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Statewide Rail Capacity and System Needs Study

Final Report

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Washington State
Transportation Commission

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STATE OF WASHINGTON

TRANSPORTATION COMMISSION

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January 5, 2007

The Honorable Christine Gregoire
Office of the Governor
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The Honorable Members
Washington State Senate
P.O. Box 40482
Olympia, Washington 98504-0482

The Honorable Members
Washington State House of Representatives
P.O. Box 40600
Olympia, Washington 98504-0600

Dear Governor Gregoire, Senators, and Representatives:

The Washington State Transportation Commission respectfully submits the enclosed *Statewide Rail Capacity and System Needs Study*, which was approved by the Commission at its meeting on December 12, 2006. Your interest in and attention to the need for policies to govern the State's participation in the rail transportation system is important to the mobility and commerce of the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity passenger rail service. In the last decade, it has also provided emergency funding to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature of this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The study concludes that the economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. However, it also concludes that the rail system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. The pressure on the rail system will increase as the Washington State economy

grows. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent between 2005 and 2025. The State's role is necessarily shaped by the fact that nearly all freight railroads are privately owned for profit companies.

The major freight railroads are investing to add capacity and improve service in Washington State, but their business practices and investment priorities are understandably driven primarily by the railroads' national-level needs and competition. The needs of Washington State businesses and communities are just one part of the railroads' considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets Washington State's economic needs, as well as the railroads' business needs.

A carefully planned program of state investments and other actions that are consistent with the policies recommended by the study will allow the State to realize a higher level of public benefits – in economic growth, jobs, tax revenues, and reduced community impacts – from the rail system than would be obtained without state participation. However, the State should invest only when it has been demonstrated that projects will deliver public benefits to the citizens and businesses of Washington State, and when it has been demonstrated that there is a low likelihood of obtaining those benefits without public involvement.

The study recommends policies, procedures, and approaches to governance and management of the State's rail programs and assets that will help the State make effective and responsible improvements to the rail system – improvements that will serve the economic development, transportation, social, and environmental goals of Washington State and its citizens.

The study points to but does not recommend specific improvements to the rail system. If the Legislature chooses to adopt the policies and procedures recommended by the study, it may wish to apply the policies and procedures to determine the high-priority projects.

We appreciate your support for transportation improvements statewide, and hope that these recommendations will help to expedite projects that will keep Washington moving and keep Washington's economy thriving.

Sincerely,

Richard Ford
Chairman
Washington State Transportation Commission

Enclosure

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Cover photographs of Amtrak *Cascades* service and BNSF 4937 courtesy of David Honan.

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1.0 Executive Summary

The Washington Rail Capacity and System Needs Study was requested by the Washington State Legislature to:

- Assess rail needs in the State;
- Determine the State's interest in the rail system;
- Develop policies to govern the State's participation in the rail system; and
- Develop a plan for managing the rail lines, railcars, and service rights owned by the State.

The State has had a longstanding involvement in passenger rail service, investing heavily to develop the Amtrak *Cascades* intercity rail service. In the last decade, it also has provided emergency relief to failing short line railroads and purchased specialized freight cars to ensure that agricultural shippers in the State have access to service and equipment.

The key question asked by the Legislature for this study was: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?" Our conclusion is that the State should continue to participate in the freight and passenger rail systems.

The Economic Vitality of Washington State Requires a Robust Rail System

The economic vitality of Washington State requires a robust rail system capable of providing its businesses, ports, and farms with competitive access to North American and overseas international markets. For example:

- Manufacturers, lumber and wood products producers, and central and eastern Washington agriculture and food products businesses rely on rail transportation to move heavy, bulky products to market cost effectively. These businesses generate 14 percent of the State's gross state product and 15.5 percent of its employment. If rail service deteriorates, these businesses may shift their freight to trucks, but this will increase their transportation costs and may increase the cost to state and

local government of maintaining roads. In some cases, the loss of rail service could drive businesses to relocate or close.

- The State's ports and international trade industry depend on rail to export grain and other agricultural products and to import intermodal containers of consumer goods. The ports generate more than 200,000 jobs directly and indirectly, and over $500 million in state and local tax revenues. If the rail system cannot deliver high-quality transportation services, especially for intermodal cargo that is not destined for Washington State, shippers will quickly shift to other ports. This could result in lower growth at Washington ports and a loss of port-related jobs. In addition, export trade plays a major role in the Washington economy, ranking it first among states in export value per capita. Without good rail connections to support both import and export trade, the Washington ports will become less attractive to ocean carriers, and ultimately, the State will become a less attractive location for export businesses.

- A high-quality intercity passenger rail service offers an alternative to automobile and air travel that can help reduce congestion, energy use, and environmental impacts of highways. If the rail system cannot accommodate frequent and reliable intercity passenger rail service, the State risks losing the benefits of passenger rail as an alternative to highway and air travel.

The System Is Nearing Capacity

The benefits that Washington State can obtain from a robust rail system are threatened because the system is nearing capacity. Service quality is strained and rail rates are going up for many Washington State businesses. For example:

- The Everett-Spokane line over Stevens Pass is the Burlington Northern Santa Fe Railway's (BNSF) major transcontinental route for double-stack intermodal trains. It operates today at about 123 percent of practical capacity.[1]

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[1] Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is the point at which the system ceases to operate freely and reliably and begins to suffer slowdowns and congestion. At higher percentages, rail congestion increases and service reliability deteriorates quickly. For more information about how rail capacity is determined, see Technical Memorandum #3, *Rail Capacity Needs and Constraints*.

- The BNSF's Auburn-Pasco line over Stampede Pass operates today at about 60 percent of practical capacity. However, the line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains.

- The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Columbia River and Puget Sound ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity. With the Everett-Spokane line nearing capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line.

- The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights in some segments with the Union Pacific Railroad (UPRR), Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

The pressure on the rail system will increase in the next decades. Between 2005 and 2025, the output of the Washington State economy (measured as gross state product) is expected to grow at an average of 3.5 percent per year. The total freight tonnage moved over the Washington State rail system is expected to increase by about 60 percent over the period. To accommodate this growth, many more rail lines within Washington State will be operating at or above their practical capacity.

Growth in rail traffic and rail congestion issues are also affecting Washington communities by increasing delays for automobile and truck drivers at rail-highway crossings, creating noise and safety problems, and disrupting communities and environmentally sensitive areas with construction projects. Dealing with these

problems in an uncoordinated fashion on a case-by-case basis is often frustrating for both the communities and the railroads.

As freight and passenger trains compete for time and space on the rail system, the capacity constraints may also frustrate the service and ridership plans for the State's passenger-rail program. The cost of resolving the rail choke points in the I-5 corridor to meet passenger service and ridership goals is increasing, potentially reducing the cost-effectiveness of the passenger rail program. Without capacity improvements, rail will not maintain its share of the Washington State freight market, rail shipping prices will increase, and service reliability will deteriorate for many of the State's industrial and agricultural shippers.

The Rail Industry Is Expanding Capacity, But May Not Meet All the State's Needs

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines. They are operating longer trains and maximizing the number of containers packed on intermodal cars; consolidating pick-up and delivery of railcars at central terminals; and eliminating mainline switching wherever possible (i.e., minimizing the number of times trains are 'parked' on the mainline while picking up cars from individual shippers). These changes favor a hook-and-haul operations strategy, where the railroads pick up a full train in Seattle or Tacoma and haul it directly to Chicago, or pick up a full grain train in the Midwest and haul it directly to a Columbia River port. Hook-and-haul operations allow the railroads to achieve economies of scale that keep costs down and services profitable. However, capacity will remain constrained in Washington even with these changes.

The move toward wholesale rail service helps meet the needs of Washington State's ports, which handle high volumes of imported intermodal containers and exported grain. But it is problematic for Washington State's manufacturers and agricultural shippers. They need low-cost, shorter-haul carload service and do not generate the high volumes attractive to the railroads. In general, international intermodal container traffic has been outbidding domestic carload traffic for space on the rail system, and the railroads have been pricing out lower-volume, lower-profit shippers to meet the demands of higher-volume, higher-profit freight.

The shift toward high-volume, hook-and-haul operations is also problematic for Washington State's short line railroads. They provide a link between smaller shippers and the Class I railroads. If they cannot generate enough volume to get service

commitments from the Class I railroads, they lose revenue and customers. This makes it difficult financially to maintain track and service quality, further undermining their ability to provide service to their customers and compete with trucking.

While the Class I railroads are investing in the Washington State rail system to increase capacity and improve service, their business practices and investment priorities are driven primarily by the railroads' national-level needs and competition. The needs of Washington State businesses and communities are just one part and not the largest part of the railroads' considerations. Additional investment and incentives for investment are needed to ensure a robust rail system that meets Washington State's economic needs, as well as the railroads' business needs.

The State Should Participate in the Rail System in Partnership With the Private Sector to Increase Rail Capacity

A carefully planned program of state investments and other actions, consistent with the policies recommended by the study, will allow the State to realize a higher level of public benefits – in economic growth, jobs, tax revenues, and reduced community impacts – from its rail system than would be obtained without state participation.

The State should participate in the rail system through a mix of direct investment, financial incentives to private parties, and advocacy on behalf of Washington businesses and communities. However, the State should do so only when the projects or actions can be demonstrated to deliver public benefits to the citizens and businesses of the State of Washington, and when it has been demonstrated that there is a low likelihood of obtaining these benefits without public involvement.

The cost of state participation in the private rail system must be weighed against the benefits and costs of alternative modes. For example, in some cases, the costs of maintaining and improving rail service may be higher than the costs of maintaining and improving highways to accommodate added truck and automobile traffic. The cost of improving rail service must also take into account the cost of mitigating the impacts of increased rail traffic on communities near terminals and along mainlines. Finally, the cost of state participation should weigh Washington State benefits against national benefits. When a substantial share of the benefits of a project accrue to rail users outside of Washington State, the State's contribution should be limited. This study recommends an approach to evaluating costs and benefits to the State and other beneficiaries in a systematic decision-making framework.

Washington State is not alone in facing challenges in the rail system. The nation is entering the early stages of a freight transportation capacity crisis. The American Association of State Highway Officials (AASHTO), the congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, and Congress, as it takes up renewal of the national transportation program, are trying to establish forward-looking national policies and visions for the rail system. Washington State should take an active role in influencing the development of national policies and programs, and should look to multistate and Federal programs to help implement the recommendations of the report.

The Washington State Transportation Commission recommends six policies. They are summarized here and described in detail in Section 5.0, pages 38 to 53. The recommendations are as follows:

- **Policy Recommendation #1: Washington State should continue to participate in the preservation and improvement of both the freight and passenger rail transportation system where there are public benefits to Washington State, its businesses, and its communities.** The study provides guidance on how state actions can be used to address the needs of carload industrial shippers, agricultural shippers, ports and international trade industries, and the passenger-rail users. These include suggestions for mainline, terminal, and access improvements; development of consolidation facilities and shipper rail sidings; assistance to short line railroads; and mitigation of rail impacts on Washington communities.

- **Policy Recommendation #2: The State should base its decisions to participate in projects, programs, and other rail initiatives on a systematic assessment and comparison of benefits and costs across users and across modes.** The State should estimate quantifiable costs and benefits; economic impacts; and qualitative benefits for the State, rail users, the railroads and other carriers, and communities. Where appropriate, these benefits and impacts should be compared to the benefits and impacts of alternative investments in truck and barge services for freight, and the benefits and impacts of alternative investments in highway, bus, ferry, and air services for passengers.

- **Policy Recommendation #3: Where the State determines there are sufficient public benefits to justify public participation in the preservation and improvement of the rail transportation system, its actions should be guided by the following general principles:**

- Emphasize operations and nonfinancial participation in projects before capital investment;
- Preserve and encourage competition;
- Target actions to encourage private investment that advances Washington State economic development goals;
- Leverage state participation by allocating cost responsibility among beneficiaries; and
- Require projects to have viable business plans.

- **Policy Recommendation #4: The State should designate a single entity to coordinate and direct the State's participation in the preservation and improvement of the rail transportation system. This entity should have the authority to negotiate directly with the railroads.** The Class I railroads are large national corporations. The State can be an effective advocate for a multiplicity of state, business, and community interests, but cannot do so without a coordinated and unified vision and voice.

- **Policy Recommendation #5: The State should take an active role in influencing and shaping the development of national rail policies and programs. The State should also develop a multistate coalition to address rail system needs across the Pacific Northwest.** The Washington State rail system is an integral part of the national and Pacific Northwest rail systems. The State's rail needs transcend the State's boundaries. The congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, the American Association of State Highway and Transportation Officials, the Association of American Railroads, Congressional committees, and other groups are working to establish forward-looking national visions, policies, and programs for the rail system. Washington State should participate actively in these discussions. As part of this process, Washington State and its neighbors should also establish a multistate coalition to address rail system needs across the Pacific Northwest. Washington State and its neighbors should use the coalition as a forum to establish their common needs and work with the railroads to identify, prioritize, and implement the most cost-beneficial regional improvements.

- **Policy Recommendation #6: The State should implement the asset management plan developed as part of this study to govern investment and management decisions for state-owned rail assets.** The asset management plan sets objectives for the rail lines, specialized railcars, and service rights that the State owns; establishes performance measures to

determine if these objectives are being met; and describes management practices to ensure that the State's rail assets return maximum benefit to the public.

2.0 Introduction and Background

2.1 Purpose of the Study

Study Mandate from 2005-2007 Transportation Budget Proviso

The Purpose of this study is to –
a) assess the rail freight and rail passenger infrastructure needs in this State; b) review the current powers, authorities, and interests the State has in both passenger and freight rail;
c) recommend public policies for state participation and ownership in rail infrastructure and service delivery, including, but not limited to, planning and governance issues; and
d) develop a rail asset management plan.

The commission shall report their findings and conclusions of this study to the transportation committees of the legislature by December 1, 2006.

The *Washington Rail Capacity and System Needs Study* was initiated by the Washington State Legislature to answer the question: "Should the State continue to participate in the freight and passenger rail system, and if so, how can it most effectively achieve public benefits?"

2.2 Issues

The State has had a longstanding involvement in passenger rail service. In the last decade, it has provided emergency relief to failing short line railroads and purchased specialized railcars to ensure that agricultural shippers in the State have access to cars and service. The state rail policy has evolved through multiple major policy reviews (the most recent in 1995), legislation, and the Washington Transportation Plan (WTP).

The pressure to provide more structured guidance for state investments and actions has grown sharply in the last several years as the demand for rail service has begun to outstrip capacity and the price of rail service to Washington State shippers has increased. Today, the State faces some difficult issues.

The Railroads Are Focusing on High-Volume and Long-Haul Services, But the State's Industrial and Agricultural Shippers Also Need Low Volume and Short-Haul Services

Long-haul intermodal container trains and long-haul unit grain trains moving to and from Washington State's ports are the least complex and the most profitable for the Class I railroads to operate. As a result, the railroads have reoriented their operations to accommodate this business. But many Washington State shippers are low-volume carload shippers who generate only a few dozen carloads a week or a month, and they are being priced out of the rail market. When should the State help meet the needs of the ports and international trade business for premium long-haul rail service, and when should the State help meet the needs of

agricultural and local shippers for low-cost, shorter-haul rail services?

Rail Is Being Asked to Absorb Some of the Traffic Growth from Congested Highways

The I-5 corridor and many of the State's urban highways are congested. The public sees expanded freight and passenger rail services as part of the solution to highway congestion. But most rail shipments are long-distance shipments. Investment in new rail capacity may not moderate growth in truck traffic – most of which is associated with short- and medium-distance trips – on the State's congested urban highways. When and where should the State invest in freight and passenger rail capacity to help relieve highway congestion? How can the State ensure that the best use is made of each of its transportation modes?

Short Line Railroads Are Being Asked to Support Agricultural Shippers and Communities

Short line railroads provide low-cost transportation to manufacturers across the State and to shippers in the agricultural communities of eastern and central Washington, enabling these shippers to compete in world markets. But with low traffic volumes and high operating costs, many short lines are at risk of failing financially. When should the State invest in short lines to support existing jobs and communities?

The Intercity Passenger Rail Program Is Being Asked to Increase Ridership

The Legislature established an intercity passenger-rail program. Ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. Some of the investments may benefit freight rail, as well as passenger rail. When should the State invest to improve passenger rail service and reliability?

2.3 Structure of the Report

The report is organized as follows:

- **Chapter 3.0 – Washington State Rail System, Rail Users, Capacity, and Issues** describes the rail system, identifies the

key rail users, summarizes the study findings about current and projected capacity, and discusses the implications of capacity and service shortfalls for rail users and Washington State;

- **Chapter 4.0 – Washington State Powers, Authorities, and Interests** summarizes the State's current rail policies and programs; lists the State's recent investments in rail lines, railcars, and other rail equipment; and identifies – in broad terms – the roles that the State can play to shape the future of the rail system; and

- **Chapter 5.0 – Policy Recommendations** details the six policy recommendations.

3.0 Washington State Rail System, Rail Users, Capacity, and Issues

3.1 Washington State Rail System

The Washington State rail system comprises mainlines, branch lines, industrial spurs and leads, and rail yards and terminals operated by a variety of public and private rail carriers. (See Figure 1.) The freight railroads operate 3,628 miles of rail service in Washington State over 2,523 miles of rail lines.[2]

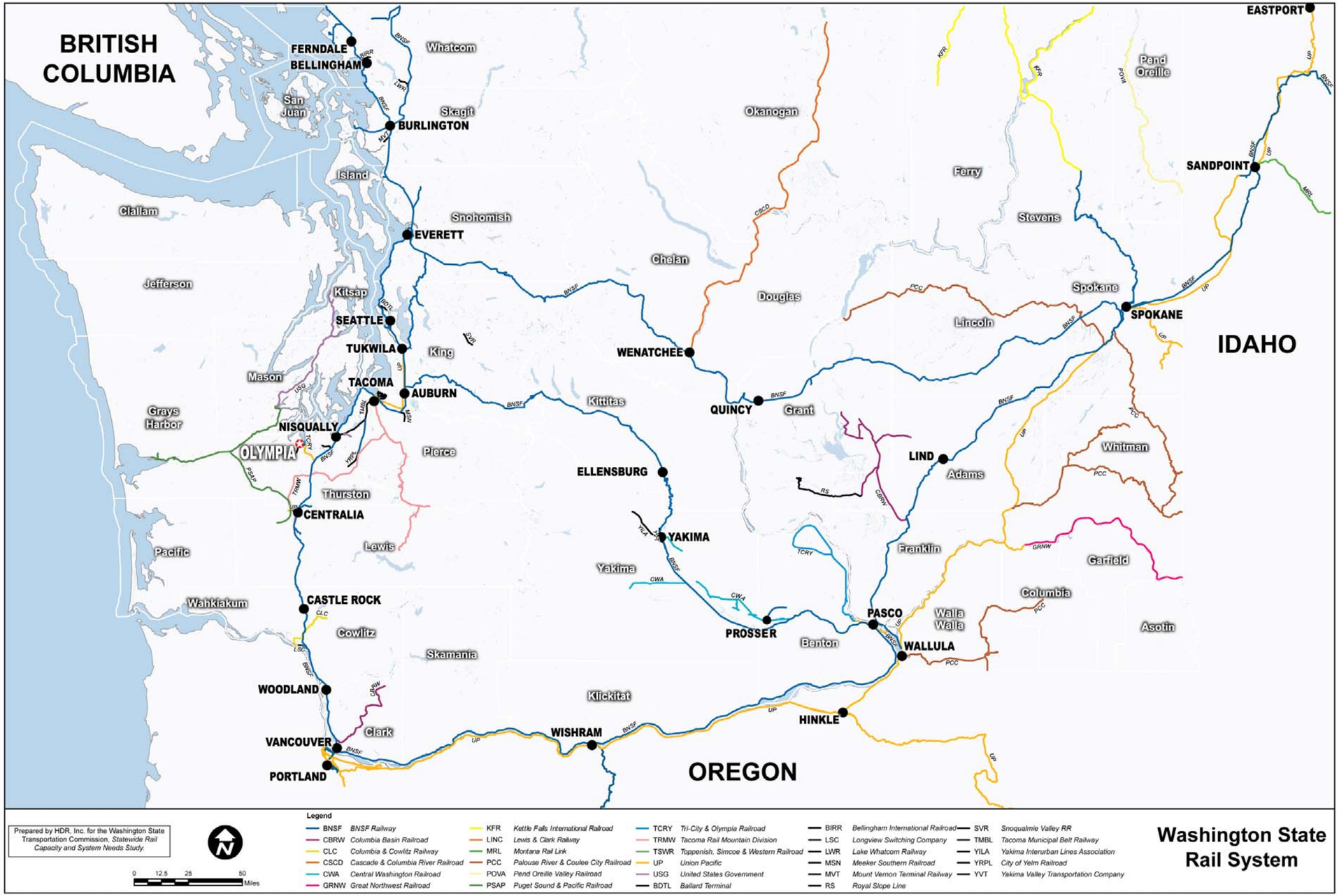
Who Operates the Rail System?

Railroad classification is determined by the Federal Surface Transportation Board. In 2004, Class I railroads were defined as railroads having $289.4 million or more in operating revenues. Class II railroads (referred to regional railroads) were defined as non-Class I line-haul railroads operating 350 miles or more with operating revenues of at least $40 million. Class III railroads (or short line railroads) were defined as all remaining non-Class I or II line-haul railroads. Switching or terminal railroads are railroads engaged primarily in switching and/or terminal services for other railroads.

Long-haul rail transportation is provided by two Class I railroads – BNSF and UPRR. The BNSF owns and operates the most mileage in the State – 1,572 in-state-operated miles, constituting 5 percent of the BNSF's total system mileage. The dominant position of the BNSF in many of the State's rail markets has significant implications for the degree of leverage that the State, rail shippers, and communities have in influencing its business decisions.

[2] Operated miles are greater than owned miles, because owning railroads lease operating rights over their lines to other railroads. And in a few areas, the U.S. Department of Transportation (DOT) Surface Transportation Board, which has economic regulatory oversight of the railroads, has mandated provision of operating rights to ensure competition between railroads.

Figure 1. Washington State Rail System



What Types of Services Do Freight Railroads Provide?

Intermodal services *receive fully-loaded and sealed truck trailers or containers from ships or trucks directly onto railcars for transport. Intermodal shipments are generally higher-value, lower-weight commodities than unit or carload trains.*

Carload services *are those that use a variety of railcar types to carry a range of commodities to a variety of customers. They generally carry lower-volume, higher-weight commodities than Intermodal trains. Examples of commodities shipped by carload include farm products, lumber, chemicals, and paper products.*

Unit carload trains *are those in which every car in the train is shipped from the same origin to the same destination. They are used for high-volume goods, such as coal, garbage, wheat, or any other suitable product gathered at one location for shipment.*

The BNSF System in Washington State

The BNSF owns and operates three east-west lines: The Everett to Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is BNSF's primary route for double-stack intermodal traffic. The Auburn to Pasco route crosses the mountains through the Stampede Pass tunnel. The ceiling of the Stampede Pass tunnel is too low for double-stack intermodal container trains, limiting the capacity of this route. The third route follows the north side of the Columbia River from Vancouver, Washington to Pasco. This is the primary route for export grain trains inbound to the Columbia River ports, but due to heavy traffic through Stevens Pass, this has become a reliever route for intermodal traffic moving from Seattle and Tacoma to Vancouver, Washington, and then east along the river.

These BNSF east-west corridors converge in Spokane to feed the two major BNSF routes providing access to grain producers in the Midwest and intermodal freight connections in Chicago.

The three east-west routes are linked by the north-south I-5 rail corridor. The I-5 corridor rail line runs the length of the State from the Canadian border through Bellingham, Everett, Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights over the line with the UPRR, Amtrak's intercity-rail services, and Sounder commuter-rail operations. (The UPRR also owns sections of rail line in the Auburn-Tacoma area that parallel the BNSF line.)

The UPRR System in Washington State

The UPRR's primary east-west corridor serving traffic in and out of Washington State is in Oregon, running between Portland and Hinkle on the south side of the Columbia River Gorge. At Hinkle, the line forks: one line runs northeast from Hinkle to Spokane, linking up with the Canadian Pacific near Eastport, Idaho; and the other line runs southeast from Hinkle to Pocatello, Idaho, connecting to the UPRR's Central Corridor and the heavily trafficked lines serving the Powder River Basin coal fields. This line is the UPRR's major connection between the grain producing regions of the Midwest and the Columbia River and Puget Sound ports. For the last 12 miles of the Hinkle to Spokane line (from Fish Lake to Spokane), the UPRR operates on the BNSF Lakeside Subdivision via trackage rights.

North of Vancouver, Washington, the UPRR has operating rights over the BNSF's I-5 rail line as far as Tacoma and Seattle. This is the UPRR's primary intermodal route connecting to the Ports of Seattle and Tacoma. South of Portland, the UPRR owns and operates the I-5 mainline, which is the major conduit for forest products from British Columbia, Washington, and Oregon to the growing population centers of Southern California and the Southwest. (The BNSF serves these markets using its line through Bend, Oregon, which parallels the UPRR line. The BNSF and the UPRR then share operating rights over the UPRR line through southern Oregon and Northern California.)

Short Lines

Each of the large Class I railroads is served by a number of smaller regional, short line and terminal railroads, which pick up and distribute railcars to individual industrial and agricultural shippers and receivers. These railroads provide critical services, particularly in lower-density rail corridors and markets where the Class I railroads cannot operate cost-effectively. In a number of cases, the short lines operate on branch lines that were previously owned and operated by the Class I railroads.

Intercity Passenger Rail

Intercity passenger rail service in Washington State is provided by Amtrak. The service with the highest ridership is the Amtrak *Cascades* service, operated by Amtrak in partnership with Washington State DOT. The Amtrak *Cascades* provides service along the I-5 rail corridor from Vancouver, British Columbia in the north through Everett, Seattle, Tacoma, and Olympia, and then south to Portland, Oregon. Oregon is a funding partner, underwriting Amtrak *Cascades* service to Eugene, Oregon. Amtrak also operates the Coast Starlight train between Seattle and Portland, and the Empire Builder train between Seattle and Spokane and between Portland and Spokane, with connections from Spokane east to Chicago.

3.2 Washington State Rail Users

Rail provides critical transportation for manufacturers, agricultural producers, lumber and wood products producers, the food products industry, and the ports and international trade sector – all important sectors of the Washington economy. Consider these statistics:

- Manufacturers, agricultural producers, and lumber and wood products producers generate 14 percent ($37 billion) of the State's $262 billion economic output value (gross state product) and 15.5 percent (425,700 jobs) of the State's employment.
- The Washington State ports generate between 200,000 and 300,000 direct, indirect, and trade-related jobs in the State. A portion of these jobs depend directly or indirectly on rail service.
- Sixteen percent of all freight tonnage moved in Washington State moves by rail.

Rail service is critical because it enables these Washington State industries to ship heavy or bulky commodities over long distances at low costs. Table 1 lists the top 10 outbound Washington State rail commodities by tonnage for 2004 and the forecast tonnages for 2015 and 2025. These are commodities that are shipped out of Washington State by rail. "Miscellaneous mixed shipments" are primarily merchandise and retail trade goods; many are moving in intermodal containers.

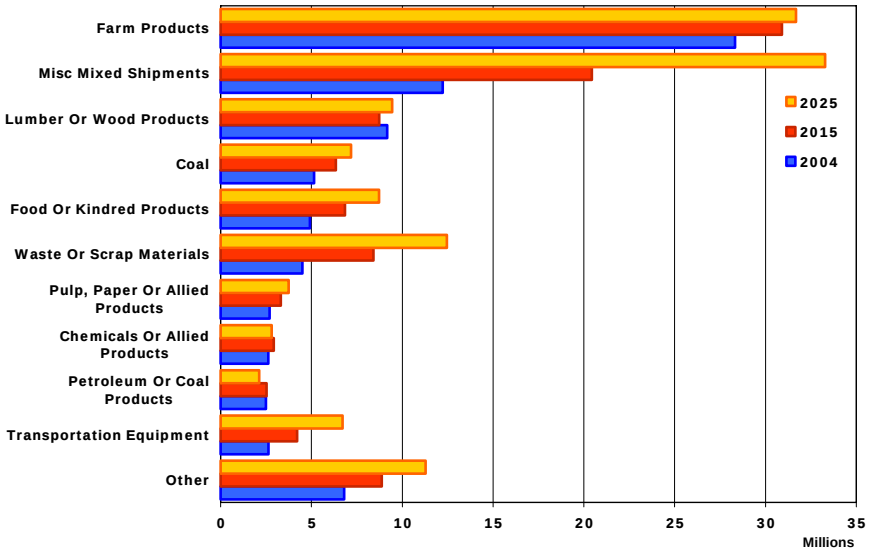
Table 1. Top 10 Outbound Commodities by Tonnage, 2004, 2015, and 2025

		Rail Tonnage			Compound Annual Growth Rate		
STCC	Commodity	2004	2015	2025	2004-2015	2015-2026	2004-2025
46	Miscellaneous mixed shipments	6,516,304	11,309,371	19,060,968	5.1%	5.4%	5.2%
24	Lumber or wood products	4,506,679	4,072,939	4,183,956	-0.9%	0.3%	-0.4%
11	Coal	2,142,403	2,743,497	3,184,686	2.3%	1.5%	1.9%
40	Waste or scrap materials	1,543,296	2,377,099	3,260,635	4.0%	3.2%	3.6%
26	Pulp, paper, or allied products	1,231,469	1,556,870	1,752,517	2.2%	1.2%	1.7%
20	Food or kindred products	1,075,792	1,662,293	2,389,104	4.0%	3.7%	3.9%
37	Transportation equipment	826,102	2,090,719	4,523,959	8.8%	8.0%	8.4%
1	Farm products	700,653	997,648	1,385,204	3.3%	3.3%	3.3%
33	Primary metal products	606,415	677,274	597,161	1.0%	-1.3%	-0.1%
28	Chemicals or allied products	353,040	381,960	367,654	0.7%	-0.4%	0.2%

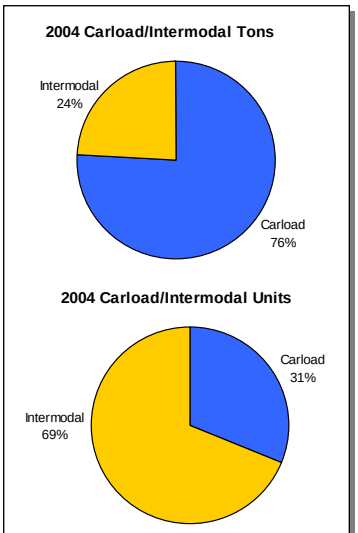
Source: Global Insight, Inc., 2006.

Figure 2 compares the 2004 tonnages to the forecast tonnages for 2015 and 2025. This figure includes commodities that are shipped into and out of Washington State; the previous figure showed only outbound commodities.

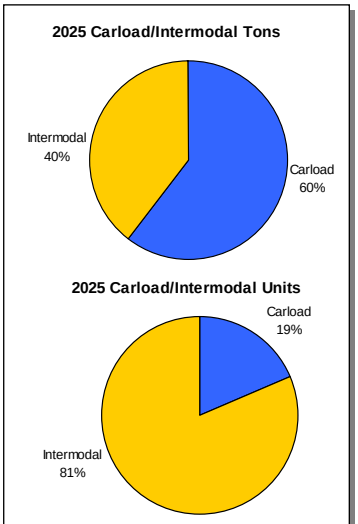
Figure 2. Washington State Rail Tonnage by Commodity (2004) and Forecast Tonnage (2015 and 2025)



Source: Global Insight, Inc., 2006.



Source: Global Insight, Inc., 2006.



Source: Global Insight, Inc., 2006.

Lighter commodities, such as merchandise and retail trade goods moving in intermodal containers, take up more railcar space and generate more trains than heavy, densely packed commodities, such as wheat or chemicals. While intermodal container shipments (a portion of miscellaneous mixed shipments) represent only 24 percent of tonnage in 2004, they represent 69 percent of railcar units. By 2025, intermodal container shipments will be 40 percent of tonnage and 81 percent of railcar units.

Without rail service, some of the Washington State businesses shipping by rail today would shift their rail freight to trucking, increasing their transportation costs and the cost to state and local government of highway maintenance; some would relocate to other states with the necessary rail service; and others might be forced out of business if higher transportation costs make them less competitive in global markets. This is of particular concern in the agricultural sector, where many traditional Washington crops are already under intense price competition in both domestic and international markets and where small increments of added cost can have significant impacts on competitive position.

3.2.1 Manufacturers/Industrial Carload Shippers

Manufacturing and industrial products industries are among the largest rail-using Washington State businesses, and they primarily

use rail carload services. Shippers include producers of metals, machinery, transportation equipment (including airplanes), wood and paper, and petroleum and plastic products. In 2004, the largest tonnage volumes of outbound shipments from these industries were waste and scrap materials; pulp, paper, and allied products; transportation equipment; primary metal products; and chemicals and allied products. Inbound manufactured or industrial products included coal; chemicals; clay, concrete, glass and stone; pulp and paper; and primary metal products.

Manufacturers interviewed for this study expect their volume of shipments to grow steadily, and economic forecasts show the demand for carload shipments growing at a compound rate of 1.8 percent per year for general manufacturing and 1.4 percent for lumber and wood products. However, many of the shippers reported that they were paying higher prices, were getting lower-quality service, and were often having business turned away by the railroads. These shippers will substitute truck for rail when they can, but for shippers of bulky, semifinished products or primary materials, trucking may not be feasible or cost-effective. In the longer term, there is a risk that Washington State will lose some of the businesses that depend on carload shipments to relocation or closure.

3.2.2 Ports and International Trade Sector/Intermodal Container Shippers

International trade generates huge flows of intermodal containers through the Ports of Seattle and Tacoma. Between 1994 and 2004, container traffic grew at an average annual rate of 3.7 percent at the Port of Tacoma, and 2.6 percent at the Port of Seattle. Much of the container traffic consists of merchandise and retail goods imported from Asia through the Ports, and then transferred to rail for shipment to Midwest and eastern U.S. markets. Intermodal rail traffic supporting the Ports and international trade is forecast to grow at a compound annual growth rate of 5.8 percent between 2005 and 2025.

Businesses and consumers across the U.S. benefit from this international trade, but healthy deepwater ports also provide benefits to Washington State. The Ports of Seattle, Tacoma, and Vancouver estimate that the total number of statewide jobs connected to each port are: 166,680 for the Port of Seattle; 113,000 for the Port of

Tacoma; and 15,500 for the Port of Vancouver.[3] The Ports also contribute over $500 million in state and local taxes associated with their maritime cargo operations. Washington State ranks third among all states in annual export value, and first in export value per capita. While many Washington State exporters do not use the rail system to deliver goods to the State's ports, the existence of a healthy rail system is important, because it brings more traffic to the ports and more shipping services that can be used by Washington State exporters. Ocean carriers make decisions about which ports to call, at what frequency, and with what services offered based on the overall market potential associated with the port. Strong long-haul rail services allow ocean carriers to access larger and more distant inland markets. Local export shipments help to balance import and export flows for the carrier. Thus, a strong rail system helps attract ocean carrier services to Washington State's ports and makes the State a more attractive location for national, regional, and local export businesses.

The ability of the Washington State trade sector to deliver these benefits to the economy is critically dependent on the ability of the Ports to compete with other North American ports. This is confirmed by experience of the last decade; first with loss of market share to Southern California ports, and then with gains as the California gateway experienced capacity problems. Looking forward, the Ports will face new competition from the Port of Vancouver, British Columbia; a new port being built specifically for North American inland container traffic at Prince Rupert, British Columbia; and "all-water" services that use the Panama Canal to reach East Coast ports. In this environment, an efficient rail system with good on-dock and near-dock connections is an important competitive advantage.

3.2.3 Agriculture and Foods Products Industry/Bulk and Specialized Carload Shippers

Agriculture and food products manufacturers are an important economic sector in the State, generating 3 percent of the gross state product and accounting for 6 percent of the employment. Washington State ranked 11th among states in agricultural

[3] These job estimates are self-reported by each port based on economic impact studies conducted by Martin Associates in 2001 (Vancouver), 2004 (Seattle), and 2005 (Tacoma). The Port of Seattle explains that their estimates include direct, indirect, and induced jobs related to marine cargo activities, as well as jobs with associated regional manufacturing and distributions firms moving cargo through the Port.

production in 2002, producing crops and livestock valued at over $5.3 billion. Agriculture is the major source of employment in many of the State's rural counties.

By tonnage, 36 percent of all Washington State agricultural shipments move by rail. Agricultural rail traffic outbound from Washington State is expected to grow at a compound annual growth rate of 3.3 percent over the next 20 years. Washington State also has a growing food products industry with particular strengths in frozen foods (7.3 percent of U.S. output) and wine production.

However, most of the agricultural tonnage moving on the Washington State rail system is Midwestern grain moving to the Lower Columbia River and Puget Sound ports for export. And because Midwestern grain is moving long distances by unit train, it is generally more profitable for the railroads than local Washington State agricultural shipments, which often are moving shorter distances for export or require specialized handling.

The Class I railroads are asking Washington agricultural shippers to consolidate their shipments at new facilities (such as the Ritzville loader), and this may prove economical for those shippers who can accommodate the changes. But these changes will affect the short lines, which may see declines in their markets; operators of small grain elevators along the short lines who also stand to lose business; and the remaining shippers on the short lines who could see reductions in service and increased costs.

The challenge faced by Washington State agriculture is to maintain competitive rail service as it focuses on higher-value added crops and produce that may not generate the volumes that are attractive to the Class I railroads.

How do Amtrak Cascades ridership forecasts compare with other intercity corridors?

Amtrak Cascades – ***In 2005, three round-trip trains between Seattle to Portland served 0.4 million riders. In 2023, 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) are forecast to serve 3.0 million riders.***

Capitol Corridor* **–** ***In 2003, 12 round-trip trains between San Francisco Bay Area and Sacramento served 1.14 million riders.***

Surfliner Corridor* **–** ***In 2003, 11 daily round-trip trains between San Diego, Los Angeles, and San Luis Obispo served 2.2 million riders.***

Northeast Corridor – ***In 2001, 42 round-trips trains between Boston to New York to Washington, D.C. served 10.9 million riders.***

*Source: *Amtrak Strategic Plan FY2005-2009, Amtrak, June 2004.*

3.2.4 Passenger Rail Riders

Washington State supports intercity passenger rail and commuter rail services. The major service is the Amtrak *Cascades* intercity rail program, which provides service from Vancouver, British Columbia through Everett, Seattle, Tacoma and Olympia, and then south to Vancouver, Washington and Portland and Eugene, Oregon. The program currently provides four round trips daily between Seattle and Portland, with one round trip daily between Seattle and Bellingham, and one round trip daily between Seattle and Vancouver, BC. Ridership in 2005 was about 421,000 on the

four trains that were supported financially by Washington State at that time, and about 637,000 on the entire *Cascades* service.[4] The State's passenger rail plans envision serving up to 3.0[5] million riders with 17 round-trip trains (13 between Seattle and Portland and 4 north of Seattle) in 2023.

Sound Transit provides Sounder commuter rail services in the Puget Sound region, with weekday peak-period service between Seattle and Tacoma and between Seattle and Everett. Both services operate over BNSF tracks. The *Cascades* service is operated by Amtrak; the Sounder commuter trains are operated by BNSF and maintained by Amtrak.

In the Puget Sound region, Sounder ridership is projected to grow from 1.2 million passenger trips in 2006 to 2.6 million passenger trips in 2011, a five-year increase of 117 percent.

Forecasts for both the Amtrak *Cascades* and the Sounder services are predicated on substantial investments to increase capacity and improve operations along the I-5 rail corridor. Full build out of the draft Long-Range Plan for the *Cascades* program calls for additional investments of $6.5 billion (in 2006 dollars) by 2023.

Rail Capacity ***is calculated in a two-step process.***

First, a "theoretical capacity" is determined, assuming perfect conditions and operations.

Second, "practical capacity" is determined by considering factors, such as possible disruptions, signal needs, human decisions, weather, possible equipment failures, supply and demand imbalances, and seasonal demand.

Practical capacity is about 60 percent of the theoretical capacity and provides reliable service; it is similar to a highway level of service of "C." At higher percentages, rail congestion increases and service reliability deteriorates quickly.

3.4 Capacity of the Washington State Rail System and Implications for Rail Users

The Washington State rail system is nearing capacity; service quality is strained, and rates are going up.

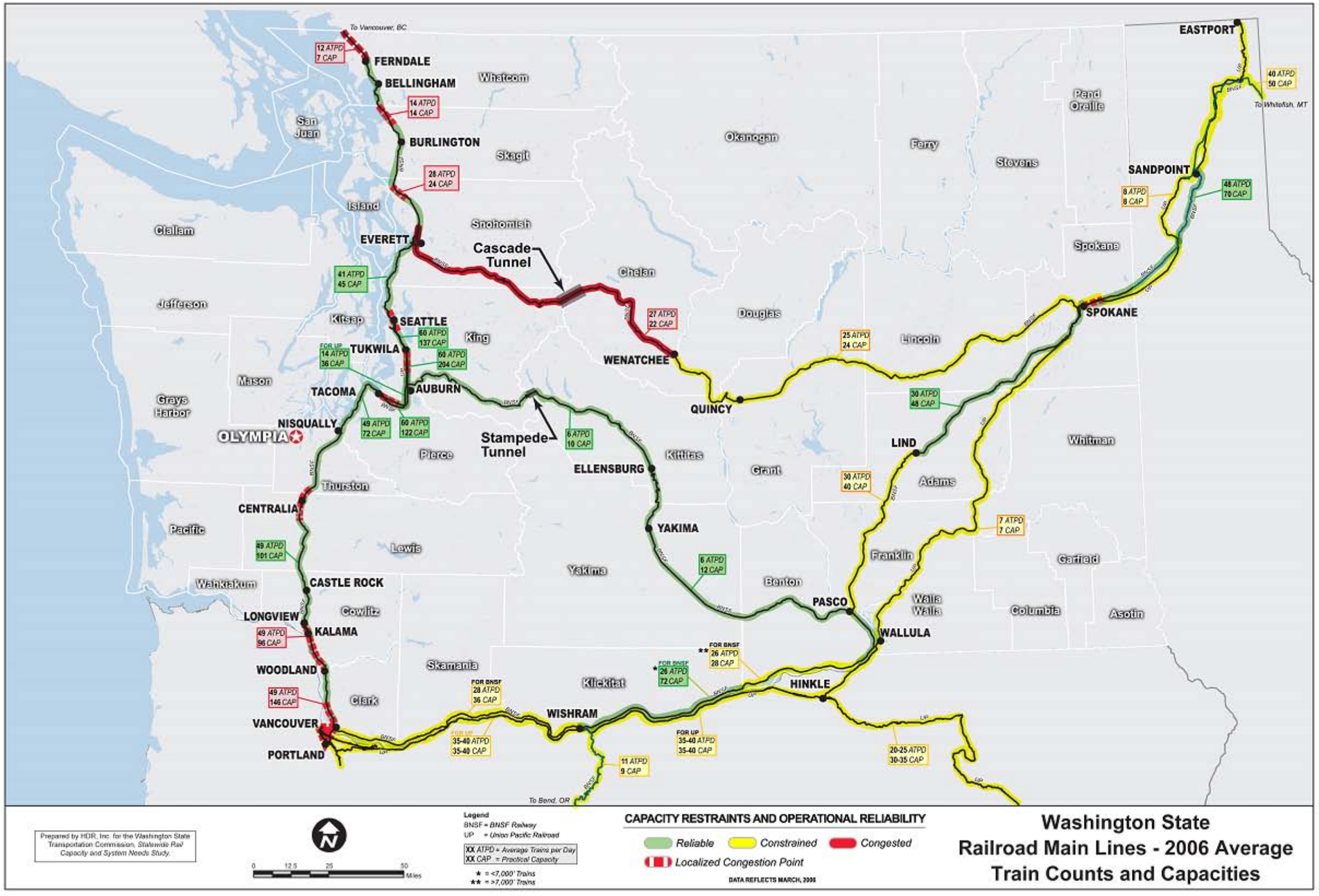
Figure 3 compares the average number of trains operated on each line to the practical capacity of the line.

The Everett-Spokane line, which passes through the Cascade Tunnel at Stevens Pass, is the BNSF's major transcontinental route for double-stack intermodal container trains. It is heavily used, operating today at about 123 percent of practical capacity.

[4] As of July 1, 2006, there are four round trips daily on the Seattle to Portland segment. Prior to this, there were only three round trips daily.

[5] A range of ridership projections were produced that varied based on fare structure and other variables. 3 million is a higher end projection.

Figure 3. Washington State Rail System: Mainline Capacities, 2006



The BNSF's Auburn-Pasco line, which passes through the Stampede Tunnel, operates today at about 60 percent of practical capacity. The line cannot be used to relieve the Everett-Spokane line, because the ceiling of the Stampede Tunnel is too low to accommodate double-stack intermodal container trains. Grades over Stampede Pass also make it difficult to haul heavy-loaded unit grain trains along this line.

The BNSF's Vancouver-Pasco line, which follows the Columbia River along the north side of the Gorge, is used by double-stack intermodal container trains moving east, grain trains moving west to the Puget Sound and Columbia River ports, and carload trains moving both east and west to serve Washington State industrial and agricultural shippers. The line is operating today at about 70 percent of practical capacity.

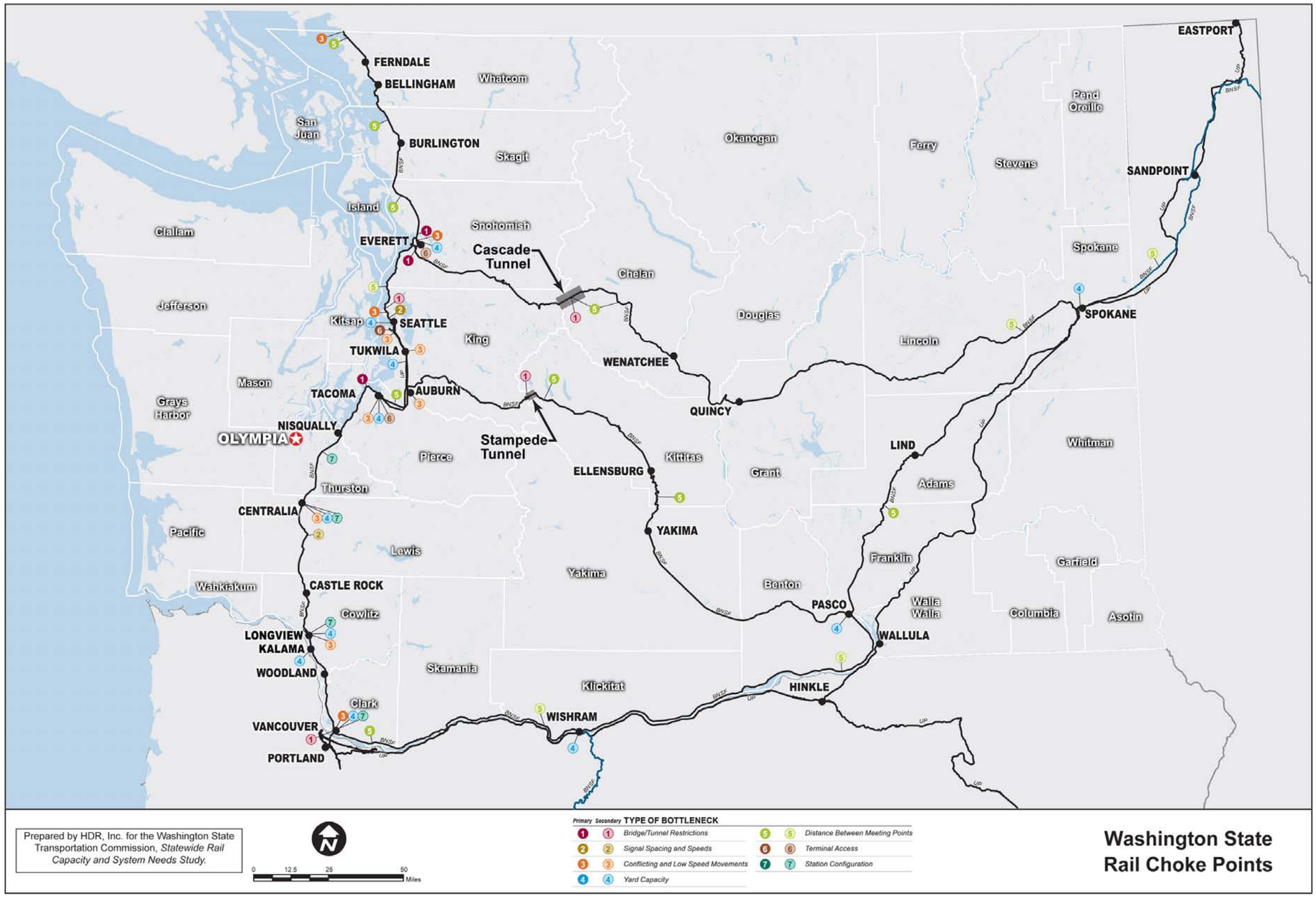
The I-5 corridor rail line runs the length of the State from the Canadian border, Bellingham and Everett through Seattle, and Tacoma to Vancouver and Portland. It is the backbone of the Washington State rail system, controlling access to the east-west lines. Most of the line is owned by the BNSF, but the BNSF shares operating rights over the line with the UPRR, Amtrak's intercity-rail services, and the Sounder commuter-rail operations. The line operates at between 40 and 60 percent of practical capacity in most sections, but is subject to frequent stoppages when trains tie up the mainline to enter and exit the many ports, terminals, and industrial yards along the corridor. Some half dozen sections are chronic choke points, causing delays that ripple across the entire Washington State and Pacific Northwest rail system.

Rail Choke Points

Figure 4 locates the major rail choke points by type across the Washington State rail system.

With the Everett-Spokane line nearing its maximum capacity, the BNSF has been routing more intermodal trains south along the I-5 rail corridor to Vancouver, Washington, and then east. This has added considerable volume to the Vancouver-Pasco line along the Columbia River Gorge, and made the scheduling of train moves through the Gorge and along the I-5 rail corridor more complex.

Figure 4. Washington State Rail System: Rail Choke Points, 2006



The on-time performance of the Amtrak *Cascades* service has dropped, and delays for both BNSF and UPRR freight trains have increased, although recent changes in freight operating practices have improved performance somewhat. The problem is particularly acute in the Portland/Vancouver area, where the railroads' north-south and east-west routes intersect. Rail simulation studies of grain trains bound for the ports, intermodal trains running through, industrial carload trains serving local industries, and intercity passenger trains shuttling up and down the I-5 corridor show that the delay hours per train moving through the Portland/Vancouver area are greater than the delay hours for trains in the Chicago area, one of the nation's most congested rail hubs.[6]

The Class I railroads are adjusting their operations to increase the volume of freight moved through the system over the existing rail lines, but the operational changes may not be sufficient to satisfy the future needs of Washington shippers. The short-term operating strategies being pursued by the railroads include the following:

- Operating longer 8,000-foot trains and maximizing the number of containers packed on intermodal flat cars;
- Marketing and operating single origin and destination unit trains for carload traffic;
- Consolidating pick-up and delivery of railcars at central terminals operated by third parties (examples include new rail-served industrial parks, logistics hubs, and transload centers);
- Eliminating mainline switching whenever possible (i.e., picking up and setting out individual cars or sets of cars for specific shippers and receivers while the train is "parked" on the mainline; this blocks the mainline and reduces line and system capacity); and
- Transferring responsibility for branch-line switching from the Class I railroads to local short lines, wherever possible.

These strategies will help meet the needs of the ports and intermodal shippers, but will likely complicate the problem of

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[6] "Freight, Intercity Passenger and Commuter Rail," PowerPoint presentation to the Portland-Vancouver I-5 Transportation and Trade Partnership on May 21, 2002; and "Final Strategic Plan: June 2002," prepared by Willard F. Keeney and HDR, Inc. for the Portland-Vancouver I-5 Transportation and Trade Partnership.

industrial carload shippers who cannot take advantage of longer and better packed intermodal trains. The Class I railroads are asking shippers, wherever possible, to reorganize and upgrade their tracks and track layouts to improve switching efficiency and be more compatible with the railroads' hook-and-haul operations. The more track space within the shipper's property and the longer the entrance and exit tracks, the faster and more efficiently the railroad can pick up or set out cars. This saves time and labor costs for the railroads and keeps high-volume mainlines open more hours of the day for through train movements. But for low-volume shippers, the costs of these site improvements are usually prohibitive. The same problems apply to consolidating rail pick-up and delivery of railcars at central terminals operated by third parties; unless the consolidation centers are well located, designed, and financed, the financial risks to shippers and operators may be very high.

Consolidation and outsourcing of terminal operations to third parties and transfer of branch-line switching from Class I to short line railroads can result in the replacement of union rail jobs with lower-paying nonunion jobs. Unless offset by future growth in Class I business that generates new union jobs, the loss of union jobs can mean a lower income and standard of living for some Washington State residents with jobs in the rail industry.

The new operating strategies also impact the State's agricultural shippers. Low-cost rail service keeps product costs competitive, but the increasing cost of rail service and the Class I railroads' focus on higher-profit, hook-and-haul intermodal traffic has made it more costly and more difficult for some agricultural shippers to get service at acceptable prices. The Class I railroads also have been asking Washington State grain and other bulk agricultural shippers to consolidate shipping points so that the railroads can operate more unit trains. Notable examples of this trend are the Ritzville grain-loading facility and the new Railex produce service at Wallula.[7]

While these new rail operating strategies have the potential to partially address future capacity needs, the analysis conducted for this study suggests that they may not be sufficient in the longer term. Table 2 lists the lines where mainline practical capacity will be exceeded within 20 years even with the additional capacity gained by operating longer trains and implementing better scheduling. The existing choke points will persist and worsen, some more quickly than others.

[7] http://www.wsdot.wa.gov/Projects/Rail/Freight/PortWallaWalla/.

Nationally, rail capacity is not keeping pace with demand. The rail industry today is stable, productive, and competitive with enough business and profit to operate, but it is not yet attracting capital fast enough to replenish its infrastructure quickly or keep pace with demand and public expectations. This trend has been documented in several recent reports.[8]

Table 2. Rail Lines in Washington State Exceeding Practical Capacity, 2015 and 2025
Based on Peak Day Train Volumes and Assuming Operation of 8,000-Foot Trains

2015	2025
Everett-Burlington	Everett-Burlington
Burlington-Ferndale	Burlington-Ferndale
Ferndale-New Westminster	Ferndale-New Westminster
Everett-Spokane, Washington (BNSF)	Everett-Spokane, Washington (BNSF)
Vancouver-Wishram	Vancouver-Wishram
Wishram-Roosevelt	Wishram-Roosevelt
Roosevelt-Pasco	Roosevelt-Pasco
	Pasco-Spokane, Washington (BNSF)
Pasco (Wallula)-Spokane, Washington (UP)	Pasco (Wallula)-Spokane, Washington (UP)
Spokane, Washington-Sandpoint, Idaho (UP)	Spokane, Washington-Sandpoint, Idaho (UP)
Auburn-Yakima	Auburn-Yakima
Yakima-Pasco	Yakima-Pasco

Railroading is one of the most capital intensive industries in the U.S., and investment in fixed assets can be a risky proposition.

[8] See for example: AASHTO, *Freight-Rail Bottom Line Report*, Washington, D.C., 2003; and United States Government Accountability Office, *Freight Railroads: Industry Health Has Improved, But Concerns About Competition and Capacity Should Be Addressed*, Washington, D.C., October 2006.

During the 1990s, when railroads found themselves with excess capacity and profits were down, Wall Street downgraded bond ratings and railroad stock prices fell. In the last several years, this trend has reversed and Class I railroads are reinvesting heavily to maintain and add capacity to their systems. However, much of this investment is replacing existing infrastructure and maintaining existing capacity, because rail traffic places enormous wear and tear on rails, bridges, tunnels, and locomotives. To reduce longer-term financial risk, both the BNSF and the UPRR have investment strategies that emphasize increasing capacity through operations first and infrastructure expansion last.

To manage demand while new capacity is being added, the railroads are using pricing to turn aside lower-profit carload freight in favor of intermodal and coal traffic, which can be handled more cost-effectively and profitably in unit or destination-specific trains. In some markets and corridors, international intermodal traffic is squeezing out industrial and low-density agricultural carload traffic. Shippers, who are used to being price setters, are now price takers. This is a painful change for all shippers, especially captive shippers, who are being forced to rethink their supply chains and markets.

The national capacity crunch is focusing more rail traffic and railroad investment on the Pacific Southwest at the expense of the Pacific Northwest and Washington State. Continuing high levels of growth and the competition between the BNSF and the UPRR for the lucrative Southern California rail market have made Southern California the key focal point of investment for both railroads. This has shifted investment away from the Pacific Northwest and Washington State.

Capacity shortfalls will complicate the improvement of intercity passenger rail service. As a condition of the deregulation of the railroad industry in 1980, Federal law requires that freight railroads share the use of their lines with intercity passenger rail providers and give passenger trains priority over freight trains. But the differing needs of the passenger and freight railroad create tension between the needs of the passenger rail operators and the needs of freight rail operators as each tries to maximize the performance of their respective operations.

In general, frequent passenger rail service, especially frequent high-speed rail service, requires relatively wide time-space slots on the mainline to ensure that the passenger trains do not

overtake and collide with slower-moving carload freight trains.[9] The freight railroads, who own the track, are focused on obtaining the maximum benefit from each available train slot and the revenue they receive for providing train slots to the passenger railroads is usually modest.

When the Amtrak *Cascades* program was initiated, the freight railroads were willing to sell slots to the State, especially in return for physical improvements to the rail lines that would benefit both the passenger and freight railroads. With capacity tightening and increasing shipper pressure to improve throughput and reliability, the freight railroads are less willing or able to accommodate expansion of the intercity rail program. As a result, passenger services are often asked to pay a premium when they purchase slots or contribute to mainline capacity improvements.

Amtrak *Cascades* ridership and revenues have been increasing, but on-time performance has been decreasing as freight traffic increases and the freight railroads give priority to freight trains. Considerable additional investment is needed to achieve the program's longer-term goals of more frequent service and higher ridership. However, if congestion continues to build and the cost of improvements increases, on-time performance may deteriorate further, undermining ridership growth and reducing the cost-effectiveness of the program. Unless a coordinated solution is examined, the future cost of the Amtrak *Cascades* program may exceed the public benefits anticipated in the original plans, and the State may need to examine alternative strategies for the passenger rail program.

[9] Intermodal trains are also significant consumers of rail capacity, because they are long, move at speeds similar to passenger trains, and require priority of movement. The railroads market these trains as premium services, and they generate substantial revenue for the railroads.

4.0 Washington State Powers, Authorities, and Interests

Given the State's need for a robust rail system and the emerging capacity needs, what are the State's powers and authorities? What can the State do to address the capacity needs of the system?

4.1 Washington State Powers and Authorities in Freight and Passenger Rail

The State of Washington has a longstanding interest and involvement in both freight and passenger rail. Many of the needs of the Washington State rail system can be addressed by building on the existing freight and passenger rail policies in the Revised Code of Washington (RCW). The policy recommendations of this study build on this foundation, and in many instances, confirm existing policy. The existing statutes include the following:

The Essential Rail Assistance Account is a dedicated rail account created in the state treasury and governed by RCW 47.76.250. Money in the account can only be used for purposes specified in the RCW, including:

- *Acquiring, rebuilding, or rehabilitating rail lines;*
- *Purchasing or rehabilitating essential railroad equipment;*
- *Railroad improvements to mitigate port or mainline congestion;*
- *Construction of loading facilities; and*
- *Preservation of future rail corridors.*

- **RCW 47.76, Freight Rail Services –** This section, which reflects recommendations to the Legislature by the 1995 Washington State Freight Rail Policy Development Committee and others, spells out State policies and interests in freight rail. The statutes:
  - Recognize the critical role of a healthy freight-rail system in supporting the economic vitality of the State and key economic sectors;
  - Mandate continuing roles and responsibilities for the Washington State DOT and the Washington Utilities and Transportation Commission in administering the State's freight rail programs;
  - Provide for technical assistance in the establishment of county rail and port districts;
  - Create an Essential Rail Assistance Account to provide financial assistance for acquisition and improvements to rail lines, purchasing or rehabilitating rail equipment for essential services, and construction of loading facilities to increase business on light density lines or mitigate impacts of abandonment;

- Describe criteria for prioritizing projects that include cost-benefit analysis and cofunding from other beneficiaries; and
- Create a rail preservation program aimed at rail lines and rights-of-way abandoned by the Class I railroads.

- **RCW 47.79, High-Speed Ground Transportation –** This section establishes a program to promote a high-quality, high-speed, intercity rail system. The statute was enacted based on the Legislative recognition that major intercity transportation corridors in Washington are becoming increasingly congested; that high-speed ground transportation offers a safer, more efficient, and environmentally responsible alternative to increasing highway capacity; and that high-speed ground transportation can complement existing air transportation systems, as well as regional growth management plans. Some of the goals of this statute include the following:

  - Reduce travel time between downtown Portland and downtown Seattle to a maximum of two hours by 2010;
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Everett and Portland, Oregon by 2020;
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Everett and Vancouver, BC by 2025; and
  - Implement high-speed ground transportation service offering top speeds over 150 mph between Seattle and Spokane by 2030.

  In addition, this statute recognizes the Legislature's intent to develop public support and awareness of the benefits of a high-speed ground transportation system through the incremental upgrading of existing service. The statute makes the Department of Transportation responsible for developing a prioritized list of projects to improve existing passenger rail service.

- **RCW 47.46 Public-Private Transportation Initiatives –** This section spells out the benefits, roles, and responsibilities of public-private partnerships as a means of developing innovatively financed transportation infrastructure projects. The statute was enacted to create incentives for private investment in road and bridge projects, but many of the policies and approaches specified in the statute could be applied to public-private financing of private rail projects, where the State can demonstrate a clear public interest and significant benefits.

These existing statutes define the State's interest in freight and passenger rail, assign roles and responsibilities for the oversight of the State's interest in rail, and establish a number of specific passenger and freight investment programs. The statutes provide a broad foundation for continued state participation in the preservation and improvement of the rail transportation system, where there are public benefits to Washington State, its businesses, and its communities.

Any rail improvement strategies suggested for State participation also must be consistent with the Washington State Constitution. There are a number of provisions in the Constitution that may limit the State's involvement in the private rail system. The guidelines outlined in Article VIII of the Constitution, "State, County and Municipal Indebtedness," limit the extent to which the State, counties, or cities can give or loan credit to corporations. The provisions of RCW 47.76 and 47.46 address this limitation by making it clear that the State may not participate in projects with private ownership unless there are clear and demonstrated public benefits. The policies recommended in this report also recognize this need to demonstrate public benefit before the State can invest in the private rail system. Nevertheless, before the Legislature enacts specific investment or financial assistance programs that are rooted in the policies proposed in this report, a thorough legal evaluation of the programs' compliance with the constitutional provisions should be undertaken.

4.2 Washington State Investments in the Rail System

Over the last 15 years, the State has used its powers and authorities to:

- Develop the Amtrak *Cascades* service as part of its high-speed intercity rail program;
- Acquire and preserve rail lines and rights-of-way abandoned by the Class I and other railroads;
- Provide assistance to short line railroads to maintain service for shippers and receivers who do not have access to mainline rail service; and
- Purchase specialized railcars (e.g., hopper cars for the Washington Grain Train, and refrigerated produce cars) to

ensure an adequate pool of equipment for Washington State growers.

The State has contributed consistently to both the passenger and freight rail systems. Table 3 lists the passenger and freight rail projects that the State has participated in since 2003. By 2005, the State had contributed a total of about $120 million to the Amtrak *Cascades* program capital budget (including the projects listed below). Freight rail investments by the State have totaled about $31.5[10] million since 1990, with 2003 to 2005 funding alone reaching $12.5 million.

All the State's investments were authorized – some with clear policy guidance and analysis of the public benefits, others with less clear guidance and more limited assessment of longer-term benefits. As a result of these investments and other prior investments, the State now owns a number of rail lines, specialized railcars, rail maintenance equipment, and rights to use privately owned rail lines. But the State does not have a centralized inventory of these assets, nor does it have a comprehensive plan for their use, maintenance, and eventual replacement or disposal.

[10]This number represents actual state expenditures and does not include money programmed or set aside for future use.

Table 3. Recent and Ongoing Washington State Rail Investment Projects

Project	Year Complete	State Contribution
Crossover Projects		
Woodland Crossover	2005	$4 million
Ruston Crossover	2005	$3.6 million
Titlow High Speed Crossovers	2005	$4 million
Felida Crossover	2005	$2.2 million
Tenino High-Speed Crossover	In progress	$3.8 million
Centennial High-Speed Crossovers (Leary, Pattison)	In progress	$3.4 million
Winlock High-Speed crossovers	In progress	$3.4 million
Track Rehabilitation, Construction, or Realignment Projects		
PA Junction Curve Realignments and Delta Yard Storage Tracks	2008	$14 million
Chehalis Junction to Blakeslee Junction Via Centralia	In progress	$7 million
King Street Station Track Improvements	In progress	$15 million
Columbia Basin Railroad Wheeler-Warden 286K	In progress	$400,000
Northern Columbia Basin Railroad Project	In progress	$2 million
Point Defiance Bypass	In progress	$59 million
Port of Pend Oreille 286K Upgrades	In progress	$695,000
Tacoma RMDRR Morton Line Repairs	2005	$3.18 million
Stanwood Siding Upgrade	In progress	$3 million
Kelso-Martin's Bluff Rail Project	In progress	$53 million
Bellingham Waterfront Redevelopment	In progress	$5 million
Bellingham GP Area Upgrades	In progress	$200,000
Lewis and Clark Railroad Rehabilitation	In progress	$300,000
Mt. Vernon Siding Upgrade	In progress	$3.8 million
Railroad Yard Reconfiguration or Expansion Projects		
Dayton Yard Rehabilitation	In progress	$270,000
Vancouver Rail Project	In progress	$100 million
Swift Customs Facility at Blaine/White Rock	In progress	$3 million

Table 3. Recent and Ongoing Washington State Rail Investment Projects (continued)

Project	Year Complete	State Contribution
Actions to Support Agricultural or Industrial Carload Shippers: Spur Track Construction or Improvement and Short Line Acquisition, Other		
Industrial Spur Track to Winlock Glass Manufacturing Plant	2006	$800,000
Geiger Spur Connection	In progress	$5 million
PCC Cheney-Coulee City-Pullman Acquisition and Upgrades	In progress	$28 million
Produce Railcar Pool	In progress	$2 million
TS and W Yakama Sawmill Traffic Upgrades	In progress	$640,000
Increased Passenger Service		
New Seattle to Portland Roundtrip	2006	$2.75 million
Sound Transit: Sounder Track Improvements	2003	$17 million
Equipment Purchase or Upgrade		
One Existing Train Set from Oregon	2003	$7.5 million
Cascades Trainsets Overhaul	In progress	$10 million
Port Access		
Port of Grays Harbor Grain Terminal Loop Track	2003	$2 million
Port of Olympia On-Dock Rail Spur	2006	$375 thousand
Port of Columbia Railroad Improvements	In progress	$5.3 million
Port of Pasco Intermodal Facility Improvements	In progress	$5.4 million
Port of Pend Orielle 286K Upgrades	In progress	$695,000
Port of Walla Walla Railex Project	In progress	2.5 million
Transload Facility		
Quincy Transload Facility	2005	$2 million
Quincy Short-Haul Intermodal Pilot Project	In progress	$900,000
Feasibility Studies		
BNSF Skagit River Bridge Replacement Study	In progress	$150,000
Eastern Skagit Rail Study	2006	$50,000

4.3 Washington State Governance of Rail

Four groups within the state government have legislatively mandated roles and responsibilities for oversight, management, and implementation of the State's interest in passenger and freight rail.

Washington State Utilities and Transportation Commission (WUTC)

The Washington Utilities and Transportation Commission (WUTC) is responsible for railroad safety. The rail group is part of the WUTC safety and consumer protection division, but separate from the transportation safety group, which covers persons and property traveling Washington State roads. A primary responsibility of the rail group is to work with the Federal Railroad Administration (FRA) to inspect rail shipments of hazardous materials. There are more than 300 inspection points throughout the State, including shippers' facilities, railroad yards, and terminals.

Washington State Department of Transportation

Washington State Department of Transportation (WSDOT) is charged with planning, funding, implementation, construction, and maintenance of the multimodal transportation system in Washington State. As such, it is the conduit for state and Federal transportation dollars. The WSDOT freight rail program is housed within the Office of Freight Strategy and Policy. The passenger program is housed within the Public Transportation and Rail Division.

Freight Mobility Strategic Investment Board (FMSIB)

The Freight Mobility Strategic Investment Board (FMSIB) was created by the Washington State Legislature in 1998 to administer projects and strategies to lessen the impacts of freight movement on local communities and to facilitate efficient and profitable freight movement in Washington State. The 10-member board has representatives from Washington ports, railroads, cities, counties, WSDOT, the governor's office, truckers, steamship operators, and private citizens. Periodically, FMSIB issues a call for projects in order to maintain a six-year list of active projects. Its past rail funding has gone primarily to grade separations and crossing improvements.

Washington Community Economic Revitalization Board (CERB)

Washington Community Economic Revitalization Board (CERB) issues grants and loans that will retain existing jobs and create new ones, boosting business growth across the State. CERB can provide funding for rail projects that promote industrial development and has done so in the past. An example of this type of project was its $1,000,000 low-interest loan to the Port of Longview to help construct a second rail line and rail spurs serving a planned new facility for processing newly imported cars.

Each of these groups has knowledgeable and effective staff, and each carries out its mandates effectively; however, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to deal with the State, and in some cases, weakens the State's negotiating position.

4.4 Using State Powers and Authorities to Further State Interests in the Rail System

Building on its existing powers and authorities, the State can:

- Influence the investment decisions of the Class I railroads to resolve rail choke points of critical importance to key rail user groups in the State and, thereby, provide more capacity for Washington State rail users. This will generally involve public-private partnerships in which the State is a minority partner, but the State's investment can influence the timing and priority of the Class I railroads' investment decisions.

- Increase its advocacy for a Federal program that addresses critical national rail capacity needs. Many of the key capacity choke points in the Washington rail system affect the national economy and shippers outside of the State. The State should look for Federal action and funding to address these choke points.

- Work with rail users in industrial and agricultural markets to assist in the transition to rail service models that preserve high quality, reasonably priced, rail service options. The State can help ensure that these transitions occur in a timely fashion before the lack of action has negative economic consequences for the State.

- Work with third-party service providers and advocate for innovative operations practices and services that support the economic development goals of the State and its communities.

- Establish local governance models that allow shippers and affected communities to be involved directly in the resolution of short line problems.

- Support cost-effective intercity passenger rail options that improve the overall balance and performance of the State's highway and air passenger systems.

- Create a more effective, centralized, rail management function within state government with authority to advocate and negotiate state interests with the railroads.

5.0 Policy Recommendations

This report makes six policy recommendations that address capacity issues and system needs in the Washington State rail system. The policy recommendations address the justification for continued action in the rail system (Policy Recommendation #1), provide a framework for determining if specific actions are appropriate for the State (Policy Recommendation #2), present guiding principles for action in the rail system (Policy Recommendation #3), offer a new governance framework (Policy Recommendation #4), recommend involvement in national and regional rail policy discussions (Policy Recommendation #5), and propose adoption of a rail asset management plan (Policy Recommendation #6). These policy recommendations are consistent with the five prioritized guidelines for future transportation investments set forth in the Washington Transportation Plan:

- **Preservation –** Preserve and extend prior investments in existing transportation facilities and the services they provide to people and commerce. The guiding principles contained in Policy Recommendation #3 below emphasize investment in operational improvements and use of existing rail infrastructure prior to investment in new capacity.

- **Safety –** Target construction projects, enforcement, and education to save lives, reduce injuries, and protect property. Policy Recommendation #2 below lays out a framework for evaluating the benefits and impacts of action in the rail system and calls for an evaluation of safety impacts as one of the benefit measures.

- **Economic Vitality –** Improve freight movement and support economic sectors that rely on the transportation system, such as agriculture, tourism, and manufacturing. Throughout this report it is argued that rail transportation is critical to the economic vitality of key industries in Washington State. This is emphasized in Policy Recommendation #1 below.

- **Mobility –** Facilitate movement of people and goods to contribute to a strong economy and a better quality of life for citizens. The framework for evaluating potential actions in the rail system includes assessment of mobility impacts for both passengers and freight.

- **Environmental Quality and Health –** Bring benefits to the environment and citizens' health by improving the existing transportation infrastructure. The evaluation of environmental impacts of actions in the rail system is an important aspect of the decision-making process laid out in Policy Recommendation #2.

5.1 Policy Recommendation One

Policy Recommendation #1: Washington State should continue to participate in the preservation and improvement of both the freight and passenger rail transportation system where there are public benefits to Washington State, its businesses, and its communities.

The freight rail system in Washington State provides critical transportation for major manufacturing and resource industries and rail links to the State's international trade ports. Key segments of the rail system are already operating at or near their practical capacity. Given the current investment priorities and new operating strategies of the Class I railroads, it is likely that capacity will continue to be constrained, that shippers within Washington State (particularly those in traditional industrial and agricultural carload markets) will see declines in service or price increases, that growth at the ports could be slowed, and that there will continue to be conflicts between passenger and freight trains. Without state action, the businesses and citizens of the State will not realize the potential benefits that rail transportation could provide.

Working with the railroads, rail users, and communities, Washington State should develop a description of the rail transportation system needed for the 21st Century as a framework for policy and investment. The description of the rail system and its evolution should address the rail transportation needs of the major rail user groups in Washington State, and should be focused on the high-priority problems identified in this study. The specific types of actions that could be supported will vary by user group.

Table 4 lists examples of the types of strategies that would address the rail service needs of Washington State rail users. For each strategy, examples also are provided of specific projects and actions that could be undertaken to implement the strategy.

Table 4. Examples of Projects Addressing the Rail Service Needs of Washington State Rail Users

Possible Strategies	Possible Projects/Actions
Industrial Manufacturers	
• Offer financial assistance and technical assistance to shippers for site improvements. Assistance can be in the form of tax-exempt bond financing repaid with user fees, industrial development tax credits, or CERB assistance. • Provide assistance for development of industrial carload transload/consolidation facilities, including financial assistance programs (similar programs to those described for site improvements), site identification; investments in supporting infrastructure (both through CERB and state DOT programs), and expedited permitting processes. • Develop rail improvement districts for service preservation on low density lines. This could include expansion of the existing Local Rail Assistance program or new financing programs targeted to these districts.	• New on-site storage track. • Site access improvements off mainline. • New loop tracks on-site. • Proposed carload consolidation facilities in the South Sound area – possibly a rail-served industrial park for carload consolidation to rationalize a dispersed, low-density system of carload shippers near Tacoma and provide more efficient rail service for these customers.
Ports and International Trade	
• Develop a comprehensive strategy to increase State's east-west rail capacity in partnership with Class I railroads, ports, and Federal government.	• Investments that resolve high priority east-west bottlenecks, such as crown cutting the Stampede Pass Tunnel to allow double-stack trains and providing supporting infrastructure and grade separations to allow for increased usage of this line. • Advocate for Federal funding of high priority east-west bottlenecks and designation as Corridors of National Significance. An example would be the development of a high capacity corridor over Stampede Pass with a new tunnel, lengthened sidings, construction of new track from Lind to Ellensburg, and other downstream capacity improvements. • Investments that resolve high priority north-south bottlenecks, such as completing the Vancouver Rail Project that provides access to east-west corridors for trade traffic. • Advocating to railroads and ports beneficial operating strategies such as directional running (e.g., running directionally on Stevens Pass line and Stampede Pass line after crown cutting Stampede Pass) and scheduling alternatives. • Expedited permitting processes for projects that eliminate high priority bottlenecks.
• Increase domestic and international intermodal terminal capacity through financial assistance, identification of and local advocacy for sites, and development of expedited permitting processes.	• Work with Port of Seattle and Port of Tacoma to investigate potentially feasible sites for new near-dock/off-dock intermodal terminals.

Table 4. Examples of Projects Addressing the Rail Service Needs of Washington State Rail Users (continued)

Type of Action	Illustrative Examples
Ports and International Trade (continued)	
• Partner with ports, Class I railroads, and third-party switchers to resolve critical port access bottlenecks.	• Port of Vancouver Rail Extension Project (providing direct access to the Port from the Columbia River Corridor eliminating mainline diamond crossings on the I-5 Rail Corridor). • Advocating to railroads and ports beneficial operating strategies. • Expedited permitting processes for projects that eliminate high priority bottlenecks.
• Partner in community impact mitigation to allow for higher rail traffic associated with international trade.	• Rail crossing grade separations along the Stampede Pass line to accommodate increased traffic associated with crown cutting the tunnel.
Agriculture and Food Products Businesses	
• Encourage formation of Railroad Transportation Improvement Districts (under existing or expanded TID authorities) to assist rail carriers and shippers in low density agricultural and industrial carload corridors. Districts should receive financial assistance through the Local Rail Assistance program.	• Track upgrades to meet specified service objectives; • Maintenance of rights-of-way and track owned by the State or district; and • Development of consolidation facilities, including collaborative work with multiple interested parties (such as the Railex project).
Passenger Rail Users	
• Continue to support incremental development of high-quality intercity passenger rail programs where documented demand exists and high levels of farebox recovery of operating and maintenance costs can be achieved.	• Partner with Class I railroads in mainline infrastructure improvements that provide positive benefit-cost tradeoffs. • Identify traffic thresholds and key track segments where separating passenger rail and freight rail on their own track is cost-beneficial. • Advocate alternative operating strategies to the Class I railroads that will increase combined operating efficiencies for passenger and freight rail. • Give priority to projects that provide benefits to freight and passenger rail service.

Source: Cambridge Systematics, Inc.; and HDR, Inc., 2006.

Table 5 lists some of the worst choke points in the system, which affect many Washington State rail users, and projects that could help relieve these strategic choke points.

The State should base its decisions to participate in these or similar projects, programs, and rail initiatives based on a systematic assessment and comparison of benefits and costs across users and across modes, as described further in the next policy recommendation.

Table 5. Major Choke Points in the Rail System and Potential Projects to Increase Capacity

Choke Points	Potential Projects
Port of Seattle Access and Argo Yard Operations	Duwamish Corridor and Second Lead Improvements
Mainline access to Port of Tacoma	Tacoma Tideflats Improvements: North Wye Connection, Puyallup River Crossing
Port of Vancouver access	Port of Vancouver Rail Extension Project
I-5 Corridor and access to Ports of Kalama and Longview	Kelso to Martins Bluff Third mainline
I-5 Corridor Centralia-Chehalis Segment	Centralia-Chehalis Rail Corridor Consolidation Project (Blakeslee Junction)
I-5 Corridor-Everett and Delta yard segments	Everett Passenger Rail Speed Improvements and Delta Yard Expansion
I-5 Corridor-Bellingham segment	Bellingham Mainline Track realignment
East-West Corridor: Stampede Pass	Stampede Pass High Capacity Rail Improvement Project (including Lind-Ellensburg connection)
East-West Corridor: Spokane Improvements and Spokane to Sandpoint Corridor	Bridging the Valley Projects, including improving mainline capacity, 72 grade crossings, additional trackage, etc.
Lack of yard capacity in South Sound Region	Proposed carload consolidation facilities in the South Sound area.
Congestion at Vancouver (WA) Yard, including safety concerns	Vancouver Rail Project
Seattle to Portland Freight/Passenger Train conflicts	WSDOT Point Defiance Bypass Phase 1 Project

Source: HDR, Inc., 2006.

5.2 Policy Recommendation Two

Policy Recommendation #2: The State should base its decisions to participate in projects, programs, and other rail initiatives on a systematic assessment and comparison of benefits and costs across users and across modes.

The assessment should:

- Assess the benefits and costs of the projects, programs, and other rail initiatives for each of four major groups: the State; rail users, including shippers and passengers; carriers, including railroads, ports, and truckers; and affected communities.
- Consider qualitative and nonmonetary benefits and costs, as well as quantifiable benefits and costs.
- Compare the benefits and costs for the project to the benefits and costs of taking no action.
- Where appropriate, also compare the benefits and costs of the project to investment in other transportation modes and service that might achieve the same goals.
- Use the assessment of benefits and cost to determine who the State should partner with and how the partnership should be structured so that project costs are allocated in accordance with benefits.

The assessment of benefits and costs should focus on the key measures listed in Table 6. Using a short list of measures helps to simplify the assessment process and focus on the benefits and costs that are most important to the affected groups. For the State, key measures would include jobs created or retained in the private and public sectors, and the impact on rail-related union jobs; tax benefits gained through the growth of new or retained businesses; contribution to transportation system efficiency and balance; and costs. Details on how the benefits and costs can be measured are provided in the technical memoranda prepared for the study.[11]

[11] See Interim Report 2 and Task 7 Technical Memorandum for background information on the selection and use of the benefit and cost measures. Task 8 Technical Memorandum also provides examples of how the assessment methodology can be applied to evaluation of a set of illustrative case examples.

One of the measures recommended for the State is a benefit-cost ratio. RCW 47.76 requires that freight-rail projects be subject to a benefit-cost analysis. Some states rely exclusively on a benefit-cost analysis, but this report recommends using a benefit-cost ratio as one of several measures. This allows decision-makers to consider specific benefit measures – such as jobs created by a project – independent of costs.

The measures typically included in formal benefit-cost analysis of rail projects are listed in Table 7. The technical memoranda accompanying this report describe the process for conducting a benefit-cost analysis using techniques recommended by the FRA and adopted by other states.[12] The specific techniques used to calculate the benefits and costs will vary depending on the type of project. WSDOT's recent analysis of the PCC short line acquisition provides a good case study on how to apply some of the cost analysis techniques to freight rail projects.

Benefit-cost analysis has not been required for Washington State passenger rail projects, although WSDOT has conducted cross-modal cost analyses of passenger-rail projects, comparing the total cost per passenger mile for rail, highway, and air modes. This report recommends conducting benefit-cost analysis for passenger-rail projects, as well as for freight-rail projects. The analysis should compare state benefits to state costs for passenger-rail projects and, where appropriate, alternative investments. On-time performance, which strongly affects intercity ridership, must be examined carefully when conducting benefit-cost analysis of passenger rail projects.

If a freight-rail project is expected to have significant national economic benefits that might justify Federal funding, an economic impact analysis should be conducted using the framework recommended by the U.S. DOT in its "Toolbox for Regional Policy Analysis."[13]

The results of the assessment of benefits and costs for all rail users should be summarized in a decision matrix. The format for the decision matrix is illustrated in Table 8. A decision matrix allows for direct comparisons among alternative rail project packages and, where appropriate, comparisons of the benefits and costs of alternative investments in truck and barge services for freight, and

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[12]See Interim Report 2 and Technical Memorandum 7 for summary information on benefits and impacts used by other states and organizations.

[13]See "Toolbox for Regional Policy Analysis" at http://www.fhwa.dot.gov/Planning/toolbox/index.htm.

the benefits and costs of alternative investments in highway, bus, ferry, and air services for passengers.

Table 6. Recommended Benefit and Cost Measures

Rail User	Benefit and Cost Measures
State	• Jobs created/retained (private sector, public sector, and impact on rail-related union jobs) • Tax benefits (through new or retained businesses) • Contribution to transportation system efficiency/ balance (measured in terms of reduced travel delays, improved system reliability, or system redundancy, as appropriate) • Environmental benefits (air pollution and water quality impacts) • Safety benefits (reduced property damage, injuries, and fatalities) • Availability of partner funding • Cost to State • Benefit-cost ratio (using recommended benefit-cost analysis methodology)
Shippers	• Business cost impact (through impact on cost of service) • Access to service (does project increase rail/ transportation service options) • Service reliability (on-time performance) • Transit time
Passengers	• Rail capacity for passenger trains • Travel costs • Travel time • Increased modal choice/access
Railroads	• System velocity improvements • Hours of train delay • Yard dwell time • Increased revenue traffic • Equipment availability
Ports	• Throughput • Market share
Communities (Similar to State)	• Environmental benefits • Safety benefits • Reduced roadway delays and truck/auto delay at grade crossings • Local jobs created or retained

Source: Cambridge Systematics, Inc., 2006.

Table 7. Recommended Measures to Include in Estimating a Benefit-Cost Ratio

Measure	Explanation
Transportation and Economic Benefits	
Avoided maintenance costs	If the project preserves rail service, the no-action alternative may put more trucks on the highway. This may produce a net positive or negative benefit to be evaluated based on the type of road affected and the cost of maintaining the rail line.
Reduction in shipper costs (for shipments originating in State) – freight only	Benefits derived from lower logistic costs to the shippers, which ultimately can lead to lower consumer prices.
Reduction in automobile delays at grade crossings	Benefits resulting from improving grade crossing and decreasing automobile delays.
Economic Impacts	
New or retained jobs	Jobs that a particular project/action may keep from moving out of the State (e.g., by construction of a rail spur serving a factory or warehouse, etc.), or new jobs that are created within the State. Also to be considered are changes in job quality and pay levels (e.g., adding, losing, or changing union jobs).This measure accounts for both retained and new jobs.
Tax increases from industrial development	A rail action/project may foster industrial development that results ultimately in increased industrial property taxes to the State.
External Impacts	
Safety improvements	By diverting truck freight to rail, savings on highway safety improvements can occur.
Environmental benefits	Railroads are on average three or more times more fuel efficient than trucks. The State can benefit from savings due to environmental improvements.

Source: Cambridge Systematics, Inc., 2006.

Table 8. Sample Decision Matrix for Comparison of Alternative Rail Projects and Actions

	Measures	No Action	Alternative A	Alternative B
State	Jobs			
	Tax/Fee Benefits			
	System Efficiency			
	Environmental Benefits			
	Safety Benefits			
	Partner Funding			
	Cost to State			
	Benefit-Cost			
	Summary State			
Shippers	Business Cost Impacts			
	Access to Service			
	Service Reliability			
	Transit Time			
	Summary Shippers			
Passengers	Rail Capacity for Passenger Trains			
	Travel Costs			
	Travel Time			
	Increased Modal Choice/Access			
	Summary Passengers			
Railroads	System Velocity Improvements			
	Hours of Train Delay			
	Yard Dwell Time			
	Increased Revenue Traffic			
	Equipment Utilization			
	Summary Railroads			
Ports	Throughput			
	Market Share			
	Summary Ports			
Communities	Environmental Benefits			
	Safety Benefits			
	Reduced Roadway Delays			
	Local Jobs			
	Summary Communities			
National	Pct Benefits in WA State			
	Other States Benefiting			
	Summary National			

Source: Cambridge Systematics, Inc., 2006.

The decision matrix can accommodate quantitative measures, as well as qualitative measures. A simplified case study of how this framework can be used is provided in the appendix to this report.

Table 9 shows how the assessments of benefits and costs by affected group might be arrayed to determine who the State should partner with and how the partnership should be structured, so that project costs are allocated in accordance with benefits.

The assignment of an overall assessment of benefits and costs as "high," "medium," or "low" is a process of value judgment by the decision-maker. This study does not recommend a specific weighting scheme at this time, preferring that the initial applications of this process be as open and transparent as possible. As the State gains experience in assessing and weighting the benefits and costs of rail projects, the Legislature may wish to direct the WUTC and WSDOT to adopt a formal weighting procedure, such as that used by the FMSIB. The Board's weighting scheme is summarized in Table 10.

In states that conduct rail benefit-cost assessments and analyses, the technical work is done by a variety of different organizations that have responsibility for rail programs and policies. This may include state DOT rail offices, separate rail agencies or commissions, or policy offices at the secretarial level. For example, at Florida DOT, the Rail Office is responsible for rail investment benefit-cost assessment and analysis; in Virginia, it is the Rail Division of the Virginia Department of Rail and Public Transportation; at Pennsylvania DOT, it is the Bureau of Rail Freight Ports and Waterways; and at New Jersey DOT, it is the Bureau of Freight Services. At Louisiana DOTD, coordination is done through the secretarial Office of Intermodal Transportation, and at Maryland DOT, coordination is through the secretarial Office of Freight. In all cases, these offices draw on the technical and policy expertise and advice of other state and local agencies involved in rail-related finance, regulation, safety, environmental protection, and economic development.

Table 9. Benefit Evaluation Cross-User Group Comparison

Proposed Action	WA State	Shippers	Passengers	Railroads	Community	Likely Recommendation	Level of Action	Example
A	H	H	H	H	H	State should participate, but only if other beneficiaries contribute appropriate share	Consider direct investment and supporting legal and institutional mechanisms	Consider sources such as additional dedicated state freight rail funds, Federal funding sources through the Safe Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), and other state matching sources
B	H	L	L	L	H	State should participate and be prepared to contribute more than other groups	Consider direct investment and supporting legal and institutional mechanisms	Consider sources such as additional dedicated state freight rail funds, Federal funding sources through SAFETEA-LU, and other state matching sources
C	M	M	M	M	M	State should participate with caution and only if costs to do so are low	Consider tax exempt financing loans or other methods that have limited costs to State, but benefit private industry	Consider public-private partnerships, tax credits, and other nonfinancing incentives
D	L	H	H	H	L	State should probably not participate	State should probably not participate with financial, institutional, or legal mechanisms	No state role is anticipated
E	L	L	L	L	L	State should probably not participate	State should probably not participate with financial, institutional, or legal mechanisms	No state role is anticipated

Source: Cambridge Systematics, Inc., 2006.

H = High; M = Medium; and L = Low.

Table 10. Freight Mobility Strategic Investment Board Evaluation Criteria and Weights

Evaluation Criteria Category	Weight
Freight Mobility for the Project Area	35 maximum
Freight Mobility for the Region, State, and Nation	35 maximum
General Mobility	25 maximum
Safety	20 maximum
Freight and Economic Value	15 maximum
Environment	10 maximum
Partnership	25 maximum
Consistency with Regional and State Plans	5 maximum
Cost	10 maximum
Special Issues	8 maximum
Total	**188 points**

Source: http://www.fmsib.wa.gov.

5.3 Policy Recommendation Three

Where the State determines there are sufficient public benefits to justify public participation in the preservation and improvement of the rail transportation system, its actions should be guided by the following general principles:

- **Emphasize operations and nonfinancial participation in projects before capital investment –** The State should give priority to preserving and improving rail transportation through leadership, planning, permitting, maintenance, and operations that leverage existing rail infrastructure and services rather than through capital investment.

- **Preserve and encourage competition –** Investment in one railroad's infrastructure can change the competitive balance among railroads to the detriment of the overall system. Before making an investment that directly benefits only one rail company, the State should conduct a comprehensive analysis of competitive impacts on other rail carriers and users.

- **Target actions to encourage private investment that advances Washington State economic development goals –** State

The State Can Promote Operational Strategies That Maximize Benefits for Washington Rail Users and Communities

- *Careful scheduling to avoid conflicts;*
- *Longer trains;*
- *Consolidating primary switching locations;*
- *Consolidated dispatch center;*
- *Carrier and routing alternatives;*
- *Scheduled point-to-point service;*
- *Improved intermodal terminal production;*
- *Reducing/eliminating main line work events;*
- *Co-production;*
- *Switching zone agreements; and*
- *Rationalizing carload network with regards to the truck/rail transloading facilities, new carload gathering/distribution centers, and remarketing of unprofitable traffic.*

actions should influence railroad investment decisions so that rail improvements generate greater benefits to Washington State than could be achieved if the State did not invest.

- **Leverage State participation by allocating cost responsibility among beneficiaries –** The State should not invest in the private rail system unless the railroads and other beneficiaries participate in proportion to their benefits and risks.

- **Require projects to have viable business plans –** Funding from the State should be contingent upon demonstration that the project proponent has rail service and customer agreements in place in order to make the project financially viable.

5.4 Policy Recommendation Four

Policy Recommendation #4: The State should designate a single entity to coordinate and direct the State's participation in the preservation and improvement of the rail transportation system. This entity should have the authority to negotiate directly with the railroads.

The responsibility for oversight and management of Washington State's rail programs and investments is divided among the WSDOT, the FMSIB, the Washington Community Economic Revitalization Board, and WUTC. Each has knowledgeable and effective staff, and each carries out its mandates effectively; however, the lack of a central point of contact and coordination makes it difficult for businesses, communities, and the railroads to deal with the State, and in some cases weakens the State's negotiating position.

This situation exists in many states and is only now becoming a significant problem as states move to deal with increasingly congested freight transportation systems and insistent demands from businesses and communities that they create more comprehensive policies and undertake larger investment programs.

Some states have moved to address the problem by organizing cross-agency policy committees or by designating a single entity or position, such as an undersecretary of transportation to coordinate state policies and programs and negotiate with shippers and carriers.

Having a single entity coordinate all Washington State's rail activities would give the State the ability to:

- Represent the interests of multiple stakeholders in negotiations with rail carriers more effectively than would individual stakeholders by themselves;

- Develop strategic packages of projects and actions across the State that would effectively promote state interests and be more attractive to the rail carriers than dealing with projects on a case-by–case basis;

- Represent the interests of multiple communities in resolving common rail issues; and

- Work more effectively with partners in other states and at the national level.

Washington State may wish to explore one or both of the approaches that are being taken by other states. Any approach taken by the Legislature should include oversight over freight and passenger rail systems, both public and private, and adequate authority to represent the interests of the State with the carriers, the Federal government, and other states.

5.5 Policy Recommendation Five

Policy Recommendation #5: The State should take an active role in influencing and shaping the development of national rail policies and programs. The State should also develop a multi-state coalition to address rail system needs across the Pacific Northwest.

The Washington State rail system is an integral part of the national and Pacific Northwest rail systems. The State's rail needs transcend the State's boundaries. The nation is entering the early stages of a freight transportation capacity crisis. The congressionally-mandated National Surface Transportation Policy and Revenue Study Commission, the American Association of State Highway and Transportation Officials, the Association of American Railroads, the Congressional committee charged with reauthorization of the national transportation program, and other groups are working to address the emerging crisis and establish forward-looking national visions, policies, and programs for the rail system. Washington State should participate actively in these discussions.

As part of this process, Washington State and its neighbors should also establish a multistate coalition to address rail system needs

across the Pacific Northwest. Washington State and its neighbors should use the coalition as a forum to establish their common needs and work with the railroads to identify, prioritize, and implement the most cost-beneficial regional improvements. There is precedent for this in the I-95 Corridor Coalition and its Mid-Atlantic Rail Operations Program. The Pacific Northwest rail coalition could be formed as part of the newly established West Coast Corridor Coalition; as an independent coalition advising the Pacific Northwest states, the West Coast Corridor Coalition, and national groups; or as a formal multistate compact. There is existing legal precedent for multistate compacts, which are contracts among states that carry the force and effect of statutory law. A multistate compact could create the legal framework to develop policies, plans, and regulatory mechanisms for multistate rail programs in the Pacific Northwest.

The State should use the procedures recommended in this report to begin to identify projects of national and regional significance. And it should look to national and multistate programs to help fund and implement these projects.

5.6 Policy Recommendation Six

Policy Recommendation #6: The State should implement the asset management plan developed as part of this study to govern investment and management decisions for state-owned rail assets.

The guiding principles of the asset management plan are as follows:

- The asset management plan should be based on a business-case analysis of the goals and objectives for each class of assets;
- The plan should use clear performance measures and a monitoring system to determine how assets are performing;
- Benchmarks for each performance measure should be established based on industry standards; and
- An inventory management system (including information about condition and disposition of the assets) should be adopted.

The State currently owns the following classes of assets: freight rail lines, freight railcars (grain cars and refrigerated cars),

maintenance-of-way equipment, right-of-way, passenger train sets and passenger service agreements (train slots). A more complete inventory of these assets is provided in the full asset management plan. For each class of assets, the key features of the asset management strategy are summarized in Table 11.

Table 11. Asset Management Principles for State Rail Assets

Freight Rail Lines (Short Lines)	• State should be owner of last resort and should encourage private ownership and/or operation in conjunction with Rail Improvement Districts if public involvement is warranted. • Purchase decisions should be based on benefit-cost analysis. • Operate lines in conformance with business plan that specifies projected customer base and monitors performance measures (carloads carried, revenues earned, and return on invested capital) against specified benchmarks. • Implement inventory maintenance and monitoring system with periodic inspections and assessments of condition. Use annual and life-cycle costs as performance measures. • Third-party operating agreements should specify obligations of operator with respect to meeting specified performance benchmarks.
Freight Railcars	• Implement inventory and equipment tracking system. • Track location of each car (using global position systems where feasible). • Track usage by Washington State shippers, including level of revenue service. • Specify periodic condition inspections. • Adopt performance measures and benchmarks, including costs of operation and maintenance per revenue mile and life-cycle costs.
Miscellaneous Rail Equipment	• Develop inventory of equipment and conduct condition assessment. • Over longer term, consider disposal of the equipment and outsourcing the activity to the private sector.
Passenger Train Sets	• Continue with current Amtrak asset management program. • Investigate approaches to develop a sinking fund to cover depreciation of train sets that would be protected from use in meeting general fund current obligations.

Source: Cambridge Systematics Inc., and HDR Inc., 2006.

Appendix A. Benefit Assessment Illustrative Case Study – East-West Capacity Projects

As described in Section 3.4 of this report, constraints on the east-west lines of the Washington State rail system could inhibit future rail traffic growth, particularly intermodal growth through the ports. As an illustration of how the benefit assessment matrices can be used to evaluate strategic project packages, this case study presents an evaluation of a package to increase east-west capacity. A version of this case study that provides a detailed description of all of the calculation methodologies and data inputs, along with several other case studies, is included in Technical Memorandum 8.

The projects in this package include improving Stampede Pass to allow for double-stack containers, and incorporating "Bridging the Valley" improvements for the Spokane to Sandpoint, Idaho section. The State must decide if it should participate in this east-west rail capacity expansion program, and if so, at what level of involvement. There are two alternatives for Washington State to consider in this illustration:

- **Do Nothing –** Under this scenario, the State does not invest public funding to improve east-west capacity. Any investment is done by the railroads.

- **Alternative A: East-West Capacity Expansion Project –** A $350 million investment, shared between the State and the railroads, for selective capacity improvements. This will add approximately 50 percent more capacity (from 22 to 24 trains per day to 34 to 36 trains per day).

A summary of the improvements for Alternative A is contained in Table A.1. Table A.2 provides the results of the benefit/impact evaluation of Alternative A and a No Action case. Table A.3 provides a summary of the final assessment of benefits/impacts across all affected groups.

Table A.1 East-West Capacity Expansion: Summary of Alternative A

Project
Crown cut Stampede Pass
Construct Lind, WA to Ellensburg, WA connection
Install 8,000-ft siding tracks to provide 20-minute headways between Auburn, WA and Ellensburg, WA and between Lind, WA and Spokane, WA
Install CTC train control system overlaid with ETMS
Grade separated the corridor from Spokane, WA to Athol, ID as suggested in "Bridging the Valley"

Table A.2 East-West Capacity Expansion: Benefit/Impact Evaluation

	Measures	No Action	Alternative A: East-West Capacity Expansion Project
State	Jobs	Net New Jobs = 0	Net New Jobs = 500
	Tax/Fee Benefits	None	None
	System Efficiency	Congested	Reliable
	Environmental Benefits	Negative: emissions from YY trains x 400 mi x 12,000 tons	Negative: emissions from 12 trains x 300 mi x 6,480 tons
	Partner Funding	BNSF & UP make improvements	Expect railroad participation
	Benefit/Cost	n/a (Cost = $0)	B/C = 0.181
	Summary State	*LOW*	*MEDIUM*
Shippers	Business Cost Impacts	Increases due to increased rail cost, loss of service, and deteriorating reliability	Improvements to international intermodal traffic; little benefit to WA shippers
	Access to Service	Railroads disinvest from selected rail markets	Improved access for international shippers
	Service Reliability	Poor	Reliable in short term
	Summary Shippers	*LOW*	*MEDIUM*
Passengers	Rail Capacity for Passenger Trains	Limited to current services	Potential 1 or 2 train expansion
	Summary Passengers	*LOW*	*LOW*
Railroads	System Velocity Improvements	Further delays due to capacity issues	Crown cutting Stevens Pass, installing CTC, and eliminating grade crossings will increase velocity.
	Hours of Train Delay	Requires simulation analysis	Requires simulation analysis
	Yard Dwell Time	Requires simulation analysis	Requires simulation analysis

Table A.2 East-West Capacity Expansion: Benefit/Impact Evaluation (continued)

	Measures	No Action	Alternative A: East-West Capacity Expansion Project
	Increased Revenue Traffic	Yes	12 trains x 100 cars/train x $6000 car
	Equipment Utilization	Little change	Reduction in car cycle time; requires simulation analysis to quantify
	Summary Railroads	*LOW*	*MEDIUM*
Ports	Throughput	Current Capacity = XX	Additional 12 trains/day = 2400 containers per day
	Market Share	Decline	Requires complete analysis of West Coast Ports
	Summary Ports	*LOW*	*HIGH*
Communities	Environmental Benefits	Negative: emissions from YY trains x mileage x 12,000 tons/train	Negative: emissions from 12 trains x 300 miles x 6,480 tons/train
	Safety Benefits	More potential train incidents and grade crossing accidents due to increased trains	More potential train incidents; safety improvements from elimination of 20 grade crossing
	Reduced Roadway Delays	No change.	Elimination of 20 grade crossings
	Local Jobs	Mostly at the port; some increase in train crews	Mostly at the port; some increase in train crews
	Summary Communities	*LOW*	*MEDIUM*
National	Pct Benefits in WA State	Requires detailed economic analysis.	Requires detailed economic analysis
	Other States Benefiting	ID, IN, IL, MT, MN, NE, NJ, OH, PA, NY	ID, IN, IL, MT, MN, NE, NJ, OH, PA, NY
	Summary National	*LOW*	*MEDIUM*

Table A.3 Summary Decision Matrix

	No Action	Alternative A: East-West Capacity Expansion Project
State	Low	Medium
Shippers	Low	Medium
Passengers	Low	Low
Railroads	Low	Medium
Ports	Low	High
Communities	Low	Medium
National	Low	Medium

Appendix B. Glossary

A

Automatic Block Signaling (ABS) – An automatic system that prevents two trains moving in the same direction from occupying the same section of track simultaneously. As the lead train exits a section of track, it automatically triggers the signal to allow the following train to enter.

B

Branch Lines – A subsidiary, secondary, local, or feeder line of railway, which extends from the principal lines of rail traffic to connect to external shipping points.

C

Carload –

1. Carload services are those that use a variety of railcar types to carry a range of commodities to a variety of customers. They generally carry lower-volume, higher-weight commodities than Intermodal trains.

2. A rail-car loaded to its weight or space-carrying capacity.

Carload Manifest – Another name for mixed-carload shipments, or those that move a diverse range of commodities on a single train.

Centralized Traffic Control (CTC) – Train movements are controlled by signals, which are in turn controlled by dispatchers at a centralized location. The dispatchers will generally have a computerized graphical depiction of all or part of the railroad, allowing them to monitor train movements. Software prevents conflicting signal settings that could lead to an accident.

Class I – A railroad with average annual gross operating revenue of $250 million or more, in 1991 dollars. The threshold is adjusted every several years by the Surface Transportation Board to reflect

the effects of inflation and other factors. For example, in 2004, the threshold was $277.7 million.

Class II – A railroad with average annual gross operating revenue of between $20 million and $250 million, in 1991 dollars. In 2004, the lower and upper thresholds were $20.5 million and $277.7 million. Railroads considered by the Association of American Railroads (AAR) as "Regional Railroads" are typically Class II railroads

Class III – A railroad with average annual gross operating revenue of less than $20 million, in 1991 dollars. In 2004, the threshold was $20.5 million. Local short-line railroads typically fall under this category.

Commuter Rail – Urban passenger train service for local short-distance travel operating between a central city and adjacent suburbs. Service must be operated on a regular basis by or under contract with a transit operator for the purpose of transporting passengers within urbanized areas, or between urbanized areas and outlying areas. It does not include heavy rail rapid transit or light rail/street car transit service. Intercity rail service is excluded, except for that portion of such service that is operated by or under contract with a public transit agency for predominately commuter services.

Containers – Standard-sized rectangular box used to transport freight by ship, rail and highway. International shipping containers are 20 or 40 feet long, conform to International Standards Organization (ISO) standards and are designed to fit in ships' holds. Containers are transported on roads atop a container chassis towed by a tractor. Domestic containers, up to 53 feet long and of lighter construction, are designed for rail and highway use only.

D

Dark Territory – Unsignalized sections of the railroad.

Double-stack – The movement of containers on articulated rail cars which enable one container to be stacked on another container for better ride quality and car utilization.

Drayage – The movement of a container or trailer between an intermodal terminal and a customer's facility for loading or unloading. The vast majority of drayage takes place by truck.

Dynamic Capacity – The ability of a yard to receive, process, and dispatch traffic, generally described in trains per hour for receiving and dispatching, and cars per hour for switching.

Dynamic Track Occupancy – The density or spacing of moving trains.

H

Hopper Cars – A railroad freight car that can be either covered or uncovered, and has doors on its sides or undersides. Hopper cars are used to transport loose bulk commodities such as grain, ore, and coal.

G

Grade Crossing – A highway crossing that is at the same level (grade) as the rail.

Gross State Product (GSP) – The total market value of all final goods and services produced for money in a state within a given period of time, after deducting the cost of goods and services used in the process of production, but before depreciation.

I

Integrator – Marketing companies that assume the all-in organization and handling of complete shipping orders from the consignor to the consignee.

Interchange – A junction of highways on different levels that permits traffic to move from one to the other without crossing traffic streams.

Intermodal –

1. The use of two or more modes of transportation to complete a cargo move. For example, truck/rail or truck/ship.

2. Freight that is packed in an intermodal unit (trailer or container) and can therefore be transferred directly from the container ship to rail or truck for transportation. Intermodal shipments generally hold higher-value, lower-weight commodities than unit or carload trains.

Intermodal Units – Trailers and containers that can be transported, fully-loaded, from ship to rail or truck.

L

Line-haul – The movement of a railroad unit from origin to destination.

Long-haul – A freight shipment having a long distance between the origin and destination.

Logistics – Movement and supply of goods through the economy from raw materials, through all stages of the manufacturing process, to the final delivery of the finished product to companies and consumers.

M

Mainlines – A designation by each railroad of its own track signifying a line over which through-trains pass with relatively high frequency. Mainlines generally have heavier weight rail, more sophisticated signaling systems, and better maintenance than branchlines.

Multimodal – Representing more than one mode of transportation.

P

Practical Capacity – This is the capacity at which trains on the system are all moving without incurring significant delay or experiencing significant operational problems. Also defined as "The percentage of theoretical capacity that provides reliable and predictable train operation." The rail industry considers this to be between 50 and 60 percent of theoretical capacity.

R

Railcar – Double- stack railcars vary in length from 70 to 325 feet, with an industry average (for purposes of estimating capacity) of 305 feet. 270-foot railcars are better suited to the conveyance of international containers and are currently being developed by the major carriers to maximize the mainline capacity.

Rail Capacity – The number of trains that can occupy a given segment of track over a given period of time.

S

Short-haul – A freight shipment over a short distance between origin and destination.

Shortline – A switch carrier or roadhaul carrier that is not a Class I carrier. The carrier usually owns less than one hundred miles of track.

Sidings – A track parallel to a main track, having switches at both ends, used for meeting and passing trains.

Single-track – Rail right-of-way comprised of only one line of track, used by trains running in either direction.

Static Capacity – The ability of a yard to accommodate standing equipment (i.e., cars that are stored, awaiting movement, or awaiting processing).

Surface Transportation Board – The Surface Transportation Board (STB) is an economic regulatory agency created by Congress to resolve railroad rate and service disputes and review proposed railroad mergers. Although administratively affiliated with the U.S. Department of Transportation, it is decisionally independent. It serves as both an adjudicatory and a regulatory body.

Switch – A mechanical installation enabling trains to be guided from one line of rail tracks to another.

T

TEU – See Twenty-Foot Equivalent Unit.

Terminal – Area where docking and handling of freight takes place. In the case of intermodal shipping, it is the area where modal transfer of containers/trailers takes place.

Theoretical Capacity – The maximum amount of traffic that the infrastructure can accommodate.

Trackage Rights – The legal right to use a rail line.

Track Warrant Control (TWC) – A verbal authorization, usually with a radio, from a dispatcher to the train engineer permitting the train to occupy a specific section of the track. Used in unsignalized (dark territory) sections of the railroad.

Transload – To physically transfer commodity from one transportation vehicle to another, such as unloading freight from a rail car into a truck. This is a labor-intensive process that is usually performed manually.

Twenty-Foot Equivalent Unit (TEU) – The unit of measure for international container volumes. A 20-foot container is counted as one TEU, and a 40-foot container is counted as two TEUs. The 40-foot container is the most common type used in waterborne transportation.

U

Unit Train – A freight train composed of cars carrying a single type of commodity that are all bound for the same destination. By hauling only one kind of freight for one destination, a unit train does not need to switch cars at various intermediate junctions and so can make nonstop runs between two terminals. This reduces shipping time and shipping costs.

Washington State

Amtrak *Cascades* Mid-Range Plan

Washington State
Department of Transportation

December 2008

Prepared by the Freight Systems Division
State Rail and Marine Office
Washington State Department of Transportation

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- Fax your comments to (360) 705-6821; or
- E-mail your comments to rail@wsdot.wa.gov

Persons with disabilities may request this information be prepared and supplied in alternate forms by calling the WSDOT ADA Accommodation Hotline collect 206-389-2839. Persons with vision or hearing impairments may access the WA State Telecommunications Relay Service at TT 1-800-833-6388, Tele-Braille 1-800-833-6385, or Voice 1-800-833-6384, and ask to be connected to 360-705-7097.

Washington State Amtrak *Cascades* Mid-Range Plan

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Executive Summary

The Washington State Legislature directed the Washington State Department of Transportation (WSDOT) to develop a mid-range plan for Amtrak *Cascades* that identifies specific steps to achieve additional service beyond current levels. As stated in ESHB 1094, Section 226, WSDOT is required to submit a mid-range plan to the Office of Financial Management and the transportation committees of the legislature by December 31, 2008. The *Amtrak Cascades Mid-Range Plan* fulfills the legislative mandate by identifying and developing options that outline steps to achieve incremental Amtrak *Cascades* services for the next eight years.

Background

Washington State faces both challenges and opportunities resulting from the fundamental changes in our economy and society. Public investment policies embrace solutions that address multiple issues such as economic globalization, population growth, increased roadway congestion, higher fossil fuel prices, global climate changes, and increases in natural and man-made disasters.

Passenger rail, once used as a means to address only mobility problems, is increasingly viewed and used, at both national and regional levels, as an integrated part of robust and resilient multimodal transportation systems. Such robust transportation systems will help policymakers achieve multiple policy ends, including economic viability, societal mobility, environmental sustainability, and public safety.

Amtrak *Cascades* is an intercity passenger rail service between Eugene, Oregon, and Vancouver, British Columbia (B.C.). It is sponsored by the states of Washington and Oregon in partnership with other parties. The service, known as the Amtrak *Cascades*, provides travelers with a viable transportation alternative for their intercity trips.

Rail development in the Pacific Northwest began in 1864, when President Abraham Lincoln signed the Northern Pacific Railroad Charter to build a direct rail connection between the Great Lakes and Puget Sound. Washington State investment in Amtrak intercity passenger rail service began in 1994. After incremental infrastructure enhancements by Washington State and its partners, intercity passenger rail service with Talgo trains began in 1999, and was branded Amtrak *Cascades*.

Amtrak currently operates Amtrak *Cascades* intercity passenger rail service on the Pacific Northwest Rail Corridor (PNWRC), which runs roughly parallel to the I-5 corridor between Vancouver, British Columbia, and Eugene, Oregon. The PNWRC is owned by BNSF Railway (BNSF) in Washington State and by Union Pacific Railroad (UP) in Oregon State. Amtrak *Cascades* offers one daily round trip between Seattle and Vancouver, B.C.; one daily round trip between Portland and Bellingham; two daily round trips between Eugene and Portland; and four daily round trips between Portland and Seattle.

Plan Purpose

In response to a legislative mandate, the *Amtrak Cascades Mid-Range Plan* FY2010 to FY2017 is to provide Washington State policymakers with four strategic investment options for infrastructure development. These plan options incrementally enhance service capacity, improve on-time performance, and increase ridership on the segment between Seattle and Portland over the next eight years.

The mid-range plan:

- Identifies the needs of intercity passenger train services.
- Assesses potential of passenger rail as a strategic multimodal transportation solution.
- Specifies the steps of improving infrastructure to deliver additional intercity passenger services.
- Links capital and operational investment to ridership growth and economic and societal benefits.
- Provides a variety of information to support informed decision-making processes—legislative budgeting and prioritizing.

Methodology

The strategy adopted by WSDOT to develop the mid-range plan is fact-based and demand-driven. WSDOT strengthened its ridership forecast and analytic capacity by developing robust ridership databases and forecast models. WSDOT improved capital project cost estimation through a specific cost study of all historic rail projects.

Based on management directives, the mid-range plan provides policymakers with options that are designed, analyzed, and presented to address socioeconomic policy issues. Results of investment in infrastructure improvements to add additional services are assessed and measured in terms of enhanced capacity, improved reliability, and increased ridership for considering funding additional Amtrak *Cascades* services. Economic impact assessment, benefit/cost analysis, and cross

modal comparison were also performed to assist policymakers in linking the investment of an option to its effects on the economy and society.

Public Involvement

In the development of the mid-range plan, an advisory committee was formed, involving identifiable stakeholders. The advisory committee's role was to help WSDOT assess and evaluate beneficial impacts of rail infrastructure improvement on society, to help WSDOT understand concerns of local communities, and to share information and provide feedback during the mid-range plan development process. Advisory committee stakeholders involved in the development of the mid-range plan include:

- Metropolitan Planning Organizations and Regional Transportation Planning Organizations in the I-5 corridor
- Counties and cities within the study area
- Oregon State
- Province of British Columbia
- Private railroads
- Amtrak
- Washington Public Ports Association
- WSDOT planning units in different modes
- WSDOT regions
- All tribes in Washington State with an interest in the I-5 corridor
- Passenger rail advocacy groups

Two public/advisory committee meetings were held at WSDOT, led by State Rail and Marine Office staff, providing progress reports and opportunities for public comments and discussion. After the public/advisory committee meetings, the draft plan was available for two weeks for public review and comment. Some public comments were incorporated into the final draft and the remainder are included in Appendix 13 with WSDOT's responses.

Mid-Range Plan Options

Options presented in the mid-range plan are designed in the context of the current macroeconomic policymaking environment. The options build on incremental strategies with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. The four options presented in this plan are different approaches to achieve incremental Amtrak *Cascades* services for the next eight years between Portland and Seattle, where the greatest concentration of ridership and the most service improvements are needed (Exhibit ES-1).

Exhibit ES-1: Mid-Range Plan Options

Option 1 – Maintaining the Current Operation	• Option 1 is an analytical baseline. • No capital investment is needed. • It maintains capacity at four daily round trips between Seattle and Portland. • On-time performance is about 60 percent.
Option 2 – Incremental Strategy – Minimizing Capital Investment	• Completes four capital projects already underway by FY2012. • Capital investment is $141 million. • Capacity increases from four to five daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 95 percent.
Option 3 – Incremental Strategy – Matching Supply and Demand	• Completes all four projects in Option 2 and five additional new capital projects bye FY2017. • Capital investment is $537 million. • Capacity increases from four to six daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 97 percent.
Option 4 – No Financial Constraints	• Completes all four projects in Options 2 and 3 and five additional new capital projects by FY2014. • Capital investment is $817 million. • Capacity increases from four to eight daily round trips between Seattle and Portland. • On-time performance improves from about 60 percent to about 92 percent.

Investment in Capital Projects

Exhibit ES-2 shows Amtrak *Cascades* proposed infrastructure improvements and investment. Capital projects are incrementally developed as project groups. Project groups are building blocks that combine a number of projects to deliver an incremental service level. The cost estimates are based on prices during the implementation timeframe of each specific mid-range option.

Exhibit ES-2: Capital Investment by Option

Project Group*	Year of Completion	Capital Cost Estimates* ($ Million)				Deliverables
		Option 1: $0	Option 2: $141 Million	Option 3: $578 Million	Option 4: $817 Million	
Project Group A***: $141M for Options 2, 3, and 4	Option2,3,and 4: 2012		$141.2	$141.2	$141.2	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.
Project Group B: Option 3 $437M; Option 4 $334M	Option 3: 2017 Option 4: 2015			$437.1	$334.2	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.
Project Group C: $341M for Option 4	Option 4: 2015				$341.4	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.

* A project group is a set of projects or project stages to be implemented collectively to achieve additional service.

** Costs do not include anticipated expenditures prior to July 2009 in 2008 Transportation Supplemental Budget. These projects were currently funded as: Tacoma – Bypass of Pt. Defiance – 66th St. to Nisqually, $57.1 million; Vancouver – Yard Bypass and W 39th St., $59.9 million; King Street Station – Track Improvements, $13 million; Cascades Train Sets – Overhaul, $4 million. The cost estimates listed in options are additional costs needed to complete these projects starting July 2009.

*** Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.

Source: WSDOT State Rail and Marine Office

Operating Costs, Revenue, and Investment in Operations by Option

Operating costs include the costs to operate Amtrak *Cascades* intercity passenger train services and costs to maintain service equipment. Since each option in the mid-range plan operates at a different level, the operating costs vary. However, Options 3 and 4 operate more efficiently due to economies of scale.

Revenue includes ticket revenues and revenues from services provided on the trains such as food and beverage revenues.

Net state costs in operations is the state's net investment from public funds for Amtrak *Cascades* operation. It is the total operation costs minus revenues from operation. It is a public investment that aims for gaining greater economic and societal benefits.

Exhibit ES-3 shows the sum of operating costs, revenue, and investments in operations for all plan options from FY2010 to FY2017.

Exhibit ES-3: Total Operating Costs, Revenue, and Net State Costs for Amtrak *Cascades* Operations Sum of FY2010 - FY2017 ($ Millions)

Plan Options	Operating Costs*	Revenue**	Net State Costs for Amtrak Cascades Operation***
Option 1: Maintaining Current Operation	$235.7	$118.4	$117.3
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$360.2	$144.4	$215.8
Option 3: Incremental Strategy 2 - Supply Meets Demand	$366.7	$153.0	$213.8
Option 4: No Financial Constraints	$428.2	$157.2	$270.9

* Include operating costs, Talgo maintenance costs, maintenance costs enhancing reliability, and Amtrak administrative costs. Estimated based on historical data, Amtrak FFY2009 Cost Estimates, and planned activities.

** Include revenues from tickets and passenger services. Estimated based on historical revenue data assuming price neutral policy. Total revenue is the product of total forecasted passenger miles and revenue earned per passenger mile, adjusted for inflation.

*** This is the estimated costs Washington State pays for contracted Amtrak *Cascades* operation.

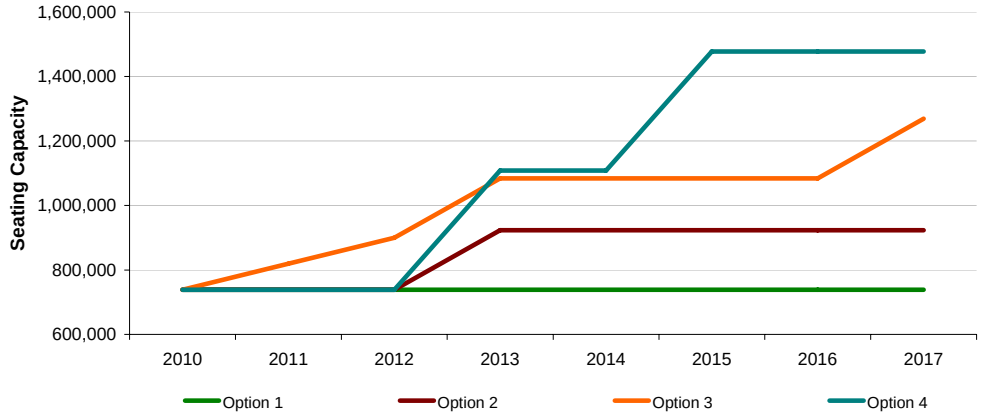
**** The sixth round trip starts in FY2017, the total operation cost here for Option 3 does not show full effect of the operation at the capacity built.

Source: WSDOT State Rail and Marine Office

Capacity Increase

The capacity growths for plan options are based on capital projects that build capacity for each plan option (Exhibit ES-4). The capacity increase and reliability improvement of capital projects are presented in Chapter 4. Exhibit 6-6 in Chapter 6 provides a dynamic view of capacity changes by option over the time frame of the mid-range plan.

Exhibit ES-4: Maximum Annual Seating Capacity by Option
Seattle to Portland FY2010-FY2017



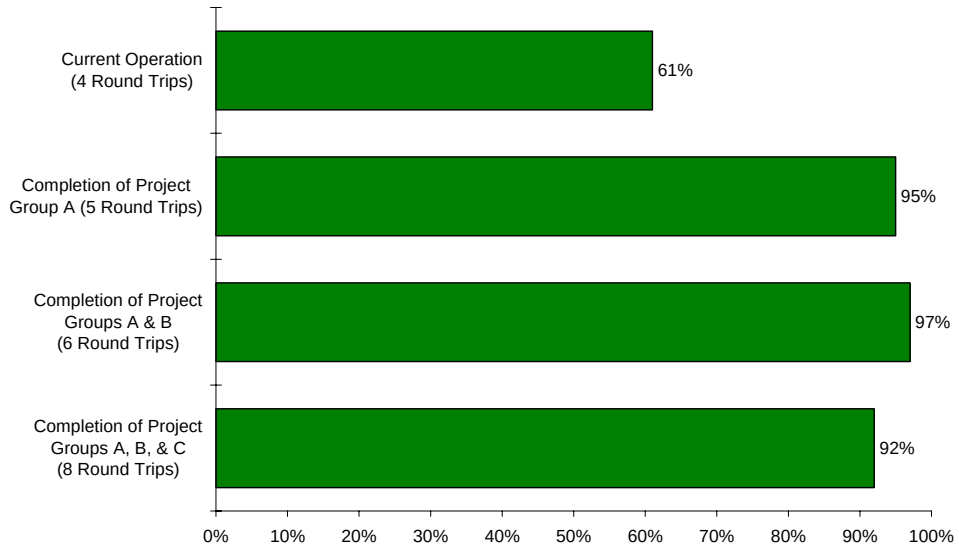
Note: Maximum seating capacity = Seats per train X Trains per day X 365 days

Source: WSDOT State Rail and Marine Office

Reliability Improvement

Operational analysis by the WSDOT State Rail and Marine Office in 2007-2008 reviewed the infrastructure necessary to support each mid-range plan option. The analysis included traffic conditions and growth expectations for Amtrak *Cascades*, Sounder, BNSF, and the UP. The analysis validated the investment in capital projects and their impacts on service capacity and on-time performance (Exhibit ES-5). Please note that on-time performance decreases slightly resulting from the operation of eight round trips.

Exhibit ES-5: Reliability Improvement by Option



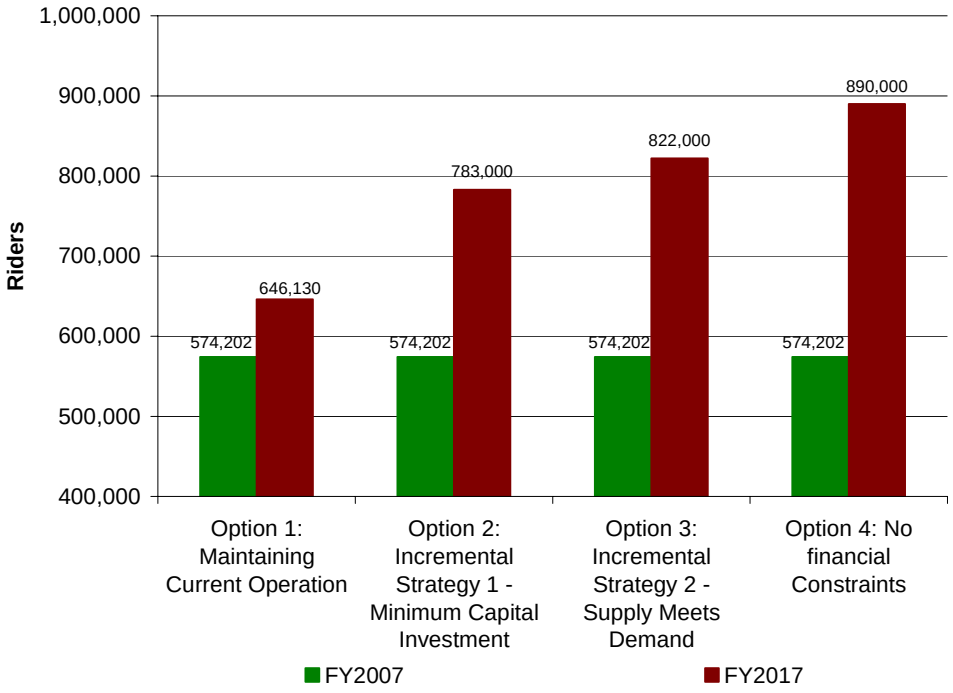
Source: Transit Safety Management

Ridership Growth

The ridership growth for plan options is estimated through two processes. First, the ridership forecast model is developed to forecast long-term growth of ridership based on factors such as population, gas prices and service availability. Second, based on improvement on on-time performance and scheduled time savings resulted from implementation of plan options, additional ridership growth is estimated using demand elasticity of time reduction published for Amtrak passenger trains.

The ridership growth for the mid-range plan options is demonstrated in Exhibit ES-6.

Exhibit ES-6: Annual Ridership Growth by Option
FY2007 vs. FY2017
Vancouver, B.C. to Portland



Source: WSDOT State Rail and Marine Office

Economic Impacts

When public funds are used to invest in Amtrak *Cascades* intercity passenger train services, the investment generates economic impacts that would benefit the state and local communities in general. The magnitudes of economic impacts are dependent on the size of investment and how the funds are invested. WSDOT used the Washington State input-output

economic model, developed using IMPLAN[1], to estimate the ripple effects of the increases in Amtrak *Cascades* services. The IMPLAN model was used to estimate the total economic impacts of mid-range plan options, including the cascading effects of the investments of each option. The economic impacts are assessed in terms of the following two indicators:

- **Employment** represents the jobs created by the investment. Amtrak *Cascades* service directly creates jobs in construction, maintenance, food service, and transportation operations. It also creates jobs indirectly by the affect of the outputs of other industries and government incomes.
- **Value added** is an indicator that reflects the net benefit of the investment. Both labor income (wages and salaries) and business incomes are counted as value added.

Exhibit ES-7 demonstrates economic impacts of the four plan options.

Exhibit ES-7: Economic Impacts of *Amtrak Cascades Mid-Range Plan* Options: Sum of FY2010 to FY2030*

Impact	Area	Option 1: Maintaining Current Operation	Option 2: Incremental Strategy 1 - Minimum Capital Investment	Option 3: Incremental Strategy 2 - Supply Meets Demand	Option 4: No Financial Constraints
Support Employment (Job-Year**)	Benefits to Local Communities Along I-5 Corridor	4,887	11,725	17,454	23,752
	Statewide Benefits (Include benefits to local communities)	6,202	15,024	22,825	31,138
Value Added*** ($ Million, 2008 Dollars)	Benefits to Local Communities Along I-5 Corridor	$306.5	$746.8	$1,139.9	$1,555.1
	Statewide Benefits (Include benefits to local communities)	$399.7	$977.6	$1,500.6	$2,048.1

Note: Economic impacts are assessed using IMPLAN Input-Output model for Washington State and its local areas.

* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017.

** A job-year means that a person is employed as a full-time employee for a year.

*** Difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the gross domestic product (GDP).

Source: WSDOT State Rail and Marine Office

Benefit/Cost Analysis

The benefit/cost analysis looked at investments, benefits, and impacts of the Amtrak *Cascades* projects completed during the mid-range plan period

[1] IMPLAN is a commercial input-output model developed using input-output data from Bureau of Economic Analysis, U.S. Department of Commerce. The model used to estimate economic impacts in this plan is a Washington State specific model.

of FY2010 to FY2017. Because the projects can generate benefits for local communities and Washington State for many years beyond FY2017, the analysis looked at benefits and costs through FY2030. Economic benefits (revenue and value added) and societal benefits (congestion relief, safety improvement, and environmental impact reduction) were analyzed to calculate net benefit, which was used in the benefit/cost analysis. Exhibit ES-8 highlights this analysis.

Exhibit ES-8: Estimated Benefit/Cost Ratio by Investment Option

Plan Option	Sum of FY2010 to FY2030* - $ Million (2008 Dollars)			
	Total Cost** ($ Million)	Total Benefit** ($ Million)	Net Benefit ($ Million)	B/C Ratio
Option 1: Maintaining Current Operation	$310	$625	$315	**2.02**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$733	$1,853	$1,120	**2.53**
Option 3: Incremental Strategy 2 - Supply Meets Demand	$1,129	$2,744	$1,615	**2.43**
Option 4: No Financial Constraints	$1,536	$3,400	$1,864	**2.21**

Note: Option 1 is the baseline.

* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.

** Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).

Source: WSDOT State Rail and Marine Office

Connectivity

Multimodal connectivity at Amtrak *Cascades* train stations includes travel by Sound Transit (Light Rail, Sounder, and Express Bus), marine (Washington State Ferries service, cruise ships), bus (public and private intercity bus services), air, and bicycle. Service improvements to enhance connectivity include integrated fares, travel packages, integrated schedules, passenger information systems, signage, and parking/bicycle storage.

Marketing

Amtrak *Cascades* marketing is operated by the WSDOT State Rail and Marine Office to optimize ridership and service capacity usage. It

promotes the achievement of ridership and revenue targets and builds strong brand awareness (Amtrak *Cascades* as differentiated from Amtrak and other transportation modes). It primarily targets adults ages 25-54 in the Seattle and Portland markets, where potential ridership is most concentrated. Marketing currently operates with a flat budget of $1 million to $1.3 million and is focused on non-business travelers. Depending on the mid-range plan option, Amtrak *Cascades* marketing can be positioned with an industry-standard, ridership-based budget to promote the ease, comfort, and environmental sustainability of train travel as a viable transportation alternative for business and non-business travelers.

Challenges and Opportunities

Mobility, reliability, environmental sustainability, safety, and tourism are important considerations when planning Amtrak *Cascades* intercity passenger rail development. A strategic investment in Amtrak *Cascades* infrastructure development, depending on the mid-range option, can:

- Increase mobility and reduce congestion on the I-5 corridor and at Sea-Tac International Airport.
- Increase reliability and attract business travelers.
- Increase energy efficiency and reduce environmental impacts of other more polluting and energy consuming transportation modes.
- Improve passenger safety and offset the safety of other transportation modes.
- Support and enhance tourism development, one of Washington's top industries.

Policymakers, in considering the *Amtrak Cascades Mid-Range Plan* options, are faced with strategic investment challenges that include the lack of dedicated federal funding, limited multimodal state funding, and uncertain Oregon State and British Columbia funding.

Policymakers are also presented with strategic investment opportunities that can reduce travel time up to 30 minutes, increase reliability (on-time performance) from 60 percent to 90 percent, reduce greenhouse gas emission and fuel consumption, and increase ridership.

Amtrak *Cascades* is experiencing double-digit ridership growth due to higher fuel prices and favorable socioeconomic trends as discussed throughout this plan. The trends are likely to continue beyond the mid- and long-range planning horizons as population and transportation demand increases and resources become scarcer. Strategic investment in Amtrak *Cascades* intercity passenger rail infrastructure development, as an integrated part of the multimodal solution of resilient transportation

systems in Washington State, provides policymakers an opportunity to meet societal needs from a long-term perspective.

To manage the risk of cost escalation, WSDOT plans to develop a better contract management practice. To this end, WSDOT should examine methods of lowering risk to the state including the development of a price agreement with BNSF to run a pre-determined number of round trips at a certain level of performance.

Chapter 1: Introduction

Since 1994 the Washington State Department of Transportation (WSDOT) has partnered with Amtrak, the state of Oregon, the province of British Columbia, the railroads, and others to provide fast, reliable, and more frequent intercity passenger rail service along the 466-mile Pacific Northwest Rail Corridor (PNWRC). As one of 11 federally designated corridors, the PNWRC extends from Eugene, Oregon to Vancouver, British Columbia (B.C.). The service, known as the Amtrak *Cascades*, provides travelers with a viable transportation alternative for their intercity trips.

Following the legislature's directive, WSDOT developed and published the *Long-Range Plan for Amtrak Cascades* (2006). The incremental approach, outlined in the plan, would allow the state of Washington to add faster, more frequent Amtrak *Cascades* service based on market demand, partnership investment, and legislative authorization. In order to ensure that public funds are expended in the most efficient manner, construction projects have been designed and grouped as "building blocks" to deliver incremental services. This strategy would allow projects to be constructed in a logical sequence to meet system performance objectives while providing flexibility for funding.

The Amtrak *Cascades* program is being implemented in stages, using a step-by-step approach for development. Service is added over time, based on available state and federal funding and market demand.

Legislative Mandates

Washington State Legislature has directed WSDOT to develop a mid-range plan for Amtrak *Cascades* that identifies specific steps to achieve additional service beyond current levels. ESHB 1094, Section 226, requires WSDOT to submit a mid-range plan to the Office of Financial Management and the transportation committees of the legislature by December 31, 2008. The *Amtrak Cascades Mid-Range Plan* fulfills the legislative mandate by identifying and developing options that outline steps to achieve incremental Amtrak *Cascades* services for the next eight years. Relevant legislative directives (Appendix 1) were reviewed and implemented as applicable to this mid-range plan.

The purposes of the mid-range plan include:

- Providing policymakers (the Governor and Washington State Legislature) with information, based on benefit and cost analyses, for further development of strategic economic investment policy for Washington State's Amtrak *Cascades* intercity passenger rail program.
- Describing four options to increase intercity passenger rail service along the I-5 corridor based on analysis of supply and demand, and estimating resources needed to implement these options.
- Specifying steps that increase capacity and improve reliability for additional intercity passenger rail services associated with each of the four mid-range plan options.
- Helping policymakers assess the potential of rail as part of an integrated transportation solution that addresses interwoven problems, such as economic development, road congestion, public safety, and environmental impacts.

Macro Policy Environment

Washington State faces both challenges and opportunities resulting from the fundamental changes in our economy and society. Challenges within the macroeconomic policy environment include economic globalization, population growth, increases in I-5 corridor congestion, higher fossil fuel prices, global climate changes, and increases in natural and man-made disasters. Passenger rail, once used as means to address only mobility problems, is increasingly viewed and used as an integrated part of macro solutions to achieve multiple ends. These macro solutions include economic viability, societal mobility, environmental sustainability, public safety, and transportation system redundancy and resiliency.

As directed in RCW 47.82, WSDOT has been monitoring and analyzing socioeconomic and technical conditions that affect intercity passenger rail development. These conditions are directly aligned with state and national policy priorities of transportation, economy, energy, and environment. Several chapters in this plan, specifically Chapter 2, discuss these factors in more detail.

In response to these driving factors, and given our competing needs for limited resources (capital and land), Washington State is increasing its policy efforts to address greenhouse gas emissions, congestion, and health and safety improvements, and to develop a more sustainable economy. WSDOT is seeking policies to increase efficiency, relieve highway congestion, and develop robust and resilient transportation systems.

Methodology

The strategy adopted by WSDOT to develop the mid-range plan is fact-based and demand-driven. WSDOT strengthened its ridership forecast and analytic capacity by developing ridership database and forecast models. WSDOT improved capital project cost estimation through a specific cost study of all historic rail projects.

Based on management directives, the mid-range plan provides policymakers with options that are designed, analyzed, and presented to address socioeconomic policy issues. These are used to integrate transportation solutions, when considering funding additional Amtrak *Cascades* services. Economic impact assessment, benefit/cost analysis, and cross modal comparison were also performed to assist policymakers in linking the investment of an option to its effects on the economy and society.

Options presented in the mid-range plan are designed in the context of the current macroeconomic policymaking environment. The options build on incremental strategies with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. This mid-range plan presents four options for future program development.

Relationship with Other Plans

The mid-range plan is implementing the vision of WSDOT's multimodal plan—the *Washington Transportation Plan*—and the incremental strategy developed in the *Long Range Plan for Amtrak Cascades* under the guidance of the legislature.

The *Washington Transportation Plan* is a 20-year multimodal plan that includes Amtrak *Cascades* development. It establishes guiding principles for investments in current and future facilities through 2026. These investment guidelines are meant to direct funding and resources toward programs and investments that yield the greatest benefits. The mid-range plan is an implementation of the rail section. It states, "as the projects currently underway move forward and the investment priorities are implemented, future planning efforts will build on what we learn about system operations, the pace and challenges of global warming, and the opportunities and limitations of different travel modes such as *rail*, bike, and transit."

The *Long Range Plan for Amtrak Cascades* is a 20-year plan that meets federal requirements for high-speed intercity rail service development through 2023. Based on the long-range plan, the mid-range plan builds for more in-depth planning and economic analysis of projects and investment

opportunities for Amtrak *Cascades* development. It states, "WSDOT will continue to work with the freight railroads, ports, and other partners to ensure the rail system has adequate capacity to meet the demands of its various users. The ability for freight and passenger traffic to coexist on a common infrastructure and continue to grow is important to our regional mobility and economy."

The plans were all developed in coordination with Metropolitan Planning Organizations (MPOs) and Regional Transportation Planning Organizations (RTPOs), and other state, regional, tribal, and local stakeholders within their respective planning areas. See the list below for the mid-range plan stakeholder list.

Public Involvement

In the development of the mid-range plan, an advisory committee was formed, involving as many stakeholders as possible. The advisory committee's role was to help WSDOT assess and evaluate beneficial impacts of rail infrastructure improvements on society, to help WSDOT understand concerns of local communities, and to share information and provide feedback during the mid-range plan development process. Advisory committee stakeholders involved in the development of the mid-range plan include:

- MPOs and RTPOs in the I-5 corridor
- Counties and cities within the study area
- Oregon State
- Province of British Columbia
- Private railroads
- Amtrak
- Washington Public Ports Association
- WSDOT planning units in different modes
- WSDOT regions
- All tribes in Washington State with an interest in the I-5 corridor
- Passenger rail advocacy groups

Two public/advisory committee meetings were held at WSDOT, led by State Rail and Marine Office staff, providing progress reports and opportunities for public comments and discussion. After the public/advisory committee meetings, the draft plan was available for two weeks for public review and comment. Some public comments were incorporated into the final draft and the remainder are included in Appendix 13 with WSDOT's responses. The mid-range plan was then submitted to WSDOT executive management for final approval. Appendix

2 provides a complete list of stakeholders and active participants involved in the process.

Organization of this Plan

This chapter introduces the mid-range plan, its legislative mandates, management direction, socioeconomic contexts, and the strategy and methodology WSDOT adopted to develop the plan.

Chapter 2 discusses the macroeconomic environment and its impact on intercity passenger rail infrastructure using historical, current, and future trends and data. This chapter also introduces the mid-range plan options.

Chapter 3 reports the results from ridership and capacity analyses, including models, methods, data sources, and forecasts that were used to develop plan options.

Chapter 4 lists detailed capital projects for "building block" infrastructure improvements, and the costs associated with these projects. The information on the capacity increases and reliability improvements of completing each "building block" for each plan option is included.

Chapter 5 addresses operations and maintenance issues. A simulation analysis provides on-time performance estimates used in the development of the options. Operational cost estimates are also provided, based on historic data and projected costs for each plan option.

Chapter 6 describes the mid-range plan options for achieving additional Amtrak *Cascades* service. It specifies the steps needed for each plan option. It presents detailed information on capital and operation costs, capacity increases and reliability improvements, ridership growth, and economic impacts of investment.

Chapter 7 provides the results of a benefit/cost analysis for all mid-range plan options. It includes assessment of public benefits and costs, discussion of economic and societal impacts, and analysis of full transportation costs.

Chapter 8 is an analysis of the importance of providing easy connections between the different modes of transportation, and how WSDOT is working with other modes to achieve this connectivity.

Chapter 9 is a marketing analysis, including a history of major marketing efforts, marketing goals, trends, updated costs, anticipated impacts, and efforts to measure performance.

Chapter 10 discusses past, present, and future funding challenges and opportunities.

This mid-range plan does not require additional environmental review. The 2006 *Long-Range Plan for Amtrak Cascades* has been determined, jointly by the Federal Railroad Administration and Federal Highway Administration, to sufficiently address the requirements of a Tier 1 Environmental Impact Statement. Individual projects will require a detailed environmental review to determine the need for additional environmental study and documentation. The projects contained in the options either already have completed environmental documentation, are nearing completion of required National Environmental Policy Act (NEPA) documentation, or are categorically excluded from environmental review.

Washington State
Department of Transportation

Chapter 2: Amtrak *Cascades* Development, Socioeconomic Context, and Mid-Range Plan Options

Intercity passenger rail benefits society by reducing congestion, pollution, and fuel consumption, while increasing safety by complementing other more heavily used modes of transportation. This plan assesses benefits and costs and evaluates investment strategies related to Amtrak *Cascades* development within its socioeconomic context. This chapter provides an overview of the development Amtrak *Cascades* passenger train service, socioeconomic trends, and macro policy environment.

Amtrak *Cascades* Development

Rail development for the Pacific Northwest began in 1864. At that time President Abraham Lincoln signed the Northern Pacific Railroad Charter to build a direct rail connection between the Great Lakes and Puget Sound. In the mid-1890s passenger rail service reached its peak in ridership when its share of the market was estimated to be about 95 percent. Largely due to interstate highway system development and competition from airlines, passenger rail ridership reached its lowest point in 1970.

Washington State infrastructure investment in intercity passenger rail service began in the late 1980s, when some state funds were expended to improve train stations. The first state-sponsored Amtrak intercity passenger rail service began in 1994. After incremental enhancements by Washington State and its partners, the service was branded Amtrak *Cascades* in 1999, with the introduction of the European-style, custom-built equipment. In 2007 annual ridership reached 676,760 passengers, the highest in the history of the state-sponsored program. Incremental enhancements continue to improve service and ridership. Appendix 3 provides a more detailed history of rail development in Washington State.

Currently, Washington State provides Amtrak *Cascades* intercity passenger service for four daily round trips between Seattle and Portland as shown in Exhibit 2-1. Note that one of the four state-sponsored daily round trips between Seattle and Portland continues on to Bellingham.

Exhibit 2-1: Amtrak *Cascades* Daily Schedule

Amtrak *Cascades* Daily Schedule

Fall 2008

Southbound *Read Down*					Station	Northbound *Read Up*					
517	509	507	513	501		510	500	504	506	516	508
5:45 pm					Vancouver, BC	11:35 am					
7:40			8:35 am		Bellingham	9:44				9:05 pm	
8:12			9:04		Mount Vernon	9:13				8:13	
8:54			9:55		Everett	8:31				7:31	
9:19			10:21		Edmonds	8:07				7:07	
10:05 pm			10:55 am		Seattle	7:40 am				6:40 pm	
	5:30 pm	2:20 pm	11:20 am	7:30 am	Seattle		12:00 pm		3:55 pm	6:20 pm	9:45 pm
	5:45	2:35	11:35	7:45	Tukwila		11:26		3:11	5:46	9:11
	6:15	3:05	12:05 pm	8:15	Tacoma		10:56		2:41	5:16	8:41
	6:54	3:44	12:44	8:54	Olympia/Lacey		10:18		2:03	4:38	8:03
	7:13	4:03	1:03	9:16	Centralia		9:57		1:42	4:17	7:42
	7:54	4:44	1:44	9:54	Kelso/Longview		9:18		1:03	3:38	7:03
	8:29	5:19	2:19	10:29	Vancouver, WA		8:45		12:30	3:05	6:30
	9:00	5:50 pm	3:00 pm	11:00 am	Portland		8:30 am		12:15 pm	2:50 pm	6:15 pm
	9:10	6:15 pm			Portland		8:05 am	11:35 am			
	9:31	6:36			Oregon City		7:24	10:54			
	10:17	7:22			Salem		6:42	10:12			
	10:46	7:51			Albany		6:13	9:43			
	11:45 pm	8:50 pm			Eugene		5:30 am	9:00 am			

The railroad tracks that span the Pacific Northwest Rail Corridor (PNWRC) are owned by the BNSF Railway (BNSF) in Washington, by the Union Pacific Railroad (UP) between Portland and Eugene, Oregon, by BNSF between the Canadian Border and Fraser River, and by Canadian National Railway from the Fraser River to the Vancouver, B.C. station. Freight and passenger rail traffic run on the same tracks. The Washington State Department of Transportation (WSDOT) partners with federal, state, provincial, tribal, and local jurisdictions; railroads including Amtrak, BNSF, UP, Canadian National Railway (CN), VIA Rail Canada; and others under many agreements to provide Amtrak *Cascades* service.

The state-supported Amtrak *Cascades* service continues to demonstrate record growth in ridership. Ridership of 594,970 in the first three quarters of 2008 increased 16.3 percent over the same period in 2007. High gasoline prices, population growth, and many other factors have contributed to this increase.

Many planning documents have guided Amtrak *Cascades* development over the years. In 1995 WSDOT published *Options for Passenger Rail in the Pacific Northwest* and in December 1997, WSDOT produced the *Pacific Northwest Rail Corridor Operating Plan* for public review.

WSDOT published the *Long-Range Plan for Amtrak Cascades* (2006) that meets the U.S. Department of Transportation's recommended planning framework for high-speed intercity rail service development, a requirement for Washington State to be eligible for federal funding. The long-range plan outlines a 20-year progression of incremental improvements that increase train frequency, reliability, and safety, and reduce travel times.

Socioeconomic Context

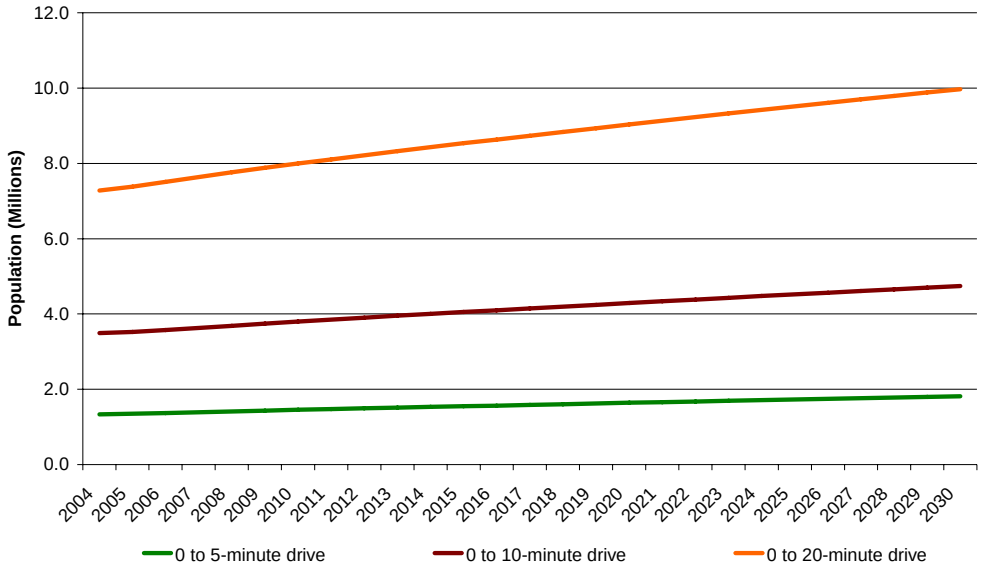
Population/Congestion

Western Washington and the Puget Sound region, anchored by major metropolitan areas, is the densest, most heavily populated area in Washington State. As of 2008 an estimated 3,664,000 people (four out of ten people) reside within 10 driving minutes of Oregon and Washington Amtrak *Cascades* stations.

Exhibit 2-2 shows increasing I-5 corridor population growth from 2004 to 2030, in terms of proximity to nearby Amtrak *Cascades* stations at 5-minute drive, 10-minute drive, and 20-minute drive times. Increasing travel demand on the I-5 corridor impacts mobility, safety, the environment, and energy consumption. Strategies that promote viable

transportation alternatives, such as intercity passenger rail cause mode shifts that can reduce travel demand on the I-5 corridor and improve mobility, safety, environmental sustainability, and the economy.

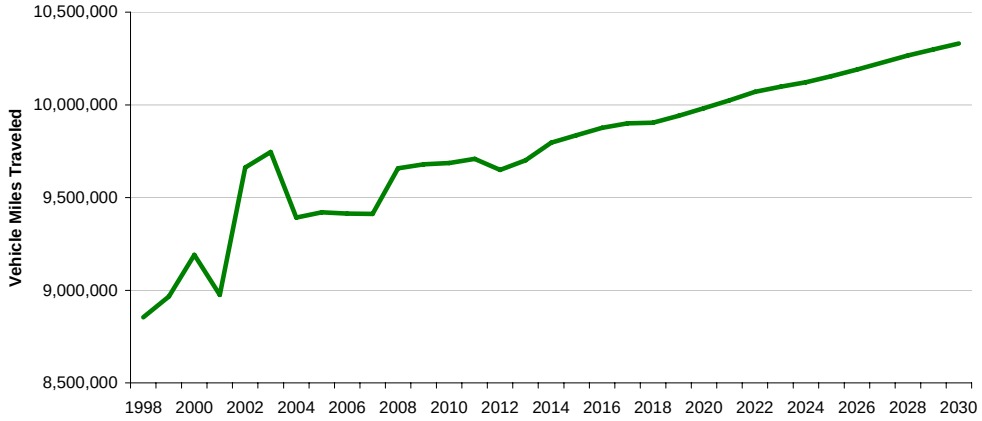
Exhibit 2-2: Population Surrounding Amtrak *Cascades* Services Vancouver, B.C. to Eugene, OR
Drive Times to Amtrak Stations



Source: Data developed by WSDOT State Rail and Marine Office based on U.S. Census using WSDOT GIS tools.

Exhibit 2-3 shows the increase in I-5 vehicle miles traveled from 1998 to 2030.

Exhibit 2-3: Vehicle Miles Traveled Along the I-5 Corridor



Source: WSDOT Transportation Data Office, and FY2010 to FY2030 projections by State Rail and Marine Office.

With national highway congestions cost estimated at $70 billion annually, states are turning to rail as part of their transportation strategy. Specific

markets, like the Seattle, Portland, and Vancouver, B.C. metropolitan areas, have the most potential to generate public benefits from reduced highway congestion now and in the future. Intercity passenger rail is even more beneficial in regional markets with well-developed *intra*city mass transit systems, because intercity rail is more likely to be more competitive with driving on those routes.

The Amtrak *Cascades*' route goes along the same sections of the I-5 corridor. WSDOT estimates that daily delay along the I-5 corridor is about 300,000 hours and cost about $7 million a day. Amtrak *Cascades* passenger rail can help reduce congestion by diverting traffic away from the crowded I-5 corridor, increasing the serviceability of the overall transportation system.

According to a WSDOT Urban Planning Office model, a 5 percent reduction in I-5 traffic will reduce 70 percent of the delay caused by congestion. Therefore, it doesn't take a huge quantity of travelers switching to intercity passenger rail to generate substantial public benefits by reducing highway congestion.

Intercity passenger rail service could potentially ease air travel congestion (take-off and landing delays) and it could reduce the number of flights between cities. In areas with little to no additional space for runways, airports have fewer options for increasing capacity. In those areas, intercity passenger rail service would be more competitive.

There is an economic advantage for passenger rail in locations where train stations are located in central business districts, especially with convenient access to mass transit.

Safety and Security

On October 16, 2008, President George W. Bush signed into law a 2-part legislation: HR 2095, the Railroad Safety Enhancement Act of 2008, and HR 6003, the Passenger Rail Investment and Improvement Act of 2008. The legislation gives $12.9 billion for intercity passenger rail development over five years, almost double what the U.S. is currently spending. Safety and rail passenger improvements include increased rail safety inspectors, at-grade crossing improvements or eliminations, positive train control technology on rail main lines by 2015, and reporting required on service delays and poor on-time performance for the Amtrak Coast Starlight and Amtrak *Cascades*.

According to the National Safety Council (NSC), the safety of intercity passenger rail travel is comparable to commercial bus and air travel. The 2008 NSC Injury Facts report shows that passenger autos have a 0.81 U.S.

passenger fatalities per 100 million passenger miles ratio (1996-2005 data); buses have a 0.04 ratio; railroad passenger trains have a 0.05 ratio; and airlines have a 0.02 ratio. Passengers may choose to travel by rail to improve their own safety, if they believe passenger rail is safer than other modes.

In addition global development and global warming may cause transportation systems to be more vulnerable to natural and man-made disasters. The ability to respond to and recover from adversity is largely due to society's degree of resiliency. Regions and communities with viable transportation alternatives are better positioned to deal with adversity and successfully recover from emergencies.

A robust intercity passenger rail service is an asset in times of emergency. After the September 11, 2001 attack on the World Trade Center, Amtrak service resumed days before highways were open to the public. Likewise, after I-5 was flooded by the Chehalis River and its tributaries in December 2007, Amtrak *Cascades* service resumed in two days, while I-5 service resumed for public use after four days.

Environment/Energy

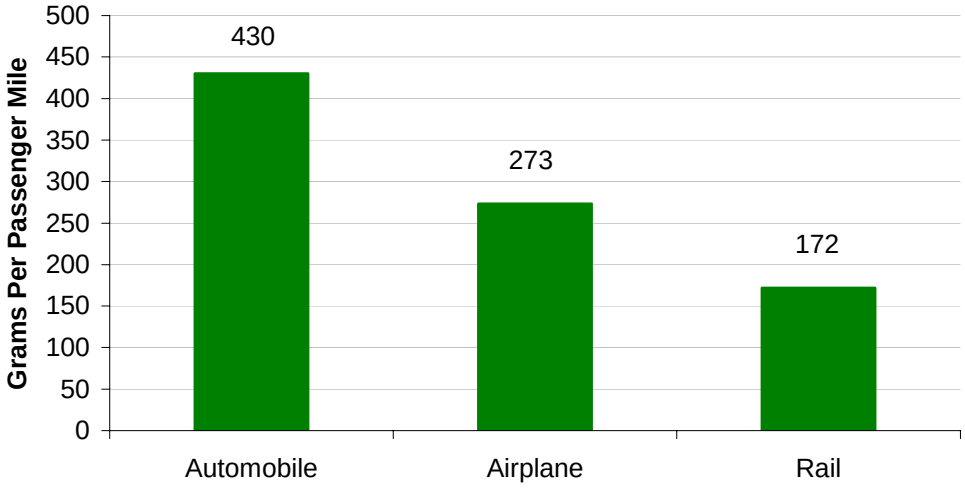
Transportation is the fastest growing source of carbon dioxide (CO_2) in the United States. CO_2 emissions are projected to exceed 175 percent of year 2000 levels by 2025. Personal cars and trucks now account for 40 percent of our nation's oil consumption. Cars and trucks produce about a third of the greenhouse gas emissions in the U.S. Increasing travel demand is expected to cancel out the CO_2 savings from the fuel economy and renewable fuel requirements as specified in the Energy Independence and Security Act of 2007.

The University of California at Berkley recently completed the first comprehensive environmental life-cycle assessment of passenger transportation in the U.S. The assessment includes significant indirect supply chain costs that are harder to measure. It analyzes the real costs of all system components in terms of their energy use and polluting by-products "from cradle to grave."

The University of California study shows that greenhouse gas emissions per passenger mile traveled is less for rail than for cars or airplanes, as indicated in Exhibit 2-4. Rail systems are the best energy and greenhouse gas performers, but they require much larger infrastructure requirements per passenger-mile served. High-speed rail can perform better than automobile and aircraft, but only if ridership is optimized. In the study, intercity passenger rail service similar to Amtrak *Cascades* was not included. Caltrain has a similar type of diesel propulsion system, but

offers a commuter service with shorter distances and more frequent service.

Exhibit 2-4: Greenhouse Gases by Transportation Mode



Source: University of California at Berkeley, Center for Future Urban Transport

Amtrak provides long-distance rail service and intercity passenger rail service throughout the U.S. Current initiatives to increase energy efficiency and reduce fuel consumption include a range of Amtrak programs. With its participation in the Chicago Climate Exchange, Amtrak is committed to cutting diesel emissions by 6 percent by 2010, the largest voluntary reduction commitment in the U.S., and the first commitment made by a national transportation company.

Intercity passenger rail can generate some public benefit by reducing dependency on gasoline and fossil fuels. Another public benefit would be to reduce vulnerability to an energy supply disruption.

Economy

Amtrak *Cascades* investments can increase the economic potential of an area. There are model approaches used around the world to stimulate the economy and improve intercity passenger rail infrastructure and service with established and clearly defined national policy goals, stakeholder roles, and committed funding. In the U.S. where passenger rail is all public sector, Amtrak is taking action to reduce costs, but it is not positioned to address broader goals, roles, and funding issues.

Intercity passenger rail services along designated corridors have a comparative advantage over other transportation modes in terms of financial viability and public benefits. However, currently there isn't a national policy framework for rail and transportation in general. This is a

major finding of the National Surface Transportation Policy and Revenue Study Commission Report of December 2007. The report was developed by an advisory group of 12 delegates, led by the U.S. Department of Transportation Secretary with a vision to create and sustain the pre-eminent surface transportation system in the world. Their recommendation to increase multimodal transportation infrastructure investment will guide future rail policy. The report's call to action states, "…our nation will need to put more emphasis on transit and intercity passenger rail and make them a priority for our country. A cultural shift will need to take place across America to encourage our citizens to take transit or passenger rail when the option is given."

Consumer and Travel Industry Trends

Eco-tourism is growing both in trips to important environmental sites and in ways travelers choose travel alternatives that are more environmentally sustainable. Rail, as part of "green travel," is emerging as the transportation alternative of choice for those who want to benefit local communities, reduce their carbon footprint, and experience the natural scenery in comfort and convenience as they travel.

Global warming is of high concern for 41 percent of Americans and 59 percent believe the affects are apparent now. Approximately 50 percent of Americans changed their summer travel plans due to high gas prices. Almost 25 percent of Americans working in the private sector don't get paid vacations. With soaring gas prices influencing consumer's travel plans, shorter, domestic trips are likely to continue to dominate travel destinations. Amtrak *Cascades* can be a preferred travel alternative for local and regional trips.

In the next five years, America is expected to experience an 80 percent growth in the number of households headed by someone 55+ years old. Their availability to travel, their established and stable income, and their nostalgia for trains is expected to stimulate rail travel, especially if their rail experience is favorable.

Wireless Internet (WiFi), cell phone reception, and electronic media are becoming standard amenities in all sectors of society, particularly among youth and young adults. The availability of convenient, state-of-the-art technology appeals to passengers and is an economic advantage for intercity passenger rail travel.

Mid-Range Plan Options

Washington State is facing both challenges and opportunities resulting from the fundamental changes in our economy and society. The main

factors that shape policy development have been discussed in a previous section. Transportation solutions, once used as a means to address only mobility problems, are increasingly viewed and used as strategies to achieve multiple ends, such as economic viability, societal mobility, and environmental sustainability. The options of the mid-range plan are designed, analyzed, and presented to assist policymakers in determining funding for the Amtrak *Cascades*, to achieve additional services that benefit society and the economy.

Purposes of Mid-Range Plan Options

The purposes of the plan options are identified as:

- Articulating the needs of intercity passenger train services and discussing supply and demand issues for various scenarios.
- Providing alternatives needed by policymakers in developing strategic investment policy, which might help achieve multiple policy ends using transportation solutions.
- Assessing potential of passenger rail as a strategic alternative of long-term transportation solutions, rather than a niche market segment for tourists and intercity travelers.
- Specifying the steps of improving infrastructure to deliver additional intercity passenger services, and link capital and operational investment to ridership growth and economic and societal benefits.
- Providing a variety of information to support informed decision-making processes—legislative budgeting and prioritizing.

Defining Options for Achieving Additional Services

Option 1: Maintaining Current Operation Strategy

This option is designed to maintain current Amtrak *Cascades* operation at four daily round-trip trains between Seattle and Portland and two daily round-trip trains between Seattle and Vancouver, B.C. This option would not have additional capital investment and infrastructure improvements in the mid-range plan period. All previous capital investments for incomplete projects would become sunk costs[1], as no additional investments for completing projects, which increase service capacity and reliability, will

[1] Sunk costs are costs that cannot be recovered once they have been incurred. If there is no additional investment to complete projects that increase service capacity, then the costs of the uncompleted projects are lost or sunk.

occur. Ridership growth will be confined at current capacity levels. The growth opportunity would be to attract additional riders to the non-peak seasons and low ridership days.

This option informs policymakers about the current status of Amtrak *Cascades* services and the outlook of maintaining the current status. It also serves as an analytic baseline for other options.

Option 2: Incremental Strategy 1 – Minimum Capital Investment

By identifying the cost to deliver the minimum increase of additional service, this option would deliver five daily round-trip trains between Seattle and Portland and maintain two daily round-trip trains between Seattle and Vancouver, B.C. in 2012. This option would complete capital projects that have already been started, and would sustain the capital costs that were already invested into the system to achieve incremental service gains. The increased service would be used to meet the demands that would rise due to improved schedule reliability and rail line capacity.

Option 2 helps decision-making by specifying the investments needed to complete the capital projects for minimum service increase. This option also assesses benefits and costs associated with additional investments that would revive the sunk costs and deliver minimum incremental service.

Option 3: Incremental Strategy 2 – Supply Meets Demand

By best analyzing and matching supply and demand in a dynamic economy and a changing society, this option assesses both supply and demand and the interactions between them. It provides essential information about ridership growth, cost and revenue, local and state economic impacts, and environmental and social benefits for incremental investments. These investments would achieve additional service levels, where the increased supply (Amtrak *Cascades* service capacity) essentially meets the increased demand (ridership growth).

This option is essential because it supports decision-making by specifying investment levels, where the supply meets the demand, and provides information about a variety of benefits associated with such investments.

Option 4: Rail as a Long-Term Alternative Strategy – No Financial Constraints

By maximizing engineering feasibility, this option provides information about the maximum capacity that can be built during the mid-range plan horizon, FY2010 to FY2017, given the level of investment necessary to develop such infrastructure improvements. However, this option does

exclude a few reliability improvement projects that are expensive when compared to achieved improvements.

Option 4, which allows eight daily round trips between Seattle and Portland by FY2015, is a viable option in an environment where policymakers might be willing to promote rail as a strategic alternative and part of the solution to highway congestion. It also helps to explore the potential benefits and costs for such a strategic movement to address greenhouse gas reductions, congestion relief, public safety improvements, and transportation resilience to disasters.

Chapter 3: Ridership for Amtrak *Cascades*

Ridership for Amtrak *Cascades* on the Pacific Northwest Rail Corridor (PNWRC) has been increasing. This chapter highlights the changes in ridership in the past, present, and future and includes:

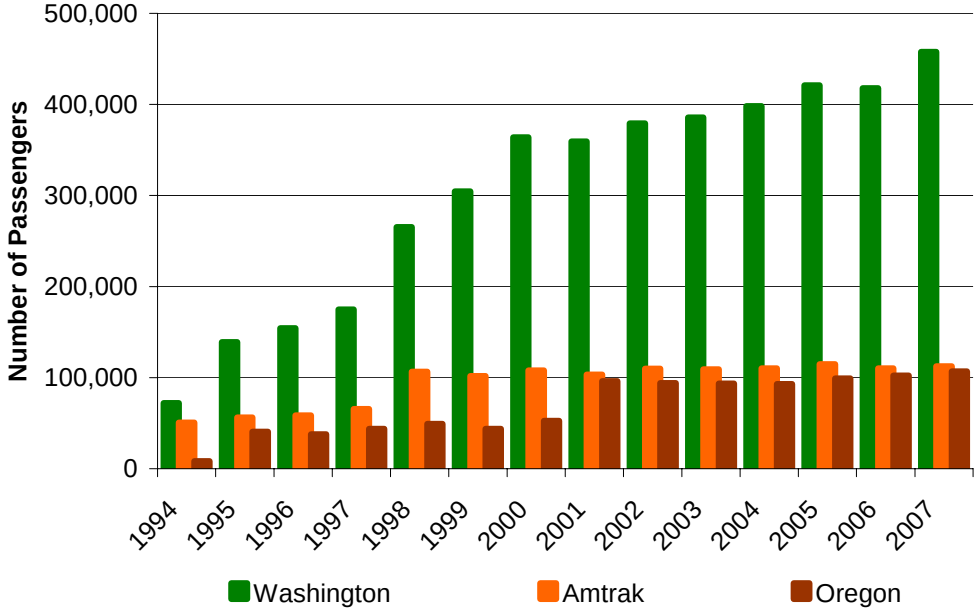
Ridership History

In 1993 Amtrak offered only one daily round trip between Seattle and Portland. Washington State saw the need and demand for more passenger rail service in the PNWRC, and in 1994 expanded service by introducing passenger trains sponsored by Washington State. This new Washington-sponsored train service first leased a train set from Renfe Talgo of America (Talgo) to provide a second daily regional round trip between Seattle and Portland. In 1995 Oregon sponsored a state-funded train and one of two existing Seattle to Portland daily round trips was extended to Eugene, Oregon. Also in 1995, after a 14-year absence, service was restored between Seattle and Vancouver, B.C. In 1996 Washington leased a second Talgo train to support service. The Amtrak *Cascades* brand debuted in 1999 and WSDOT expanded Seattle to Portland service by offering a third daily round trip.

Washington State initiated a new phase for Amtrak *Cascades* in 1999 by replacing leased equipment with custom-built trains purchased from Talgo. Currently there are five train sets in the Amtrak *Cascades* service. Washington State owns three train sets and Amtrak owns two. WSDOT signed a lease/purchase agreement for two train sets with Talgo in 1995, and took delivery in late 1998-early 1999. In 2000 a second daily Seattle to Portland train was extended to Eugene, sponsored by Oregon. A new stop in Tukwila was added in 2001. A fourth daily Seattle to Portland regional round trip started in July 2006, which completed the extent of current Amtrak *Cascades* regional service between Seattle and Portland.

Ridership has risen steadily on the PNWRC from Eugene, OR to Vancouver, B.C., from less than 200,000 annual passengers in 1994 to 676,760 passengers in 2007. Ridership for the three Washington-sponsored trains increased over 500 percent from 1994 to 2007, even though there were service disruptions for approximately three months in 2007. A complete history of the Amtrak *Cascades* annual ridership is shown in Exhibit 3-1.

Exhibit 3-1: Amtrak *Cascades* Annual Ridership 1994-2007



Source: WSDOT State Rail and Marine Office

Annual ridership for 2008 is expected to surpass all previous years in annual growth. Year-to-date ridership through October for Amtrak *Cascades* shows 27.4 percent growth over the same time in 2007. One reason for this growth is the rapid rise in gasoline prices in the last year, prompting consumers to consider train travel rather than driving for their travel needs. More convenient schedules and better connections have also fostered higher growth rates in the last several years.

Since 1994 when Washington began actively supporting Amtrak service, consumers have responded to the increased frequency of daily train service. In every case when or where the supply of passenger train capacity increased, higher ridership has quickly followed. Ridership increases are most pronounced in the Seattle to Portland corridor, now that it has four daily Amtrak *Cascades* regional round trips.

Ridership Distribution

Public use of Amtrak *Cascades* is also measured by station on-offs, which measure passenger volumes per station. This measurement is determined by counting the number of passengers who get on and off trains at each station along the Amtrak *Cascades* corridor. Station volumes can assist planners and businesses in determining local train station activity. This knowledge can support greater connectivity with bus systems and other transportation modes. It can also be of help in land use planning for residential and business expansion.

Station on-offs provide a good measurement of the distribution of ridership along the rail corridor. Amtrak *Cascades* currently has 17 stations, with an additional station scheduled for opening in Stanwood, WA in 2009. Originally, Amtrak *Cascades* had 15 stations in operation in 1995. Tukwila, WA opened in 2001, followed by Oregon City, OR in 2004. Restoration of older stations and building of new stations in more strategic locations led to greater volumes of passengers at stations. For passengers traveling between major cities (i.e. Seattle and Portland), having all trains stop at all stations increases travel time. Future consideration should be given to adding express trains between major cities.

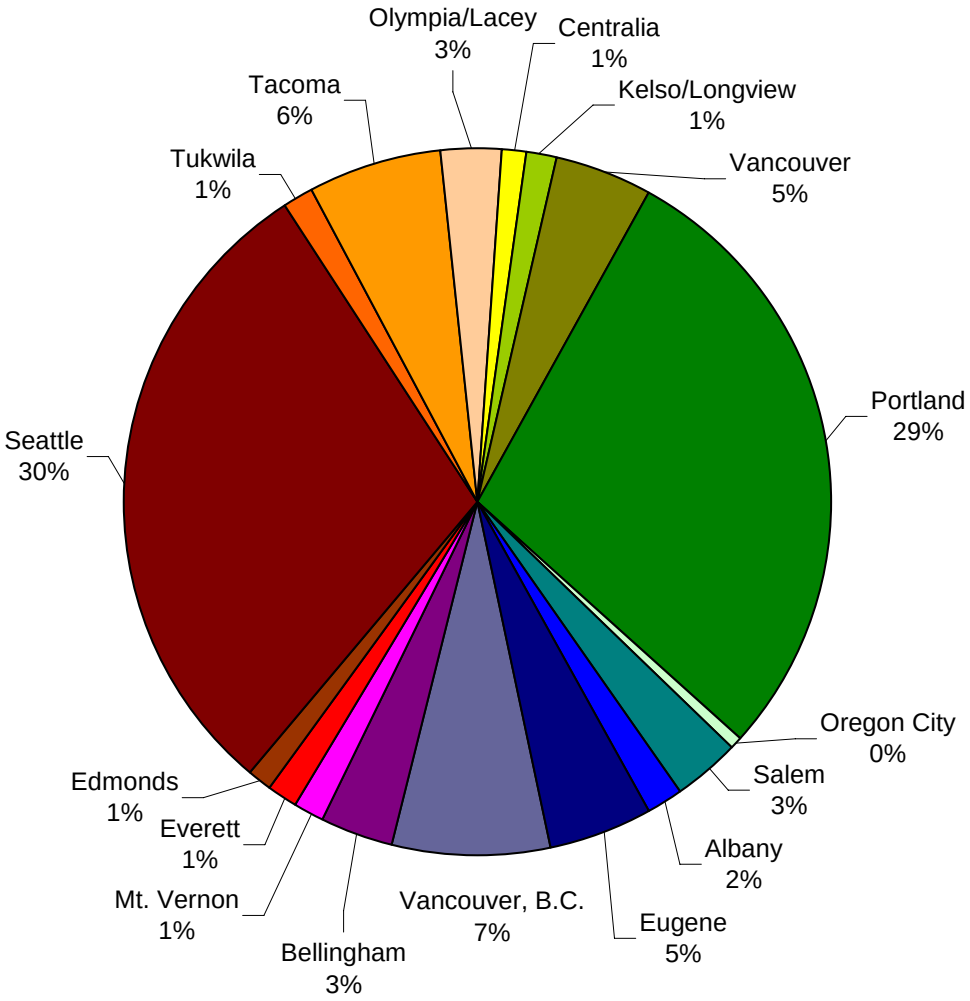
Station locations with 2007 total on-offs are listed from north to south in Exhibit 3-2. Nearly six out of every ten passengers begin or end their train travel at either the Seattle or Portland stations. These two cities serve as hubs for north and south traffic from each station and as beginning or end points for the four daily Seattle to Portland round trips. Exhibit 3-3 illustrates in a pie chart the share of on-offs by station in 2007.

Exhibit 3-2: Station On-Offs – 2007

Stations	Number	Percentage
Vancouver, B.C.	***105,960***	***7.2%***
Washington Stations		
Bellingham	51,291	3.5%
Mt. Vernon	19,321	1.3%
Everett	18,211	1.2%
Edmonds	18,200	1.2%
Seattle	438,845	29.8%
Tukwila	18,884	1.3%
Tacoma	87,996	6.0%
Olympia/Lacey	41,119	2.8%
Centralia	17,509	1.2%
Kelso/Longview	20,314	1.4%
Vancouver	66,761	4.5%
Total	***798,451***	***54.3%***
Oregon Stations		
Portland	421,658	28.7%
Oregon City	7,186	0.5%
Salem	42,303	2.9%
Albany	24,661	1.7%
Eugene	71,040	4.8%
Total	***566,848***	***38.5%***
Grand Total	**1,471,259**	**100.0%**

Source: WSDOT State Rail and Marine Office

Exhibit 3-3: Amtrak *Cascades* On-Offs by Station – 2007



Ridership Profile

Passenger demographics are important in determining characteristics of current passengers and potential growth of additional passengers. Surveys, periodically conducted by Amtrak, collect national and regional data to provide updated information on Amtrak *Cascades*. Current demographics of riders have been identified for targeting advertising campaigns:

- Adults 25-54.
- Household income $50,000+.
- Slightly skewed female (60 percent).
- Employed (52 percent full time, 12 percent part time).
- Educated (54 percent college graduate, 31 percent some college).
- Travels an average of seven one-way trips along the I-5 corridor per year, for business or leisure.

Approximately 81 percent of passengers are riding Amtrak *Cascades* for leisure. Ridership peaks during Friday, Saturday, and Sunday; and seasonally in the summer months and during the winter holidays. Attracting business travelers, especially those willing to pay higher fare tickets, is essential for increasing demand for current capacity and proposed capacity expansion. Providing frequent and reliable service with flexible timetables is important in attracting business customers.

Factors that Drive Ridership Growth

Ridership has grown over time, in part, because of underlying demographic characteristics of potential rail passengers. Population density and proximity to Amtrak stations is important in determining ridership growth. As of 2008 an estimated 3,664,000 people reside within 10 minutes of Oregon and Washington Amtrak *Cascades* stations. Employment opportunities and income levels of the same nearby populations are also important.

Greater capacity in the number of daily trips between stations is instrumental in increasing demand for passenger rail service. More daily trips expand the daily timetable, attracting more customers who may find an earlier or later travel time more attractive, especially for taking day trips. Business travelers especially respond to more flexibility and choices.

Passengers are sensitive to ticket pricing. Amtrak offers four categories of ticket prices. Similar to airlines, prices rise as the trains fill up. Historically when additional trips were added to the Seattle to Portland segment, ridership responded quickly. More seats were available per day which drove down ticket prices, as more seats were available at a lower price. Saving money can be a great incentive for switching to other travel times.

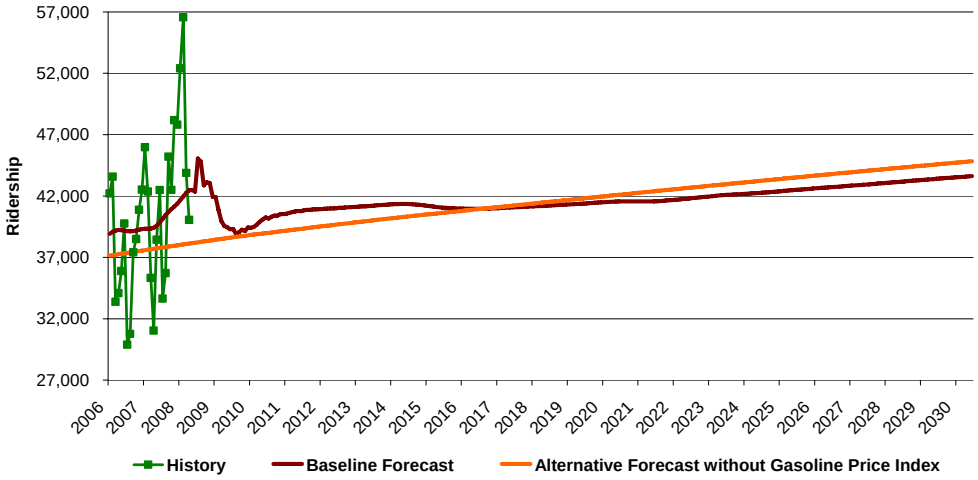
Higher costs for competing transportation modes also increase growth of ridership. Higher gasoline prices for automobile travel have been a big contributing factor for higher ridership, especially this past year. Nationwide, more highways and bridges are charging tolls, which add an additional cost to automobile travel. A new bridge, being planned for the I-5 crossing of the Columbia River between Washington and Oregon, is considering a toll for financing. This has the potential of furthering rail passenger growth between Portland and Seattle by increasing the cost of automobile travel.

Growth Forecast: Methods and Results

Ridership growth on Amtrak *Cascades* trains was forecasted using statistical methods relating ridership to population, capacity increases, and

inflation-adjusted gasoline prices. For more technical information concerning ridership forecasting, please refer to Appendix 4. The Seattle to Portland segment is highlighted here because of the proposed expansion of capacity for this portion of the PNWRC. Monthly ridership from 1996 to October 2008 was available for reference and forecasting. The baseline forecast used monthly ridership, average monthly train occupancy, population based upon driving time from Amtrak stations, inflation-adjusted gasoline prices, and capacity in number of daily round trips. An alternative forecast excluded gasoline prices for comparison. Exhibit 3-4 shows three data series: history starting in January 2006; the baseline forecast; and the alternative forecast. The baseline forecast provides a better fit to actual historical ridership, specifically gasoline prices have increased substantially since 2006. From FY2010 to FY2017, the baseline forecast projects an average of 3 percent higher ridership by including gasoline prices. After FY2017 the alternative forecast projects an average of 2 percent higher forecast.

Exhibit 3-4: Comparison of Monthly Ridership History, Baseline Forecast, and Alternative Forecast without Gasoline Price Index
Seattle to Portland



Stations included are Seattle, Tukwila, Tacoma, Olympia/Lacey, Centralia, Kelso/Longview, Vancouver, and Portland.

Source: WSDOT State Rail and Marine Office

Growth Analysis: Peak Ridership and Capacity, Time Saving and Reliability Improvement Effect – Discussion and Results

When Amtrak *Cascades* ridership is forecasted in total for the Seattle to Portland corridor, it does not take into consideration peak ridership that occurs when the train is at its fullest along the corridor. For the Seattle to Portland segment, this maximum regularly occurs between Olympia/Lacey and Centralia, whether traveling north or south. During the peak months of

ridership in summer, during the winter holidays, and for weekend days of Friday through Sunday, the Olympia/Lacey to Centralia segment is usually where a train is sold out and passengers are possibly turned away.

An analysis of the distribution of daily ridership in this peak section was conducted for a full year from July 2007 through June 2008 for all four Seattle to Portland daily round trip trains. Nearly 0.5 percent, or 2,348 passengers, was not provided reserved seating as ridership exceeded train capacity for the peak ridership segment between the Olympia/Lacey and Centralia stations. Passengers not securing reserved seating are provided, if possible, overflow seating in the Bistro and Lounge cars. Passengers provided overflow seating are classified as unsupplied marginal demand for the purposes of the following discussion about peak capacity and loading.

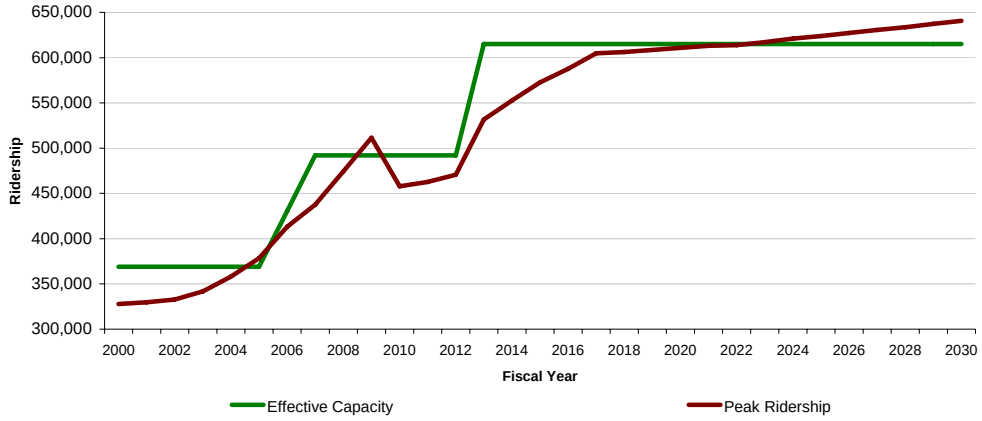
Passengers securing reserved seating, plus the overflow, determine a level of ridership or demand for the peak section. For the year's duration, from July 2007 through June 2008, the peak section demand totaled 474,800 riders. The four Seattle to Portland daily round trips provide a total of 738,760 seats annually. Dividing 474,800 by 738,760 determines an average peak-loading calculation of 64 percent. The difference of 263,960 seats between peak section demand riders and annual total seats reflects lower ridership in non-peak sections: lower ridership during spring and fall seasons and lower ridership levels from Monday through Thursday.

Sensitivity analysis of unsupplied marginal demand levels from 1 percent to 5 percent indicated a range of 5,515 to 27,518 riders. One percent unsupplied demand leading to a peak loading of 67 percent was chosen as a reasonable amount of unsupplied marginal demand. Meeting demand during peak trips is imperative, given the potential lost revenue of high paying passengers and resulting dissatisfied customers.

Ridership can also be responsive to travel time reductions and reliability improvements of adhering to schedules. Option 2 is used as an example for explanation. Option 2 provides for an additional daily round trip (total of five) between Seattle and Portland, starting in July 2012. The Tacoma – Bypass of Point Defiance – 66th St. to Nisqually, included with Options 2 through 4, results in a time savings of 6 minutes per one-way trip. A literature review of elasticity factors cites that train ridership increases 1.58 percent as time decreases by 1 percent. By using the same elasticity factor, expenditures for rail maintenance that improve on-time reliability from the current 61 percent to 95 percent also increases ridership by 18 percent when fully implemented.

Exhibit 3-5 provides a comparison of peak capacity and peak ridership for Option 2. The peak ridership line also incorporates the time and reliability enhancements inherent to Option 2. The chart shows that from 2000 through 2007, peak capacity accommodated the peak ridership levels. Starting in 2008, peak ridership begins to exceed peak capacity with rapidly increasing ridership due to higher gasoline prices and other factors. Both peak capacity and peak ridership rise rapidly from 2012 to 2014, when an additional daily round trip is added and time and reliability enhancements begin to take effect. From 2015 through 2030, peak ridership exceeds peak capacity and demonstrates a need for additional capacity. Options 3 and 4 provide for those additional capacities.

Exhibit 3-5: Peak Ridership vs. Effective Capacity
Option 2 – Minimum Capital Investment
Seattle to Portland



Stations included are Seattle, Tukwila, Tacoma, Olympia/Lacey, Centralia, Kelso/Longview, Vancouver, and Portland.

Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Washington State
Department of Transportation

Chapter 4: Amtrak *Cascades* Needed Infrastructure Improvements: FY2010 to FY2017

In 1993 the Washington State Legislature directed the Washington State Department of Transportation (WSDOT) to develop high-quality intercity passenger rail service through the incremental upgrading of the existing BNSF Railway Company's (BNSF) north-south main line. Since that time, WSDOT has been working with railroad companies and other organizations to identify, develop, prioritize, and build infrastructure projects. The 2006 long-range plan identified opportunities to improve existing services between 2004 and 2023. It proposed a set of infrastructure improvement projects that can, depending on the investment strategy "building blocks," enable WSDOT to fulfill the legislature's directive to provide safe, faster, more frequent, and more reliable passenger rail service through an incremental approach.

This chapter outlines major infrastructure improvements that can be implemented during the mid-range plan horizon—FY2010 to FY2017. The infrastructure improvements are designed to achieve additional services, given scenarios of ridership growth and investment goals described in Chapter 6. The economic, societal, and environmental benefits of these services, as well as investment levels to achieve these services, are further assessed in later chapters.

Identifying and Refining Infrastructure Improvements

Since the early 1990s, WSDOT has partnered with Amtrak *Cascades* stakeholders (i.e. BNSF, Amtrak, and others) to increase service—improving safety and building rail line capacity—through phased infrastructure project development. Projects are developed in a very specific order to achieve a range of operational goals—individual projects solve individual problems; groups of projects solve larger operational challenges.

The *Amtrak Cascades Mid-Range Plan* includes operations analysis focused on service goals and strategic investment options between FY2010 and FY2017. By phasing infrastructure projects for incremental implementation, WSDOT provides policymakers with additional flexibility to fund Amtrak *Cascades* services at a desirable level, given a variety of factors that affect state budget and priorities. Meanwhile, WSDOT can better identify solutions, analyzing how to implement projects and maximize public benefit at the given investment level.

Updating Costs to Implement Infrastructure Improvements

With all transportation projects, including rail, cost escalation is a challenge. Transportation projects are huge investments. They often take many years to complete. They contain many uncertainties (i.e. real estate, engineering design, public-private partnerships, societal and environmental challenges). These factors can easily drive cost estimates for transportation projects much higher than originally anticipated.

To better manage cost escalation and deliver transportation projects on time and within budget, WSDOT began use of cost validation processes called Cost Risk Assessment (CRA) and Cost Estimate Validation Process® (CEVP). While the cost validation processes were effective with highway projects, they were marginally effective with rail projects for several reasons:

- Unlike highway projects that have dedicated funding for system inventory and system preservation, rail projects have no dedicated funding sources to develop or manage such systems.

- Unlike highway projects with available historical data, rail projects have limited historical data. Consequently, less information is available for reliable cost estimates and risk analysis processes.

- Highway projects and rail projects have different inflation trends for their major components. Inflation indices that work for highway projects may not produce reliable cost projections for rail projects.

To address cost escalation concerns for rail projects, WSDOT State Rail and Marine Office staff conducted a study based on a set of 1994 to 2008 rail projects (mainly BNSF projects) experiencing cost escalation. The study identified cost escalation drivers and trends. It categorized rail project costs into five cost groups: pre-construction engineering, right of way, track, signal, and earthwork. It found specific indices to analyze inflation trends and quantify inflation effects. It deducted inflation effects, scope-of-work changes, and original cost estimate errors from the cost escalation.

The study found cost escalation for rail projects averaged about 60 percent (ranging from 2 percent to more than 100 percent) depending on cost type, cost categories, initial estimates, and project implementation timeframe. The rail signal system cost inflation index was also systematically understated.

To address the uncertainty of cost escalation and control risks, three cost estimation improvements were developed by the WSDOT State Rail and Marine Office to improve cost estimates:

- A set of rail project specific inflation indices were used to reflect cost inflation between cost estimates and project implementation.

- Cost escalation, due to scope-of-work changes, would be minimized with a developing rail project management system, which includes a database of historical and current information about project location, type, size, economic climate, and other factors.

- Cost escalation, due to estimation errors, was minimized with staff management control of the data and process. A cost item database that represents rail projects will be developed to help validate the cost estimates produced by consultants using their proprietary databases.

Exhibit 4-1 presents cost estimates for rail projects based on the improved methodology described above. Although WSDOT made its best effort to incorporate risk analysis into cost estimation processes, actual costs may still vary, depending on the funding availability, the outcome of environmental analysis for each project, the outlook of the national economy, and the project completion timeline (generally, the longer the timeline, the rougher the cost estimate).

Infrastructure Improvements and Service Capacity

Exhibit 4-1 describes the rail projects that could be implemented, depending on the funding level, to achieve additional service. Each project solves a particular problem (i.e. eliminate a chokepoint, increase safety) and fulfills a specific operational goal. Because operations analysis is based on an incremental approach to project development, if funding is not available to complete all of the listed projects, a sub-set or phase of each project can be implemented and achieve certain passenger service levels associated with that particular investment level.

Exhibit 4-1: Projects and Project Stages that Could Be Implemented to Achieve Additional Service Levels During the Mid-Range Planning Horizon: FY2010 to FY2017

Project Group	Project Name	Year of Completion	Capital Cost Estimates* ($ Million)			
			Option 1: $0	Option 2: $141 Million	Option 3: $578 Million	Option 4: $817 Million
Project Group A***: $141M for Options 2, 3, and 4	Tacoma – Bypass of Pt. Defiance – 66th St. to Nisqually**	2012		$42.8	$42.8	$42.8
	Vancouver – Yard Bypass and W 39th St.**	2012		$90.4	$90.4	$90.4
	King Street Station – Track Improvements**	2011		$2.0	$2.0	$2.0
	Cascades Train Sets – Overhaul**	2011		$6.0	$6.0	$6.0
	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.					
Project Group B: Option 3 $437M; Option 4 $334M	Increase Capacity of Existing Train Sets	2011			$48.4	
	Kelso-Martin's Bluff – New Siding	Option 3: 2017 Option 4: 2013			$83.4	$60.2
	Kelso-Martin's Bluff – Kelso-Longview Jct. – 3rd Main Track	Option 3: 2017 Option 4: 2013			$151.0	$125.8
	Cascades – Two New Train Sets	Option 3: 2016 Option 4: 2012			$56.8	$50.8
	Blaine to Vancouver, WA – Main Line Track Upgrade	Option 3: 2013 Option 4: 2014			$97.4	$97.4
	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.					
Project Group C: $341M for Option 4	Centralia – New Crossover Near China Creek	2011				$3.7
	Cascades – Two New Train Sets & Four Locomotives	2012				$69.9
	Kelso-Martin's Bluff – Kalama 3rd Main Track	2013				$77.8
	Cascades – Higher Speed Locomotives	2014				$88.4
	Tacoma – Reservation to Stewart – New 3rd Main Track	2014				$101.7
	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.					

* A project group is a set of projects or project stages to be implemented collectively to achieve additional service.

** Costs do not include anticipated expenditures prior to July 2009. These projects were currently funded as: Tacoma – Bypass of Pt. Defiance – 66th St. to Nisqually, $59.5 million; Vancouver – Yard Bypass and W 39th St., $115 million (include $55 million in 09-11 bienium); King Street Station – Track Improvements, 13 million; Cascades Train Sets – Overhaul, $4million. The cost estimates listed in the options are additional costs needed to complete these projects starting July 2009.

*** Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.

Source: WSDOT State Rail and Marine Office.

There are a number of smaller incomplete projects that are underway or are planned to be underway as of this writing. These projects have reliability benefits and in some cases capacity benefits to increase passenger rail service frequency. Some of these projects will be completed prior to the start of this plan's study period, July 1, 2009, and some will carry forward beyond that date. Exhibit 4-2 lists the detail of these projects and their overall costs and anticipated costs to be expended prior to July 1, 2009. These projects are not discussed further in this chapter as

they are planned to be complete, or nearly so, prior to the beginning of the mid-range planning horizon.

Exhibit 4-2: Projects with Reliability Benefits

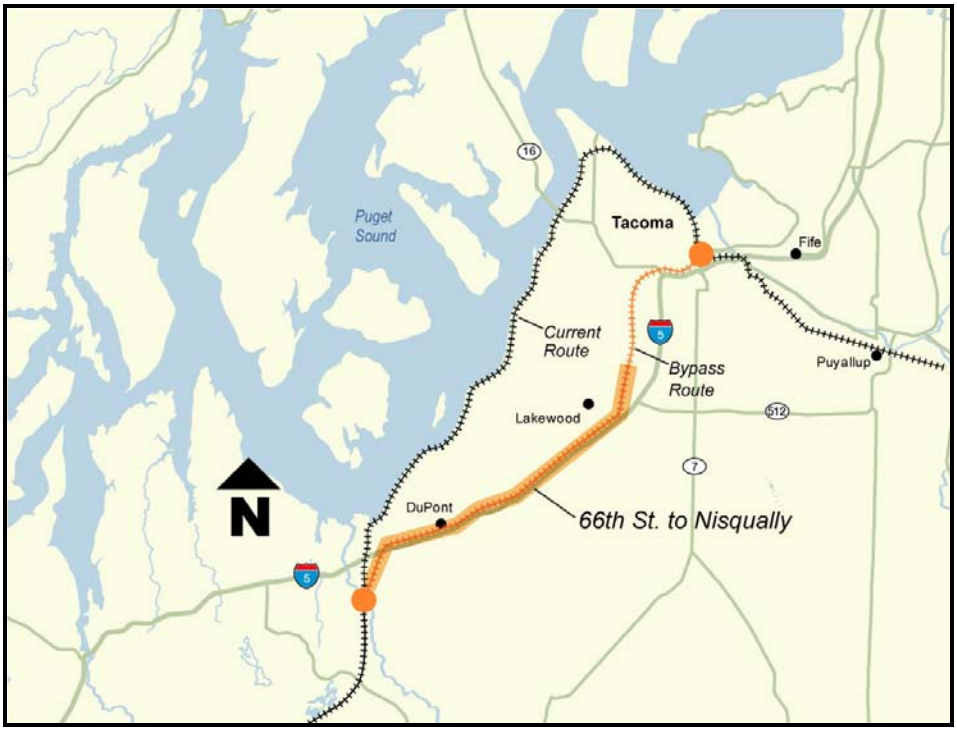
Project Name	Total Budget	Planned Expenditures Prior to July 1, 2009	Planned Expenditures Starting July 1, 2009
Tenino – High Speed Crossovers	$3,875,000	$3,875,000	$0
Mt Vernon – Siding Upgrade	$3,800,000	$3,800,000	$0
Everett – Curve Realignments and Storage Tracks	$14,000,000	$14,000,000	$0
Stanwood – Siding Upgrades	$15,950,000	$15,950,000	$0
Blaine – Customs Facility Siding	$6,000,000	$6,000,000	$0
King Street Station – Track Improvements	$15,000,000	$13,000,000	$2,000,000
Cascades Train Sets – Overhaul	$10,000,000	$4,000,000	$6,000,000
Stanwood – New Station	$5,000,000	$5,000,000	$0

Budgets and planned expenditures are based on the 2008 Supplemental Transportation Budget.

The remainder of this chapter contains information about specific rail projects between Seattle and Portland. Each rail project contains the following information: title, beginning and ending rail milepost (MP) [1], project components, map or photo, cost and funding information, timeframe, and a brief explanation of why it is needed and how it can independently solve a particular problem.

[1] Mileposts or rail mileposts are designations by the railroad indicating the railroad track distance from an established starting point to an ending point.

Tacoma – Bypass of Point Defiance – 66th St. to Nisqually (Rail mileposts 24.7 to 24.2, 11.5 to 0.0, and 9.0 to 0.6)



This project is the first phase of a much larger project listed as Point Defiance Bypass in the long-range plan. Since then, the project has been separated into two phases.

Currently passenger trains must slow down to use the curved tracks along Puget Sound and the single-track tunnels under Point Defiance. The first phase of this project builds a bypass so that passenger trains can avoid those areas. Freight trains would continue to use the existing tracks in the Point Defiance area. This project would increase capacity to allow increases in passenger service, as well as provide reliable Amtrak *Cascades* service by reducing travel time by six minutes and eliminate conflicts with freight trains.

The proposed route of this WSDOT project is the same that Sound Transit would use to extend *Sounder* Commuter Rail service to Lakewood. After both the WSDOT-sponsored and Sound Transit-sponsored projects are completed, Amtrak trains and *Sounder* Commuter Rail would share the route with infrequent freight trains currently serving, Fort Lewis, and other shippers in Lakewood, south Tacoma, and Roy.

This first phase improvement on this bypass route includes a new second track between 66th Street in south Tacoma and Bridgeport Way in Lakewood. It reconstructs the remainder of the existing Sound Transit-

owned track between Lakewood and Nisqually and reconfigures the rail junction at Nisqually on the BNSF's Seattle Subdivision main line. The current cost estimate for this portion of the project is $42.8 million with delivery by 2012 (Exhibit 5A-2, Appendix 5). This project is listed in the 2003 Legislative Transportation Package and the 2005 Transportation Partnership Account, but it would require additional funding beyond the $59.8 million allocated by the state legislature. The design and environmental documentation is complete. The initial work between S. 66th Street and Bridgeport Way is planned to begin construction, along with Sound Transit-funded improvements, in late 2008.

Vancouver – Yard Bypass and W. 39th Street (Rail mileposts 9.9 to 10.4 and 133.3 to 136.5)

This project consists of a single-track bypass of the heavily congested Vancouver rail yard, a siding[2] extension, and associated turnouts from rail MP 133.3 to rail MP 136.5 of the BNSF's Seattle Subdivision and connecting tracks, crossovers[3], and track improvements from rail MP 9.9 to rail MP 10.4 on the BNSF's Fallbridge Subdivision. The bypass separates grain freight traffic from passenger traffic to allow for projected increased traffic in both freight and passenger rail. All the improvements relieve congestion for freight coming from eastern Washington. West 39th Street, which bisects the rail yard, would also be grade separated[4], thus providing a safer crossing for vehicles and pedestrians.

The current estimated construction cost of this project is $150.7 million. This project is listed in the 2003 Legislative Transportation Package. To deliver the project in 2012 it will cost $90.4 million (Exhibit 5A-3, Appendix 5). The design and environmental documentation for this project has been completed, and portions of the rail improvements and the W. 39th Street Bridge are under construction as of this writing.

Add Fifth Seattle to Portland Daily Round Trip

By completing the Vancouver and Tacoma projects described above, the number of daily round trips between Seattle and Portland can be increased from four to five and maintain the two Seattle to Vancouver, B.C. daily round trips.

[2] A siding is an auxiliary track located next to a main line that allows a train to move out of the way of an oncoming train. Sidings are also used to store trains or to add/subtract rail cars.
[3] A crossover is a set of turnouts connecting multiple tracks. A crossover allows a train to move from one track to another.
[4] Grade separated means the crossing lines of rail, auto, or pedestrian traffic are vertically separated from each other (i.e. a roadway that crosses over or under a railroad track).

Increase Capacity of Existing Train Sets

The current fleet of train sets was built from 1996 to 1998 by Renfe Talgo of America (Talgo). Each set has 12 cars and has a relatively fixed consist[5], as it takes a crew of five to seven people up to six hours to add or remove cars for any one train set. Thus, the train set cannot be increased or decreased easily to react to short-term peaks or valleys in ridership. Riders may be turned away during times of peak demand.

In addition each train has one locomotive, usually an Electro-Motive Diesel (EMD) F59 of 3,500-horsepower provided by Amtrak, as well as a cab car.[6] The cab car is required to provide a place for the engineer to operate the train when the powered locomotive is pushing the train instead of pulling. It also provides additional safety in case of a collision. The existing fleet of 12-car train sets is based on the ability of one locomotive to keep to schedule while pulling or pushing the train set and cab car. To move a larger train set and stay on schedule, the cab car needs to be replaced with a second locomotive on each train.

There is a very limited availability of the model of Talgo cars in the current fleet on the used market. This model of train car is no longer in production and has been replaced with a new model that meets current

[5] A consist is the number of cars forming a train set, not including the locomotive or current cab car.
[6] A cab car is an unpowered locomotive.

U.S. rail equipment regulations without modifications. These newer model cars, although similar, are not compatible mechanically with the cars in the current fleet. Further, there is a very limited availability of the model of car in the current fleet on the used market.

This project would purchase a new train set of 14 cars and purchase five new locomotives to supplement the Amtrak-provided fleet of locomotives. The addition of a new type of train set would allow the cars in the existing train sets to be re-arranged to form four train sets consisting of at least 14 cars. This would increase the overall capacity of all trains in the Amtrak *Cascades* service without additional "on the ground" infrastructure improvements.

The cost of the one train set and five locomotives is estimated to be $48.4 million, with delivery by 2012 (Exhibit 5A-4, Appendix 5). As the EMD F59 is no longer in production, the estimate also assumes that locomotives, either of a new design or second-hand from inside the U.S., will be available. While the existing fleet is comprised of equipment from specific manufacturers, the purchase of additional equipment would be a competitive process open to all qualified equipment manufacturers.

Kelso to Martin's Bluff – New Siding (Rail mileposts 105.5 to 110.0)

This project is a phase of a much larger rail improvement project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project consists of adding a Centralized Traffic Controlled[7] arrival and departure track capable of holding up to two full-length trains and associated switches and crossovers on BNSF's Seattle Subdivision. This would allow grain trains inbound for Kalama and empty trains outbound from Kalama to move off the main line, when the Port of Kalama tracks at the two grain terminals are filled with other trains. The project is needed because current congestion on the rail line in this area negatively affects reliability and the ability to add service for additional Amtrak *Cascades* trains. Once this project is completed, service would be more reliable and additional service could be added.

This project can be delivered as early as 2013 at a cost of $60.2 million with Option 4, or 2017 at a cost of $83.4 million with Option 3 (Exhibit 5A-5, Appendix 5). This project is listed in the 2003 Legislative Transportation Package, but would require additional funding beyond the $49 million allocated by the state legislature. Conceptual design and environmental documentation for this project began in 2001. It is anticipated that final design will begin by 2013.

[7] Centralized Traffic Controlled track means the track is dispatcher controlled.

Kelso to Martin's Bluff – Kelso-Longview Jct. – 3rd Main Track (Rail mileposts 96.2 to 102.1)

This project is a phase of a much larger project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project will build on other phases and construct a 4.5-mile third main line track from the passenger station in Kelso to Longview Junction South at the south end of Longview Yard. The Longview Yard is an area of congestion with trains of cars bound for and coming from the Port of Longview and the Weyerhaeuser paper mill. Here cars are switched by BNSF, Union Pacific Railroad (UP), and the Longview Switching Company. The third track would allow passenger and freight trains to move around freight trains leaving or bound for Longview Yard. A new rail bridge over the Coweeman River, as well as two bridges over private access roads, would also be built.

A 5,000-foot storage track in south Kelso would be replaced and converted to main track. This siding would cross Yew Street and Mill Street in Kelso at grade. This project will not require these two grade crossings[8] south of the station to be closed or replaced. They are planned to be replaced in a later phase of the overall project.

[8] A grade crossing is the area along the track where a roadway or pathway crosses on the same grade level.

This project could be delivered as early as 2013 at a cost of $125.8 million with Option 4, or in 2017 at a cost of $151.0 million with Option 3 (Exhibit 5A-6, Appendix 5).

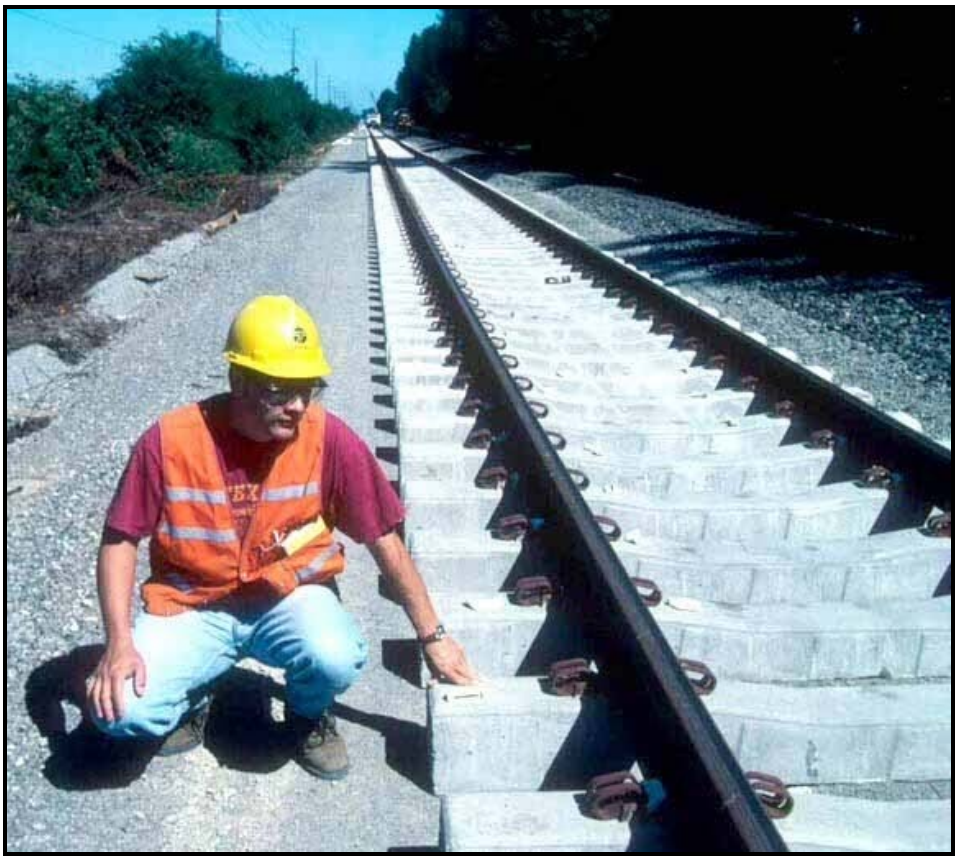
Cascades - Two New Train Sets

In order to increase service capacity between Seattle and Portland, either the service elsewhere would have to be reduced, or more train equipment would be required to supplement the existing fleet of five Talgo-built train sets. While more equipment could be leased from elsewhere in the U.S., it is more conservative to assume that the program would acquire new equipment.

This project would acquire two new train sets for this purpose. It is assumed Amtrak would be able to provide the required locomotives, if WSDOT has not purchased the new high-speed locomotives described later.

The purchase of equipment is difficult to predict as purchasing rail equipment in small quantities, such as two at a time, can increase unit costs substantially. The cost of two new train sets is estimated to be $50.8 million with delivery by 2013 with Option 4 or $56.8 million in 2017 with Option 3 (Exhibit 5A-7, Appendix 5), but could be as much as 25 percent less, if the purchase is associated with a larger order. The estimate assumes a 14-car train set similar to the current fleet, but the equipment purchase would be a competitive process open to all qualified equipment manufacturers.

Blaine to Vancouver, WA – Main Line Track Upgrade



Currently, all the main line tracks that the Amtrak *Cascades* operate on are maintained to Federal Railroad Administration (FRA) "Class IV"[9] standards. Class IV tracks are limited to a maximum speed of 79 mph on straight or nearly straight track. When a track falls out of compliance with the Class IV standard, a "slow order"[10] is imposed by the owning railroad until repairs can be made.

This project will upgrade and maintain all existing main line tracks to FRA "Class V"[11] standards. However, trains would still be limited to 79 mph maximum due to signal limitations. When tracks are brought up and maintained at a higher track standard, then if they fall into disrepair, the Amtrak *Cascades* trains would still be able to operate at 79 mph. This will eliminate nearly all slow orders, thus increasing on-time performance

[9] Class IV is a Federal Railroad Administration (FRA) safety standard focused on track structure, geometry, inspection, and road bed. The Class IV maximum allowable speed for passenger trains is 79 mph.
[10] A slow order is a track condition, usually temporary in nature, that can cancel or severely delay train service (i.e. track damage due to a winter storm, track maintenance in process).
[11] Class V is a higher FRA track safety standard. The maximum allowable speed for passenger trains is 90 mph.

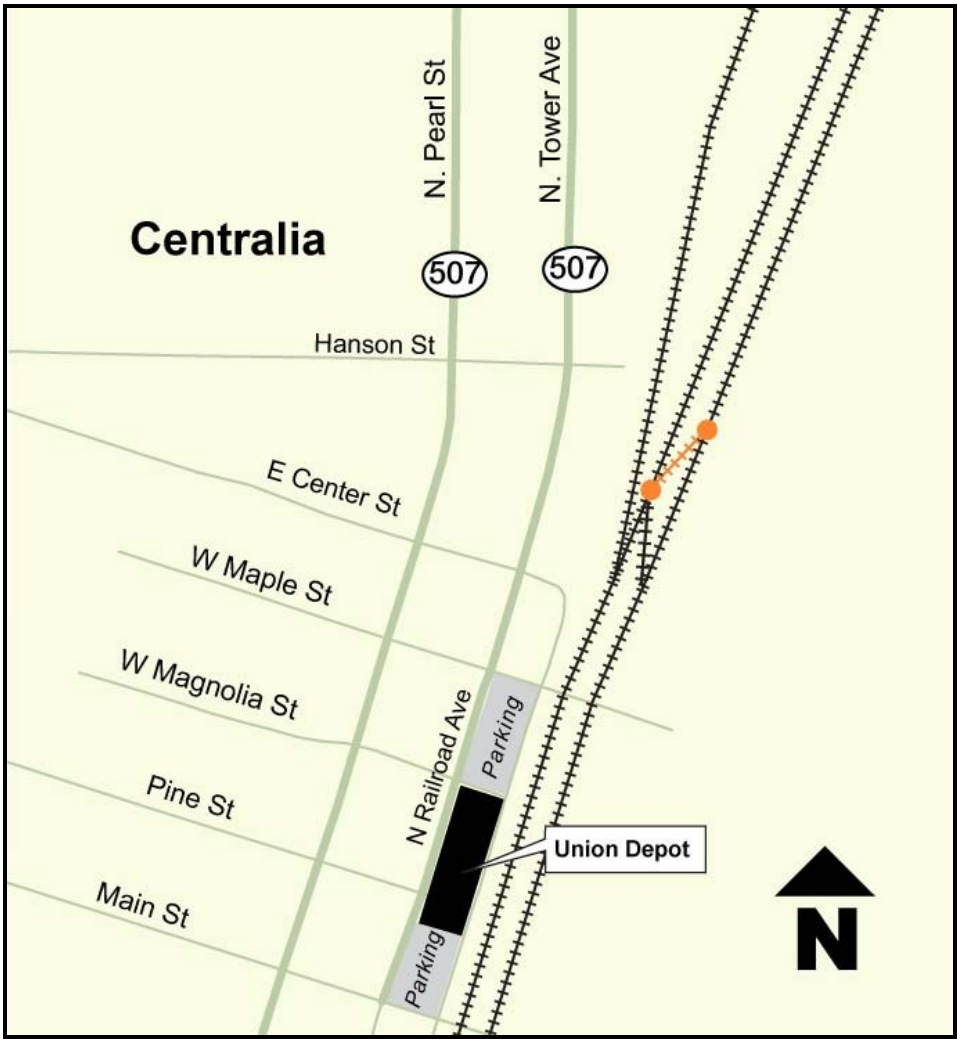
and increasing schedule reliability. A similar project is underway on California's Capital Corridor.

WSDOT estimates it will cost more than $200,000 per track mile. This equates to $97.4 million with delivery in 2014 (Exhibit 5A-8, Appendix 5). In addition, the cost of maintaining the tracks to the higher standard will be higher than today. This will take about four years to implement without severely disrupting existing service. BNSF estimates it will cost between $10,000 and $13,000 (2008 estimates) per track mile annually for ongoing maintenance at the higher track standard.

Six Seattle to Portland and Two Seattle to Vancouver, B.C. Daily Round Trips

By completing the above projects (increasing train capacity, completing the first two phases of Kelso-Martin's Bluff, purchasing two new train sets, and main line track upgrades), the number of daily round trips between Seattle and Portland can be increased to six.

Centralia – New Crossover Near China Creek
(Rail mileposts 53.5 to 53.6)



Construction of this crossover provides flexibility for trains to move between tracks when entering and departing Centralia's Union Depot, ensuring that passengers can exit the train on the west side of the rail line, adjacent to the station. Without this crossover, there would be situations when a passenger train on the east main line would require passengers to cross the west main line, which reduces passenger safety. This project would provide increased capacity, reliability, and safety. The estimated construction cost of this project is $3.7 million with delivery by 2011 (Exhibit 5A-9, Appendix 5).

Cascades - Two New Train Sets & Four Locomotives

As described earlier, in order to add more service between Seattle and Portland, more train equipment would be required to supplement the existing fleet. This project would acquire an additional two new train sets for this purpose. This project would also purchase four additional high-speed locomotives, as described later.

The purchase of rail equipment is difficult to predict because small purchase orders, such as two at a time, can increase unit costs substantially. The cost of two new train sets and four locomotives is estimated to be $69.9 million with delivery by 2013 (Exhibit 5A-10, Appendix 5), but they could cost as much as 25 percent less, if they are part of a larger order. The estimate assumes a 14-car train set similar to the current fleet with a capacity of approximately 300 passengers, but the purchase of the equipment would be a competitive process open to all qualified equipment manufacturers.

Kelso to Martin's Bluff – Kalama 3rd Main Track (rail mileposts 105.8 to 108.9)

This project is a phase of a much larger project listed as Kelso to Martin's Bluff Rail Project in the long-range plan. Since then, the project has been separated into six phases.

This project would build on other phases and construct a 2.9-mile third main track around the congested Port of Kalama area. Here 7,000-foot BNSF and UP grain trains move between the main tracks and one of the largest grain terminals on the west coast. These movements, on and off the main line, create congestion on the main tracks. The third main track would allow passenger and freight trains to move around freight trains that are waiting to enter or are leaving the Port of Kalama.

This project is estimated to cost $77.8 million with delivery by 2014 (Exhibit 5A-11, Appendix 5).

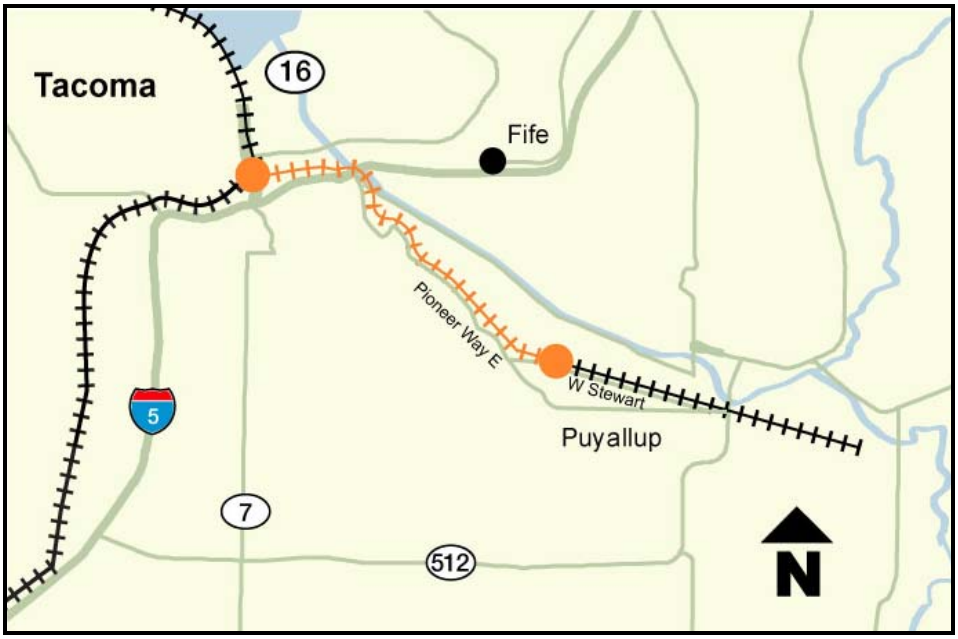
Cascades - Higher Speed Locomotives

As stated earlier, currently each train has one locomotive, usually an EMD F59 of 3,500 horsepower provided by Amtrak and a cab car. This project would purchase 16 new locomotives that are capable of operating consistently and economically with higher speeds (up to 110 mph) and higher acceleration rates than the current F59 locomotive fleet. This project would provide two locomotives per train set plus two reserve locomotives for scheduled maintenance and in case of break-downs.

The estimated cost is $88.4 million with delivery by 2015 (Exhibit 5A-12, Appendix 5), however, as previously stated, the purchase of equipment is difficult to predict since purchasing rail equipment in small quantities, such as two at a time, can increase unit costs substantially. Purchasing the rail equipment as part of a larger order would reduce costs.

For a more detailed discussion of the type of locomotives needed for higher-speed travel, see the 2006 long-range plan, Volume 1; Amtrak *Cascades* Operating and Infrastructure Plan Technical Report, page 4-46.

Tacoma - Reservation to Stewart – New 3rd Main Track (rail mileposts 38.2 to 33.9)



A new main line will be built next to the existing double track. The purpose of this track is to provide a dedicated track for lower speed freight trains that originate, terminate, or stop in Tacoma. The track is needed because freight traffic is predicted to continue to grow in this area over the next 20 years. Without increased capacity additional traffic would result in increased congestion and reduced reliability.

The estimated construction cost of this project is $101.7 million with delivery by 2015 (Exhibit 5A-13, Appendix 5)**.**

Eight Seattle to Portland and Two Seattle to Vancouver, B.C. Daily Round Trips

By completing the above projects (new cross-over in Centralia, two new train sets and higher speed locomotives, the 3rd main track at Kalama, and a new main line in Tacoma), the number of daily round trips between Seattle and Portland can be increased to eight.

Chapter 5: Operational Analysis and Costs

This chapter of the *Amtrak Cascades Mid-Range Plan* reviews the operating environment of Amtrak *Cascades* service in support of mid-range plan options that can allow up to four additional daily Amtrak *Cascades* round trips between Seattle and Portland. Computer simulation modeling was performed throughout 2007-2008 to validate infrastructure requirements necessary for new service, and to identify opportunities to improve the on-time performance and reliability of the service. Appendix 6 provides detailed information regarding the operational analysis and costs described throughout this chapter.

Appendix 6 includes details about the operational analysis, additional reliability projects, service enhancements, and passenger train delays.

Operational Analysis

Operational analysis uses computer simulation modeling to validate Amtrak *Cascades* timetables, track capacity, and service capacity. It looks at proposed infrastructure improvements to increase frequency, improve reliability, and meet on-time performance targets between Seattle and Portland. Operational analysis also helps determine the order of infrastructure and operating projects to be included in Options 2, 3, and 4. Project types include:

- Timetable (schedule) improvements.
- Track capacity improvements.
- Reliability improvements.

It also examines the feasibility of increasing the frequency (up to four daily round trips) and the fleet (up to four additional trains) for Amtrak *Cascades* service between Seattle and Portland.

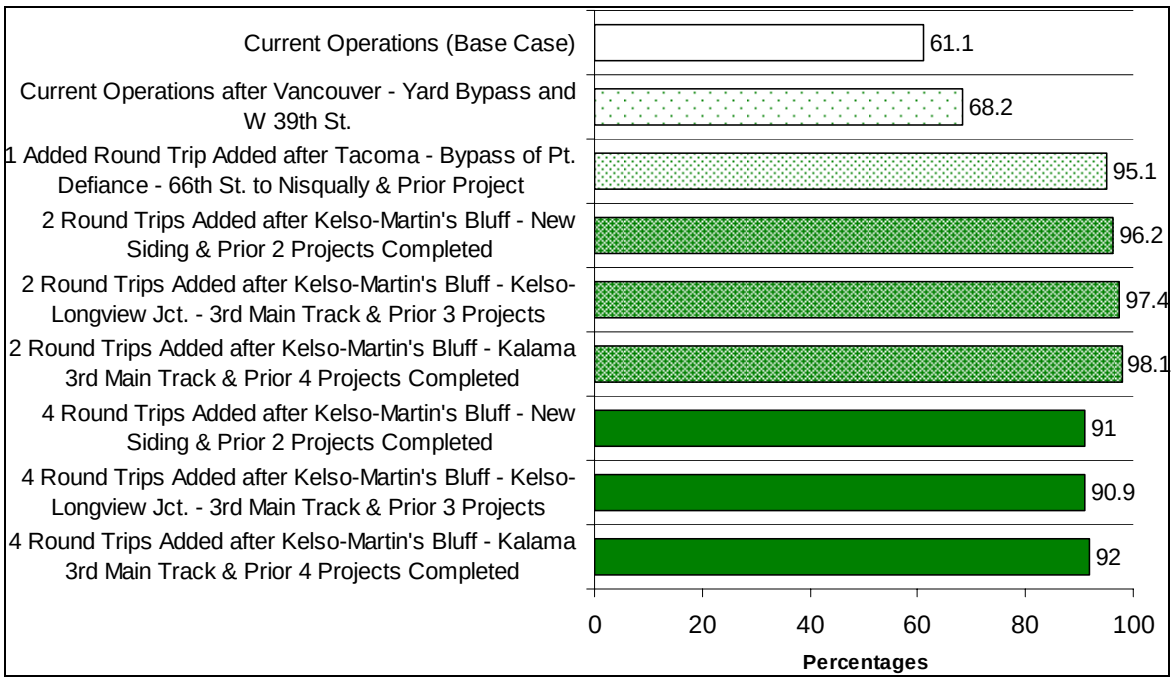
The operational analysis for this plan examined four weeks of railroad operation in randomized traffic patterns to represent the current railroad conditions. It analyzed over 2,800 trains in each of 16 simulations. Each simulation began with a base case that was subjected to extensive analysis before proceeding. Each simulation contained many variables, including the differentiations between freight and passenger rail movements. The modeling process ensured that the results represent the infrastructure requirements as accurately as possible.

Modeling results validated and confirmed the previous 2003 operations analysis. The model addressed on-time performance; it didn't address reliability, slow orders, or the "state of good" railroad repair and maintenance.

Exhibit 5-1 shows anticipated on-time performance when a cumulative set of improvements, adding 1, 2, or 4 additional daily Amtrak *Cascades* round trips between Seattle and Portland, is complete.

Exhibit 5-1: Passenger Service On-Time Performance Based on Five Cases of Randomized Freight Service

WSDOT (Seattle-Portland) Rail Traffic Controller Simulation Results
WSDOT Trains' On-Time Performance Percentage – 3 hr. 40 min. (including 10 min. tolerance)



Source: BNSF Railway Company

The exhibit above shows that the Amtrak *Cascades* has a base case of 61.1 percent on-time performance (a key measure of service reliability), which is relatively consistent with current operations, particularly during peak traffic periods. Completion of the Vancouver – Yard Bypass & W 39th St. Project increases on-time from 61.1 percent to 68.2 percent, but not enough for an additional Amtrak *Cascades* Seattle to Portland daily round trip. Completion of the Tacoma – Bypass of Pt. Defiance Project – 66th St. to Nisqually increases on-time performance and track capacity dramatically, enough to add one additional Seattle to Portland daily round trip to the system and improve on-time performance from 68.2 percent to 95.1 percent.

With the completion of the first two phases of the Kelso-Martin's Bluff Project, an additional Seattle to Portland daily round trip can be implemented with on-time performance in the range of 96 percent to 97 percent.

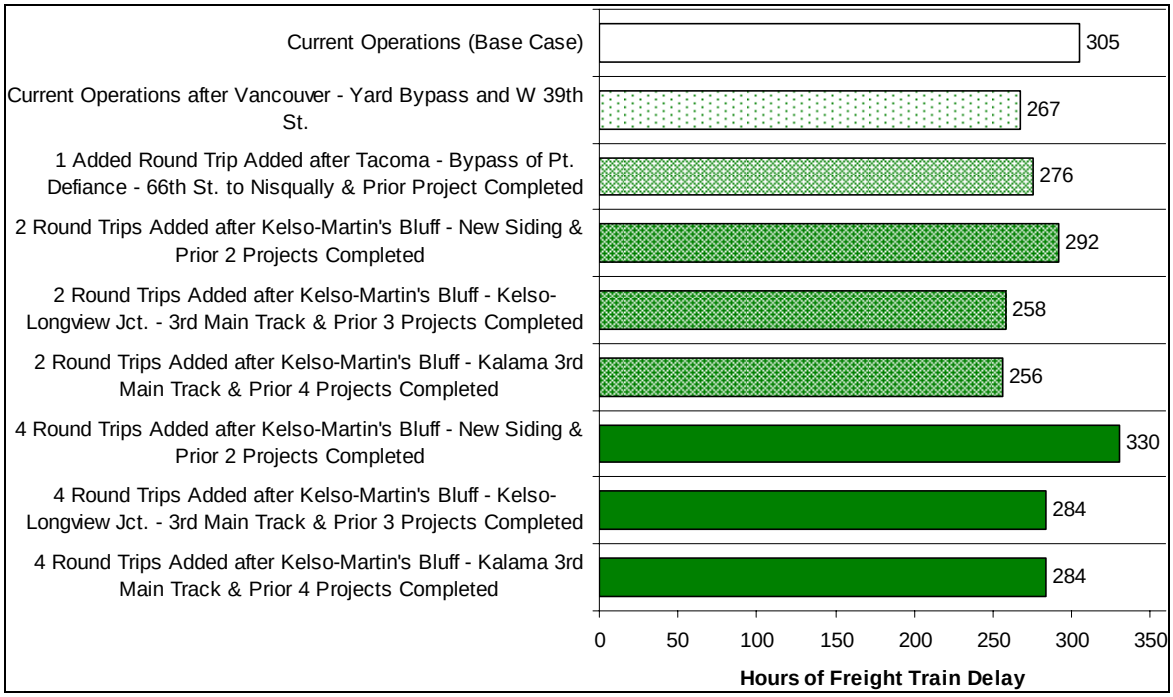
It is important to note that although four daily round trips could be operated, the operation occurs at slightly reduced levels of reliability. This demonstrates that the remaining Kelso-Martin's Bluff – Kalama 3rd Main Track project should be completed and will provide some reliability benefit when the full complement of four additional daily round trips between Seattle and Portland are implemented.

As previously discussed, BNSF is agreeable to allowing additional Amtrak *Cascades* service as long as it will not negatively impact freight service. Impacts to freight service are measured in hours of delay. Current freight train delays, as replicated in the base case, are 304.6 hours per week. It is BNSF's position that intercity passenger rail service expansion can be accommodated as long as their freight business is not adversely impacted.

Exhibit 5-2 shows the relationship between infrastructure improvements, additional Amtrak *Cascades* service, and freight train delay. The modeling confirms that the infrastructure plan can be implemented without negatively impacting freight business.

Exhibit 5-2: WSDOT Plan's Impact on Freight Service

WSDOT (Seattle-Portland) Rail Traffic Controller Simulation Results
Freight Train Delay in hours per week (all main line freight trains)



Source: BNSF Railway Company

Opportunities to Enhance Reliability and Improve Performance

Reliability Improvement

Operational analysis confirms, with a high level of probability, that the incremental infrastructure developments related to Options 2, 3, and 4 would enable additional Amtrak *Cascades* daily round trips between Seattle and Portland, as well as improvement of reliability and overall system performance.

Achieving the 90 percent on-time performance goal in Options 2, 3, and 4 will make Amtrak *Cascades* service punctual and dependable. People who are not satisfied with their service are much more likely to tell others as people who receive a satisfactory rail experience. Amtrak *Cascades* can not achieve broader acceptance unless service is punctual and dependable, regardless of other infrastructure and operating improvements.

Amtrak *Cascades* uses a limited amount of rolling stock (equipment) making multiple trips within the Pacific Northwest Rail Corridor (PNWRC) each day. One delayed train can cause a domino effect of successive delays for passenger and freight trains using the same corridor.

When frequencies (additional daily round trips) are added, operating tolerances become tighter. Amtrak *Cascades* service not only needs the rail line capacity for additional service, but it needs operational changes for much tighter precision and punctuality in the daily operating environment.

Additional Recommended Reliability Improvements

At the request of WSDOT, BNSF ran operational analysis to address three recommended reliability improvements that are currently outside the scope of the mid-range plan. They also have a high potential to increase the capacity for future expansion.

1. **Oregon.** There is a highly congested section of the corridor between the Columbia River and Portland's Union Station. The segment contains several drawbridges and crossing movements of freight traffic to and from port facilities and yard traffic. Four projects have been identified. Two are funded by the state of Oregon and two are unfunded.

2. **Napavine – Winlock to Chehalis 3rd Main Track.** Between Chehalis Junction and Winlock, there is a need for a dedicated main line track, which would allow passenger trains to travel unimpeded by slow moving freight trains traveling on the gradient of Napavine Hill. The dedicated passenger train track would also eliminate sharp curvature, allowing higher travel speeds, which would reduce travel times. This project is unfunded.

3. **Kelso-Martin's Bluff – Longview to Kalama 3rd Main Track.** This project phase adds a third main line track between Kalama and Longview Junction to enhance reliability and achieve an on-time performance of 96 percent or better. This phase is currently unfunded.

Other Reliability Improvements

- **Maintenance Facility.** At the Seattle Maintenance Facility, where trains receive more intensive servicing and maintenance every four days, Amtrak is finalizing plans to reconstruct the facility for current and future needs of Amtrak *Cascades* intercity passenger service, Amtrak long distance service, and Sounder commuter trains.

- **Stations.** Train station access improvements are needed to enhance safety, capacity, wheelchair access, baggage loading, and boarding and de-boarding time.

- **Integrated Scheduling.** Between Seattle, Tacoma, and Nisqually, there are plans to minimize Amtrak *Cascades* and Sound Transit scheduling conflicts. This would allow opportunities to provide rail-to-rail connections and passenger transfers at common stations in Tacoma, Tukwila, and Seattle, where Amtrak *Cascades* and Sound Transit offer complementary services.

Maintenance of Track

The current methods of performing track maintenance during normal daylight hours require "work windows" that limit rail capacity to move freight and passenger trains efficiently through the system. As freight and passenger frequencies increase, the ability to perform track maintenance decreases and the result is slow orders, which can cancel or severely delay train service. Slow orders are placed on a track when conditions exist (i.e. damage to track or crossovers largely due to storm-related events) that restrict the ability for freight and passenger trains to operate at designated track speeds. Slow orders, which are temporary in nature, are problems particularly during construction seasons, when new construction and capitalized maintenance projects are underway.

WSDOT and BNSF are considering additional track maintenance enhancements that limit slow orders, achieve track maintenance goals, accommodate infrastructure growth, and meet the need for absolutely reliable service. Enhancements include:

- **Night maintenance.** Performing maintenance activities at night when traffic is lighter.

- **Alternative methods or equipment.** Multi-function, high-speed track maintenance machines.

- **Capitalized maintenance.** Upgrading from Class IV to Class V track maintenance standards. This is included in Chapter 4 in the project titled "Blaine – Vancouver, WA – Main Line Track Upgrades."

Traffic Management

BNSF is evaluating a "movement planner" program for use throughout their entire system to increase reliability and better manage traffic flow.

Positive Train Control

New rail safety laws require the installation and operation of positive train control, an advanced signal system, by 2015 on rail lines that have mixed

passenger and freight traffic. BNSF is currently testing them on select corridors within their system.

Opportunities for Service Enhancements

In quarterly Amtrak customer satisfaction index surveys, Amtrak *Cascades* service has been ranked in the top five in the nation in customer satisfaction throughout its history. Customers have enjoyed a level of service that is considered better in overall quality than "typical" Amtrak service.

In 2008 Amtrak surveyed existing and potential Amtrak *Cascades* customers. Participants were asked about amenities and improvements to further enhance customer satisfaction. The survey resulted in several recommendations for Coach Class and Business Class travelers. The largest segment of potential new riders is more likely to be business travelers. Their main suggestions are:

- Wireless Internet (WiFi) onboard the passenger coaches.
- WiFi in separate Business Class lounges and in stations.
- Quiet car.
- Business Class amenity upgrades.
- Enhanced passenger information display system.

Analysis and Estimation of Operating Costs

Cost estimation analysis provides detailed and accurate forecasts of Amtrak *Cascades* operating costs for the four strategic investment options discussed in this plan. Operating cost categories, which are defined further in this section, include:

- **Train costs** are direct costs associated with each train. Train costs change with the number of operating trains.

- **System costs** are indirect costs that change with the number of trains, passengers, and train sets. The system cost is allocated equally among the trains.

- **Passenger costs** are individual costs allocated to trains by their ridership. The cost estimation analysis projections do not accurately reflect the relationship of passengers to individual trains, which is an overly complex calculation. The total passenger cost is allocated equally among the trains.

Train Costs

- **Labor and Support for Train and Engine:** Labor costs for engineers, conductors, and other train operating staff.

- **Labor and Support for Onboard Service:** Labor costs for staff involved in dispensing food and beverages on trains to passengers.

- **Fuel:** Costs for locomotive fuel.

- **Commissary Provisions and Management:** Costs for food, beverages, and consumable supplies dispensed on trains to passengers and non-consumable supplies used for customer service on trains.

- **Host Railroad Maintenance-of-Way**: Costs for maintaining track (e.g. track, signals, crossings) and facilities (e.g. stations, other buildings).

- **Host Railroad Performance Payments**: Payments to the railroad for keeping trains on schedule.

- **Insurance**: Purchased property and liability insurance and costs of self-insurance.

System Costs

- **Advertising:** Costs for advertising Amtrak *Cascades* service.

- **General Support:** Expenses not related directly to train operation and the use of resources not dedicated entirely to Amtrak *Cascades* operation (e.g. general counsel, claims services, customer communications, payroll, safety and environmental control, engineering, materials management, human resources, technical training, police and safety services, and procurement/purchasing).

- **Transportation:** Personnel supervising and managing the service and associated costs as well as the costs of buses in lieu of train service and alternative transportation for passengers during service interruptions. Includes itemized categories of yard operations, terminal payments, passenger inconvenience, and transportation supervision and training.

- **Maintenance of Equipment:** Costs of vehicle maintenance.

- **Other Railroad Costs:** Charges by the railroad (BNSF in Washington State and UP in Oregon for the Amtrak *Cascades*) that

are not specific to train operation (e.g. administration, control center functions, avoidable costs).

- **Reservations:** Costs related to managing passenger reservations and the maintenance of information technology systems used for passenger reservations.

- **Other Amtrak Costs:** Includes itemized sub-categories of Amtrak operations and transportation support and amtrak fixed infrastructure maintenance.

Passenger Costs

- **Station Services:** Labor costs for station staff (e.g. ticket agent, janitors) and utility expenses for stations.

- **Commissions:** Fees paid to travel agents and to credit card services.

- **Sales:** Marketing support and the costs of non-station ticketing (e.g. tickets by mail).

The Amtrak *Cascades* cost estimation timeframe is Federal Fiscal Year 2009 (FFY09), which is October 1, 2008 through September 30, 2009. FFY09 cost estimates are split between the partners: Washington at 65 percent, Oregon at 20 percent, and Amtrak at 15 percent. Some cost estimates, such as the cost of Washington State's higher performance Talgo trains, are split differently per agreement with each set of stakeholders.

Analysis results show that cost estimates change based on escalating factors, when capacity changes for additional daily round trips on the Seattle to Portland and Seattle to Vancouver, B.C. segments.

Exhibit 5-3 shows economies of scale.[1] On the Seattle to Portland daily round trip, the "cost per trip" decreases as capacity increases. Factors influencing the "cost per trip" reduction include:

- The cost of adding passenger coaches to existing Talgo train sets.

- The costs of adding locomotives to Talgo train sets that receive an additional passenger coach (a power requirement).

[1] Reduction in cost per round trip resulting from increased round trips, realized through operational efficiencies. Economies of scale can be accomplished because as roundtrip increases, the cost of operate additional roundtrip falls.

- The cost of adding more trains to the fleet.
- The cost of additional Talgo maintenance.
- The cost of enhanced reliability (capitalized maintenance) associated with Options 2, 3, and 4 that eliminate slow orders and improve on-time performance.

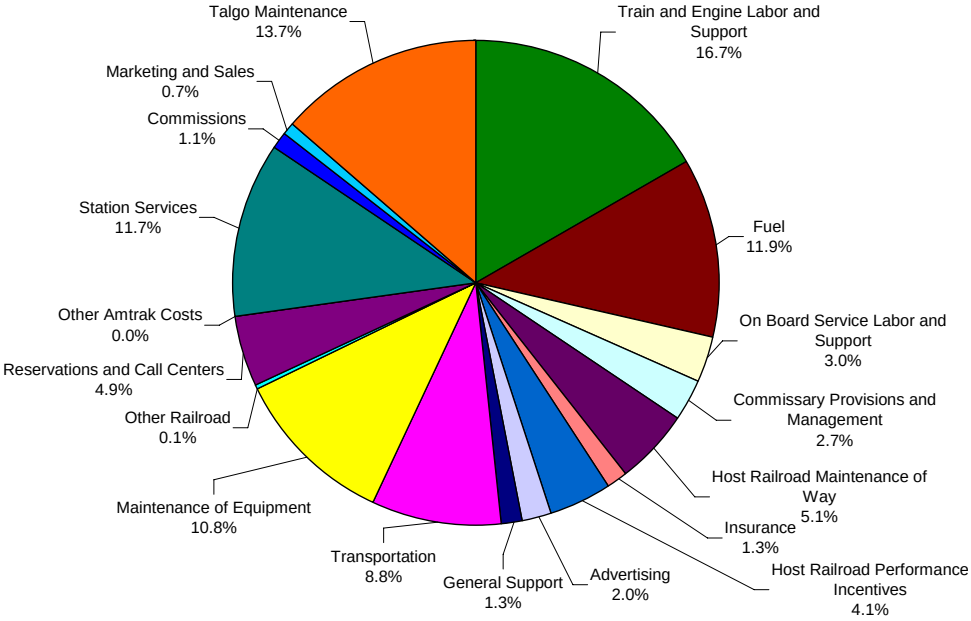
Exhibit 5-3: Estimates of Annual Operating Costs and Maintenance Costs (2008 Dollars)

Daily Round Trips	Amtrak Operating Cost Per Round Trip	Amtrak Operating Cost Per One-Way Trip	Talgo Maintenance Cost Per Round Trip	Talgo Maintenance Cost Per One-Way Trip	Reliability Enhancement Maintenance Cost Per Round Trip	Reliability Enhancement Maintenance Cost Per One-Way Trip
4	$5,753,341	$2,876,671	$913,540	$456,770	$940,125	$470,063
5	$5,499,419	$2,749,710	$899,596	$449,798	$940,125	$470,063
6	$5,293,188	$2,646,594	$890,774	$445,387	$940,125	$470,063
8	$4,997,243	$2,498,622	$873,709	$436,854	$940,125	$470,063

Source: WSDOT State Rail and Marine Office

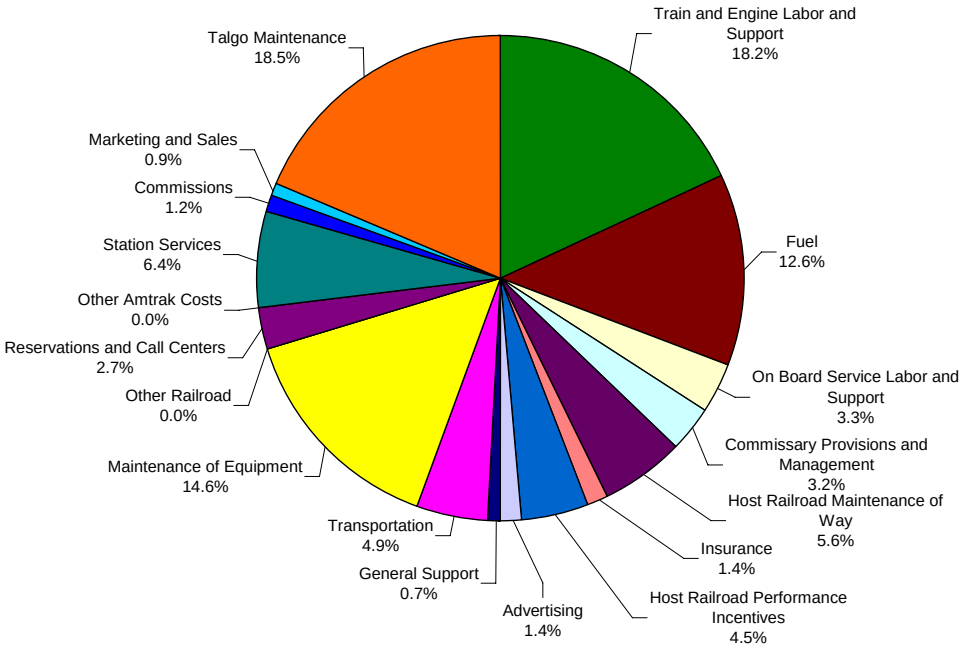
Exhibits 5-4 and 5-5 show analysis results on how Amtrak *Cascades* operating costs change as capacity is added to the Seattle to Portland daily round trip segment as incrementally developed in Options 2, 3, and 4.

Exhibit 5-4: Amtrak *Cascades* Operating Costs for Seattle to Portland Four Daily Round Trips (2008 Dollars)



Source: WSDOT State Rail and Marine Office

Exhibit 5-5: Amtrak *Cascades* Operating Costs for Seattle to Portland Eight Daily Round Trips (2008 Dollars)



Source: WSDOT State Rail and Marine Office

Chapter 6: Options for Achieving Additional Amtrak *Cascades* Service

The analysis in this chapter articulates the needs of intercity passenger train services and discusses supply and demand issues for various scenarios. Comparing the alternatives available to policymakers, the option analysis provides information to help develop strategic investment policies that achieves multiple policy ends using transportation solutions. The option analysis specifies the steps of improving infrastructure to deliver additional intercity passenger services, and link capital and operational investment to ridership growth and economic and societal benefits to support informed decision-making processes—legislative budgeting and prioritizing.

Options for Achieving Additional Services

Options presented in the *Amtrak Cascades Mid-Range Plan* are designed in the context of the current macroeconomic policymaking environment. They build on incremental strategy with stakeholder involvement and are supported by capacity analyses and benefit/cost analysis. This mid-range plan presents four options for future program development described in details in Chapter 2. The following is a brief summary of these options.

Option 1 – Maintaining Current Operation Strategy

This option has no additional capital investment and infrastructure improvements in the mid-range planning period. It maintains the current operation level of Amtrak *Cascades* service. All previous capital investments become sunk costs[1], due to no additional investment for completing projects that would increase service capacity.

Options 2 and 3 – Incremental Strategies

These options address specific investment goals based on the supply and demand interactions of our dynamic economy and changing society. They provide essential information about ridership growth, cost and revenue, local and state economic impacts, and environment and social benefits/costs.

[1] Sunk costs are costs that cannot be recovered once they have been incurred. If there is no additional investment to complete projects that increase service capacity, then the costs of the uncompleted projects are lost or sunk.

Option 4 – Rail as a Long-Term Alternative Strategy – No Financial Constraints

This option examines the engineering feasibility of the maximum capacity that can be built, given the availability of investment to develop such infrastructure improvements.

Option 4 is viable in an environment where policymakers are willing to promote rail as a strategic component in integrated transportation solution. In such an environment, rail, while providing transportation service, would help address issues such as greenhouse gas reduction, congestion relief, public safety improvement, and transportation resilience to natural and man-made disasters.

Investment in Capital Projects by Option

Investment options are designed to achieve multiple goals using passenger rail as part of an integrated solution. Investment in capital projects is used to improve infrastructure and acquire additional equipment that is needed to expand the level of operations. The planning period for capital investment is from fiscal year 2010 to fiscal year 2017.

Exhibit 6-1 demonstrates investments in capital projects and shows the capacity and reliability to be achieved by these capital projects.

Exhibit 6-1: Costs of Capital Projects to Achieve Additional Service Level: FY2010 to FY2017

Project Group*	Project Name	Year of Completion	Capital Cost Estimates* ($ million)			
			Option 1: $0	Option 2: $141 Million	Option 3: $578 Million	Option 4: $817 Million
Project Group A***: $141M for Options 2, 3, and 4	Tacoma – Bypass of Pt. Defiance – 66th St. to Nisqually**	Option 2, 3, and 4: 2012		$141.2	$141.2	$141.2
	Vancouver – Yard Bypass and W 39th St.**					
	King Street Station – Track Improvements**					
	Cascades Train Sets – Overhaul**					
	Five Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 95 percent on-time performance.					
Project Group B: Option 3 $437M; Option 4 $334M	Increase Capacity of Existing Train Sets	Option 3: 2017 Option 4: 2015			$437.1	$334.2
	Kelso-Martin's Bluff – Stage 1 – New Siding					
	Kelso-Martin's Bluff – Stage 2 – Kelso-Longview Jct. – 3rd Main Track					
	Cascades – Two New Train Sets					
	Blaine to Vancouver, WA – Main Line Track Upgrade					
	Six Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 97 percent on-time performance.					
Project Group C: $341M for Option 4	Centralia – New Crossover Near China Creek	Option 4: 2015				$341.4
	Cascades – Two New Train Sets & Four Locomotives					
	Kelso-Martin's Bluff – Stage 3 – Kalama 3rd Main Track					
	Cascades – Higher Speed Locomotives					
	Tacoma – Reservation to Stewart – New 3rd Main Track					
	Eight Seattle to Portland and two Seattle to Vancouver, B.C. daily round trips, 92 percent on-time performance due to running two additional round trips without taking additional expensive reliability projects.					

* A project group is a set of projects or project stages to be implemented collectively to achieve additional service.

** Costs do not include anticipated expenditures prior to July 2009 in 2008 Transportation Supplemental Budget. These projects were currently funded as: Tacoma – Bypass of Pt. Defiance – 66th St. to Nisqually, $57.1 million; Vancouver – Yard Bypass and W 39th St., $59.9 million; King Street Station – Track Improvements, $13 million; Cascades Train Sets – Overhaul, $4 million. The cost estimates listed in options are additional costs needed to complete these project starting July 2009.

*** Projects anticipated to be complete prior to July 1, 2009 in the 2008 Transportation Supplemental Budget are not listed.

Source: WSDOT State Rail and Marine Office

Operating Costs, Revenue, and Investment in Operations by Option

Operating Costs

Operating costs include the costs to operate Amtrak *Cascades* intercity passenger train services and costs to maintain service equipment. Since

each option in the mid-range plan operates at a different level, the operating costs vary. However, Options 3 and 4 operate more efficiently due to economies of scale.

Revenue

Revenue includes ticket revenues and revenues from services provided on the trains such as food and beverage revenues.

Investment in Operations

Investment in operations is the state's net investment of public funds to maintain the operation. It is the total operation costs minus revenues from operation. It is a public investment that aims for gaining greater economic and societal benefits.

Exhibit 6-2 shows the sum of operating costs, revenue, and investments in operations for all plan options from FY2010 to FY2017.

Exhibit 6-2: Total Operating Costs, Revenue, and Net State Costs for Amtrak *Cascades* Operations FY2010 - FY2017 ($ Millions)

Plan Options	Operating Costs*	Revenue**	Net State Costs for Amtrak *Cascades* Operation***
Option 1: Maintaining Current Operation	$235.7	$118.4	$117.3
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$360.2	$144.4	$215.8
Option 3: Incremental Strategy 2 - Supply Meets Demand	$366.7	$153.0	$213.8****
Option 4: No Financial Constraints	$428.2	$157.2	$270.9

* Include operating costs, Talgo maintenance costs, maintenance costs enhancing reliability, and Amtrak administrative costs. Estimated based on historical data, Amtrak FFY2009 Cost Estimates, and planned activities.

** Include revenues from tickets and passenger services. Estimated based on historical revenue data assuming price neutral policy. Total revenue is the product of total forecasted passenger miles and revenue earned per passenger mile, adjusted for inflati

*** This is the estimated costs Washington State pays for contracted Amtrak Cascades operation.

**** The sixth round trip starts in FY2017, the total operation cost here for option 3 does not show full effect of the operation at the capacity built.

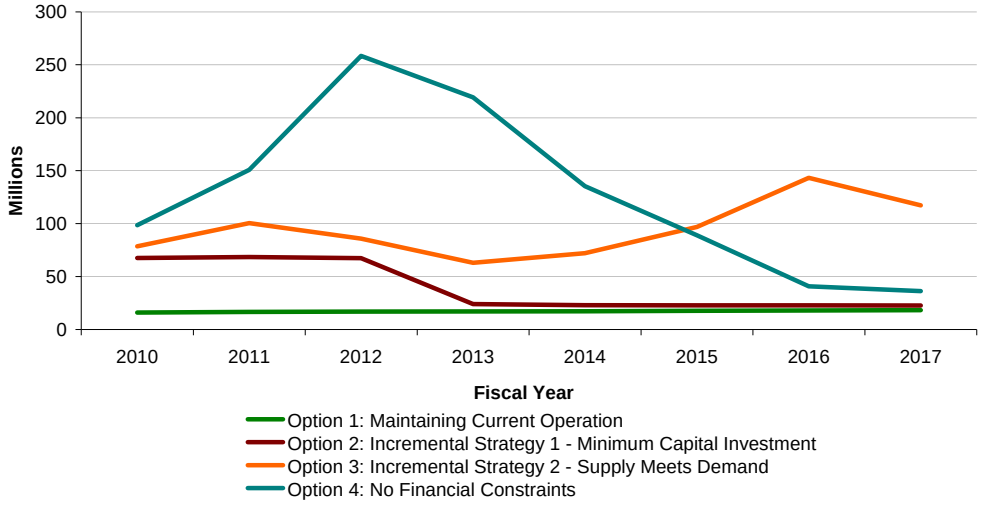
Source: WSDOT State Rail and Marine Office

Total Public Investment by Option

Total public investment includes both capital investments and operational costs. It reflects public costs for a specific option of Amtrak *Cascades* intercity passenger train service.

Exhibit 6-3 shows the total investment (sum of capital projects and operations) over time for the four options. The chart only reflects capital investments during the mid-range planning period of FY2010 to FY2017.

Exhibit 6-3: Dynamics of Total Public Investment
Passenger Rail Investment by Option: FY2010 to FY2017



Source: WSDOT State Rail and Marine Office

Operation Investments

Annual operation investments for FY2010 to FY2017 are present in all incremental strategy options, from around $14 million to $48 million, per year depending on capacity development level of each option.

Capital Investments

The timing of capital investments depend on each option's construction schedule. Depending on the option, estimated project completion dates are 2011, 2013, 2015, and 2017.

Option 1 has no investment in capital projects, since this option only invests in operations. Its line in Exhibit 6-3 is relatively flat.

Option 2 would invest and build capacity of five daily round-trip trains between Seattle and Portland at $141 million as soon as possible to complete ongoing projects that increase reliability/on-time performance

and capacity. The investment improves reliability (on-time performance) from approximately 60 percent currently to above 90 percent.

Option 3 would invest in capital project investments and train sets gradually, based on the market demand. For a total capital of roughly $578 million, this option gradually increases equipment and capacity to 14 cars per train in 2011, five daily round trips between Seattle and Portland in 2013, and six daily round trips between Seattle and Portland to meet demand in 2017. The investment improves reliability (on-time performance) from roughly 60 percent currently to above 90 percent.

Option 4 would invest in even more capital projects to build capacity to eight daily round trips between Seattle and Portland in the shortest time based on engineering feasibility. A total capital of roughly $816 million would be invested by 2015. The reliability would be improved to above 90 percent.

In the "supply meets demand" financially constrained strategy of Option 3, the capital investment is over a longer period of time than the "no financial constraints" strategy of Option 4. This is because Option 3 is designed to meet the growth of demand for a policy neutral scenario, while Option 4 is designed for policies that stimulate demand of train services.

Exhibit 6-4 lays out the annualized investment details for all four options. It shows the distribution of investments between capital projects and operation. The operation investments are the total operating costs minus revenues. It is the public costs for Amtrak *Cascades* services.

Exhibit 6-4: Passenger Rail Investment by Year and Option
FY2010 to FY2017 ($ Million)

Year	Option 1: Maintaining Current Operation			Option 2: Incremental Strategy 1 - Minimum Capital Investment			Option 3: Incremental Strategy 2 - Supply Meets Demand			Option 4: No Financial Constraints		
	Net State Costs for Amtrak *Cascades* Operation*	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment	Net State Costs for Amtrak *Cascades* Operation	Costs of Capital Projects	Total State Investment
2010	$13.6	$0.0	**$13.6**	$14.7	$48.4	**$63.1**	$14.7	$72.2	**$86.9**	$14.7	$92.6	**$107.3**
2011	$13.6	$0.0	**$13.6**	$15.3	$48.4	**$63.7**	$15.3	$107.1	**$122.5**	$15.3	$157.9	**$173.2**
2012	$14.2	$0.0	**$14.2**	$17.4	$44.4	**$61.8**	$16.2	$77.0	**$93.2**	$17.4	$249.2	**$266.6**
2013	$14.5	$0.0	**$14.5**	$34.0	$0.0	**$34.0**	$32.7	$39.0	**$71.6**	$40.6	$196.8	**$237.5**
2014	$14.9	$0.0	**$14.9**	$33.8	$0.0	**$33.8**	$32.4	$26.6	**$59.0**	$38.4	$85.2	**$123.5**
2015	$15.2	$0.0	**$15.2**	$33.6	$0.0	**$33.6**	$32.1	$47.4	**$79.5**	$49.0	$35.0	**$84.0**
2016	$15.5	$0.0	**$15.5**	$33.6	$0.0	**$33.6**	$32.0	$116.1	**$148.2**	$47.7	$0.0	**$47.7**
2017	$15.8	$0.0	**$15.8**	$33.5	$0.0	**$33.5**	$38.3	$92.8	**$131.1**	$47.9	$0.0	**$47.9**
Total Cost	**$117.3**	**$0.0**	**$117.3**	**$215.8**	**$141.2**	**$357.0**	**$213.8**	**$578.1**	**$791.9**	**$270.9**	**$816.7**	**$1,087.6**

* This is the estimated costs Washington State pays for contracted Amtrak *Cascades* operation.

Source: WSDOT State Rail and Marine Office

Growth of Ridership and Capacity by Option

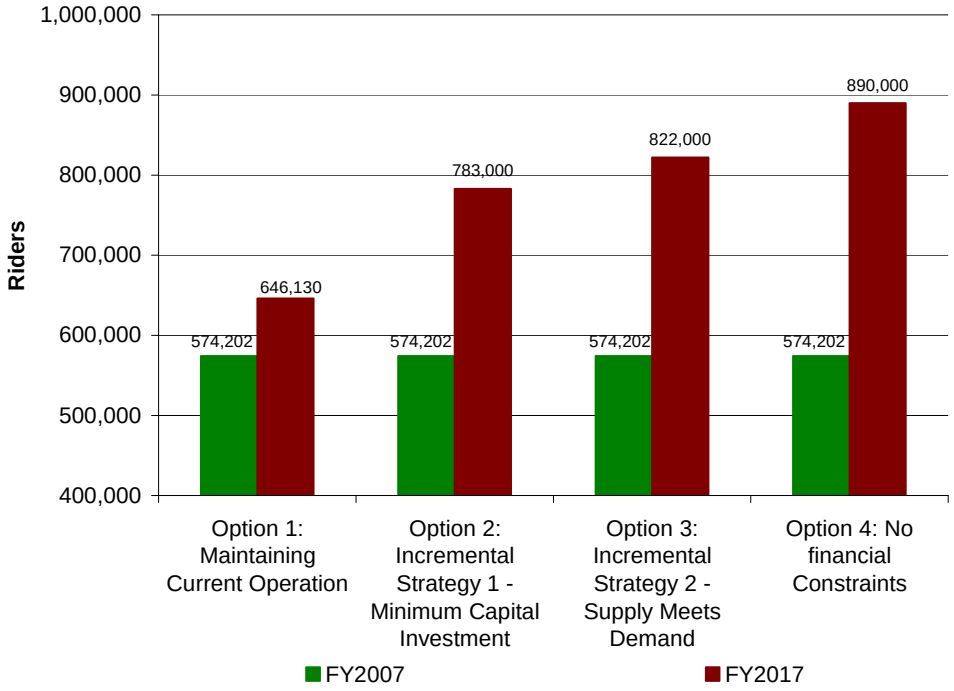
Ridership Growth - Demand

The ridership growth for plan options is estimated through two processes. First, the ridership forecast model is developed to forecast long term growth of ridership based on factors such as population, gas prices, and service availability (Chapter 3 and Appendix 4).

Second, based on improvement on on-time performance and scheduled time savings resulting from implementation of plan options, additional ridership growth is estimated using demand elasticity of time reduction published for Amtrak passenger trains.

The total ridership growth for options is demonstrated in Exhibit 6-5.

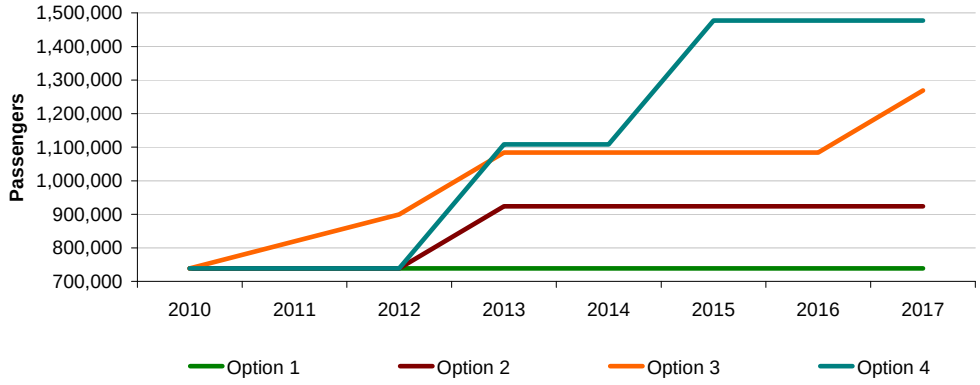
Exhibit 6-5: Annual Ridership Growth by Option
FY2007 vs. FY2017
Vancouver, B.C. to Portland



Capacity Growth – Supply

The capacity growth for plan options is based on capital projects that build capacity for each plan option. The capacity increase and reliability improvement of capital projects are presented in Chapter 4. Exhibit 6-6 provides a dynamic view of capacity changes by option over the time frame of the mid-range plan.

Exhibit 6-6: Maximum Annual Seating Capacity by Option
Seattle to Portland FY2010 to FY2017



Demand and Supply Analysis

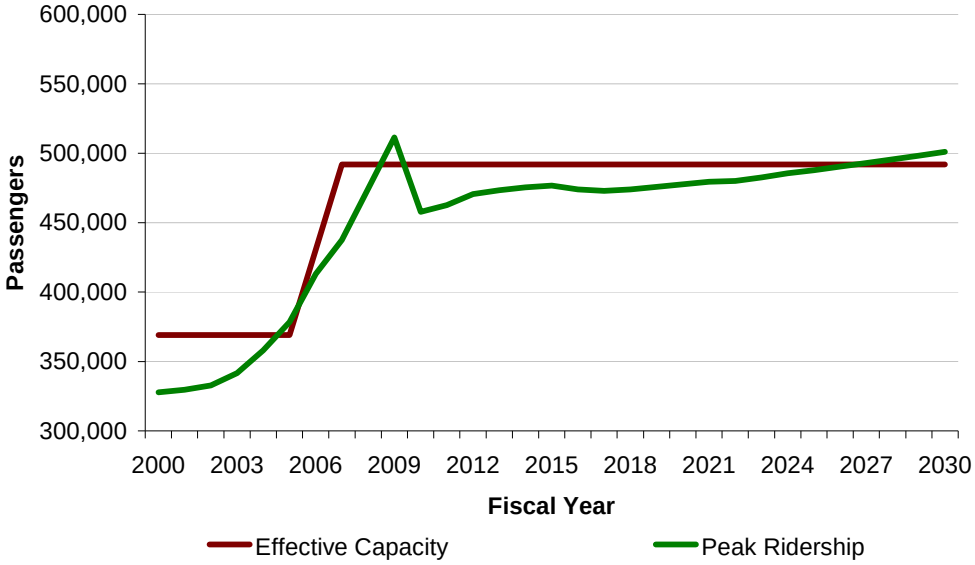
The demand of Amtrak *Cascades* intercity passenger rail service, like utilities such as electricity, is seasonal. While electricity production usually has scalability that allows the electric company to adjust production for peaks and valleys, passenger rail has little flexibility to adjust due to the fixed schedule. The big gap between peak and valley demands makes capacity use and development much more challenging. If WSDOT builds sufficient supply to meet the peak demand, the average capacity use will be low due to the valley in demand. If WSDOT limits the capacity growth, peak demand will not be met. Therefore, there is a trade-off between economic efficiency and policy to meet the societal demand. This is a policy issue similar to policies to regulate and subsidize electrical industries, where economic efficiency does not guarantee sufficient supply. However, the efficiency can be improved through attracting riders in non-peak time through both service improvement and marketing.

Appendix 7 discussed effective or peak capacity and peak ridership—supply and demand indicators. The supply and demand analysis, which is based on peak demand and effective capacity defined, provides information on how growth of the Amtrak *Cascades* service is related to ridership growth.

The following charts demonstrate the relationship between supply and demand for the four policy options of Amtrak *Cascades* investment.

Option 1 – Maintain Current Operations Strategy: Ridership would exceed the capacity in FY2008, and could exceed the capacity for the future by any factor that cause ridership jumps since there is little room to meet the additional growth of ridership (Exhibit 6-7).

Exhibit 6-7: Peak Ridership vs. Effective Capacity (Seattle/Portland): Option 1 - Maintain Current Operation

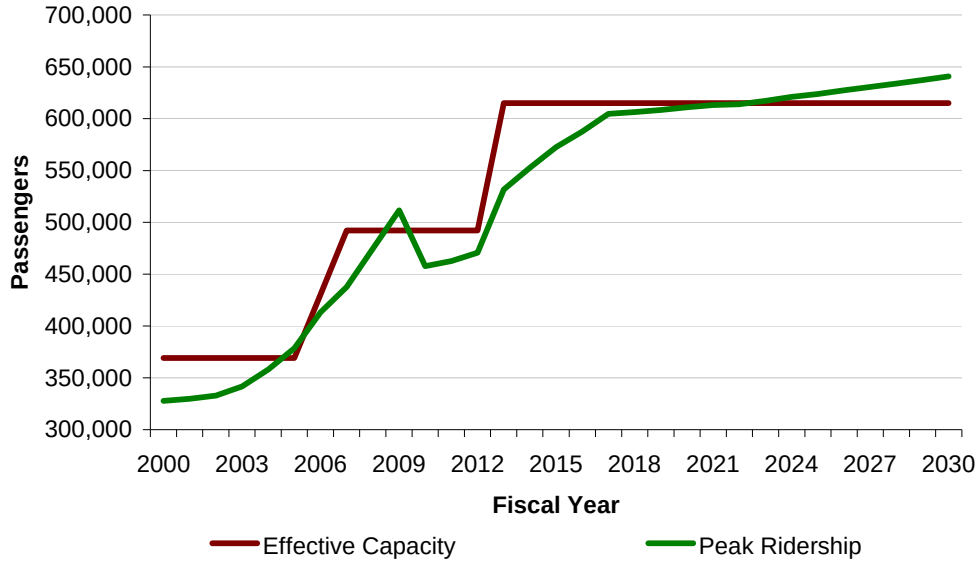


Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 2 – Minimum Capital Investments: Peak ridership would exceed seating capacity in FY2008 and could exceed the capacity for the future by any factor that causes ridership jumps until FY2013, when the minimum capital investments would increase service levels to five daily round-trip trains between Seattle and Portland. The improved reliability and increased capacity resulting from completion of capital investments and operational improvements would continue to drive up ridership. The demand indicated by ridership would exceed supply in about ten years (Exhibit 6-8).

Exhibit 6-8: Peak Ridership vs. Effective Capacity (Seattle/Portland): Option 2 - Minimum Capital Investment



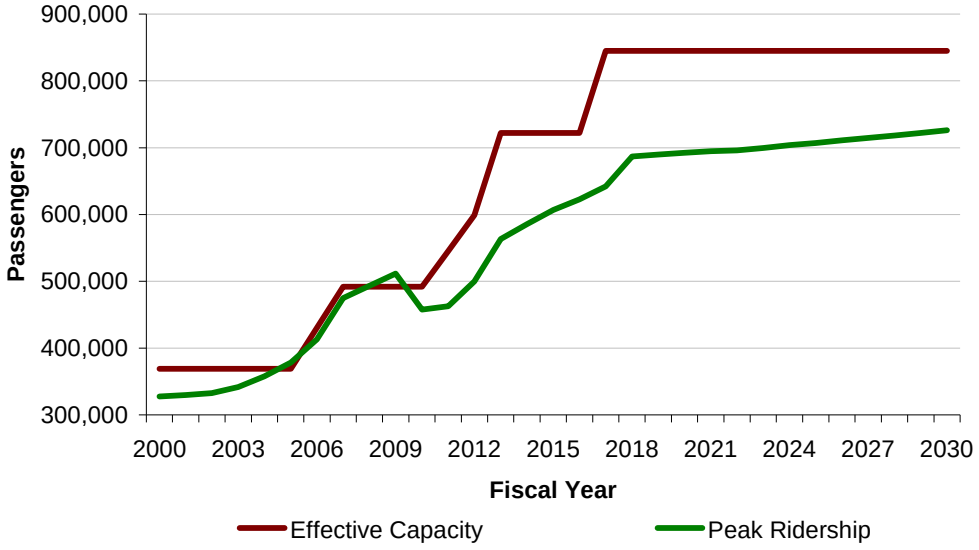
Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 3 – Supply Meets Demand: Peak ridership would exceed capacity in FY2008. Capacity would stay above ridership in FY2009 and could exceed capacity at any time. The investment in a new train set would add two additional cars to each train set and the longer trains would increase service levels for additional riders in FY2011.

The capital investment would deliver a fifth daily round-trip train between Seattle and Portland in FY2013. Ridership would continue to increase due to reliability improvements and other factors. The capital investments would deliver a sixth daily round-trip train between Seattle and Portland in FY2017, to ensure that sufficient seating capacity is available to meet the ridership growth. Since higher frequency and reliability improvements could trigger the demand for business riders, the ample capacity could be filled by such a demand. Since the increase in such a demand was not estimated by the ridership model due to lack of data, ridership indicated by the demand curve may be understated (Exhibit 6-9).

Exhibit 6-9: Peak Ridership vs. Effective Capacity (Seattle/Portland): Option 3 - Supply Meets Demand

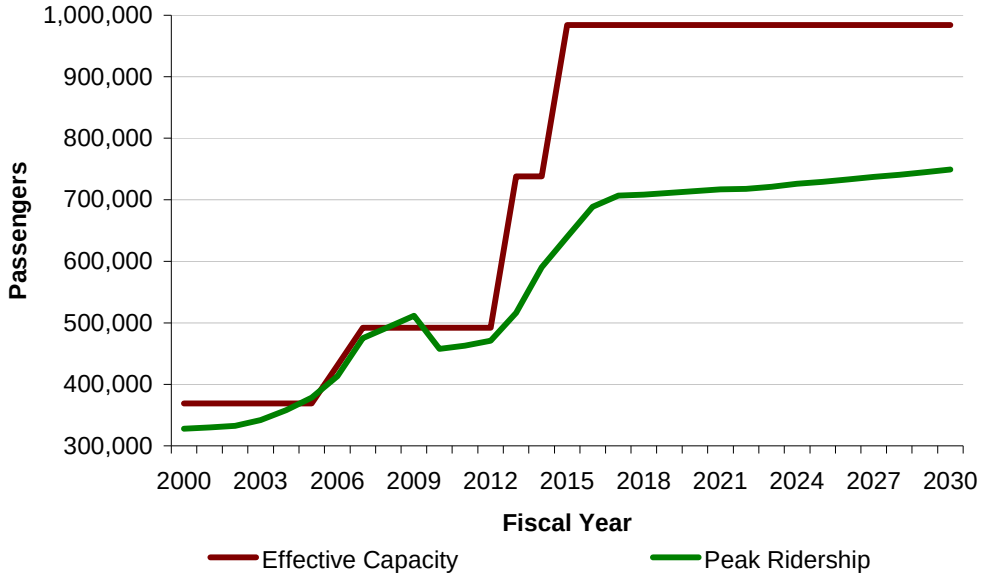


Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Option 4 – No Financial Constraints: Peak ridership would exceed the capacity in FY2008. Capacity would stay above the capacity in FY2009. In this option, rail service would be used as a strategic solution to address multiple issues related to transportation. Ample capacity would be built for policies that encourage the use of passenger rail services. Investments in capital projects are only subject to engineering feasibility during this period. The invested capital projects would deliver two additional daily round-trip trains between Seattle and Portland in FY2013, and another two daily round-trip trains in FY2015, for a total of eight daily round trips between Seattle and Portland. The improved reliability, the higher capacity, and frequency would attract additional riders to Amtrak *Cascades* service. This option also opens other incentive policies, such as a modified fare structure, that could increase rail ridership substantially. The ample capacity could be used for any promotional policies that view passenger rail as part of a solution to address multiple issues (Exhibit 6-10).

Exhibit 6-10: Peak Ridership vs. Effective Capacity (Seattle/Portland): Option 4 - No Financial Constraint



Peak Ridership: *Peak ridership is defined as annual ridership measured at peak segment of the route (Olympia/Lacey to Centralia is the peak segment of Seattle to Portland route).*
Effective Capacity: *Effective capacity is defined as average occupancy level where one percent of unsupplied demand happens due to peak time and peak section constraints.*

Source: WSDOT State Rail and Marine Office

Economic Impacts

When public funds are used to invest in Amtrak *Cascades* intercity passenger train services, the investment generates economic impacts that affect the state's economy, employment, people's income, business' profits, and taxes to governments. These economic impacts would benefit the state and local communities in general. The magnitudes of economic impacts are dependent on the size of investment and how the funds are invested.

WSDOT used the Washington State input-output economic model, developed using IMPLAN[2], to estimate the ripple effects of the increases in Amtrak *Cascades* services. The IMPLAN model was used to estimate the total economic impacts of mid-range plan options, including the cascading effects of the investments of each option (direct, indirect, and

[2] IMPLAN is a commercial input-output model developed using input-output data from Bureau of Economic Analysis, U.S. Department of Commerce. The model used to estimate economic impacts in this plan is a Washington State specific model.

induced impacts). The economic impacts are assessed in terms of the following two indicators:

- **Employment** represents the jobs created by the investment. Amtrak *Cascades* service directly creates jobs in construction, maintenance, food service, and transportation operations. It also creates jobs indirectly by the affect of the outputs of other industries and government incomes.

- **Value added** is an indicator that reflects the net benefit of the investment. Both labor income (wages and salaries) and business incomes are counted as value added.

Exhibit 6-11 demonstrates economic impacts of the four plan options.

Exhibit 6-11: Economic Impacts of *Amtrak Cascades Mid-Range Plan* Options: Sum of FY2010 to FY2030*

Impact	Area	Option 1: Maintaining Current Operation	Option 2: Incremental Strategy 1 - Minimum Capital Investment	Option 3: Incremental Strategy 2 - Supply Meets Demand	Option 4: No Financial Constraints
Support Employment (Job-Year**)	Benefits to Local Communities Along I-5 Corridor	4,887	11,725	17,454	23,752
	Statewide Benefits (Include benefits to local communities)	6,202	15,024	22,825	31,138
Value Added*** ($ Million, 2008 Dollars)	Benefits to Local Communities Along I-5 Corridor	$306.5	$746.8	$1,139.9	$1,555.1
	Statewide Benefits (Include benefits to local communities)	$399.7	$977.6	$1,500.6	$2,048.1

Note: Economic impacts are assessed using IMPLAN Input-Output model for Washington State and its local areas.

* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017.

** A job-year means that a person is employed as a full time employee for a year.

*** Difference between the total sales revenue of an industry and the total cost of components, materials, and services purchased from other firms within a reporting period (usually one year). It is the industry's contribution to the gross domestic product (GDP).

Source: WSDOT State Rail and Marine Office

Chapter 7: Benefit/Cost Analysis

Studies show that passenger rail has many benefits. With its fuel efficiency, safety records, and lower environmental impacts, passenger rail has resurfaced as an attractive candidate that can be included in policy options aimed at solving economic, social, and environmental problems with integrated solutions.

The common public benefits associated with passenger rail include stimulating the state's economy, supporting local communities and businesses with jobs and revenues, reducing congestion, improving public safety, offering a transportation choice, reducing environmental pollution, and saving energy.

This chapter will assess benefits and costs associated with the four plan options that provide various Amtrak *Cascades* service levels. The impacts of these options on the state budget, the state's economy, local communities, highway congestion, public safety, and the environment will be evaluated to determine the likely effects of these policy options. This chapter includes three sections:

- Understanding Public Investment and Benefit
- Benefits and Costs Assessment
- Transportation Cost Analysis

Understanding Public Investment and Benefit

Investment analysis in the public sector is very different from private sector analysis. There are several principles that must be understood in analyzing public investment and public benefits.

Discounting

Discounting addresses the problem of translating values from one time period to another. The larger the discount rate, the more weight that is placed on benefits and costs in the near-term over benefits and costs in the future. Unlike the private sector, long-term benefits, such as environmental quality, are important public policymaking criteria. Consequently, public investment analysis usually uses a relatively lower discount rate than the private sector.

Leveraging

Public projects usually involve multiple sources of investment and partnership. While the analysis of such an investment assesses the efficiency of total investment, public investment analysis also assesses the effectiveness of public investment only. In other words, a measure of the effectiveness of public investment is how much additional investment a public investment can bring into a specific project. This measure is called leveraging.

Distributional Benefits

Many public investment projects provide distributional benefits to the public by transferring public resources to where they are needed most. Such a transfer payment is not a traditionally defined benefit. It could be measured as a public benefit, if it helps reach the goal of public policy to benefit the targeted public group.

With/Without Principle

Many public investment projects provide benefits to the public by mitigating negative impacts. While such investment does not create positive value, it reduces the negative value. The difference between the larger negative value and the smaller negative value is defined as a benefit based on the with/without principle. For example, with an investment in Amtrak *Cascades* capacity, more people would ride trains instead of driving cars. This results in less emissions, due to the fact that rail has a lower emission level per passenger mile compared to auto. The difference of the higher emission (auto) and lower emission (rail) will be defined as a benefit of the investment in Amtrak *Cascades*. Without such an investment project, societal loss due to higher emissions would be much larger. The reduced societal loss would be the benefit of the investment project. Also, as more people choose to ride the train, the emission per passenger would decrease.

Public Benefits and Public Costs

Based on the above discussion about the characteristics of public investment analysis, the benefit/cost analyses performed and presented in this chapter will be based on an assessment of public benefits and public costs.

Period of Analysis

Although the capital investment projects for this plan are implemented from FY2010 to FY2017, the benefits of the plan options are assessed for a longer period: FY2010 to FY2030. The reason for using a longer period for benefit/cost analysis is to demonstrate the benefits of capital projects.

Although projects will be completed in the mid-range plan period, their benefits last for many years.

Benefits and Costs Assessment

This section is a summary of the benefit/cost analyses for the plan options. Appendix 8 will provide the detailed analysis and methodology.

Public Benefit Assessment

Public benefits of statewide rail investment are those benefits directly or indirectly received by the public due to the specified investment. There are three categories of benefits from public investment:

- **Taxes** are generated from investment. These taxes are direct incomes from the public investment and can be spent and reinvested for public benefit.

- **Economic impacts** resulting from the investment, such as the employment and personal incomes, are generated from the investment projects.

- **External impacts**, such as greenhouse gas emissions and accidents, are reduced.

There are multiple benefits associated with passenger rail from all three types of public benefits described above. The magnitude of benefits received by the people of Washington State depends on how passenger rail will be integrated into the policies that embrace integrated solutions for interconnected problems. In general passenger rail has been identified by many studies to have the following benefits:

- ***Tourism Market:*** Passenger rail is one of the major ways for tourists to access Washington State's bountiful cultural and amenity resources, natural beauties, and historical heritages.

- ***Supports Local Communities:*** Passenger rail construction projects bring jobs and revenue to local communities and businesses.

- ***Generate Government Incomes for Public Programs:*** While rail, like highways, is a publicly funded infrastructure improvement and operation, it supports growth of many businesses in various industries that pay business taxes to governments.

- ***Congestion Relief:*** Passenger rail helps solve congestion problems. As the economy and population continue to grow, the

congestion problems on the I-5 corridor will increase. The potential of passenger rail as part of the solution for congestion is promising.

- ***Public Safety:*** Passenger rail transportation has a strong safety record with a national accident fatality rate of 0.08 per 100 million passenger miles, about 1/10 that of motor vehicles. Replacing motor vehicle drivers with passenger rail riders will help improve public safety.

- ***Energy Benefit:*** Passenger rail is much more efficient than airplanes and motor vehicles. Increasing passenger rail services will reduce the growth of other energy inefficient modes and help tackle the energy dependence problems.

- ***Pollution Reduction:*** The level of released toxic substances and greenhouse gas emissions for passenger rail is lower than auto. Replacing motor vehicle users with rail riders will help reduce environmental pollution.

- ***Transportation Choice:*** Passenger rail provides the public another transportation option, especially for the mobility-impaired and the non-driving public.

Public benefits of the mid-range plan options are measured in terms of the following indicators:

Economic Benefits

- ***Revenue:*** Revenue from Amtrak *Cascades* operations, in this analysis, is not counted as an economic benefit. It actually offsets the state's investment in Amtrak *Cascades* infrastructure improvement, operation, and maintenance. In other words, public investments (costs) would be larger without Amtrak *Cascades* service revenue.

- ***Value Added:*** Value added includes personal income from employment, profits for businesses, and taxes paid to governments. Amtrak *Cascades* train services support industries such as tourism, transportation, construction, and maintenance. The value added to the economy resulting from direct and secondary impacts of Amtrak *Cascades* services is measured as economic benefits using IMPLAN—an Input-Output model that measures economic impacts. Other indicators of economic impacts of the plan options, such as economic output, jobs created, and taxes, were presented in Chapter 6 and not used as a measure of net benefits.

Societal Benefits

Societal benefits measured in these plan options include congestion benefits, safety benefits, and environmental benefits. The methodology used to assess these benefits is described in Appendix 7.

- ***Congestion Relief:*** Congestion on the I-5 corridor continues to increase. By diverting traffic away from the I-5 corridor, incremental services of Amtrak *Cascades* can help relieve the congestion of I-5. Amtrak *Cascades* currently accounts for less than one percent of traffic volume along the I-5 corridor. However, as Exhibit 7-1 demonstrates, a small fraction of I-5 traffic reduction could lead to tremendous improvement in reducing delay hours that are costs to travelers. In addition, the potential return on investment is very promising, if rail is considered a strategic alternative for transportation resilience to natural and man-made disasters.

Exhibit 7-1: Benefit of Reducing Congestion

I-5 Interstate Highway Average Daily Traffic Reduction and Hours of Delay				
	Traffic Reduction %			
	0%	-5%	-10%	-20%
Hours of Delay	302,000	90,000	64,000	30,000
Reduced Hours of Delay Due to Traffic Reduction	-	212,000	238,000	272,000
% Delay Reduction from Today	0	-70%	-79%	-90%

Source: WSDOT Urban Planning Office

- ***Safety Improvement:*** The societal costs of motor vehicle collisions on Washington State highways were estimated at $2.5 billion in 2007. Passenger rail transportation has a strong safety record. The national fatality rate is only one tenth of that of highway travel (Exhibit 7-2).

Exhibit 7-2: Comparison of Passenger Safety

Fatality and Injury: Highway vs. Rail			
	Fatality Per Million Passenger Mile	**Injury Per Million Passenger Mile**	**Sum**
Rail	0.0005	0.0590	0.06
Highway	0.0119	0.7689	0.78
Rail to Highway Ratio	0.0387	0.0768	0.08

Source: USDOT Bureau of Transportation Statistics

It is clearly evident that passenger rail travel benefits public safety and is in the public interest. Work remains to further improve rail safety, including rail crossings and trespassing. If more passengers use rail instead of auto, the societal cost of motor vehicle collisions for roadways will be reduced. Since passenger rail has lower fatality and injury rates, passenger safety improves. Reduced societal costs will be assessed as public benefits of using passenger rail.

- ***Health Benefit of Environmental Pollution Reduction:*** Passenger rail has lower emission rates for many greenhouse gases and toxic substances. Exhibit 7-3 provides a comparison of emission rates for three modes.

Exhibit 7-3: Emission Rates – Grams per Passenger Mile

	Automobile	**Airplane**	**Rail**
Carbon Dioxide (CO_2)	430	273	172
Volatile Organic Compounds (VOC)	2.68	0.15	0.16
Carbon Monoxide (CO)	16.40	0.46	0.60
Nitrogen Oxides (NO_X)	0.90	0.21	0.90
Particulate Matter (PM)	0.01	Not Applicable	0.08
Road Dust	0.88	Not Applicable	Not Applicable
Sulfur Oxides (SO_X)	0.03	Not Available	0.05

Source: Compiled by WSDOT State Rail and Marine Office based on multiple sources.

If more travelers use passenger rail instead of motor vehicles, the total emission rates of pollutants would be much lower. The social

costs caused by pollution would be reduced. Such reduction in social costs will be measured as environmental benefits of using passenger rail. The environmental benefits assessed in this plan are mostly health impacts caused by pollutants.

The environmental impacts of global warming, resulting from greenhouse gases, could cost society billions of dollars. Such societal costs have not been well studied and documented. WSDOT was not able to assess them in this chapter. Therefore, the environmental benefits assessed by this chapter might understate the real benefits, which could be substantially higher.

Total Public Benefits

Total public benefits include both economic benefits and societal benefits. Many public benefits are intangible; they are therefore not included in the assessment.

Exhibit 7-4 provides an overview of public benefits for the four plan options. Detailed benefit assessment is provided in Appendix 8. In general, the magnitude of benefits is correlated to investment size. However, the efficiency criteria presented later in this chapter will provide information on which options are more efficient.

Exhibit 7-4: Estimated Public Benefits by Investment Option (2008 Dollars, $ Million)

Plan Option	Economic Benefit	Societal Benefits			Sum
	Value Added	Congestion Relief Benefit	Safety Benefit	Environmental Benefit	
Option 1: Maintaining Current Operation	$399.7	$0.0	$67.2	$158.0	**$625**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$977.6	$598.3	$81.1	$196.3	**$1,853**
Option 3: Incremental Strategy 2 - Supply Meets Demand	$1,500.6	$939.9	$87.7	$215.4	**$2,744**
Option 4: No Financial Constraints	$2,048.1	$1,041.0	$89.6	$221.0	**$3,400**
Note: Option 1 is the baseline.					
* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.					

Source: Benefits estimated by WSDOT State Rail and Marine Office based on multiple data sources. See Appendix 8 for details.

Public Cost Assessment

Based on the above discussion about the characteristics of public investment analysis, WSDOT assessed public costs of the mid-range plan options by two categories: cost of capital projects and cost of operation and maintenance.

Cost of Capital Projects

Cost of capital projects includes costs for projects to increase capacity and improve reliability, and equipment investment for locomotives and cars. WSDOT estimated the capital costs based on cost estimates provided by external consultants in the long-range plan and the recent study on historical costs of rail projects. Costs of capital projects planned for implementation between FY2010 and FY2017 are listed in Chapter 4. An annual summary of capital cost estimates for each plan option is presented in Chapter 6, Exhibit 6-1.

Costs of Operation and Maintenance

Costs of operation and maintenance include both operating costs for Amtrak *Cascades* passenger train services and maintenance costs of train equipment owned by the state of Washington. Chapter 5 discussed the estimation process and economies of scale for operating costs and maintenance costs among plan options, from FY2010 to FY2030.

Public Costs for Amtrak Cascades Program

Total public costs the for Amtrak *Cascades* program include all costs for capital projects and state support for operation and maintenance of Amtrak *Cascades* services. State support is the total program costs minus operational revenue received from tickets, food, and other services. Revenue is estimated based on a revenue neutral policy, which means that revenue estimates reflect no change in price except adjustments for inflation and change in operation costs.

While WSDOT estimates revenue based on revenue neutral policy (no price increase), it is noted that increased ridership, higher capacity and frequency, and improved reliability provide an opportunity to raise prices and increase revenues for the program. Therefore, the revenues estimated for this plan options are conservative (see Exhibit 7-5).

Exhibit 7-5: Estimated Public Costs for Amtrak *Cascades* Passenger Rail Sum of FY2010 to FY2030 (2008 Dollars, $ Million)

Options	Service Level	Costs of Subsidize Operation and Maintenance	Capital Investment	Administrative and Marketing Costs	Total Cost
Option 1: Maintaining Current Operation	Four round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	$280	$0	$29	$310
Option 2: Incremental Strategy 1 - Minimum Capital Investment	Five round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	$563	$133	$37	$733
Option 3: Incremental Strategy 2 - Supply Meets Demand	Six round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	$573	$516	$40	$1,129
Option 4: No Financial Constraints	Eight round trips between Seattle and Portland and two round trips between Seattle and Vancouver, B.C.	$746	$749	$41	$1,536
Note: Option 1 is the baseline.					
** Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both costs are discounted to present value (2008 dollars).					

Source: WSDOT State Rail and Marine Office

Benefit/Cost Ratio and Net Benefit

As noted in an earlier section, a benefit/cost ratio is used to measure economic efficiency for each option, as investment size usually dictates the magnitude of benefits. A net benefit measure is used to measure the size of the benefits with no linkage to how much is invested.

Exhibit 7-6 demonstrates the total benefit/cost ratio for public investment options outlined in the mid-range plan. All options involve capital project investments to achieve higher benefit/cost ratios. This is because the capital projects increase capacity and improve reliability to meet the increased demand of ridership growth. Such gain in capacity and improvement in reliability allow much higher service levels to serve more riders, while improving program efficiency by economies of scale.

Exhibit 7-6: Estimated Benefit/Cost Ratio by Investment Option

Plan Option	Sum of FY2010 to FY2030 - $ Million (2008 Dollars)			
	Total Cost ($ Million)	Total Benefit ($ Million)	Net Benefit ($ Million)	B/C Ratio
Option 1: Maintaining Current Operation	$310	$625	$315	**2.02**
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$733	$1,853	$1,120	**2.53**
Option 3: Incremental Strategy 2 - Supply Meets Demand	$1,129	$2,744	$1,615	**2.43**
Option 4: No Financial Constraints	$1,536	$3,400	$1,864	**2.21**

Note: Option 1 is the baseline.

* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.

** Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).

Source: WSDOT State Rail and Marine Office

Exhibit 7-7 shows the incremental benefit/cost ratios for Options 2, 3, and 4. Option 1 is used as a baseline for the analysis. The results indicate incremental investments generate higher benefit/cost ratios. This indicates that additional public investments will improve current efficiency of the Amtrak *Cascades* program.

Exhibit 7-7: Incremental Benefit/Cost Ratio by Investment Options

Plan Option	Sum of FY2010 to FY2030 - $ Million (2008 Dollars)		
	Incremental Investment**	Incremental Benefit	Incremental Investment B/C Ratio
Option 1: Maintaining Current Operation	Baseline	Baseline	Baseline
Option 2: Incremental Strategy 1 - Minimum Capital Investment	$423	$1,228	2.90
Option 3: Incremental Strategy 2 - Supply Meets Demand	$819	$2,119	2.59
Option 4: No Financial Constraints	$1,226	$2,775	2.26

Note: Option 1 is the baseline.

* The projects completed during the mid-range plan period of FY2010 to FY2017 will generate benefits for local communities and Washington State for many years beyond FY2017. Benefits are sum of FY2010 to FY2030.

** Operation costs are sums of FY2010 to FY2030. Capital investment is sum of FY2010 to FY2017. Both benefits and costs are discounted to present value (2008 dollars).

Source: WSDOT State Rail and Marine Office

Transportation Cost Analysis

For an individual to travel from one place to another, different types of costs are incurred based on their mode of travel. This section discusses the cost composition of three modes (rail, highway, and air), the methods to assess these costs, and comparison of the full costs to travel for these modes. Detailed information and methods about environmental costs will be described in Appendix 9.

Costs of Passenger Rail Travel

User Costs

User costs for passenger rail modes are the price of the tickets to ride the train. These costs are calculated based on historical data from operation of the Amtrak *Cascades* program.

System Utilization Costs

There are two types of system utilization costs. The first type is the public capital investments necessary to develop and maintain infrastructure improvements. These types of costs are estimated based on life-cycle

analysis methods. Life cycles used in this analysis are 25 years and 50 years depending on the types of capital projects. The second type of system utilization costs is the net costs the state pays to operate and maintain the systems that are not recovered from the service revenue. These costs are estimated using reported data from prior operation costs.

Safety Costs

These are societal costs of collision-caused deaths and injuries. Rail has a much smaller probability to have accidents that cause passenger deaths and injuries. Data from the Bureau of Transportation Statistics are used to assess the probabilities of death and injury for both rail and highway travel. Then highway safety costs are used to estimate the safety costs for rail based on comparison of the probabilities.

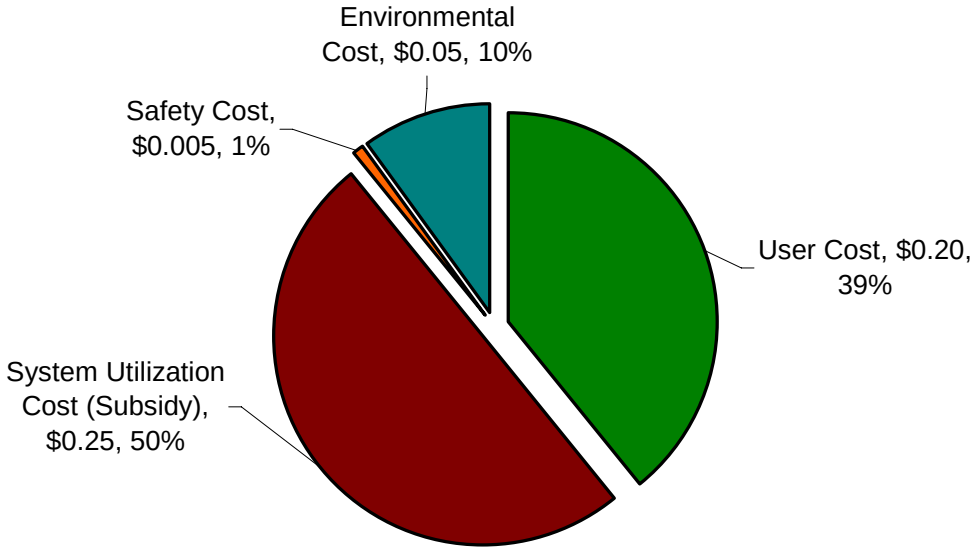
Environmental Pollution Costs

Environmental costs are determined based on emission levels of locomotives and their costs to society. The data used for the assessment are published government data and research findings. These data sources include both rail and highway modes (Appendix 9).

Exhibit 7-8 describes the full rail transportation costs in 2008 dollars. The full cost per mile for rail transportation is $0.51.

Exhibit 7-8: Composition of Cost Per Passenger Mile – Passenger Rail

Full Cost Per Mile: $0.51 (2008)



Source: WSDOT State Rail and Marine Office

Costs of Highway Travel

User Costs

User costs for the highway mode include car depreciation, insurance, fuel cost, and maintenance of the car. There are various ways to calculate highway user costs per mile. The costs published by the Internal Revenue Service are used and adjusted for Washington State. Taxes and fees that are assessed to fund highway system operations and improvements are excluded from the user costs to avoid double counting.

System Utilization Costs

System utilization costs are public costs to develop and maintain highway systems. Although travelers use the system essentially free of charge (tolling is an exception), highway system utilization costs are actually a part of user costs. This is because highway systems are mostly funded by special taxes and fees such as motor fuel taxes and vehicle license fees. These costs are assessed using historical data, WSDOT expenditures—excluding non-highway modes—and historical data on vehicle miles traveled.

Safety Costs

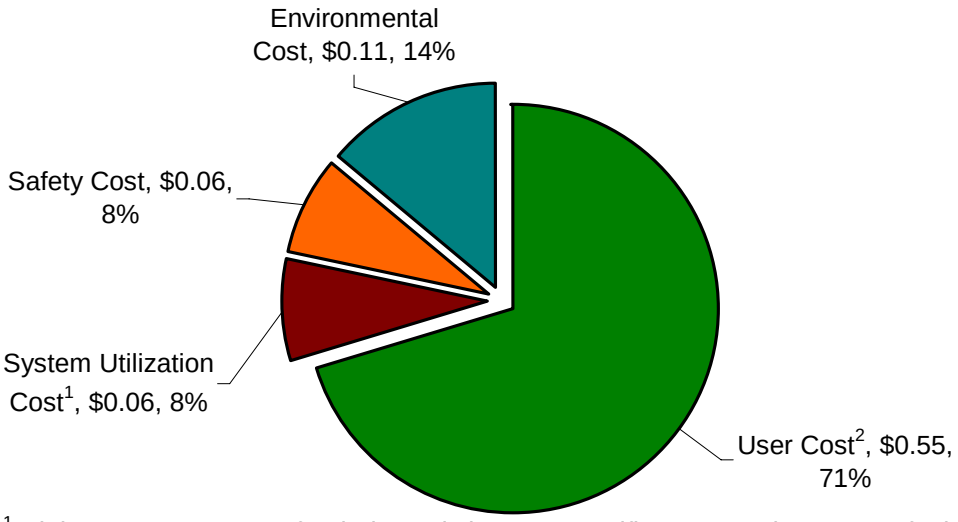
These are societal costs of collision-caused deaths and injuries. WSDOT Transportation Data Office estimates the annual cost to the state based on total deaths and injuries occurred. Safety costs per mile are developed using the annual cost and miles traveled on state highways.

Environmental Pollution Costs

Environmental pollution costs are assessed based on emission levels of motor vehicles and their costs to society. The data used for the assessment are published government data and research findings (Appendix 9).

Exhibit 7-9 describes the full highway transportation costs in 2008 dollars. The full cost per mile for highway transportation is $0.78.

Exhibit 7-9: Composition of Cost Per Passenger Mile – Highway
Full Cost Per Mile: $0.78 (2008)



[1] Highways systems are funded mostly by user specific taxes such as motor fuel taxes and vehicle license fees.
[2] Special user taxes and fees paid by users such as motor fuel tax and license fee are excluded.

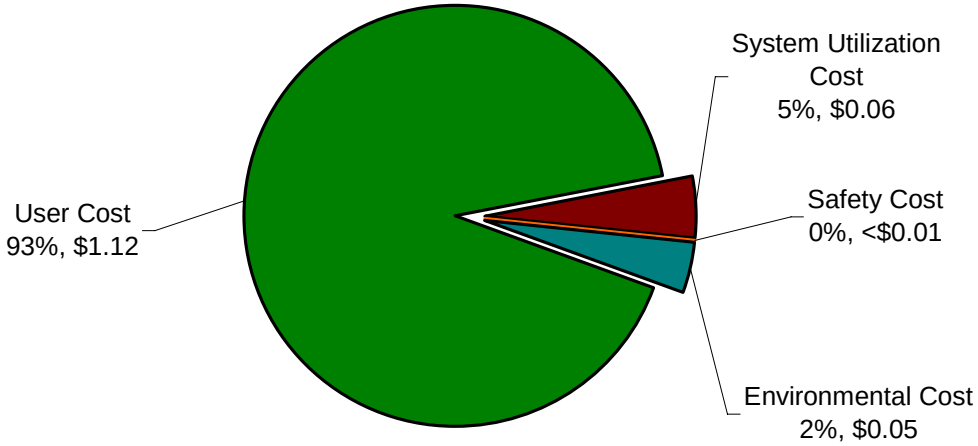
Source: WSDOT State Rail and Marine Office

Costs of Air Travel

The composition of costs of air travel and definitions are similar to rail travel. These data are adopted from Berk and Associates (2006).

Exhibit 7-10 describes full air transportation costs in 2008 dollars. The full cost per mile for air travel is $1.23.

Exhibit 7-10: Composition of Cost Per Passenger Mile – Air
Full Cost Per Mile: $1.23 (2008)



Source: WSDOT State Rail and Marine Office

Cross Modal Comparison

Exhibit 7-11 compares full costs of transportation for highway, rail, and air for 2008. Please note WSDOT used Option 3 as an example of rail system utilization costs because Option 3 has heavy capital and operation investments for increasing capacity and improving reliability.

Exhibit 7-11: Transportation Costs: Cross Modal Comparison

Esitmated Transportation Cost by Mode ($/Passenger Mile)				
Year	**Cost Type**	**Rail**	**Highway/Motor Vehicle**	**Air**
2008	User Costs*	$0.20	$0.55	$1.12
	System Utilization Costs**	$0.26	$0.06	$0.06
	Environmental Costs	$0.05	$0.11	$0.05
	Safety Costs	$0.00	$0.06	$0.00
	Other Costs***	N/A	N/A	N/A
	Total Costs	**$0.51**	**$0.78**	**$1.23**

* User costs: Rail user costs are the ticket price based on historical operations data. Highway user costs are car depreciation, insurance, fuel, and car maintenance. Special user taxes and fees paid by users such as motor fuel tax and license fees are excluded from highway user costs to avoid double counting.

** System utilization costs: Rail systems are mostly funded by public investments (subsidies besides what is recovered from service revenue). Highway systems are mostly funded by specific user taxes, such as motor fuel taxes and vehicle license fees.

*** Cost such as flexibility is not assessed because lack of data.

Source: WSDOT State Rail and Marine Office

Chapter 8: Amtrak *Cascades* and Connectivity

Connectivity is an important aspect of the *Amtrak Cascades Mid-Range Plan*. Nobody starts their journey at the train station; travelers reach the station by another mode or, in some cases, a combination of modes. Therefore, if a mode does not exist or is unknown by a potential passenger, ridership would suffer. The more seamless the transfer, the more the likelihood that people will make use of it.

This chapter examines the importance of providing easy connections between modes of transportation, with special focus on the Amtrak *Cascades* passenger service.

This chapter has two main but complimentary areas of focus—station location and transportation mode. This chapter and exhibits describe what exists, what could exist, and shows these by each Amtrak station.

Other issues that can influence traveler choice were examined. They include communication of the alternatives, clarity of the message and pricing, and through-ticketing opportunities.

Connections with Other Modes

Public Transportation

Vancouver, B.C.

Translink, the regional transportation authority in the greater Vancouver, B.C. area, provides extensive transit services throughout the region. SkyTrain's 30.8 miles of track, making it the longest automated light rapid transit system in the world, operates on multiple routes with stations at key locations. The Main Street Skytrain Station is located adjacent to the Pacific Central Station served by Amtrak *Cascades*, providing an effective connection to and from the trains. Depending upon time of day, Skytrain locations are served every four to twelve minutes.

The Skytrain Waterfront Station, in the heart of downtown Vancouver, provides access to cruise terminals, and links with West Coast Express commuter trains and the Vancouver SeaBus. In 2009 the station will link with the new Canada Line, connecting downtown Vancouver with the Vancouver International Airport.

Translink also provides extensive bus service throughout the region with routes that stop at Pacific Central Station. Greyhound Canada Thruway connections also depart from Pacific Central Station.

Translink has implemented an extensive "trip planner" to assist individuals in determining schedules and the most effective methods of reaching their destinations.

Washington State

Most communities served by Amtrak *Cascades* are also served by local/regional transit agencies. In some cases stations—like Centennial Station in Olympia/Lacey and Skagit Station in Mount Vernon—are owned and operated by local transit agencies as multimodal facilities. Although some public transit agencies have coordinated schedules to coincide with Amtrak *Cascades* arrivals and departures, there are opportunities to improve these connections. Exhibit 8-1 lists Amtrak *Cascades* stations within Washington State and types of transportation connections that are available. Individual station stops throughout the corridor are highlighted on the Amtrak *Cascades* Web site (www.amtrakcascades.com/RoutesAndDestinations.aspx), where additional information on available connecting services is provided.

Exhibit 8-1: Amtrak *Cascades* Stations in Washington State and Transportation Connections

Station	Transportation Connections
Fairhaven Station, Bellingham	• Whatcom Transportation Authority • Greyhound • San Juan Island Commuter • Alaska Marine Highway System • Taxi
Skagit Station, Mt. Vernon	• Skagit Transit • Greyhound • Taxi
Everett Station, Everett	• Everett Transit • Sound Transit • Community Transit • Greyhound • Northwestern Trailways • Taxi
Edmonds Station, Edmonds	• Community Transit • Sound Transit • Washington State Ferries • Taxi
King Street Station, Seattle	• King County Metro • Sound Transit • Greyhound • Northwestern Trailways • Washington State Ferries • Victoria Clipper • Community Transit • Taxi
Tukwila Station, Tukwila	• Seattle Express • Sound Transit • Metro Transit • Taxi
Tacoma Amtrak Station, Tacoma	• Pierce Transit • Sound Transit • Tacoma Link Light Rail • Greyhound • Washington State Ferries • Northwestern Trailways • Taxi
Centennial Station, Olympia/Lacey	• Intercity Transit • Taxi
Union Depot, Centralia	• Twin Transit • Taxi
Kelso Multimodal Transportation Center, Kelso	• CUBS (Community Urban Bus Services) • Taxi
Vancouver Station, Vancouver	• C-TRAN (Clark County Transportation Benefit Area) • Taxi

Portland, OR Area

Tri-Met, the public transit agency in greater Portland, provides MAX light rail throughout Portland and surrounding suburbs, as well as extensive bus service. The north end of the Portland Transit Mall is located at Portland Union Station. Additional construction is underway at the station and will provide dedicated bus and MAX lanes that will extend to points throughout the Portland area. Currently, MAX service is located several blocks from Union Station. MAX service connects with neighboring suburbs, the Portland Exposition Center, and Portland International Airport. The system further integrates with the Portland Streetcar and Westside Express Service commuter rail that will open in early 2009.

Tri-Met, like Translink, provides an extensive "trip planner" to allow passengers to determine routing, schedules, and options to coordinate their trips.

Sound Transit: Light Rail, Sounder, and ST Express Bus

Sound Transit, the regional transportation authority in the Central Puget Sound, is developing a network of commuter rail, light rail, and express bus services in the region.

Sounder Commuter Rail currently operates between Tacoma, Seattle, and Everett during peak commuting hours. Sounder and Amtrak *Cascades* use the same route, and both serve stations at Everett, Edmonds, Seattle, Tukwila, and Tacoma. Sounder provides additional intermediate stops along the route. Sound Transit and WSDOT are exploring opportunities to provide for coordinated ticketing, which would allow persons to travel between sites (i.e. Auburn to Portland via Sounder and Amtrak *Cascades*) that are uniquely served by one or the other, similar to coordination of services in Europe. Between Seattle and Everett, the "Rail Plus" program allows Sounder travelers to ride Amtrak *Cascades* using their Sounder monthly pass and vice versa. Sounder operating schedules are already coordinated with Amtrak *Cascades* to eliminate operational conflicts.

Sound Transit will be operating light rail in Seattle in 2009. The International District light rail station at the Metro Bus Tunnel is one block from King Street Station. Construction is underway to provide a light rail link to Sea-Tac International Airport.

In Tacoma, Sounder, Tacoma Link Light Rail, and ST Express Bus services operate from the Tacoma Dome Station at Freighthouse Square. Amtrak *Cascades* will be moving to that facility upon completion of the Tacoma—Bypass of Point Defiance – 66th St. to Nisqually project, described on page 4-7.

Washington State Ferries

Washington State Ferries operate a ferry service from several places in the Puget Sound. Edmonds and Seattle are located near Amtrak *Cascades* stations. Amtrak is not mentioned on the Washington State Ferries Web site, although it indicates connections by road, local transit, and Sound Transit Sounder trains.

Edmonds Ferry Terminal is the closest, with a 5-minute walk connecting the train station and the ferry terminal. The Seattle ferry terminal (Coleman Dock) is within walking distance of Seattle's King Street Station. A regular connection runs on Metro Transit Service 99 (Waterfront Streetcar) from the ferry terminal to within a block of King Street Station and vice versa.

Amtrak Thruway Motorcoach

Thruway motorcoach service provides coordinated train/bus service with connections at Amtrak stations as well as through integrated fares and ticketing.

Amtrak has contracted with Olympic Trailways to provide "thruway" bus service between Seattle and Vancouver, B.C. This service meets up with Amtrak long-distance and Amtrak *Cascades* trains in Seattle.

Since May 2008, WSDOT has sponsored a round-trip thruway bus connection with trains 500 and 509 in Seattle that provides service to Everett, Mount Vernon, and Bellingham. This bus provides direct connections and ticketing with Amtrak *Cascades* and provides for a southbound link to Amtrak's Empire Builder, which travels east to Chicago via Spokane and Minneapolis.

Oregon's Department of Transportation sponsors multiple daily round-trip thruway bus connections to Amtrak trains that serve Portland Union Station.

Intercity Bus

There are a variety of intercity bus providers (i.e. Greyhound, etc.) that parallel the Amtrak *Cascades* route. Greyhound Canada serves Pacific Central Station in Vancouver. In Portland, the Greyhound terminal is one block from Union Station. Greyhound serves most Amtrak stations throughout the route. These bus companies do not have coordinated ticketing/interline connections with Amtrak at this time, but they do provide information on Amtrak service to potential customers who are not well served by existing bus schedules.

The initial phase of WSDOT's Travel Options (intercity travel planner) is anticipated to be in place by January 2009. Amtrak *Cascades* schedules are integrated in the travel planner to be proposed as travel options.

Sea-Tac International Airport

Tukwila station is less than five miles from Sea-Tac International Airport. In the future a more direct shuttle bus connection between the two facilities should be explored, as a more seamless connection between the airport and the train station could attract more riders.

Bellingham Cruise Terminal

The Bellingham Cruise Terminal, located adjacent to Bellingham's Fairhaven Station (Amtrak *Cascades*), provides cruise ship and ferry connections to southeast Alaska, Victoria, B.C., and the San Juan Islands.

Rental Cars

Amtrak has explored providing rental car satellites at train stations on the Amtrak *Cascades* route. Currently, rental cars are available at Union Station in Portland and Vancouver's Pacific Central Station.

Car Sharing Services

Another option that is open to visitors to a different city is the use of car sharing. There are a number of car sharing services, such as *Zipcar* and *Car Sharing US*. The service operates when a user pays a subscription fee and then makes use of the service of a car. Not all locations offer this service, but it is possible for it to be available in Seattle, Portland, and other locations.

Taxi

Taxis are available at the stations shown in Exhibit 8-1, but it is important to note that they are limited to particular areas. Edmonds and Centralia have limited taxi service. The current Amtrak *Cascades* timetable does not indicate if taxi service is available at stations, or what hours they operate if they are available. Adding an entry on this aspect may influence some people to travel by train.

Bike

There are two ways that bike riders could build ridership numbers. One concerns the "on the ground" facilities at stations (racks and lockers) and dedicated bike lanes to and from stations. The other is the ability to transport bicycles onboard the trains. Both of these impact whether bike users will take the train.

Cruise Ships

Passengers who use the cruise ship service are usually one-way passengers. They either travel to Seattle or Vancouver, B.C. to catch a cruise ship, which then takes them back to a different port, or they arrive in Seattle or Vancouver, B.C. having boarded in a different port.

They are very unlikely to be local residents of the Vancouver, B.C. or Seattle area. The vast majority of cruise ship passengers is on an inclusive tour package that includes bus or shuttle transfers between the train station and the docks.

Amtrak often works cooperatively with cruise ship lines to develop "packages" that include travel by rail as part of the trip. As an example, coordinated travel between Amtrak *Cascades*, Victoria Clipper, and other major cruise lines provide for coordinated travel for thousands of passengers annually on Amtrak *Cascades* to Vancouver, B.C.

Other Issues Impacting the Integration of Transportation

Integrated Fares/Travel Packages

Many passengers, who use the Amtrak *Cascades* service to connect with cruise ships, are taking advantage of an integrated fare that was put together by the tour operator. However in addition to these fares, there are many other avenues that could be explored. WSDOT needs to work with the Washington State Ferries and local transit agencies to explore what opportunities exist for integrated fares.

Travel Planners

Also mentioned, as part of the marketing of the Amtrak *Cascades* service, is the ability for these trains to be shown alongside other services in timetables and journey planners that operate in the corridor. WSDOT should pursue connections with these other agencies and organizations that produce these documents, and work with them to obtain maximum visibility for the service.

Integrated Schedules

An issue that has been raised by passengers in the past has been the lack of integration between services that are operated by different organizations. While it is never possible to cater for late running services, it should be possible to ensure that buses, ferries, and trains make every effort to coordinate their timetables to ensure that passengers, who are not using only the one mode, are able to make reasonable connections.

WSDOT could improve coordination of schedules and, where it is practical, show these connections in published literature.

Passenger Information Systems

One aspect of travel, which is gaining in importance as technology becomes more readily available, is access to real-time information systems on train arrival and departure times. Passengers are becoming accustomed to finding out how flights are performing from the Internet. This avoids arrival at the terminal too early for services that are running late. As the timetable develops and reaches multiple journeys each day, it will become even more important that real-time running information be available over the Internet and cell phones.

Signs Including Pictograms

Some parts of the state enjoy a far greater degree of tourism, and thus non-English speaking people could be users of the Amtrak *Cascades* services. WSDOT knows that tourism is an important aspect of the service. The Amtrak *Cascades* service must cater to the non-English speaker, and one way to accomplish that is to use internationally recognized pictograms for signage on the stations throughout the network.

WSDOT found several examples where there are a few signs from different modes of transportation. Signs from I-5 to Amtrak *Cascades* stations were good, but signs for pedestrians from ferry terminals, transit centers, and bus stops are rarely found. A full survey of locations that could benefit from better signage should be performed and submitted for future funding consideration.

Parking

An inventory of parking availability appears in Exhibit 8-2. Some locations have insufficient parking at this time. WSDOT should determine how to add to the pool of parking spaces. In addition WSDOT noted that at locations such as Tacoma, when the service moves to Freighthouse Square in the future, parking will become a major issue. WSDOT will need to work with Sound Transit to explore options for expanding parking availability at this location.

Exhibit 8-2: Parking Availability at Amtrak *Cascades* Stations
Portland, OR to Vancouver, B.C.

Station	Free at Station	On-Street Parking	Pay Lots	Disabled	Bikes	Other
Union Station Portland, OR	0	45 & 1 motorcycle	177 @ 1.25/hr or $6.50/day	9	5	There is a 411-stall Smart Park two blocks north at $1.25/hour or $6.00/day, limit 24 hours. It also has motorcycle parking.
Vancouver Station Vancouver, WA	30 – 2 hr. max. 60 – long term	0	0	3	0	None
Kelso Multimodal Transportation Center Kelso, WA	15 – 7AM to 9PM, no overnight 45 – 1 week max	16	0	2	8 + lockers	None
Union Depot Centralia, WA	72	15 + street parking within two blocks	0	1	16	None
Centennial Station Olympia/Lacey, WA	126	0	0	6	5 + lockers	None
Tacoma Amtrak Station Tacoma, WA	80	0	0	0	0	2,400 spaces at Tacoma Dome Station, 3 blocks west
Tukwila Station Tukwila, WA	250	0	0	0	0	None
King Street Station Seattle, WA	0	Metered $1.50/day	Day only $9/day	0	0	Several other garages within 3 blocks, day/overnight $20/day
Edmonds Station Edmonds, WA	6 pickup /dropoff only	0	210 $12/day	0	0	None
Everett Station Everett, WA	25 +8 rideshare	0	0	0	6	4 Park & Ride lots with 750 stalls adjacent to station
Skagit Station Mt. Vernon, WA	90	13 free, 2 hr. limit	0	4	8	None
Fairhaven Station Bellingham, WA	18	0	160 $6/day, $30/week	0	8	None
Pacific Central Station Vancouver, B.C.	0	19 $2 Canadian, 2 hr. max.	21 $1 Canadian, 1 hr. max.	0	0	37 Free, 2 hr limit within 1 block; 20 long-term within 3 blocks northwest, $12/day Canadian

An outcome of the two Advisory Committee meetings included different options to improve connectivity. Although there wasn't enough time to examine or test these options, WSDOT will need to explore them further in the future.

Chapter 9: Amtrak *Cascades* Marketing

Introduction

Marketing and advertising efforts for Amtrak *Cascades* is a cooperative effort shared by Amtrak and the Washington State Department of Transportation (WSDOT). A comprehensive advertising campaign has been employed annually focusing on brand building and awareness to reach a mass media target market. In addition to media advertising, Amtrak employs two regional field marketing representatives to develop and implement grassroots marketing in designated markets serving the Amtrak *Cascades* route.

Looking ahead to the next eight years, the marketing plan is focused on the following key elements:

- The travel experience—delivery of service, frequency/schedule, ease of travel.
- Customer satisfaction—onboard customer service, amenities offered, consistency.
- Execution and attention to detail.

Goals and Objectives

1. To support the achievement of ridership and revenue targets.
2. To establish strong brand awareness for Amtrak *Cascades.*
3. To differentiate Amtrak *Cascades* from other transportation options in this market and position it as the preferred method of intercity travel.
4. To establish Amtrak *Cascades* as the preferred choice for business travel in the I-5 corridor.

Marketing Analysis

Market Size

In Washington State about 2.4 million people live within a 10-minute drive of an Amtrak *Cascades* train station as of 2008. Population growth in this area is expected to climb to over 3 million by FY2030.

Current Ridership

Total ridership on Amtrak *Cascades* has risen from 94,000 in 1993 to over 676,000 in 2007. In the history of the service, ridership has risen steadily with losses sustained in only one year.

Rising gas prices, on-going construction projects along the I-5 corridor, and growing concerns about the quality of the environment have helped to drive consumers to consider alternative transportation options. These conditions have contributed to substantial growth in ridership in 2008.

Current Travel Options

Multimodal travel options include personal vehicles, public and private transit, aviation, marine, and rail. The current primary mode of travel is the automobile.

The main thoroughfare available to consumers traveling within the PNWRC is Interstate 5 (I-5). On average, people are making roughly seven
one-way trips on I-5 during a given year. Seattle, Tacoma, and Portland remain the most popular destinations, and more than twice as many trips are for leisure, as opposed to business. Travel times for Amtrak *Cascades* are very competitive with private vehicles and transit alternatives due to the congestion on I-5.

Air travel is accommodated by a choice of domestic and international carriers, operating out of Seattle-Tacoma International, King County International/Boeing Field (Seattle), Portland International, and Vancouver (Canada) International. Amtrak *Cascades* will compete directly with air travel in the I-5 corridor that it serves. Air travel may provide faster flight plan times, but once airport access, check-in, security, and baggage claim wait times are factored in, the total travel time by Amtrak *Cascades* is relatively comparable.

Travel by Amtrak *Cascades* also allows customers to take advantage of onboard amenities and facilities and make more productive use of their travel time.

Segments and Target Markets

The Amtrak *Cascades* market comprises a mix of local residents and visitors, traveling for a variety of purposes including intercity travel, vacation/recreation, business travel, and personal business.

The business traveler is a “golden egg” in that they represent the potential for significant revenue and ridership increases. In order to capitalize on this segment, significant improvements in service, frequency, and on-time performance will need to be made to accommodate the business traveler’s needs.

Demographics

Current demographics (advertising target):

- Adults 25-54.
- Household income (HHI) $50,000+.
- Slightly skewed female.
- Employed (52 percent full time, 12 percent part time).
- Educated (54 percent college graduate, 31 percent some college).
- Travels an average of seven one-way trips along the I-5 corridor per year, for business or leisure.

Pricing

Current pricing for Amtrak *Cascades* ranges from as low as $10 one-way to/from neighboring cities, to as high as $114 for one-way travel on the entire route between Vancouver, BC and Eugene, OR.

Amtrak *Cascades* service between Seattle and Portland is as low as $28 one-way. Comparable one-way air travel between Seattle and Portland (depending on airline restrictions and policies) ranges from $95 to $150, inclusive of all taxes and fees. For travel by automobile, the estimated cost between Seattle and Portland is $0.61 per mile. This makes the comparable cost of traveling the 173 miles between Seattle and Portland by automobile roughly at $106 (one-way).

Marketing Strategy

Opportunities and Challenges

Strengths

- Convenience.
- Alternative to driving a car on already congested roads.
- High levels of customer service and access to amenities.
- Traditional allure of passenger rail services.
- High level of public support.

Weaknesses

- Dependence on the host railroad (Amtrak does not own railroad).
- Service reliability (on-time performance).
- Speed of service/travel time.
- Frequency/schedule.
- Perception of cost, relative to automobile use.
- Dependency on other services for trip connections/completion.

Threats

- Continuing challenges with on-time performance (rail line capacity—congestion from increased freight rail traffic).
- Equipment maintenance and malfunctions.
- Harsh weather conditions resulting in mudslides and flooding.
- Limited political support/funding.
- Volatile gas prices:
  - Reduce discretionary spending.
  - Increase Amtrak's fuel costs, creating pressure for fare increases.

Opportunities

- Volatile gas prices help increase awareness and consideration of alternative travel.
- Development of partnership and alliances with other transportation service providers, attractions, and the travel industry to deliver a seamless, integrated customer travel experience.
- Unique Pacific Northwest brand.
- Promotion of "green" travel.

Branding and Positioning

Amtrak *Cascades* is a unique Northwest brand. Awareness of train travel is fairly significant and Amtrak is well known. However, there is still confusion among consumers regarding the difference between Amtrak and Amtrak *Cascades*. Most consumers assume that Amtrak and Amtrak *Cascades* are one and the same. It is important to establish Amtrak *Cascades* as its own independent identity from Amtrak (similar to Amtrak's *Coast Starlight* and *Empire Builder*) and highlight the Northwest appeal and branding.

More than just a convenient way to travel, trains are also energy efficient. Amtrak *Cascades* intercity passenger rail can move more people for each energy dollar, minimize damage to the environment, and increase the safety of our transportation system. Highlighting Amtrak *Cascades*' energy efficiency will be an effective way to reach out to the consumer's consciousness and desire to choose travel options that reduce carbon emissions.

Advertising and Promotion

An annual marketing and advertising plan is executed through the advertising agency under contract by Amtrak and WSDOT. The advertising budget is funded cooperatively by Amtrak and WSDOT.

Media Strategy

The current media strategy is a broad-based reach campaign to educate the total target market about Amtrak *Cascades*. Primary target markets are focused on Seattle and Portland, with secondary targets in Tacoma, Bellingham, and Eugene. Vancouver, B.C. is a primary target as well, but the media strategy has been put on hold due to the fluctuation between U.S. and Canadian currencies and the uncertainty of the second train service.

Current time frame for advertising campaigns remain focused on the spring season (March – May) and the fall season (September – November). These time frames are considered the "shoulder" seasons between the "peak" seasons of the summer and holiday travel periods. Ridership is usually lower during these times and the need to fill seats is greater.

Promotions

Currently, promotions are executed at two levels: grassroots marketing and regional promotions. Amtrak employs two field marketing representatives who work assigned markets, executing grassroots marketing and promotions, and drive trial (sampling) through cooperative marketing efforts with travel and tour operators. Regional promotions, with properties such as professional sports, state and regional tourism bureaus, and hotel chains, are executed through the advertising agency jointly employed by Amtrak and WSDOT.

Promotions allow Amtrak *Cascades* to:

- Drive immediate train ridership in low—or moderate—use periods, or on specific routes with low ridership.
- Stimulate trial (sampling), which could lead to repeat ridership.
- Generate awareness and exposure when no advertising is running.
- Generate awareness and exposure in markets not included in the media buy.
- Extend marketing budget.
- Reward repeat ridership with consumer loyalty/rewards program (Amtrak Guest Rewards).

Customer Service

Customer service is the cornerstone to the success of any service-based business. It is crucial that customer service needs on Amtrak *Cascades* are addressed on a consistent and proactive basis.

Service Reliability – Passenger Guarantee

Service and travel reliability will be paramount to the ongoing success of Amtrak *Cascades*. No other single factor is more critical to the current and future success of Amtrak *Cascades* than on-time performance. In order to continue to be a viable transportation option and to become a preferred method of intercity travel, on-time performance will have to be improved to a level of consistency.

Real-Time Information

In an increasingly wired and wireless society, there is growing expectation that service providers will have the capability to assemble and disseminate real-time schedule information. Amtrak *Cascades* must be able to deliver real-time service information (delays, cancellations, etc.) using the latest technology.

Enhanced Amenity Package

There are a wide range of amenities that could be considered both onboard the trains and at stations that will enhance the customer experience. For business travelers, wireless Internet capability is critical. Vacationing families could choose from a variety of onboard entertainment options (games, movies, and designated play areas) to keep their children occupied for the duration of their trip.

Marketing Action Plan

Option 1: Maintaining Current Operation Strategy

Option 1 investment strategy would maintain the current advertising and promotion levels with a flat budget. In this option, the advertising and promotions budget would continue to be invested strategically with the expectation of diminished returns on our investment due to the annual increase in media costs that cannot be met by our current budget.

Options 2 and 3: Incremental Investment Strategies

Options 2 and 3 investment strategy would require a significant increase in the advertising and promotion budget. With the proposed budget increase, the advertising plan could reach more consumers and develop more targeted campaigns aimed at the business traveler to meet the added service. This would make a significant impact in media reach, brand awareness, and driving demand.

Option 4: Rail as a Long-Term Alternative Strategy – No Financial Constraints

Option 4 investment strategy would require a comparable budget for advertising and promotion as Options 2 and 3. This would continue to reach the mass market while investing in targeted media aimed at the business traveler.

Build Usage and Market Share

- Retain core ridership constituencies through effective service delivery and customer communications.
- Build loyalty and ridership frequency among occasional riders through service improvements, appropriate fare media, and promotional efforts.
- Attract new riders from population segments with viable ridership potential, through targeted promotional programs.

Price

- **Pricing objectives** – pricing should be managed along with market demand (what the market will bear) and operational costs.
- **Sales promotion** – promotional pricing should be used as an incentive to drive trial (sampling) and promote brand awareness.

Promotion and Public Relations

- Maintain an ongoing image campaign to educate the general public about Amtrak *Cascades*.
- Use aggressive public relations efforts to maximize positive media coverage and news media support.
- Leverage brand awareness by developing cooperative promotion opportunities.

Advertising

A combination of radio, outdoor, online, and newspaper are used to provide message continuity throughout the advertising campaigns.

Financial Forecast

Option 1: Maintaining Current Operation Strategy

Option 1 investment strategy would maintain the current advertising and promotion levels with a flat budget. The current advertising and promotion budget is $600,000 annually and has not changed since the inception of the service. In this option, the current budget would remain static while

media costs will continue to increase annually, which will result in diminishing returns on our advertising investment.

Options 2 and 3: Incremental Investment Strategies

Options 2 and 3 investment strategies would require a significant increase in the advertising and promotion budget. In order to effectively reach our consumers, raise awareness levels of the service expansion, and develop demand for the service, the advertising investment must be seriously considered. As Exhibit 9-1 shows, the amount of advertising investment is significantly larger in Options 2, 3, and 4 as compared to Option 1. This is because the advertising investment has not changed in the last 14 years, although media costs have risen at approximately 7 percent annually. In order to meet the rising costs of today's (and future) advertising opportunities and drive demand, the budget must grow with the service.

Option 4: Rail as a Long-Term Alternative Strategy – No Financial Constraints

Option 4 investment strategy would require a comparable budget for advertising and promotion as Options 2 and 3.

Exhibit 9-1: Proposed Marketing Budget

FY	Option 1	Option 2	Option 3	Option 4
2010	$600,000	$915,000	$915,000	$915,000
2011	$600,000	$940,000	$940,000	$940,000
2012	$600,000	$989,000	$1,054,000	$949,000
2013	$600,000	$1,032,000	$1,095,000	$1,078,000
2014	$600,000	$1,038,000	$1,100,000	$1,109,000
2015	$600,000	$1,035,000	$1,097,000	$1,228,000
2016	$600,000	$1,030,000	$1,091,000	$1,221,000
2017	$600,000	$1,030,000	$1,151,000	$1,222,000

Performance Measurements

- Reviewing monthly ridership and revenue reports can help determine if the marketing message is effective.
- Market research using focus groups, surveys, and advertising awareness research will help gain insight to the effectiveness of our campaigns.
- Obtain feedback from customers using comment cards and on-board surveys to gather information about key attributes such as service reliability, personal safety, employee presentation and

helpfulness, condition of equipment and facilities, and quality and availability of customer information.

- Operating statistics such as on-time performance and customer service ratings are important performance indicators related to the execution of the advertising strategy and marketing promotions, and the effectiveness of customer service delivery.

Chapter 10: Financing Amtrak *Cascades* Service: The Challenges and Opportunities

The 2006 long-range plan identified various construction projects for infrastructure improvements, equipment requirements, capital investments, and operating expenditures for providing and expanding Amtrak *Cascades* services. The *Amtrak Cascades Mid-Range Plan* outlines the implementation options and steps for each option to achieve additional services over the next eight years. Capital and operating investments that improve capacity and service are developed for the four mid-range plan options. The benefits and costs of these options are assessed.

The options analyzed in the mid-range plan provide information for policymakers to consider in how Amtrak *Cascades* service can be funded. The implementation of improved Amtrak *Cascades* service will depend on funding availability.

This chapter discusses how the Amtrak *Cascades* was funded in the past and what the challenges and opportunities are to fund Amtrak *Cascades* services in the future. This chapter includes three sections:

Funding History

The states of Washington and Oregon, Amtrak, Sound Transit, the Province of British Columbia, the federal governments of the United States (U.S.) and Canada, railroads, other participating organizations and agencies, and passengers that use the service are all direct or indirect sources of funding to the Amtrak *Cascades*.

Since Washington State began providing public funds for intercity passenger rail service in April 1994, it has been assumed that major capital construction projects, which are needed to support expanded Amtrak *Cascades* service, would be funded in the following manner:

- Projects necessary to provide faster, more frequent Amtrak *Cascades* service, between downtown Portland, OR and the Columbia River, would be funded by the state of Oregon, with potential funding coming from the U.S. federal government and Amtrak.

- Projects necessary to provide faster, more frequent Amtrak *Cascades* service, between the Columbia River and the Canadian

border, would be funded by the state of Washington, with potential funding coming from the U.S. federal government and Amtrak.

- Projects needed to improve Amtrak *Cascades* service in British Columbia would be funded by the Province of British Columbia, the Canadian federal government, and regional transportation agencies.

- Train sets and locomotives would be funded by the states of Washington and Oregon, with additional funds provided by the U.S. federal government and Amtrak.

- Projects necessary for increased Sounder commuter rail service in the Central Puget Sound would be funded by Sound Transit and the federal government.

Funding of the Amtrak *Cascades* program and related projects is listed by funding entity in Exhibit 10-1:

Exhibit 10-1: Amtrak *Cascades* Investment History: 1994-2007

Capital Investments
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Funding Source	Types of Projects	Amount
BNSF Railway Company	Track and signal work to support reintroduction of rail service between Seattle and Vancouver, B.C.	$ 9.4 million
State of Washington (WSDOT and the Washington State Transportation Improvement Board)	Traffic control and safety systems; rail replacement and track relocations; crossovers; siding extensions; storage tracks; train sets; station restorations and improvements.	124.4 million
Amtrak	Track relocation; train sets; locomotives; Seattle Maintenance Facility; station improvements.	62.0 million
Federal Funds (non-Amtrak, Federal Transit Administration, and Federal Railroad Administration)	Station renovations and improvements; crossing signals and closures.	44.1 million
Sound Transit and the Federal Transit Administration	Capacity improvements between Everett and Tacoma that benefit commuter, intercity passenger, and freight services.	284.3 million
	Capacity improvements between Tacoma and Lakewood that benefit commuter and intercity passenger service.	165.7 million
Oregon (Union Station to the Columbia River)	Traffic control system; track adjustments; improvements at Portland's Union Station.	13.7 million
Local/Other	Station improvements.	13.6 million
Total Capital Investment		**$717.2 million**

Operating Subsidies
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Funding Source	Amount
State of Washington	$176.0 million
Amtrak	91.4 million
Total Operating Funds	**$267.4 million**

Total Capital and Operating Investments for Amtrak *Cascades*
Portland, OR-Seattle-Bellingham-Vancouver, B.C.

Total	**$984.6 million**
Washington State Share of Total	**$300.4 million**

Source: WSDOT State Rail and Marine Office

Current Funding Status

The primary source of funding for the Amtrak *Cascades* capital and operating programs are state funds. These funds, which are generated from non-fuel tax revenues such as licenses, permits and fees, rental car tax, vehicle weight tax, and a portion of the sales tax on new and used vehicles, are deposited in the Statewide Multimodal Account. The state constitution restricts the use of motor vehicle fuel tax revenues exclusively to highway related expenditures.

The Washington State Legislature provided up to $29 million in the 2007-2009 biennial budget for Amtrak operations of Amtrak *Cascades* and for the maintenance of Talgo train sets attributable to state-supported services.

The state legislature has provided direction on capital investments with an approved project list and 10-year spending plan for rail capital investment. Currently programmed passenger rail investments are $360.4 million through 2025. The approved project list provides funding for several major projects, including the Vancouver – Rail Bypass and W. 39th St. Bridge, the Tacoma – Bypass of Point Defiance Phase 1, and a $49 million phase of the Kelso-Martin's Bluff project, as discussed earlier in this mid-range plan.

Limited federal funds have been available for intercity passenger rail development. The Pacific Northwest Rail Corridor (PNWRC), between Vancouver, B.C. and Eugene, OR, is one of 11 regional corridors identified by the USDOT for high-speed rail development. The corridor is one of the original five corridors designated in 1992. An average of $690,000 per year has been made available through the federal "High-Speed Rail Grade Crossing and Hazard Elimination" program. In September 2008, the Federal Railroad Administration announced the award of a $6 million grant to WSDOT for intercity passenger rail capital assistance. This grant will be used to partner with Sound Transit to help fund the Tacoma – Bypass of Point Defiance project.

Challenges and Opportunities

The mid-range plan focuses on infrastructure and operating improvements in the "highest transportation demand" segment of the PNWRC, Seattle to Portland, a segment that is traditionally funded by the state of Washington.

Challenges

- **Limited Multimodal Funding:** The Statewide Multimodal Fund, the primary source of state funding that is available for investment in the Amtrak *Cascades* program, also provides funding for transit, the Washington State Ferries system, bike, pedestrian, and some

highway activities. The amount of funds available is tied to vehicle registrations, various fees, and a percentage of the sales tax on new and used vehicles. The recent economic recession, witnessed by unprecedented volatility of capital market, may adversely impact the overall funding available for multimodal activities. Meanwhile, policies to heavily invest in infrastructure, which are often used by governments to stimulate the economy in prolonged economic recession or depression, could create emerging opportunities in passenger rail funding given its multiple benefits to society. In addition, there will be tremendous competition for available funds due to budget shortfalls and increased costs. Policymakers will be challenged to prioritize the limited resources. This mid-range plan attempts to provide comprehensive information through both quantitative and qualitative analyses to help policymakers make informed decisions.

- **No Dedicated Federal Funding:** Historically, there has not been a dedicated multi-year source of federal funding to provide a partnership similar to other modes of surface transportation.

- **Capital Funding in Oregon and Canada:** The availability of capital funding for improvements south of the Columbia River and north of the U.S./Canadian border is uncertain. Each of those entities needs to participate in rail capacity and reliability projects, if there is to be Amtrak *Cascades* service expansion, as described in the long-range plan.

Opportunities

Future Capital Funding Opportunities

After many years of deliberation, in October 2008, the US Congress passed the Rail Safety and Investment Act of 2008. This legislation provides, for the first time, a multi-year federal matching program with the states to fund intercity rail passenger capital projects. The legislation authorizes $1.9 billion in federal grants over five years. This 80 percent federal and 20 percent state program will allow WSDOT the opportunity to use state funds as leverage for federal funds for rail capital projects (infrastructure and equipment) in a manner that is similar to how other modes of surface transportation have been supported at the federal level. This program, if and when funds are actually appropriated, would need to be an essential component for the future development of Amtrak *Cascades*.

Provisions in the legislation allow states like Washington to use state investments as a 20 percent match for federal funds, up to a maximum of

$15 million per year, applying for up to $60 million in federal capital funds annually—prior to expending "new" state capital funds. The ability to use state funds as a match will be an important factor to consider when policymakers make determinations on future program funding levels.

Funding for Future Amtrak *Cascades* Operations

Ticket-buying passengers, the states of Washington and Oregon, and Amtrak currently fund the operating costs for Amtrak *Cascades* service in the PNWRC. It is assumed that any proposed increases in service as provided for in this mid-range plan, which focuses on enhanced Seattle to Portland service, would be funded by ticket buying passengers and by the state of Washington. Projected additional operating costs for each of the options presented in this plan are described in Chapter 6.

One of the major challenges is how to capture the opportunity of strong ridership growth to make the program more self-funded. Currently the farebox recovery ratio is about 50 percent—with strong ridership growth this year, it could reach a higher level. A 50 percent farebox recovery is considered very good for publicly-funded transportation. Policymakers need to determine the appropriate balance of farebox and public costs. It is possible that policymakers could view the many benefits of rail transportation as worthy of an appropriate level of public support. There are several factors that could drive a long-term growth of ridership.

- **High Energy Prices:** Rising fuel costs and the environmental advantages of rail passenger service have contributed to strong ridership growth. As Washington State and other entities in the region attempt to reduce greenhouse gas emissions and make environmentally responsible infrastructure choices, intercity passenger rail development as a method of travel should receive stronger consideration in the future. The mid-range plan options provide information on environmental impacts of multimodal investments for consideration.

- **Reliability Improvements:** There is tremendous opportunity to improve Amtrak *Cascades* service reliability through targeted investments in capital and in enhanced maintenance as discussed in this report. On-time performance can be expected to improve from the current 60+ percent to more than 90 percent in the next several years with investments outlined in this plan.

- **Reduced Travel Times:** Mid-range plan options for investment can reduce scheduled travel times in the range of 4 to 30 minutes due to infrastructure and reliability improvements, boosting

ridership by providing a more attractive and dependable rail transportation option in our region.

- **High Frequency of Train Service:** Higher frequency of train services, along with higher reliability (on-time performance and time savings) could trigger significant growth as business travelers start to use reliable train service. The mid-range plan did not forecast such growth due to lack of data. However, experiences in other corridors show this is a likely scenario as Amtrak *Cascades* operates at a service level of eight daily round trips.

Higher ridership could create a strong opportunity for the program to reduce net public costs.

- Higher ridership could increase occupancy that in turn decreases cost per passenger mile. If ticket prices hold, the lower costs mean lower public costs.

- If higher ridership is met by higher levels of service, economy of scale of running train services could also lead to lower costs per passenger mile.

This plan uses conservative estimates in analyzing ridership and farebox recovery. Actions proposed in the plan could lead to further improvements of revenue and cost performance.

- **Marketing Concepts:** For the first time, the mid-range plan includes marketing concepts that lay out actions to expand market reach to targeted customers. With the right marketing concepts, ridership fluctuation caused by seasonality could be improved and the average occupancy rate could be higher. Consequently, state support could be lowered. An investment in marketing could be fruitful in support of infrastructure and operation improvements. More people seek alternative transportation choices for many reasons, including concerns about high energy prices, congestion, and the environment.

- **Increased Ticket Prices:** Higher prices could lead to higher revenue, if the demand is not price sensitive for such a price increase. As the cost of using other modes (auto and airplane) increases sharply due to the fuel price hikes, people might select less expensive modes, such as rail and bus. This creates an opportunity for price increases. A study is proposed in the operation plan to further explore such an opportunity.

- **Improve Revenue Opportunity:** Revenues could be increased by improvements to onboard service quality, improving existing amenities such as the food and beverage service.

The Eastman Company

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October 30, 2012

Mr. Ross Macfarlane
Senior Advisor, Business Partnerships
Climate Solutions
1402 Third Avenue, Suite 1305
Seattle, WA 98101

RE: Increased Coal Train Traffic and Real Estate Values:
A study of the potential impact of increased coal train traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA
Eastman Company File No. 2036.1

Dear Mr. Mcfarlane:

As requested, I have completed my Valuation Consultation assignment that addresses and examines the impacts of increased coal train freight traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA, and my conclusions are summarized in this report. Generally, this project required the consultant to provide a document for use in assisting the client, Climate Solutions, in evaluating the impacts of this proposed new rail traffic on affected real estate. The depth of discussion contained in this report is specific to the needs of the client, and this report is for the intended use and users specifically stated on Page Two. The consultant is not responsible for unauthorized use of this report. The following summarizes my research and conclusions.

Client: Mr. Ross Macfarlane, on behalf of Climate Solutions

Consultant: Paul Zemtseff

Overview of Problem to be Considered: Pacific International Terminals, a subsidiary of SSA Marine, has proposed building a deep-water, multi-user, import and export marine terminal at Cherry Point, west of Ferndale in Whatcom County, WA. The proposed Gateway Pacific Terminal would eventually handle import and export of up to 54 million dry metric tons per year of bulk commodities – mostly exporting coal (48 million tons annually) to destinations in Asia. Coal mined in the Powder River Basin by Peabody Energy would be hauled by trains along the Burlington Northern and Santa Fe Railway Company (BNSF) rail lines. The proposed coal train transportation corridor route extends from mines in Montana and Wyoming through Sandpoint, Idaho to Spokane down through the Columbia River Gorge, then up along the Puget Sound coast, passing through the Washington state cities of Longview, Tacoma, Seattle, Edmonds, Everett, Marysville, Stanwood, Mount Vernon, Bellingham, Ferndale and all points in-between. It is understood that up to an additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) would

be expected to transport the coal along this the main line route, and the shipping terminal at Cherry Point would expect the addition of approximately 30 miles of coal trains daily along the BNSF rail line that runs along the Puget Sound coast. It is understood that nothing in the proposed project materials specifies a maximum; therefore, the 18 trains per day round trip could be increased if export capacity of the proposed port were expanded in the future.

A wide variety of physical, environmental and other potential impacts have been anticipated from resultant unprecedented levels of regional rail usage. As segments of the Washington state rail system are already nearing or at practical capacity, the dramatic increase in rail traffic would likely constrain passenger rail and adversely affect the transport of freight other than coal. Negative impacts also associated with coal trains include concerns due to train length, weight, content, and polluting capacity.

This valuation consultation assignment was specifically undertaken primarily as an attempt to provide an opinion of the impact on property values and/or real estate tax revenues (if any) resulting from the influence of an additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) using the main line route expected to transport the coal to the terminal at Cherry Point[1]. This study and analysis is specifically intended to address BNSF's main rail line areas running through Whatcom, Skagit, Snohomish, King and Pierce Counties, which comprise the areas expected to be most adversely impacted as they are the most densely populated, intensely improved, and therefore, potentially the most affected metropolitan and urban areas along this route.

Purpose, Intended Use / User of the Consultation and Restrictions On Use: The purpose of this consultation is to provide my opinion of the range of diminution in property values for various affected property types resulting from the influence of an assumed additional 18 trains per day (9 loaded and 9 returning empty of 125 to 150 uncovered rail cars each) using BNSF's main line (running through Whatcom, Skagit, Snohomish, King and Pierce Counties in Washington state) to transport coal to the proposed Gateway Pacific Terminal at Cherry Point[2]. The intended use of this consultation to assist the client and other intended users in understanding and evaluating the impacts of this new rail traffic. The "broad brush" conclusions rendered within this report are intended to provide the user a framework to consider and address anticipated potential effects on property value resulting from a number of widely recognized value influencing factors that vary in impact due to their varying degrees of intensity and the unique attributes of different affected properties amongst a range

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[1] **Note** that empty coal trains are expected to use a different route from Everett, returning easterly to pass through the Cascade Tunnel (not the Stampede Pass Tunnel); therefore the rail traffic north of Everett is greater than south of Everett.

[2] Ibid.

of differing property types. This consultation is intended for use by the Client (Climate Solutions), or persons specifically authorized by the Client for the indicated purpose and intended use. All others reading or relying on this report are unintended users.

Effective Date of Consulting Service: October 30, 2012

Scope of Work and Data Collection Process: The scope of this assignment was iterative with initial and possible future phases based upon what was found during the investigation and research process. The first phase was to determine if any loss in real estate value and/or real estate tax revenues would occur as a consequence of the new coal freight train traffic, assuming the levels of increased service previously described. The next phase was to determine if it was feasible to create a reliable model that could be used to quantify the dollar loss in value to various affected types of real estate, either on an individual property or some form of aggregate basis.

In preparing this report, I initially familiarized myself with the nature and extent of the proposed new coal train traffic and the rail corridors proposed for use in transporting coal to the Gateway Pacific Terminal (GPT) at Cherry Point. Numerous sources of public information were used to investigate and fully understand the background, scope, history and status of the project relative to the permitting process, the environmental impact statement (EIS), anticipated levels of use, and a variety of other meaningful parameters associated with the GPT project as proposed. I researched, assessed and reviewed fairly recent historical to the most current available data describing the status of the levels of service, capacities, anticipated increases and future projections for increased freight rail traffic along the previously defined subject areas of interest along BNSF's main line rail corridor and for Washington State as a whole. These documents included detailed analyses and recommendations along with detailed data regarding rail choke points, rail system needs, rail impacts and proposed mitigation measures and recent, anticipated and recommended rail corridor improvement projects. Studies and EIS's from other (non Washington State) rail corridor improvement projects were also reviewed and considered, as they address many of the same issues, elements and influences. I examined and reviewed various maps, online aerial mapping and other resources and exhibits to understand the rail route and property types within the areas of interest.

Access to a proprietary GIS based database identifying all tax parcels and various other information for properties located within 600 lineal feet of either side of BNSF main line route within the areas of interest was made available to me for possible use in this assignment. I familiarized myself with this tool, as well as with the transportation route corridor and the nature and type of surrounding properties. I visited many areas along the corridor to assess the nearby real estate as well as the nature and quality of crossings to obtain firsthand knowledge of existing conditions. I visited a representative sampling of the

various property types considered and addressed in this report (single family residential, multi-family, commercial and industrial properties) in all of the counties that abut the main rail line within the subject area of interest and/or that might be impacted by various adverse elements associated with the increased coal freight train traffic. (Note that while agricultural properties abut the area of interest, they were not specifically addressed or evaluated in this study). During this process, I was able to observe and experience coal trains traveling along this route. I reviewed recently conducted studies performed by Gibson Traffic Consultants, Inc. (GTC) that identify some of the possible rail impacts associated with transport of commodities to the proposed Cherry Point facility that affect the cities of Bellingham, Burlington, Mount Vernon, Stanwood, Marysville, Edmonds and Seattle and their access roads.

I was assisted by staff from the Appraisal Institute's Y.T. and Louise Lee Lum Library (which provides reference services in the subject area of real estate appraisal) and performed my own research, exploring numerous areas of interest associated with diminution in value issues involving rail and many other adverse influences. I found, read and/or reviewed numerous empirical research studies, statistical analyses utilizing hedonic models and regression analyses, professional research abstracts, and other publications that might provide support for my rail impact study and valuation analyses and conclusions. Although many of the studies reviewed did not specifically deal with rail impacts, they did function as proxy studies, demonstrating anecdotal evidence supporting the relative range of diminution in property values experienced in response to a variety of types of adverse influences. I surveyed a sample of a range of active, knowledgeable, real estate market participants and other experts for input as to their opinion of the extent of the influence of the proposed new coal train freight traffic on property values for the various property types. I performed extensive internet research on all of the above-referenced topics in order to maximize my understanding of the nature and extent of effects on real estate values due to a wide variety of adverse influence generating externalities including freight rail traffic.

All of the foregoing information gathered from these resources was considered from my personal experience perspective as a real estate appraiser/consultant, having been involved with numerous assignments and situations requiring the analysis of simple to complex real estate valuation problems for the purpose of rendering my opinion of diminution in value. Based upon the information and resources available to me for this assignment and my understanding of the wide variety of, and vastly differing types of, adverse influences associated with the increased coal train rail traffic, I concluded that the information and tools available would be insufficient to allow me to provide a reliable model that could be used to quantify the dollar loss in value to various affected types of real estate and/or real estate tax revenues, either on an individual property or some form of aggregate basis.

The as-described body of knowledge gathered, however, was deemed sufficient in its theoretical and functional application as background information to support and form the

basis for me to provide my opinion of a range of diminution in property value for the various property types considered, resulting from the range of adverse impacts associated with the increase in coal train freight rail traffic, as assumed. The final process required taking the perspective of an unbiased consultant and synthesizing this data in order to develop my conclusions. The nature of such real estate problems is often unique and involves a considerable degree of complexity; therefore, this consultation is seen as a means of bringing professional objectivity to, and market based support for, a framework that can generally be utilized to consider and address anticipated potential effects on property value resulting from the proposed additional coal freight train traffic assumed.

Subject Property: The subject property addressed in this study generally includes all properties with the potential to be adversely impacted by the proposed increase in coal train freight rail traffic along BNSF's main rail line areas running through Whatcom, Skagit, Snohomish, King and Pierce Counties. Although the nature of this assignment and scope of investigation required the consultant to visit a representative sampling of the different property types considered in these counties in order to acquire a good understanding (and a real sampling) of the range of potential situations to be considered, this assignment is not intended to address any specific subject properties or situations.

Elements of Adverse Influence Associated With Increased Coal Train Traffic: The literature reviewed generally identifies a number of categories of adverse influences associated with increased coal train freight rail traffic that have the potential to adversely influence real estate values. These elements and a summary of the perceived and potential impacts are briefly summarized as follows:

Access and Vehicular Traffic: The GTC traffic studies focus on six cities with a significant number of non-grade-separated (typically at grade/gate controlled) main line rail crossings, mostly in or near their central business districts in areas that experience substantial traffic, particularly during traditional "traffic times." The studies state language similar to the following (excerpted from their 6/21/12 Bellingham report) for each of the cities, but in some cases, the reports address somewhat different crossing conditions: "Each coal train will be up to 1.6 miles long, which at 50 mph would mean approximately 3-4 minutes between train approach warning/gate closure and ultimate gate opening. At 35 miles per hour, it could take approximately 6-7 minutes to clear a crossing as the siding near this area is rated for 35 mph. The 18 trains per day would equate to approximately one additional coal train every 1.3 hours, all day long, in addition to existing train traffic. Thus, train crossing delays in Bellingham can be estimated to increase with an additional train every 1.3 hours, if train trips were evenly spaced throughout the day and night, at between 3-4 minutes and 6-7 minutes depending on if they are having to use sidings or speed restricted crossing. Assuming just a 5-minute average (consistent with the existing smaller coal trains traveling through Bellingham) would lead to every crossing on the track in Bellingham being closed for an

additional 90 minutes a day not including the additional clearance time for back ups to clear after a crossing arm lifts. Based on current data, the existing numbers of trains in the Bellingham area is averaging 15 trains a day. . . . The *Washington State 2010-2030 Freight Rail Plan* published by WSDOT in December 2009 identified that the rail line North from Everett in 2008 was already at its capacity of 18 trains per day. The State plan shows that it hopes to increase that capacity to 30 trains per day; however, the design and cost of the specific improvements needed to do that have not yet been identified. Additional study and inquiry should be conducted to determine whether federal or state funding is committed to expand the capacity of the BNSF freight system, sufficient to allow the projected additional 16-18 trains per day and still leave adequate capacity for local freight and future commuter services."

The increased traffic and reduced quality of access not only have the potential to cause isolation and business interruption effects for properties in the immediate corridor area (say, within 800 feet of the track), but depending upon whether or not, and to what extent, alternative access potential exists, the area of adverse effect could, and in many cases does, cover a substantially larger area.

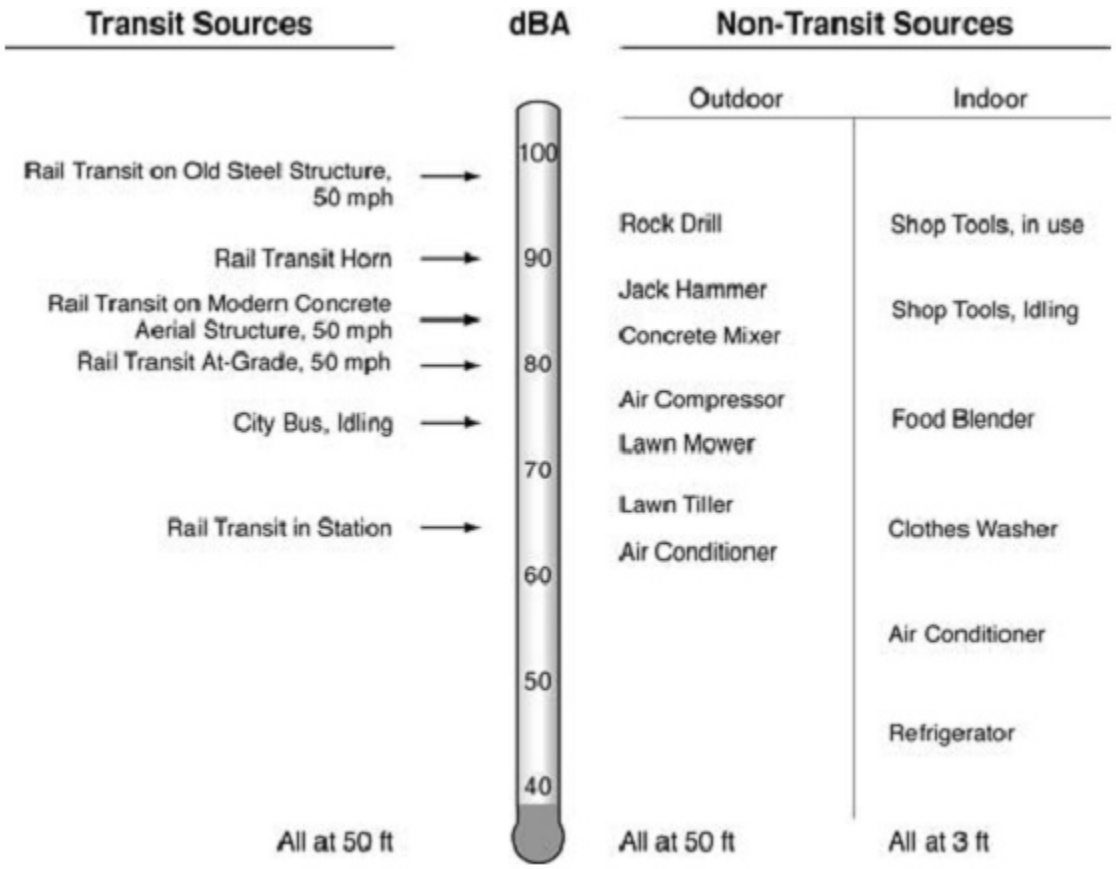
Life Safety Issues: Although infrequent, a potential problem associated with freight train traffic is that accidents occur at crossings and along the tracks, and fear of accidents is a perception that has the potential to affect nearby real estate values. Another duly noted life-safety consequence of the increased traffic identified for all of the GTC study areas is the potential for a first responder, such as an ambulance, police car, fire truck, aid car or utility provider, to suffer increased response times in reaching their destination at a critical time when emergency responses are needed.

Vibration: "Local and long-distance freight trains are similar in that they both are diesel-powered and have the same types of cars. They differ in their overall length, number and size of locomotives, and number of heavily loaded cars. Locomotives and rail cars with wheel flats are the sources of the highest vibration levels. Because locomotive suspensions are similar, the maximum vibration levels of local and long-distance freights are similar. It is not uncommon for freight trains to be the source of intrusive ground-borne vibration. Most railroad tracks used for freight lines were in existence for many years before the affected residential areas were developed. . . . . Vibration mitigation is very difficult to implement on tracks where trains with heavy axle loads will be operating. . . .

Although the perceptibility threshold is about 65 VdB, human response to vibration is not usually significant unless the vibration exceeds 70 VdB. Rapid transit or light rail systems typically generate vibration levels of 70 VdB or more near their tracks. On the other hand, buses and trucks rarely create vibration that exceeds 70 VdB unless there are bumps in the road. Because of the heavy locomotives on diesel commuter rail systems, the vibration levels

average about 5 to 10 decibels higher than rail transit vehicles. If there is unusually rough road or track, wheel flats, geologic conditions that promote efficient propagation of vibration, or vehicles with very stiff suspension systems, the vibration levels from any source can be 10 decibels higher than typical. Hence, at 50 feet, the upper range for rapid transit vibration is around 80 VdB and the high range for commuter rail vibration is 85 VdB. If the vibration level in a residence reaches 85 VdB, most people will be strongly annoyed by the vibration."[3]

Horn Noise: "In a large number of community attitudinal surveys, transportation noise has been ranked among the most significant causes of community dissatisfaction. . . . . The percentage of high annoyance is approximately 0 percent at 45 decibels, 10 percent around 60 decibels and increases quite rapidly to approximately 70 percent around 85 decibels." [4]



[3] Transit Noise and Vibration Impact Assessment, Federal Transit Administration, May 2006.

[4] Ibid

The noise from a train is produced by a variety of sources and determined by numerous variables including the diesel locomotive noise, wheel noise (squeal, rolling noise), braking, signal horns and crossing gate bells, the type, quality and condition of the train, and the quality, condition and composition of the track and track bed.

Pollution: Sources of air and ground pollution include the exhaust from diesel locomotive engines, coal dust from open coal cars and other petrochemicals that typically fall from the train on to the tracks (such as lubricants). Concerns exist that adverse influences from coal dust due to open car transportation practices and from diesel exhaust that are expected to result from the increased coal train traffic may be sufficient to potentially cause negative human health effects. Even if studies are conducted that do not support these concerns, the public perception about them is sufficient to have an adverse effect on property values.

Stigma and Perception: Effects on real estate values are colored by the perception of the market participants (typically the buyer or seller) and not based on objective factors or parameters that can easily be measured or quantified. For example, fear of accidents is a subjective factor that can be quite variable in perception by different individuals. Some segments of the market are more sensitive to the preceding element items, and at the extreme, would not consider the possibility of owning property located nearby to, or significantly affected by, such freight rail influences, while others are less sensitive to these influences. Studies reviewed conclude that real estate values are increasingly adversely impacted as the level of dissemination of information to the public that concerns exist increases. Considering that the potential adverse effects of the additional coal train traffic have been very widely publicized, it is expected that the adverse effect on the market already exists to some extent. Anecdotally, more than one Realtor interviewed cited an example of property value or marketability being directly affected by the proposed increases in coal train traffic.

Property Types, Variables and Comments: The coal trains typically have two locomotive diesel engines at the front and two at the rear of the train. The distance of the real estate from the rail line traffic and/or crossing is a *most* significant variable in determining the extent of most of the aforementioned value-influencing elements. Other factors influencing the extent of adverse effect include the time of day (or night) that trains travel, and for noise and vibration effects, the duration, frequency of occurrence, noise frequency (i.e. hertz range), existing non-rail noise conditions, type of crossing (trestle, at grade or grade-separated), nature of the surrounding topography (relative elevation of tracks versus the real estate) and acoustical conditions, intervening property improvements, vegetation or other features that may exist between the rail line and the property to dampen or amplify the noise. Note that it is generally accepted that night noise is far more disturbing than daytime noise, and is therefore more heavily weighted as an adverse influence.

Differing property types are typically influenced to differing degrees by the aforementioned elements of adverse influence. **Single family residences** are generally acknowledged as the most sensitive property type to all of these elements, as the consequential impacts can be perceived as having the capacity to directly influence the quality of life of the occupant(s). In my opinion, all of the aforementioned elements have the potential to significantly impact the value of affected single family residential property. The train's signal horn, which is typically repeatedly blown prior to at grade crossings, is generally acknowledged as one of the loudest noises produced by freight trains, and is the primary negative externality generated by train traffic. The duration of the horn blast and time of day is a significant factor determining its grade on the nuisance scale. It has been found that residents living within 1,000 feet of the rail line were severely annoyed by train horns. During my survey, one Realtor who lives near the rail line noted that a "whistle happy" conductor blew the horn for 15 seconds at 4:30 to 5 AM the other morning. Hedonic price models and studies have shown that the loss in value for residences is amplified with each additional freight train trip.

Multi-family properties similarly have the potential to be strongly influenced by these elements. Multi-family properties observed near the rail line included a mixture of sizes, with many being larger mid-rise buildings containing many units, a number of which front Puget Sound. In many of these properties, due to the size of the buildings, some units face the rail line, while others face upland or toward the sound. In these cases, the units facing the tracks are more influenced by the noise, vibration and pollution factors, while those further away can be perceived as experiencing little or no adverse effects in this regard. Particularly in the case of multi-family properties located seaward of the tracks, with limited or no alternative access, the access and vehicular traffic elements tend to carry significant weight. Also of consideration for multi-family properties is the occupancy status - whereas apartment dwellers have the ability to be more transient and relocate if ambient conditions do not meet their preferences, condominium owners are more like single family residential owners to the extent that relocating represents a substantial barrier to changing their situation.

Commercial properties include restaurants, retail stores, offices and other similar uses. A number of the potentially most affected properties observed are located seaward of the tracks. Although noise and vibration are seen as influencing factors relative to the adverse influences of the increased coal freight train rail traffic, in my opinion, the access and vehicular traffic elements are considered to have the greatest potential to adversely influence property value for commercial properties. Also, depending upon proximity, the pollution factors also have potential to represent a substantial negative influence.

Industrial properties are the category of real estate considered to be least influenced by the increased rail traffic. By nature, these properties are typically in locations zoned to allow for a variety of vibration, noise and pollution influences. They are often sited near, and many specific properties benefit from or require, rail access or service. The access and vehicular

traffic elements are considered to have the greatest potential to adversely influence the value of industrial properties, particularly if they are located in areas where the presence of a train precludes vehicular and employee ingress and egress, as is typical for numerous facilities observed. Freight trains, unlike commuter trains, are often not on a specific or predictable schedule. This can create a substantial nuisance for companies with large workforces if access is blocked near the time employees need to arrive at or leave work. Often the industrial properties that are exposed to being landlocked by trains are marine dependent facilities that have no option to relocate to the other side of the tracks as they need to retain their waterfront location or proximity.

Conclusions: This assignment required the consultant to provide an opinion of a range of diminution in property value for the various property types considered resulting from the range of adverse impacts associated with the increase in coal train freight rail traffic, as described in this report. As discussed, the wide variety of elements of influence and their variations in intensity of impact which are dependent upon numerous variable factors and a wide variety of physical conditions and influences impacting a single property within a given property type result in an almost unlimited number of diminution in value situations. Based upon all of the research and study undertaken in performing this assignment, and because of this extreme variability, the concluded diminution in value has been expressed in a percentage range intended to capture the most probable effects on a given property type. Although the range is intended to reflect the "less" to the "most" affected diminution in value situations, it should be understood that in some specific instances, a specific property may be more affected than indicated by the range concluded; however, in my opinion, such cases are rare. At the low end are properties that suffer no adverse impact, which typically would be properties lying outside of the area of rail influence.

Most of the literature relied upon addressed studies of residential real estate, and they tend to specify the outer limit of rail traffic influence at a distance in the approximate 750 to 1,000 foot range from the tracks. Unfortunately, due to the unique nature of real estate and the variety of influencing factors determining the net intensity of adverse influence, there is no set distance that is certain to suffer influence. It is clear, however, that the closer the distance of the property to the rail line or crossing, the greater the influence. Because of this, in general, the upper end of the range of diminution in value concluded would be expected to strongly correlate with properties located closest to the rail line or crossing. At the opposite end of the spectrum, although property with the least net total intensity of adverse influence might be expected to experience a diminution in value of less than five percent, such minimal impacts are generally considered so slight as to be effectively immeasurable; therefore, five percent has been used at the lower end of the range.

As noted, empty coal trains are expected to use a different route from Everett, returning easterly to pass through the Cascade Tunnel (not the Stampede Pass Tunnel).

Property located north of Everett with 18 new train trips daily: Based upon all of the information and data gathered, in my opinion, the applicable range of diminition in value for **single family residences**, the property type expected to suffer the most severe impacts, has been concluded to range from **five to twenty percent** of market value. **Multi-family properties** as a whole, are considered to be less intensely impacted for reasons discussed in this report and would be expected to suffer a loss in market value ranging from **five to fifteen percent** of market value. It is anticipated that impacted **commercial properties** would experience loss in market value in the approximate **five to ten percent range**. Industrial properties, considered the least impacted of the property types overall, would be expected to suffer a **five to eight percent** range of loss in market value.

Property located south of Everett with 9 new train trips daily: Because the property south of Everett would experience half of the anticipated new rail traffic compared to property north of Everett, and because the nine trains south of Everett would all be fully loaded coal trains with no returning empty rail cars, the effects of pollution, coal dust and traffic would result in a decreased range of net overall impacts. In my opinion, the impacts for **all property types** considered would be approximately **three to five percent less** than the diminutions in value concluded for property located north of Everett, with a five percent threshold setting the lower end of the limit of measurable diminution in value for affected properties.

The suggested conclusions may not provide a reliable range of diminution in value for each and every property of a given property type in all possible situations that may be found, due to the fact that real estate is unique, and the variety of conditions that may be encountered are unlimited as they are "situation dependent." Therefore, the methodology and conclusions rendered in this report are intended to be viewed and used as general guidelines. Specific appraisals are suggested as the most effective means of providing defensible solutions to complex real estate problems. Solutions to complex valuation problems often rely upon subjective judgements based upon expertise that is primarily gained through familiarity and experience.

Although this report is not intended to be used to provide an aggregate loss in value for property that would be affected by the proposed increase in coal train freight rail traffic, it is felt that the total loss in value due to such influence would be substantial in terms of property market value and real estate tax revenues to taxing districts. The proprietary database provided and used in this assignment indicates a total of 21,548 tax parcels for properties identified as located within 600 feet of the BNSF main line railroad tracks in the subject area of interest, with a total aggregated assessed value of $26,556,663,168. If one were to assume these properties would suffer a loss in assessed value of one percent, the loss would be equal to approximately $265 million, which applied at a one percent millage rate is equivalent to an approximate $2,655,000 in annual tax revenue loss. In my opinion, the

effects and impacts of the additional freight rail traffic not only affect the properties within 600 feet of the main line, but also potentially affect property beyond this identified zone. At the very least, this information indicates that the aggregate losses to market value and tax revenues could be quite substantial.

This report is subject to the enclosed limiting conditions and has been prepared in conformity with, and subject to, the requirements of the Uniform Standards of Professional Appraisal Practice promulgated by the Appraisal Standards Board of the Appraisal Foundation. I hope this report addresses your needs and concerns. If you are in need of further assistance, please do not hesitate to contact me.

Respectfully Submitted,

Paul Zemtseff
Washington State Certified General
Real Estate Appraiser (1100208)

Partial List of Resources:

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CONSULTATION CERTIFICATION

I, Paul Zemtseff, certify that, to the best of my knowledge and belief:

The statements of fact contained in this report are true and correct.

The reported analyses, opinions, and conclusions are limited only by the reported assumptions and limiting conditions, and are my personal, impartial, and unbiased, professional analyses, opinions, conclusions and recommendations.

I have no present or prospective interest in the property that is the subject of this report, and I have no personal interest with respect to the parties involved.

I have performed prior appraisal services with regard to the property that is the subject of this report within the three year period immediately preceding acceptance of this assignment.

I have no bias with respect to any property that is the subject of this report or to the parties involved with this assignment.

My engagement in this assignment was not contingent upon developing or reporting predetermined results.

My compensation for completing this assignment is not contingent upon the development or reporting of a predetermined value or direction in value that favors the cause of the client, the amount of the value opinion, the attainment of a stipulated result, or the occurrence of a subsequent event directly related to the intended use of this appraisal consulting assignment.

My analyses, opinions and conclusions were developed, and this report has been prepared, in conformity with the Uniform Standards of Professional Appraisal Practice.

I have made personal inspection of portions of the property that is the subject of this report.

No one provided significant real property appraisal or appraisal consulting assistance to the person signing this certification.

The reported analyses, opinions, and conclusions were developed, and this report has been prepared, in conformity with the Code of Professional Ethics and Standards of Professional Appraisal Practice of the Appraisal Institute

The use of this report is subject to the requirements of the Appraisal Institute relating to review by its duly authorized representatives.

As of the date of this report I have completed the Standards and Ethics Education Requirement of the Appraisal Institute for Associate Members.

I do not authorize the out-of-context quoting from, or partial or full reprinting of this consultation report.

Paul Zemtseff
Washington State Certified General
Real Estate Appraiser (1100208)

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1. This is an appraisal consulting report that is intended to comply with the reporting requirements set forth under Standard Rule 5 of the Uniform Standards of Professional Appraisal Practice. Report. The information contained in this report is specific to the needs of the client and for the intended use stated in this report. As such, it includes a summarized discussion of the data, reasoning, and analyses that were used in the appraisal process to develop the appraiser's opinion of value. The appraiser is not responsible for unauthorized use of this report.

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EDUCATION
Bachelors of Science Degree in Finance/Real Estate from the College of Commerce and Business Administration, University of Illinois at Urbana, Champaign, 1979.
Masters in Business Administration from DePaul University, Chicago, 1984.

Appraisal Institute (Including former American Institute of Real Estate Appraisers and Society of Real Estate Appraisers Courses):
101 – An Introduction To Appraising Real Property
1BA & B – Capitalization Theory and Techniques, Parts A & B
2-1 – Case Studies In Real Estate Valuation
VII – Industrial Valuation
SPP A & B – Standards of Professional Practice, Parts A & B
540 – Report Writing and Valuation Analysis

University of Illinois:
Real Estate Principles
Real Estate Finance
Valuation Theory and Methods
Urban and Regional Economics

Numerous additional ongoing, continuing-education courses – often related to various specialty aspects of right-of-way and partial interest appraisal.

EMPLOYMENT HISTORY
Appraiser and consultant with the Eastman Company from 1991 through the present (currently principal).
Self-employed real estate appraiser and consultant during 1986 through 1991 working for various clients – firms and individuals.
Staff appraiser for Real Estate Analysis Corporation, Chicago, from 1979 through 1986.

APPRAISAL EXPERIENCE
Property types appraised include commercial, industrial, vacant, special purpose, and multi-family and single family residential for assessment, mortgage, estate, purchase and condemnation (right-of-way and easement) purposes. Appraisal assignments have included apartments/duplex complexes (4-350 units), office and medical office buildings, shopping centers, grocery and retail stores, department stores, restaurants, hotels/motels, automobile dealerships, nursing homes, subdivisions, mobile home parks, service stations, bowling centers, manufacturing plants and factories, truck terminals and warehouses.

Approximately 20 years of right-of-way and acquisition appraisal experience (partial takes of all types), as well as in reviewing appraisals (both Eastman Company and outside appraisals). Specialty appraisal expertise in valuing acreage and properties with environmentally critical features and hazards, generally affected by environmentally critical area zoning ordinances. These difficult-to-develop properties have often consisted of steeply sloping sites, many of which have been improved with a wide variety of residential and/or commercial improvements.

COURT EXPERIENCE
Qualified as an expert witness and have testified in the Superior Court of the State of Washington.

CERTIFICATIONS
Washington State Certified General Real Estate Appraiser, License Number 1100208

PROFESSIONAL AFFILIATIONS
Associate Member of the Appraisal Institute
Listed as a Washington State Department of Transportation approved appraiser and reviewer

VALUATION CONSULTATION
INCREASED COAL TRAIN TRAFFIC AND REAL ESTATE VALUES ©

A study of the potential impact of increased coal train traffic on property values resulting from the proposed Gateway Pacific Terminal at Cherry Point, WA

As of
October 30, 2012

For
Mr. Ross Macfarlane
Senior Advisor, Business Partnerships
Climate Solutions

By
Paul Zemtseff

THE EASTMAN COMPANY
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File No. 2036.1

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Entrepreneur

The effect of freight railroad tracks and train activity on residential property values.

By Robert A. Simons & Abdellaziz El Jaouhari | Summer, 2004

Appraisal Journal

abstract

This study evaluates the impact of freight railroad tracks on housing markets. A hedonic price model is used to estimate reduction in the sale price of residential properties near freight railroad tracks in Cuyahoga County, Ohio for 1996 and 1999. The findings indicate an average loss in value between $3,800 and $5,800 (5%-7%) for houses under 1,250 square feet located within 750 feet from a railroad track. Larger houses showed mixed results. After substantial publicity about a freight train company merger, freight trip counts showed a negative and statistically significant impact on the sale price of smaller houses, and some larger houses, for each additional daily freight train trip.

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The benefits of transportation in linking markets and generating positive externalities are well established in economic theory. Access to transportation links, such as highway interchanges, airport hubs, train stations, and boat landings, is a positive factor. However, being too close to transportation uses that are far away from access links can have a negative effect on property values due to the nuisance and potential problems of accidents. This is particularly true for railroads that crisscross the country carrying freight and have very few access points. For freight railroads, the access points are not directly used by residential property owners. In addition, there is train noise and whistle blowing as the trains pass by, the fear of accidents exists, and potential for other related nuisances. The main questions addressed by the research here are how much markets discount houses near railroad tracks and whether the discount decreases with distance from the track and less freight trip volume.

Variables Related to Railroad Freight Lines

Periodically, train companies merge and consolidate track activity; sometimes this can lead to changes in trip volumes on specific segments. Because proximity to train tracks is considered a nuisance, nearby property values can be affected. The effect could be related solely to proximity or to the volume of activity (e.g., freight train cars passing by the property). Effects may also be more pronounced on properties adjacent to where the freight lines cross streets. Also, if trip counts change due to rerouting, would there be any differential effect on property values? This study finds that rail traffic, as opposed to simply proximity to tracks, makes a difference in the sale price of residential properties. Further, publicity is found to increase public awareness of this issue.

In the Cleveland, Ohio area in the mid- to late-1990s, CSX Corporation (CSX) and Norfolk Southern Corporation (Norfolk Southern) decided to reorganize and acquire another railroad, Consolidated Rail Corporation (Conrail). An environmental impact statement (EIS) was done to determine track reconfiguration. Freight trip counts on various segments were scheduled to change. Beginning in 1997, there was a lot of publicity regarding the reconfiguration, and the railroad lines negotiated with various cities about the impacts of the train reconfiguration on property values. Cities received millions of dollars, but none of the money went toward property damage awards. By 1999, the EIS process had been completed and changes to track volumes had been implemented.

This study examines the "before" and "after" of the reconfiguration in freight railroads in Cuyahoga Count, Ohio, and comments on the inclusion of property damage awards in a process of this type. The study focuses on the effect of freight-carrying railroad tracks on single-family housing in Cuyahoga County, Ohio, which includes a total of 15 rail segments with over 50 miles of track. After a review of the extant literature, this article discusses the study area, data collection, and variables. Size-stratified hedonic regression models of the county residential real estate market are developed, and the proximity to railroad tracks is tested in various forms. The results are presented, as well as conclusions and implications for appraisers.

Overview and Literature Review

This study was inspired, in part, by a project done in a graduate urban planning class on the factors affecting the desirability of an urban neighborhood. A questionnaire was administered in person to 105 prospective homebuyers of inner-city homes on the near-west side of Cleveland, Ohio, during the summer of 2000. The questions mainly related to neighborhood characteristics that could have a positive or a negative effect on housing values. Residents were asked to weigh their willingness to live close to various urban factors (e.g., an auto junkyard, interstate, railroad tracks, city park) on a seven-point scale, where -3 was strongly negative and +3 was very desirable. The results of the questionnaire are shown in Table 1.

The least desirable site characteristics were junkyard (-2.81), leaking underground storage tank (LUST) (-2.71), and factory (-2.60). Living next to a train track had the next most negative score of -2.07, closely followed by proximity to a highway and main street (both about -1.9). Scores ranged up to +2.2 for lake views. (1)

Effects of Other Linear Urban Uses on Residential Property

Roads are a linear land use similar in some ways to railroad tracks. Hughes and Sirmans found a significant 1% negative change in residential property values for each 1,000 annual average daily traffic (AADT) in city areas, and a 0.5% change per 1,000 AADT in suburban areas in Baton Rouge, Louisiana. (2) A related study by the same authors showed an 11% decrease in value for houses on high traffic streets, compared with low traffic streets. (3) However, this study did not explicitly control for street design. This same research also showed an average reduction of 0.8% in property values per 1,000 AADT. (4) For a typical collector street with 5,000 to 10,000 more trip counts per day than a purely residential street, this would equate to a 5%-10% reduction in property values, holding all else constant.

Another linear and visible type of land use that is somewhat similar to railroad tracks is high-voltage overhead electrical transmission lines (HVOTL). Studies by Colwell, and Kinnard and Dickey showed a significant reduction of 5%-8% in residential property values within a few hundred feet of the transmission lines. (5) Another use similar to trains in its linearity is pipelines. In a study of the effect of a pipeline rupture on non-contaminated residential property on the pipeline easement in Fairfax County, Virginia, Simons estimated that single-family housing experienced a loss in value of 4%-5% after the rupture. (6)

Rail Impact Studies

Noise, especially from train horns, is the primary negative externality generated by train traffic. A study by Rapoza, Rickley, and Raslear (7) found that residents living within 1,000 feet of a railroad track were severely annoyed by train horns. Consistent with this unsurprising finding, many communities have enacted regulations to ban the use of train horns especially during nighttime hours to reduce the interference of train noise with the comfort of local residents. However, numerous studies funded by the Federal Railroad Administration (FRA) have proven that banning train horns increases fatalities and that the bans are costly to both residents and railroad companies. (8)

The FRA's numerous studies on the impact of noise on communities have also evaluated the effectiveness of warning systems, specifically the wayside train horn at crossing sections. A study conducted by the U.S. Department of Transportation and the FRA indicated that the use of railroad horns in addition to wayside horns could reduce accidents by 69%. The same study surveyed actions taken by residents to reduce the interference of noise with their daily activities. While most residents, as reported by the study, would stop talking or close windows, 14% considered moving. (9)

Most studies measure the frequency and level of noise to assess their impact on residents or property values. Few studies have examined the effect of proximity to a railroad track in terms of distance. Clark used distance from a railroad track to measure loss in property values for the mostly rural districts of Middletown and Niles in Ohio. (10) The findings indicate property values decreased by 2.1% in Middletown and 2.8% in Niles for every additional rail line within a buffer of 1/4 mile. The loss is

even higher for properties located near a crossing section where the use of train horns is more frequent. Another study in Oslo, Norway, looked at the relationship between tracks and residential sale price, based on pure proximity. Residential sale price decreased by up to 7%-10% within 100 meters (about 330 feet) of a railroad track. (11) These results were derived from both hedonic modeling and a type of contingent valuation analysis done by real estate salespeople.

To summarize, the benefits of railroad transportation in connecting markets are well established in economic theory but there is still a tension between the need for safety and the need to reduce the level of annoyance generated by railroad activities. Based on previous train studies and the negative effect on property values from other similar urban land uses, property value decreases in the single digits are expected from trains and train traffic.

Railroad Merger in Cleveland

Railroads sometimes merge and consolidate. As previously noted, in Cleveland this began in 1997 as CSX and Norfolk Southern sought to combine operations, acquire Conrail, and streamline and consolidate track utilization in Cuyahoga County. The negotiations were accompanied by an environmental impact statement that examined reconfiguring lines and train volumes. Trip counts on various segments ranged from 0-75 trips per day before the merge, with 15-30 trains per day being typical. The reconfiguration was finalized and operational by 1998. As a result, some lines experienced substantial reductions in traffic (e.g., from 50 per day down to 5 per day), some increased (10 to 45 per day), while other segments remained the same. (12)

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Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles

Michael Futch*

November 11, 2011

Abstract

This paper measures the impact of infrastructure expansion on local home values and examines the persistence of that impact over distance. Specifically, I exploit a natural experiment in which rail traffic from the Los Angeles seaport, one of the busiest in the country, was permanently redirected from several tracks to a central line, termed the Alameda Corridor. I link a rich, repeat-sale housing dataset to plausibly exogenous changes in local rail traffic to estimate these effects, controlling for local price trends using a Case-Shiller style housing index. Using the actual traffic changes the result is an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. The welfare impact of concentrating a negative externality on a smaller population should depend on the convexity of the cost function, but I find evidence that suggests the marginal cost is symmetric for winners and losers. Instead, the total welfare impact hinges on the efficiency gains achieved by relocating the traffic from circuitous routes to the more direct Alameda Corridor, thereby affecting fewer homeowners. While the net gains are minimal, the re-routing of traffic resulted in a transfer of housing wealth of approximately $200 million.

*Email: mfutch@ucsd.edu. I would like to thank Craig McIntosh, Gordon Dahl, Paul Niehaus, Mark Jacobsen, Josh Graff Zivin and UCSD seminar participants for their helpful comments.

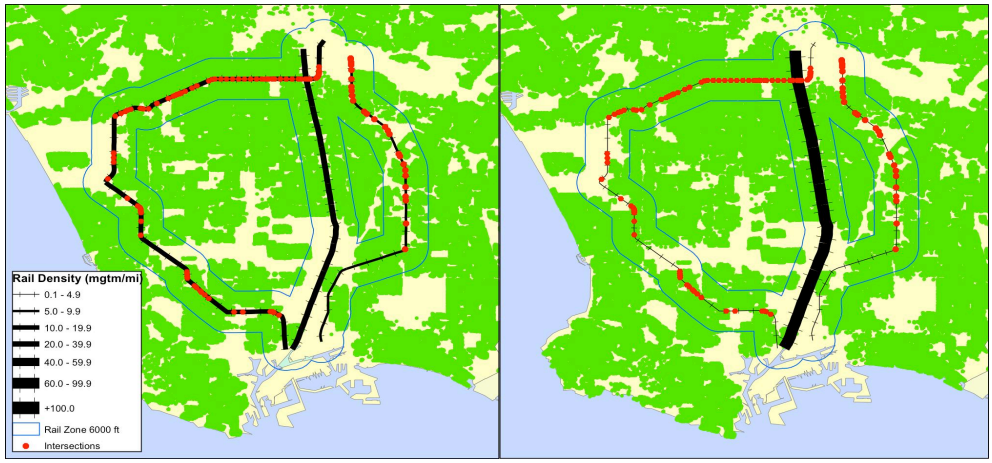
1 Introduction

Economic reforms often do not benefit everyone involved; instead, there are typically winners and losers. Identifying who wins and who loses and by how much is important when evaluating policy options especially because many of the groups affected often do not have representation at the negotiating table. This process is further complicated when policy actions impact groups or individuals external to the original intent of the policy.

This is particularly true of public infrastructure projects. Causal identification of public infrastructure impact is often challenging as the location is rarely random and may correlated with wealth and political clout. Using year to year changes in the intensity of an externality is also problematic as these changes are also likely to be correlated with local growth patterns. When concentrating a negative externality on a segment of the population it is important not just to measure the marginal effect at a point, but to understand the convexity of the cost imposed on individuals. If the marginal cost of the externality were increasing, this would suggest distributing the exposure to the externality among as many people as possible. If the marginal cost were decreasing, a case could be made for concentrating greater amounts of a negative externality on a smaller population.

This paper examines these issues in the context of urban rail in Los Angeles. This setting offers an attractive natural experiment, solving some of the identification issues discussed above by exploiting a shift in the way rail traffic travels through the city. The Alameda Corridor, an urban infrastructure project in Los Angeles, allowed for consolidation of most freight rail traffic into and out of the San Pedro port facilities from three geographically distinct tracks into one higher capacity line. Figure 1 depicts the level of rail traffic in the region before and after the opening of the Alameda Corridor. Rail traffic involves negative environmental spillovers onto local communities in the form of air and noise pollution, along with congestion effects caused by long waits at rail crossings. Because the rail traffic involved is freight and not transportation, there are fewer demand-side effects that could cause upward or downward pressure on housing values apart

Figure 1: Rail Traffic Density - Before and After



from the pollution and congestion caused by rail traffic alone. Most interestingly, the change in the flow of rail traffic was approximately zero-sum overall, providing a very straightforward window on the extent to which a redistribution generated net social gains or harm.

This setting allows me to directly measure the distribution of an externality using the cost inflicted on homeowners, exploiting substantial variation (both upwards and downwards) in the intensity of the externality. Many papers relate the existence of an externality to house prices, but most lack the data to clearly identify the costs actually induced by the environmental harm. I find that an increase in rail traffic by 10 million gross ton miles per mile (MGTM/mi) causes a 0.7 percentage point lower growth in home values within a 1/3 mile band around the tracks. Furthermore, under a stronger set of assumptions our results suggest that the response of property values is linear in the degree of damage in both positive and negative directions for an identical size change, indicating that a zero-sum redistribution of environmental damage has no overall effect on total welfare. Using the actual traffic changes this results in an estimated $3500 decrease in average home value where traffic increased and a $1300 increase in average home value where rail traffic was reduced. Aggregating our estimates over the number of homes affected yields a net home value increase of $23 million - a negligible sum considering the total housing value for homes inside the one-mile zone was roughly $36 billion in 1997.

The rest of the paper is organized as follows: Section 2 discusses identification strategies and the data available, Section 3 outlines the estimation strategy and counterfactual selection, Section 4 presents the estimating equations, Section 5 discusses the results, and Section 6 concludes.

2 Identification Strategy and Data

2.1 Causal Identification Issues

While understanding the impacts of public infrastructure on local communities is of much interest, clean causal identification is typically difficult or impossible in many circumstances. The first hurdle to causal identification is due to the non-random nature in which locations are chosen for infrastructure. If the location for a project, say a new railroad track, is chosen based on unobservable factors that are related to the outcome of interest, OLS estimates of the treatment effect will be biased. There have been many papers that have taken this approach using cross-sectional data: Espey and Lopez (2000) and Cohen and Coughlin (2006) both look at the impact of airport proximity on housing values. Kim, Phipps, and Anselin (2001) use a cross section of home values and to measure the impact of air pollution on housing prices in South Korea. Chay and Greenstone (2005) look at air pollution and housing values, but circumvent this identification hurdle by instrumenting for air pollution using regulation changes triggered by county pollution levels.

If the housing data available spans several time periods, it could be tempting to use changes in pollution or changes in the external costs of public infrastructure (greater freeway or airport traffic) to identify the causal impact on house price changes. However, changes in infrastructure intensity or air pollution are likely to be correlated with other important variables that may drive the outcome measure. Greater freeway traffic may negatively impact nearby home values, but that increased traffic may be a result of higher employment in the city center which could drive up home prices. If causal effects are to be identified using changes in the externality, an argument

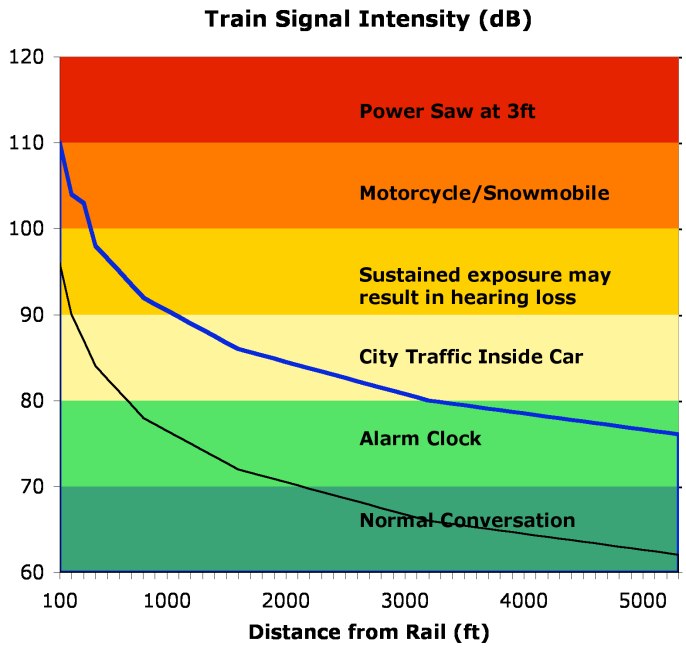
must be made for the exogeneity of the changes. If the changes are not exogenous, an instrumental variables or a natural experiment approach could be used if possible. Currie and Walker (2010) use a repeated cross section data set to exploit the creation of EZ-Pass toll lanes to find the impact of automobile congestion and poor birth outcomes. The main results of their paper are focused on health outcomes, but they do look for house price impacts and find none.

A housing data set that includes repeated sales of the same property is especially attractive once the exogeniety issues have been ironed out. Repeat sale data are useful because they allow better control of individual house idiosyncrasies. There have been several recent papers that utilize repeat sale data to estimate the impact of some spatially sourced event. Case et al. (2006) looks at the effect of water contamination on home prices. Cutter et al. (2009) follow a similar approach but look at the positive impact of open space preserves on home prices and raise the issue of finding the appropriate counterfactual. They craft an appropriate counterfactual using matching methods of Ho, Imai, King, and Stewart (2007). The data Case et al. use has a narrow time window before the sudden water contamination, so there is little opportunity to gauge the appropriateness of the counterfactual house trends.

2.2 Natural Experiment

This paper exploits a natural experiment to avoid the common identification pitfalls highlighted in the previous section. The setting for the natural experiment is freight rail traffic between the Los Angeles/Long Beach port complex and transfer facilities near downtown Los Angeles about 20 miles away. The Los Angeles and Long Beach seaports rank first and second in terms of container traffic into and out of the United States and combined comprise the fifth busiest port in the world. Until recently, much of that traffic passed through the city of Los Angeles on a collection of low speed rails to reach Union Pacific and BNSF transfer facilities. From there containers continue on to destinations throughout the United States. In April 2002, the Alameda Corridor opened,

Figure 2: Bounds on Rail Noise Decay



connecting the port facilities to the rail yards by a more direct and higher capacity track. Also installed were a series of bridges, trenches, and underpasses at intersections with the purpose of eliminating more than 200 street level crossings. The goal of the $2.2 billion Alameda Corridor project was to increase the speed at which cargo travels through the port and to reduce the noise and traffic congestion caused by slow freight trains at street level. The opening of the Alameda Corridor should have reduced air and noise pollution in neighborhoods near the tracks through reduced rail traffic and fewer idling automobiles at railroad crossings. Upper and lower bounds on the noise decay from train signals are plotted in Figure 2, illustrating the potential noise impact fading to conversation level after approximately one mile.

The shift in rail traffic induced by the Alameda Corridor was a structural redistribution that decreased traffic along two of the three main routes between the port and the transfer facilities increased traffic on the third line. This exogenous redistribution is used to identify the causal impact of pollution and congestion from freight traffic on local home prices. The spatial shift can be seen clearly in Figure 1 while the annual changes are plotted in Figure 4. The y-axis in

Figure 4 is the rail density code indicating the level of rail traffic as reported by the Federal Rail Administration and the year is on the x-axis. The west and east rails are the non-corridor rails where traffic decreased, while the center graph shows the sharp spike in traffic on the Alameda Corridor after the completion of the project.

2.3 Timing of Experiment and Perfect Foresight

Consolidation of the three rails into one higher speed track had been a topic of discussion in Los Angeles since the early 1980s, but did not become a reality until the late 1990s. Because the Alameda Corridor required nearly five years of construction before it opened in 2002 it is unlikely that homeowners near the corridor were taken by surprise when rail traffic skyrocketed after the opening. Due to the premeditated nature of this intervention, I am likely to see the impact begin to be capitalized into house prices before the actual opening of the corridor. The housing data available begin in 1995, before funding was secured or construction commenced, allowing capture of the full treatment period.

2.4 Housing Data

The housing data from DataQuick include all home sales in ZIP codes within 25 miles of the rails. The data set includes parcel number, address, sale price, sale date, lot size, bathrooms, bedrooms, and square feet. The data span the years 1995 to early 2009 and contain nearly 400,000 households that appear more than once - allowing for creation of a rich panel data set. The data is geolocated using the address and a streetline GIS file. After geocoding the housing data, a number of additional variables can be linked to each house including distance from rail lines, proximity to rail crossings, and Census block/tract.

Table 1 displays summary statistics for housing sales in the different rail zones. A house is considered to be in a rail zone if it is within one mile of the affected rail. This distance will be broken out into smaller increments in later analysis. Homes in the rail zones are on average smaller

Table 1: Home Sale Summary Statistics: 1995-2009

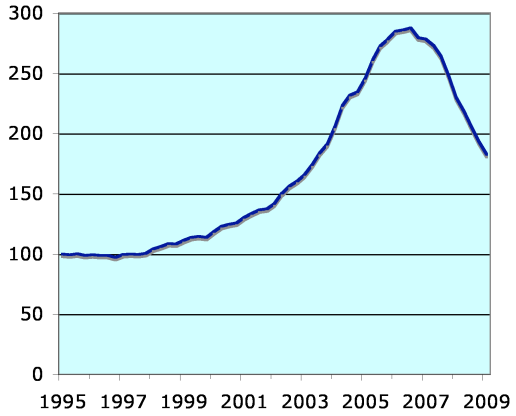
	Sales	Price	Sq. Feet	Beds	Baths
Corridor Zone	10,991	171,705	1,165	2.67	1.46
West Rail Zone	33,222	276,197	1,392	2.80	1.89
East Rail Zone	19,634	208,478	1,246	2.64	1.63
Greater LA	519,258	356,324	1,582	2.84	2.05

Table 2: Difference-in-Difference Estimates

One Mile Bands		Incremental Bands DID	
Log Price in Corridor Before	11.68	Corridor 0 - 1/3 mile	-0.033
Log Price in Corridor After	12.29		(0.015)**
Difference	0.61	Corridor 1/3 - 2/3 mile	-0.025
Difference-in-Difference w/ LA	-0.018		(0.013)**
Standard Error on DID	(0.008)**	Corridor 2/3 - 1 mile	-0.002
			(0.013)
Log Price in Non-Corridor Before	12.03	Non-Corridor 0 - 1/3 mile	0.034
Log Price in Non-Corridor After	12.67		(0.010)***
Difference	0.64	Non-Corridor 1/3 - 2/3 mile	0.002
Difference-in-Difference w/ LA	0.013		(0.009)
Standard Error on DID	(0.006)**	Non-Corridor 2/3 - 1 mile	0.012
			(0.009)
Log Price in LA Before	12.32		
Log Price in LA After	12.95		
Difference	0.627		
Standard Error on Difference	(0.002)***		

and less expensive compared to homes in the rest of the city. Among the rail zones, the homes around the Alameda Corridor tend to be the smallest and least expensive. The differences in value and size of the homes in different zones highlight the need for care in controlling for localized price trends. As motivation for further study of home price trends in the rail zones we provide a simple difference-in-difference in Table 2. This table shows that the prices for homes within a mile of the Alameda Corridor, where rail traffic increased considerably, grew about 1.8 percent slower than homes in the rest of Los Angeles. The negative effect was also stronger for homes closest to the rail as can be seen when the one mile zone is broken into increments. For homes nearest to the non-corridor rails, where traffic was decreased, home prices outpaced the rest of Los Angeles by 1.3 percent. Again, the effect is strongest for homes nearest to the rail. Using the rest of Los Angeles as the counterfactual may not be correct and this will be explored later, but the simple difference in difference result motivates further inquiry.

Figure 3: Los Angeles HPI (1995=100)



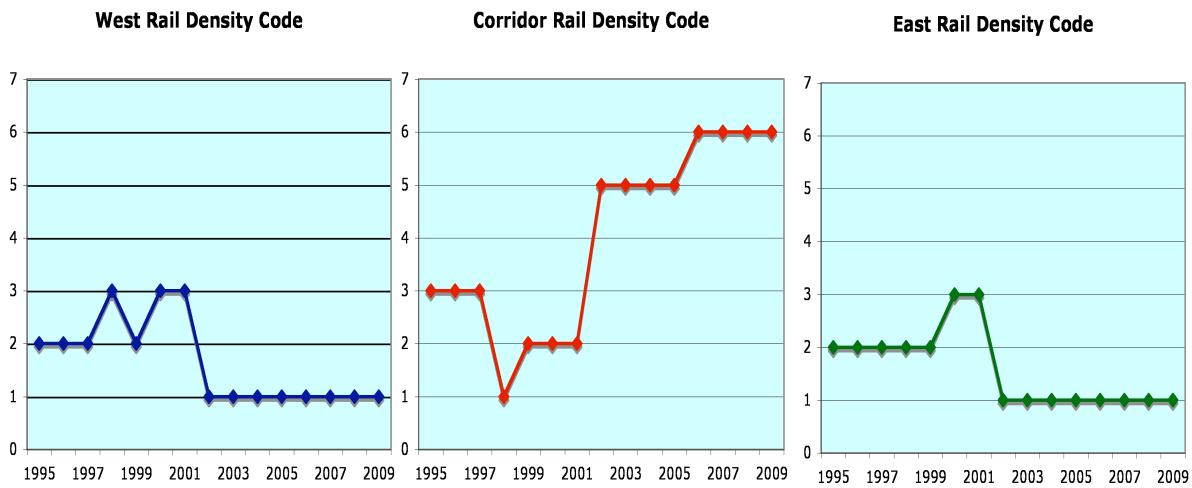
2.5 Housing Boom and Bust

The period under examination here contains the growth and subsequent popping of the house price bubble in the United States. Home prices in Los Angeles were not exempted from this phenomenon in the slightest. Figure 3 shows the rapid price growth witnessed in Los Angeles during the late 1990s and early 2000s and an equally rapid decline in prices when the bubble burst in 2006. The volatile nature of home prices during this period is even more reason to be careful when choosing a counterfactual set. Additionally, we want to be sure that our estimates are not being driven by the unusual events of the time period. We will report estimates that include the entire time period, boom and bust, and as a robustness check we restrict the sample to the period directly after the opening of the Alameda Corridor and drop transactions that occurred during the crash.

2.6 Rail Traffic Data

Rail traffic data are provided by the National Transportation Atlas published by the Bureau of Transportation Statistics. The data include a GIS map of the rail network along with a categorical measure of rail traffic density for each rail segment from 1995 to 2006. Rail density is a measure of the gross ton-miles of cargo traveled over a section of rail, divided by the length of the rail segment.

Figure 4: Annual Rail Traffic Density



For example, if a 100 mile track had only one gross ton of cargo traveling its length it would have a density of one gross ton mile per mile. A shorter track with the same number of gross ton miles would clearly have a much higher density. While not a perfect measure of the number of trains traveled, we believe it is an excellent proxy.

3 Estimation Strategy

3.1 Repeat Sale Framework

To estimate the causal impact of an increase in rail traffic on local home values we begin with the assumption that home prices follow a hedonic price function:

$$p_{i,t} = \alpha_i + \tau_t + \beta DEN_{i,t} * Proximity_i + \eta' x_i + u_{i,t} \tag{1}$$

where $p_{i,t}$ is the log price of home i at time t, τ_t is the local home price index at time t, $DEN_{i,t}$ is the rail density of the nearest rail interacted with some indicator for proximity to the rail, and x_i is a vector of home characteristics. Because our data contain repeated observations we can difference this equation with its previous sale, eliminating individual home idiosyncrasies and giving us the

following equation:

$$\Delta p_{i,t} = \Delta\tau_t + \beta\Delta DEN_{i,t} * Proximity_i + v_{i,t} \tag{2}$$

The term $\Delta\tau$ represents the change in the local house price index between time t and the period in which the home was last sold. In order to estimate β we will need to first identify the appropriate counterfactual group, then use the methods pioneered by Case and Shiller (1987) to estimate local house price trends and find fitted values $\widehat{\Delta\tau_t}$ for each home sale. If a home was sold in 1995Q2 and again in 1999Q4, the fitted value for $\Delta\tau$ for that home will yield the expected price change for a home that sold in those time periods if the rail traffic pattern had not changed. The x_i could contain time-varying characteristics capturing home remodels or additions, though our housing characteristic data are limited in this respect and do not vary over time.

3.2 House Price Index Calculation

To control for counterfactual price changes and to evaluate whether a set is an appropriate counterfactual we estimate Case-Shiller style house price indices. Standard repeat sale estimation begins with log home price as the dependent variable and an indicator for time period sold on the right hand side of the equation.

$$P_i = \gamma + \tau_1 T_{i,1} + ... + \tau_n T_{i,n} + u_i \tag{3}$$

We arrive at the estimating equation by taking a first difference:

$$\Delta P_i = \tau_1 \Delta T_{i,1} + ... + \tau_n \Delta T_{i,n} + v_i \tag{4}$$

so that a home sold first in period s and subsequently in period t would have a value of 1 for $\Delta T_{i,t}$ and a value of -1 for $\Delta T_{i,s}$. The predicted log price change would then be given by $\hat{\tau}_t - \hat{\tau}_s$

or, fitting with earlier notation, $\Delta\tau_t$. The τ coefficients are estimated using GLS, applying the standard heteroskedasticity correction for differing lengths of time between sales.

3.3 Selection of Counterfactual Set

Measuring the impact of rail traffic on housing prices requires an appropriate counterfactual to control for local price trends. House price trends are location specific, so the overall trend in a city or region may not be a good predictor of changes in a neighborhood. Other approaches have used matching methods to create a counterfactual group that resembled the affected homes in physical attributes. The approach taken here is to create a house price index (HPI) using homes that closely follow the pre-treatment trend in the rail zones, but are outside the one mile radius that we use to define the rail zone. The house price index can then be used to generate predicted values for the expected price change.

To find an appropriate counterfactual for homes in the affected rail zones we first compare the house price index for Los Angeles in general with the indices generated by homes in each zone. This is accomplished by running the standard repeat sale estimation equation and also interacting the housing index regressors with indicators for the relevant zone. If homes in each zone follow the same house price trend as the rest of the city, the difference in coefficients for each time period before the treatment should be insignificant. These differences are plotted for each zone in Figure 5. Panel (a) shows the difference between HPI coefficients for the west zone versus those for the rest of Los Angeles, panel (c) shows the same difference but for homes in the east zone, and finally panel (e) shows the differences for the corridor zone versus the rest of Los Angeles. Each of the three zones show statistically different house price index coefficients from Los Angeles as a whole. This is especially true for the east and corridor zones in panels (c) and (e). This indicates that using home prices for the rest of Los Angeles is not going to provide the correct counterfactual changes.

As an alternative to using city-wide trends as the counterfactual, we propose using homes in the "marginal" rail zone, homes one to two miles from each affected rail. To test the validity of this counterfactual group we follow the same method as before. The difference in coefficients for each zone and its marginal zone are plotted in panels (b), (d), and (f) of Figure 5. In each case the HPI coefficients are statistically indistinguishable from those for the accompanying marginal zone - confirming that the marginal zones are indeed providing the correct counterfactual changes. For the remainder of the paper, the marginal zones around each rail will be used to produce fitted values to control for counterfactual changes in the absence of the rail shift, though using the city of Los Angeles as the counterfactual instead does not fundamentally alter the results.

4 Estimation

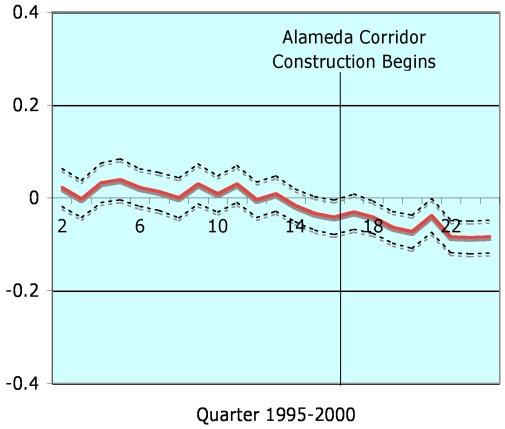
This section presents the basic estimation equations for measuring the impact of rail traffic density. While the rail traffic density decreased in the east and west zones and increased in the corridor zone, the coefficients on each density change regressor below are all expected to be negative reflecting the disamenity value of rail traffic in a neighborhood. The magnitude of the coefficients should be decreasing in absolute value as the distance from the rail increases, as homes further from the track are likely to experience lower noise, pollution, and congestion. In each specification below, the log price change for a home is regressed on the change in rail density, the predicted house price based on the relevant WRS index, and a vector of seasonal and neighborhood dummies. The method for choosing a predicted house price will be addressed in the following section.

4.1 Model 1 - Baseline

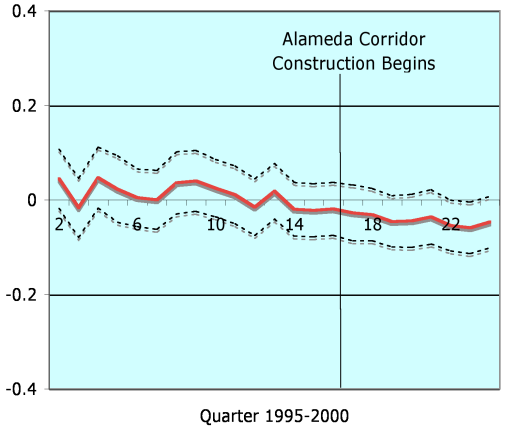
The first model examines the impact of the rail traffic changes in 1/3 mile-incremental bands around each affected rail without distinguishing between the Alameda Corridor and the other two rails. The assumption that all rail traffic affects home prices in the same way will be relaxed in later

Figure 5: HPI Coefficient Differences and 95% Confidence Bands on Point Estimates

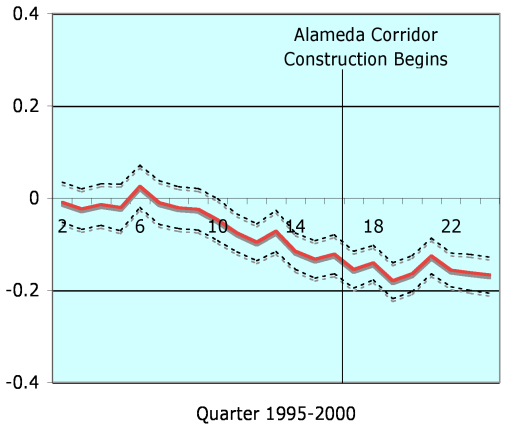
(a) West vs. LA



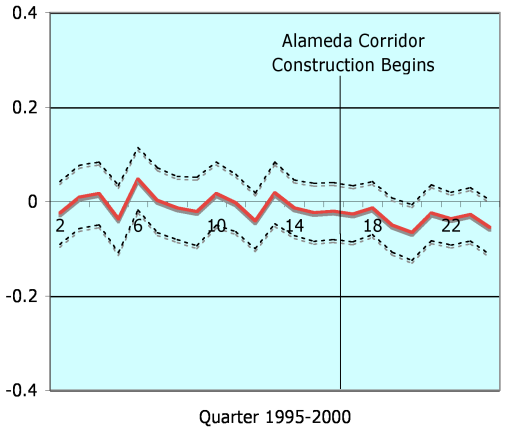
(b) West vs. Marginal West



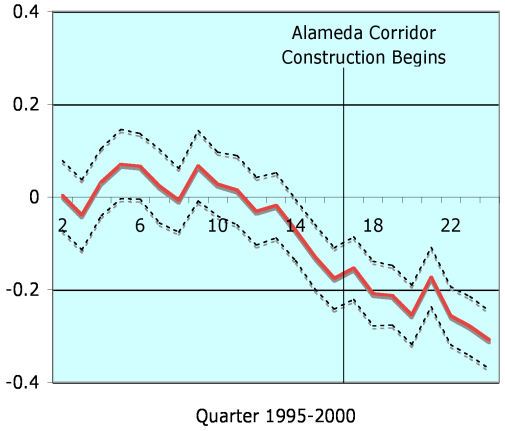
(c) East vs. LA



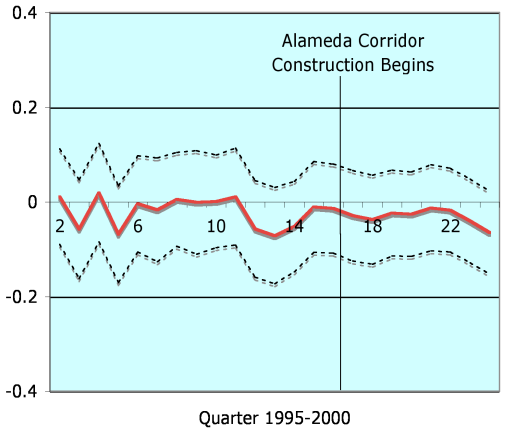
(d) East vs. Marginal East



(e) Corridor vs. LA



(f) Corridor vs. Marginal Corridor



analysis.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \beta' x_i + u_i$$

The format for regressors indicating the zone in which the house is located is as follows:

$$AnyRail_{1,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (0,\ .33) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{2,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.33,\ .67) \\ 0 & \text{otherwise} \end{cases}$$

$$AnyRail_{3,i} = \begin{cases} 1 & \text{if Distance (mi) to Rail} \in (.67,1) \\ 0 & \text{otherwise} \end{cases}$$

4.2 Model 2 - Railroad Crossing Increments

The second specification includes an indicator for proximity to railroad crossings. Federal law requires trains to sound their horn when approaching street crossings, which is likely to augment the already negative impact of train traffic through a neighborhood. Train signals are required to be heard between 96 and 110 dB from a distance of 100 feet. Figure 2 displays lower and upper bounds on the sound decay of a train signal as you move further away from the track. Because the Alameda Corridor was constructed using a series of trenches and bridges, railroad crossings only exist on the east and west rail lines. This model divides the intersection zone into 500 foot increments to explore how the impact of rail density evolves with distance around these intersections. Each home in the intersection crossing zone will also be located in the zone closest to the rail, so the full effect of a density change for these houses will be the sum of ψ_1 and λ. As with the incremental zone variables, the impact of the traffic change at an intersection is expected to fade with increased distance.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * AnyRail_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * (Crossing_{j,i} * AnyRail_{1,i}) + \beta' \bar{X}_i + u_i$$

4.3 Model 3 - Heterogeneous Rail Traffic Impacts

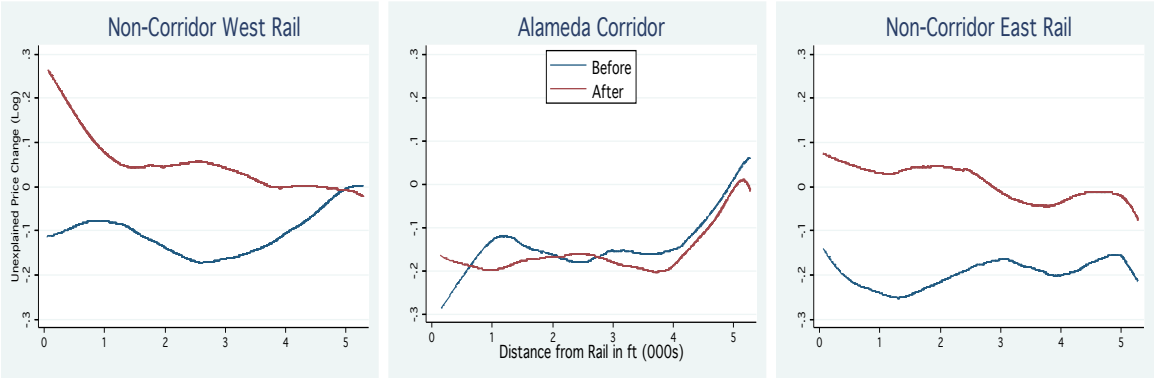
Part of the intent for the Alameda Corridor was to move containers through the city without the need for rail crossings. This was accomplished through a series of bridges, trenches and underpasses. To allow for heterogeneous impacts from rail traffic density, the previous two models are expanded to distinguish between corridor and non-corridor rail traffic. The non-corridor traffic will be further disaggregated by geography.

$$\Delta P_i = \gamma \widehat{\Delta P_i} + \sum_{j=1}^{3} \psi_j \Delta DEN_i * NonCorr_{j,i} + \sum_{j=1}^{3} \phi_j \Delta DEN_i * Corridor_{j,i} + \sum_{j=1}^{3} \lambda_j \Delta DEN_i * Crossing_{j,i} + \beta' \bar{X}_i + u_i$$

5 Results

5.1 Locally Weighted Regressions

Before presenting the full regression results, inspection of Figure 6 helps to motivate the more detailed study. In each figure, the unexplained price change is non-parametrically regressed on the distance from the rail for home sale pairs both before and after the opening of the Alameda Corridor. The unexplained price change is found by taking the actual log price change less the predicted price change using the appropriate "marginal" rail zone discussed above. Panels (a) and (c) include homes within one mile of the rails where traffic was drastically reduced. Homes closest to the rail that were sold before the change in rail traffic grew in price about 10 percent less than expected, an effect that gradually fades toward zero as the distance increases, at least for the westernmost rail. The price-distance pattern is clearly different for the homes sold after the rail change. Homes close to the rail sold for more than expected and as the distance from the



(a) Non-Corridor West Rail (b) Alameda Corridor Zone (c) Non-Corridor East Rail

Figure 6: Locally Weighted Distance Regressions

rail increases the difference between the actual and expected price change falls toward zero. These patterns give evidence that the rail change was not anticipated by home buyers in the rail zone and that the redirection of traffic has given a noticeable boost to home prices close to the rail, eventually fading as you get further from the line.

The plot in panel (b) shows the same non-parametric regression but for the homes around the Alameda Corridor itself where rail traffic was significantly increased. Regardless of whether it was sold before or after the opening of the corridor, homes closer to the corridor sold for less than expected. The gap between sale price and expected sale price narrows for homes located further from the corridor both before and after the opening, which fits with the idea that the impact of the rail traffic should die off with distance. The similar price-distance pattern for homes sold before and after indicates that prices in the corridor area were negatively impacted before the corridor opened. With an infrastructure project of this scale, it is not surprising at all that prospective home buyers and sellers in the area were aware of the potential impact. The fact that the pattern persisted even after the opening suggests that the negative impact of the rail traffic was not completely capitalized into home prices beforehand.

5.2 Basic Model Results

The regression results for the first two models described earlier are summarized in Table 3. The units of the rail density measure in these regressions are hundred millions of gross ton miles per mile. In Panel A, the first column does not include zone or seasonal dummy variables or any housing characteristics, only the density change of the nearest rail interacted with the indicator for which zone in which the home is located. Column I shows a strong negative effect of an increase in the rail density for the homes within 1/3 of a mile of a rail. This indicates that for these homes, an increase in rail density of 100 million gross ton miles per mile will cause home prices in the area to fall by -0.6 percent. While this may seem small, the re-routing of traffic due to the Alameda Corridor increased traffic in the corridor zone by 50 to 90 million gross ton miles per mile. The negative effect of a density increase is lessened, but still statistically different from zero, for the next set of homes 1/3 to 2/3 of a mile from the rail. A one unit increase in rail density causes a -0.3 percent fall in the home price in this zone. Finally, for homes between 2/3 of a mile and one mile from the track the negative effect disappears. The coefficient for this last group is small and positive, but not significant. Column II includes zone indicators for all homes, seasonal dummies, and housing characteristics. All coefficients move towards zero and the standard errors are larger, but the overall pattern where the impact diminishes with distance remains.

Column III introduces indicators for proximity to a rail crossing interacted with the rail density change. The coefficient on density change for homes nearest an intersection (within 500 ft) is considerably more negative than for the rest of the zone but is not statistically significant. The period under study can be considered to be anomalous as the growth and subsequent popping of the real estate bubble characterizes the second half of the housing data. As a robustness check, Column IV restricts the data set to homes sold before the crash in housing prices. Truncation of the data pushes the coefficient on density change for homes nearest a crossing further negative. Since traffic was falling at these intersections we can interpret this result to mean the housing bubble

likely sapped some of the price boost felt by homes in this area.

Thus far it has been implicitly assumed that homebuyers and sellers are myopic about the impact of the Alameda Corridor on home values. This assumption is especially strong for homes near the corridor itself, as construction spanned several years and was by no means a minor project. Ideally it would be possible to use a timeline of the corridor's construction or news stories about the planning of the corridor as the points in time when agents became aware of the potential home price impacts. Unfortunately, the housing data available for this paper begin in 1995 and planning for the corridor began in the early 1980s. Instead I exclude homes that were sold during the construction period of the corridor and report the results in Panel B of Table 3. Despite the reduction in observations, the coefficients do not change much and are more precisely estimated.

5.3 Heterogeneous Effects

The regressions above were re-run to allow the coefficients on rail density to differ for corridor and non-corridor traffic. We see in Table 4 the pattern of negative impacts dissipating with distance persists, but the coefficients for corridor traffic are larger and more precisely estimated. For homes in the zone closest to the non-corridor rails, a 10 MGTM/mi increase in density causes a -0.5 percent decline in home prices. However, rail traffic in these areas fell so homes were appreciating at a faster pace than expected. The impact of a density change in the next zone around non-corridor rails is negative, but only statistically different from zero if the housing crash is excluded. In the corridor zone a 10 MGTM/mi increase in density causes a -0.8 percentage point lower growth than expected. This translates to a 4 percent lower home price growth when rail traffic increased by 50 MGTM/mi.

It should be noted that, while they are not statistically different, it is somewhat unexpected that the coefficient on corridor traffic is larger in absolute value. My expectation was that the coefficient would be smaller, capturing the concavity created by diminishing effect of greater amounts of traffic

Table 3: Impact of Rail Traffic on Home Prices

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Any	-0.062	-0.050	-0.032	-0.024	-0.062	-0.049	-0.016	-0.008
	(0.010)***	(0.022)**	(0.026)	(0.039)	(0.015)***	(0.018)***	(0.020)	(0.027)
1/3 - 2/3 mi. from Any	-0.035	-0.044	-0.051	-0.086	-0.039	-0.051	-0.063	-0.111
	(0.012)***	(0.020)**	(0.018)***	(0.019)***	(0.014)***	(0.020)**	(0.022)***	(0.027)***
2/3 - 1 mi. from Any	0.019	0.010	0.004	-0.020	0.025	0.018	0.006	-0.029
	(0.018)	(0.011)	(0.026)	(0.023)	(0.014)*	(0.015)	(0.014)	(0.020)
500 ft from Crossing			-0.248	-0.298			-0.286	-0.353
			(0.169)	(0.121)**			(0.105)***	(0.107)***
1000 ft from Crossing			-0.015	-0.010			-0.067	-0.076
			(0.059)	(0.071)			(0.066)	(0.074)
1500ft from Crossing			-0.040	-0.082			-0.079	-0.122
			(0.076)	(0.080)			(0.070)	(0.077)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	Yes
Observations	28586	28586	28586	20578	24833	24833	24833	17675
R-squared	0.8518	0.8536	0.8537	0.8283	0.8339	0.8358	0.8358	0.8058

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

- a hypothesis that will be tested later. One possible explanation is that homeowners and sellers surrounding the non-corridor rail were better informed as to the impact of the rails, they could have acted on this information prior to the redirection of traffic, dampening the total effect. Under this circumstance, excluding the construction period should bring the estimates for each zone closer together, which we can see in Panel B is the case.

Once construction period homes are excluded, we find that rail density changes have similar impacts for homes in the first two zones around corridor and non-corridor rails. While the impact of density changes for the first two zones are similar, the effect dies out faster for non-corridor homes. Homes located between 2/3 of a mile and one mile from the Alameda Corridor still felt a negative impact, falling -0.2 percent for each additional 10 MGTM/mi. However, homes that are the same distance from non-corridor rails do not experience a measurable impact from a rail change. Whether using Panel A or B, the strength of the density effect is greatly magnified for homes in the immediate vicinity of rail road crossings. Rail density in this area fell from about 30 MGTM/mi to 2.5 MGTM/mi meaning homes nearest the rail grew about 8.3 percent above the expected price.

When the non-corridor traffic is disaggregated even further (Table 5), separating the rail west of the corridor from the rail to the east, we find that the effect of the rail density change is concentrated around the railroad crossings and is stronger in the west. In fact, there is no effect for homes around the east railroad unless located near an intersection. The coefficient on density change for homes nearest to an east intersection should be disregarded as very few homes are located in this zone and even fewer (16) have sale pairs spanning a density change. These coefficients for rail crossing homes are negative, but only significant if we consider home sales before the housing bust, suggesting that any stronger growth felt in the area was given back when housing prices began falling. There are two possible explanations for the weaker results along the east rail. First, if container traffic from the port does not leave on rail, it leaves on trucks. Interstate 710 is the major truck route leaving

Table 4: Impact of Rail Traffic on Home Prices: Heterogeneous Impacts

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III	IV	I	II	III	IV
Δ Rail Traffic:	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor	-0.050	-0.037	0.005	0.000	-0.068	-0.058	-0.006	-0.007
	(0.029)*	(0.023)	(0.030)	(0.046)	(0.027)**	(0.024)**	(0.036)	(0.045)
1/3 - 2/3 mi. from Non-Corridor	-0.023	-0.033	-0.032	-0.073	-0.042	-0.056	-0.056	-0.108
	(0.019)	(0.026)	(0.032)	(0.026)***	(0.028)	(0.027)**	(0.029)*	(0.038)***
2/3 - 1 mi. from Non-Corridor	0.032	0.022	0.022	-0.007	0.023	0.013	0.013	-0.025
	(0.017)*	(0.019)	(0.024)	(0.025)	(0.020)	(0.021)	(0.020)	(0.031)
0 - 1/3 mi. from Corridor	-0.080	-0.088	-0.088	-0.138	-0.071	-0.076	-0.076	-0.148
	(0.016)***	(0.013)***	(0.024)***	(0.036)***	(0.015)***	(0.022)***	(0.022)***	(0.030)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.056	-0.056	-0.056	-0.068	-0.063	-0.063	-0.059
	(0.014)***	(0.020)***	(0.018)***	(0.024)**	(0.014)***	(0.014)***	(0.022)***	(0.021)***
2/3 - 1 mi. from Corridor	-0.035	-0.033	-0.033	-0.062	-0.024	-0.027	-0.027	-0.040
	(0.013)***	(0.016)**	(0.016)**	(0.020)***	(0.013)*	(0.017)	(0.020)	(0.022)*
500 ft from Crossing			-0.276	-0.314			-0.290	-0.349
			(0.122)**	(0.183)*			(0.113)***	(0.111)***
1000 ft from Crossing			-0.044	-0.026			-0.072	-0.071
			(0.069)	(0.083)			(0.058)	(0.065)
1500 ft from Crossing			-0.069	-0.098			-0.084	-0.117
			(0.044)	(0.084)			(0.066)	(0.083)
Zone Indicators	No	Yes	Yes	Yes	No	Yes	Yes	No
Housing Characteristics	No	Yes	Yes	Yes	No	Yes	Yes	No
Seasonal Indicator	No	Yes	Yes	Yes	No	Yes	Yes	No
Observations	28586	28586	28586	20578	24833	24833	24833	24833
R-squared	0.8520	0.8537	0.8538	0.8283	0.8341	0.8359	0.8359	0.8059

Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

the port and cuts directly through the east rail, so it is possible that rail traffic has been substituted for truck traffic in this area; something that could be explored further. Additionally, the homes in the most densely populated area of the east rail zone are also located adjacent to the rail yards where idling train have created a health risk for neighboring communities (ARB 2007). For the west rail, the coefficients are comparable to the earlier estimates, but the precision is reduced. If the construction period is excluded, we get the familiar pattern of a strong negative effect of rail density that diminishes as you move further from the rail.

5.4 Convexity of Costs

The nature of traffic shift that occurred due to the Alameda Corridor offers an opportunity to explore how homeowners react to differing levels of an externality. Homeowners along the corridor were faced with sharp increases in rail traffic near their homes, while homes in other areas experienced a sharp decline in traffic. This tandem upward and downward shift allows us to gain some insight into the marginal cost structure associated with the intensity of this externality. If the marginal cost of an increase in traffic is different in absolute value than the marginal cost of a decline in traffic the welfare implications of rail traffic will hinge on where these burdens are borne. Consider a situation where two equally populated neighborhoods each had a track running through. If the marginal cost of traffic were increasing total welfare would be largest with an equal distribution of traffic. However, if the marginal cost were diminishing an argument could be made that one of the neighborhoods should carry the traffic and could be compensated in some way by the other. If the marginal cost were constant, distribution of the traffic would be less important as it does not impact the magnitude of the welfare impact.

The test we perform to determine whether marginal costs are increasing or decreasing is to use a approximation to the marginal cost and compare the regression coefficients for a change in density in the corridor zone versus the non-corridor zone. Because the the areas have different

Table 5: Impact of Rail Traffic on Home Prices: Disaggregated Zones

	Panel A - Includes Construction Period				Panel B - Excludes Construction Period			
	Log Price Change				Log Price Change			
	I	II	III		I	II	III	
Δ Rail Traffic :	Baseline	Covariates	Intersections	No Crash	Baseline	Covariates	Intersections	No Crash
0 - 1/3 mi. from Non-Corridor West	-0.069	-0.063	-0.027	-0.030	-0.098	-0.088	-0.046	-0.050
	(0.039)*	(0.038)*	(0.045)	(0.060)	(0.040)**	(0.041)**	(0.064)	(0.066)
1/3 - 2/3 mi. from Non-Corridor West	-0.035	-0.051	-0.051	-0.102	-0.063	-0.079	-0.078	-0.155
	(0.030)	(0.029)*	(0.039)	(0.048)**	(0.032)**	(0.040)*	(0.033)**	(0.042)***
2/3 - 1 mi. from Non-Corridor West	0.022	0.014	0.015	0.000	0.016	0.012	0.012	-0.024
	(0.029)	(0.024)	(0.031)	(0.035)	(0.033)	(0.041)	(0.032)	(0.045)
0 - 1/3 mi. from Non-Corridor East	-0.012	0.009	0.034	0.021	-0.009	0.011	0.045	0.040
	(0.050)	(0.031)	(0.050)	(0.069)	(0.052)	(0.033)	(0.042)	(0.049)
1/3 - 2/3 mi. from Non-Corridor East	0.004	0.000	-0.000	-0.028	0.005	0.001	0.000	-0.019
	(0.038)	(0.037)	(0.047)	(0.037)	(0.059)	(0.042)	(0.043)	(0.040)
2/3 - 1 mi. from Non-Corridor East	0.051	0.035	0.035	-0.026	0.043	0.032	0.032	-0.020
	(0.036)	(0.036)	(0.039)	(0.024)	(0.044)	(0.031)	(0.035)	(0.050)
0 - 1/3 mi. from Corridor	-0.080	-0.087	-0.087	-0.139	-0.070	-0.071	-0.071	-0.147
	(0.015)***	(0.013)***	(0.025)***	(0.035)***	(0.017)***	(0.023)***	(0.022)***	(0.028)***
1/3 - 2/3 mi. from Corridor	-0.065	-0.055	-0.055	-0.058	-0.067	-0.059	-0.059	-0.057
	(0.015)***	(0.019)***	(0.019)***	(0.026)**	(0.018)***	(0.016)***	(0.021)***	(0.022)**
2/3 - 1 mi. from Corridor	-0.035	-0.032	-0.032	-0.063	-0.022	-0.022	-0.022	-0.039
	(0.016)**	(0.017)*	(0.016)**	(0.020)***	(0.010)**	(0.018)	(0.019)	(0.023)*
500 ft from West Crossing			-0.275	-0.325			-0.275	-0.344
			(0.137)**	(0.228)			(0.143)*	(0.138)**
1000 ft from West Crossing			0.004	0.045			-0.015	0.009
			(0.090)	(0.096)			(0.066)	(0.088)
1500 ft from West Crossing			-0.050	-0.047			-0.055	-0.059
			(0.071)	(0.110)			(0.083)	(0.099)
500 ft from East Crossing			-0.120	0.123			-0.129	0.091
			(0.232)	(0.483)			(0.273)	(0.480)
1000ft from East Crossing			-0.124	-0.219			-0.151	-0.251
			(0.136)	(0.116)*			(0.168)	(0.144)*
1500 ft from East Crossing			-0.061	-0.184			-0.084	-0.197
			(0.085)	(0.064)***			(0.087)	(0.100)**
R-squared	0.8520	0.8537	0.8539	0.8283	0.8341	0.8359	0.8361	0.805
Observations	28586	28586	28586	20578	24833	24833	24833	17675

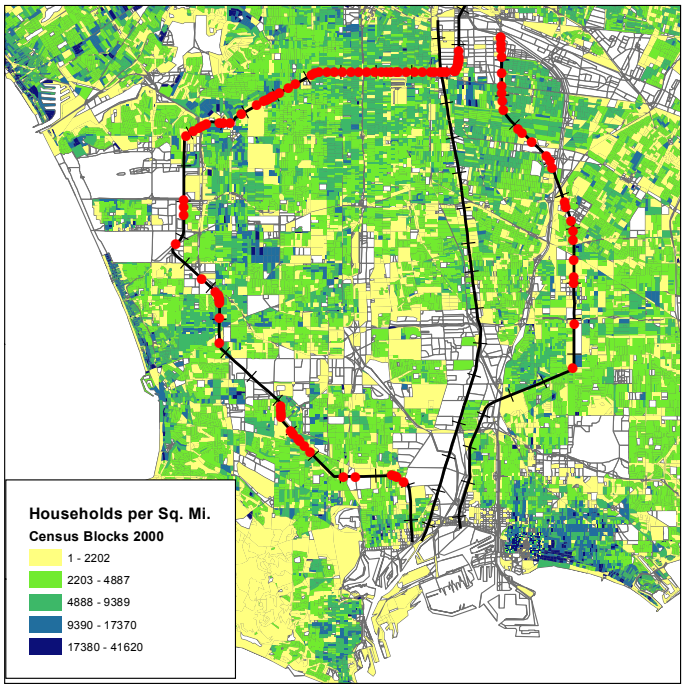
Bootstrapped standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

home values we will need to incorporate this difference into the test in order to find the marginal dollar cost. Additionally, to test convexity of the cost structure some stronger assumptions have to be made. I am forced to assume that an increase in rail traffic in each area causes the same level of negative impact and that the difference in how it is capitalized into home prices is due to individuals preferences over these impacts. This may be a difficult assumption to accept as the Alameda Corridor was constructed such that trains would no longer cross streets at surface level. Removing traffic from surface level interactions is likely to reduce the impact that homeowners perceive, so our test is possibly biased towards accepting the hypothesis that marginal costs are diminishing. The hypothesis test is as follows:

$$\begin{aligned} H_0 &: \psi_1 AvgPrice_{NonCorridor1} = \theta_1 AvgPrice_{Corridor} \\ H_1 &: \psi_1 AvgPrice_{NonCorridor1} > \theta_1 AvgPrice_{Corridor} \end{aligned} \tag{5}$$

Using estimates from Table 4 we fail to reject the null hypothesis that marginal costs are constant. The coefficients on density change are similar or higher in the corridor zone, but the average home value is higher in the non-corridor zone. A change of 10 MGTM/mi in rail density causes a change in home value of $1,180 in the western non-corridor zone, $863 in east rail zone, and a $832 change in home value in the corridor zone. The difference between these estimates is not statistically significant at any conventional level. While this test is imperfect due to the strong, and possibly invalid, assumptions required, it does still provide some evidence against diminishing marginal cost of the externality as the test is biased in the direction of finding diminishing marginal costs, but finds no evidence of this. Performing a joint test of the hypothesis that the marginal effects for each distance band are the same between corridor and non-corridor rails brings us to the same conclusion.

Figure 7: Household Density

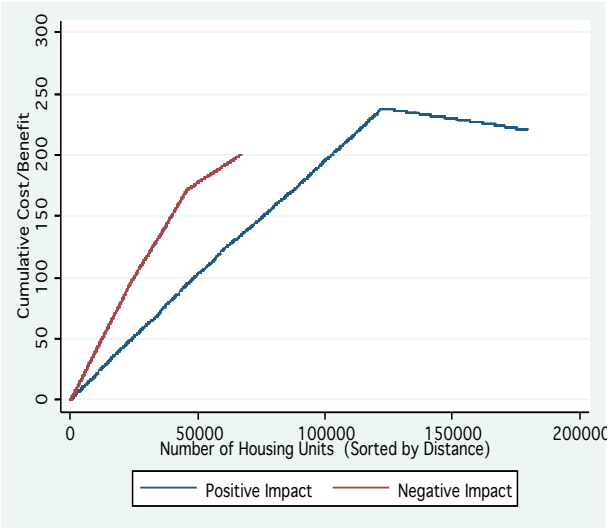


5.5 Aggregating Impact

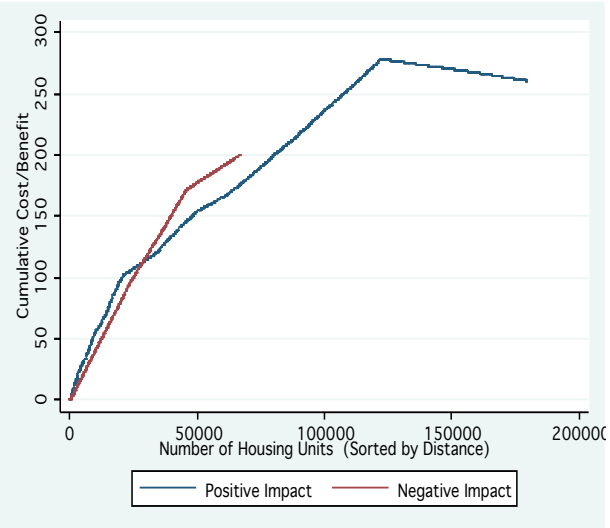
If the population density and distance of each affected line were identical we would only need the marginal effect and density change to determine whether the net effect capitalized into home prices was positive or negative. As can be seen in Figure 7, the population density is not constant along each line and, in fact, there are very few homes near the lower section of the central Alameda Corridor. In addition to changing population densities, the length of each line differs. To understand how this affects the overall impact of the rail shift, we must tabulate the number of homes and the average price in each zone. Using Census 2000 data we find the number of housing units in each Census block and using our housing data we find the average pre-treatment price. Using this information and the marginal effects calculated in the earlier regressions we can add up the total impact capitalized into home prices. Figure 8 displays number of housing units affected on the x-axis, sorted by distance to a rail, and the cumulative impact on the y-axis with the negative and positive impacts plotted separately. In panel (a) we use the regression coefficients from Panel B Column II of Table 5 to estimate the total effect on housing, finding the positive impact to be

Figure 8: Cumulative Impact of Rail Shift

(a) Disaggregated Impacts



(b) Intersections



roughly $23 million greater than the negative impact. It should be noted that line for the negative impact is more steeply sloped, not because of a difference in the marginal effect, but because the change in rail traffic was greater on the Alameda Corridor than on the individual non-corridor rails. Finally, when we use the most detailed specification including the effect on homes around the railroad crossings we see in panel (b) that the positive impact is now steeper initially due to the magnified effect around the rail crossings and that the gap between the positive impact and negative impact is wider. Considering the magnitude of the housing value in the one-mile zone around the rails totaled $36 billion in 1997, the small total positive impact is negligible. While the net impact may be negligible, there has been a significant transfer of housing value from the communities surrounding the Alameda Corridor, which tend to be predominantly minority and lower income, to higher income neighborhoods surrounding the non-corridor rails.

6 Conclusion

This paper exploited a natural experiment to measure the positive and negative impacts of rail traffic on neighboring homes. I find strong evidence negative spillovers from local rail traffic nega-

tively impact home values. Additionally, the case for concentration of a negative externality is not supported as I did not find evidence of concavity or convexity of the cost of rail traffic on homes. Therefore a zero-sum redistribution of traffic would be expected to have no impact. In this case, there was a small positive impact on housing values as a result of the more direct routing of traffic. Because the Alameda Corridor saw a larger increase in absolute value than the decrease on the other lines, the negative impact felt by a home along the Alameda Corridor was greater in absolute value than the positive impact received by a home along a rail where traffic was reduced. However, there were many more homes along the non-corridor rails leading to the small net positive effect. The positive gain was muted by the narrowly focused impact felt around the eastern non-corridor rail. Because of the confounding effect of the 710 interstate and nearby inter-modal railyards, the positive benefit was confined to the homes near rail crossings.

The rail traffic setting explored here is ideal for investigating the negative externality effects of infrastructure expansions with little interference from demand side effects. If the re-routing experiment had been for highway or airport traffic the negative impacts would have been more difficult to measure as the positive effects of proximity to airports or reduced commute times would have likely influenced home values. The use of freight rail traffic allowed for cleaner estimation of this impact. The most likely source of this type of demand side impact from freight rail would be from greater employment opportunities during construction, though the longer window of data available allows this issue to be circumvented.

Infrastructure expansions are often touted as local job creators, but there are also costs borne by the localities. Understanding the spatial dispersion of the costs and whether there are convexities is necessary when evaluating these projects. From this paper, the lack of evidence of diminishing marginal cost suggests that concentrating the negative impacts of an infrastructure project yield no reduction in the welfare costs. The fact that we uncover a relatively linear marginal damage curve for winners and losers from this infrastructural redistribution indicates that there are no complex

welfare dynamics at work, at least as revealed by home prices. This would indicate that planners considering future projects will maximize welfare simply by making transportation infrastructure as direct and efficient as possible when local impacts are unavoidable.

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The Impact of the Development of the Gateway Pacific Terminal on the Whatcom County Economy

March 6, 2012

Prepared by

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for

Communitywise Bellingham

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I. Executive Summary

In November 2011, Communitywise Bellingham retained Public Financial Management, Inc. (PFM) to conduct an independent review of the potential economic impacts associated with the development of the Gateway Pacific Terminal (GPT) at Cherry Point.

A prior study by Martin Associates, conducted on behalf of the developers of GPT, projected the economic benefits that would result from the development and operation of the terminal. That study and a subsequent third party review of its results did not address either potential costs that could result from the development and operation of GPT or the degree to which the development of GPT could reduce potential benefits from other sources of economic development or job growth in Whatcom County.

Our analysis suggests that the potential for cost is real. To the extent that the development and operation of GPT would lead to an increase in rail traffic in Bellingham and other parts of Whatcom County, there would be costs to mitigate the impact – particularly given the number of active rail crossings in the City.

The impact on other job growth and economic development strategies may be even more significant. To the extent that GPT's construction and operation could put other projected or planned growth at risk, it is possible that even if all of the projected employment benefits of GPT were achieved it could still have a net negative employment impact on Whatcom County's economy. If the development and operation of GPT led to the loss of more than 17 percent of projected job growth in Whatcom County between 2012 and 2021, or more than 13 percent in the ten year period after construction begins, the result would be a net loss in employment in the County.

Moreover, the planned development and operation of GPT could pose a specific risk to redevelopment plans for the Bellingham waterfront. State and local agencies have committed more than $40 million to the redevelopment of the former Georgia Pacific site in downtown Bellingham. The Port of Bellingham projects that over 25-30 years, redevelopment of the site could produce $1 billion in investment – including a net increase of 5,600 direct jobs alone. To the extent that development and operation of GPT increases rail traffic, it could reduce the feasibility of redevelopment and projected resulting jobs.

The risk of offsetting reductions in projected job growth is largely due to train traffic. First, the operation of GPT would lead to a significant increase in rail traffic through Whatcom County – especially through downtown Bellingham. Phase I operation would add five trains traveling to GPT through Bellingham on a daily basis. Each train would be between 7,000 and 8,500 feet – 1.3 to 1.6 miles – in length. Additional traffic is likely due to the return of rail cars from GPT.

Impacts to Bellingham – positive and negative – are significant for Whatcom County due to its role as the economic center of the County. Approximately 60 percent of all employment in the County is in Bellingham; Bellingham businesses generate more than three-quarters of all retail sales and more than half of all revenue related to accommodation and food services; in 2010, more than half of all residential home sales occurred in Bellingham; and, despite accounting for just 1.3 percent of total land in the County, 36 percent of total assessed county property value was in Bellingham.

Additional potential risks to growth beyond baseline projections are related to tourism and the in-migration of skilled workers and entrepreneurs to the region's economy. Again, these risks are related to both the projected increase in rail traffic and stigma associated with the transport of large amounts of coal through Whatcom County.

If the development of GPT proceeds, steps can be taken to reduce the impact of additional rail traffic through re-routing of rail traffic or new overpasses or changes to the street grid. Those steps could reduce potential risk and thereby increase the likelihood of net economic benefits for Whatcom County and Bellingham. Such steps, however, come at a cost that – to date – no party has assumed. To the extent that those costs are assumed by the public, it would reduce the net fiscal benefit of the GPT development to the public – especially if local governments were asked to bear those costs.

In assessing the findings of this report, different decision makers may not view the risks imposed by the development and operation of GPT in the same way and reach dissimilar, yet valid conclusions. The purpose of the study is not to recommend a specific course of action. Instead, the purpose is to provide policymakers – and the public – with additional information about the potential economic impact to reach a better-informed decision. With that aim, other communities along the rail line may find the economic analyses and risk-based approach in this report to be a template for undertaking their own review of the economic impact of GPT.

II. Introduction and Project Overview

In November 2011, Communitywise Bellingham retained Public Financial Management, Inc. (PFM) to conduct an independent review of the potential economic impacts associated with the development of the Gateway Pacific Terminal (GPT) at Cherry Point. In particular, Communitywise Bellingham asked PFM to assess some impacts not considered in the report by Martin Associates (Martin) which projected employment and other economic benefits associated with the development and operation of GPT.

PFM is a national consulting and financial advisory firm, headquartered in Philadelphia, Pennsylvania, that serves public-sector clients. With 30 offices and over 450 professionals located across the country, PFM is the nation's leading provider of independent government financial advisory services. Throughout the remainder of this report, the professionals representing PFM in this engagement will be referred to as the project team or PFM.

To facilitate its work on this report, the project team spent four days in Washington conducting meetings in Bellingham, Olympia, and Bellevue. During this time, the project team met with over 50 people representing a diverse set of interests, viewpoints, and backgrounds – including representatives of SSA Marine (SSA), the State of Washington, Whatcom County, the City of Bellingham, the Port of Bellingham, the Whatcom County Chamber of Commerce, Northwest Washington Central Labor Council, not-for-profit entities, and local businesses. The meetings provided an opportunity for the project team to ask questions, receive information, seek clarification, and obtain verification of its approach, assumptions, and analysis.

The project team met with the SSA representative in Bellingham and a representative of SSA was invited to – and did – participate in the project team's meeting with state officials in Bellevue. The project team welcomed the opportunity to include SSA and saw two distinct benefits from their participation: 1) an opportunity to understand SSA's process and views; and 2) provide the opportunity for SSA to raise concerns with the project team's approach and methodologies. On more than one occasion, SSA offered to provide additional information to aid in the study. Unfortunately, SSA subsequently declined to provide information or additional input.

To supplement the meetings described above, the project team reviewed extensive documentation including documents regarding the development of GPT, demographics and economic data for the City of Bellingham, Whatcom County, and State of Washington, and academic and professional research pertinent to this report. Sources of data and information are cited throughout this report in footnotes.

The projected benefits of GPT have already been the subject of a prior study – the Martin study.[1] In addition, SSA retained Finance & Resource Management Consultants, Inc. (FRMC) to review methodologies used in the Martin analysis, and that review produced a different set of projected economic impacts. While our report includes a discussion of the findings and underlying assumptions in the Martin study and FRMC's review, it does not attempt to calculate – for a third time – projected job, economic activity and tax revenue benefits that might be realized from the completion of GPT.

A traditional economic impact analysis presents projections of benefits based on known or assumed inputs to an economic model. A cost-benefit analysis calculates offsetting costs that would be necessary to realize those benefits. In this report, we provide what we hope is a broader look at overall benefits and costs as well as a discussion of risk and uncertainty related to costs and benefits. In particular, we identify the degree to which proceeding with

1 The project team discloses that PFM has previously engaged in collaborative work with Martin Associates on behalf of other clients.

development and operation of GPT might impose risks to other potential economic growth in Bellingham and in Whatcom County. Understanding those risks – and any uncertainty related to costs and benefits – should allow policymakers and the public to make a more informed decision on the merits of the project.

Thus, this report attempts to answer the following questions:

- What are the projected economic benefits of GPT?
- Are there assumptions or other factors related to the development of GPT that should be considered in assessing the economic impact of GPT on Whatcom County?
- Are there potential costs that might be borne by the public in the development of GPT that could offset projected economic benefits?
- Would the development of GPT create a risk for other potential economic growth strategies in Whatcom County?
- What should the public and policymakers understand about the risks, the potential to mitigate those risks and uncertainty related to potential costs and benefits?

This study is presented to contribute to the public discourse by presenting additional information for consideration as policy makers and the public consider the development of GPT. With that goal in mind, other communities along affected rail lines may find it useful to build upon the work contained in this document or use a similar methodology to understand the specific potential risks to their respective communities and the resulting economic impacts due to the development of GPT.

This report should not, in any manner, be construed as taking the place of the scoping process of the Environmental Impact Study (EIS), the EIS itself, or any other formal review of the project. As such, the failure to consider certain issues as part of this report and analysis should not be inferred as dismissing the importance of those issues. As with any such review, individual components of our analysis rely on the validity, accuracy, and comprehensiveness of the information supplied to us, and projections of future events and outcome are inherently uncertain and subject to change. Similarly, time and resources limit the ability to consider all factors.

III. Gateway Pacific Terminal

Overview

SSA Marine (SSA) through one of its subsidiaries – Pacific International Terminals, Inc. (PIT) – is proposing to develop Gateway Pacific Terminal (GPT) in Whatcom County.[2] In February 2011, PIT submitted a Project Information Document (PID) to the State and Whatcom County "to provide the public, the [multi-agency permitting team], decision-makers, and other stakeholders, including affected Native American Tribes, with a detailed description of the proposed project, the potential environmental effects of the project, and measures incorporated into the proposed project to reduce such effects."[3]

According to the project's website, the port is to be developed in a naturally occurring deep-water location and will be a full-service dry bulk commodity export-import facility on 1,092 acres in the Cherry Point Industrial Urban Growth Area. This area is zoned for heavy-impact industrial use and is located near the BP Refinery and INTALCO facility. The website indicates GPT would be the largest facility of its type on the west coast of the United States, capable of handling up to 54 million metric tons per year of dry bulk commodities.[4]

GPT is designed to accommodate 'capesize' ships in order to allow for the movement of the forecasted volume of dry bulk commodities. Capesize ships, which take their name from the fact that they are physically too large to fit through locks of either the Panama or Suez Canals and therefore must travel via Cape Horn or Cape of Good Hope, are capable of carrying up to 250,000 dead weight tons of cargo. Due to the natural deep-water at Cherry Point, the development does not include the need for dredging.[5] The facility is being built to accommodate 1 to 9 loaded trains per day that will travel to Cherry Point on the Burlington Northern Santa Fe (BNSF) rail line.

In addition to deep water access and projected tonnage, the Cherry Point location provides an additional benefit to PIT due to its proximity to Asia – and growing importers like China and India – when compared to other US ports. The result is a shorter duration (and associated lower cost) to deliver/return cargo.

In February 2011, SSA and Peabody Energy (Peabody) announced an agreement to initially export up to 25 million metric tons of Powder River Basin (PRB) coal per year through GPT. Peabody, the world's largest private-sector coal company, is the leading coal producer in the PRB. The agreement provided Peabody with rights to throughput over the life of the operation of GPT and the ability to expand capacity in future years.[6]

Proposed Phasing of Construction and Operations

The PID outlines two construction development stages. According to the PID, SSA (PIT) projects construction of the first phase to begin in 2013 – "when all required federal, state, and local permits and authorizations have been obtained and environmental review under the [National Environmental Policy Act (NEPA)] and [State Environmental Policy Act (SEPA)] has

2 SSA is a division of holding company Carrix, the largest US owned and privately held container terminal operator and cargo handling company in the world. In 2007, Goldman Sachs Infrastructure Partners acquired a 49 percent share of Carrix. The project team uses the abbreviations 'SSA' and 'PIT' throughout this report.

3 PID, p. 1-1.

4 Pacific International Terminals, Inc. Project Information Document, February 28, 2011, p. 4-1. The PID indicates GPT construction would occur in two phases. The first phase would allow for capacity of 25 million metric tons per year. At full build-out – after phase 2 – GPT would be designed to handle up to 54 million metric tons per year.

5 Hhttp://www.gatewaypacificterminal.comH (accessed January 4, 2012).

6 Peabody Energy Press Release, February 29, 2011.

been completed."[7] SSA (PIT) estimates that the first construction phase will be complete by 2015 and the second phase complete by 2017. After the completion of the first phase, GPT would have capacity to handle 25 million metric tons of dry bulk commodities per year. The second phase would only begin if sufficient demand is present to handle an additional 29 million metric tons per year. If so, construction of phase two would begin after the first phase is completed and operational. After the completion of the second phase, GPT would be at its maximum throughput capacity of 54 million metric tons per year. PIT estimates that construction cost for both phases will total $665 million.

Economic Impact Overview

The project team reviewed the Martin study regarding the development of GPT[8] and the FRMC review of Martin's methodologies.[9] Martin and FRMC data were produced using input-output models, though the model types varied.

Martin Associates Analysis

Martin used the BEA's Regional Input-Output Modeling System (RIMS II) multiplier for construction activity in Whatcom County.[10] Martin arrived at an estimate of 7.4 million person hours supported by direct phase one construction (based upon input construction costs of $536 million) and 10.1 million person hours of indirect and induced activity.

The analysis estimated that the operation of the terminal upon completion of phase one would create 294 direct jobs and 569 induced and indirect jobs, for a total of 863 jobs. Among the 294 direct jobs, the report estimated 170 would be members of the International Longshore and Warehouse Union (ILWU), 46 would be railroad-related, 32 would be in maritime services, 29 would be terminal operators, and 17 would be for pilots and tugs. The Martin report also estimated that upon completion of phase one construction, GPT's operation would annually generate approximately $12.0 million of local purchases and the total state and local tax benefits associated with phase one operation would be approximately $8.1 million per year.

FRMC Review of Martin Methodology

FRMC used the Impact Analysis for Planning (IMPLAN) modeling system to generate its employment estimates. FRMC used this input-output model to assess the assumed economic impact of phase one construction costs of $536 million. The IMPLAN model yields a total that is reported in person hours, but also described person hours in worker years; FRMC assumed 2,080 hours worked as a worker-year.[11] IMPLAN calculations for phase one construction yielded an estimate of 6.85 million person hours of direct employment and 5.48 million hours of induced and indirect employment.

FRMC used Martin's estimate of direct jobs created by operation of the terminal and estimated that 576 induced and indirect jobs would result, for a total of 870 jobs. The FRMC and Martin analyses differ on the potential induced and indirect employment attributable to phase one

7 PID, p. 4-1. The US Army Corps of Engineers, the WA Department of Ecology, and Whatcom County will conduct a coordinated environmental review under the NEPA and SEPA. The US Army Corps of Engineers has determined that an EIS is required. Additional information regarding these processes may be obtained at:

Hhttp://www.ecy.wa.gov/geographic/gatewaypacific/

Hhttp://www.co.whatcom.wa.us/pds/plan/current/gpt-ssa/index.jsp

8 Martin Associates, "The Projected Economic Impacts for the Development of a Bulk Terminal at Cherry Point." July 2011.

9 Finance & Resource Management Consultants, Inc., "Review of Martin Associates Economic Impact Study." October 2011.

10 The BEA indicates that, "RIMS II provides users with five types of multipliers: final-demand multipliers for output, for earnings, and for employment and direct-effect multipliers for earnings and for employment."

11 A person working a 40 hour week for 52 weeks a year will work 2,080 hours.

construction. The FRMC estimate of indirect and induced jobs is 45.7 percent below that of Martin's assessment. Due to this difference, and a slightly smaller direct jobs estimate (7.5 percent less), the FRMC estimate for total person hours is 29.5 percent below the Martin assessment.[12] As FRMC notes, the variance could be due to classifications used as well as the different input-output models used in each analysis.

SSA (PIT) Projection

SSA (PIT) projects that during construction of the first phase, GPT would create approximately 3,600 job years per year and provide $74 million in tax revenue for state and local governments during the estimated two-year construction period.[13] This includes 1,700 direct job years[14] and 1,900 indirect[15] and induced job years annually.[16]

Once operating, after the first phase of construction, SSA (PIT) projects that GPT will provide over $8 million per year in state and local tax revenues as well as create 867 ongoing jobs (294 of which are direct jobs).[17]

If there is demand for additional capacity, SSA (PIT) projects that the second construction phase of GPT would create an approximate addition of 840 job years[18] annually and provide an additional $18 million in tax revenue for state and local governments during the estimated construction period. This phase would include approximately 400 direct job years[19] and 440 indirect and induced job years annually.[20]

At full operation upon completion of the second phase, SSA (PIT) estimates GPT would provide over $11 million per year in state and local tax revenues as well as create 1,250 ongoing jobs (430 of which are direct jobs – including the original 294 direct jobs from the operation of phase one).[21] SSA (PIT) projects the direct jobs to pay an annual average wage of $94,900.[22]

There is an important distinction to be made between the discussion of job years during the construction phases and permanent jobs projected to be created during operation of the terminal. Construction jobs are temporary in nature because once a structure or entity is built and operational, the construction ceases. On the other hand, jobs created during terminal operation are projected to be ongoing – and thus more likely to have a permanent impact on the local economy.

Martin and FRMC both discuss person-hours and do not convert the person-hours to 'jobs' because the length of the construction period is uncertain. As FRMC notes, the person-hours

12 FRMC's review of phase two estimates of construction direct jobs and induced and indirect jobs resulted in similar divergences from Martin; most notably in induced and indirect jobs.

13 Job years includes direct, indirect and induced jobs. The information below sets forth the employment impact projections that appear on the GPT website: the employment impact is an average of the Martin and FRMC estimates. Where employment estimates, timing, or other details diverge from the PID, the project team represents the figures provided on the GPT website because those figures appear to have been more recently revised and the PID is a static document from February 2011.

14 SSA (PIT) defines direct jobs are those jobs directly generated by the construction of the terminal.

15 SSA (PIT) defines indirect jobs as those jobs that are created locally due to purchases of goods and services by firms for the construction of the Terminal.

16 SSA (PIT) defines induced jobs as those jobs that are created throughout the local economy because individuals directly employed by the activity at the terminal will spend their wages locally on goods and services (i.e. food, housing and clothing).

17 Includes direct, indirect, and induced jobs.

18 This figure is the average of the Martin and FRMC estimates.

19 This figure is the average of the Martin and FRMC estimates.

20 This is the average of the Martin and FRMC estimates.

21 These figures include the phase one job years (867) and revenues ($8 million).

22 Hhttp://gatewaypacificterminal.com/economic-benefits/creating-new-jobs/H (accessed January 4, 2012).

number is difficult for a typical individual to interpret. FRMC suggests a "conversion of person hours to job years (i.e. the number of workers it would take to build the project in one year), which can be used as well in place of the number of 'jobs' and would make the findings generally more interpretable."[23] The project team uses job years to discuss potential employment during construction, not 'jobs.'

One way to think about this is over a fixed period of time. Over a 10 year period, based on the projections provided by SSA (PIT), construction and operation of phase one would lead to:

- 3,400 direct job years and 3,800 induced and indirect job years during the two year construction phase
- 294 direct jobs per year and another 573 induced and indirect jobs per year – a total of 2,352 direct job years and 4,584 indirect and induced job years during the first eight years of operation

Taken together, based on SSA's (PIT's) projections, GPT would produce the equivalent of an average of 575 direct jobs and 838 indirect and induced jobs per year during the first 10 years of construction and operation.

Assumptions and the Impact of Projected Economic Benefits on Whatcom County

The project team did not review – and therefore has no basis for questioning – the methodology utilized by Martin Associates or FMRC. Nor did we conduct our own independent impact analysis. In considering the projected economic benefits of the GPT project, however, it is important to understand some of the underlying assumptions of those projections and the resulting impact specifically on Whatcom County.

Phase I Construction Jobs are Unlikely to be Created Until 2016 and Permanent Jobs are Unlikely to be Created Until 2018

Critical data and assumptions were provided to Martin Associates by SSA (PIT) including the projected construction phasing, projected cost of construction, projected terminal employment, throughput assumptions, and salary ranges for select terminal employees.

SSA (PIT) provided Martin with a timeline that assumed terminal operations begin in 2015, with permitting completed in 2012 and construction beginning in 2013.[24] The timeline, however, is subject to change. First, representatives of SSA suggested that actual construction would depend on contractual guarantees for throughput. Second, the timing of construction depends on the completion of the EIS process. State officials told the project team that the scoping process for the EIS is likely to begin in the first or second quarter of 2012.

The scoping process and the final EIS must both be completed before the projected two-year construction timeline begins. While some officials estimated the EIS could be completed within two years, a greater number of parties suggested the process could take up to four years to complete. As a result, construction jobs would not be created until 2016 and permanent jobs would not be created until 2018.

23 FRMC, p.3.

24 Martin, p. 1.

Most, but not all, GPT Jobs Will Go to Whatcom County Residents

Even if all SSA (PIT) projected job gains are realized, not all jobs created as a result of the construction and operation of GPT will go to residents of Whatcom County.

During the construction of large scale projects, it is typical that a significant number of workers come from other parts of a region (or nationally) – on a temporary basis – to the project location for short-term work assignments. Our understanding is that construction of GPT would be the subject of a project labor agreement (PLA) with local labor unions, guaranteeing that all work on the site goes to a unionized labor force. PLAs appear to reduce the use of non-local labor on major construction projects, both through explicit local hiring requirements and by reducing the use of 'independent contractors' as part of the labor force.[25]

The ability to staff the construction phase of the project will depend upon the capacity of the local construction workforce. Based on the number of job years and the projected construction period, phase one of GPT construction will require approximately 1,700 construction workers per year. Peak construction employment in the Bellingham MSA reached 6,310 in 2006 – some 1,900 more construction jobs than in 2010.[26] The combination of the PLA and existing capacity in the local construction workforce suggests that the majority of construction jobs during phase one will be held by local workers.

Yet, even if a PLA requires that all – or most – workers on the construction of GPT are local residents, it would have no effect on the share of induced and indirect jobs during construction, direct jobs during operation or induced and indirect jobs during operation going to non-Whatcom County residents.[27] Currently, among the general workforce, approximately 21.0 percent of jobs in Whatcom County are held by non-Whatcom County residents. This could suggest a similar percentage of induced and indirect jobs from GPT construction – as well as direct, induced, and indirect jobs from GPT operation – would go to non-Whatcom residents.[28]

Most GPT Tax Revenue Will Go to the State, Not Local Government

The Martin report defines the tax impact as "tax payments to the state and local governments by firms and by individuals whose jobs are directly dependent upon and supported by (induced jobs) activity at the bulk terminal."[29] Thus, projected tax benefits include taxes that are the direct result of the construction and operation of GPT – such as sales tax related to goods purchased during construction – and taxes that are the result of indirect and induced economic activity – such as property taxes paid by individuals who are employed as a result of jobs created by GPT's activity.

Martin used SSA's (PIT's) estimated phase one construction cost ($536 million) to project state and local tax impact of $74.4 million. Similarly, SSA's (PIT's) projected annual throughput of 25 million metric tons (upon completion of phase one construction) was used to project the

25 See, Uyen Le and Lauren Applebaum, "Project Labor Agreements in Los Angeles: The Example of the Los Angeles Unified School District," UCLA Institute for Research on Labor and Employment, December 2011 at Hhttp://www.irle.ucla.edu/publications/pdfs/ResearchBrief11.pdfH.

26 US BLS OES 2000-2010 data.

27 In understanding the effect of the project on local employment, it is worth noting that not all directly created jobs will go to individuals who are currently unemployed. In fact, as is the case with many new jobs, the likely beneficiaries are individuals who are already currently working. See: Geoffrey C. Ho, Todd L. Pittinsky, Margaret Shih, Daniel J. Walters. "The Stigma of Unemployment: When joblessness leads to being jobless." UCLA Institute for Research on Labor and Employment, December 2011. Thus, employment projections measure the net impact – i.e. by creating new vacancies in other positions, the effect will be to create a net increase in employment.

28 US Census Bureau 2009 OnTheMap data.

29 Martin, p. 3.

associated state and local tax impact of $8.1 million.[30] These tax revenue projections are based on both direct activity related to the terminal and related economic activity.

Most tax benefits from the project will likely go to the state, rather than to local governments. Every state has a different tax structure. Nationally, in 2009, state governments received 56.3 percent of general revenue tax dollars that were collected by state and local governments. In most states – all but five – state tax share exceeded local government share. In Washington, 60.8 percent of general tax revenue went to the state government.[31]

The precise division of revenue generated by GPT will depend, to a certain degree, on the types of tax revenue generated by the project.

Sales and property tax revenue are among the largest sources of revenue for both state and local governments in Washington. Washington does not have a state personal or corporate income tax.

According to the City of Bellingham – the largest city in the Whatcom County and the location of 60 percent of total jobs in the County – 75 percent of sales tax revenue collected in the Bellingham goes to the State of Washington; 10 percent goes to the City; 7 percent goes to the Whatcom Transportation Authority; 2 percent each goes to Whatcom County and the Transportation Benefit District; and 1 percent each goes to jail construction, the criminal justice fund, EMS, and the County mental health tax. Statewide, general sales tax revenue (not including taxes on alcohol, tobacco, gasoline or utilities) accounted for 21.7 percent of local government tax revenue in Washington in 2009.[32]

According to the Whatcom County 2011 Tax Book, approximately 33 percent of all property tax revenue goes to school districts; 24 percent goes to the State; 11 percent goes to both the City and the County; 7 percent goes to road districts; and 6 percent goes to fire districts. No other entity receives more than one percent of property tax revenue. Statewide, property tax revenue accounted for 59.8 percent of local government tax revenue in Washington in 2009.

Based on the above information, and accepting the SSA (PIT) tax revenue projections, it is possible to roughly model likely revenue flow during the first decade of construction and operation of Phase I:

30 Martin, p.3.

31 US Census Bureau, 2009 Annual Surveys of State and Local Government Finances.

32 City of Bellingham, obtained from: Hhttp://www.cob.org/documents/finance/publications/sales-tax-distribution.pdfH.

Ten-Year Revenue Projection (all dollars in millions)[33]

Year	1	2	3	4	5	6	7	8	9	10
Total State and Local Revenue	**$37.0**	**$37.0**	**$8.0**	**$8.0**	**$8.0**	**$8.0**	**$8.0**	**$8.0**	**$8.0**	**$8.0**
State Revenue	$22.5	$22.5	$4.9	$4.9	$4.9	$4.9	$4.9	$4.9	$4.9	$4.9
Local Revenue	$14.5	$14.5	$3.1	$3.1	$3.1	$3.1	$3.1	$3.1	$3.1	$3.1
Local Property Tax Revenue[34]	**$8.7**	**$8.7**	**$1.9**	**$1.9**	**$1.9**	**$1.9**	**$1.9**	**$1.9**	**$1.9**	**$1.9**
Schools	$3.8	$3.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8	$0.8
County Government	$1.3	$1.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
City Government	$1.3	$1.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
Road District	$0.8	$0.8	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
Fire District	$0.7	$0.7	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1	$0.1
Local Sales Tax Revenue	**$3.1**	**$3.1**	**$0.7**	**$0.7**	**$0.7**	**$0.7**	**$0.7**	**$0.7**	**$0.7**	**$0.7**
City[35]	$1.4	$1.4	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3	$0.3
County (including WTA, Jail, Mental Health, CJ,EMS)	$1.8	$1.8	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4	$0.4

33 Just as not all employment will go to Whatcom County residents, at least some of the local tax revenue will likely go to cities, counties and districts outside of Whatcom County.

34 Does not include property tax revenues that go to support State entities.

35 Does not include Transportation Benefit District revenue.

IV. Potential Public Costs Related to Development and Operation of Gateway Pacific Terminal

The PID outlines infrastructure costs in the immediate area surrounding the GPT at Cherry Point. Issues such as at-grade rail crossings – meaning they are on the same level as vehicular traffic – and traffic congestion are detailed. The PID also suggests that the operational cost impacts in the immediate area of Cherry Point may be minimal – with greater instance during construction phases than operational phases.[36]

The PID does not address infrastructure-related costs along this rail line (either in Bellingham or other communities through which it travels) such as crossings, improvements, realignments, bypasses, overpasses, and separations. The PID mentions that the Bellingham Subdivision main line connects to the Cherry Point Line (Railway Custer Spur).[37] The Bellingham Subdivision main line is operated by BNSF and, as its name indicates, runs through Bellingham – much of the way along the waterfront.

Bellingham, as the hub of retail activity in the County, may have a greater use of its public infrastructure due to the development of GPT (roads, water and sewage systems, etc.) than other areas of the County. Without a consistent revenue stream to offset increased costs, the City, and potentially other communities along the BNSF railway, could face increased budget pressures in an already strained fiscal environment.

Rail crossing data from the Federal Rail Administration (FRA) indicate there are 29 active rail crossings in Bellingham on the BNSF rail line in question.[38] Of the 29 crossings, 2 are private crossings, 24 are public crossings, and 3 are pedestrian crossings. Of the public crossings, 16 are at-grade crossings and the other 7 are over/underpasses.

According to a 2009 report prepared for the Washington Department of Transportation (DOT) and Washington Public Ports Association, in 2008, an average of 15 trains per day traveled north from Everett on the BNSF line.[39] The report indicates the line has a maximum capacity of 18 trains per day. By 2028, the report projects that maximum capacity would be 30 trains per day and traffic would be approximately 24 trains per day.

The PID indicates that upon completion of Phase I and operation of the GPT, an additional 5 loaded trains will travel to GPT along the train route through Bellingham on a daily basis. The PID states up to 9 loaded trains are projected to arrive on a daily basis upon completion of Phase II.[40] There may be additional rail traffic attributable to empty/unloaded trains returning from GPT.

SSA (PIT) anticipates servicing GPT using 7,000 foot-long trains (approximately 1.3 miles) and eventually 8,500 foot-long (approximately 1.6 miles) trains may be used.[41] The PID makes no mention of the potential infrastructure costs to remediate infrastructure and other service issues such as at-grade rail crossings, traffic congestion, access issues for business and commerce, access issues for recreational parks, or related issues. Similarly, the PID does not discuss additional operation costs such as maintenance, emergency management, and public safety along the rail line.

36 PID, pp. 5-91 – 5-130.

37 PID, p. 5-103.

38 FRA data available at: Hhttp://safetydata.fra.dot.gov/OfficeofSafety/publicsite/crossing/crossing.aspx

39 BST Associates, HIS Global Insight, and Mainline Management, Inc. "2009 Marine Cargo Forecast – Technical Report." March 23, 2009. A June 2011 study by Cascadia Center for Regional Development indicates that BNSF reports an average of 15 trains per day.

40 PID, p. 4-51.

41 PID, p. 4-31.

The project team met with Bellingham City officials and discussed the potential costs and challenges associated with increased rail traffic along the rail line. City officials identified three primary points of concern.

First, access to certain areas of the waterfront could be severely restricted or cut off. From a public use standpoint, this could be a concern as residents and tourists routinely use the City's parks and trails for recreational activities. Additionally, public safety and emergency service access to the waterfront could be jeopardized if a train was stopped or moving slowly through the rail line that separates some portions of the waterfront from the rest of the City.

A second concern was the safety of the rail crossings in the City. Many of the rail crossings in the City are 'at-grade.' Traffic delays, and increased traffic and use of side streets as a result of increased rail traffic (and longer trains) may cause greater wear and tear on main thoroughfares and alternate roads, a higher need for traffic management and direction activities, and overall challenges to move throughout the City (particularly in and around the waterfront area). Absent any mitigation, there is concern that the City's costs will increase and ease of transportation may suffer.

The third concern was noise impact for residents and businesses in Bellingham. Rail traffic results in two different types of noise. Some noise is experienced as a result of vibrations due to train movement and most greatly affects residents living close to the rail line. As trains pass through Bellingham, they are also required to use their horns as a safety precaution going through at-grade crossings.

Fully addressing these concerns would require infrastructure investments to eliminate at-grade crossings through the creation of either overpasses or re-routing of the rail line. Absent detailed engineering studies, the total cost of these investments is outside the scope of this report.

Noise reduction – related to train horn use – could be achieved through the creation of quiet zones pursuant to Federal Railroad Administration (FRA) rules. A September 2007 study prepared for the City of Bellingham notes that "[I]mplementing a quiet zone will not guarantee that the train will stop blowing its horn at all times and in all situations. A quiet zone will only reduce the train horn noise."

Quiet zones would require capital investments – gates and signage – and maintenance. The 2007 report evaluated the creation of two quiet zones in Bellingham – a Fairhaven zone (5 grade crossings) had a projected capital cost of $1.3 to $2 million. A waterfront zone (7grade crossings) had a projected capital cost of $1.4 to $3.5 million. At the time, there was also a projected annual maintenance cost of $5,500 per crossing, per year.

It remains unclear what party or parties would be responsible for bearing these costs – both in and around Cherry Point and in communities like Bellingham along the rail line that would require mitigation for commercial, public, or safety interests.

The project team spoke with County officials, who indicated the County would not pay for any mitigation-related expenses. SSA (PIT) does not address such costs in their PID outside of the immediate Cherry Point area. Thus, mitigation costs and/or the associated economic and quality of life losses likely to occur absent mitigation could be borne by the communities along the rail line and would reduce the net fiscal benefits – offsetting the projected local government tax revenue discussed in the prior section.

V. GPT Related Risks to Economic Development

To address the question of whether development and operation of GPT would put at risk other economic development, it is important to understand the recent economic history of Bellingham and Whatcom County.[42]

- Employment: From 2001 to 2010, the Bellingham MSA's rate of job growth was almost four times the state rate. The Bellingham MSA (Whatcom County) added 8,100 non-farm jobs – an 11.6 percent increase. Statewide, non-farm jobs grew by 3.0 percent. Compared to the state, the Bellingham MSA grew jobs at a greater percentage or shed jobs at a smaller percentage for every super-sector for which data were available.

- Population Growth: From 2000 to 2010, Bellingham and Whatcom County both grew in population by slightly more than 20 percent – greater than the State's growth rate of just over 14 percent. The US Census Bureau reported Bellingham's 2010 population as 80,885, an increase of 13,714 individuals from the 2000 Census. Whatcom County's 2010 population of 201,140 represented an increase of 34,326 from the 2000 Census. Migration played in important role in driving the increase. New residents – most from other parts of Washington, but significant numbers from other states as well – brought new income with them: IRS data suggest that Whatcom County realized a net growth of over $172.3 million in aggregate Adjusted Gross Income (AGI) from migration between 2004 and 2010.

- Income and Wages: Whatcom County's inflation adjusted per capita income has consistently been below both the State and US averages since 1969. Average earnings per job in Whatcom County have consistently lagged the Washington average since 1987 when the data set began; Whatcom County also remained below the State and US average earnings per job, while Washington has been largely been near or above the national average. Between 2000 and 2008, however, Whatcom County's per capita income grew at a compound annual growth rate (CAGR) of nearly double that of the nation and significantly greater than the State. Whatcom County's CAGR was 2.1 percent; US CAGR was 1.1 percent, and Washington's CAGR was 1.3 percent.

- Bellingham's Importance to the Regional Economy: Approximately 60 percent of jobs in Whatcom County are located in Bellingham and the City accounts for approximately 76 percent of all retail sales in Whatcom County. Bellingham – with just over 1 percent of the County's total square miles also accounts for nearly 36 percent of the County's total assessed value of real property.

The State of Washington currently projects that population will grow in Whatcom County at an average annual rate of 1.5 percent between now and 2030. Similarly, the State projects employment growth in Whatcom County at a rate that would lead to 15,000 new jobs in Whatcom County by 2021. These projections are based, in part, on the County's relative economic strength over the last decade.

42 The project team reviewed economic data for the State of Washington, Whatcom County, and Bellingham and analyzed the data to quantify several important economic factors. In certain instances, data are only available for Whatcom County and/or the Bellingham metropolitan statistical area (MSA) (the MSA is defined as Whatcom County) and not at the City level for Bellingham. In these cases, City-level data are not included. Additional detail and content are available in the appendices of this report and specific sources for the economic findings are detailed in footnotes to those appendices.

Assessing Risks

A more detailed analysis might identify other potential risks, but for the purposes of our analysis we focus on three possible GPT-related scenarios that would put economic growth in Bellingham and Whatcom County at risk:

- Development and operation of GPT could reduce the projected baseline growth in population and employment
- Development and operation of GPT could reduce the possibility of redevelopment of the Bellingham waterfront
- Development and operation of GPT could limit potential population and job growth related to tourism, in-migration of skilled workers and entrepreneurs

Rail Traffic

An increase in rail traffic through Bellingham resulting from the operation of GPT discussed above could increase the likelihood of all three of the risk scenarios. An increase in rail traffic could:

- Limit access to and redevelopment of the waterfront, its businesses, and recreational areas for residents and visitors
- Increase noise and nuisance making Bellingham less of a livable city and less attractive to tourists
- Reduce the capacity of existing rail infrastructure to provide service for residents and visitors

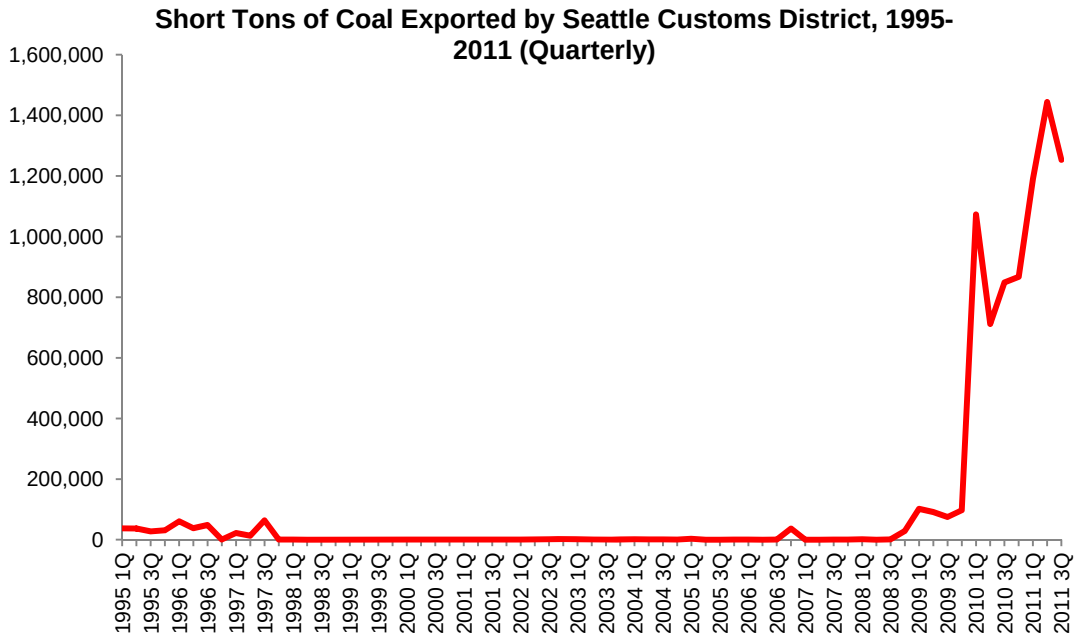
As noted above, rail traffic already travels through Bellingham on a daily basis. Rail traffic has recently increased due to the increase in transport of coal through Canadian ports. Statewide, DOT reported that as of 2007 10.6 million tons of coal was moved by train in Washington each year.[43] More recent data, however, suggest that amount has increased – with a specific increase due to exports that affect the rail line through Bellingham.

The project team reviewed reports that indicate most, if not all, coal from the Seattle Customs District is transported to Canada, primarily on trains that run through Whatcom County and Bellingham.[44] US Customs and Border Patrol data indicate that the Seattle Customs District (which encompasses Northwest Washington – including Whatcom County) experienced a significant increase in the amount of coal exported beginning in 2009 and 2010.[45] Prior to 2009, the annual volume of coal exported by the Seattle Customs District was often below 30,000 short tons per year – in some instances below 5,000 short tons per year. From 2010 through the 3rd quarter of 2011, the average quarterly short tons exported by the Customs District was 1.1 million short tons; approximately 4.4 million short tons on an annual basis. The graph below displays the 1995-2011 quarterly short tons of coal exported by the Seattle Customs District.

43 WSDOT 2010-2030 Freight Rail Plan, p. 4-21. This data likely includes the coal consumed at the Centralia power plant. A recent agreement was reached to end the use of coal-fired generators (one in 2020 and the other in 2025). This may alter the amount of coal tonnage projected to move through Washington in the future and would not be included in the above projections.

44 PFM did not perform its own analysis of this statement.

45 US Customs and Border Patrol Quarterly and Annual Reports, 1995 to present.



Source: US Customs and Border Patrol Quarterly and Annual Report 1995-present

PIT projects the first phase of GPT to handle 25 million metric tons (approximately 27 million short tons) of throughput on an annual basis – much of which would be coal.[46] This suggests that the amount of coal moving through Bellingham by rail could increase six-fold.

More and longer trains will increase the amount of time that rail crossings in Bellingham are blocked. This will impact businesses currently located on the waterfront side of the rail tracks that can only be accessed by at-grade crossings. More and longer trains also may result in greater noise – both noise related to blowing of train whistles to comply with rail crossing rules and noise for property owners; including those immediately abutting the tracks and those nearby.

It is also likely that the additional rail traffic will have a negative impact on the property value of residential properties that abut the rail lines. A November 2011 study examined the impact of rail freight traffic on home values in Los Angeles after the Alameda Corridor, an urban infrastructure project in Los Angeles, consolidated most rail traffic into and out of San Pedro port facilities into one higher capacity rail line.[47] The study measured the impact of increased rail traffic along one corridor and the decreased traffic elsewhere. On average, the study found approximately a 2.0 percent decrease in average home value where rail traffic was more prevalent and approximately a 0.6 percent increase in home value where rail traffic was reduced.

Lower property values resulting from increased rail traffic could have an impact for all residents of Bellingham and Whatcom County – not just the individual property owners. As noted earlier, sales price data suggest that properties in the Fairhaven, South Hill, and Edgemoor sections of Bellingham had among the highest values in the County. Thus, a loss in property value of these properties could also eventually lead to reductions in property tax revenue.

46 Upon completion of phase two, GPT's throughput is projected to be approximately 54 million metric tons per year.

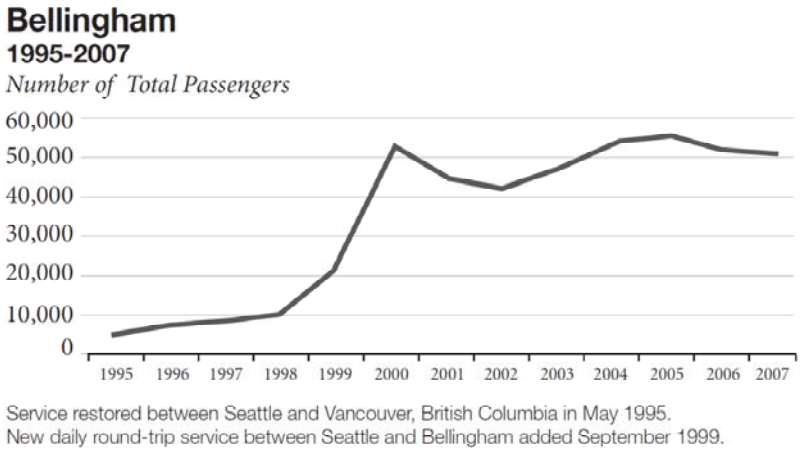
47 Michael Futch. "Examining the Spatial Distribution of Externalities: Freight Rail Traffic and Home Values in Los Angeles, (November 2011).

Even those properties not directly affected by additional rail traffic could suffer from proximity to properties that are affected. Stigma – associated with proximity to the increase in rail traffic or even resulting specifically from the fact that the rail was increasingly being used to transport coal – could affect property value even if the properties would not be affected by additional noise.[48]

On the other hand, the negative impact on property value of properties near or abutting rail tracks could be offset by increased property values in Bellingham or Whatcom County that are not near the rail traffic. To the extent that demand would remain consistent for property in or near certain areas, the values of affected properties could bear a discount while other properties nearby enjoy a premium.

An increase in rail freight traffic could also limit the use of passenger rail in Bellingham and Whatcom County. In 2010, the Amtrak *Cascades* service had total passenger on-offs in Bellingham of 62,562, an increase of nearly 20,000 per year from 2002 levels.[49] Some of the County's tourism industry – discussed in detail below – is dependent on passenger rail. Increased use of tracks in and near Bellingham for freight access to GPT could limit passenger rail and impact tourism.

***Cascades* Total Passengers – Bellingham**



Source: WSDOT, Amtrak *Cascades* Ridership and Station On-Off Information, March 2008

<u>Highest and Best Use of former Georgia Pacific site in Bellingham</u>

Redevelopment of the Bellingham waterfront has been the subject of significant planning and investment. Much of the proposed redevelopment activity centers on the former Georgia Pacific (GP) site.

From the early 1960's through the early 2000's, GP was the heart of the Bellingham waterfront, producing not only consumer and industrial goods, but also significant employment for the region – employing as many as 1,200 workers in the late 1970's. By 2001, the company ended its pulp-mill operations, but continued its tissue-manufacturing operations through 2007, when it

48 Two example studies reviewed were:

Kevin J. Boyle, Nicolai V. Kuminoff, Congwen Zhang, Michael Devanney, and Kathleen P. Bell. "Does a Property-Specific Environmental Health Risk Create a 'Neighborhood' Housing-Price Stigma? Arsenic in Private Well Water." September 2009.

Kai-yan Lee. Federal Reserve Bank of Boston. "Examining REO Sales and Price Discounts in Massachusetts." September 2010.

49 WSDOT, "Amtrak Cascades 2010 Performance Report", May 2011.

closed all operations at the site.[50] During its operational years, the site produced a myriad of products including tissue products, sulfuric acid, paperboard, chlorine, and sodium chlorate, among others. The manufacturing processes caused odors that led some to refer to the City as 'Smellingham." In addition to the noticeable odor from the GP site, the site's operations also resulted in the introduction of harmful chemicals to the waterfront and Bellingham Bay.

Over the past decade, significant time, energy, and money have been contributed by the State, Port, City, and the City's Public Development Authority (PDA) in efforts to remediate the site and create a new game-changing redevelopment plan for the City and region. While the plans of the PDA and Port plans are not the same, they are complementary and both suggest the opportunity for significant private investment and economic opportunity.

In 2005, the Port of Bellingham (Port) purchased the property known as Georgia Pacific West as part of its long-term plan, in partnership with the City, to transform the larger 216.3 acre Waterfront District.[51] Part of this plan calls for the formulation and implementation of "a Master Development Plan for the Waterfront District that would gradually transform this historically industrial waterfront property into a new neighborhood with residences, shops, offices, marine and light industry, and institutional uses [e.g. Western Washington University], as well as parks, trails and shoreline improvement" along the Bellingham Bay.[52]

The Port's Final Environmental Impact Statement (FEIS) – submitted in July 2010 – indicates that "substantial new opportunities for public access to the waterfront that do not exist under current conditions" would be part of the project. The Port projects the full build out of the project – occurring over a 20 year period – to include "a diversity of uses that are complimentary to the downtown Bellingham [CBD], Old Town, and surrounding neighborhoods; an infrastructure network that integrates with and connects the waterfront to the surrounding area; and, a system of parks, trails and open space that opens up the waterfront to the community."[53] A map of the proposed preferred option follows:

50 Port of Bellingham data.

51 The GP-West site required extensive environmental cleanup was necessary and as of December 2011, the first phase of interim cleanup was completed. This initial phase cost approximately $1 million and the State Department of Ecology is reimbursing all costs incurred by the Port for cleanup at the site. In the spring of 2012, it is anticipated a second phase – removing contaminated soils/debris and demolishing a building – will be completed.

52 Port of Bellingham (Port), The Waterfront District Redevelopment Project, Final Environmental Impact Statement (FEIS), July 2010.

53 Port, FEIS.

Port of Bellingham – Waterfront Redevelopment Preferred Alternative

AREA	Use	Total SF
Marine Trades 51.35 ACRES	Jobs	1,150,000
	Housing	450,000
	Goods & Services	90,000
	Subtotal	1,690,000
Downtown Waterfront 44.20 ACRES	Jobs	1,200,000
	Housing	930,000
	Goods & Services	87,500
	Subtotal	2,217,500
Log Pond 42.30 ACRES	Jobs	465,000
	Housing	410,000
	Goods & Services	156,900
	Subtotal	1,031,900
Shipping Terminal 20.80 ACRES	Jobs	530,000
	Housing	120,000
	Goods & Services	33,600
	Subtotal	693,600
Cornwall Beach 21.70 ACRES	Jobs	10,000
	Housing	360,000
	Goods & Services	7,000
	Subtotal	367,000
Total 180.35 ACRES	Jobs	3,355,000
	Housing	2,270,000
	Goods & Services	375,000
	Total	6,000,000
	Park, Trail & Habitat	33 ac

BLUMEN CONSULTING GROUP, INC

The Waterfront District Final EIS

Figure 1-2

Updated Preferred Alternative

The Port of Bellingham's current plan calls for:[54]

- Redevelopment of 6 million square feet of office and commercial space
- 1,892 housing units
- Site population of 3,614 residents
- Up to 460 slips
- 33 acres of public parks and open space
- Maximum building heights

The redevelopment of the GP site is well beyond the planning phase. A September 2010 draft SubArea Plan estimates that the Port and City costs would be approximately $365 million for environmental remediation, streets, infrastructure, and parks to prepare the site for redevelopment.[55] At full build out, the Port suggests the project would potentially attract upwards of $1 billion in public (i.e. university) and private development. Some of this funding will come from other government sources (i.e. State grants, etc.). Combined, the Port and the City have received and authorized approximately $41 million of State grant funds and their own funds to remediate the waterfront and to plan for its future development.

State Grants Received by Port of Bellingham for Remedial Action

Description	Dates		Agency Funding
	Effective	Expires	
Current Ecology MTCA Grants			
Central Waterfront (2)	1/1/2009	12/31/2012	$2,604,057
Cornwall Avenue (2)	1/1/2009	12/31/2012	$3,166,650
GP Mill (1)	1/1/2004	12/31/2012	$5,681,472
Whatcom Waterway (2)	12/1/2006	12/31/2013	$26,047,141
Sub-total			***$37,499,320***
Closed Ecology MTCA Grants			
Central Waterfront (1)	4/1/1998	12/31/2010	$646,736
Cornwall Avenue (1)	1/1/2005	11/30/2009	$90,000
Whatcom Waterway (1)	5/1/2004	3/31/2008	$348,300
Sub-total			***$1,085,036***
Total			**$38,584,356**

54 Port, FEIS.

55 Port of Bellingham's Draft SubArea Plan, Chapter 8 – Capital Facilities, September 2010.

Authorized Joint City/Port Expenditures for New Master Plan for City Waterfront

Task	Total Cost	City share (50%)	Port share (50%)
Preliminary Design	$300,000	$150,000	$150,000
Outside funding	$250,000	$125,000	$125,000
Branding	$60,000	$30,000	$30,000
SEPA (EIS)	$854,174	$427,087	$427,087
Assumptions, market	$315,332	$157,666	$157,666
EIS data support	$655,626	$327,813	$327,813
Public Involvement	$118,256	$59,128	$59,128
Master Plan	$393,000	$196,500	$196,500
Devel. Regulations	$164,000	$82,000	$82,000
LEED ND	$20,000	$10,000	$10,000
Total Authorized Joint Expenditures	**$3,130,388**	**$1,565,194**	**$1,565,194**

Source: Port of Bellingham

In addition to the remediation efforts, the City's PDA is moving forward with the first steps toward actual redevelopment.[56] As part of its October 2011 strategic plan, the PDA has identified five potential priority projects including four related to waterfront redevelopment.

The Army Street Project would serve as a jumping off point for waterfront redevelopment.[57] According to plans, the project "would span the BNSF railroad tracks and Chestnut Street/Roeder Avenue, including properties on both sides, providing a major urban plaza and pedestrian connection joining the Central Business District, Old Town District and the Waterfront District."[58] The project area would include two acres north of the BNSF rail tracks and 22 acres south of the tracks within the former GP West property.

As of 2011, PDA estimates that the waterfront's "total build-out value could be in the realm of $350 million with public sector undertaking $120 million and the private sector...$230 million. [T]his public investment would yield benefits reflecting a 'whole greater than the sum of its parts' in terms of the multiplier effects of higher development feasibility and asset values in the CBD and Old Town."[59] The Strategic Plan estimates that earliest development and construction would be projected for 2015 or 2016.

PDA notes that "[a]n attractive, safe and convenient access way between the CBD/Old Town and the GP West property is considered a fundamental key to successful development of this portion of the waterfront and for the CBD (and Old Town) to accrue economic benefits from development of the Army Street Project."[60] The PDA indicates that without such an access way, the "barrier imposed by the inconvenience and hazard of an at-grade crossing of the combination of the trail tracks and Chestnut/Roeder will...negatively [impact] development feasibility...and would be aggravated by increased vehicular or rail traffic if not mitigated."[61] The

56 Bellingham Public Development Authority mission statement: "to maximize the public good by attracting sustainable development that generates capital investment, contributes to the vitality of the economy, and creates employment opportunities, while improving and preserving those historical and environmental assets that define the city's character." The PDA is an independent legal entity created by the City to develop public properties together with private investment, focusing on Bellingham's Waterfront, Old Town, and Downtown districts.

57 Bellingham Public Development Authority (PDA) Strategic Plan CY2011-CY2015, adopted October 25, 2011.

58 PDA Strategic Plan, p. 6.

59 PDA Strategic Plan, p. 16.

60 PDA Strategic Plan, p. 15.

61 PDA Strategic Plan, p. 15.

Port's overall plan also recognizes that rail realignment will be necessary for full build out of the Georgia Pacific site. The site plan calls for relocation of the BNSF rail track to the east, allowing for passenger and freight trains to move through the area without bisecting the site.[62]

Both the Port and PDA waterfront development plans call for activity that could likely bring long-term construction, investment, and economic opportunity. Over the course of 25-30 years, the number of direct, induced/indirect jobs that would be created could serve as a significant economic opportunity for Bellingham and the region.

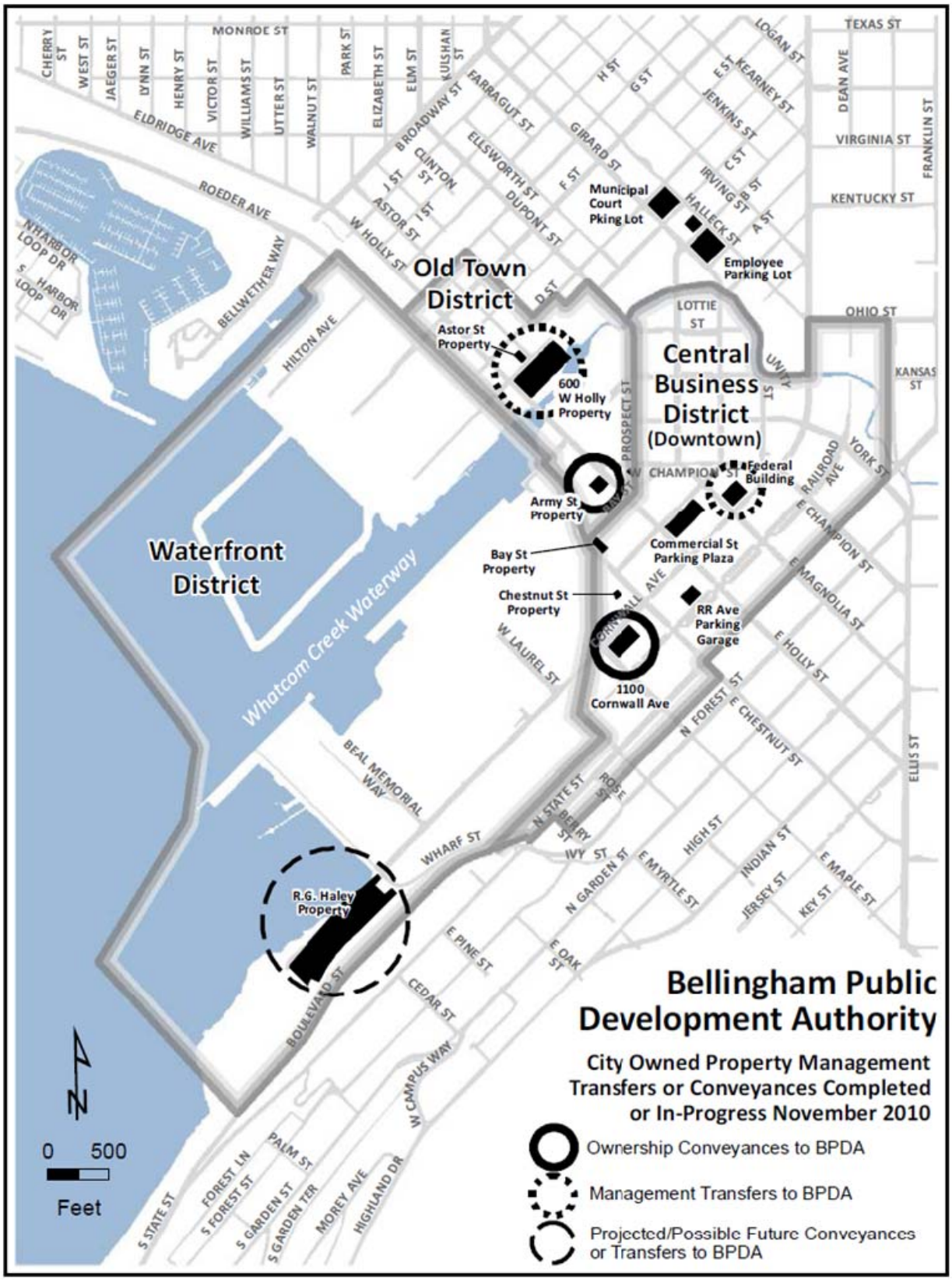
A 2007 analysis by Western Washington University estimated that full build out of the Georgia Pacific site – at a projected investment of $1 billion over 20 to 35 years – would result in between 17,250 and 23,000 job years of employment. The Port of Bellingham EIS for the Georgia Pacific site estimates that at full development, the site could be the home to as many as 7,200 jobs.[63]

To the extent that both the Port of Bellingham and PDA waterfront development projects hinge on access to the waterfront, increased train traffic that reduces access and/or safety (real or perceived) could reduce development potential if current access issues are not addressed. Prospective developers of the waterfront site – or investors – may be discouraged by the fact that there is even a pending proposal to increase rail traffic and further limit access.

62 It is important to note that the FEIS assumes the relocation, but the relocation itself would be subject to a separate permitting and environmental review process that would be undertaken by BNSF and Washington State DOT.

63 As is the case with the development of GPT, some of these jobs – as well as some of the resulting tax and other economic benefits – would go outside of Whatcom County.

Bellingham PDA City Project Map



Impact on Tourism and the Ability to Attract New Residents

In addition to the impact on baseline growth, GPT development and operation could also impose risk by reducing the likelihood of significant growth related to tourism opportunities, as well as the ability to attract new residents and jobs to Bellingham and Whatcom County.

Bellingham and Whatcom County Tourism (Tourism) actively markets the region's natural resources and amenities to attract visitors. According to a recent report commissioned by Tourism, total spending by visitors to the County increased each year since 2000, reaching $460 million in 2008.[64] The report also indicated that "the largest age segment of the primary market will continue to be relatively young people, indicating the importance of attracting families and young, active visitors."[65] Additionally, it suggested that Canadians are likely to continue to represent an important target market – dependent upon exchange rates and border crossing ability.

The study indicated that most visitors to Bellingham and Whatcom County fit the following categories:

- Return visitors
- Relatively high incomes (over 50 percent of all visitors have family incomes of at least $75,000)
- Almost 70 percent of visitors to Bellingham and Whatcom County possess a bachelor's degree or graduate degree

Four out of five visitors to Whatcom County traveled through Bellingham. While in and around Bellingham, visitors found Chuckanut Drive and Boulevard Park among the top attractions. Additionally, the study suggested that activities such as visiting downtown Bellingham (especially among first-time visitors), dining, shopping, hiking, and attending fairs are popular with visitors to the region. The highest rated quality of the County and City by visitors was its physical environment, as well as its parks, scenic areas, and recreational trails.[66]

The report concluded that the ambiance of downtown Bellingham and Fairhaven was a particularly important draw.[67] Similarly, the County's waterfront attractions and attributes, outdoor recreation activities, and natural beauty and environment were critical components of its tourism attraction.

The same attributes that appear to be driving increases in tourism may also be contributing to the attraction of Whatcom County and Bellingham to new residents who are bringing higher levels of education attainment and income. The County has attracted residents who migrate with higher AGIs than those who leave the County: migration between 2004 and 2010 resulted in an aggregate net increase of approximately $172.3 million in AGI. Similarly, the County has a higher number of residents who commute outside of the County and earn higher wages than those who commute into the County (and earn lower wages). Home prices remain high when compared to income, and individuals with higher education attainment levels are locating in Whatcom County despite lower wages and income. The choice of living in the County or City is worth something to individuals and they appear willing to pay for the region's location, lifestyle, and geography.

64 Dean Runyan Associates. Bellingham and Whatcom County Tourism Analysis, p. 14.

65 Runyan Associates, p. 11.

66 Runyan, p. 43.

67 Runyan, p. 53.

Beyond the risk of an impact on baseline growth, GPT's development and operation could have a risk of jeopardizing growth in tourism and in-migration of skilled workers and entrepreneurs because of its effect on the building brand of Whatcom County, particularly Bellingham. Both tourism and the in-migration attraction are based in part on the perception of the area as environmentally conscious. Currently, the region is seen as a green, clean, and socially responsible area. The region's view of itself as socially responsible and environmentally oriented is likely a leading reason why the Bellingham/Whatcom Chamber of Commerce will place an emphasis on the triple bottom line (TBL) with a focus on profit, people (i.e. social responsibility), and planet (environmental responsibility).[68] To the extent that GPT changes current residents' experiences with lifestyle characteristics they value, out-migration (particularly among those in the mobile class of skilled workers and entrepreneurs) could be a risk to the region.

The risk exists, in part, because the principal freight to be transported to GPT is coal. To the extent that the perception of Bellingham and Whatcom County as 'clean and green' wanes, it could put potential gains in tourism and in-migration of skilled workers and entrepreneurs at risk.

Quantifying the Risk

Researchers suggest that "decisions are said to be risky because the outcome following a choice may result in a potential loss, including lost opportunities or sub-optimal outcomes."[69] Intuition and/or ad-hoc decisions where risk is present are unlikely to result in the best outcomes for decision makers; especially where decision makers hold the public trust. As a result, a focus on understanding the decision and its potential impacts – pro and con – is critical to develop a sophisticated understanding of the decision.

While it is possible that none of the risks identified in the prior section will be realized, a plausible case exists that the three scenarios outlined, in fact, pose some level of risk.

We do not attempt to quantify a specific level of risk. Instead, we know that if baseline growth rates are in fact reduced to a certain level as a result of GPT, the effect will be that the economic benefits of development and operation of the terminal will be more than offset by those lost opportunities. In other words, we can determine what level of risk would be sufficient to preclude any net economic benefit to Whatcom County.

Our analysis of risk makes a series of assumptions – each of which is uncertain. First, we assume that GPT will produce the level of economic benefits projected by PIT. Given the difference in projections from Martin Associates and FRMC, it is possible that those projections are too high or too low. Second, we assume that the baseline growth projections established by the state will be achieved. Again, these projections could be too low or too high. Third, we assume that project construction will not begin until 2015. As previously noted, it seems likely that the EIS process will not be concluded prior to 2016. Fourth, we base our analysis solely on the construction and operation of Phase I of the terminal. SSA (PIT) has indicated that they are prepared to proceed with construction of Phase I and Phase II would await additional throughput commitments. At this point, Phase II economic benefits seem more speculative. Finally, for purposes of this analysis, we assume that job years associated with construction will be equally divided over a two year period.

Our analysis examines two time horizons. The first is a 10 year time horizon beginning in 2012. Under this analysis, GPT development would not create any jobs until its fourth year. At the same time, while the proposal was pending, it could have an effect on other potential job

68 From discussions with Ken Oplinger, CEO/President – Bellingham/Whatcom Chamber of Commerce.

69 Martin T. Schultz, Kenneth N. Mitchell, Brian K. Harper, and Todd S. Bridges, "Decision Making Under Uncertainty, US Army Corps of Engineers", Washington, DC, November 2010, p. 1.

growth. The second analysis is a 10 year time horizon that begins in 2015, the assumed year that construction would begin.

Without the development of GPT, by 2021, the current projections indicate that Whatcom County's employment will increase from its 2010 level by 14,969, or 20.4 percent. By comparison, from 2000 to 2010, employment in the County grew by 11,510, or 18.6 percent. Over the next 10 years, total projected GPT related employment will equal 11,509 job years. Over the same period, the County's projected baseline employment gains (absent GPT) are equal to 67,653 job years. By comparison, from 2000-2010 factoring in both recessions, there was an increase of 86,630 jobs years in Whatcom County.[70]

The project team also compared the projected trajectory of Whatcom County's employment and that of GPT from 2015-2024 (assuming construction begins in 2015). In this time frame, without the development of GPT, it is projected that employment will grow in Whatcom County by 13,603, or 15.4 percent. Over the same period, the total projected GPT-related employment would equal 14,110 job years. By 2024, baseline employment gains in Whatcom County would equal 107,597 job years.

Thus, to the extent that development and operation of GPT would reduce baseline employment gains by less than 17 percent (between 2012 and 2021) or less than 13 percent (between 2015 and 2024), it would produce net gains in employment for Whatcom County. If, however, based on the scenarios outlined above – or for other reasons – development and operation of Phase I of GPT would result in the loss of more than 17 percent (between 2012 and 2021) or more than 13 percent (between 2015 and 2024) of baseline growth, it would have a net negative impact on the Whatcom County economy. Said another way, even if all of the PIT assumptions are accepted, there is a possibility that the development of GPT may have a negative net impact on the Whatcom County economy.

70 It is possible to have less job growth and more job years because growth focuses on point in time comparisons, while the job years analysis takes into account higher employment numbers during the period.

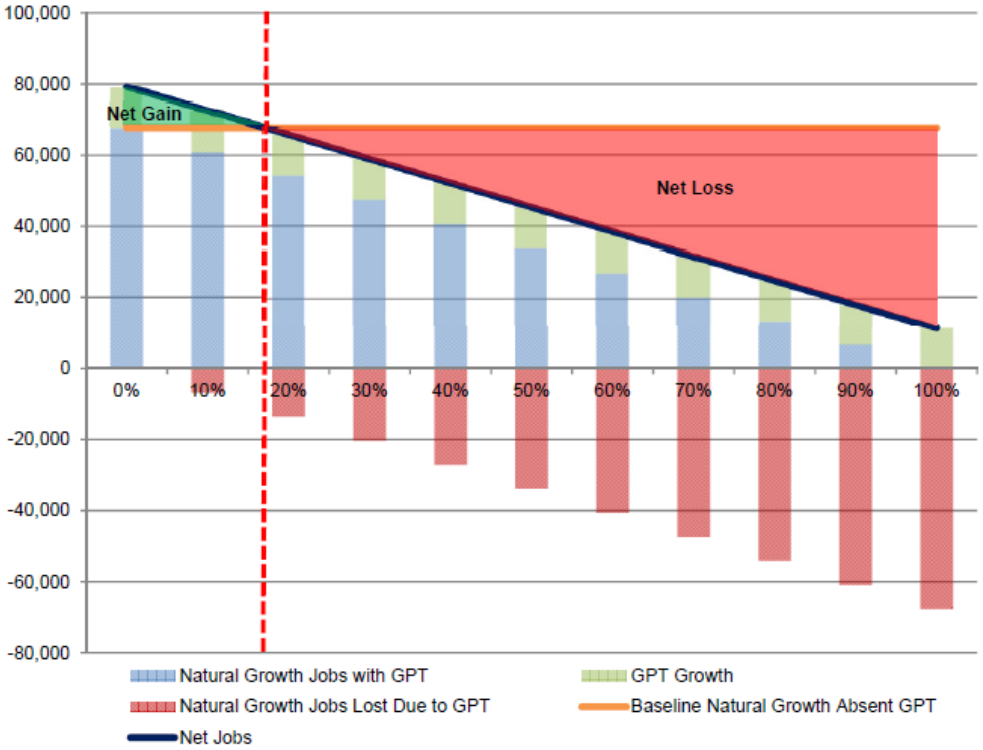
Whatcom County Natural Trajectory Job Years and GPT Projected Job Years (2012-2021)

GPT Jobs Years Created by 2021	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total
Direct Jobs											
Temporary Construction	0	0	0	1,715	1,715	0	0	0	0	0	**3,430**
Permanent Operations	0	0	0	0	0	294	294	294	294	294	**1,470**
Indirect & Induced Jobs											
Temporary Construction	0	0	0	1,872	1,872	0	0	0	0	0	**3,744**
Permanent Operations	0	0	0	0	0	573	573	573	573	573	**2,865**
Total Direct, Indirect & Induced Jobs											
Temporary Construction	0	0	0	3,587	3,587	0	0	0	0	0	**7,174**
Permanent Operations	0	0	0	0	0	867	867	867	867	867	**4,335**
Grand Total											**11,509**
Job Years Created Absent GPT	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
Whatcom County	1,135	2,286	3,455	4,721	6,006	7,313	8,640	9,988	11,359	12,750	**67,653**

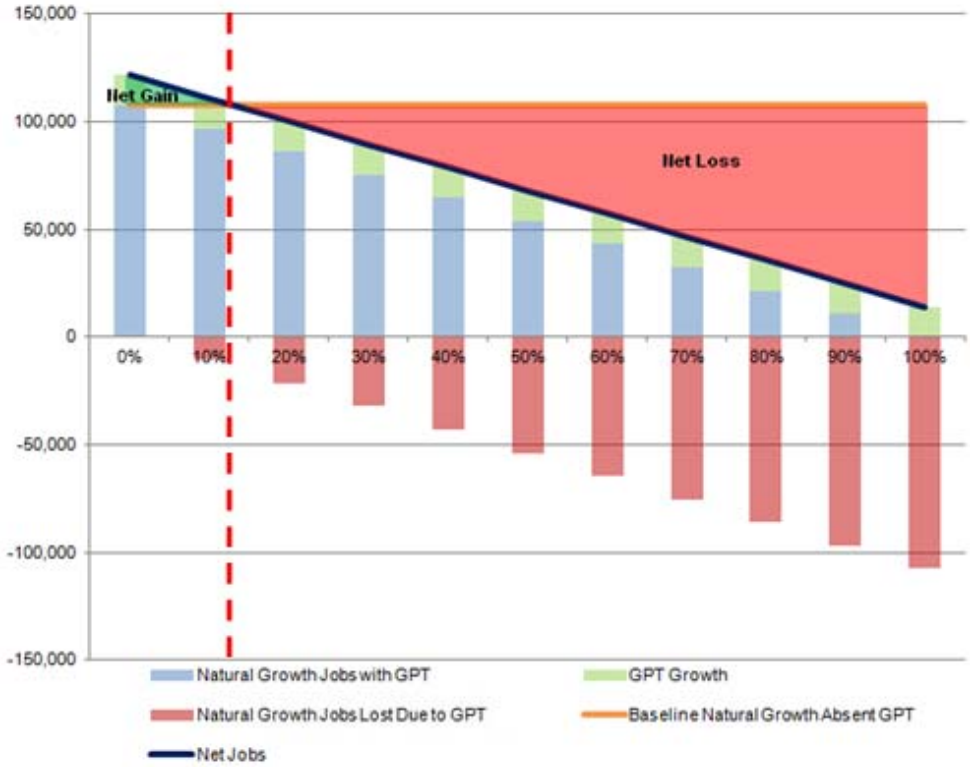
Whatcom County Natural Trajectory Job Years and GPT Projected Job Years (2015-2024)

GPT Job Years Created by 2024	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Total
Direct Jobs											
Temporary Construction	1,715	1,715	0	0	0	0	0	0	0	0	**3,430**
Permanent Operations	0	0	294	294	294	294	294	294	294	294	**2,352**
Indirect & Induced Jobs											
Temporary Construction	1,872	1,872	0	0	0	0	0	0	0	0	**3,744**
Permanent Operations	0	0	573	573	573	573	573	573	573	573	**4,584**
Total Direct, Indirect & Induced Jobs											
Temporary Construction	3,587	3,587	0	0	0	0	0	0	0	0	**7,174**
Permanent Operations	0	0	867	867	867	867	867	867	867	867	**6,936**
Grand Total											**14,110**
Job Years Created Absent GPT	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Whatcom County	4,721	6,006	7,313	8,640	9,988	11,359	12,750	14,163	15,599	17,058	**107,597**

From 2012-2021, if development of GPT reduces otherwise projected job growth by more than 17%, the project will be a net loss.



From 2015-2024, if development of GPT reduces otherwise projected job growth by more than 13%, the project will be a net loss.



VI. Understanding and Managing the Risk

Some have suggested, that to the extent most of the risk involved with the development of GPT is related to the increased rail traffic to the site, other developments could lead to the same level of risk without the same level of benefits.

The project team heard from several entities that indicated if GPT is not located at Cherry Point, coal could be shipped by rail through Whatcom County to ports in British Columbia. If this occurred, the region would still have the rail traffic, but none of the economic benefits associated with the development and operation of GPT. At this time, there is not sufficient evidence to support the claim that if GPT is not located at Cherry Point, the same magnitude of coal-related train traffic as caused by GPT would occur as a result of coal delivery to ports in British Columbia.[71]

In 2007, approximately 90 percent of Canada's coal exports were shipped through terminals in British Columbia.[72] The main coal export locations in British Columbia are Prince Rupert[73] (Ridley), which accounts for approximately 20 percent of all Canadian exported coal, and Port Metro Vancouver (Neptune and Westshore), which accounts for approximately 80 percent of all Canadian exported coal.[74] Prince Rupert is likely to receive some US coal in future years, adding to its larger Canadian-based demand, to increase annual coal export capacity; though there is some concern from at least one US coal company that shipping coal to Prince Rupert is uneconomic.[75]

Still, expansion of shipments of U.S. coal to Canada will depend upon the capacity of both the ports and rail. Westshore does not currently have plans to expand its physical footprint but has made operational and equipment adjustments to add incremental capacity. According to Washington DOT information and its Marine Cargo Forecast, rail capacity for the BNSF rail line along coastal Whatcom County (and Bellingham) has a capacity for 18 trains per day currently, and 30 trains per day by 2028. Additionally, a factor affecting capacity is that BNSF has performance and on-time agreements with Washington DOT (and Amtrak) to provide passenger rail service on the *Cascade* line.

While there is clearly an increase in demand for coal in Asia – particularly China – any additional cost related to transportation could tip the competitive advantage to other sources. More of China's demand for coal could be met domestically. According to the US Energy Information Administration's (EIA) 2011 International Energy Outlook, China has the ability to meet "substantial portions of their future coal demand with domestic production."[76] According to the EIA, China's domestic production of coal is expected to grow from 70.5 quadrillion Btu to 107.6 quadrillion Btu in 2035. Over the same time frame, US coal production is projected to increase from 22.6 quadrillion Btu to 26.5 quadrillion Btu.

Australia and New Zealand are both expected to become larger exporters of coal, increasing production from 10.1 quadrillion Btus in 2010 to 15.6 quadrillion Btus by 2035. Peabody, which has contracted with SSA for shipment of coal through GPT, has invested heavily in Australia - recently purchasing assets belong to Macarthur Coal for a reported $5.1 billion. Peabody

71 Requests for such information were made to SSA representatives.

72 British Columbia Ministry of Energy, Mines and Petroleum Resources. 2010 Coal Resources in British Columbia: Opportunities, Logistics and Infrastructure, p. 15.

73 Ridley Terminals Inc. is owned by the Canadian government.

74 Canadian Minerals Yearbook -- 2009.

75 Ridley Terminals, Inc. 2010 Annual Report: Building On A Strong Foundation, p. 9. In its 2011 Fourth Quarter and Full Year Highlights, Cloud Peak Energy, Inc. – a large Powder River Basin coal producer indicated that it had no additional shipments planned through Ridley because it was uneconomic.

76 US Energy Information Administration (EIA), 2011 International Energy Outlook, p. 69.

executives recently indicated that Australian mines are expected to supply roughly half of the growth in global coal exports in 2012, driven by demand in China and India.[77]

It is also possible that some U.S. coal could be shipped through ports that would not affect rail traffic in Whatcom County – such as ports on the Gulf of Mexico. For instance, Arch Coal recently signed a deal with Kinder Morgan Energy Partners LP to ship PRB coal from its Gulf ports and is in talks to ship additional coal from Kinder Morgan's east coast ports.[78]

Some of the risks to economic development posed by the development and operation of GPT can be managed. Plans for the redevelopment of the Georgia Pacific site already call for moving the existing BNSF tracks and for a series of projects that would eliminate grade crossings. The Army Street Project, the first step in the proposed redevelopment by PDA, calls for a design that specifically addresses the issue of rail traffic by bridging over existing tracks.

To the extent that noise and access issues are addressed,[79] the risks related to limitation on other economic growth can be reduced. It may not be possible to limit risks related to image or reputation – and their potential impact on tourism and attraction of in-migration among the mobile class of skilled workers and entrepreneurs – resulting from the proximity to GPT.

Risk management, however, comes at a cost. While some might argue that investments related to rail were already planned, the potential of the GPT development would clearly increase the need to act. The question then becomes who would pay and whether local governments and residents should be asked to bear the cost of risk management.

In the absence of risk management, decision makers need to determine how much risk they are willing to tolerate. If our analysis indicated that it would require the loss of 90 percent of projected baseline job growth for the GPT project to produce net negative employment impact, it would be relatively clear that the risk was relatively low. Similarly, if our analysis suggested that a loss of just 1 percent of projected baseline job growth would offset any benefits of GPT, it would be fairly clear that the risk was relatively high.

As noted earlier, different decision makers can look at our findings and reach different, yet valid conclusions. The important thing is that they weigh the risk and understand the need to manage it.

77 Steve James, "Peabody profit misses estimate, sees U.S. coal slump." *Reuters*. January 24, 2012.

78 Jeremy Fugleberg, "Powder River Basin coal to ship from Gulf Coast," Casper Star-Tribune. February 12, 2012.

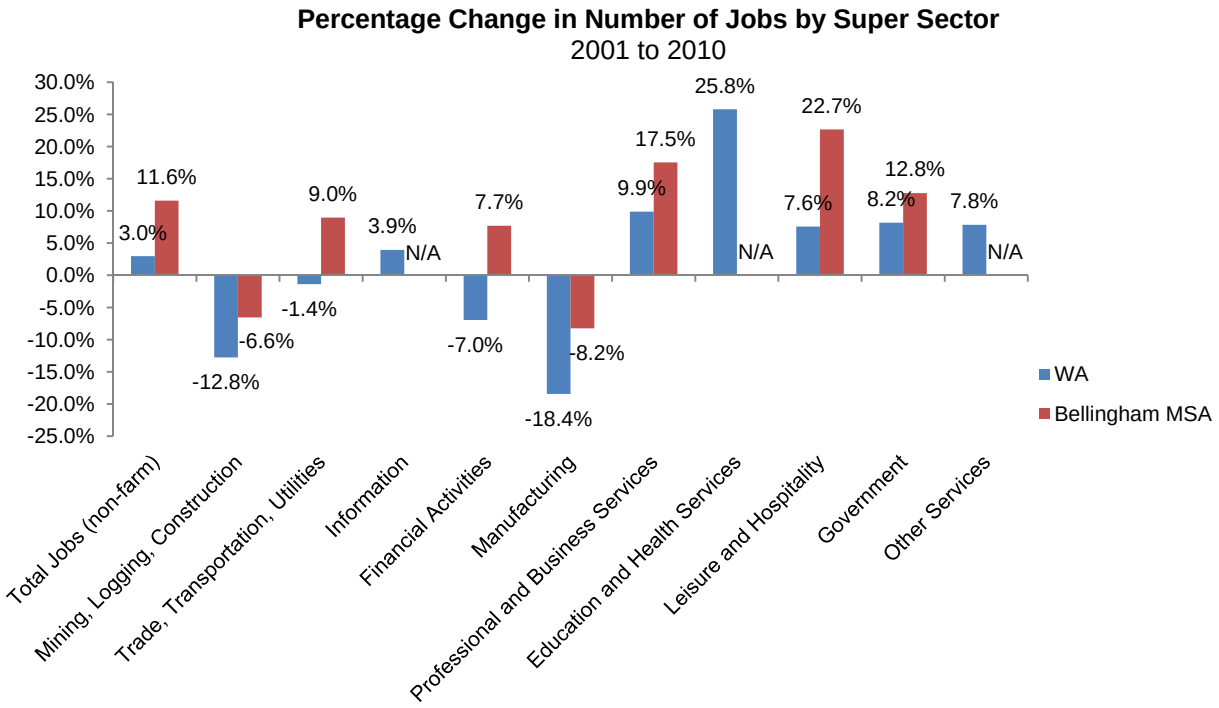
79 It should be noted that some noise problems can be mitigated (i.e. horn noise, crossings, etc.), but vibrations, rail screeches, and other likely occurrences of rail traffic cannot be fully mitigated.

Appendices: Whatcom County and Bellingham Economy

Appendix A: Employment and Unemployment

From 2001 to 2010, the Bellingham MSA's rate of job growth was almost four times the state rate. The Bellingham MSA (Whatcom County) added 8,100 non-farm jobs – an 11.6 percent increase. Statewide, non-farm jobs grew by 3.0 percent.

Compared to the state, the Bellingham MSA grew jobs at a greater percentage or shed jobs at a smaller percentage for every super-sector for which data were available.[80]



Source: BLS CES Data – Not Seasonally Adjusted

The super-sectors with the largest increase in number of jobs in the MSA were:

- Education and Health Services (1,900 jobs)[81]
- Government (1,800 jobs)[82]

80 Those super sectors for which data are available accounted for the growth of 4,800 of the 8,100 jobs from 2001 to 2010. While data from the CES database are not available individually for all super sectors, calculations indicate the missing super sectors accounted for 12,000 jobs in 2001 and 15,300 jobs in 2010. Given the composition of Bellingham and Whatcom County's economy, it could be argued that, of the super sectors that are not available at the Bellingham MSA level (and for the City of Bellingham in particular), education and health services sector was the most likely to be driving the significant increase in jobs during the 2001 to 2010 time period. The most recent BLS Occupational Employment Statistic (OES) data available for the Bellingham MSA estimated there were approximately 73,420 jobs in the Bellingham MSA. OES defined jobs of these types accounted for 14.8 percent of the MSA's total jobs. Applying that percentage to the total estimated number of jobs in 2010, yields 11,550 jobs, or 75.5 percent of the total jobs not included in a defined super sector. From 2001 to 2010, healthcare practitioner and technical operations occupations grew by 30.5 percent and healthcare support occupations grew by 52.6 percent. If applied to the CES data, it could be estimated that the health and education sector was responsible for job growth in the range of 1,900 jobs. While combining/comparing OES data and CES data is not a perfect or even ideal method for a variety of important reasons, the process suggests there is likely support to suggest that the education and healthcare sector (particularly healthcare) was an important driver of job growth in the Bellingham MSA over the last decade.

81 Estimated – see previous analysis. Education includes jobs in private higher education institutions. Government (specifically state government) includes jobs in public higher education institutions (i.e. WWU).

- Leisure and Hospitality (1,700 jobs)
- Trade, Transportation, Utilities (1,200 jobs).

Collectively, from 2001 to 2010, the four super-sectors above accounted for 81.5 percent of the total job growth in the Bellingham MSA. The education and health services super-sector grew at an estimated 20.5 percent from 2001 to 2010.

By comparison, the super-sectors with the largest increase in number of jobs at the state level were:

- Education and Health Services (76,900 jobs)
- Government (41,300 jobs)
- Professional and Business Services (29,300 jobs)
- Leisure and Hospitality (18,700 jobs).

The project team met with several individuals and groups that suggested public sector growth was responsible for the majority of the increase in jobs in Whatcom County. The data suggest that while local government in the MSA added a greater percentage of jobs than the state average for local government, the likely increase in education and health services, leisure and hospitality produced more total jobs than the growth in government. Similarly, job growth in the Bellingham MSA exceeded statewide growth across all super sectors. Even where it lost jobs, the Bellingham MSA losses were at a lower rate than statewide.

For example, Bellingham's role as the regional retail center for the MSA was likely a significant driver behind the MSA's retail trade job growth of 9.0 percent from 2001 to 2010 – significantly greater than the Statewide experience in which jobs declined by 1.3 percent over the same time period.

Given the overall trend for the Bellingham MSA as compared to the State, government employment contributed to the growth, but was among many drivers – and not the sole driver – to affect job increases in the region. Even if there had been no increase in government jobs from 2001 to 2010, the Bellingham MSA would have still added jobs and added them at a rate approaching three-times greater than the rate of statewide job growth.

82 The project team received information that suggested the 600 job increase in Federal government jobs was primarily due to increased border security post September 11, 2001.

Job Changes by Super Sector
2001 to 2010

Sector	WA			Bellingham MSA	
	Jobs +/-	Jobs % Chg		Jobs +/-	Jobs % Chg
Total Jobs (non-farm)	**80,400**	**3.0%**		**8,100**	**11.6%**
Mining, Logging, Construction	**(21,500)**	**-12.8%**		**(400)**	**-6.6%**
Mining and Logging	*(3,900)*	*-39.8%*			
Construction	*(17,600)*	*-11.1%*			
Trade, Transportation, Utilities	**(7,200)**	**-1.4%**		**1,200**	**9.0%**
Wholesale Trade	*1,200*	*1.0%*			
Retail Trade	*(4,200)*	*-1.3%*		*800*	*8.9%*
Transportation and Utilities	*(4,100)*	*-4.4%*			
Information	**3,900**	**3.9%**			
Financial Activities	**(10,100)**	**-7.0%**		**200**	**7.7%**
Finance and Insurance	*(8,400)*	*-8.6%*			
Real Estate and Rental and Leasing	*(1,600)*	*-3.4%*			
Manufacturing	**(58,300)**	**-18.4%**		**(700)**	**-8.2%**
Professional and Business Services	**29,300**	**9.9%**		**1,000**	**17.5%**
Professional, Scientific, and Technical Services	*18,800*	*13.2%*			
Management of Companies and Enterprises	*1,900*	*6.4%*			
Administrative and Support and Waste Mgmt and Remediation Services	*8,500*	*6.8%*			
Education and Health Services	**76,900**	**25.8%**			
Educational Services	*9,200*	*23.1%*			
Health Care and Social Assistance	*67,500*	*26.1%*			
Leisure and Hospitality	**18,700**	**7.6%**		**1,700**	**22.7%**
Arts, Entertainment, and Recreation	*4,300*	*10.6%*			
Accommodation and Food Services	*14,300*	*6.9%*			
Government	**41,300**	**8.2%**		**1,800**	**12.8%**
Federal Government	*7,600*	*11.2%*		*600*	*66.7%*
State Government	*4,500*	*3.1%*		*(200)*	*-3.8%*
Local Government	*29,200*	*9.9%*		*1,300*	*16.0%*
Other Services	**7,600**	**7.8%**			

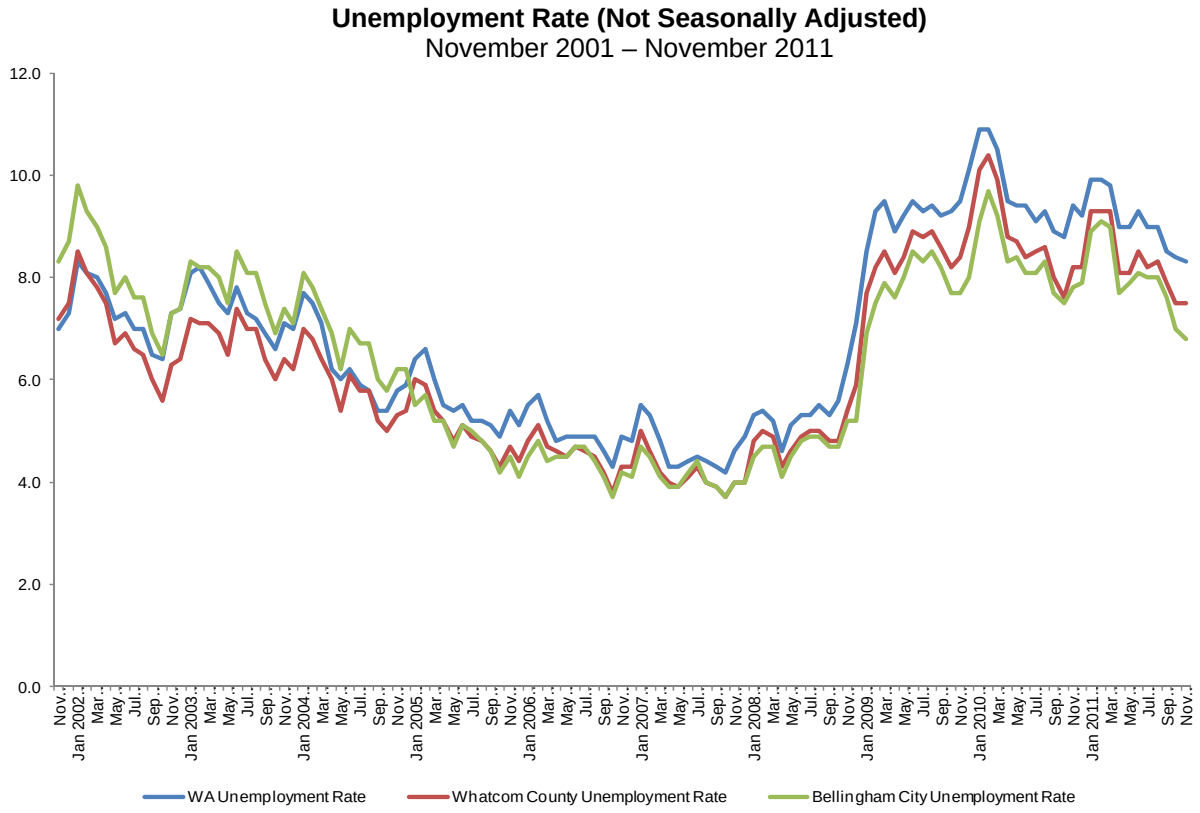
Note: totals may not sum due to rounding

Source: BLS - Current Employment Statistics - Not Seasonally Adjusted

Unemployment

As the graph below shows, since 2005, Bellingham's unemployment rate has been nearly equal or slightly less than Whatcom County's unemployment rate and consistently below the State's unemployment rate.[83]

83 US Bureau of Labor Statistics – Local Area Unemployment Statistics (LAUS), November 2001 – November 2011, Not seasonally adjusted data.


Unemployment Rate (Not Seasonally Adjusted)
November 2001 – November 2011
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Nov.
Jan 2002
Mar.
May.
Jul.
Sep.
Nov.
Jan 2003
Mar.
May.
Jul.
Sep.
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Jan 2004
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Jan 2009
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May.
Jul.
Sep.
Nov.
Jan 2010
Mar.
May.
Jul.
Sep.
Nov.
Jan 2011
Mar.
May.
Jul.
Sep.
Nov.
WA Unemployment Rate
Whatcom County Unemployment Rate
Bellingham City Unemployment Rate

Appendix B: Population Growth

From 2000 to 2010, Bellingham and Whatcom County both grew in population by slightly more than 20 percent; greater than the State's growth rate of just over 14 percent.[84] The US Census Bureau reported Bellingham's 2010 population as 80,885, an increase of 13,714 individuals from the 2000 Census.[85] Whatcom County's 2010 population of 201,140 represented an increase of 34,326 from the 2000 Census.

Much of the population growth in both Bellingham and Whatcom County was attributable to increases in the number of residents between the ages of 20-39 and those between the ages of 50-69. These two age groups accounted for 84.0 percent of all population growth in Bellingham and 78.1 percent of all population growth in Whatcom County – statewide, these two age groups accounted for 86.9 percent of the State's net population growth.

Examining the data by 10-year age bands shows that there were several notable differences in the population changes experienced by Bellingham, Whatcom County, and Washington. For example, the number of residents between the ages 30 and 39 declined statewide by 2.1 percent and in the parts of Whatcom County outside of Bellingham by 0.3 percent: in Bellingham, the number of residents between 30 and 39 increased by 13.5 percent. While the number of 60-69 year old residents increased statewide by more than two-thirds, population in that age range nearly doubled in Bellingham and grew by more than 90 percent in the non-Bellingham parts of Whatcom County.

84 US Census Bureau 2000 and 2010 Decennial Census Data. Bellingham's population grew by 20.4 percent, Whatcom County's population grew by 20.6 percent, and Washington's population grew by 14.1 percent.

85 According to Bellingham's Planning & Community Development Department, annexations that occurred in Bellingham between 2000 and 2010 accounted for a population increase of 1,216 residents.

Population Change from 2000 to 2010

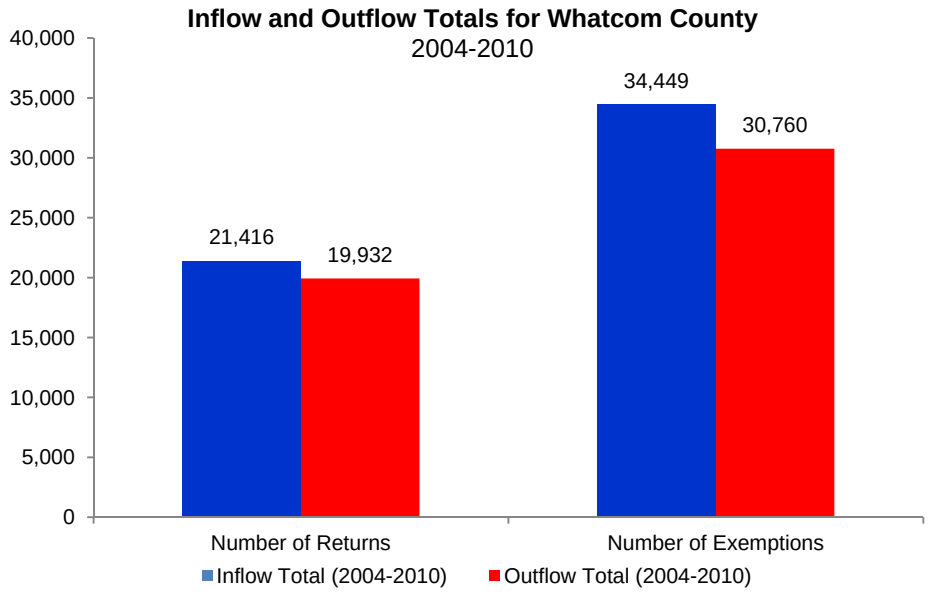
Total Population	WA 2010 vs 2000 (#)	WA 2010 vs 2000 (%)	Whatcom County 2010 vs 2000 (#)	Whatcom County 2010 vs 2000 (%)	Bellingham 2010 vs 2000 (#)	Bellingham 2010 vs 2000 (%)	Non-Bellingham 2010 vs 2000 (#)	Non-Bellingham 2010 vs 2000 (%)
Total Population	**830,419**	**14.1%**	**34,326**	**20.6%**	**13,714**	**20.4%**	**20,612**	**20.7%**
Total Population Under Age 10	49,319	6.0%	1,080	5.0%	482	7.2%	598	4.0%
Total Population Age 10-19	37,557	4.4%	2,311	9.0%	993	10.4%	1,318	8.2%
Total Population Age 20-29	148,073	18.7%	6,849	25.0%	4,256	25.1%	2,593	24.7%
Total Population Age 30-39	(19,438)	-2.1%	1,092	4.8%	1,133	13.5%	(41)	-0.3%
Total Population Age 40-49	7,247	0.8%	544	2.1%	(119)	-1.4%	663	4.0%
Total Population Age 50-59	271,120	40.0%	8,653	45.6%	2,548	38.6%	6,105	49.3%
Total Population Age 60-69	265,261	68.5%	10,212	93.8%	3,585	99.5%	6,627	91.0%
Total Population Age 70-79	25,165	8.3%	1,518	17.0%	67	1.8%	1,451	27.6%
Total Population Age 80 and Over	46,115	25.3%	2,067	38.7%	769	26.1%	1,298	54.1%
					0			
Population Age 60 and Over	336,541	38.5%	13,797	54.8%	4,421	43.2%	9,376	62.8%
Population Age 65 and Over	165,529	25.0%	7,240	37.3%	2,027	24.3%	5,213	47.2%
Population Age 70 and Over	71,280	14.7%	3,585	25.1%	836	12.6%	2,749	35.9%
Population Age 75 and Over	45,475	14.0%	2,405	25.1%	631	13.1%	1,774	37.4%

Working Age (25-64) Population Change from 2000 to 2010

Working Age Population	WA 2010 vs 2000 (#)	WA 2010 vs 2000 (%)	Whatcom County 2010 vs 2000 (#)	Whatcom County 2010 vs 2000 (%)	Bellingham 2010 vs 2000 (#)	Bellingham 2010 vs 2000 (%)	Non-Bellingham 2010 vs 2000 (#)	Non-Bellingham 2010 vs 2000 (%)
Total Population 25-64	506,687	16.0%	20,194	24.2%	7,880	25.5%	12,314	23.5%
Total Population Age 25-29	76,746	19.0%	3,348	31.4%	1,924	36.0%	1,424	26.7%
Total Population Age 30-34	15,905	3.6%	1,392	12.9%	853	20.0%	539	8.3%
Total Population Age 35-44	(66,782)	-6.8%	(423)	-1.7%	435	5.3%	(858)	-5.3%
Total Population Age 45-54	142,233	16.8%	3,311	13.8%	75	0.9%	3,236	21.1%
Total Population Age 55-59	167,573	58.7%	6,009	76.9%	2,199	85.1%	3,810	72.8%
Total Population Age 60-61	72,128	79.9%	2,783	114.9%	1,074	137.5%	1,709	104.1%
Total Population Age 62-64	98,884	81.9%	3,774	112.4%	1,320	120.0%	2,454	108.7%

Population Growth – Migration

IRS migration data for tax years 2004 through 2010 suggest the important role that migration played in the County's population growth.[86] The data show that Whatcom County experienced a greater amount of population inflow than population outflow during the years reviewed. The chart below displays the total number of income tax returns and the associated number of exemptions for those moving to and moving from Whatcom County.



The large majority of inflow to Whatcom County (68.7 percent) was from other Washington counties. Specifically, based upon the number of returns, King County (4,092 returns), Snohomish County (2,377 returns), and Skagit County (2,340 returns) accounted for 41.1 percent of all inflow, and 59.9 percent of all intra-state inflow, to Whatcom County from 2004-2010.

The remaining 31.3 percent of inflow was attributable to migration from 19 states and other countries. Former Californians represented 12.6 percent of total migration to Whatcom County (2,694 returns) and 40.2 percent of inflow from states excluding Washington. Within California, Los Angeles County (537 returns), San Diego County (435 returns), and Orange County (291 returns) represented 46.9 percent of all inflow from the State. Oregon was the next most popular previous state of residence for new Whatcom residents with 801 former citizens migrating to the County. Multnomah County (281 returns), Lane County (148 returns), and Washington County (134 returns) comprised the majority of the inflow from Oregon. Residents abroad/those moving from other countries (736 returns) and former Arizona residents (571 returns accounted for the next two most popular location of residence prior to moving to Whatcom County.[87]

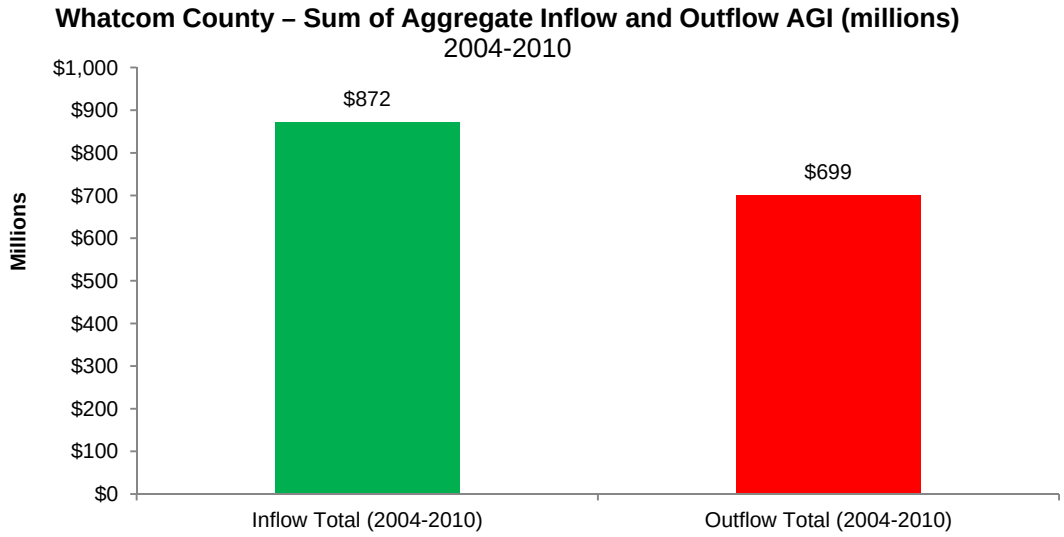
86 Bellingham and Whatcom County each experienced significant population growth from 2000 to 2010. The project team explored Internal Revenue Service (IRS) migration data to obtain a greater understanding of the previous location of newcomers to Whatcom County. IRS migration data is available on a County-to-County level and is based upon year-to-year address changes reported on individual income tax returns filed with the IRS. The data track inflows and outflows and where residents went.

The IRS defines inflows as "the number of new residents who move to a county or state…" Outflows are defined as "the number of residents leaving a county or state…" The IRS data report both the location of origin and the new location. The IRS notes that the data represent between 95 and 98 percent of total annual filings (those filed prior to late September of each calendar year).

87 172 returns listed AFO/AFP addresses as previous locations and are included within the 'foreign' category.

Whatcom County outflow destinations were similar to its inflow patterns. From 2004-2010, the great majority (72.8 percent) of all outflow was to other Washington counties. Similar to inflow data, King County (4,820), Snohomish County (2,316), and Skagit County (2,275) had the most returns associated with outflow data and accounted for 64.8 percent of all outflow to other Washington counties and 47.2 percent of all outflow from Whatcom County.

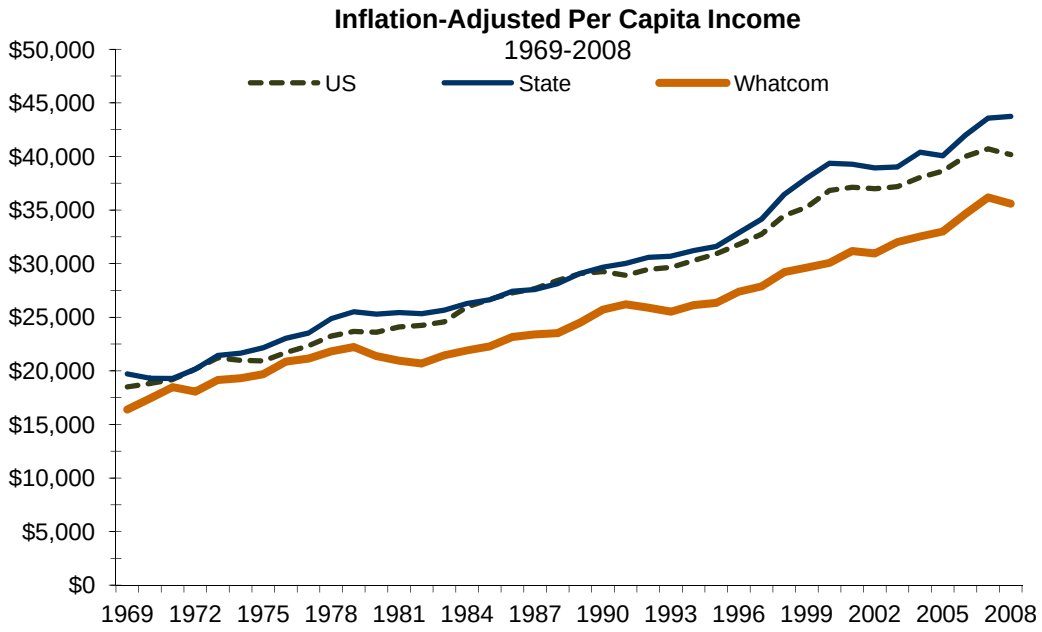
The IRS data also provide a summation of AGI from each of the jurisdictions from/to which people migrated. The chart below shows that, on the whole, Whatcom County realized a net aggregate growth of over $172.3 million in AGI from migration between 2004 and 2010.



Appendix C: Income and Wages

Washington's Office of Financial Management (OFM) data indicate that Whatcom County's inflation adjusted per capita income has consistently been below both the State and US averages since 1969; the graph below shows this trend.[88] Analysis by the Washington Regional Economic Analysis Project (WA REAP), which used data published by the US Bureau of Economic Analysis (BEA), demonstrates that Whatcom County's per capita income has maintained its relative position below the State per capita income through 2009.[89]

Between 2000 and 2008, Whatcom County's per capita income grew at a compound annual growth rate (CAGR) of nearly double that of the nation and significantly greater than the State. Whatcom County's CAGR was 2.1%; US CAGR was 1.1%, and Washington's CAGR was 1.3%.



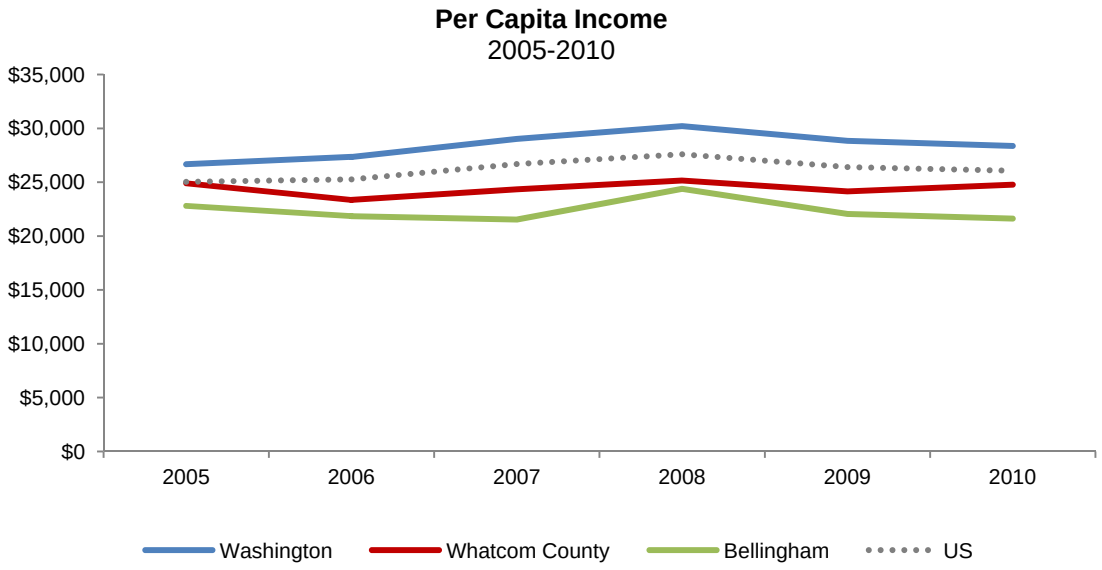
Source: WA Office of Financial Management (OFM)

Just as Whatcom County has consistently lagged the State and the national per capita income, Bellingham's per capita income has consistently lagged the per capita income of Whatcom County (and naturally the State and the nation). As of 2010, Bellingham's per capita income ($23,308) was 8.3 percent less than Whatcom County's per capita income ($25,429), 13.5 percent below US per capita income ($26,942), and 20.8 percent below the State's per capita income ($29,420).[90] Per capita income is sensitive to special populations (i.e. students, inmates, etc.) that can result in lower estimates than are experienced by the rest of the population.

88 OFM data are presented through 2007. Since 2008, Whatcom County has remained below both State and US per capita income levels according to the US Census Bureau's ACS 1-year Estimates in 2008, 2009, and 2010 and 2010 ACS 3-year Estimates data.

89 WA REAP data is available at: http://washington.reaproject.org.

90 US Census Bureau 2010 ACS 3-year Estimates data.



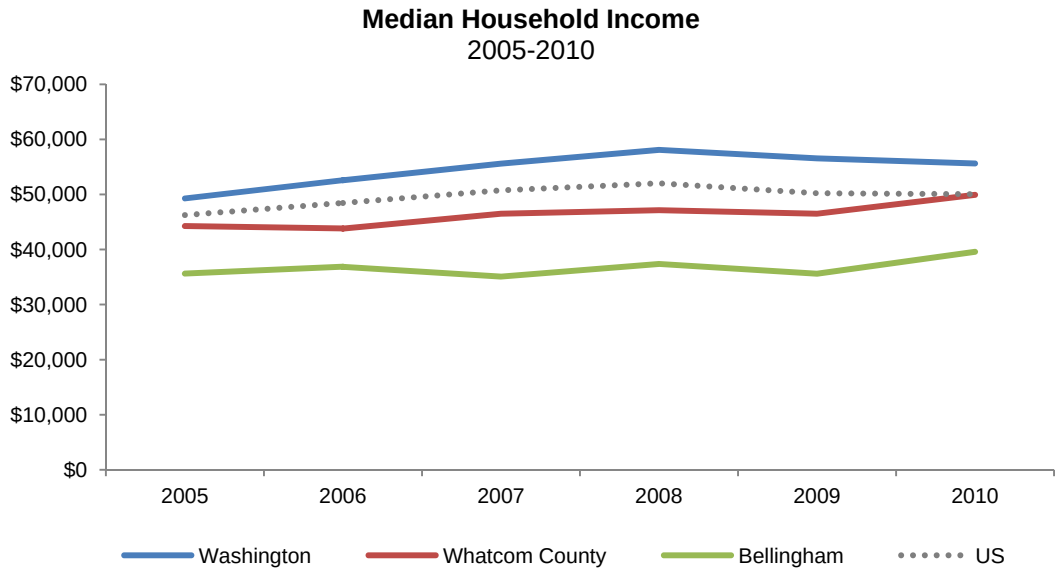
Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

Income may also be viewed at the household level.[91] Similar to per capita income, median household income can be sensitive to student-aged populations as several or many students residing in a household could lower the median household income below the experiences of the rest of the population. However, it provides a useful measure to assess the relative levels of incomes across jurisdictions.

The US Census Bureau's ACS 1-year data for 2010 indicated that Bellingham's median household income ($39,599) was less than that of Whatcom County, Washington, and the nation.[92] In 2010, Whatcom County's median household income of $49,938 was 3.3 percent above the US average ($50,046) and 7.7 percent below the State median household income ($55,631).

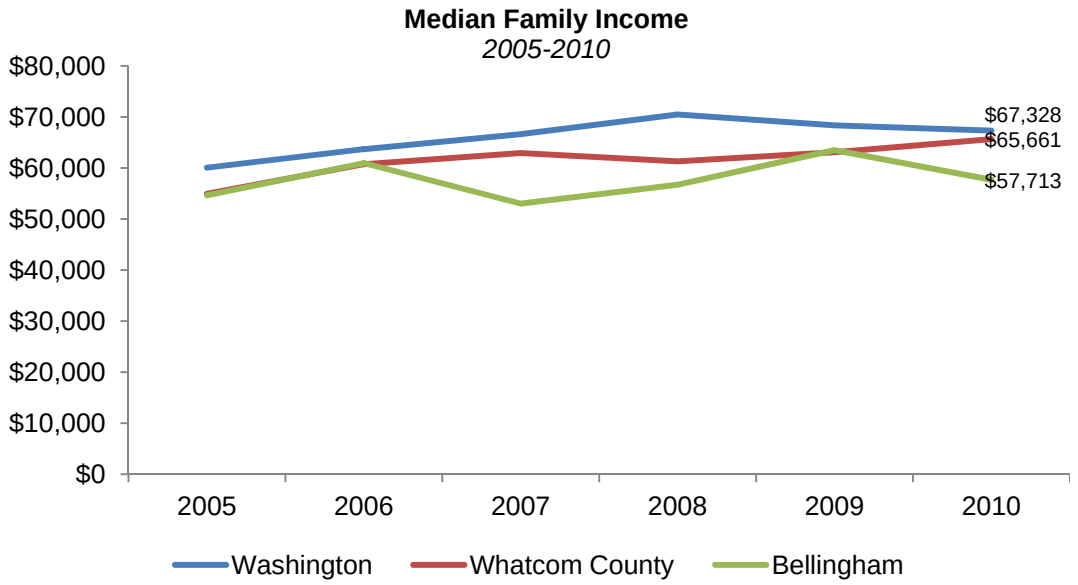
91 The US Census Bureau defines household income as including income of the householder and all other people 15 years and older in the household, whether or not they are related to the householder.

92 The project team endeavored to use US Census Bureau ACS 3-year Estimates data for the graphs on pages 23 through 25, but due to data issues experienced by the US Census Bureau, used ACS 1-year Estimates data for the charts on the aforementioned pages. The data are slightly different, but the patterns and relative rankings of the jurisdictions are largely unchanged. The primary objective of these graphs is to show relative relationships between jurisdictions and that is maintained by using the ACS 1-year Estimates data.



Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

Median family income data are less affected by student population data.[93] In four of the last six years, Bellingham's median family income was below that of Whatcom County, Washington, and the US. However, in 2006 and 2009, Bellingham's median family income was greater than both Whatcom County and the US average. Whatcom County's median family income was above the US average in four of the six years reviewed (2006-2007, 2009-2010), though it remained below the Washington state median household income in all six years.



Source: US Census Bureau ACS 1-year Estimates – 2005 through 2010

93 The US Census Bureau defines family household as a householder and one or more other people living in the same household who are related to the householder by birth, marriage, or adoption. All people in a household who are related to the householder are regarded as members of his or her family. A family household may contain people not related to the householder, but those people are not included as part of the householder's family in tabulations.

Wages

Overall, Whatcom County's average annual wage was below the State's average wage.[94] Similarly, in 18 of the 20 sectors reviewed, Whatcom County's average annual wage was below the State's average annual wage for the respective sector. In the two instances where Whatcom County had a higher average annual wage, both were less than 4.0 percent greater than the State average. In all 18 sectors where the County lagged the State average annual wage, all lagged the State average by more than 4.0 percent.

Growth industries in the Whatcom/Bellingham region that were discussed earlier in this report included leisure and hospitality (accommodation and food services; arts, entertainment, and recreation), health care and social assistance, government, and retail trade. Among these growth sectors, all had an annual average wage in Whatcom County below their peers in similar sectors in the State.

94 Washington's OFM and the State's Employment Security Department (ESD) collaborate to compile median and hourly wage information for each County. Similar, but different, data are available from the BEA and WA REAP. While methodologies may vary slightly causing different results, both data sets provide quality data that are useful in reviewing income and wages. For the remainder of the income – wages discussion, the project team will use data from Washington's ESD (in partnership with the BLS). Neither State nor BEA data for the full year 2011 are available as of January 10, 2012.

Whatcom County's Variance from State – 2010 Jobs and Wages by Occupation[95]

Sector	Whatcom County Percent of Total Jobs	WA Average Annual Wage	Whatcom County Average Annual Wage	2010 Difference in Average Annual Wage ($)	2010 Difference in Average Annual Wage (%)
All Industries	**100.0%**	**$48,521**	**$37,312**	**($11,209)**	**-23.1%**
Ag., forestry, fishing & hunting	3.9%	$24,034	$24,977	$943	3.9%
Mining	0.2%	$55,654	$51,050	($4,604)	-8.3%
Utilities	0.2%	$77,591	$73,842	($3,749)	-4.8%
Construction	6.2%	$51,127	$51,891	$764	1.5%
Manufacturing	9.8%	$64,925	$53,740	($11,185)	-17.2%
Wholesale trade	3.4%	$63,348	$47,072	($16,276)	-25.7%
Retail trade	12.5%	$30,021	$25,136	($4,885)	-16.3%
Transportation & warehousing	2.4%	$47,743	$37,127	($10,616)	-22.2%
Information	1.9%	$109,777	$42,615	($67,162)	-61.2%
Finance & insurance	2.4%	$70,137	$53,210	($16,927)	-24.1%
Real estate & rental & leasing	1.1%	$38,359	$27,494	($10,865)	-28.3%
Professional & technical services	3.8%	$75,376	$55,156	($20,220)	-26.8%
Mgmt. of companies & enterprises	0.6%	$95,731	$58,393	($37,338)	-39.0%
Administrative & waste services	3.8%	$41,466	$30,903	($10,563)	-25.5%
Educational services	0.9%	$35,158	$21,141	($14,017)	-39.9%
Health care & social assistance	12.4%	$44,673	$37,532	($7,141)	-16.0%
Arts, entertainment, & recreation	2.0%	$25,121	$16,078	($9,043)	-36.0%
Accommodation & food services	9.6%	$17,632	$14,482	($3,150)	-17.9%
Other services, ex. public admin.	4.4%	$24,227	$22,808	($1,419)	-5.9%
Government	18.4%	$51,394	$45,430	($5,964)	-11.6%

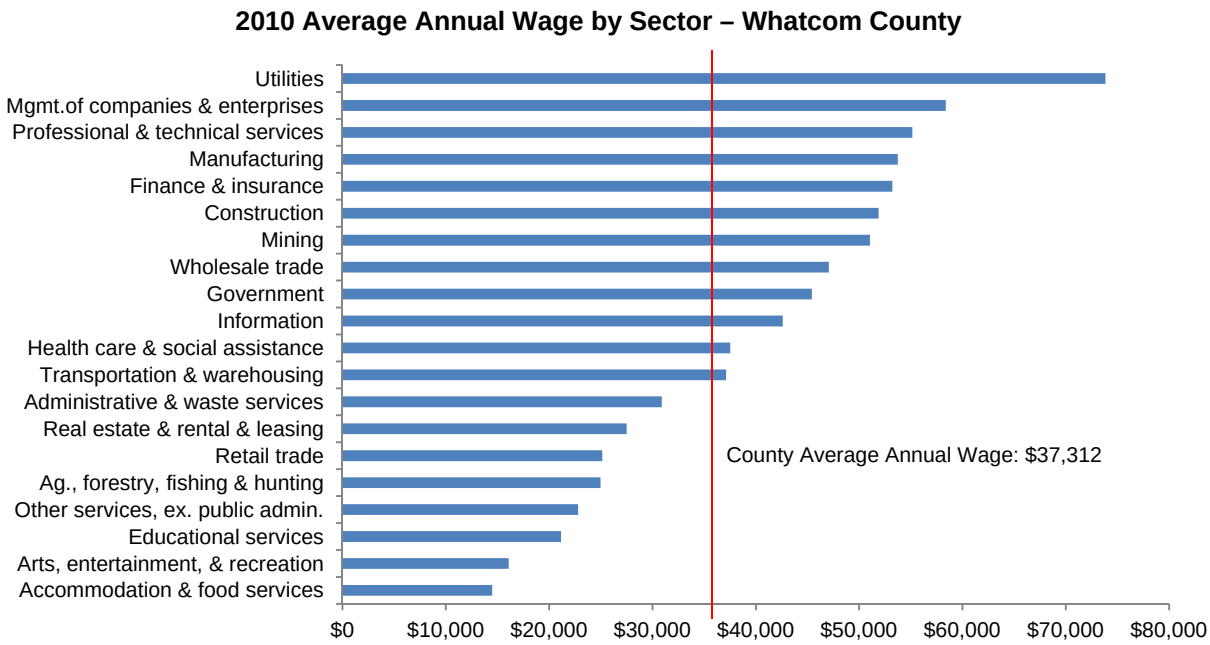
Source: WA ESD – Covered Employment Classified By Industry – Annual Averages 2010 (Revised)

One of the super-sectors that added the most jobs in Whatcom County since 2001 was leisure and hospitality (accommodation & food services and arts, entertainment & recreation sectors); which is also the sector with the lowest annual wage in Whatcom County. Similarly, the retail trade sector and education and health services sectors both experienced growth in Whatcom County and were comprised of industries that have average annual wages at or below the County's average annual wage. The only significant growth sectors in the County with wages above the County's average annual wage were Finance and Insurance and Government.

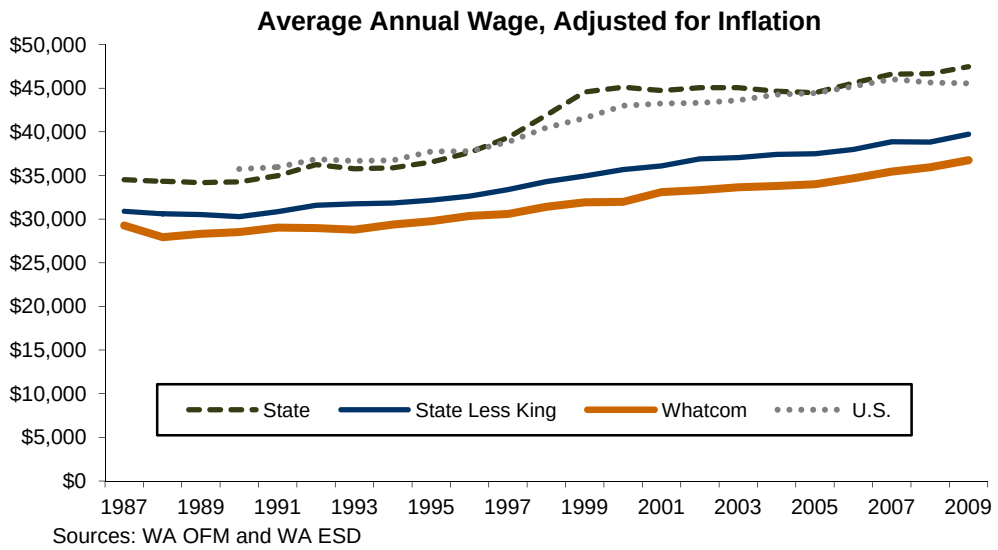
Taken together, this suggests that while the County added many good paying jobs relative to the annual average wage, it also added a significant number of jobs that provide annual wages at or below the County average.[96]

95 Washington ESD.

96 Additional information is available from the WA ESD. In July 2011, ESD published a 2011 Occupational Employment and Wage Estimates Guide that provides estimated employment, average wage and percentiles of wages for a multitude of professions. The data are presented for MSAs, regions, and Statewide. While a profession by profession comparison is beyond the scope of this report, a cursory review of the data seems to support the trend of Whatcom County (Bellingham MSA) having lower average wages than Statewide averages. The ESD publication is available at: Hhttps://fortress.wa.gov/esd/employmentdata/docs/occupational-reports/occupational-employment-wage-estimates-2011.pdfH.

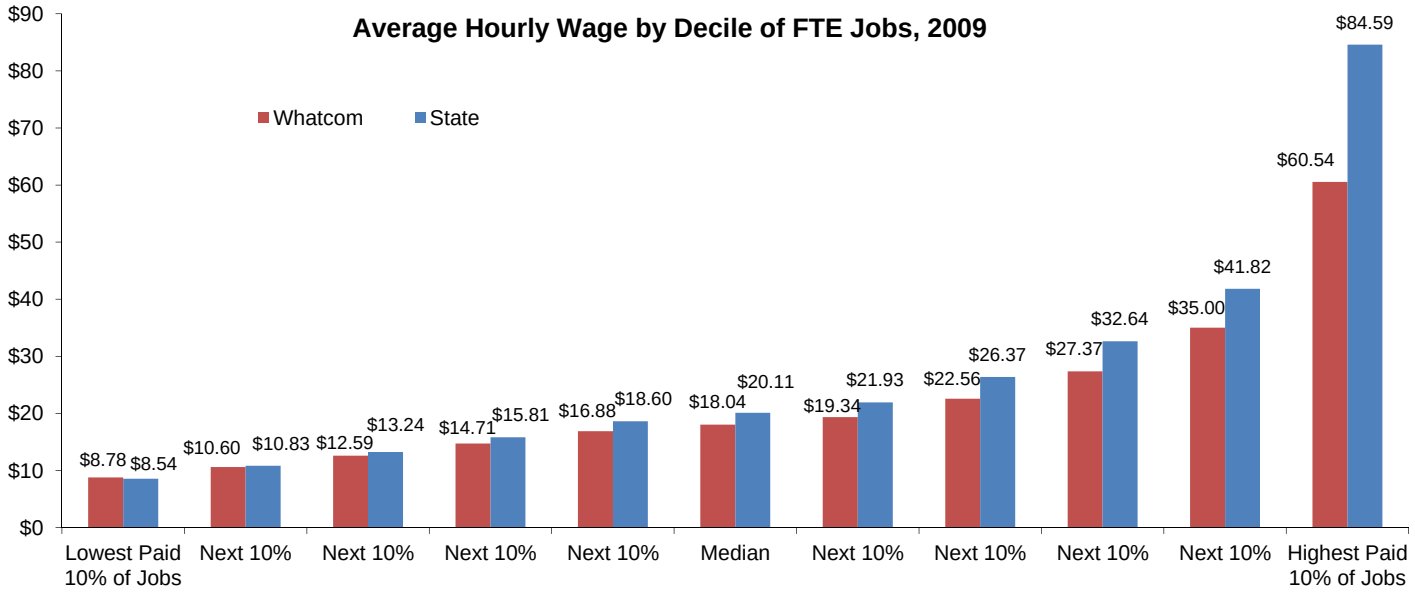


According to OFM and ESD data, the average earnings per job in Whatcom County have consistently lagged the Washington average since 1987 when the data set began; Whatcom County also remained below the State and US average earnings per job, while Washington has been largely been near or above the national average.



Whatcom County's average hourly wages were closer to the State's average hourly wages among those on the lower-end of the wage scale.[97] As hourly wages increased, the County's lag significantly increased. In other words, the proverbial wage-floor to wage-ceiling was more compressed in Whatcom County than for the State.

97 The wage scale shown is for hourly wages by decile. This range begins with the lowest-paid 10 percent of jobs and increases by 10 percent intervals up to the highest paid 10 percent of jobs (based upon average hourly wage).

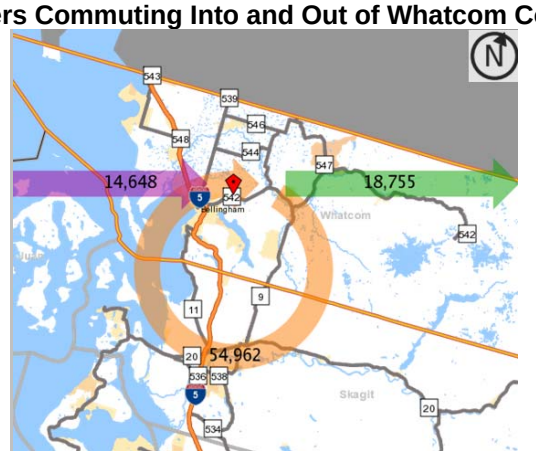


Wage data is based on location of employment. OFM and ESD historical data showed an important distinction that wages earned in Whatcom County are not equal to wages earned by Whatcom County residents. The data showed that the inflow of earnings from cross-county commuters was consistently greater than the outflow of earnings from cross-county commuters. This suggests that workers who resided in Whatcom County and commuted outside of the County for work earned higher wages than those who resided in other counties and commuted into Whatcom County.[98] Similarly, US Census OntheMap application data also showed that more Whatcom County residents commuted outside of the County for work than non-Whatcom residents who commuted into the County for work. In 2009, the difference was estimated to be 4,107 individuals; as shown in the below graphic.[99] Importantly, according to this data, 40.1 percent of those leaving Whatcom County earned more than $3,333 per month as compared with 32.8 percent of those who commuted into Whatcom County, and 34.6 percent of Whatcom residents who lived and worked in the County.

98 WA OFM and ESD personal income data.

99 It is possible that data from OnTheMap understates the effect of Whatcom residents who commute outside the County for work due to the Canadian border affecting its estimates.

Workers Commuting Into and Out of Whatcom County

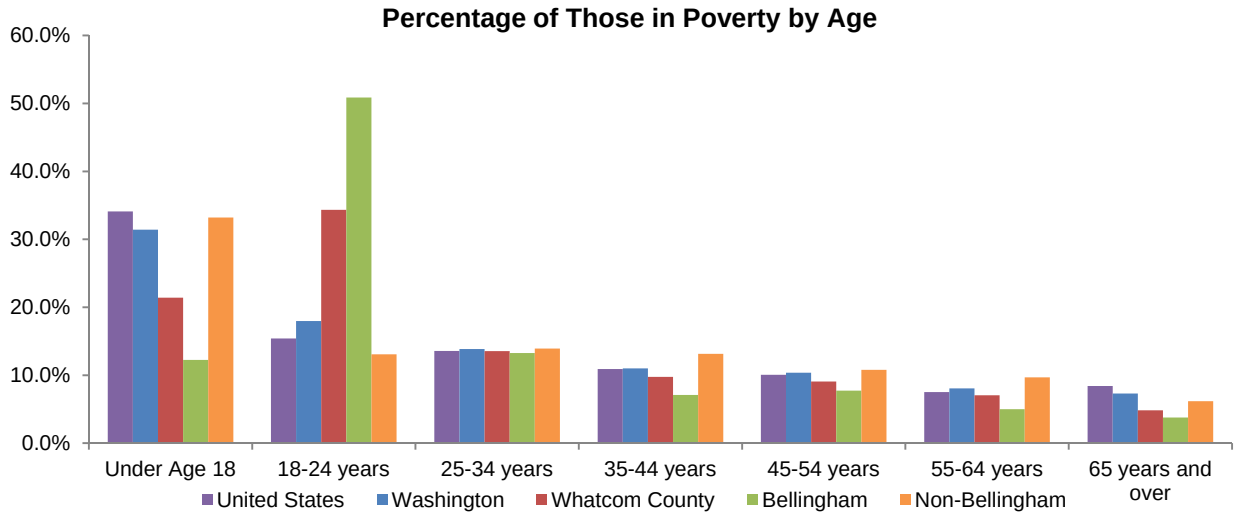


Further evidence that Whatcom County's labor market pays a lower wage in comparison to other regions is found in the County's trend of trailing the State average in wages for those with a Bachelor's degree or higher. Specifically, those with a Bachelor's degree or higher earned an average of $1,706 less per month than the State average for those with a Bachelor's degree or higher; equating to over $20,000 less per year.[100] This result suggests that in addition to being a lower-wage region than the State average – as mentioned previously – Whatcom County and Bellingham may have instances of underemployment among residents. Underemployment is discussed at greater length below.

100 US Census Bureau Quarterly Workforce Indicators (QWI) – 2010 Quarters 1-4.

Appendix D: Underemployment and Poverty

Bellingham's poverty rate of 21.0 percent was greater than the poverty rates for both Whatcom County (14.6 percent) and Washington (12.5 percent).[101] Bellingham accounted for 56.2 percent of Whatcom County's total population in poverty and 68.6 percent of those in poverty between the ages of 18-64. As shown in the chart below, much of Bellingham and Whatcom County's poverty was concentrated among those between the ages 18-24.[102] The City's poverty rate was likely impacted by the significant post-secondary student population in Bellingham; many of whom lived below the poverty line. Bellingham residents ages 18-24 with incomes below the poverty line accounted for 50.9 percent of the City's total and 83.3 percent of all age 18-24 County residents living in poverty.



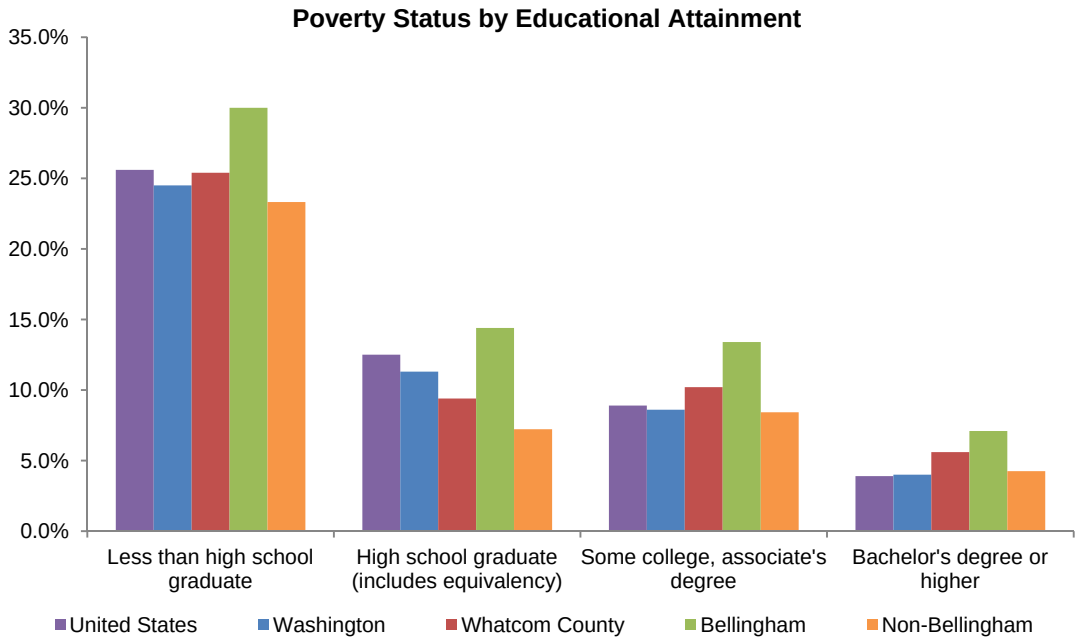
Source: US Census Bureau 2010 ACS 3-year Estimates

Across all educational attainment levels, Bellingham's poverty rate was greater than the remainder of the County, State, and national rates. Almost one-quarter (22.4 percent) of Bellingham residents age 25 and over who live in poverty possessed a Bachelor's degree or greater.[103] This percentage was significantly more than that seen in both the remainder of Whatcom County (13.4 percent) and Washington (13.3 percent) for the same population. The remainder of Whatcom County's poverty rate is generally below or on par with that of the State. The relative high level of poverty experienced by those in Bellingham with high educational attainment suggests there is some level of choice or desire to reside in Bellingham as opposed to other locations.

101 US Census Bureau 2010 ACS 3-year Estimates.

102 US Census Bureau 2010 ACS 3-year Estimates.

103 Source: US Census Bureau 2010 ACS 3-year Estimates.



Source: US Census Bureau 2010 ACS 3-year Estimates

Appendix E: Cost of Living

An important consideration to contextualize income – and economic conditions independent of income – is the associated cost of living for the region. One measure of this is the BLS Consumer Price Index (CPI) data.[104] The Bellingham MSA is not one of the local areas for which BLS produces an index.

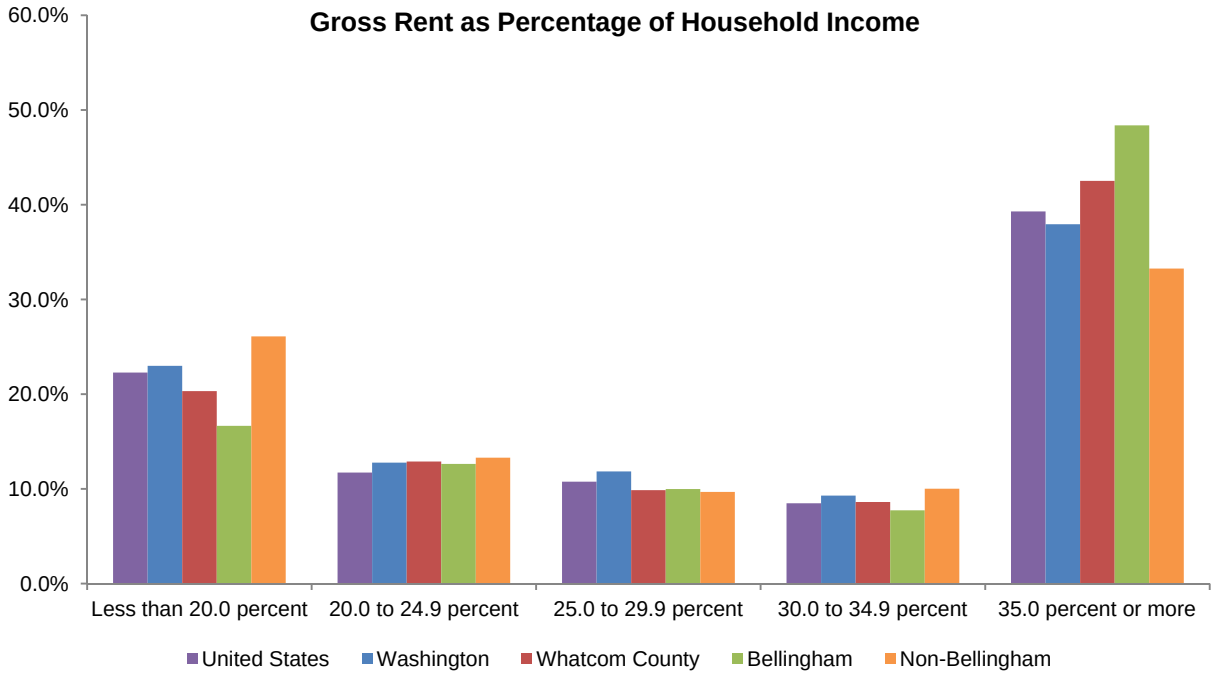
As CPI data are not available for Whatcom County or Bellingham, the project team reviewed the cost of housing to help inform discussions of the cost of living. Over half (51.1 percent) of Whatcom County households who rented their residence and 45.0 percent of those who owned their residence spent 30.0 percent or more of their income on housing – compared with 47.2 percent of renters and 41.0 percent of homeowners in Washington.[105]

As shown in the following graphs, all jurisdictions had a significant portion of renters and home owners who paid 35 percent or more of household income for their residence. Bellingham had the highest percentage of households among renters and home owners who paid over 35 percent of household income toward their residence; 48.4 percent of all Bellingham renters and 35.3 percent of Bellingham home owners. A portion of Bellingham's high rent as a share of household income may have been attributable to the student population, many of whom may have rented apartments or homes.

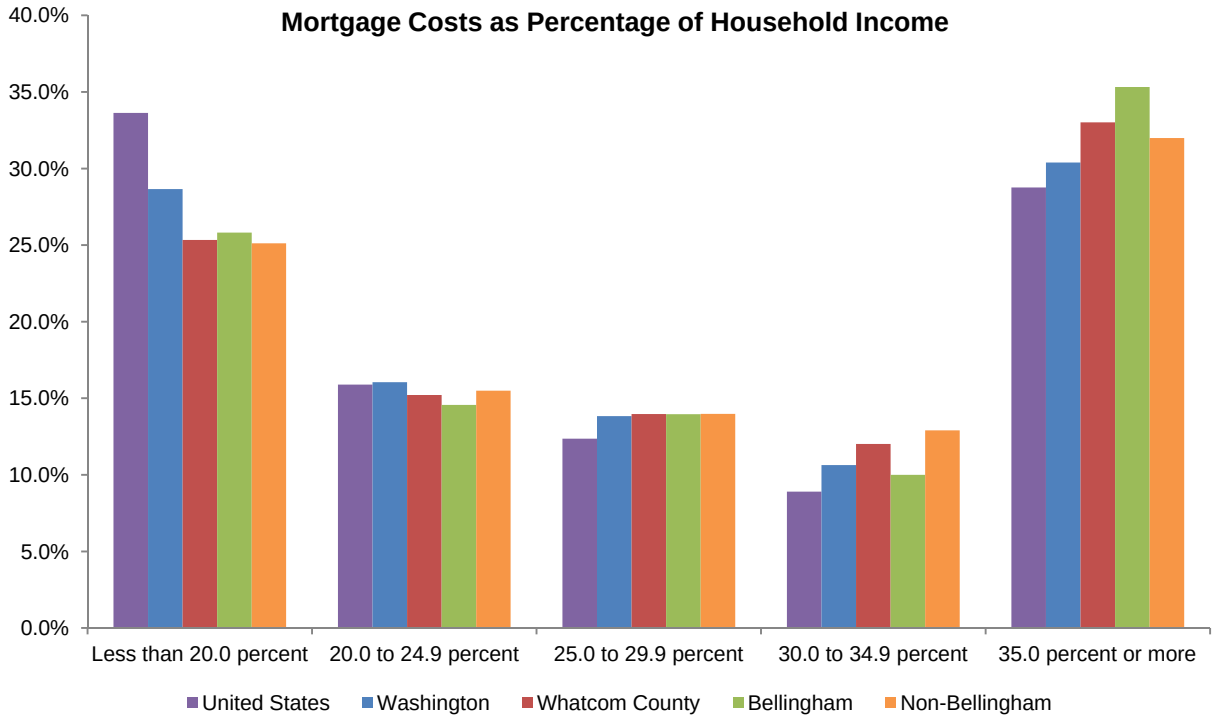
The remainder of the County tended to be more similar to the State than to Bellingham. However, rental and housing prices as a whole appeared to consume a greater percentage of total household income in Whatcom County and Bellingham as compared to the rest of the state. This could have been due to the jurisdictions' lower wages, higher housing prices, or a combination of both.

104 The BLS publishes various CPI measures of 'market basket' price changes as indicators of cost-of living. BLS cites the Chained CPI-U as its most accurate measure for cost-of-living. This index is produced on a national basis, and is available dating back to 1999. To provide insight into more localized changes, BLS also produces indexes for local areas covering all urban wage earners. While available for a longer duration and regionally focused, the BLS advises that such area series are less reliable due to sample size volatility.

105 OFM analyzes the cost-of-living by measuring housing costs (rent or mortgage) as a percent of household income. OFM considers households to be in distress when gross rent or mortgage costs are 30 percent or more of household income. OFM data use 2000 Census data as the base year and is current through 2009 ACS 1-year estimate data. In the data discussed, the project team used the 2010 ACS 3-year estimates. The project team examined mortgage costs as a percentage of household income for owner-occupied housing units in order to review housing costs as a percentage of household income without large potential for interference from the student population.



Source: US Census Bureau 2010 ACS 3-year Estimates.



Source: US Census Bureau 2010 ACS 3-year Estimates.

Washington State University's Washington Center for Real Estate Research (WCRER) publishes a myriad of housing-related data, including an affordability index and data on median sales prices. WCRER compiles an affordability index for home purchases that measures the ability of a typical family to make payments on a median price home. For example, if a jurisdiction had an affordability index of 110, it would mean that a family earning the median

income would have 10.0 percent more income than the bare minimum required to qualify to purchase a median-priced home with a 20.0 percent down payment and a 30-year mortgage.

Traditionally, Whatcom County's affordability index was slightly above the State's index until early 2004. Since that point, the County's index has generally remained below the State's index, meaning home purchases are slightly more affordable in the State as compared to Whatcom County. It is possible that Whatcom County's lower wages as compared to the State average (discussed above) contributed to this affordability lag, though the wage trend existed for a significant period prior to 2004.

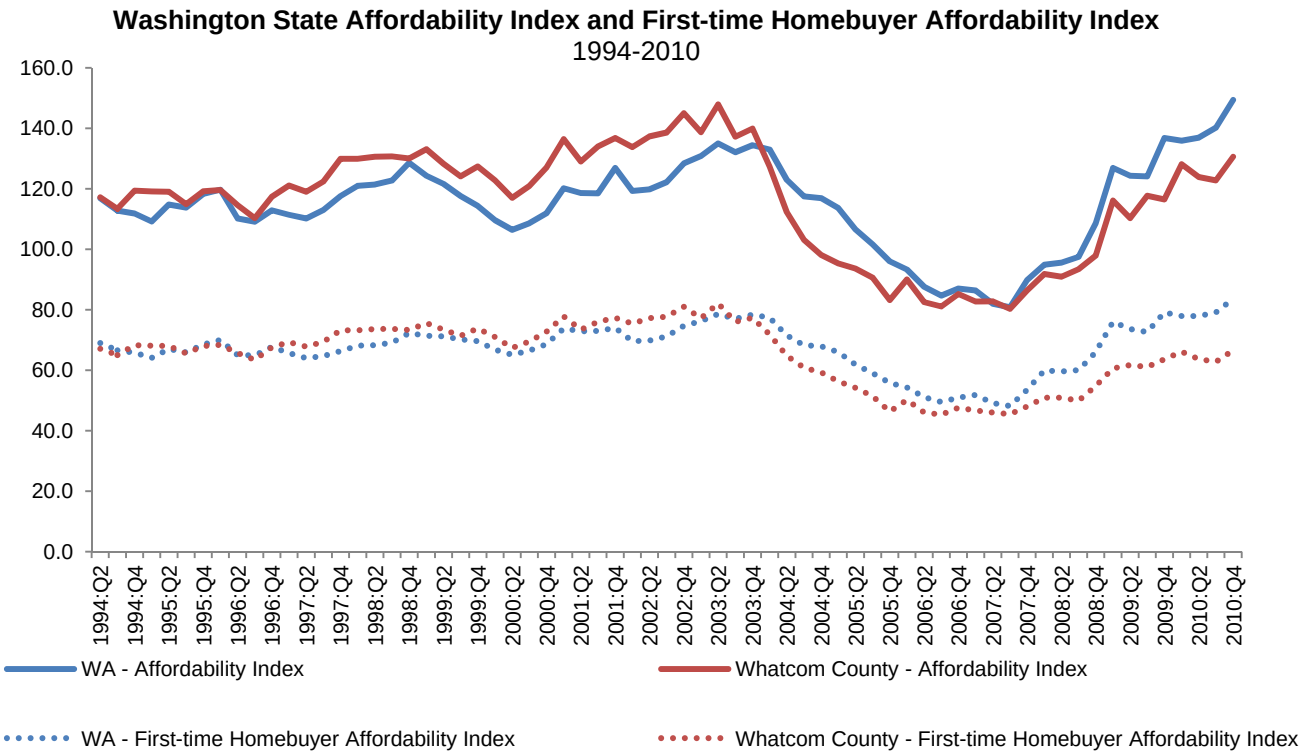
The second chart below reviews the median home price for the State and County on a quarterly basis from 2004-2010.[106] Whatcom County's median home price was below the State's median home price until the middle of 2004. At this point, the County's median home price was nearly equal to the State's for the next 18 months; even briefly spiking above the State average. From early 2006 through early 2010, the County's median home price was lower than or nearly equaled that of the State.

Since mid-2010, the County's median home price has been greater than the State's median home price. A portion of the County's increase could be due to the types of individuals migrating to the County from outside areas. These individuals (discussed in a previous section) have higher AGIs and may have helped sustain the housing prices by creating demand in the market whereas similar demand was not present in other markets. To the extent this supply/demand effect occurred, it increases the likelihood that people chose to move to Whatcom County and Bellingham because of the quality of life, quality of place, and/or amenities, as they were willing to pay more for a home in Whatcom County or Bellingham than other locations.

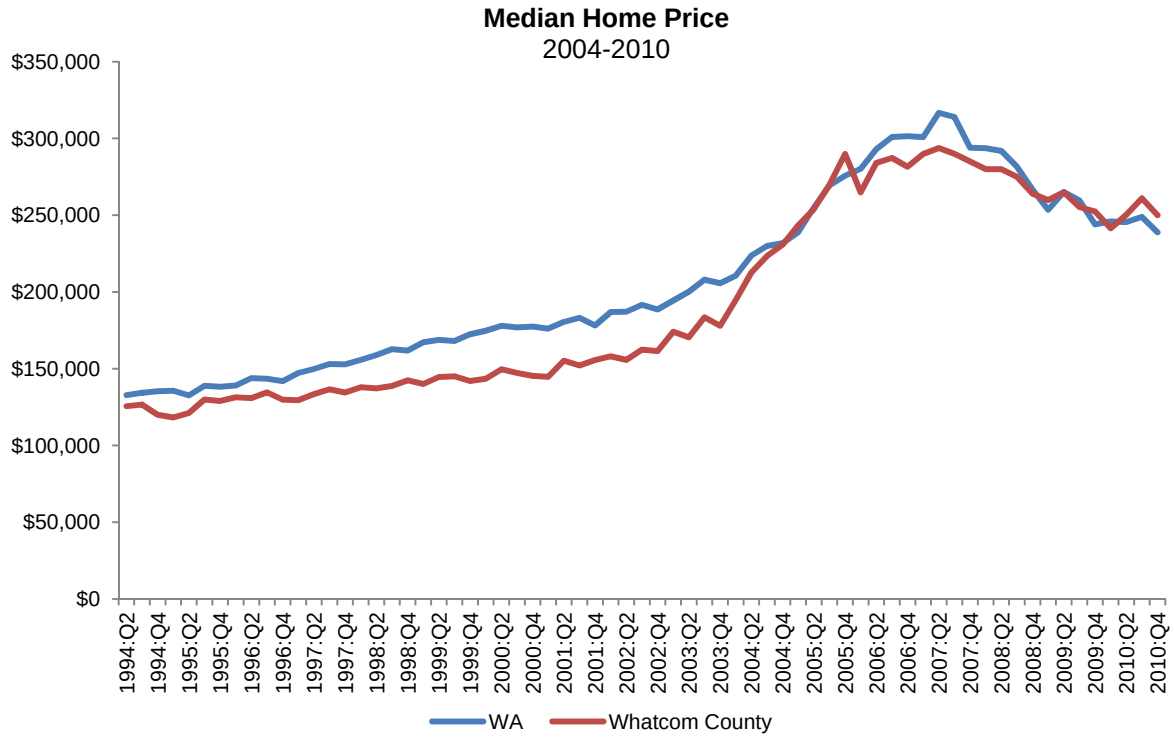
Considering both the affordability index data and median home price data, there may be two variables combining to create a lower affordability and higher median home price as compared with the State; this experience may even be potentially greater in Bellingham. The County and City's consistently lower wages coupled with the home prices that didn't fall as far from their peak as the State likely each play a role in the more expensive real estate (on an affordability measure and a median price measure) than the State average.

Given these facts, it could be argued that Whatcom County and Bellingham could be expected to have seen a small decrease in population as individuals and families seek more commensurate wages and home prices. However, this did not occur. In fact, the opposite occurred which again could suggest some level of desirability and choice associated with wanting to reside in Bellingham and or Whatcom County – even if it was less affordable.

106 The Federal Housing Finance Agency (FHFA) House Price Index for the same period also reports similar data.



Source: Washington Center for Real Estate Research

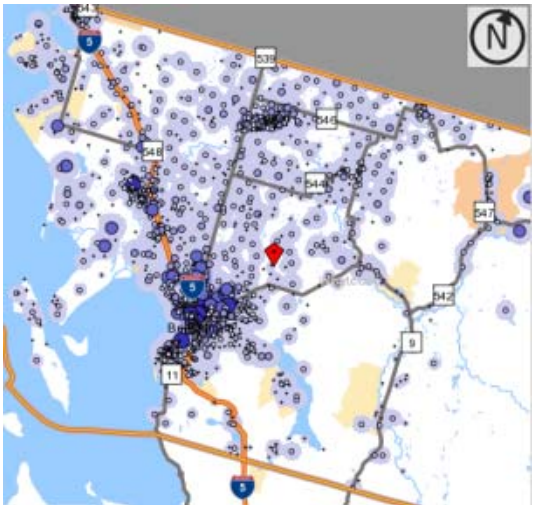


Source: Washington Center for Real Estate Research

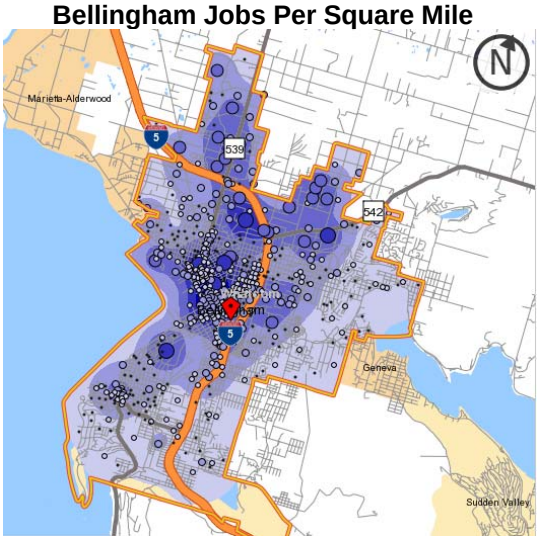
Appendix F: Bellingham's Importance as a Regional Economic Center

Approximately 60 percent of jobs in Whatcom County are located in Bellingham.[107] Countywide, jobs are concentrated in Bellingham and, within Bellingham, are concentrated west of Interstate 5 (I-5) and clustered near the Central Business District and within short distance to the waterfront.

Whatcom County Jobs Per Square Mile



Bellingham Jobs Per Square Mile



Source: US Census Bureau Local Employment Dynamics (LED), 2009.

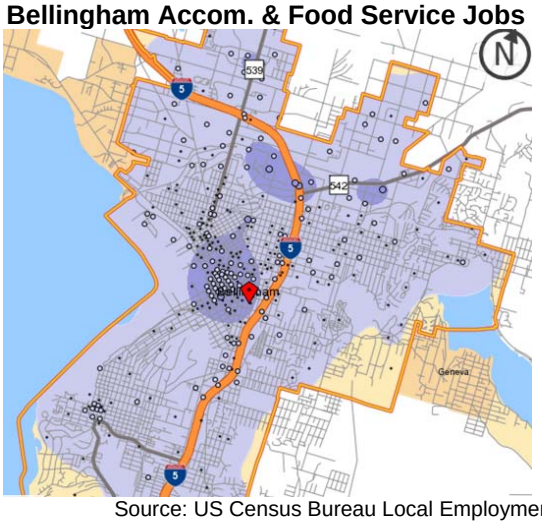
According to the US Census Bureau's 2007 Economic Census, the City also accounted for 76.1 percent of all retail sales in Whatcom County. In addition, Bellingham's retail sales per capita ($25,169) was nearly double the sales per capita of the County ($13,254). The City's accommodation and food services sales accounted for $226.6 million (55.6 percent) of the County's total accommodation and food services sales of $407.8 million.[108] The US Census Bureau's Local Employment Dynamics (LED) 2009 Work Area Comparison Report for Whatcom County indicates that the retail trade sector, as seen in other data earlier in this report, is one of, if not the largest industry sector in the County.

Specifically, as seen in the below maps, it appears that a significant portion of the City's retail, accommodation, and food services jobs are located in and around the waterfront area.

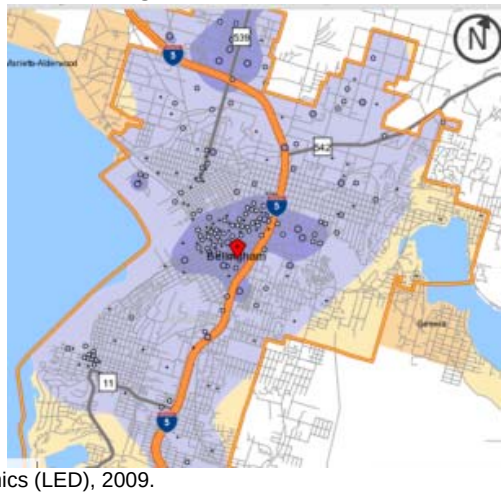
107 US Census Bureau Local Employment Dynamics (LED) 2002-2009 data.

108 US Census Bureau 2007 Economic Census.

Bellingham Accom. & Food Service Jobs



Bellingham Retail Trade Jobs



Source: US Census Bureau Local Employment Dynamics (LED), 2009.

Property Values

Just as Bellingham is the commercial center for Whatcom County, it also has a significant portion of the County's property value. As of 2010, Bellingham accounted for 35.8 percent of the County's total assessed value of real property. Bellingham achieved these results despite representing only 1.3 percent of the County's total square miles – further highlighting the importance of property value (for residential and commercial parcels) in the City for the rest of the County.[109]

In 2010, Bellingham accounted for 56.0 percent of the total residential sales volume in the County (in dollar amount) and 52.1 percent of total residential transactions in the County; suggesting the City's average house price is greater than the County's average price – a trend that has existed since the data set used began in 2006. Similarly, while Bellingham and the remainder of Whatcom County have both seen significant declines in residential sales volume (in dollars) since 2006, the City's decline is marginally slower than the decline experienced by the remainder of the County (-44.8 percent versus -47.1 percent).

Between 2005 and 2010, Bellingham's median and average home prices have been higher than the median and average prices for the County as a whole. It is important to note that the data for Whatcom County include the Bellingham data and are not presented in a disaggregated form. As a result, Bellingham's median and average home values are likely even greater than the non-Bellingham portion of the County.

During the peak of the housing bubble (2006-2008), Bellingham's home prices were not as far above the County's home prices as after the burst of the bubble (2009-2010), when the City's home prices appear to have increased the value difference with the County's home prices. This suggests that the Bellingham housing market did not decrease in value to the same extent as the remainder of the County (keeping in mind that County data are not disaggregated and include Bellingham's prices).

109 US Census Bureau, 2010 data.

Median and Average Prices of Houses Sold, 2005-2010

Median Sales Price	Bellingham	Whatcom County	Difference ($)	Difference (%)
2010 Median Sales Price	$264,950	$255,000	$9,950	3.9%
2009 Median Sales Price	$274,000	$259,990	$14,010	5.4%
2008 Median Sales Price	$285,000	$278,533	$6,467	2.3%
2007 Median Sales Price	$300,000	$290,725	$9,275	3.2%
2006 Median Sales Price	$295,000	$283,000	$12,000	4.2%
2005 Median Sales Price	$269,000	$259,900	$9,100	3.5%
Average Sales Price	**Bellingham**	**Whatcom County**	**Difference ($)**	**Difference (%)**
2010 Average Sales Price	$313,813	$291,985	$21,828	7.5%
2009 Average Sales Price	$320,767	$301,124	$19,643	6.5%
2008 Average Sales Price	$333,731	$323,172	$10,559	3.3%
2007 Average Sales Price	$351,063	$340,448	$10,615	3.1%
2006 Average Sales Price	$341,105	$324,852	$16,253	5.0%
2005 Average Sales Price	$302,749	$288,277	$14,472	5.0%

Most recently, the 2011 report reviews the differences in median sales price for new and existing homes in Whatcom County and Bellingham. In both 2009 and 2010, the City's median sales prices for new and existing homes were greater than the County's median sales prices for new and existing homes. New homes in Bellingham had a particularly higher median sales price than did new homes in Whatcom County (2009: $336,650 vs. $262,500; 2010: $313,500 vs. $256,750).

According to the report, in 2010, houses in Bellingham's Census tracts had a higher average sales price for new homes than new homes sold in the rest of Whatcom County. In the nine Census tracts in Bellingham with new home sales in 2010, eight had an average sales price of over $300,000. Of the ten Census tracts in the remainder of the County with new homes sales in 2010, only one Census tract had an average sales price over $300,000.[110]

Among single family sales by Census tract in 2010, the properties in the Fairhaven, South Hill, and Edgemoor sections of the City had significantly higher sales prices than the rest of the City. The average sales price in the Fairhaven/South Hill section was $574,167 and the average sales price in Edgemoor was $555,433. Sales volumes were the highest in the Mount Baker, Alabama Hill/Silver Beach, North and South Short/Lake Whatcom, and Puget/Whatcom Falls/Samish areas of the City.

110 Similar data for condominium sales are also included in the report. Bellingham accounted for 63.0 percent of condominium sales in Whatcom County during 2010 and had a higher average sales price than the remainder of the County.

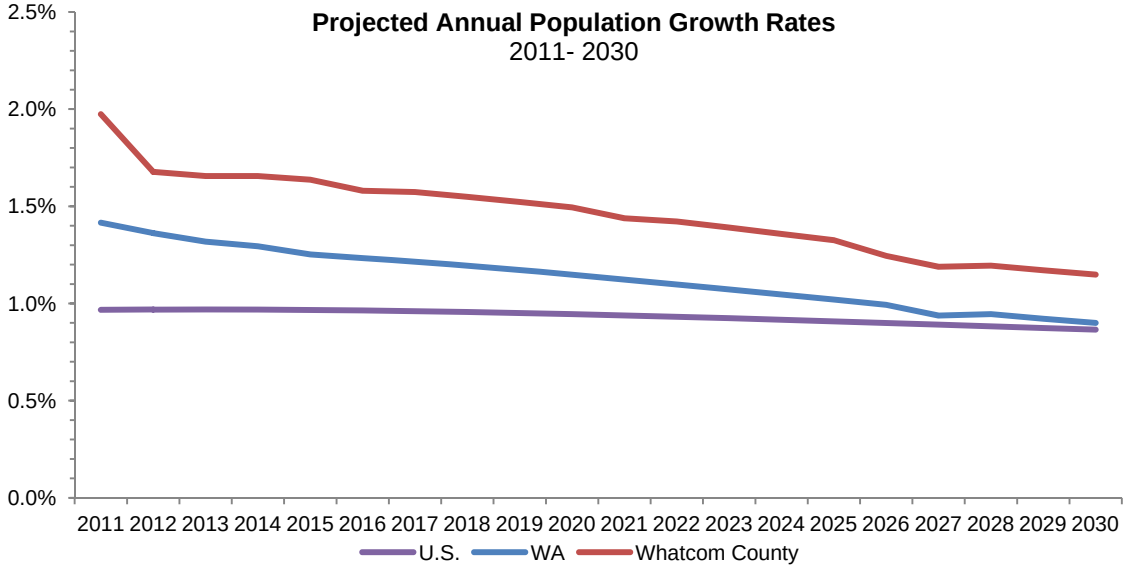
Appendix G: Projections for the Future – Population and Job Growth

Population Growth

WA OFM produces projections for future population growth on the State and County levels.[111] OFM projects the State's population growth rate from 2010 to 2030 to be 1.1 percent, just above the US rate of 0.9 percent. OFM projects Whatcom County's 2010-2030 population growth rate to be 1.5 percent.

Population growth forecasts for the City of Bellingham are not included in the OFM data. Bellingham's population growth rate is assumed to be similar, though not identical, in real experience to the County's population growth rate. It should be noted that Bellingham's CAGR for the most-recent 10 years (1.9 percent) is the same as Whatcom County's most-recent 10-year CAGR, for this reason, the project team used the same out-year CAGR for Bellingham as projected in OFM's estimates for Whatcom County.

For purposes of calculations later in this report, the project team used OFM's compound annual growth rate projections for Whatcom County for Bellingham; 1.6 percent through 2019 and 1.5 percent through 2030. This is in line with OFM's projections for a decreased rate of population growth for Whatcom County and the State in future years.



Source: WA OFM

OFM estimated that Whatcom County accounted for 2.9 percent of the State's total population.[112] By 2030, OFM projects the Whatcom County population to reach approximately 261,000 individuals and represent 3.1 percent of the State's population. Whatcom County's proportional increase in State population share occurs due to OFM's long-term forecasted population growth rate for Whatcom County being greater than the State's long-term forecasted population growth rate; this can be seen in the graph above.

111 OFM produces a *Forecast of State Population* (released in November 2011) that solely forecasts the population of Washington through 2040. OFM, as part of the Growth Management Act (GMA), produces population estimates every five years. New estimates are to be released in March of 2012 and were not available for use in this report. This report uses OFM 2007 Growth Management Projections through 2030. Historical differences between OFM projections and actual occurrences have been small. OFM's 2007 projections for 2010 were 97.3 percent of 2010 Census data. Similar or smaller margins were also seen in prior data.

112 OFM's estimates were made prior to the release of data from the 2010 Census. The 2010 Census suggested Whatcom County comprised 3.0 percent of the State's total population; up from 2.8 percent in 2000.

On a State level, it is worth noting that OFM's November 2011 *Forecast of State Population* (statewide projections) projects significant growth in the age 65 and over population from 2010 levels (24.2 percent) by 2040. Specifically, between 2010 and 2040, those age 65 and over account for 49.7 percent of OFM's projected total net population growth in the State. OFM's projections are consistent with growth in the population from the 2000 census to the 2010 census. OFM's projections likely account for baby boomers continuing to age and live longer, thus driving the increase in the population age 65 and over.

Job Growth

Washington's ESD produces Occupational Employment Projections for the State and its sub-regions that forecast the 2019 estimated levels of employment for over 800 occupation types.[113] Statewide, ESD projects an average annual growth rate of 1.4 percent for all occupations through 2019 resulting in an increase in employment of approximately 495,000 from 2009 levels. Over two-thirds of the State's projected increase is attributable to projected gains in nine occupational categories:

- Office and Administrative Support
- Sales Related
- Computer and Mathematical
- Computer Specialists
- Food Preparation and Serving Related
- Transportation and Material Moving
- Healthcare Practitioners/Technical Related
- Personal Care and Service
- Building and Grounds Cleaning and Maintenance.

ESD projects the Northwest Washington region[114] (includes Whatcom County) to grow at a slightly greater average annual growth rate than the State estimate through 2014 (1.5 percent versus 1.4 percent). Thereafter, through 2019, it projects the region will grow at annual average rate of 1.6 percent and the State will remain at the same average annual growth rate of 1.4 percent. In total, ESD projects the Northwest region's 2019 employment level will be 16.6 percent greater than its 2009 employment level; higher than the Statewide projected 15.3 percent increase during the same time period. By 2019, Northwest Washington is projected to have estimated employment of 207,449; an increase of nearly 30,000 over 2009 levels. Similarly to the State, over two-thirds of the region's projected increase is attributable to projected gains in nine types of occupations:

- Office and Administrative Support (3,900 new jobs; accounts for over 13.2 percent of total increase)
- Sales Related (2,400 new jobs)
- Production (2,300 new jobs)
- Transportation and Material Moving (2,100 new jobs)
- Food Preparation and Serving Related (2,000 new jobs)
- Personal Care and Service (1,900 new jobs)
- Education, Training, and Library (1,900 new jobs)
- Building and Grounds Cleaning and Maintenance (1,800 new jobs)
- Construction and Extraction (1,700 new jobs).[115]

113 The project team reviewed ESD's May 2011 (most recently available) projections.

114 ESD indicates that Northwest Washington region is comprised of Island County, San Juan County, Skagit County, and Whatcom County.

115 ESD differentiates between Construction and Extraction occupations and Construction Trades Workers.

Baseline Growth for Whatcom County and Bellingham

Without the planned development of GPT, the State has already projected significant population and job growth for Whatcom County that build upon the County's historical growth trend. These projections are outlined above. Based on the state's projections, it is possible to state a baseline scenario for county population and job growth over a ten-year period.

Population Growth

The project team used OFM's projected annual growth rates from 2011 through 2030 to project the growth of the 2010 Census population data for Whatcom County and Bellingham.[116] By 2021, Whatcom County's projected population is approximately 240,000 and Bellingham's projected population is approximately 96,000. Through 2021, the OFM's projected average annual growth rate is approximately 1.6 percent, and 1.5 percent through 2030. Whatcom County's 2030 population is projected to be 269,000 and Bellingham's 2030 population is projected to be 108,000.

Projected Population Growth

	2010 Census Population	Average Annual Growth Rate Through 2021	Average Annual Growth Rate Though 2030	Proj. 2021 Population	Proj. 2030 Population
Whatcom County	201,140	1.6%	1.5%	240,000	269,000
Bellingham	80,885	1.6%	1.5%	96,000	108,000

Job Growth

In 2009, Washington's ESD projected that the northwest region of Washington (including Whatcom County) will see an average annual job growth of 1.5 percent from 2009-2014 and a 1.6 percent annual average job growth from 2014-2019.[117] At the projected rates, Whatcom County would have 88,389 jobs by 2021, an addition of almost 15,000 jobs from 2010. Similarly, Bellingham would have 53,034 jobs by 2021, an increase of almost 9,000 jobs from 2010.

116 The project team used Bellingham's 2010 population as a percentage of total Whatcom County population throughout the estimates. This ratio is used purely for the purposes of estimations; actual results will vary and are subject to tangible and intangible occurrences that cannot be incorporated in projections.

117 The project team used these annual average growth rates and applied them to the BLS OES data for 2010 jobs in Whatcom County. To calculate the number of Bellingham jobs, the project team used took 60 percent of all jobs in the County (per LED data suggesting an average of 60 percent of all jobs in the County exist in Bellingham). The calculation did not include the estimated job growth for 2009 as the OES figure is from 2010. However, the project team did apply the 2010 growth rate to this figure so as to ensure it captured the possible net increase and not artificially lower job growth. For 2020-2022, the project team used the projected 1.6 percent average annual growth rate to estimate the number of jobs.

Projected Job Growth[118]

	Growth Multiplier	Whatcom County Jobs	Net Increase	Growth Multiplier	Bellingham Jobs	Net Increase
May-10	-	73,420	-	-	44,052	
2010	1.015	74,521	1,101	1.015	44,713	661
2011	1.015	75,639	1,118	1.015	45,383	671
2012	1.015	76,774	1,135	1.015	46,064	681
2013	1.015	77,925	1,152	1.015	46,755	691
2014	1.015	79,094	1,169	1.015	47,457	701
2015	1.016	80,360	1,266	1.016	48,216	759
2016	1.016	81,645	1,286	1.016	48,987	771
2017	1.016	82,952	1,306	1.016	49,771	784
2018	1.016	84,279	1,327	1.016	50,567	796
2019	1.016	85,627	1,348	1.016	51,376	809
2020	1.016	86,998	1,370	1.016	52,199	822
2021	1.016	88,389	1,392	1.016	53,034	835
Total		**88,389**	**14,969**		**53,034**	**8,982**

118 The project team also assessed US Census Bureau LED data from 2009 for Bellingham and Whatcom County. The 2009 LED data indicated 69,610 jobs in the County and 41,613 jobs in the City. Applying an annual average growth rate of 1.015 percent for 2009-2014 and an annual average growth rate of 1.016 percent for 2015-2021, yielded a total job growth in the County of 14,193 and 8,484 in Bellingham. Ultimately, the project team used the OES data as it is more recent and showed a higher number of actual jobs than projection based upon the 2009 data. The OES data were used so as to not artificially discount 'trajectory' growth when comparing to projected growth from GPT.

Exhibit 1

U.S. Army Corps of Engineers
Walla Walla District

Minimizing Effects of Over-Water Docks on Federally Listed Fish Stocks in McNary Reservoir: A Literature Review for Criteria

Anadromous Fish Evaluation Program Report 2010-W68SBV91602084

January 2010

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Minimizing Effects of Over-Water Docks on Federally Listed Fish Stocks in McNary Reservoir: A Literature Review for Criteria

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Executive Summary

McNary Lock and Dam were completed in 1953, creating McNary Reservoir, or Lake Wallula. The shoreline of the reservoir is federally owned and as a result the U.S. Army Corps of Engineers (USACE) has certain land and fish habitat management responsibilities to balance with other multipurpose benefits. The Endangered Species Act (ESA) listing of Columbia and Snake River salmon stocks has changed the management of salmon harvest, hydropower operations, hatchery practices, and habitat management in recent years. There are 12 salmon *Oncorhynchus* spp., steelhead *Oncorhynchus mykiss*, and bull trout *Salvelinus confluentus* evolutionarily significant units (ESU's) that use this reach of the Columbia River at one or more stages in their life history. Of those 12, 8 are listed as threatened or endangered under the federal Endangered Species Act. The entire portion of the Columbia River in the Hanford Reach and McNary Reservoir is designated critical habitat for seven ESA-listed salmon species.

The USACE is in the process of updating the 1983 McNary Lakeshore Management Plan. The updated Shoreline Plan provides criteria for private use of the federal shoreline of McNary Reservoir, specifically the permitting of private docks, over-water structures, and modifications to shoreline vegetation by adjacent land owners. The previous Shoreline Plan was written prior to the federal listing of salmon species. At the request of the USACE, the purpose of this report is to review information from the literature and determine the extent to which the criteria proposed by USACE for the docks and over-water structures are supported by the current body of scientific knowledge.

A large body of scientific literature was reviewed, including two previous literature reviews conducted to better understand the impacts docks might have on salmonids (Carrasquero 2001; Chapman 2007). Our review of the available literature has yielded the following conclusions (proposed criteria are in *italics*).

- *To prevent damage to shallow water habitat, piers and/or ramps shall extend at least 40 feet perpendicular from the ordinary high water mark (OHWM).*

This proposed criterion serves to locate docks off the nearshore and in deeper water. We have found that there is ample evidence that motor boat activity near shore has a negative impact on vegetative communities. There is also ample evidence that placing the docks in deep water helps to avoid interactions between piscivorous predators and juvenile salmonids.

- *Piers and ramps shall be no more than 4 feet in width.*

- *Grating shall cover the entire surface area (100%) of the pier and/or ramp. The open area of grating shall be at least 50% as rated by the manufacturer.*

- *Grating shall cover 100% of the surface area of the float(s). The open area of the grating shall be no less than 50% as rated by the manufacturer.*

- *Nothing shall be placed on the over-water structure that will reduce natural light penetration through the structure.*

There is strong evidence that changes in the lighting regime can cause changes in fish behavior and predator-prey interactions. We concluded that near docks or over-water structures, the most likely important piscivorous fish species are the introduced smallmouth bass *Micropterus dolomieu* and the native northern pikeminnow *Ptychocheilus oregonensis*. In general, the literature supports the conclusion that as lighting decreases, predation on juvenile salmonids by piscivorous fishes increases. Minimizing the width of the dock and ramp, as well as allowing the maximum amount of light to pass through the dock, helps to reduce the changes in natural daytime lighting.

- *The bottom of the pier or bottom of the landward edge of the ramp shall be elevated at least 2 feet above the plane of OHWM.*

Elevating the landward edge of the ramp above the OHWM raises the ramp, allowing more light to penetrate the water beneath the ramp. The benefits of maximizing light levels are outlined above. We have found no additional biological science to support raising the ramp above OHWM.

- *Skirting shall not be placed on piers, ramps, or floats. Protective bumper material will be allowed along the outside edge of the float as long as the material does not extend below the bottom edge of the float frame or impede light penetration.*

We found no mention of skirting in the literature except where other authors also reported finding no data linked to how skirting might impact predation on juvenile salmonids. Skirting does provide a visual barrier that may be used by predators to ambush prey. Additionally, skirting will likely reduce the amount of light under the dock. Based on our review of predator-prey interactions and reduced light associated with over-water structures, we believe that the literature supports not permitting skirting.

- *Shoreline concrete anchors must be placed at least 10 feet landward from the OHWM and shall be sized no larger than 4 feet wide by 4 feet long, unless otherwise approved by NMFS, USACE, and WDFW.*

No biological science regarding the placement of anchors was found while conducting this review. Minimizing the "footprint" of the anchor would minimize impact to riparian vegetation. The importance and function of riparian vegetation is well documented. Because subyearling Chinook salmon in the nearshore areas of McNary Reservoir consume numerous terrestrial insects apparently associated with riparian vegetation and the surrounding landscape, minimizing the footprint of the anchors and maintaining riparian vegetation has merit.

- *Piling shall not exceed 5 inches in diameter.*
- *Each over-water structure shall utilize no more than 6 piles total for the entire project.*

There are many studies indicating that bass and other predators utilize in-water structure. Pilings also create low velocity areas which are preferred by predators. Minimizing the numbers and size of pilings is supported by the scientific literature.

- *Floats shall not be located in shallow water habitat where they could ground or impede the passage or rearing of any life stage of salmonids. Floats shall be in at least 10 feet of water at all reservoir pool levels including Minimum Operating Pool (MOP) (which is 335 feet above sea level). Depth is measured from the bottom of the landward-most edge of the float.*

Reviewing available literature provides many reasons why newly-constructed docks should be placed in relatively deep water. Smallmouth bass will be attracted to structure. Where bass and juvenile salmonids overlap in habitat, the bass will predate upon the juvenile salmon. Juvenile salmonids use the littoral zone (shallow area along the shoreline where light reaches all the way to the bottom) for rearing (i.e., feeding, resting, refuge from predators). By avoiding the locating of docks in the shallow littoral zone, the impact that docks or over-water structures have on juvenile salmonids can be minimized. Additionally, constructing docks in deeper waters avoids damage to aquatic vegetation and the re-suspension of sediments by boating activity. Both of these deleterious effects may be caused by the operation of motorboats in shallow water near dock.

We reviewed peer reviewed scientific journal articles, technical reports, and other literature reviews regarding predator-prey interactions, habitat use by juvenile salmonids, and the potential impacts docks may have on ESA-listed juvenile salmonids. We found no specific studies or articles that assigned discrete values for the proposed criteria. We have, however, found that maximizing depth, minimizing structure (number and size of pilings), and maximizing light levels all contribute in a significant way to minimizing the impacts that docks and other over-water structures have on federally listed salmonids and other aquatic organisms. Furthermore, we found no studies specifically estimating a change in survival of juvenile salmonids associated with the cumulative effects of intensive development of over-water structure.

Introduction

The U.S. Army Corps of Engineers (USACE) is in the process of updating the 1983 McNary Lakeshore Management Plan. The updated Shoreline Plan provides criteria for private use of the federal shoreline of McNary Reservoir, specifically the permitting of private docks, over-water structures, and modifications to shoreline vegetation by adjacent land owners (Appendix A). The previous Shoreline Plan was written prior to the federal listing of salmon species under the ESA, which provides certain protections. In February 2008, the National Marine Fisheries Service (NMFS), Washington Department of Fish and Wildlife (WDFW), and USACE (Walla Walla District) released the objectives and proposed criteria for docks for public comment. The period of public comment was extended from February 17, 2009 to July 15, 2009. The USACE has received considerable public comment on these criteria and wants to ensure that the criteria are appropriate. The purpose of this report is to review information from the literature and determine the extent that the criteria proposed for the docks and over-water structures are supported by the current body of scientific literature.

McNary Lock and Dam Project was completed in 1953 and created McNary Reservoir, or Lake Wallula which extends from the dam (RM 292) to the free-flowing Hanford Reach (RM 353) of the Columbia River. The multipurpose benefits of the project include navigation, flood control, irrigation, power, and recreation. The reservoir shorelines provide recreational opportunities to visitors and residents of the Tri-Cities (Pasco, Kennewick, and Richland), Washington located upstream of the confluence of the Columbia and Snake rivers (Figure 1). The three municipalities have a combined population of about 235,000 people. The Tri-Cities has over 10,000 registered boats with about a 10% per year growth in boat numbers in recent years (Port of Kennewick 2007). The shoreline of the reservoir is federally owned, and as a result, the USACE has certain land and fish habitat management responsibilities to balance with multipurpose benefits. The USACE has recognized that "there are trade-offs which must be carefully weighed against each other as we all face new decisions about water use in our future" (Mighetto and Ebel 1994). Upstream of McNary Reservoir is the regulated, but free-flowing Hanford Reach of the Columbia River. On June 9, 2000, portions of the Hanford Site, including the Hanford Reach and associated islands, wildlife management areas to the north, White Bluffs, Hanford Dunes, Arid Lands Ecology Reserve, and the McGee Ranch/Riverlands area, were designated as the Hanford Reach National Monument (RM 347-385) to be administered by the Department of Interior.

The ESA listing of Columbia and Snake River stocks of salmon changed the management of salmon harvest, hydropower operations, hatchery practices, and habitat management. During the 1990s, 12 Columbia River Basin (above the Willamette River) salmon and steelhead populations were listed under the ESA (endangered or threatened). Of those 12 Evolutionarily Significant Units (ESU), eight are likely to be found migrating through McNary Reservoir as juveniles or adults (Table 1). The ESA includes a 4(d) section that requires NMFS and U.S. Fish and Wildlife Service (USFWS) to issue regulations to protect listed species by prohibiting "take". Examples of the "take" of a listed species would be the killing or harming of a listed species or destroying or destructively altering the habitat of the species. These definitions led us to question the presence or absence of listed species and to more broad questions about the functioning of riverine and reservoir ecosystems to support restoration of listed salmonid species.

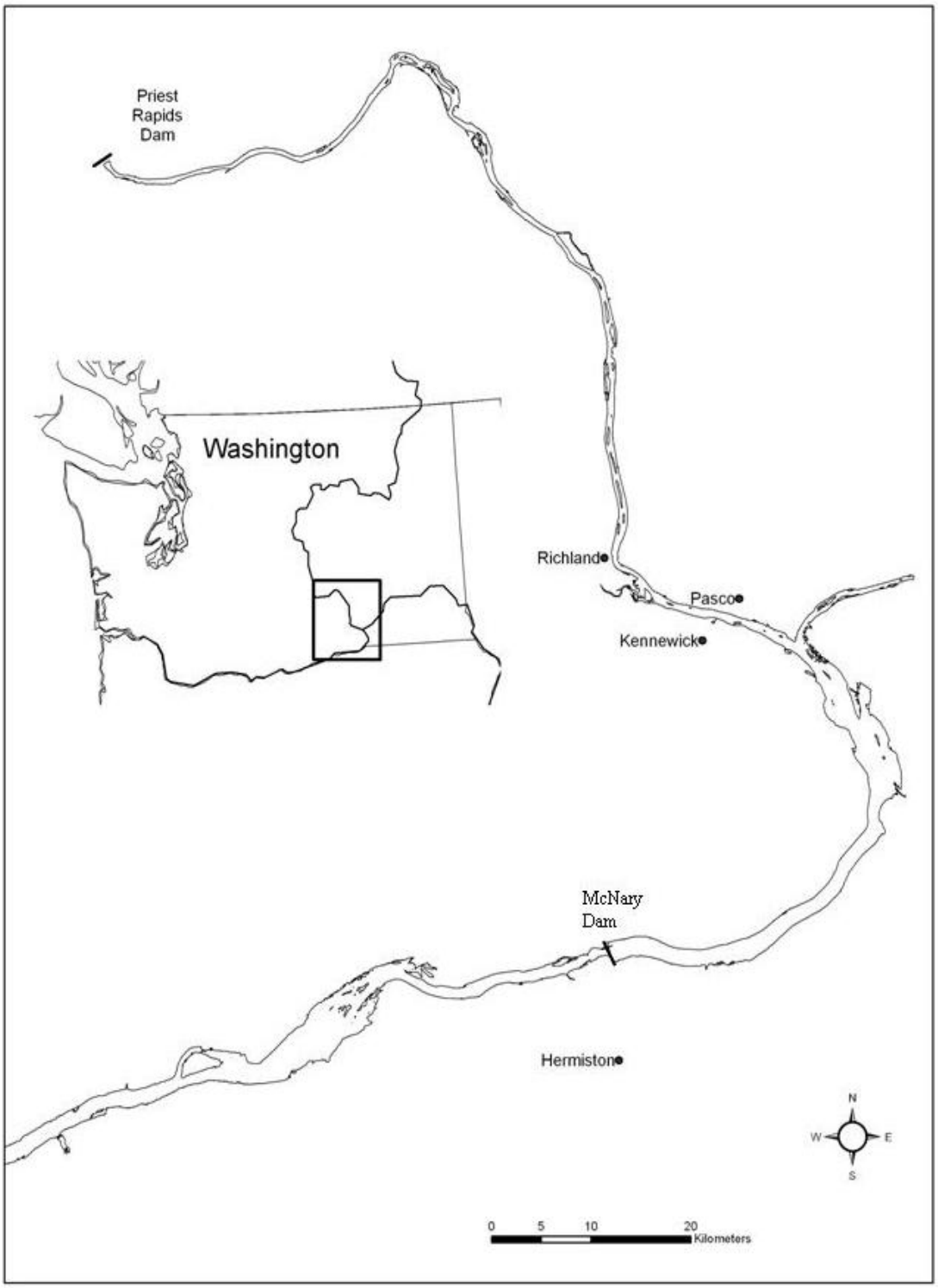

Figure 1. Map of study area on the Columbia River, including McNary Dam, Hanford Reach, and Priest Rapids Dam. McNary Reservoir extends from McNary Dam upstream to Richland, WA and the Hanford Reach extends from Richland, WA upstream to Priest Rapids Dam.

Table 1. Salmonid populations in the Columbia (above the Willamette River), and Snake rivers and their federal protection status.

Species	**Evolutionarily Significant Unit (ESU)**	**Federal ESA status**
Chinook	Snake River Fall Chinook[a,b]	Threatened
	Snake River Spring/Summer Chinook[a,b]	Threatened
	Upper Columbia River Spring Chinook[a,b]	Endangered
	Upper Columbia River Summer/Fall Chinook[a]	Not Warranted
	Mid-Columbia River Spring Chinook[a]	Not Warranted
	Lower Columbia River Chinook	Threatened
Coho	Lower Columbia River Coho	Threatened
Chum	Columbia River Chum	Threatened
Sockeye	Snake River Sockeye[a,b]	Endangered
	Okanogan River Sockeye[a]	Not Warranted
	Lake Wenatchee Socheye[a]	Not Warranted
Steelhead	Snake River Steelhead[a,b]	Threatened
	Upper Columbia River Steelhead[a,b]	Threatened
	Middle Columbia River Steelhead[a,b]	Threatened
	Lower Columbia River Steelhead	Threatened
Bull Trout	Columbia River Bull Trout[a]	Threatened

[a]Fish which use the Hanford Reach and McNary Reservoir as a migration and/or rearing corridor.
[b]Fish with designated critical habitat in the Hanford Reach and McNary Reservoir.

The reach of the Columbia River including the Hanford Reach and McNary Reservoir is designated critical habitat for seven ESA-listed salmon species (Table 1). The ESA protects threatened and endangered species in several ways. Under Section 7, all federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat. These complementary requirements apply only to federal agency actions, and the latter only to habitat that has been designated. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation. A critical habitat designation does not set up a preserve or refuge, and applies only when federal funding, permits, or projects are involved. Critical habitat requirements do not apply to citizens engaged in activities on private land that do not involve a federal agency.

Although this review is in response to issues directly related to the ESA listing of salmonid species that use McNary Reservoir as rearing habitat or a migration corridor, the ESA is not the only federal responsibility. Below are several federal regulations that may have jurisdiction for activities related to docks and over-water structures (Carrasquero 2001). In addition to these regulations, state and local governments have jurisdictional responsibility and it is in their interest to restore listed species in order to avoid future costs and regulations.

Regulatory Framework Governing Over-water Structures:

- *National Environmental Policy Act (NEPA)*

Federal agencies making funding decisions or issuing permits for over-water structures are required to comply with the National Environmental Policy Act.

- *Clean Water Act Section 404*

Construction of over-water structures that would result in discharge or excavation of dredged or fill material requires a Clean Water Act section 404 permit.

- *Rivers and Harbors Act Section 10*

Any work affecting navigable waters of the United States that extends to the ordinary high water mark in freshwater areas (including the construction of piers, docks, and floats) requires a section 10 permit issued by USACE.

- *Endangered Species Act (ESA)*

The Endangered Species Act provides broad protection for fish, wildlife, and plant species that are listed as threatened or endangered. The shoreline development activities that have federal nexus (i.e., federal funds or federal permits) are subject to review under the statute.

- *Fish and Wildlife Coordination Act*

This act requires consultation with the USFWS and the fish and wildlife agencies of States where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted, or otherwise controlled or modified" by any agency under a Federal permit or license.

- *Magnuson-Stevens Fishery Act*

The Magnuson-Stevens Fishery Act provides a national program for the conservation and management of the fishery resources of the United States. It provides broad powers to the National Marine Fisheries Service to rebuild overfished stocks, insure conservation, and to facilitate long-term protection of essential fish habitats.

- *Other State and Local Regulations*

There are many other state and local regulations including the State Environmental Policy Act, Shoreline Management Act, Clean Water Act, National Pollutant Discharge Elimination System, Hydraulic Project Approval Code, Forest Practices Act, Aquatic Lands Act, Water Pollution Control Act, Aquatic Resource Mitigation Act, Salmon Recovery Act, Wetland Mitigation Banking, and various county and city shoreline management plans.

We reviewed a wide variety of information to determine if the proposed dock criteria were supported by facts in the scientific literature. We started with several recent reviews on the biological effects of docks and over-water structures. We recognized that such reviews may or may not be biased, but they do represent the work of other authors that have evaluated the merit of relevant studies in the literature. Subsequently, we examined the peer-reviewed articles published in scientific journals and gave those articles the greatest weight in this review. Concurrently, we identified many technical reports prepared by other scientists and professionals that present information we considered relevant.

Criteria for the construction of over-water structures, such as private docks, have been developed by local, state, and federal agencies as guidance to parties within their jurisdiction proposing to construct over-water structures. To add perspective and understand the reasoning leading to dock criteria, we briefly reviewed some criteria from other regions of the U.S. such as the Southeast and Midwest (NOAA 2003; USACE 2005). To add a Northwest regional perspective, we reviewed dock criteria or reviews from the Puget Sound area and the Wells Dam Pool on the mid-Columbia River (Simenstad et al. 1999; Carrasquero 2001; Chapman 2007). We looked to entities having jurisdiction in the Columbia River Basin and reviewed proposed dock and over-water structure criteria of the Washington Department of Fish and Wildlife.

We have organized the results of this review paper in two primary sections followed by a brief discussion. The first section is the “Background” and the second section is the “Proposed Criteria and Findings”. During the review, it became evident that the risk of predation for juvenile salmonids may increase for juvenile salmonids near docks and over-water structures. Because no studies specifically evaluated docks and predation risk to juvenile salmon in McNary Reservoir, some readers may feel the available literature provides little information. That is not the case. Most scientists strive to demonstrate broadly applicable functional relations in biology and peer-reviewed journals prefer to publish papers that are broadly applicable. Therefore, in

this review we start by presenting compelling findings about predators, predator-prey relations, light, and habitat from a wide range of locations and habitats. However, in weighing the information during our review, we did not restrict our observations to predator-prey relations to large rivers, but selectively included lakes, streams, and marine environments. In an attempt to be selective, we relied most heavily on descriptions of the distribution and biology of juvenile salmonids from McNary Reservoir and the nearby reaches of the Columbia and Snake rivers. In the Proposed Criteria and Findings section, we present information from the literature most applicable to the proposed criteria along with our findings.

Background

Dock Criteria of Other Jurisdictions

We conducted a literature search to survey dock criteria as required in other jurisdictions. We have examined city, county, state, and federal documents from several regions of the United States and Canada. Many regulatory agencies have some criteria regarding the permitting of docks in their jurisdiction. We did not find any dock criteria specifically addressing concerns posed by the Endangered Species Act. However, most localities share some of the same concerns related to over-water structures such as:

- Adverse impacts to biological communities that provide functions to fish and wildlife, such as seagrass and other aquatic vegetation (such as marshes and mangroves) - due to shading and dredge/fill activities.
- Loss of endangered species
- Adverse effects of docks on other wetland-dependent species - for instance, those that nest and breed in the uplands and in adjacent shellfish beds.
- Degradation of water quality - turbidity from installation of related pilings and leaching of chromium, arsenic, and copper from such pilings.
- Propeller dredging and other dredging of access channels sometimes associated with dock use
- Loss of archaeological and historical resources

Specifically, we have found that in North and South Carolina, Georgia, and Florida dock criteria regulate maximum length, width, minimum height above the water and total square footage. Federal managers in these states cite a lack of conclusive research on cumulative impacts of docks, and finding and accessing the research that has been done as the main difficulty in managing the permitting of docks and piers (NOAA 2003).

Wisconsin regulates residential docks on private lands, and has requirements regarding the construction, size, and placement of the dock. Again there seem to be no “listed salmonid specific” criteria. Other states such as Oregon and Minnesota are in a transitional period. They have recognized the need for reform and regulation of over-water structures but have not yet published specific criteria for the construction of residential docks.

Salmonids in the Nearshore

Bull trout are listed as threatened under the ESA (Table 1) and have fluvial, adfluvial, and anadromous forms (Brenkman and Corbett 2005; USFWS 2008). Bull trout show diverse life histories and most live in cold-water tributaries in the Columbia River Basin. However, bull trout can also move from natal watersheds to other watersheds and marine waters (Brenkman and Corbett 2005). McNary Reservoir may provide connectivity between populations of bull trout in watersheds such as the Walla Walla River and the Yakima River. As habitat in the lower reaches of tributaries is restored, it is possible that the connectivity provided by reservoirs will become more evident. Reservoir habitats are probably mainly used by adult bull trout for overwintering and migration. Nelson and Nelle (2008) showed that some adult bull trout overwinter in reservoirs in the upper mid-Columbia River where several tributaries have bull trout populations. We did not find information indicating that juvenile or adult bull trout specifically used the littoral areas of the reservoir, and the current available information does not suggest that use of reservoir littoral habitats would be very high if populations are restored in tributaries.

Adult fall Chinook salmon historically spawned from the main-stem Columbia River, near The Dalles, Oregon, upstream to the confluence of the Kootenai River in British Columbia (Fulton 1968; Dauble and Watson 1997). Impoundment by hydroelectric dams has blocked access to more than 75% of their historic spawning habitat (Van Hyning 1969; Horner and Bjornn 1979; Dauble and Watson 1997). Primary spawning areas for upriver fall Chinook salmon in the Columbia River are now restricted to the Hanford Reach, RM 341-397 (Dauble 2000) and the tailraces of main-stem dams (e.g., McMichael et al. 2005). Spawning surveys conducted on the Hanford Reach have shown that redds are concentrated upstream of RM 348 (Groves 1999; Geist 2000; Dauble 2000). These redds are produced by fall Chinook salmon and no steelhead redds were found during aerial surveys conducted by Mueller (1999). As much as 80% of spawning in the Columbia River probably occurs in water too deep to be observed by above-water surveys (Chapman 1986; Swan 1989; Groves 1999). We concluded adult salmon and steelhead use of the nearshore area is probably minimal so we further restricted our review to the juvenile life stages of salmon.

The life history patterns of Pacific salmonids are complex and are expressed by high diversity in the seaward migration timing and habitat use by juvenile salmonids. However, even observations made in recent decades about migration patterns of juvenile salmonids may not capture the richness or plasticity of salmon life history patterns that were historically present in the Columbia River. For example, a wide variation in life history patterns is evident from the observations of Rich (1922) in the lower Columbia River. In the upper Columbia River, steelhead can migrate to the ocean at ages ranging from one to seven years (Peven et al.1994). Chinook salmon can be divided into ocean-type and stream-type, as well as spring, summer, and fall runs (Carl and Healey 1984). Ocean-type salmon migrate to the ocean during their first year and stream-type salmon spend one or more years rearing in natal streams. Upper Columbia River sockeye *Oncorhynchus nerka* migrate from Lake Okanagan and Lake Wenatchee at different sizes. In general, juvenile salmon of different sizes often have different behavior, disposition to migrate, and distribution in reservoirs (Peven 1987).

Millions of juvenile salmonids migrate through McNary Reservoir each year. The Hanford reach alone produces 20-30 million subyearling fall Chinook salmon annually, (Washington Department of Fish and Wildlife, unpublished data) many of which rear in Lake Wallula. These fall Chinook salmon are not ESA-listed (Table 1). Wild and hatchery stocks of fall and spring Chinook salmon, sockeye salmon, coho salmon *Oncorhynchus kisutch*, and steelhead migrate through this reach each spring and summer. Of these species, juvenile fall Chinook salmon are the most likely to inhabit the littoral zone (Dauble et al. 1989; Rondorf et al. 1990). However, other stocks are occasionally found near shore in smaller numbers (Mains and Smith 1956, Dauble et al. 1989). Moreover, juvenile salmonids in the littoral zone commonly assumed to be fall Chinook salmon are probably intermixed with spring Chinook salmon stocks, which are listed as endangered.

Subyearling Chinook salmon use shallow, nearshore areas from the time they emerge from the redd until the time they reach approximately 80 mm in length. They rear in the littoral zone from approximately March through June (Chapman 2007). As they grow, they increasingly use deeper water, though they continue to move into the shallows at night to rest on the bottom. Some subyearlings remain in the main-stem Columbia River to over winter and migrate downstream as yearlings. These may be either ocean or stream type fish though this is the defining life history pattern for stream-type Chinook salmon. As subyearlings become larger than 60-70 mm, their behavioral tendency to use offshore habitats reduces their susceptibility to predators in the littoral zone and, hence, their vulnerability around docks (Chapman 2007). As the subyearlings begin to move downstream, they continue to use the littoral zone for feeding and resting.

Mains and Smith (1956) conducted a two-year study on the Columbia and Snake rivers and found that juvenile Chinook salmon began migrating downstream in March and the migration was virtually over by the beginning of July. Seaward migrating Chinook salmon passed Beyers Landing (RM 341) on the Columbia at the upper end of the McNary Reach during all hours of the day. Peak movement occurred between 1800 hours and 0600 hours, but fish were caught throughout the day. Nets deployed closest to shore (about 100 ft from shore) accounted for 68% of the total sample. Approximately 76% of fish were age 0 that were 36-55 mm in length. The remaining 24% of fish were age 1+ that were 85-105 mm. These 85-105 mm fish represent spring Chinook salmon, and the 36-55 mm fish represent fall Chinook salmon. Chinook salmon were present in considerable numbers over the entire width and depth of the river. Subyearling fall Chinook salmon preferred the surface layers and water near the shoreline whereas spring Chinook salmon generally occupied deeper waters farther from shore.

Dauble et al. (1990) conducted a similar study in 1989 during the spring out-migration. They found that 52% of subyearling fall Chinook salmon were caught within 100 ft of shore in water 5.9 m deep, or less. In contrast, yearling spring Chinook salmon used deeper water with only 7% of fish being caught within 100 ft of shore in water 5.9 m deep, or less. Sockeye salmon also used deeper water with 3% of fish being caught from waters less than 5.9 m deep.

Although both of these studies demonstrate that spring Chinook and sockeye salmon mainly use deeper water during their downstream migration, they also show that some fish are

found in the littoral zone. Additionally, the most abundant group in the littoral zone—subyearling fall Chinook salmon—is likely composed of both fall and spring (ocean and stream) type Chinook salmon. In most cases, these groups are visually indistinguishable. Marshall et al. (2000) used allozyme allele frequency differences to identify subyearling Chinook salmon caught in beach seines along the lower Snake River. They found that a large proportion of subyearlings were actually spring Chinook salmon. In fact, in 1991, 50% of the subyearlings caught in beach seines were spring Chinook salmon. In 1993, 62% of the subyearlings sampled along the lower Snake River were spring Chinook salmon. In 1994 and 1995, spring Chinook salmon composed 14% and 5% of the total catch, respectively. They concluded that although the timing and sample locations were selected to capture subyearling fall Chinook salmon, numerous subyearling spring Chinook salmon were also found in non-natal, main-stem areas. In a subsequent study, Connor et al. (2001) concluded that subyearling spring Chinook salmon are capable of dispersing long distances from natal stream habitats to main-stem riverine habitats. These subyearlings that rear along the shorelines of main-stem habitats are able to exploit the higher growth opportunity found there and reach smolt sizes as subyearlings. Though these studies have not been repeated in the McNary Reservoir, it is reasonable to expect subyearling spring Chinook salmon to occasionally use nearshore, main-stem habitats just as fall subyearlings do. As spring Chinook salmon populations are restored, we believe studies will show their life histories and habitat preferences are more diverse than many expect. We conclude that although subyearling fall Chinook salmon are abundant and not listed, listed stocks of salmonids will use nearshore areas as well.

Predators

Predation by piscivorous fish and birds is the principal mechanism of mortality of juvenile salmonids migrating through Columbia River reservoirs (Chapman et al. 1994). The most significant predators of salmonids in the Columbia River reservoirs are smallmouth bass, northern pikeminnow, walleye *Sander vitreus*, and channel catfish *Ictalurus punctatus* (Rieman et al. 1991; Vigg et al. 1991). Smallmouth bass is a non-native predator that has flourished in reservoir habitats. It was introduced to the West Coast in 1874 (CA) and the Yakima River in 1925 (Boersma et al. 2006). By the early 1940's, smallmouth bass were well established and plentiful in the Columbia River up to the Snake River (Lampman 1946). Northern pikeminnow are native predators that consume large numbers of juvenile salmonids annually. Both channel catfish and walleye are known to prey on juvenile salmonids, but to a less extent than smallmouth bass and northern pikeminnow.

Much attention has been directed toward non-indigenous species in the past few years. A recent count of non-native species that have successfully established populations in WA, OR and ID is over 900 (Sanderson et al. 2009). The effects of non-native species invasions and habitat degradation are the two leading causes of decline of native species in North American freshwaters (Richter et al. 1997; Wilcove et al. 1998). On the Columbia River, reservoirs created by hydroelectric dams have created prime habitat for non-native species to thrive and spread. For example, the population of American shad *Alosa sapidissima* has dramatically increased in recent years. A peak of 5.3 million adults were counted at Bonneville Dam in 2004. Juvenile American shad may reduce zooplankton biomass and act as a food source for predators. However, it is unclear how severely shad are affecting salmon populations (Petersen et al. 2003).

The littoral zone of the Columbia River is seeing a shift from native resident fish to non-native species (ISAB 2008). Of concern is the proliferation of predators in these habitats.

Avian predation constitutes a significant source of mortality to juvenile salmonids during out-migration. Rates of predation on juvenile salmonids by piscivorous birds may range from 5-15 million out migrating smolt each year (Collis and Roby 2008). Over the past 40 years the populations of gulls *Larus spp.*, terns *Sterna spp*., cormorants *Phalacrocorax spp.*, and pelicans *Pelecanus spp.*, in the Columbia Basin have increased, in some cases dramatically (Collis et. al 2002). Construction of docks and pilings can create habitat for perching birds such as cormorants. This perching habitat may be limited by the use of pile caps and other avian exclusion devices. Over-water structures and related construction activities that modify the shoreline configuration (e.g., increasing the shoreline slope and eliminating shallow-water habitat refugia) could potentially affect predation rates by piscivorous birds on salmonids. This may occur, for example, if the shore-zone habitat and shallow habitat refugia are eliminated, forcing juvenile fish to venture into deeper waters where predator diving birds may have increased success. This is of particular importance to juvenile Chinook salmon, which have the greatest affinity to shore-zone shallow-water habitats (Garland and Tiffan 1999; Rondorf et al. 1990).

Our review led us to consider the proposed criteria and how these changes will affect predator-prey interactions in the littoral area of McNary Reservoir. Extensive literature research confirms that our knowledge on many of these topics is limited. Empirical evidence is lacking and much of the scientific information is based on research of other species and other ecological systems (free-flowing rivers or lakes). In the Northwest, studies have been conducted on predator use of over-water structures, but many of these were conducted in Lake Washington and Lake Sammamish (Stein 1970; Pflug 1981; Pflug and Pauley 1984; Kahler et al. 2000; Fresh et al. 2003). Though numerous research studies have been conducted on predator-prey relations in Columbia River reservoirs, none of the studies has addressed the use of docks and piers. Much of the literature on light and its relation to over-water structures and predator-prey interactions was derived from laboratory experiments.

The salmonid prey most likely to be found near over-water structures in the littoral zone is the migrating ocean-type juvenile fall Chinook salmon. Nearshore habitats in the main-stem Columbia River within the study area are critically important for subyearling fall Chinook salmon (Dauble et al. 1989; Rondorf et al. 1990). Since salmonid fry and juveniles use the littoral zone as rearing habitat, they are most vulnerable to predators. Most predation on juvenile Chinook salmon in the Columbia River occurs during the peak of their out-migration (Gray and Rondorf 1986; Vigg et al. 1991; Poe et al. 1991; Zimmerman 1999). After subyearlings become larger than 60 to 70 mm, their behavior greatly reduces their vulnerability to predators in littoral zones and around docks (Chapman 2007). Larger smolts (i.e., yearling Chinook salmon, steelhead, and sockeye) use deep, mid-channel areas in contrast to subyearling Chinook salmon, which use shallower shoreline areas (Dauble 2000).

Over-water structures may increase predation of juvenile Chinook salmon in several ways. First, piers and docks can provide cover and preferred habitat for ambush predators such as smallmouth bass. Second, they create shaded areas that can increase a predator's capture

efficiency of prey. Third, they interrupt migration routes and timing of migrating salmonids. The additional time spent navigating around these structures increase exposure to predators in these areas. Finally, changes in substrate, aquatic vegetation, and ambient light caused by over-water structures may indirectly increase predation through complex ecological pathways.

Since the primary disruption of predator-prey interactions associated with over-water structures is probably greatest in the littoral zone, we will focus on predators that use nearshore habitat: northern pikeminnow and smallmouth bass. Both predators are generalist piscivores, practicing visual, ambush, and habituation foraging type hunting styles. Northern pikeminnow feed primarily on juvenile salmonids (Petersen et al. 1993), are the primary predator of juvenile salmonids in Columbia River reservoirs (Poe et al 1988; Vigg et al. 1991; Zimmerman 1999), and have the greatest potential for predation of juvenile salmonids (Beamesderfer and Rieman 1988). Smallmouth bass are also a substantial predator of subyearling Chinook salmon because of the overlap in rearing habitat between the species (Curet 1993; Tabor et al. 1993; Garland and Tiffan 1999).

Consumption

Consumption rates of smallmouth bass and northern pikeminnow vary among species, habitat, and prey availability. Tabor et al. (1993) found that subyearling Chinook salmon made up 59% of smallmouth bass diets and 28.8% of northern pikeminnow diets in a study conducted during May and June upstream of McNary Reservoir. These authors showed smallmouth bass consumed 1.0–1.4 salmonids/day and northern pikeminnow consumed 0.3–0.6 salmonids/day Research conducted from 1983 to 1986 concluded that resident predator fishes consumed between 1.9 and 3.3 million juvenile salmon and steelhead annually in the John Day Reservoir alone. Northern pikeminnow accounted for 78% of the losses, which equated to 1.5-2.6 million fish or 7.2% of the run of 19 million salmon migrants (Rieman et al. 1991). Petersen et al. (1993) estimated that losses of juvenile salmonids to northern pikeminnow decreased to 1.4 million per year (7% of run) if stratified by four or more reservoir areas rather than the two areas used by Rieman et al. (1991). The findings of Beamesderfer (1996) mirrored both Rieman and Petersen's results closely: northern pikeminnow consumed an estimated 16 million migrants per year or about 8% of the population. Zimmerman (1999) suggested that salmonids are only seasonally abundant in bass diets in the Columbia River and that other fish species, crayfish and invertebrates are the major source of food during the rest of the year. There is evidence that consumption rates and energetic demands of northern pikeminnow and smallmouth bass increase between spring and summer as temperatures rise (Vigg et al. 1991; Petersen and Ward 1999).

Non-native species consume significantly more juvenile salmonids as water temperatures rise (Vigg et al. 1991). Consequently, predators that use shallower, warmer habitats near shore will consume more prey compared to those that select cooler temperature off shore. Centrarchids (e.g., sunfishes such as bass) have greater tolerance for higher expected average water temperatures than native salmonids and other resident species (ISAB 2008). Climate change models predict an increase of 1°C or greater in the Columbia and Snake River reservoirs by 2040 (Hamlet and Lettenmaier 1999; Payne et al. 2004). These increases in temperature will result in higher growth rates and consumption by predators. Subyearling fall Chinook salmon will suffer the most from these changes due to late spring and summer migrations coinciding

with the hottest months of the year and highest consumption rate by predators (Poe et al. 1991; Vigg et al. 1991).

Nearshore Habitat Use

We focused our review on nearshore, littoral habitats because these are most important for rearing salmonid and are also important to predators. Subyearling Chinook salmon rear along shallow main-stem shorelines for 2 to 4 months in the spring following emergence (Tiffan et al. 2006). After this time, larger fish migrate downstream during late spring and through the summer. As the salmon migrate downstream, they increase in size and move farther offshore. In McNary Reservoir, subyearling Chinook salmon favored water less than 2 m deep in May and moved to deeper water as they approached 80 mm in June (Grey and Rondorf 1986). In the Hanford Reach, juvenile Chinook salmon used nearshore depths of 0.75 m until about June (Vendetti et al. 1997) and preferred low lateral bed slope (<30%) with velocities less than 0.4 m/s (Tiffan et al. 2002).

These shallow shoreline habitats with low velocities and slopes offer juvenile salmon refugia from predatory fish that may be too large to enter very shallow water. Several studies have shown lack of predation in the littoral zone making this a safe place for small fish to rear and feed. Feeding rates by fish smaller than 100 mm was 10 times higher in shallow water (<10 cm) than in the rest of the littoral zone (Collins et al.1995). Brown (1998) observed no piscivores in "littoral fringe" (within 2.5 m of shore) transects in Lake Joseph, Ontario. These findings support the criteria for the minimum 10 feet depth of water and the placing of the dock 40 feet from the OHWM. Savino and Stein (1989) found that largemouth bass captured all prey fish that strayed from areas with aquatic vegetation into open water, demonstrating that refuge is critical for prey survival. Bass preyed on grazing minnows from all but the shallow sections of pools in Oklahoma streams (Power et al. 1985).

Although shallow waters provide warmer temperatures that enhance growth, seasonal warming in nearshore habitats of the Columbia River ultimately causes temperatures to become too warm for salmonids. By mid to late summer, nearshore areas often become too warm for rearing subyearling Chinook salmon (Tiffan et al. 2006). Curet (1993) observed fish moving into deeper, cooler waters when shoreline areas became too warm in the Lower Granite Reservoir. During a study in the Columbia River, Key et al. (1994) found that optimal temperatures for sampling subyearling Chinook salmon were between 12-15.9°C and that catch decreased significantly when temperatures were any warmer. Average temperatures in the Columbia River can reach 20–21.5°C in August and September, (Goniea 2006) whereas nearshore temperatures can be much higher. By this time, most subyearling Chinook salmon have left nearshore areas and are actively migrating seaward.

The littoral zone also contains the highest abundance of terrestrial insects, the preferred food for subyearling Chinook salmon in McNary Reservoir (Rondorf et al. 1990). This close relation between the diet of subyearling Chinook salmon and riparian vegetation and possibly the upland landscape is important to recognize when considering criteria for shoreline use in urban areas. The preferred diet of juvenile Chinook salmon in the Hanford Reach differs from that in McNary Reservoir. Rondorf et al. (1990) found that caddisflies (64% by weight) were preferred

by fish in the Hanford Reach, whereas zooplankton and especially terrestrial insects, were abundant in diets of fish in McNary Reservoir. These findings are consistent with those of Becker (1973) and Dauble (1980) who also observed caddisflies making up the majority of juvenile Chinook salmon diets in the Hanford Reach. Wiggins (1977) also reported caddisflies making up 64% by weight of the diet of fish in riverine reaches, but less than 1% of the diet in reservoir reaches. In a study of lower Columbia River reservoirs, Craddock (1976) showed that terrestrial insects were the major component in juvenile Chinook salmon stomachs in the spring and fall.

Developed shorelines may limit available habitat for juvenile salmonids while providing habitat for predator species. Numerous studies in the mainstem Columbia and Snake rivers report that subyearling Chinook salmon prefer sandy or small gravel/cobble substrate and avoid complex habitats such as bedrock cliffs and riprap (Bennet et al.1992; Curet 1993; Key et al.1996; Garland and Tiffan 1999). In McNary Reservoir, substrate size was the most important factor in determining subyearling Chinook salmon presence in nearshore habitats (Garland et al. 2002). These authors found that dominant substrates larger than 256 mm (i.e., riprap) have the lowest probability of subyearling salmon presence. Key et al. (1996) observed that predator species were often located in riprap areas in McNary Reservoir. Riprap shoreline constitutes 23% of the McNary Reservoir according to a study done by the USACE in 1976.

In contrast to juvenile salmonids, smallmouth bass prefer hard substrates such as cobble/gravel and steep drop-offs lacking aquatic vegetation (Coble 1975; Pflug 1981; Pflug and Pauley 1984). Ninety percent of the smallmouth bass sampled in a study of the upper McNary Reservoir were collected from low-velocity backwater areas along the shoreline (Tabor et al. 1993). When smallmouth bass are found over sandy substrates, they show an active hunting behavior and pelagic feeding (Danehy and Ringler 1991). According to Dauble et al. (1989), wild fall Chinook salmon may be more vulnerable to predation by smallmouth bass because they are often smaller and more abundant in nearshore areas than hatchery-released fall Chinook salmon. McNary Reservoir contains significant reaches of sand and gravel shoreline and bass have adapted to use this habitat in absence of more complex substrate.

Northern pikeminnow in Columbia River reservoirs occupy free-flowing areas with low-velocity (1-foot per second or less) microhabitats and back-eddies (Beamesderfer and Rieman 1988; Petersen et al 1992). Northern pikeminnow are the primary predator of juvenile salmonids in Columbia River reservoirs (Poe et al 1988; Vigg et al.; 1991; Zimmerman 1999). The predation of northern pikeminnow upon salmonids is of such great concern that since 1990, there has been a federally administered angler reward program in the main-stem Columbia and Snake rivers. From 1990 to 2008, over 3.3 million northern pikeminnow were removed by the sport reward program and it is estimated that predation on juvenile salmonids has been reduced by 37% (pikeminnow.org 2009). Pilings supporting over-water structures create backwater, low-velocity habitat preferred by these predators, likely contributing to their overall biological success.

Structure Use

Several studies suggest that bass populations benefit from use of docks and piers in lakes. Bass will use simple structures in the absence of more complex natural habitat. However, it is unclear what feature (or combination of features) is actually attracting them to the structure. Smallmouth bass in flowing systems use the overhead cover and low-velocity refuge provided by physical structure (Probst et al. 1984; Rankin 1986; Todd and Rabeni 1989). Hanes and Butler (1969) showed that structures providing shade were selected most frequently by yearling smallmouth bass. In Lake Joseph, Ontario, densities of young-of-the year smallmouth bass were highest in areas with high concentrations of shorezone structures (Brown 1998). In Spirit Lake, Iowa, smallmouth bass were the only juvenile species (of the 20 sampled) that were found in equal or greater abundance in developed sites than in undeveloped sites (Bryan and Scarnecchia 1992). During a SCUBA survey in Lake Washington, 72% of smallmouth bass were observed laying within 2 m of some sort of structure, and they preferred large docks with large numbers of pilings (Fresh et al. 2003).

Bass often build nests near over-water structures, and the protection they afford may contribute to their reproductive success. Male smallmouth bass in Lake Sammamish generally built nests within 7 to 20 m of shore, on gently sloping gravel/cobble substrates, devoid of vegetation at depths of 1 to 3 m, and near a structural element such as log, boulder, pile, or other artificial structure (Pflug and Pauley 1984; Kahler et al. 2000). Smallmouth nests were also found close to sheltered habitat in Bull Shoals Reservoir (Vogele and Rainwater 1975). Building nests adjacent to structures can provide visual isolation and reduce area that must be guarded by male parents. It is likely that the construction of over-water structures near shore and in less than approximately 3 m of depth will increase the reproductive success of smallmouth bass.

Perhaps another attraction of bass to over-water structures is due to the visual advantage gained for foraging. Helfman (1979; 1981) found that the number of fish using shade-producing objects as cover on bright days was directly related to the dimensions of the structure. Largemouth bass preferred large to small study floats that shielded them from high light intensities suggesting that the created shade provided a visual advantage for predators to see approaching prey. A shaded predator can see sunlit prey more than 2.5 times as far away compared to the distance a predator in bright light can see prey in a dark area (Helfman 1981). Therefore, prey fish may use the shade provided by small floating objects to avoid being detected by a predator approaching from the brightly lit surrounding area.

We found no empirical evidence in the literature on how northern pikeminnows use over-water structures. Studies conducted on the lower Willamette River in Oregon did not find a relation between shoreline development (including piers) and northern pikeminnow predation on outmigrating Chinook salmon (Ward et al.1994; Friesen 2006). However, it is noteworthy that these studies had small sample sizes and took place in areas with relatively low densities of predators. In contrast, pile fields and pile dikes consistently produced high electrofishing catches of northern pikeminnow in the Columbia River downstream of Bonneville Dam (Conrad Frost, U.S. Geological Survey, personal communication). It is reasonable to assume that where pilings provide sufficient refuge from surrounding velocity, northern pikeminnow will use them.

Light

Light is important to a variety of biological functions of juvenile salmonids, particularly in shallow nearshore waters. Light functions as a biomarker in such complex biological interactions as: foraging, schooling, predator avoidance, visual orientation, and migration (Simenstad et al. 1999). As such, changes in ambient light conditions could alter the physiology and behavior of juvenile salmonids that may ultimately affect their survival.

It is important to consider whether artificial illumination outside of the normal circadian cycle affects organisms. Artificial lighting that is often present on over-water structures may disorient migrating juvenile salmonids, compromise their ability to avoid nocturnal predators, and affect the photosynthesis of aquatic vegetation. Little is understood about how artificial lights affect these complex ecological systems. Many laboratory experiments have been conducted in order to test the effects of artificial light on fish behavior. However, it is not always possible to extrapolate behavioral responses from the laboratory to the field. McDonald (1960) showed that downstream migration of sockeye and coho salmon fry was inhibited when artificial lights illuminated experimental stream channels; but when the lights were turned off, migration resumed as normal.

Light also affects the efficiency of sight-feeding predators and the behavior and vulnerability of prey. For example, there is a strong correlation between illumination and foraging efficiency in juvenile Chinook salmon. Juvenile salmonids feed primarily on drifting invertebrates during sunrise and dusk, but do not feed during complete darkness (Brett and Groot 1963; Fraser et al. 1997). The presence of artificial light may facilitate juvenile fish feeding which in turn may increase their vulnerability to predation at night. The dependence of invertebrate behavior on light is also well documented. The diel vertical migrations of zooplankton and invertebrates such as *Neomysis mercedis* depend largely on light as a proximate cue (Forward and Hettler 1992; Haskell and Stanford 2006). The presence of artificial light may alter zooplankton and invertebrate behavior making them more vulnerable to predation. The role that artificial light plays in the feeding behavior of piscivorous predators may be more complex.

Intuitively, one might think that additional light would be beneficial to visual ambush predators. However, Petersen and Gadomski (1994) found that with increasing light intensity the predation rate between northern pikeminnow and juvenile Chinook salmon decreased. This suggests that northern pikeminnow feed more actively under the low-light such as at dusk and dawn. This relationship was also shown during studies between sculpin and sockeye fry (Tabor et al.1998). This was probably due to an enhanced ability of the fry to detect and avoid sculpin, rather than a suppression of sculpin predatory behavior. Sculpin are non-visual hunters; so in darkness they may use some other sensory mechanisms besides vision to detect prey. We expect the amount of illumination provided around over-water structures at night to be relatively low, and may be more typical of dawn and dusk periods when predatory fishes actively feed.

There is ample scientific literature to support the notion that migrating juvenile Chinook salmon become disoriented when confronted with shaded habitats. Migrating juvenile salmon tend to avoid overhead cover and instead maneuver along the edges rather than penetrate them (Prinslow et al. 1980; Weitkamp 1982; Ratte and Salo 1985; Dames and Moore 1994; Taylor and Willey 1997; Pentec Environmental 1997). This behavior has also been seen in other fish species that are reluctant to enter covered or darkened structures (Glass and Wardle 1995;

Welton et al. 2002). It is unclear how this may affect energetic and predatory costs to the fish, but it is commonly assumed to be detrimental to survival (Simenstead et al. 1999). Taylor and Willey (1997) observed schools of juvenile salmon splitting into groups and entering a state of confusion when confronted with overhead shading. The reason for this behavior is also unknown, but it may be a predator avoidance mechanism (Scheuerell and Schindeler 2003). Kemp et al. (2005) found that when migrating subyearling Chinook salmon (average 95 mm) were faced with the choice of covered and uncovered channels at McNary Dam, 75% of the fish avoided the covered channels. This behavior was size related with smaller fish being most likely to avoid traveling through shaded habitat.

Visual Adaptations of Predators and Salmonids

Due to the complex nature of light in water, fish have evolved well-developed and highly specialized eyes. The *Oncorhynchus* sp*p*. eye contains a large number of rods and cones, showing that it is adapted for vision in both bright and dim light (Brett and Ali 1958). Rods and cones contained within the visual cell layer respond to changes in light by changing their position. The visual cells of smolts are oriented such that they are responsive to ambient light, and not to a circadian clock (Simenstead et al. 1999).

Variances in background illumination cause changes in sensitivity of rod and cone photoreceptors. When light levels change abruptly, the eye has to adapt quickly in order to distinguish objects in the background (Dowling 1967; Riggs 1971). Light adaptation can be explored by determining incremental thresholds: as the background or adapting stimulus impinging on a receptor increases, so does the threshold level of stimulus to which the receptor can respond (Barlow 1972; Blackwell 1972; Dowling and Ripps 1972; Blaxter 1977; Northmore 1977). When the light intensity is above the thresholds levels, the cone cells contract to be near the source of light and the rods elongate away from the light. In contrast, when the light intensity falls below threshold values, the cones expand away from the light and the rods contract towards it (Ali 1959). The amount that a fish's eye must change from one state to another when encountering such a stimulus depends upon the intensity of the introduced light. When the introduced light is bright, the eye will not respond to a dim light, which it may have detected under lower light conditions (Simenstad et al. 1999). This makes it difficult for juvenile salmon to detect predators in the shaded region beyond the brightly lit area.

Over-water structures can cause sharp differences in underwater light intensities, changing the natural lighting regime for both day and night. It is important to understand the behavioral response of salmonids to these light variations. Fish will respond differently depending upon the magnitude of light to which it was exposed before it encountered shade. When the light drops below the rod threshold, schools disband and feeding stops (Ali 1958). Differences in behavior are also species dependent. Species that tend to school such as Chinook salmon, pink, and chum salmon typically react strongly to alarm (such as changes in light intensity). Whereas coho, a non-schooling salmonid, exhibit a less startled behavior (Hoar 1957).

Proposed Criteria and Findings

Proposed Criterion:
To prevent damage to shallow water habitat, piers and/or ramps shall extend at least 40 feet perpendicular from the OHWM.

- Establishes defacto no-wake zone 40 ft from the shoreline.
- A no wake zone of 100 ft from the shoreline is an effective means to protect the littoral zone from erosion and other effects caused by motorized watercraft (Asplund 2000).
- Aquatic plant community, diversity and biomass are negatively impacted by motor boat traffic (Zieman 1976; Murphy and Eaton, 1983; Vermaat and Bruyne 1993; Mumma 1996; Asplund 1997).
- There is no direct link in the literature to the 40 ft dimension. There is substantial evidence that motor boat activity near the shore negatively affects erosion and aquatic vegetation and is therefore a reasonable criterion supported by the scientific literature.

Proposed Criterion:
Piers and ramps shall be no more than 4 feet in width.

- The 4-ft width may minimize the effects of the decrease in light levels below the ramp, and still allow safe access to the dock.
- There is much data regarding fish behavior in shadows and predation interactions under different lighting regimes. In general, predation on juvenile salmonids decreases as light intensity increases (Petersen and Gadomski 1994; Tabor et al. 1998).
- Structures providing darkness are most likely to be selected by smallmouth bass Haines and Butler (1969).
- We found no scientific evidence that 4 ft was the optimum width of a ramp or pier, but there is much evidence that the lighting regime should remain as natural as possible.

Proposed Criterion:
The bottom of the pier or bottom of the landward edge of the ramp shall be elevated at least 2 feet above the plane of OHWM.

- Minimizes the risk of losing the ramp to high flows.

- Allows light to penetrate the surface of the water. The benefits of lighting are well documented both in terms of primary production and predator-prey interactions (Carrasquero 2001).

- We did not find any additional scientific literature specifically addressing this criterion.

Proposed Criterion:
Grating shall cover the entire surface area (100%) of the pier and/or ramp. The open area of grating shall be at least 50% as rated by the manufacturer.
Grating shall cover 100% of the surface area of the float(s). The open area of the grating shall be no less than 50% as rated by the manufacturer.
Nothing shall be placed on the over-water structure that will reduce natural light penetration through the structure.

- Allows light to pass through the ramp and float.

- Juvenile salmon better avoid predators at higher levels of light which suggests that shaded areas around and under docks may reduce juvenile salmonids ability to avoid predation (Peterson and Gadomski 1994; Tabor 1998).

- Migrating juvenile salmon avoid covered areas. They tend to swim around docks, forcing them into deeper water where there is a greater chance of predation (Kemp 2005).

- The cumulative effect of many individual docks limits primary production, reducing phytoplankton and insect populations (Jennings et al.1999; Simenstad et al. 1999; Carrasquero 2001).

- We infer that changing the lighting regime will have an adverse effect on predation of juvenile salmonids. Smallmouth bass, and to a lesser extent northern pikeminnow, are attracted to the cover that over-water structures provide. If over-water structures are constructed in habitat used by juvenile salmonids for rearing or migrating, we expect there will be an increase in predation upon the juvenile salmonids

Proposed Criterion:
Skirting shall not be placed on piers, ramps, or floats. Protective bumper material will be allowed along the outside edge of the float as long as the material does not extend below the bottom edge of the float frame or impede light penetration.

- Lighting issues exacerbated by skirting are noted in the above section.
- Skirting provides a visual barrier that may be used by smallmouth bass to ambush prey.

- We found no literature specifically addressing the effects of skirting.

Proposed Criterion:
Shoreline concrete anchors must be placed at least 10 feet landward from the OHWM and shall be sized no larger than 4 feet wide by 4 feet long, unless otherwise approved by NMFS, USACE, and WDFW.

- The riparian zone holds significant value by providing habitat for aquatic insects, the diet choice of subyearling Chinook salmon in McNary Reservoir (Rondorf et al. 1990).

- Minimal disturbance of riparian habitat should be weighed when deciding upon criteria for determining size and placement of concrete shoreline anchors in order to provide protection for terrestrial food sources.

- We found no discussion in the literature of how shoreline anchors might affect the littoral zone or ESA-listed species.

Proposed Criterion:
Piling shall not exceed 5 inches in diameter. Each over-water structure shall utilize no more than 6 piles total for the entire project.

- Pilings placed in flowing water create low-velocity microhabitats that allow predators such as smallmouth bass and northern pikeminnow to conserve energy by holding in these areas and catching prey as it passes (Peterson et al. 1993).

- Ward et al. (1994) found that offshore wharves supported by pilings did not affect juvenile salmon migration and predation. However, these studies had small sample sizes and took place in low-velocity habitats that contained relatively low densities of predators.

- Reducing the number of pilings reduces the potential for avian predation.

- Noise generated by pile driving is well documented to have damaging effects to fish (Carrasquero 2007).

- Limiting the size and number of piles as well as the seasonal timing of the pile driving is a justifiable criterion to reduce the effects of the piles on fish populations.

Proposed Criterion:
Floats shall not be located in shallow water habitat where they could ground or impede the passage or rearing of any life stage of salmonid. Floats shall be in at least 10 feet of water at all reservoir pool levels including MOP (which is 335 feet above sea level). Depth is measured from the bottom of the landward-most edge of the float.

- The reasons for locating docks in at least 10 ft of water are to reduce erosion of the bottom and shoreline, reduce the suspension of sediment in the water column, reduce damage to aquatic vegetation caused by propeller wash, and to minimize the effects to fish (Asplund 2000; Carrasquero 2001).

- The primary goal of this criterion is to establish a 10-ft minimum depth at a given dock site for which MOP elevation may serve as a general reference. Therefore, it is necessary to define MOP elevation at a given location. The definition of MOP elevation at McNary Dam lacks clarity as a criterion. MOP elevation is 335 ft at McNary Dam. At the Blue Bridge (RM 330), MOP varies from 349 ft at 580 kcfs, to just under 340 ft at 47 kcfs. Flows at this site ranges from 150 to 300 kcfs during the spring and summer. Therefore, pool elevations at the Blue Bridge coinciding with this time vary from 342 ft to 344 ft. The criterion should be defined at each river mile for a given flow, or other similar criterion to give the individual dock owner a clearer reference to measure the 10-ft depth.

- Wave action caused by motorboats can cause erosion of the shoreline and bottom of both rivers and lakes (Asplund 2000). The degree of erosion depends on substrate size and cohesiveness (Nanson 1994). Wakes created by motorboats can cause sediments to resuspend in the water column, reducing water clarity that can potentially alter fish behavior and give rise to algal blooms. This resuspension of sediment is well documented by the USACE (1994) Fox River Chain o' Lakes study in northeastern Illinois, and USACE work on the Mississippi (Johnson 1994). Both of these studies, however, were conducted in bodies of water having very low (or no) velocity and fine silt substrates.

- We reviewed information on substrate and shoreline materials of McNary Reservoir to determine the likelihood of shoreline sediments eroding from motorboat wakes and propeller washes. McNary Reservoir shoreline is primarily composed of alluvium and eolian sands of fine, sandy, loam. Where fine sediments are present, the maximum effects of erosion are observed in water shallower than 3 ft and no effects are observed in water deeper than 8 ft (USACE 1994). A cursory examination of shoreline composition suggested that the shoreline of McNary Reservoir is susceptible to the erosive effects of motorboat traffic, therefore supporting the10-ft depth criterion.

- There is a relatively low proportion of fine sediment in the main channel of the Columbia River. Most of the substrate in the Tri-Cities area is composed of coarse sand and gravel. Sonar surveys conducted by the U.S. Department of Energy showed the amount of fine sediment decreased from 90% at McNary Dam to 51% travelling upstream to Port Kelly. Substrate at the Port of Kenniwick is composed of 4% gravel, 82% sand, 9% silt and 5% clay (Pinza et al. 1992). At the Port of Burbank no samples were collected as the bottom was bedrock (USACE 1993). Due to its high velocity and course substrate, we would not expect motorboat use to contribute to resuspension of sediment in the main channel of Lake Wallula.

- Plant growth may be inhibited where find sediments are present. A large number of studies have demonstrated that aquatic plants grow better and have a greater biomass at sites having less boat traffic (Zieman 1976; Murphy and Eaton 1983; Vermaat and Bruyne 1993; Mumma 1996; Asplund 1997). The detrimental effects of motorboats on aquatic plant communities can be minimized by placing docks in deeper water.

- Eurasian watermilfoil *Myriophyllum spicatum* is an invasive aquatic plant that forms dense canopies that can shade out other vegetation. Fragmentation caused by boat propellers is the primary cause of spreading milfoil from one waterbody to another (Washington Department of Ecology).

- For all species of submerged aquatic vegetation, there is a direct correlation between water clarity and the depth at which the plants will grow (Chambers and Kalff 1985; Duarte 1991; Abal and Dennison 1996; Olesen 1996). Kemp et al. (2004) found that the minimum percent light through water (PLW) required for submerged aquatic plants to survive is between 10-30%. Levels of turbidity as low as 4 and 15 nephelometric turbidity units (NTUs) can interfere with the ability of aquatic vegetation to photosynthesize (Hunter and Wilhm 1984). An increase in turbidity from 0 to 75 NTUs decreased primary production, species diversity, and biomass in a study conducted in the Northwest Territories (McCart et al. 1980). Calculations from another study showed that a turbidity of only 5 NTUs decreased primary productivity by about 3-13% and an increase in turbidity of 25 NTUs decreased primary production of aquatic vegetation by 13-50% in clear-water streams (Lloyd 1987). The turbidity levels in McNary Reservoir in reference to boat use near the shoreline are unknown.

- Turbidity can affect freshwater fish communities in both positive and negative ways (Judy et al. 1984). Buck (1956) observed smaller growth rates, reduced reproduction rates, and smaller populations of fish in turbid ponds. During a study conducted by Bisson and Bilby (1982), juvenile coho salmon avoided water with turbidities of 70 NTUs and above where low light conditions prevented successful foraging. In contrast, increased turbidity can reduce predations rate on juvenile salmon (Gregory and Levings 1998) and improve the survival of migrating subyearling fall Chinook salmon (Smith et al. 2003). Turbidity from motorboat operation will be minimized if docks are built in water that is 10 ft or deeper.

- The 10-ft depth criterion is supported as a means to ensure that docks are not built where smallmouth bass and juvenile salmonid habitats overlap. Construction of docks will attract smallmouth and pikeminnow because these fish prefer structure. By constructing docks over deeper water, the interaction between predators and juvenile salmon can be reduced because juvenile salmon are rearing in shallow areas near shore.

Discussion

The proposed criteria for residential docks and over-water structures specify discrete values such as 10-ft depth, 40 ft from OHWM, 4 ft wide, and 5-in diameters. In general, we could not identify these discrete values in the available literature. However, we found that maximizing depth, minimizing structure such as the number of pilings, and maximizing light levels all contribute to minimizing the negative effects that docks have on ESA-listed salmonids and other aquatic organisms.

We found few studies that directly examine dock use by piscivorous fishes and what effect that has on juvenile salmonids. We cite the large and relatively long-term studies on predation by smallmouth bass, northern pikeminnow, walleye, and channel catfish sponsored by the Bonneville Power Administration. The results of those predation studies were sufficiently compelling to support the start of a bounty program for the northern pikeminnow. The results of sampling in reservoir habitats from these studies are applicable to predator-prey relations in McNary Reservoir because most fish were sampled with electrofishing and beach seining along shores where both of those sampling gears are effective.

An overlap in habitat use between juvenile salmon, smallmouth bass, and northern pikeminnow increases the potential for predation. The current Biological Opinion for the Federal Columbia River Power System states that agencies will work together to develop strategies to reduce non-indigenous piscivorous predation (NOAA 2008). By simply reducing the amount of shade, minimizing the number of in-water structures (pilings), and moving the docks into deeper water, we avoid this potential creation of overlapping habitat that may increase predation on listed and non-listed juvenile salmonids. Specifically, placing docks in 10 ft of water, allowing light to pass through the dock, and minimizing the number and size of piles is reasonable and scientifically supported for waters containing federally listed fish species.

As a result of this review, we have narrowed the complex life histories of eight ESA-listed species of salmonids to a few that are most likely to occur in the nearshore areas of McNary Reservoir. Numerous studies from the Snake River and Columbia River provided a strong collection of information to support our reasoning. The juvenile salmon that will be affected in the nearshore area are the abundant subyearling fall Chinook salmon. We were reluctant to dismiss the potential for deleterious effects on the subyearling fall Chinook salmon simply because they are abundant and not listed under the ESA. The evidence supports the assumption that ESA-listed yearling and subyearling spring Chinook salmon currently occur in the nearshore areas or will use the nearshore areas as tributary populations are restored.

The proposed criteria for docks address several issues not directly related to ESA-listed species, but rather to the nearshore ecosystem. The criteria for structures attempt to minimize effects on lighting, the effects of motorboats on aquatic vegetation, shoreline erosion, and vegetation. We recognize that the reservoir shorelines do not represent pristine riverine habitats to which the juvenile salmonids are well adapted. However, these effects are recognized as widely deleterious to aquatic communities. In general, modification of riparian areas and near-shore littoral zone habitat (i.e., shoreline development) degrades freshwater aquatic communities.

Local habitat modifications (e.g., construction of individual residential docks) lead to changes in fish assemblages, particularly "when many diverse incremental changes have accumulated within a basin over time" (Jennings et al. 1999). Jennings et al. (1999) encourages shore zoning and permitting to consider the cumulative effects of small habitat modifications in addition to local effects of the structure.

Historically, management decisions for the Columbia River corridor have been based primarily on species-centered and site-specific scientific research. There are inherent challenges in managing and restoring a system fragmented by hydropower and other human perturbations. However, there has been a growing trend among prominent scientists, educators, and policy makers to view the river not as a sum of its parts, but as a whole interconnected system. It is important to realize that human-caused activities occurring upstream affect environmental conditions further downstream. This connectivity is a fundamental property of all ecosystems. Management actions that target the whole landscape or ecosystem are unlikely to be socially painless or inexpensive, nor are they likely to provide short-term reward. However, this change of perspective is probably essential for the long-term survival of native species.

In 1980, Vannote et al. (1980) first introduced the concept of 'the river continuum'. This theory states that because a river changes constantly as it moves from the headwaters to the mouth, that it can only truly be understood as a continuum. He saw a river as the equilibrium between physical characteristics such as width, depth, velocity, and temperature change and other biological factors. These factors change constantly, in a predictable manner, as the water flows downstream. More importantly, he recognized that those changes are interrelated. Gregory et al. (1991) subsequently described the dynamic relationship between rivers and streams and the surrounding terrestrial ecosystems that result in healthy riparian zones. In McNary Reservoir, the remaining habitat reflects the fragmentation from the construction of dams and human disturbance (Jager et al. 2001; Quigley et al. 2001; Zabel and Williams 2002).

Due to the effects of hydroelectric dams on salmonid populations, much scientific research on the Columbia River over the past few decades has been conducted on salmonid passage and hatcheries. Biological factors such as feeding, growth, and habitat have received little attention. In a review of the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program, Williams (2006) concluded that the current program was unlikely to recover declining salmon and steelhead stocks. Adoption of a salmon life history ecosystem concept as a guiding foundation is needed to recover depressed stocks. This "Return to the River" work is a comprehensive scientific review of the programs intended to address the complex issues of habitat degradation, juvenile survival through the hydrosystem, the role of artificial production, and harvest reform. It is a new conceptual foundation for managing salmon from an ecosystem standpoint in the 21st century.

McNary Reservoir, located downstream of the Hanford Reach, includes the confluence of the Yakima, Walla Walla, and the Snake rivers. The nearshore habitat offers limited habitat connectivity for the abundant fall Chinook salmon and to certain life stages of ESA-listed species of salmon. At the same time, the Tri-Cities are typical of rapid urban growth in the interior West and a need for recreational opportunities on the water. Our review emphasized the proposed criteria and most probable biological responses to those criteria. However, in regards to ESA-

listed salmonid species, it is the interaction of these complex ecological processes from the localized effects of a single dock to the cumulative effects of numerous docks over time that is probably more important.

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Appendix A: Proposed USACE criteria for Dock Design

*Asterisks are placed by criteria for which we were asked to provide assessment.

Lake Wallula/ McNary Pool residential over-water structure design criteria

1. Objectives

- Over-water structure design, construction, and use shall minimize degradation of aquatic, nearshore, and shoreline habitats.
- Over-water structures shall not impede any juvenile or adult salmonid life stage including migration, rearing, and spawning.
- Over-water structures shall not enhance habitats used by potential salmonid predators (esp. fishes and birds).

2. Over-water structure definitions and abbreviations

- A residential over-water structure typically consists of a shoreline anchor, ramp, and float. The structure may also include pile(s) and/or float anchor(s).
- Functional grating is the area that is not covered or blocked by any objects such as framing wood, flotation tubs, etc. The percent of functional grating is in relation to the surface area of the float.
- USACE - United States Army Corps of Engineers, Walla Walla District
- NMFS - National Marine Fisheries Service
- WDFW - Washington State Department of Fish and Wildlife

3. Piers and ramps

- To prevent damage to shallow water habitat, piers and/or ramps shall extend at least 40 feet perpendicular from the ordinary high water mark (OHWM).*
- Piers and ramps shall be no more than 4 feet in width.*
- The bottom of the pier or bottom of the landward edge of the ramp shall be elevated at least 2 feet above the plane of OHWM.*
- Grating shall cover the entire surface area (100%) of the pier and/or ramp. The open area of grating shall be at least 50% as rated by the manufacturer.*

- Skirting shall not be placed on piers, ramps, or floats. Protective bumper material will be allowed along the outside edge of the float as long as the material does not extend below the bottom edge of the float frame or impede light penetration.*

- Shoreline concrete anchors must be placed at least 10 feet landward from the OHWM and shall be sized no larger than 4-feet wide by 4-feet long, unless otherwise approved by NMFS, USACE, and WDFW.*

4. Preservatives

- The dock shall be built with materials that do not leach preservatives or other materials.

- No treated wood of any kind shall be used on any over-water structure (float, pier, or ramp).

- No paint, stain or preservative shall be applied to the over-water structure.

5. Preconstruction and construction activities

- If native vegetation is moved, damaged or destroyed, it shall be replaced with a functional native species equivalent during site restoration.

- Any large wood, native vegetation, topsoil, and/or native channel material displaced by construction shall be stockpiled for use during site restoration.

- No existing habitat features (e.g., woody debris, substrate materials) shall be removed from the shore or aquatic environment.

- Construction impacts shall be confined to the minimum area needed to complete the project.

- The boundaries of clearing limits associated with site access and construction shall be flagged to prevent ground disturbance of riparian vegetation, wetlands, and other sensitive sites beyond the flagged boundary. This action shall be completed before any significant alteration of the project area.

- A supply of sediment control materials (e.g., silt fence, straw bales, coconut fiber COIR bales) shall be available onsite. This action shall be completed before significant alteration of the project area.

- All temporary erosion controls shall be in place and appropriately installed downslope of project activities within the riparian area until site restoration is complete.

6. General

- No electricity shall be provided to or on the over-water structure.
- No boat lifts or watercraft lifts (e.g., jet ski lifts) of any type will be placed on or in addition to the over-water structure.
- Shoreline armoring (i.e., bulkheads, rip-rap, and retaining walls) shall not occur in association with installation of the over-water structure.
- Construction of the over-water structure shall be completed during the in-water work window of December 1 to February 28.

7. Piling and float anchors

- Piling shall not exceed 5 inches in diameter.*
- Piling shall be spaced at least 18 feet apart on the same side of any component of the over-water structure. The pier/ramp and float are separate components.
- Each over-water structure shall utilize no more than 6 piles total for the entire project.*
- All pilings shall be fitted with devices to prevent perching by piscivorous (fish-eating) birds.
- Submerged float anchors will be constructed out of concrete and shall be horizontally compressed in form, by a factor of 5 or more, for a minimum profile above the stream bed (the horizontal length and width will be at least 5 times the vertical height).
- No in-water fill material will be allowed, with the exception of pilings and float anchors (Note: uncured concrete or its by-products shall not be allowed).

8. Floats

- Float components shall not exceed the dimensions of 8 by 20 feet or an aggregate total of 160 square feet for all float components.
- Float materials contacting the water shall be white in color.
- Flotation materials shall be permanently encapsulated to prevent breakup into small pieces and dispersal in water, (e.g. rectangular float tubs).
- Grating shall cover 100% of the surface area of the float(s). The open area of the grating shall be no less than 50% as rated by the manufacturer.*

- Functional grating will cover no less than 50% of the float.*

- Floats shall not be located in shallow water habitat where they could ground or impede the passage or rearing of any life stage of salmonid. Floats shall be in at least 10 feet of water at all reservoir pool levels including MOP (which is 335 feet above sea level). Depth is measured from the bottom of the landward-most edge of the float.*

- Nothing shall be placed on the over-water structure that will reduce natural light penetration through the structure.

- Floats shall be positioned at least 40 feet horizontally from the OHWM and no more than 100 feet from the OHWM as measured from the landward-most edge of the float.

- Project construction shall cease under high flow conditions that could result in inundation of the project area except for efforts to avoid or minimize resource damage.

Exhibit 2

OVERWATER STRUCTURES AND NON-STRUCTURAL PILING WHITE PAPER

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ACZA	ammoniacal copper zinc arsenate
ALC	aquatic life criteria
BLM	Biotic Ligand Model
BMP	best management practice
CCA	chromated copper arsenate
CCC	criterion chronic concentration
CMC	criterion maximum concentration
Corps, the	U.S. Army Corps of Engineers
DNA	deoxyribonucleic acid
Ecology	Washington State Department of Ecology
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
HCP	Habitat Conservation Plan
HPA	Hydraulic Project Approval
ITP	Incidental Take Permit
LWD	large woody debris
MHHW	mean higher high water
MLLW	mean lower low water
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OHWL	ordinary high water line
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetically active radiation
PEC	probable effects concentration
RCW	Revised Code of Washington
RMS	root mean square
SEL	sound exposure level
TEC	threshold effects concentration
TRA	Tidal Reference Area
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USC	United States Code
USEPA	U.S. Environmental Protection Agency

USFWS	U.S. Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation

C	Celsius
cfs	cubic feet per second
cm	centimeter
cm/sec	centimeters per second
dB	decibels
dB_{peak}	peak decibels during each pulse (either maximum or minimum)
dB_{SEL}	decibels sound exposure level
dB_{RMS}	decibels root mean square – square root of sound energy divided by impulse duration
F	Fahrenheit
JTU	Jackson turbidity unit
m	meter
$\mu g/cm^2/mm$	micrograms per square centimeter per millimeter
µg/L	micrograms per liter
$\mu M/m^2/sec$	micro-moles per square meter per second
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm	millimeter
NTU	nephelometric turbidity unit
ppb	parts per billion

Note: In general, English measurement units (e.g., feet, inches, miles) are used in this white paper; when the source material expresses a value in metric units, that measurement is also provided in parentheses. However, measurements that by convention are typically made only in metric units are reported in those units (e.g., mg/L, $\mu M/m^2/sec$). Temperatures are reported in both Fahrenheit and Celsius, regardless of the scale used in the source material.

EXECUTIVE SUMMARY

Overview

In Washington State, activities that use, divert, obstruct, or change the natural bed or flow of state waters require a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW). The purpose of the HPA program is to ensure that such activities do not damage public fish and shellfish resources and their habitats. To ensure that activities conducted under an HPA comply with the Endangered Species Act (ESA), WDFW is preparing a programmatic, multispecies Habitat Conservation Plan (HCP) to obtain an Incidental Take Permit from the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA) Fisheries Service (known as NOAA Fisheries). WDFW's objective is to avoid, minimize, or compensate for the incidental take of species potentially covered under the HCP resulting from the implementation of permits issued under the HPA authority. In this context, to "take" means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct (16 U.S.C. 1532(19)).

To evaluate the feasibility of and develop a scientific foundation for the HCP, the WDFW has commissioned a series of white papers that will review and summarize the best available science for up to 21 HPA activities that could be included in the HCP.

This white paper addresses the availability of scientific information on two such HPA activities, overwater structures and the installation and removal of non-structural piling. Overwater structures are defined by WDFW as "docks, piers, floats, ramps, wharfs, ferry terminals and other structures that are supported above or float on the water. This includes all structural or supporting pilings. This does not include structures associated with a Marina." Non-structural piling is defined by the WDFW as "individual, non-structural pilings, power poles, transmission lines, conduits, etc. Pilings are driven into the stream, lake, and ocean bed."

The literature review conducted for this white paper identified 12 impact mechanisms associated with the construction and operation of overwater structures and non-structural piling that could potentially affect aquatic species being considered for coverage under the HCP ("potentially covered species"). These mechanisms describe activities and

modifications to habitat arising from activities that can be temporary or permanent in duration. The impact mechanisms evaluated in this white paper are:

- Shading
- Littoral vegetation
- Freshwater aquatic vegetation
- Riparian and shoreline vegetation
- Noise
- Water quality
- Channel hydraulics
- Littoral drift
- Substrate modifications
- Channel dewatering
- Artificial light
- Vessel activities

Following a brief description of overwater structures and non-structural piling activities and potential impact mechanisms, the 52 aquatic species being considered for coverage under the HCP are described. Based on this information, the risks of direct and indirect impacts to the potentially covered species or their habitats are discussed. In addition, the potential for cumulative impacts is discussed, and the risk for incidental take of potentially covered species is qualitatively estimated. The white paper then identifies data gaps (i.e., instances in which the data or literature are insufficient to allow conclusions on the risk of take). The white paper concludes by providing habitat protection, conservation, mitigation, and management strategies consisting of actions that could be taken to avoid or minimize the impacts of overwater structures and non-structural piling. Key elements of the white paper are summarized below.

Species and Habitat Use

This white paper considers potential impacts on 52 potentially covered species and summarizes the geographic distribution and habitat requirements of those species. That information is used to assess potential impacts on the potentially covered species.

Risk of Take and Potential Mitigation Measures

The risk of take and potential mitigation measures are summarized below for each of the impact mechanisms listed above.

Shading

Shading has been identified as causing incidental take of juvenile salmon in both marine and freshwater environments. However, almost nothing is known about the effects of shading on other potentially covered species.

Various authors have suggested minimization measures to reduce shading impacts, such as:

- Increasing the height of overwater structures to allow light transmission under the structures
- Decreasing structure width to decrease the shade footprint
- Aligning the structure in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure
- Using the smallest number of pilings possible, allowing more light beneath the structure

Littoral Vegetation

Littoral vegetation includes eelgrass, macroalgae, and intertidal vascular plants. Generally, the federal agencies have treated loss or reduced density of eelgrass as equivalent to loss of essential habitat for listed species known to occur in the area; as such, it constitutes a take of listed species such as salmon and bull trout. Thus, eelgrass loss is almost certain to result in incidental take of potentially covered species that use eelgrass, including anadromous salmonids, anadromous and marine forage fishes, and certain larval pelagic fishes. Mitigation of impacts to littoral vegetation is best achieved through avoidance.

Freshwater Aquatic Vegetation

Most impacts on aquatic vegetation are not directly addressed by current best management practices or minimization measures required under the HPA authority, so they represent impacts that have a high potential to occur in practice. This oversight has likely occurred because salmonids do not show a very strong dependence on freshwater aquatic vegetation. However, some other potentially covered species, including freshwater molluscs and an array of fishes, have a strong association with freshwater aquatic vegetation and would be at relatively high risk of incidental take from projects that remove or reduce such vegetation within their habitat. There are few recommendations for how to minimize impacts to aquatic vegetation, except via avoidance.

Riparian and Shoreline Vegetation

In past biological opinions, the National Marine Fisheries Service (NMFS) has found that loss of riparian and shoreline vegetation amounts to incidental take of listed fish, even though the relationship between habitat conditions and the distribution and abundance of those individuals in the action area was imprecise. Many other potentially covered species also have demonstrated dependence on riparian and shoreline vegetation and so would be at high risk of incidental take.

The following measures could help avoid and minimize incidental take arising from impacts to riparian and shoreline vegetation:

- Prepare revegetation plans for projects that temporarily disturb vegetation during construction.
- Submit monitoring reports to WDFW as part of the revegetation plan and require remedial action if pre-established goals are not met.
- Save vegetation (specifically large trees and root wads) removed for the project for later use in restoration efforts.
- To the extent practicable, do not permit removal or disturbance of riparian vegetation in areas with high erosion hazard (Knutson and Naef 1997).

Noise

Underwater noise produced in association with the construction of overwater structures includes noise generated from pile driving (when applicable) and by construction vessels and equipment. It is well established that impact pile driving can result in incidental take to fish. However, the sound sensitivity of individual species is not well known, so it is difficult to predict the likelihood of incidental take for species other than salmonids.

Several noise reduction devices have been developed for pile driving, including air bubble curtains, fabric barriers, pile caps, cofferdams, and use of vibratory hammers. The usual strategy for minimizing other types of underwater noise is to time activities to occur when sensitive life stages of potentially covered species are less likely to be present.

Water Quality

Placing constructed features in aquatic settings may adversely impact water quality mainly by causing increases in suspended solids concentrations, reducing dissolved oxygen levels, changing pH, or releasing toxic substances from treated wood products. Stormwater runoff from constructed surfaces also poses a threat to water quality from its associated nonpoint source pollutant load. With respect to suspended solids, the take risk to potentially covered fish species increases in proportion to the magnitude and duration of the impact; vulnerability of the affected life-history stage; inability of the fish to alter behavior to avoid the impact; physiological, developmental, and behavioral impairments suffered by the fish; and indirect mechanisms such as exposure to predation. In contrast, incidental take risk associated with dissolved oxygen impacts is probably quite low and, because the potential impact of pH change from uncured concrete is avoided in standard HPA measures, the risk of incidental take from pH change is near zero. Risk of incidental take of potentially covered species due to the use of treated wood is significant but highly variable and is related to factors that include proximity, dilution, and type of treatment. Risk of incidental take due to release of stormwater treated in accordance with current Washington State Department of Ecology guidance is generally low, but this finding has reduced confidence because some data indicate high salmonid vulnerability to some stormwater constituents (such as dissolved copper), and stormwater effects on most potentially covered species have received little study.

There are a number of avoidance and minimization measures that could help to address water quality issues. Current practice effectively addresses most potential impacts, but suspended sediment impacts warrant more detailed advance studies to determine site-specific vulnerability to impacts, and there are a variety of measures that could further reduce impacts associated with use of treated wood.

Channel Hydraulics

Impacts to potentially covered species as a result of channel hydraulic changes are summarized in Table ES-1.

Table ES-1
Potential Impacts of Changes in Channel Hydraulics on Potentially Covered Species

Impact	Potentially Affected Species
No impact identified	Marine species or marine life stages of estuarine and anadromous species
Habitat destruction due to siting of structure	Species potentially occupying the affected stream
Embedding due to reduced sediment transport capacity or indirectly as a result of bank erosion	Species potentially occupying the affected streambed: gravel spawners and benthos
Scour due to locally increased transport capacity	Species potentially occupying the affected streambed: gravel spawners and benthos
Deposition downstream of scour areas	Species potentially occupying the affected streambed: gravel spawners and benthos
Loss of riparian vegetation due to bank erosion	Species potentially occupying the affected stream

Each of these changes (excepting "no impact") can potentially result in incidental take of animals or an adverse impact on their habitat. We found no studies specifically addressing the cumulative impacts of channel hydraulic changes on potentially covered species. Generally, the question of cumulative impacts emerges as a data gap. The HPA program itself offers the best means of measuring these impacts, because WDFW has authority to require monitoring of the impacts of authorized projects.

Littoral Drift

Incidental take is most likely to result from changes in littoral drift via impacts on beach-spawning fishes and through eelgrass changes. Some potentially covered species are beach spawners and these could suffer reduced reproductive success due to altered littoral drift. Other potentially covered species prey upon the beach spawners and could suffer reduced foraging success due to altered littoral drift. Littoral drift could also change the distribution of eelgrass, with effects described under "Littoral Vegetation."

Impacts to littoral drift can be avoided or minimized by the following measures:

- Design pile-supported structures with open space between pilings.
- Minimize the dimensions of floating structures placed perpendicular to shorelines.
- Perform thorough hydraulic design to determine how a structure is likely to impact littoral drift.

Substrate Modifications

Piling associated with overwater structures, as well as non-structural piling, in nearshore environments can alter adjacent substrates through shellfish deposition and changes to

substrate bathymetry. Changes in substrate type can alter the flora and fauna. Along with the minimization measures for eelgrass and macroalgae discussed above, use of fewer and more widely spaced pilings will help to reduce this risk.

Channel Dewatering

The primary risk of incidental take associated with channel dewatering results from the capture and handling of fish. Past biological opinions have found that all such activity constitutes incidental take. Potential additional causes of incidental take include impacts attributable to increases in turbidity and suspended solids. These include indicators of major and minor physiological stress, habitat degradation, and impaired homing behavior. These effects are sublethal, but are still considered take under the ESA (NMFS 2006b). Many measures can be employed to minimize or avoid incidental take during channel dewatering.

Artificial Light

Incidental take of listed fish species as a result of artificial light to build or operate overwater structures has not been quantified in past biological opinions and corresponding incidental take statements. Although artificial light responses are unknown for most potentially covered species, there is a plausible risk that nighttime illumination of the water surface may contribute to incidental take. However, such a risk is relatively easy to minimize by requiring structures to be lit so as to minimize direct illumination of the water surface.

Vessel Activities

Vessel activities associated with the installation and operation of in-water and overwater structures may adversely impact potentially covered species. Impact mechanisms include:

- Physical disturbance of sediment, organisms, and submerged vegetation through grounding or water turbulence caused by propeller wash
- Noise from vessel activity
- Propeller-wash entrained air bubbles that combine with turbidity increases from disturbed sediment, leading to a temporary reduction in the availability of light

Incidental take may result from vessel activities via each of these mechanisms. To minimize these impacts, it may be appropriate to require construction vessel operation plans for larger

projects, or projects located in particularly sensitive habitats to ensure that the potential for vessel and construction activity impacts to sensitive habitats and species is minimized.

1 INTRODUCTION

In Washington State, activities that use, divert, obstruct, or change the natural bed[1] or flow of state waters require a Hydraulic Project Approval (HPA) from the Washington Department of Fish and Wildlife (WDFW) (Revised Code of Washington [RCW] 77.55.011). The purpose of the HPA program is to ensure that such activities are completed in a manner that prevents damage to public fish and shellfish resources and their habitats. Because several fish and aquatic species in the state are listed as threatened or endangered under the federal Endangered Species Act (ESA), many of the activities requiring an HPA may also require approvals from the National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) and the U.S. Fish and Wildlife Service (USFWS). Such approvals can be in the form of an ESA Section 7 Incidental Take Statement or an ESA Section 10 Incidental Take Permit (ITP). As authorized in Section 10 of the ESA, ITPs may be issued for otherwise lawful activities that could result in the "take" of ESA-listed species or their habitats. In this context, to take means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct" (16 United States Code [USC] §1532(19)).

To ensure that the HPA program complies with the ESA and to facilitate ESA compliance for persons conducting work under an HPA, WDFW is preparing a programmatic, multispecies Habitat Conservation Plan (HCP) to obtain an ITP from the USFWS and NOAA Fisheries. An HCP must provide an operating conservation plan for avoiding, minimizing, and mitigating, to the maximum extent practicable, the impacts of the permitted take on the potentially covered species[2]. The federal agencies must also find in their biological opinion that any permitted incidental take will not jeopardize the continued existence of the species, i.e., the taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild.

To develop a scientific foundation for the HCP, WDFW has commissioned a series of white papers that will review and summarize the best available science for up to 21 HPA activities that could be included in the HCP.

[1] Bed is defined as the land below the ordinary high water line of the state waters, but does not include irrigation ditches, canals, the outflow from stormwater runoff devices, or other artificial watercourses except where they exist in a natural watercourse that has been altered by humans.

[2] In this white paper, "potentially covered species" refers to fish and wildlife species that could be covered in the HCP; however, that determination would be made at the time the HCP is finalized between WDFW and the federal agencies.

Two of those activities, overwater structures and non-structural piling, form the subject of this white paper. Overwater structures are defined by WDFW[3] as "docks, piers, floats, ramps, wharfs, ferry terminals and other structures that are supported above or float on the water. This includes all structural or supporting pilings. This does not include structures associated with a Marina." Marinas will be the subject of a separate white paper. Non-structural pilings are defined by WDFW as "individual, non-structural pilings, power poles, transmission lines, conduits, etc. Pilings are driven into the stream, lake, and ocean bed." This white paper compiles and synthesizes existing scientific and commercial information, describes potential take mechanisms, and makes recommendations for measures to avoid or minimize the impacts on potentially covered species of constructing and operating overwater structures and non-structural piling. Species being proposed for coverage under the HCP (the "potentially covered species") are listed in Table 1.

Table 1
Potentially Covered Fish and Wildlife Species

Common Name	Scientific Name	Status	Habitat
California floater (mussel)	*Anodonta californiensis*	FSC/SC	Freshwater
Mountain sucker	*Catostomus platyrhynchus*	SC	Freshwater
Margined sculpin	*Cottus marginatus*	FSC/SS	Freshwater
Lake chub	*Couesius plumbeus*	SC	Freshwater
Giant Columbia River limpet	*Fisherola nuttalli*	SC	Freshwater
Great Columbia River spire snail	*Fluminicola columbiana*	FSC/SC	Freshwater
Western ridged mussel	*Gonidea angulata*	(none)	Freshwater
Western brook lamprey	*Lampetra richardsoni*	FSC	Freshwater
Olympic mudminnow	*Novumbra hubbsi*	SS	Freshwater
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	FSC	Freshwater
Redband trout	*Oncorhynchus mykiss*	FSC	Freshwater
Pygmy whitefish	*Prosopium coulteri*	FSC/SS	Freshwater
Leopard dace	*Rhinichthys falcatus*	SC	Freshwater
Umatilla dace	*Rhinichthys umatilla*	SC	Freshwater
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	FSC	Freshwater & Anadromous
Bull trout	*Salvelinus confluentus*	FT/SC	Freshwater & Anadromous
Sockeye salmon	*Oncorhynchus nerka*	FE/FT/SC	Freshwater (kokanee) & Anadromous
Pink salmon	*Oncorhynchus gorbuscha*	SPHS	Anadromous
Chum salmon	*Oncorhynchus keta*	FT/SC	Anadromous
Coho salmon	*Oncorhynchus kisutch*	FC/FSC	Anadromous
Steelhead	*Oncorhynchus mykiss*	FE/FT/SC	Anadromous
Chinook salmon	*Oncorhynchus tschawytscha*	FE/FT/SC	Anadromous
Green sturgeon	*Acipenser medirostris*	SPHS	Anadromous
White sturgeon	*Acipenser transmontanus*	SPHS	Anadromous
River lamprey	*Lampetra ayresi*	FSC/SC	Anadromous
Pacific lamprey	*Lampetra tridentata*	FSC	Anadromous
Dolly Varden	*Salvelinus malma*	FP	Anadromous

[3] The definitions of overwater structures and non-structural piling presented here were provided by WDFW in Appendix B of Exhibit B of the Request for Proposal for this project, RFP No. 06-0005.

Common Name	Scientific Name	Status	Habitat
Longfin smelt	*Spirinchus thaleichthys*	SPHS	Anadromous
Eulachon	*Thaleichthys pacificus*	FC/SC	Anadromous
Olympia oyster	*Ostrea lurida*	SC	Estuarine
Pacific sand lance	*Ammodytes hexapterus*	SPHS	Marine & Estuarine
Pacific herring	*Clupea harengus pallasi*	FC/SC	Marine & Estuarine
Surf smelt	*Hypomesus pretiosus*	SPHS	Marine & Estuarine
Pacific hake	*Merluccius productus*	FSC/SC	Marine & Estuarine
Lingcod	*Ophiodon elongatus*	SPHS	Marine & Estuarine
Pacific cod	*Gadus macrocephalus*	FSC/SC	Marine (occ. Estuarine)
Walleye pollock	*Theragra chalcogramma*	FSC/SC	Marine (occ. Estuarine)
Newcomb's littorine snail	*Algamorda subrotundata*	FSC/SC	Marine
Northern abalone	*Haliotis kamtschatkana*	FSC/SC	Marine
Brown rockfish	*Sebastes auriculatus*	SC	Marine
Copper rockfish	*Sebastes caurinus*	FSC/SC	Marine
Greenstriped rockfish	*Sebastes elongates*	SC	Marine
Widow rockfish	*Sebastes entomelas*	SC	Marine
Yellowtail rockfish	*Sebastes flavidus*	SC	Marine
Quillback rockfish	*Sebastes maliger*	FSC/SC	Marine
Black rockfish	*Sebastes melanops*	SC	Marine
China rockfish	*Sebastes nebulosus*	SC	Marine
Tiger rockfish	*Sebastes nigrocinctus*	SC	Marine
Bocaccio rockfish	*Sebastes paucispinis*	SC	Marine
Canary rockfish	*Sebastes pinniger*	SC	Marine
Redstripe rockfish	*Sebastes proriger*	SC	Marine
Yelloweye rockfish	*Sebastes ruberrimus*	SC	Marine

Notes:

FE = Federal Endangered
FP = Federal Proposed
FT = Federal Threatened
FC = Federal Candidate
FSC = Federal Species of Concern
SC = State Candidate
SS = State Sensitive
SPHS = State Priority Habitat Species

Source: The list of species being considered for coverage under the HCP was provided in "WDFW Hydraulic Project Approval HCP Exhibit B HPA Final Grant Proposal," which was distributed with the Request for Proposal for this analysis.

Note: Species listed by habitat type; within habitat type, species listed in alphabetical order by scientific name.

This white paper focuses on overwater structures for which WDFW would benefit from securing programmatic coverage under the ESA; examples include docks, piers, ramps, and floats.

The remainder of this white paper is organized as follows:

- Objectives and methodology are detailed in Sections 2 and 3.
- Permitted overwater structures and non-structural piling activities are described in Section 4.
- Habitats used by the potentially covered species are summarized in Section 5.

- The conceptual framework for assessing impacts is presented in Section 6.
- The impact analysis appears in Section 7.
- Cumulative impacts of overwater structures and non-structural piling are discussed in Section 8.
- The potential risk of take is summarized in Section 9.
- An analysis of data gaps is presented in Section 10.
- Strategies to offset impacts and management recommendations are provided in Section 11.
- Section 12 lists publication details for the references cited in this white paper.

2 OBJECTIVES

The objectives of this white paper are:

- To compile and synthesize the best available scientific information related to the potential human impacts on potentially covered species, their habitats, and associated ecological processes resulting from the construction and operation of overwater structures and non-structural piling permitted under the HPA authority
- To use this scientific information to estimate the circumstances, mechanisms, and risk of incidental take potentially or likely resulting from construction and operation of various types of overwater structures and non-structural piling
- To identify appropriate and practicable measures, including policy directives, conservation measures, and best management practices (BMPs), for avoiding, minimizing, or mitigating the risk of incidental take

3 METHODOLOGY

We employed the following procedures in preparing this white paper:

1. Existing WDFW rules and guidance were reviewed to identify current knowledge and practices relevant to the analysis of the impacts to potentially covered species associated with overwater structures and non-structurual piling.
2. A literature review was conducted to review the current state of knowledge regarding potential impacts associated with overwater structures and non-structural piling on potentially covered species. The compiled literature set included (a) relevant previous white papers prepared for WDFW; (b) copies of HPAs for overwater structures and non-structural piling, provided by WDFW; (c) documents secured as a result of keyword searches on the Internet and in other literature databases; and (d) a review of biological opinions prepared by NOAA Fisheries and USFWS, addressing various projects involving overwater structures and non-structural piling in Washington, Oregon, Idaho, and California. The principal keyword search strategy was to look for documents linking terms describing the species (i.e., common and scientific names of all potentially covered species) with terms describing overwater structures and non-structural piling or mechanisms of impact associated with the construction and operation of such structures.
3. The compiled documents were reviewed to determine which potential mechanisms of impact were addressed in each document; the majority considered impacts to salmonids or to physical habitat features. Documents that evaluated impacts to potentially covered species and physical habitat features were identified and evaluated during the literature review. The literature review results were entered into a matrix, which allowed easy identification of literature relevant to each impact mechanism. Documents located during the literature review were in turn used in Internet searches (mostly conducted using the Google® search tool) to locate additional relevant literature addressing specific impact pathways.
4. Impact mechanism analyses were prepared for each of the principal impact mechanisms and for both overwater structures and non-structural piling.
5. The text of the white paper was prepared and subjected to review by technical specialists with Anchor Environmental L.L.C., Jones & Stokes Associates, and R2 Resource Consultants, as well as by WDFW personnel.

4 ACTIVITY DESCRIPTION

RCW 77.55.011(7) defines a hydraulic project as "the construction or performance of work that will use, divert, obstruct, or change the natural flow or bed of any of the salt or freshwaters of the state." Overwater structures and non-structural piling are addressed together in this white paper because of the overlap in potential impact mechanisms associated with the construction and presence of these structures. Overwater structures are defined by WDFW[4] as "docks, piers, floats, ramps, wharfs, ferry terminals, and other structures that are supported above or float on the water. This includes all structural or supporting pilings for the overwater structure. This does not include structures associated with a Marina, or Non-Structural (Supporting) Pilings." For the purposes of this analysis:

- A pier is defined as an elevated and stationary walkway supported by piling that extends waterward of the shoreline.
- A float and a dock are both defined as a walkway or other surface that floats on the water.
- A ramp is defined as a walkway connecting a pier or other shoreward structure to a float and providing access between the two.
- A wharf is defined as an elevated and stationary structure oriented parallel to the shoreline, such that ships can lie alongside to load and unload cargo and passengers.

Non-structural pilings are defined by WDFW as "individual, non-structural pilings, power poles, transmission lines, conduits, etc. Pilings are driven into the stream, lake, and ocean bed."

The complete legal description of these activities is contained in Washington Administrative Code (WAC) 220-110, the *Hydraulic Code Rules*, and is particularly detailed in WAC 220-110-060, *Construction of freshwater docks, piers, and floats and the driving or removal of piling,* and WAC 220-110-300, *Saltwater piers, pilings, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings*. Appendix A reproduces the full text of these WAC sections.

For this white paper, overwater structures and non-structural piling are defined as hydraulic projects that comply with all provisions specified in WAC 220-110-060 or WAC 220-110-300. The analysis presented in this white paper addresses the impacts of lawful activities, which are the

[4] The definitions of overwater structures and non-structural piling presented here were provided by WDFW in Appendix B of Exhibit B of the Request for Proposal for this project, RFP No. 06-0005.

only activities that can be authorized under an ITP. Accordingly, the impact analyses presented below were prepared with the assumption that all applicable provisions of WAC 220-110, and any other applicable laws and regulations of the United States and the State of Washington, are observed in the construction and operation of overwater structures and non-structural piling authorized by WDFW.

Most overwater structures and non-structural piling affect waters of the United States as well as waters of the State of Washington. Thus, their construction also requires a permit from the U.S. Army Corps of Engineers (the Corps; USACE) authorizing the placement of fill in waters of the United States (known as a Section 404 permit) or the placement of structures in navigable waters (known as a Section 10 permit). In many cases, the permit is some form of a Corps Nationwide Permit, meaning that standard conditions apply. However, on September 26, 2006, the Corps proposed revision of the Nationwide Permit system; therefore, it is not practical for this analysis to make assumptions about future permit conditions that might be imposed by the Corps for projects authorized under the Nationwide Permit system. Moreover, all projects authorized under Corps permits are subject to additional conditions, some of which may be derived pursuant to interagency consultation with the federal agencies as provided for under Section 7 of the ESA. The analyses presented in this white paper do not reflect assumptions about what those conditions might be.

5 SPECIES AND HABITAT USE

Table 2 identifies the approximate distribution of each of the 52 potentially covered species listed in Table 1 by noting its documented presence within Water Resource Inventory Areas (WRIAs) for freshwater and estuarine environments or Tidal Reference Areas (TRAs) for marine environments. Figures in Appendix B show the locations of WRIAs and TRAs in Washington State. The risk of incidental take is approximately zero for any species not present in the region where a given HPA is applicable. Because the WRIAs and TRAs represent large areas, species habitat requirements are further identified in Table 3, which describes the critical life-history stages of each species and the habitat dependency for each life-history stage.

Table 2
Range of Potentially Covered Species Listed in Table 1

Common Name	Scientific Name	Water Resource Inventory Area*	Tidal Reference Area (see list below)*
Green sturgeon	*Acipenser medirostris*	25, 26, 27, 28	All
White sturgeon	*Acipenser transmontanus*	3, 22, 24-37, 40-42, 44-61 (Columbia and Snake rivers)	All
Newcomb's littorine snail	*Algamorda subrotundata*	N/A	14, 15, 16, 17
Pacific sand lance	*Ammodytes hexapterus*	N/A	All
California floater (mussel)	*Anodonta californiensis*	30, 36, 37, 40, 42, 47-49, 52-54, 58-61	N/A
Mountain sucker	*Catostomus platyrhynchus*	23, 26-33, 35-41, 44-46 (Columbia, Snake, and Yakima rivers)	N/A
Pacific herring	*Clupea harengus pallasi*	N/A	1, 2, 4, 5, 8, 9, 10, 11, 12, 13, 16, 17
Margined sculpin	*Cottus marginatus*	32, 35	N/A
Lake chub	*Couesius plumbeus*	48, 61; other locations unknown	N/A
Giant Columbia River limpet	*Fisherola nuttalli*	35, 36, 40, 47-49, 54, 57; other locations unknown	N/A
Great Columbia River spire snail	*Fluminicola columbiana*	35, 45, 48, 49; other locations unknown	N/A
Pacific cod	*Gadus macrocephalus*	N/A	All
Western ridged mussel	*Gonidea angulata*	1, 3-5, 7-11, 13, 21-42, 44-55, 57-62	N/A
Northern abalone	*Haliotis kamtschatkana*	N/A	10
Surf smelt	*Hypomesus pretiosus*	N/A	All
River lamprey	*Lampetra ayresi*	1, 3, 5, 7-16, 20-40	N/A
Western brook lamprey	*Lampetra richardsoni*	1, 3, 5, 7-14, 16, 20-40	N/A
Pacific lamprey	*Lampetra tridentata*	1, 3, 5, 7-42, 44-46, 58, 61	N/A
Pacific hake	*Merluccius productus*	N/A	All
Olympic mudminnow	*Novumbra hubbsi*	5, 7-14, 20-24, 26	N/A
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	1-5, 7-30	All
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	37-39, 44-55, 58-62	N/A
Pink salmon	*Oncorhynchus gorbuscha*	1, 3-5, 7-13, 16-19, 21	1-13
Chum salmon	*Oncorhynchus keta*	1, 3-5, 7-29	All
Coho salmon	*Oncorhynchus kisutch*	1-42, 44-48, 50	All

Common Name	Scientific Name	Water Resource Inventory Area*	Tidal Reference Area (see list below)*
Redband trout	*Oncorhynchus mykiss*	37-40, 45-49, 54-57	N/A
Steelhead	*Oncorhynchus mykiss*	1, 3, 4, 5, 7, 8, 9, 10-12, 14, 15, 17-41, 44-50	All
Sockeye salmon	*Oncorhynchus nerka*	1, 3-5, 7-12, 16, 19-22, 25-33, 35-37, 40, 41, 44-50, Columbia River and Snake River	5, 8, 14
Chinook salmon	*Oncorhynchus tschawytscha*	1-41, 44-50	All
Lingcod	*Ophiodon elongatus*	N/A	All
Olympia oyster	*Ostrea lurida*	N/A	1-14, 17
Pygmy whitefish	*Prosopium coulteri*	7, 8, 19, 39, 47, 49, 53, 55, 58, 59, 62	N/A
Leopard dace	*Rhinicthys falcatus*	21, 26-41, 44-50	N/A
Umatilla dace	*Rhinicthys umatilla*	31, 36-41, 44-50, 59-61	N/A
Bull trout	*Salvelinus confluentus*	1-23, 26, 27, 29-41, 44-55, 57-62	All
Dolly Varden	*Salvelinus malma*	1, 3, 5, 7, 17-22, 24	6-10, 14-17
Brown rockfish	*Sebastes auriculatus*	N/A	All
Copper rockfish	*Sebastes caurinus*	N/A	All
Greenstriped rockfish	*Sebastes elongates*	N/A	All
Widow rockfish	*Sebastes entomelas*	N/A	All
Yellowtail rockfish	*Sebastes flavidus*	N/A	All
Quillback rockfish	*Sebastes maliger*	N/A	All
Black rockfish	*Sebastes melanops*	N/A	All
China rockfish	*Sebastes nebulosus*	N/A	All
Tiger rockfish	*Sebastes nigrocinctus*	N/A	All
Bocaccio rockfish	*Sebastes paucispinis*	N/A	All
Canary rockfish	*Sebastes pinniger*	N/A	All
Redstripe rockfish	*Sebastes proriger*	N/A	All
Yelloweye rockfish	*Sebastes ruberrimus*	N/A	All
Longfin smelt	*Spirinchus thaleichthys*	1,2,3, 6-17, 22 and 24	1-9, 15-17 (mouths of rivers and streams; Lake Washington)
Eulachon	*Thaleichthys pacificus*	20-29 (mouths of major rivers)	14-17 (tidal areas of rivers)
Walleye pollock	*Theragra chalcogramma*	N/A	All

Tidal Reference Areas:

TRA 1 – Shelton	TRA 2 – Olympia	TRA 3 – South Puget Sound	TRA 4 – Tacoma
TRA 5 – Seattle	TRA 6 – Edmonds	TRA 7 - Everett	TRA 8 – Yokeko Point
TRA 9 – Blaine	TRA 10 – Port Townsend	TRA 11 – Union	TRA 12 – Seabeck.
TRA 13 – Bangor	TRA 14 – Ocean Beaches	TRA 15 – Westport	TRA 16 – Aberdeen
TRA 17 – Willapa Bay			

*Please refer to Appendix B for figures showing WRIA and TRA locations. Estuarine and marine distributions are characterized by TRA rather than WRIA.
Note: Species listed in alphabetical order by scientific name.
Note: The distribution of all fish species in this table is based on visual examination of range maps published by Wydoski and Whitney (2003) and comparison to published maps showing WRIA and TRA boundaries. The distribution of all non-fish (invertebrate) species is based on narrative descriptions presented by the Washington Department of Natural Resources (WDNR 2006b).
N/A – Not applicable, because the species does not occur within a WRIA and/or a TRA.

Table 3
Habitat Requirements of Potentially Covered Species

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Green sturgeon	*Acipenser medirostris*	Habits and life history not well known; found in all marine waters in Washington and in estuaries; spend much of life in marine nearshore waters and estuaries, returning to rivers to spawn; spawn in deep pools, substrate preferences unclear but are likely large cobbles, although range from sand to bedrock; reside in lower reaches of fresh water for up to 3 years; age at sexual maturity uncertain; feed on fishes and invertebrates (Wydoski and Whitney 2003; Nakamoto and Kisanuki 1995; Adams et al. 2002; Emmett et al. 1991)	Spawning: Spring Incubation and Emergence: Large eggs sink to bottom, weak swimmers (Kynard et al. 2005)
White sturgeon	*Acipenser transmontanus*	Found in marine waters and major rivers in Washington; in marine settings, adults and subadults use estuarine and marine nearshore, including some movement into intertidal flats to feed at high tide; some landlocked populations behind dams; seasonally use main channels and sloughs; juveniles also occupy boulder and bedrock substrate; prefers swift (2.6 to 9.2 feet per second) and deep (13 to 66 feet) water on bedrock substrate for spawning; juveniles feed on mysid shrimp and amphipods; large fish feed on variety of crustaceans, annelid worms, molluscs, and fish (Parsley et al. 1993; Wydoski and Whitney 2003; Emmett et al. 1991)	Spawning: April to July Incubation: Approx. 7 days Emergence: Approx. 7 days
Newcomb's littorine snail	*Algamorda subrotundata*	Found in Grays Harbor and Willapa Bay on Washington coast; current distribution uncertain; algae feeder occupying narrow band in Salicornia salt marshes above mean higher high water (MHHW); not a true marine gastropod (Larsen et al. 1995)	Egg Laying: Unknown
Pacific sand lance	*Ammodytes hexapterus*	Schooling plankton feeders; spawn on sand and gravel at tidal elevations of 4 to 5 feet (+1.5 meters [m]) MHHW; larvae and young rear in bays and nearshore; adults feed during the day and burrow into the sand at night (Garrison and Miller 1982, In: Nightingale and Simenstad 2001b; WDFW 1997b, In: NRC 2001).	Spawning: November to February Incubation: On sand substrate Emergence: January to April
California floater (mussel)	*Anodonta californiensis*	Freshwater filter feeder requiring clean, well-oxygenated water; declining through much of historical range; known to occur in Columbia and Okanogan rivers and several lakes; intolerant of habitats with shifting substrates, excessive water flow fluctuations, or seasonal hypoxia; fertilization takes place within the brood chambers of the female mussel; the fertilized eggs develop into a parasitic stage called glochidia; released glochidia attach to species-specific host fish; juvenile and adult mussels attach to gravel and rocks (Nedeau et al. 2005; Larsen et al. 1995; Box et al. 2003; Frest and Johannes 1995, In: WDNR 2006b)	Spawning: Spring Incubation: In brood pouch, duration unknown; glochidia attach to host fish during metamorphosis
Mountain sucker	*Catostomus platyrhynchus*	Distribution restricted to Columbia River system; found in clear, cold mountain streams less than 40 feet wide and in some lakes; prefer deep pools in summer with moderate current; juveniles prefer slower side channels or weedy backwaters; food consists of algae and diatoms (Wydoski and Whitney 2003)	Spawning: June and July

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Pacific herring	*Clupea harengus pallasi*	18 separate stocks in Puget Sound; utilize shallow subtidal habitats (between 0 and –10 feet mean lower low water [MLLW]) for spawning and juvenile rearing; spawning has also occurred above MLLW; widely distributed throughout Puget Sound and coastal wetlands; feed on harpacticoid copepods; important forage fish (WDFW 1997a; Simenstad et al. 1979, In: NRC 2001 and In: Nightingale and Simenstad 2001b).	Spawning: Late January to early April, oviparous Egg Incubation: 10 to 14 days; eggs adhere to eelgrass, kelp, seaweed Emergence: Larvae are pelagic (i.e., free floating)
Margined sculpin	*Cottus marginatus*	Endemic to southeastern Washington; habitat is in deeper pools and slow-moving glides in headwater tributaries with silt and small gravel substrate; spawn under rocks in pools; prefer cool water less than 68 degrees Fahrenheit (F) (20 degrees Celsius [C]); avoid high-velocity areas; food is unknown (Wydoski and Whitney 2003; Mongillo and Hallock 1998)	Spawning: May to June Incubation and Emergence: Unknown
Lake chub	*Couesius plumbeus*	Bottom dwellers inhabiting a variety of habitats in lakes and streams; prefer small, slow streams; spawn on rocky and gravelly substrate in tributary streams to lakes; juveniles feed on zooplankton and phytoplankton; adults feed on insects (Wydoski and Whitney 2003)	Spawning: April to June, broadcast spawn
Giant Columbia River limpet	*Fisherola nuttalli*	Also known as the shortface lanx; occupies fast-moving and well-oxygenated streams, specifically the Hanford Reach, Wenatchee and Methow rivers; found in shallow, rocky areas of cobble to boulder substrate; species feeds by grazing on algae and small crustaceans attached to rocks (Neitzel and Frest 1990, In: WDNR 2006b)	Unknown
Great Columbia River spire snail	*Fluminicola columbiana*	Also known as the Columbia pebblesnail and ashy pebblesnail; current range is restricted to rivers, streams, and creeks of the Columbia River basin; require clear, cold streams with highly oxygenated water; found in riffle pool on substrates ranging from sand to gravel or rock; graze on algae and small crustaceans (Neitzel and Frest 1990; Neitzel and Frest 1989, In: WDNR 2006b)	Unknown
Pacific cod	*Gadus macrocephalus*	Adults and large juveniles found over clay, mud, and coarse gravel bottoms; juveniles use shallow vegetated habitats such as sand-eelgrass; opportunistic feeders on invertebrates (worms, crabs, shrimp) and fishes (sand lance, pollock, flatfishes); larval feeding unknown (Bargmann 1980; Hart 1973; Dunn and Matarese 1987; NMFS 1990; Garrison and Miller 1982; Albers and Anderson 1985, In: NRC 2001 and In: Nightingale and Simenstad 2001b)	Spawning: Oviparous Incubation: Late fall to early spring, 1 to 4 weeks Emergence: Larvae and juveniles are pelagic
Western ridged mussel	*Gonidea angulata*	Specific information on this species is generally lacking; reside on substrates ranging from dense mud to coarse gravel in creeks, streams, and rivers; found in a variety of flow regimes; species may tolerate seasonal turbidity but is absent from areas with continuous turbidity (WDNR 2006b)	Larvae generally attach to the gills of fish for 1 to 6 weeks; post-larval mussels "hatch" from cysts as free living juveniles to settle and bury in the substrate
Northern abalone	*Haliotis kamtschatkana*	Also known as pinto abalone; limited to the Strait of Juan de Fuca and the San Juan Islands; occupies bedrock and boulders from extreme low to 100 feet (30 m) below MLLW; usually associated with kelp beds (NMFS 2004; Gardner 1981; West 1997; In: WDNR 2006b)	Spawning: Broadcast spawners; release pelagic gametes that develop into free-swimming larvae; mature larvae settle on crustose corralline algae

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Surf smelt	*Hypomesus pretiosus*	Schooling plankton-feeding forage fish, spawn at the highest tides at high slack tide on coarse sand and pea gravel; juveniles rear in nearshore areas and adults form school offshore; feed on planktonic organisms; important forage fish (WDFW 1997c; Penttila 2000a, In: NRC 2001 and In: Nightingale and Simenstad 2001b)	Spawning: Year round in north Puget Sound, fall and winter spawning in south Puget Sound, and summer spawning along the coast Incubation: 2 to 5 weeks Emergence: Varies with season; 27 to 56 days in winter; 11 to 16 days in summer
River lamprey	*Lampetra ayresi*	Detailed distribution records not available for Washington; occupy fine silt substrates in backwaters of cold-water streams; larvae (ammocoetes) are filter feeders in mud substrates of cold-water streams; juveniles believed to migrate to Pacific Ocean several years after hatching; adults spend May to September in ocean before migrating to fresh water; adults attach to and feed on fish (Wydoski and Whitney 2003)	Spawning: April to July Incubation: April to July Emergence: 2 to 3 weeks after spawning
Western brook lamprey	*Lampetra richardsoni*	Found in small coastal and Puget Sound rivers and lower Columbia and Yakima river basins; spend entire life in fresh water; adults found in cool water (52 to 64 degrees F; 11 to 17.8 degrees C) on pebble/rocky substrate; ammocoetes inhabit silty stream bottoms in quiet backwaters; ammocoetes are filter feeders; mature adults do not feed (Wydoski and Whitney 2003)	Spawning: April to July Incubation and Emergence: Adhesive eggs hatch in 10 days
Pacific lamprey	*Lampetra tridentata*	Found in most large coastal and Puget Sound rivers and Columbia, Snake, and Yakima river basins; larvae (ammocoetes) are filter feeders in mud substrates of cold-water streams; juveniles migrate to Pacific Ocean 4 to 7 years after hatching; attach to fish in ocean for 20 to 40 months before returning to rivers to spawn (Wydoski and Whitney 2003)	Spawning: April to July Incubation: April to July Emergence: 2 to 3 weeks after spawning
Pacific hake	*Merluccius productus*	The coastal stock of hake is migratory; Puget Sound stocks reside in estuaries and rarely migrate; schooling fish; larvae feed on calanid copepods; juveniles and small adults feed on euphausiids; adults eat amphipods, squid, herring, smelt (Bailey 1982; NMFS 1990; Quirollo 1992; McFarlane and Beamish 1986, In: NRC 2001)	Spawning: May spawn more than once per season Incubation: January to April Emergence: Pelagic eggs and larvae
Olympic mudminnow	*Novumbra hubbsi*	Occur in the southern and western lowlands of the Olympic Peninsula, the Chehalis River drainage, lower Deschutes River drainage, and south Puget Sound lowlands west of the Nisqually River and in King County; found in quiet water with mud substrate, preferring bogs and swamps with dense aquatic vegetation; feed on annelids, insects, and crustaceans (Harris 1974; Mongillo and Hallock 1999, In: WDNR 2006a; Wydoski and Whitney 2003)	Spawning: Late November to December Early March to mid-June Incubation: 9 days Emergence: 7 days after hatching
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	NOAA Fisheries recognizes three Evolutionarily Significant Units (ESUs) in Washington: (1) Puget Sound; (2) Olympic Peninsula; (3) Southwestern Washington; coastal cutthroat trout exhibit resident (stays in streams), fluvial (migrates to rivers), adfluvial (migrates to lakes), and anadromous life-history forms; resident coastal cutthroat trout utilize small headwater streams for all of their life stages; coastal cutthroat trout are repeat spawners; typically rear in the natal streams for up to 2 years; juveniles feed primarily on aquatic invertebrates but are opportunistic feeders; utilize estuaries and nearshore habitat but has been caught offshore (Johnson et al. 1999; Pauley et al. 1988, In: WDNR 2006a)	Spawning: Late December to February Incubation: 2 to 4 months Emergence: 4 months

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Subspecies of cutthroat trout; three possible life forms: adfluvial, fluvial, or resident; all three life forms spawn in tributary streams in the spring when water temperature is about 50 degrees F (10 degrees C); fry spend 1 to 4 years in their natal streams; cutthroat trout tend to thrive in streams with more pool habitat and cover; fry feed on zooplankton, fingerlings feed on aquatic insect larvae, and adults feed on terrestrial and aquatic insects (Liknes and Graham 1988; Shepard et al. 1984; Wydoski and Whitney 2003)	Spawning: March to July Incubation: April to August Emergence: May to August
Pink salmon	*Oncorhynchus gorbuscha*	Pink salmon is the most abundant species of salmon, with 13 stocks identified in Washington; pink salmon, the smallest of the Pacific salmon, mature and spawn on a 2-year cycle; opportunistic feeder in marine habitat, foraging on a variety of forage fish, crustaceans, ichthyoplankton, and zooplankton; will spawn in rivers with substantial amounts of silt; migrate downstream almost immediately after emergence, moving quickly to marine nearshore habitats where they grow rapidly, feeding on small crustaceans, such as euphausiids, amphipods, and cladocerans (Hard et al. 1996; Heard 1991, In: WDNR 2006a)	Spawning: August to October Incubation: 3 to 5 months Emergence: 3 to 5 months
Chum salmon	*Oncorhynchus keta*	NOAA Fisheries recognizes four ESUs in Washington: (1) Hood Canal summer run; (2) Columbia; (3) Puget Sound/Strait of Georgia; (4) Pacific Coast; little is known regarding their ocean distribution; maturing individuals that return to Washington streams have primarily been found in the Gulf of Alaska; usually found in the rivers and streams of the Washington coast, Hood Canal, Strait of Juan de Fuca, and Puget Sound; in the Columbia River basin, their range does not extend above the Dalles Dam; chum salmon rear in the ocean for the majority of their adult lives; at maturity, adults migrate homeward between May and June, entering coastal streams from June to November; chum fry feed on chironomid and mayfly larvae, as well as other aquatic insects; chum fry arrive in estuaries earlier than most salmon; juvenile chum reside in estuaries longer than most other anadromous species (Quinn 2005; Salo 1991; Healey 1982, In: Wydoski and Whitney 2003 and WDNR 2006a)	Spawning: October to December Incubation: 0.5 to 4.5 months Emergence: 6 months
Coho salmon	*Oncorhynchus kisutch*	NOAA Fisheries recognizes three ESUs in Washington: (1) Lower Columbia River/SW Washington; (2) Puget Sound and Strait of Georgia; and (3) Olympic Peninsula; this species is found in a broader diversity of habitats than any of the other native anadromous salmonids; coho spend between 1 and 2 years in the ocean before returning to spawn; adult coho feed on invertebrates but become more piscivorous as they grow larger; spawning occurs in gravel free of heavy sedimentation; developing young remain in gravel for up to 3 months after hatching; coho fry feed primarily on aquatic insects and prefer pools and undercut banks with woody debris; coho rear in fresh water for 12 to 18 months before moving downstream to the ocean in the spring (Meehan 1991; Groot and Margolis 1991, In: WDNR 2006a; Wydoski and Whitney 2003)	Spawning: September to late January Incubation: 1.5 to 2 months Emergence: 2 to 3 weeks
Redband trout	*Oncorhynchus mykiss gairdneri*	Redband trout is a subspecies of rainbow trout found east of the Cascade Mountains; prefer cool water, less than 70 degrees F (21 degrees C), and occupy streams and lakes containing high amounts of dissolved oxygen; spawn in streams; food consists of Daphnia and chironomids as well as fish eggs, fish, and insect larvae and pupae (Busby et al. 1996; Wydoski and Whitney 2003).	Spawning: March to April Incubation: 1 to 3 months Emergence: 3 months

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Steelhead	*Oncorhynchus mykiss*	NOAA Fisheries recognizes 15 ESUs of steelhead, seven of which occur in Washington; during their ocean phase of life, steelhead are generally found within 10 to 25 miles of the shore; steelhead remain in the marine environment 2 to 4 years; most steelhead spawn at least twice in their lifetimes; a summer spawning run enters fresh water in August and September, and a winter run occurs from December through February; escape cover, such as logs, undercut banks, and deep pools, is important for adult and young steelhead; after hatching and emergence, juveniles establish territories feeding on microscopic aquatic organisms and then larger organisms such as isopods, amphipods, and aquatic and terrestrial insects; steelhead rear in fresh water for up to 4 years before migrating to sea (McKinnell et al. 1997, In: WDNR 2006a; Wydoski and Whitney 2003)	Spawning: March to April Incubation: 1 to 3 months Emergence: 3 months
Sockeye salmon	*Oncorhynchus nerka*	WDFW recognizes nine sockeye salmon stocks in the state; of these, three are in Lake Washington and two in the Columbia River. Sockeye are found in the Snake and Okanogan, Lake Wenatchee, Lake Quinault, Lake Ozette, Baker River, Lake Pleasant, and Big Bear Creek drainages. Kokanee (landlocked sockeye) occur in many lakes, with the larger populations in Banks and Loon Lakes and Lake Whatcom and Lake Washington-Sammamish; spawn in shallow gravelly habitat in rivers and lakes and live in lakes 1 to 2 years before migrating to ocean; juveniles feed on zooplankton, adults feed on fishes, euphausiids, and copepods (Wydoski and Whitney 2003)	Spawning: August to October Incubation: 3 to 5 months Emergence: 3 to 5 months
Chinook salmon	*Oncorhynchus tschawytscha*	Chinook exhibit one of two life-history types, or races: the stream-type and the ocean-type; Stream-type Chinook tend to spend 1 (or less frequently 2) years in fresh water environments as juveniles prior to migrating to salt water as smolts; stream-type Chinook are much more dependent on freshwater stream ecosystems than ocean-type Chinook; spring Chinook are especially dependent on high water quality and good access to spawning areas; stream-type Chinook do not extensively rear in estuarine and marine nearshore environments, rather they head offshore and begin their seaward migrations; Ocean-type chinook enter saltwater at one of three phases: immediate fry migrants soon after yolk resorption, fry migrants after 60 to 150 day after emergence, and fingerling migrants which migrate in the late summer of fall of their first year; ocean-type Chinook are more dependent on estuarine habitats to complete their life history than any other species of salmon Chinook "runs" are designated on the basis of adult migration timing. Early, spring-run chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and finally spawn in the late summer and early autumn. Late, fall-run Chinook salmon enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry Chinook generally feed on invertebrates, but become more piscivorous with age (Wydoski and Whitney 2003; Myers et al. 1998, In: WDNR 2006a; Healey 1991)	Spring Chinook: Spawning: mid-July to mid-December Incubation: 6 to 8 months Emergence: 6 to 9 months Fall Chinook: Spawning: Late October to early December Incubation: 1 to 6 months Emergence: 6 months

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Lingcod	*Ophiodon elongatus*	Spawn in shallow water and intertidal zone; juveniles prefer sand habitats while adults prefer rocky substrates; larvae and juveniles found in upper 115 feet (35 m) of water; adults prefer slopes of submerged banks with macrophytes and channels with swift currents; larvae feed on copepods and amphipods; juveniles feed on small fishes, adults on demersal fishes and squid and octopi (Adams and Hardwick 1992; Giorgi 1981; NMFS 1990; Emmett et al. 1991, In: NRC 2001)	Spawning: January to late March Incubation and Emergence: February to June; egg masses adhere to rocks
Olympia oyster	*Ostrea lurida*	Species found throughout the inland waters of Puget Sound, as well as in Willapa Bay and possibly Grays Harbor; also grown commercially in Puget Sound; occupy nearshore ecosystem on mixed substrates with solid attachment surfaces; found from 1 foot (0.3 m) above MLLW to 2 feet (0.6 m) below MLLW; intolerant of siltation; larvae settle onto hard substrate such as oyster shells, rocks (West 1997; Baker 1995; In: WDNR 2006b)	Spawning: Spring to fall; reproduce when water temperatures are between 54 and 61 degrees F (12.5 and 16 degrees C) Incubation and Emergence: After 8 to 12 days, larvae develop into free-swimming larvae; larvae are free-swimming for 2 to 3 weeks
Pygmy whitefish	*Prosopium coulteri*	In Washington, pygmy whitefish occur at the extreme southern edge of their natural range; pygmy whitefish were once found in at least 15 Washington lakes but have a current distribution in nine; most often occur in deep, oligotrophic lakes with temperatures less than 50 degrees F (10 degrees C); use shallow water or tributary streams during the spawning season; feed on zooplankton, such as cladocerans, copepods, and midge larvae (Hallock and Mongillo 1998, In: WDNR 2006a; Wydoski and Whitney 2003)	Spawning: July to November Incubation and Emergence: Unknown
Leopard dace	*Rhinicthys falcatus*	Within Washington, leopard dace currently inhabit the lower, mid, and upper reaches of the Columbia, Snake, Yakima and Similikameen rivers; utilize habitat on or near the bottom of streams and small to mid-sized rivers with velocities less than 1.6 feet/sec (0.5 m/second); prefers gravel and small cobble substrate covered by fine sediment with summer water temperatures ranging between 59 and 64 degrees F (15 and 18 degrees C); juveniles feed primarily on aquatic insects, adult leopard dace consume terrestrial insects; little is known about leopard dace spawning habitat or behavior (Wydoski and Whitney 2003)	Spawning: May to July Incubation and Emergence: Unknown
Umatilla dace	*Rhinicthys umatilla*	Umatilla dace are benthic fish found in relatively productive, low-elevation streams; inhabit streams with clean substrates of rock, boulders, and cobbles in reaches where water velocity is less than 1.5 feet/second; juveniles occupy streams with cobble and rubble substrates; adults occupy deeper water habitats; food habits are unknown (Wydoski and Whitney 2003)	Little known of reproduction Spawning: Early to mid-July Incubation and Emergence: Unknown
Bull trout	*Salvelinus confluentus*	Widely distributed in Washington; exhibits four life-history types – anadromous, adfluvial, fluvial, and resident; bull trout typically rear in their natal streams for 2 to 4 years, although resident fish may remain in these streams for their entire lives; multiple life-history forms occur together in the same water; young-of-the-year occupy side channels, with juveniles in pools, runs, and riffles; adults occupy deep pools; diet of juveniles includes larval and adult aquatic insects; subadults and adults feed on fish; bull trout in the nearshore ecosystem rely on estuarine wetlands and favor irregular shorelines with unconsolidated substrates (Wydoski and Whitney 2003; Goetz et al. 2004, In: WDNR 2006a)	Spawning: Late August to late December Incubation and Emergence: 4 to 6 months

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Dolly Varden	*Salvelinus malma*	Species restricted to coastal areas and rivers that empty into them; species occurs sympatrically in streams in Olympic Peninsula; prefer pool areas and cool temperatures; spawn and rear in streams, may feed and winter in lakes; juveniles extensively use instream cover; ages 1 to 13 utilize beaches composed of sand and gravel; opportunistic feeders on aquatic insects, crustaceans, salmon eggs, fish (Leary and Allendorf 1997, In: Wydoski and Whitney 2003)	Spawn mid-September to November; hatch 129 days after fertilization
Brown rockfish	*Sebastes auriculatus*	Utilize shallow-water bays with natural and artificial reefs and rock piles; estuaries are used as nurseries; can tolerate water temperatures to at least 71 degrees F (22 degrees C); eat small fishes, crabs, isopods (Stein and Hassler 1989; Eschmeyer et al. 1983; Love 1991, In: NRC 2001)	Spawning: March to June Incubation: June
Copper rockfish	*Sebastes caurinus*	Occur both inshore and on open coast; adults prefer rocky areas in shallower water than other rockfish species; juveniles use shallow and nearshore macrophytes and eelgrass habitat; feed on crustaceans, fish, and molluscs (Eschmeyer et al. 1983; Matthews 1990a; Haldorson and Richards 1986; Stein and Hassler 1989, In: NRC 2001)	Spawning: March to May Incubation: April to June Emergence: Larvae are pelagic
Greenstriped rockfish	*Sebastes elongates*	Adults found in benthic and mid-water columns; utilize a variety of bottom types; feed on euphausiids, small fishes, and squid (Eschmeyer et al. 1983; Love et al. 1990, In: NRC 2001)	Spawning: Viviparous; spawn two or more times per season Emergence: Late April to late June
Widow rockfish	*Sebastes entomelas*	Adults found from 330- to 1,000-foot (100- to 300-m) depths near rocky banks, ridges, and seamounts; adults feed on pelagic crustaceans, Pacific hake, squids; juveniles feed on copepods, euphausiids (Eschmeyer et al. 1983; Laroche and Richardson 1981; NMFS 1990; Reilly et al. 1992, In: NRC 2001)	Spawning: Viviparous; October to December Incubation: 14 days Emergence: March to May
Yellowtail rockfish	*Sebastes flavidus*	Adults found from 165- to 1,000-foot (50- to 300-m) depths; adults semi-pelagic or pelagic over steep-sloping shores and rocky reefs; juveniles occur in nearshore area; opportunistic feeders on pelagic animals including hake, herring, smelt, squid, krill and euphausiids (Eschmeyer et al. 1983; Love 1991; O'Connell and Carlile 1993, In: NRC 2001)	Spawning: Viviparous; October to December Emergence: February to March Larvae and juveniles are pelagic
Quillback rockfish	*Sebastes maliger*	Shallow-water benthic species in inlets near shallow rock piles and reefs; juveniles use eelgrass/sand and beds of kelp; feed on amphipods, crabs, copepods (Clemens and Wilby 1961; Hart 1973; Love 1991; Matthews 1990b; Hueckel and Slayton 1982; Rosenthal et al. 1988, In: NRC 2001)	Spawning: Viviparous; April to July Emergence: May to July
Black rockfish	*Sebastes melanops*	Low and high rock substrates in summer, deeper water in winter; kelp and eelgrass for juveniles; feed on nekton and zooplankton (Boehlert and Yoklavich 1983; Stein and Hassler 1989, In: NRC 2001)	Spawning: February to April Emergence: Larvae and juveniles are pelagic
China rockfish	*Sebastes nebulosus*	Occur inshore and on open coast in sheltered crevices; feed on crustacea (brittle stars and crabs), octopi, and fishes (Eschmeyer et al. 1983; Love 1991; Rosenthal et al. 1988, In: NRC 2001)	Spawning: January to July
Tiger rockfish	*Sebastes nigrocinctus*	Semi-demersal to demersal species occurring at depths ranging from shallows to 1,000 feet (305 m); larvae and juveniles occur near surface and range of depth; adults use rocky reefs, canyons, and headlands; generalized feeders on shrimp, crabs, small fishes (Garrison and Miller 1982; Moulton 1977; Rosenthal et al. 1988, In: NRC 2001)	Spawning: Ovoviviparous; peak May and June Emergence: Juveniles are pelagic

Common Name	Scientific Name	Habitat and Life Requirements[1]	Reproductive Timing[2]: Spawning, Egg Incubation, Emergence
Bocaccio rockfish	*Sebastes paucispinis*	Adults semi-demersal in shallow water over rocks with algae, eelgrass, and floating kelp; larvae feed on diatoms; juveniles feed on copepods and euphausiids (MBC Applied Environmental Sciences 1987; Garrison and Miller 1982; Hart 1973; Sumida and Moser 1984 In: NRC 2001)	Spawning: Ovoviviparous; year-round Incubation: 40 to 50 days Emergence: Released 7 days after hatching; larvae and juveniles are pelagic
Canary rockfish	*Sebastes pinniger*	Adults use sharp dropoffs and pinnacles with hard bottoms; often associated with kelp beds (Sampson 1996); feed on krill and occasionally on fish (Boehlert 1980; Boehlert and Kappenman 1980; Hart 1973; Love 1991; Boehlert et al. 1989, In: NRC 2001)	Spawning: Ovoviviparous; January to March Emergence: Larvae and juveniles are pelagic
Redstripe rockfish	*Sebastes proriger*	Adults found at depths between 330 and 1,000 feet (100 and 350 m) and young often found in estuaries in high- and low-relief rocky areas; juveniles feed on copepods and euphausiids; adults eat anchovies, herring, squid (Hart 1973; Kendall and Lenarz 1986; Garrison and Miller 1982; Starr et al. 1996, In: NRC 2001)	Spawning: Ovoviviparous Emergence: July; larvae and juveniles are pelagic and semi-demersal
Yelloweye rockfish	*Sebastes ruberrimus*	Adults found from 80- to 1,800-foot (25- to 550-m) depths near reefs and cobble bottom; juveniles prefer shallow, broken-bottom habitat; feed on other rockfish species, cods, sand lance, herring, shrimp, snails (Clemens and Wilby 1961; Eschmeyer et al. 1983; Hart 1973; Rosenthal et al. 1988, In: NRC 2001)	Spawning: Ovoviviparous Emergence: June
Longfin smelt	*Spirinchus thaleichthys*	Marine species that spawns in streams not far from marine waters; juveniles utilize nearshore habitats of a variety of substrates; juveniles feed on small Neomysis; adults feed on copepods and euphausiids; most adults die after spawning (Wydoski and Whitney 2003; Lee et al. 1980, In: Alaska Natural Heritage Program 2006)	Spawning: October to December Incubation and Emergence: Hatch in 40 days; larvae drift downstream to salt water
Eulachon	*Thaleichthys pacificus*	Eulachon occur from northern California to southwestern Alaska; occur in offshore marine waters and spawn in tidal portions of rivers; spawn in variety of substrates but sand most common; juveniles rear in nearshore marine areas; plankton-feeders eating crustaceans such as copepods and euphausiids; larvae and post-larvae eat phytoplankton, copepods; important prey species for fishes, marine mammals, and birds (Langer et al. 1977; Howell et al. 2001; Lewis et al. 2002; WDFW and ODFW 2001, In: Willson et al. 2006)	Spawning: During spring when water temperature is 40 to 50 degrees F (4 to 10 degrees C); eggs stick to substrate Incubation: Temperature-dependent, range 20 to 40 days Emergence: Larvae drift downstream to salt water
Walleye pollock	*Theragra chalcogramma*	Widespread species in northern Pacific; larvae and small juveniles found at 200-foot (60-m) depth; juveniles utilize nearshore habitats of a variety of substrates; juveniles feed on small crustaceans, adults feed on copepods, euphausiids, and young pollock; important prey species (Garrison and Miller 1982; Miller et al. 1976; Bailey et al. 1999; Livingston 1991, In: NRC 2001)	Spawning: February to April Incubation: Eggs suspended at depths ranging from 330 to 1,320 feet (100 to 400 m) Emergence: Pelagic larvae

Note: Species listed in alphabetical order by scientific name.

Definitions: demersal—living near, deposited on, or sinking to the bottom
oviparous—producing eggs that develop and hatch outside the maternal body
ovoviviparous—producing eggs that develop within the maternal body and hatch before or immediately after release
piscivorous—fish-eating
viviparous—producing living young rather than eggs

[1]Comments related to distribution pertain only to the Washington portion of species distribution.

[2]Spawning is given as seasonal timing, when information is available. Incubation is the time elapsed between spawning and hatching. Emergence is the time elapsed between hatching and when juveniles enter the water column; as noted above where relevant, some hatchlings enter the water column immediately.

6 CONCEPTUAL FRAMEWORK FOR ASSESSING IMPACTS

Overwater structures and non-structural piling can impact potentially covered species via a number of mechanisms affecting organisms, their habitats, or critical ecological functions. Such impacts can affect organisms either directly, such as when an organism is injured by a piece of machinery, or indirectly by affecting any of the elements shown on Figure 1 (reprinted from Williams and Thom 2001).

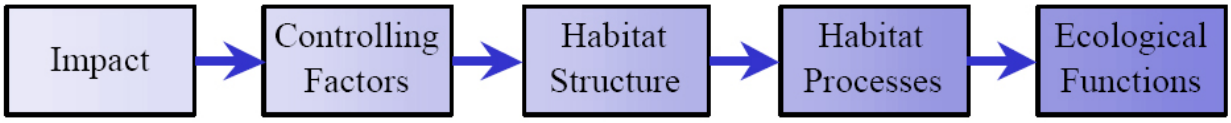

Figure 1
Conceptual Framework for Assessment

The conceptual framework begins with an impact, which in this case would consist of activities authorized under an HPA for an overwater structure or non-structural piling. That impact can in turn alter controlling factors (e.g., flow conditions or sediment sources), which are expressed in the environment via habitat structure (e.g., sediment composition or the structure of the vegetation community). Habitat structure is linked to habitat processes (e.g., shading or pool formation), which underpin ecological functions (e.g., production of forage fish) that support the ecosystem. Altering any of these elements can potentially result in an impact to one or more of the potentially covered species.

The literature reviewed for this white paper primarily identifies certain critical controlling factors, habitat structural elements, and habitat processes that have high potential to be affected by human activities in general and by overwater structures or non-structural piling in particular. The impact analysis that follows in Section 7 is based on a review of specific impact pathways associated with the controlling factors, habitat structural elements, and habitat processes. Table 4 lists and defines the impact pathways evaluated in this white paper and describes how human alteration of a pathway can affect potentially covered species. Section 7 discusses the direct and indirect impacts associated with each impact pathway.

Table 4
Principal Impact Pathways Evaluated

Pathway	Description
Shading	All shading of waters, whether by natural or artificial means.
Littoral vegetation	Artificial changes in submerged or intertidal marine or estuarine vegetation.
Freshwater aquatic vegetation	Artificial changes in submerged freshwater vegetation.
Riparian and shoreline vegetation	Artificial changes in riparian or shoreline vegetation, including all functions performed by large woody debris in or near the channel.
Noise	Artificial noise from pile driving, motors, vessel operations, and other noise-generating activities.
Water quality	Changes in water quality, primarily in turbidity but also in temperature, pH, dissolved oxygen content, and metallic or organic toxins.
Channel hydraulics	Changes in substrate composition or morphology that result when channel processes are altered by artificial means.
Littoral drift	Changes in substrate composition or morphology that result when littoral processes are altered by artificial means.
Substrate modifications	Changes in substrate composition (grain size) or restructuring by artificial means (e.g., excavation, fill).
Channel dewatering	Changes that result from altered flow, principally dewatering that occurs due to stream diversion during overwater structure construction.
Artificial light	Artificial light used during construction or operation of a structure.
Vessel activities	Changes resulting from the operation of vessels and other submerged equipment during construction or other vessel-related activities that occur during construction of the overwater structure or installation of non-structural piling.

7 DIRECT AND INDIRECT IMPACTS

Potentially covered species are vulnerable to incidental take via certain impact pathways, as identified in Section 6. These pathways correspond to controlling factors and habitat structure elements (Figure 1). The following discussion describes each of these pathways and how each pathway is linked to essential life-history traits or particular habitat requirements of potentially covered species. The risk of causing incidental take is discussed in Section 9, and potential means of avoiding or minimizing take are discussed in Section 11.

Note that there is an element of overlap among some impact pathways; for instance, vessel activities (Section 7.12) necessarily include some element of noise (Section 7.5) and artificial light (Section 7.11). In the following impact analysis, such areas of overlap are identified by cross-references.

7.1 Shading

The information summarized in this section is largely taken from two extensive literature reviews prepared for WDFW that analyze the biological impacts of overwater structures: *Marine Overwater Structures: Marine Issues* (Nightingale and Simenstad 2001b) and *Over-Water Structures: Freshwater Issues* (Carrasquero 2001). The white papers discuss relevant literature on the environmental effects, data gaps, and recommended impact reduction techniques applicable to overwater structures, non-structural pilings, marinas, and other structures found in and around water bodies of the state. More recent studies and reports published between 2000 and October 2006 were also reviewed to augment information on the impacts of shading.

Populations and diversity of aquatic species in the Pacific Northwest can be severely limited in environments shaded by overwater structures when compared to adjacent unshaded, vegetated habitats (Orth and Moore 1983, Thayer et al. 1984, Fresh et al. 1995, Parametrix and Battelle 1996, Thom et al. 1996, Ludwig et al. 1997, Fresh et al. 2000, all in Nightingale and Simenstad 2001b; Thom et al. 1998). Overwater structures can create sharp underwater light contrasts by casting shade in ambient daylight conditions, in turn limiting light availability for plant photosynthesis and growth. Limiting photosynthesis indirectly impacts the food chain for fish and invertebrates. Artificial structures affect distributions, behavior, growth, and survival of fish and invertebrates in the vicinity of the structure.

Because teleost (i.e., bony) fishes such as salmonids, rockfish, flatfish, cod, pollock, and other common fishes in Washington place strong reliance on vision and light for migration, foraging, and refuge, changes in the ambient light regime can make such fishes vulnerable to predation, starvation, or reduced fitness (Nightingale and Simenstad 2001b).

The effects of reduced underwater vegetation on potentially covered species are addressed in Sections 7.2 and 7.3, which discuss littoral vegetation (e.g., eelgrass and macroalgae) and freshwater aquatic vegetation, respectively. Therefore, the following discussion focuses on the direct impacts of shading on potentially covered species.

7.1.1 Fish Vision

In addition to affecting aquatic vegetation, shade can affect fish and invertebrates by disrupting normal migration patterns, reducing the ability to avoid predators, and reducing available refuge. Teleost fishes, which include all potentially covered fish species except sturgeon and lamprey, depend on sight for feeding and schooling. As juveniles, they utilize nearshore or shallow water habitats and share a sensitivity to ultraviolet wavelengths reflected in shallow-water habitats (Tribble 2000, Britt 2001, both in Nightingale and Simenstad 2001b). Figure 2 depicts light conditions related to juvenile salmon behavior such as schooling, predator avoidance, feeding, and migratory behavior.

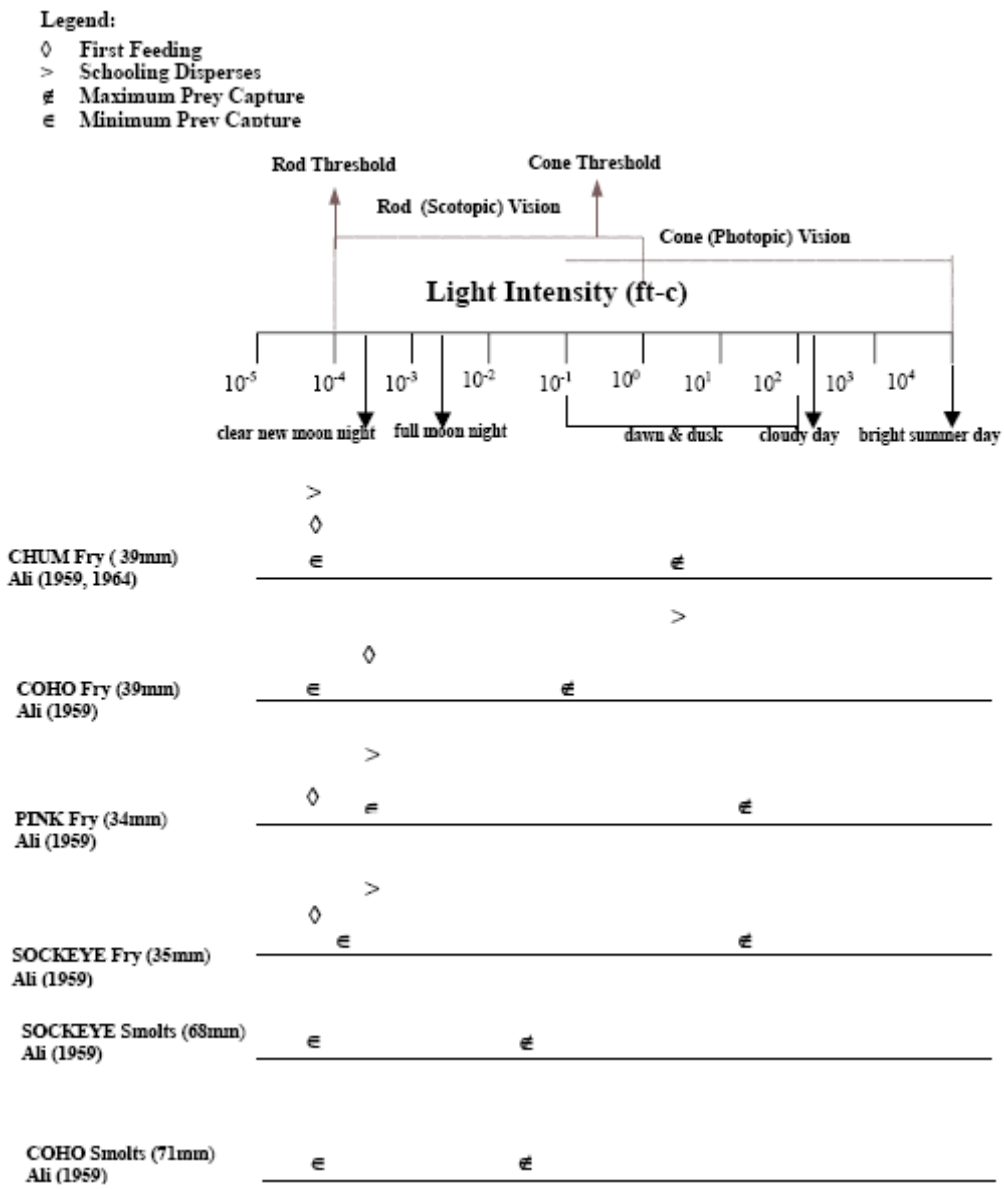

Figure 2
Juvenile Salmon Behavior Patterns Related to Light Intensity
Source: Nightingale and Simenstad 2001b

Tribble (2000, in Nightingale and Simenstad 2001b) found the swimming and feeding behavior of juvenile and larval sand lance (*Ammodytes hexapterus*) to be reduced with low light levels. Similar to other juvenile fishes with cone-based vision, the retinal cells of larval sand lance fall in the violet to green range, with limited visual acuity in low-light environments. Their visual acuity increases with growth as their cone pigments

shift from violet to blue sensitivity. Tribble (2000, in Nightingale and Simenstad 2001b) reports that sand lance visual development reflects the habitats they occupy at given total lengths. Rods appear to develop when the fish reach approximately 1 inch (24 millimeters [mm]), and full adult visual acuity develops at 1.4 inches (35 mm). At approximately 2 inches (50 mm) in size, the fish will begin to move into deeper pelagic waters, where the light environment changes, and their light requirements for prey capture change in response to the light wavelengths characteristic of that habitat. At this point they will largely depart from the range of water depths where they may be affected by overwater structures. A similar change in visual sensitivity has been observed in yellow perch. Brownan and Hawryshyn (1994, in Nightingale and Simenstad 2001b) report this loss of ultraviolet sensitivity to be size-dependent rather than age-dependent and to likely correlates with the time when fishes move from shallow to deeper water. These results suggest that shading effects attributable to overwater structures predominantly affect smaller fish, and that "shading" as an impact includes the loss of both visual and ultraviolet wavelengths of light.

7.1.2 Prey Abundance, Feeding, and Growth

Juvenile and larval fish are primarily visual feeders, and starvation is the major cause of larval mortality in marine fish populations. Early life-history stage survival is linked to the ability to locate and capture prey and avoid predators (Britt 2001, in Nightingale and Simenstad 2001b).

Capture success is often directly related to prey abundance in a given location, as well as to fish growth and fitness. Kahler et al. (2000) states that shading from overwater structures may reduce the abundance of prey organisms available to juvenile salmonids and forage fish by reducing aquatic vegetation and phytoplankton abundance. Similarly, Haas et al. (2002) found that densities and assemblages of important epibenthic prey organisms were reduced under large overwater structures. In New York Harbor, Able et al. (1998, in Nightingale and Simenstad 2001b) found juvenile fish abundance to be reduced under piers when compared to open-water areas or areas having only piles. This is likely due to limitations in both prey abundance and prey capture. In another study, Duffy-Anderson and Able (1999, in Nightingale and Simenstad 2001b) compared growth rates of caged juvenile fish under municipal piers to

those of fish caged at pier edges and to fish caged in open waters. Those fishes caged under the piers showed periods of starvation, making these individuals more vulnerable to predation, physiological stress, and disease. Along the pier edges, variability in growth rate was found to be high and likely light related. The authors concluded that light availability is likely an important component of feeding success. They also concluded that large piers do not appear to provide suitable habitat for some species of juvenile fishes and that increased sunlight enhances fish growth.

For young outmigrant salmon such as juvenile chum, pink, and ocean-type Chinook, prey availability is an important component to migration behavior.

7.1.3 Migration and Distribution

Investigations on shading impacts to fish migration and distribution have primarily focused on impacts to juvenile salmonids. Shading has been shown to have different consequences for migration and distribution of some fish in freshwater environments; therefore, shading impacts of overwater structures in freshwater and marine environments are discussed separately.

7.1.3.1 Marine Environment

Changes in ambient underwater light environments can alter juvenile salmon migration and distribution and potentially increase mortality risks. For example, studies have consistently documented a tendency for juvenile salmon to avoid passing beneath shaded habitats (Pentec 1997; Weitkamp 1982; and Heiser and Finn 1970, all in Nightingale and Simenstad 2001b; Southard et al. 2006; Tabor et al. 2006).

Studies in the Puget Sound region have found that under-pier light limitations and shadowing often change behaviors of juvenile salmonids in ways that could delay migration, alter schooling refuge behavior, and change migratory routes to deeper waters (which may increase their risk of predation). Juvenile salmonids encountering docks and piers have been observed variously to pass under the structure, pause and go around the structure, break up from schools, aggregate in the lighted portion of the water column, or pause and eventually go under the structure (Weitkamp 1982, Feist 1991, Pentec 1997, all in Nightingale and Simenstad

2001b; Feist et al. 1992; Toft et al. 2004; Southard et al. 2006; Tabor et al. 2006). Taylor and Wiley (1997, in Nightingale and Simenstad 2001b) and Weitkamp (1981, in Nightingale and Simenstad 2001b) found juvenile salmon distributed along the outer bulkheaded perimeters of marinas but did not find a significant abundance under or around floating docks. Southard et al. (2006) consistently found juvenile Chinook, chum, and coho salmon aggregating on the light side of the shadow line of ferry terminals during the day, and then sometimes passing under the terminals in the evening when the shadow was less distinct. Southard et al. (2006) also determined that, during the day, juvenile salmon may move more readily under structures at low tide, when more ambient light penetrates underneath. In an experimental release at the Port Townsend ferry terminal, Shreffler and Moursund (1999) found that released Chinook fry ceased their migration at the terminal's shadow line before consistently swimming from the shadow line to lighted areas, then darting back into the light-dark transition zone. As the sun dropped along the horizon and the shadow line moved in under the terminal dock, the Chinook school appeared to follow the shadow line, staying with the light-dark transition area. In studies of juvenile salmonid behavior around the Port of Seattle's Terminals 90 and 91, Weitkamp (1982, in Nightingale and Simenstad 2001b) observed that juvenile salmonids primarily congregated on the more sun-exposed west side rather than on the darker east side of the terminals. Salo et al. (1980, in Nightingale and Simenstad 2001b) observed that chum salmon shifted from nearshore migration to an offshore route upon encountering a wharf in Hood Canal, and Pentec (1997, in Nightingale and Simenstad 2001b) found that when juvenile chum salmon encountered piers in Everett Harbor, they milled around with no net movement for periods ranging from 30 minutes to 2 hours. Fewer and smaller schools were observed at piers, while the greatest number of and the largest schools were observed along riprapped shorelines, with feeding occurring along these shorelines but not under piers. Although the study revealed that fish encountering piers split up and moved around the piers, the conclusion was that the net effect of juvenile salmon encountering overwater structures was impossible to assess given the available data. Williams and Thom (2001), however, state that although individual shoreline structures may not impose significant impacts on salmon species, populations, or stocks, the

cumulative effect of dense, contiguous shoreline modifications has likely contributed to the decline of several Puget Sound salmon species.

7.1.3.2 Freshwater Environment

Juvenile salmonids behave similarly when approaching overwater structures in freshwater environments as they do in marine environments, according to recent studies (Tabor et al. 2006). Tabor et al. (2006) found that when migrating Chinook smolts approached piers in Lake Washington, they appeared to move into deeper water and then either pass directly under the structure or swim around the pier.

Research data on adult salmon, however, indicate that migrating adults hold at various locations within the Sammamish River, and most of the holding locations are underneath bridges, where it is shaded (King County 2000, in Carrasquero 2001).

7.1.4 Predation

In freshwater, ambush predators are often found distributed in natural or man-made shaded and covered environments (Stein 1970, Helfman 1979, both in Carrasquero 2001). Helfman (1979), studying shade-producing experimental floats in Cazenovia Lake, New York, found that several species of predator fishes are particularly attracted to the area under the floats. Carrasquero's (2001) review found that the attraction of fish to floating or overhanging objects is linked to the shade produced by the objects, and Kahler et al. (2000) suggests that piers, piles, boatlifts, and moored boats provide cover, shade, and focal points that benefit exotic predators of juvenile salmon, such as smallmouth and largemouth bass. An alternative explanation of fish attraction to on-water and overwater structures in fresh water was presented by Fresh (pers. comm., in Carrasquero 2001), who explains that both the structures and the shade they cast may provide fishes with physical reference points for orientation.

In the marine nearshore, daytime light reduction caused by shading under overwater structures could cause migrating juveniles to move into deeper waters, increasing the risk of predation by larger predators that occupy pelagic waters (Heiser and Finn 1981, Pentec 1977, in Nightingale and Simenstad 2001b). Predation mortality may increase

through altering predator detection and reducing refugia provided by the schooling behavior of juvenile salmonids (Pentec 1997, in Nightingale and Simenstad 2001b).

Although it is believed that predation risks are elevated when fish move into deeper waters around piers, the actual potential for increased predation due to aggregating predators under structures in marine environments is uncertain (Weitkamp 1981; Taylor and Wiley 1997, in Nightingale and Simenstad 2001b). Taylor and Wiley (1997) found no aggregation of avian predators and Weitkamp (1981) reported no aggregation of aquatic predators during the peak juvenile chum outmigration. Consistent with these findings, Penttila and Aguero (1978, in Nightingale and Simenstad 2001b) found no empirical evidence of predation among the marina floats in Birch Bay, but instead found evidence of competition among fish species for mutually preferred prey resources (i.e., the calanoid and harpacticoid copepods). Fresh and Cardwell (1978, in Nightingale and Simenstad 2001b) list 17 potential predators of juvenile salmon in the southern Puget Sound region and find that only three (maturing Chinook, copper rockfish, and staghorn sculpins) prey extensively on nearshore fishes. Their analysis of food habits found only staghorn sculpins with juvenile salmon in their stomachs, and there was no evidence that staghorn sculpins were in greater abundance under structures than elsewhere in the study area. Additionally, Ratte (1985, in Nightingale and Simenstad 2001b) found sea perch and pile perch, which do not prey on salmonids, to be the most abundant fish species under docks. Nightingale and Simenstad (2001b) and Southard et al. (2006) summarize these and additional studies that pertain to fish behavior, including migration, distribution, and predator/prey relationships potentially associated with overwater structures in marine areas of Puget Sound.

In freshwater environments of Western Washington, largemouth bass and smallmouth bass are common predators of juvenile salmonids, and several authors have documented the use of overwater structures by bass in Western Washington waters. Stein (1970, in Carrasquero 2001) examined the types of cover used by largemouth bass in Lake Washington and found that they prefer areas of heavy log and brush cover over other habitat types (including docks). However, largemouth bass are commonly found under docks in early spring and are thought to be present there until late summer (Stein 1970, in Carrasquero 2001). Carrasquero (2001) found studies that suggest the attraction

of predatory fish (including largemouth bass) to floating or overhanging objects is linked to the shade produced by the objects rather than to the tactile stimulus and that the larger the floating object, the greater the shaded area, and thus the greater the number of fish attracted to such objects. This assumption suggests that shading from overwater structures alters fish distribution and aggregation in fresh water.

Interactions between smallmouth bass and juvenile salmonids depend on factors such as the timing of salmonid outmigration, salmonid species, and residence time of juvenile salmonids in lentic (still-water) or lotic (flowing) environments (Warner 1972; Gray et al. 1984; Pflug and Pauley 1984; Gray and Rondorf 1986; Poe et al. 1991; Shively et al. 1991; Tabor et al. 1993; Fayram and Sibley 2000, in Carrasquero 2001; Tabor et al. 2000).

Carrasquero (2001) presents the following observations and inferences of predator/prey aggregations in freshwater environments under and around structures:

- Different fish species respond differently to the shade produced by overwater structures.
- Smallmouth bass and largemouth bass have a strong affinity to structures, including piers, docks, and associated pilings.
- Bass have been observed foraging and spawning in the vicinity of docks, piers, and pilings; where vegetation is lacking, largemouth bass seek other forms of structures, such as dock pilings.
- Smallmouth bass are opportunistic predators that consume prey items as they are encountered and are major predators of juvenile salmonids.
- Fish, particularly largemouth bass, seem to be attracted to the shade produced by floats, rather than their physical structure. In contrast, smallmouth bass do not seem to be attracted to the shade produced by such structures.
- In reservoir systems of Eastern Washington, juvenile salmonid predation is specific to the behavior and distribution of each salmonid species and its predator. The behavior and distribution of predator and prey species reportedly depend on temperature, the degree of shore-zone development, the slope and substrate of the shoreline, and the presence of man-made in-water structures.

Additional details on shading and predation in fresh water can be found in Carrasquero (2001).

7.2 Littoral Vegetation

Impacts to habitats and species may occur through the loss of littoral vegetation, which includes eelgrass, macroalgae, and intertidal vascular plants (e.g., salt marsh plants) resulting from construction of overwater structures in estuarine or marine settings. Eelgrass and macroalgae are recognized as important habitat for a wide variety of organisms. The Washington State hydraulic code rules (WAC 220-110-250) designate eelgrass, kelp, and intertidal vascular plants as saltwater habitats of special concern and require that hydraulic projects result in no net loss of these habitats. Furthermore, the hydraulic code rules require that overwater structures be designed or located to avoid shading or other impacts that could result in the loss of eelgrass and kelp habitat (WAC 220-110-300(3) and (4)).

Phillips (1984) and Wyllie-Echeverria and Phillips (1994) describe eelgrass ecology in the Pacific Northwest. Two species of eelgrass (*Zostera* spp.) grow in Washington State and are considered saltwater habitats of special concern (WAC 220-110-250): the native eelgrass, *Zostera marina*, and the smaller Asian species, *Zostera japonica* (Wyllie-Echeverria and Phillips 1994). Typically, *Z. marina* grows at lower elevations than *Z. japonica* and may either form extensive beds covering many acres or exist in smaller patches (Phillips 1984). *Z. japonica* is generally found at higher elevations than *Z. marina* and typically grows in patches or a narrow fringe (Phillips 1984). Many species of macroalgae (e.g., brown algae) also grow in the marine waters of Washington, generally attached to rocky substrates and always within the nearshore photic zone (Kozloff 1983).

Eelgrass typically grows in sand and mud substrates in sheltered or turbulent waters (Phillips 1984). Native eelgrass distributions range from approximately +2 feet mean lower low water (MLLW) to -22 feet MLLW (PSAT 2001), although light penetration in many portions of Puget Sound typically limits the lower elevation to less than -12 feet MLLW. Macroalgae have a wider tidal elevation range, and species such as rockweed (*Fucus gardneri*) can grow as high as mean higher high water (MHHW). At the other extreme, brown algae (kelp) may grow at elevations as low as -100 feet MLLW where the water is clear enough to allow light penetration and the substrate supports algal attachment (WDNR

2004). However, in Puget Sound, the depth to which sufficient light penetrates to support plant growth (i.e., photic zone) is considered to be –33 feet (-10 meters [m]) MLLW (PSNERP 2003).

Eelgrass and macroalgae provide vertical structure in nearshore marine habitats and facilitate several important ecological functions. Eelgrass and macroalgae are very productive and support marine food webs through the plant biomass and detritus that they produce, as well as provide shelter and influence the physical and chemical properties of the nearshore environment (Nightingale and Simenstad 2001b). Eelgrass provides substrate for colonies of epiphytic algae and many crustacean species that are prey items for juvenile salmon and other fish (Nightingale and Simenstad 2001b). Studies of eelgrass communities in Padilla Bay show that a specific group of copepods (*Harpacticus uniremis* and other copepods of the genera *Zaus* and *Tisbe*) is unique to the eelgrass epiphyte assemblage and the principal prey of juvenile chum salmon, Pacific herring, Pacific sand lance, and surf smelt (Nightingale and Simenstad 2001b), with *Harpacticus* spp. less likely to be found in low-light conditions and *Tisbe* spp. found in areas high in detritus, irrespective of light levels. Juvenile Dungeness crab, an important salmonid prey species, show a preference for eelgrass compared to other benthic habitats; this is thought to be due in part to the abundance of food items in eelgrass habitat (Pauley et al. 1989). The complex structure of eelgrass communities and their associated epifauna and epiflora are also thought to limit the success of predators that typically associate and feed in unvegetated communities (Heck and Orth 1980, in Nightingale and Simenstad 2001b; Heck and Thoman 1984). Given the strong association of important fish prey resources with eelgrass, reductions in eelgrass extent or vigor may also reduce prey resources for fish.

Eelgrass retards current velocity at the sediment-water interface, allowing fine particulates to settle (Phillips 1984). This action typically affects sediment dynamics and local sediment characteristics, favoring continued growth and survival of eelgrass (Phillips1984). The vertical structure of kelp forests also affords dissipation of wave energy (Jackson 1984), which can offer shoreline protection for other sensitive shoreline habitats.

Both eelgrass and macroalgae provide substrate for herring spawning (Bargmann 1998). Herring is a key species in the nutrient and energy dynamics of the Puget Sound

environment, providing an important link between zooplankton and larger predators, including Chinook salmon, bull trout, and other salmonid species (Bargmann 1998).

Blackmon et al. (2006) provides a synopsis of research on the use of seagrass and kelp habitats by fish, including many of the marine potentially covered species. Forage fish and juvenile Pacific salmon species preferentially use eelgrass over other habitats. Juvenile salmon are found in kelp habitat as well. Rockfish (*Sebastes* sp.) produce planktonic larvae that settle in eelgrass, shallow kelp beds, and floating kelp mats. Juvenile rockfish occupy shallow vegetated habitats, especially areas with eelgrass and kelp, during the summer growing period (Byerly et al. [no date]; Murphy et al. 2000), likely due to the enhanced forage opportunities and refuge from predators that the vertical structure can provide. Likewise, juvenile Dungeness crab (a major prey species for some rearing salmonids) are more frequently found in eelgrass and *Ulva* beds than in other habitats, and eelgrass beds are considered valuable nursery habitat for Dungeness crab (Blackmon et al. 2006).

HPA-regulated activities in marine waters have the potential to affect littoral vegetation through the following impact mechanisms:

- Ambient light
- Direct disturbance and displacement
- Vessel interactions

Each of these impact mechanisms is discussed below.

7.2.1 Ambient Light

Light availability is a fundamental requirement for eelgrass and macroalgae growth. Thom et al. (1998) analyzed the photosynthetically active radiation (PAR) levels at seven Washington State ferry terminal sites and found no eelgrass where instantaneous mid-day PAR levels were less than about 100 micro-moles of photons within the PAR range of wavelengths striking a square meter in one second ($\mu M/m^2/sec$). They found low eelgrass shoot densities where instantaneous mid-day PAR was less than 150 $\mu M/m^2/sec$, while maximum shoot densities required instantaneous PAR of 325 $\mu M/m^2/sec$. PAR intensities less than about 300 $\mu M/m^2/sec$ can be limiting to eelgrass, whereas intertidal macroalgae may be limited by PAR less than 400 to 600 $\mu M/m^2/sec$ (Thom and Shreffler 1996, in Simenstad et al. 1999). Subtidal macroalgae can survive lower light levels and

may be limited only by PAR less than 100 μM/m²/sec (Luning 1981, in Simenstad et al. 1999).

Overwater structures are generally expected to limit light penetration to the substrate and can shade the area underneath and adjacent to the structures. The orientation of the structures and their density (solid or open), height above water, water depth, and tidal range all affect the extent and degree of shading (Nightingale and Simenstad 2001b). Where shading reduces PAR, eelgrass and macroalgae growth may be impaired or prevented (Nightingale and Simenstad 2001b; Penttila and Doty 1990). Burdick and Short (1999) found that floating docks severely impact eelgrass. Three of the four floating docks they studied had no rooted eelgrass under them. Increased structure height above the bottom was identified as the most important pier characteristic correlating to eelgrass bed quality. Burdick and Short (1999) also found light to be the most important variable affecting canopy structure (i.e., shoot density and height) and eelgrass bed quality. A dock study in Montauk, New York (Ludwig et al. 1997) reported the exclusion of eelgrass near a floating pier due to insufficient light in the float's impact zone. Penttila and Doty (1990) found that piers and floating docks largely eliminate existing eelgrass and macroalgae, even when the structures are only partially shading. Such shading impacts to eelgrass can be seen to occur in as little as 18 days (Backman and Barilotti 1976, in Nightingale and Simenstad 2001b), although light reduction capacity varies depending on combinations of both dock and environmental factors. For example, Penttila and Doty (1990) found no apparent eelgrass loss due to shading under a floating dock secured by anchors and chains. In that case, it was thought that, given the winds and current of the site, the degree of movement allowed by the anchor-chain system resulted in no area beneath the dock being continuously shaded, thereby reducing the stress of shade on the eelgrass bed.

7.2.2 Direct Disturbance and Displacement

Aquatic vegetation may be uprooted or displaced during in-water construction of overwater structures and non-structural pilings; in-water ground disturbance has been used as a measure of habitat take in ESA biological opinions (NMFS 2006e). Structures located on or within eelgrass beds displace eelgrass. Pilings that support overwater structures may also reduce eelgrass recruitment and survival through biotic interactions

with the piling reef community (Nightingale and Simenstad 2001b). Pilings in marine waters become encrusted with mussels and other sessile organisms. Shell material from these organisms ("shellhash") is then deposited around the pilings over time, altering the local substrate and its ability to support eelgrass growth (Nightingale and Simenstad 2001b). The shellhash surrounding pilings is prime settling habitat for juvenile Dungeness crab (Nightingale and Simenstad 2001b). The burrowing activities of large numbers of crabs can also affect the establishment of eelgrass (Nightingale and Simenstad 2001b).

7.2.3 Vessel Interactions

Vessels used during construction of overwater structures may physically disturb submerged vegetation as a result of propeller wash (Lagler et al. 1950, in Carrasquero 2001; Haas et al. 2002) or grounding (direct disturbance). Propeller wash may also entrain air bubbles and cause sediment suspension (Haas et al 2002). The potential adverse impacts of vessel activities on eelgrass and macroalgae are discussed in Section 7.12.

7.3 Freshwater Aquatic Vegetation

Freshwater aquatic vegetation includes submerged and emergent plants rooted below the ordinary high water line (OHWL) of freshwater bodies (rivers, streams, lakes, ponds, and open-water wetlands). Freshwater aquatic vegetation provides fish and wildlife habitat and is important to the cycling of nutrients and materials in freshwater ecosystems (Petr 2000). Aquatic vegetation can modify its physicochemical environment by slowing water velocity, trapping sediment, and altering temperature and water quality (Chambers et al. 1999).

Aquatic plants provide shelter habitat and clinging substrate for a variety of aquatic invertebrate species, including insects and zooplankton (Petr 2000). Aquatic plants provide energy to aquatic ecosystems through photosynthesis and provide food for herbivores and detritivores (Petr 2000). Fish use aquatic plants for cover, and terrestrial wildlife species (in addition to potentially covered species) use emergent aquatic plants for food and habitat (Petr 2000). Emergent aquatic vegetation can reduce wave-induced bank erosion (Coops et al. 1996). A review of the interactions of fish and macrophytes worldwide reiterated a number of beneficial functions that macrophytes provide that have direct or indirect

benefits for fish (Petr 2000). The benefits listed by Petr (Cowx and Welcomme 1988, in Petr 2000) include:

- Water purification, both direct (for example, by oxygenation and conversion of toxic ammonia to usable nitrates) and indirect (for example, by plants providing a huge surface area for microbes to do the same tasks)
- Nutrient recycling, including nutrient removal during the growth season and return during senescence
- Physical link between water and air for many invertebrates, e.g., larvae and nymphs of caddis flies, mayflies, and chironomids, which are food for fish and have aquatic larval stages and aerial adults
- Refugia for zooplankton, which graze phytoplankton and keep water clear
- Cover for a large variety of invertebrates, many of which are food for fish
- Cover for fish, which varies as to value and type with the age and species of fish, as well as type of vegetation
- Spawning areas and sites of oviposition for many fish species, including Olympic mudminnow, a potentially covered species
- Food sources for herbivorous fish or indirect food sources from invertebrate prey living on vegetation surfaces
- Effects on flow patterns, i.e., accretion of sediments and deflection of flow, thus providing quiescent waters and faster shallows
- Creation of discrete habitat that is as functional as physical structure

The distribution of aquatic vegetation is limited by the ecological conditions of the water body and the requirements of aquatic plant species (Chambers et al. 1999). Aquatic vegetation can provide valuable cover habitat for a number of fish species, including some freshwater potentially covered species. Olympic mudminnow lay eggs in aquatic vegetation and juveniles stay close to vegetation (Wydoski and Whitney 1979; Mongillo and Hallock 1999). An indirect link between aquatic vegetation and the California floater exists, in that the larvae (glochidea) of the California floater in Curlew Lake depend primarily on the Tui chub (*Gila bicolor*) as a host (Pacific Biodiversity Institute 2006), and juvenile Tui chub typically stay close to vegetation until they are longer than 0.5 inch (Wydoski and Whitney 1979).

HPA-regulated activities in fresh waters have the potential to affect freshwater aquatic vegetation through the following impact mechanisms:

- Ambient light
- Direct disturbance and displacement
- Vessel interactions
- Introduction of noxious weeds

Each of these impact mechanisms is discussed below.

7.3.1 Ambient Light

Light availability is a fundamental requirement for plant growth. The light requirements of different plant species vary, but reduced light in the littoral zone of freshwater environments can potentially limit the growth of aquatic vegetation (Chambers et al. 1999). Light limitations can lead to local reductions in primary production and reductions in other functions of aquatic vegetation, including cover, substrate for invertebrate species, and food for herbivores (Hruby et al. 1999).

7.3.2 Direct Disturbance and Displacement

Human activity associated with the installation of overwater structures can reduce submerged and floating leaved vegetation. This results in temporary and sometimes permanent loss of the affected vegetation, with associated loss of the ecological functions described above.

7.3.3 Vessel Interactions

The potential impacts of vessel activities on freshwater aquatic vegetation are discussed in Section 7.12. Briefly, vessels used during installation of overwater structures may physically disturb submerged vegetation through increased velocity from propeller wash. As discussed in Section 7.12, Lagler et al. (1950, in Carrasquero 2001) reported that outboard motor use has been shown to clear a swath when the propeller was used within 1 foot of aquatic vegetation. In addition, propeller use may entrain air bubbles and cause sediment suspension that results in a temporary reduction in light availability.

7.3.4 Introduction of Noxious Weeds

The introduction of noxious weeds can be a concern in aquatic environments (Chambers et al. 1999; WNWCB 2006). These plants are opportunistic and under the right conditions can out-compete native vegetation and reduce habitat quality for native fish species (Chambers et al. 1999). For example, the Lake Washington shorelines have developed extensive beds of Eurasian milfoil since it was first observed in the lake in 1974 (WNWCB 2005). The impacts of invasive plants on potentially covered species are not clear and depend on a variety of highly variable factors. However, Eurasian milfoil can cause several adverse habitat conditions, including reduced dissolved oxygen and reduced access to habitat (Chambers et al. 1999). Interlake transfer from boats is thought to be the chief means by which Eurasian milfoil is spread (WNWCB 2005). Thus, support vessels used during the construction of overwater structures could facilitate the introduction of invasive aquatic plants by transporting invasive plants from one water body to another.

7.4 Riparian and Shoreline Vegetation

Riparian zones form the transition zone between terrestrial and aquatic systems. Riparian/shoreline vegetation is an important component of freshwater, estuarine, and marine systems, providing shade, streambank and shoreline stability, and allochthonous inputs (material that is produced in one area and consumed in another), as well as influencing groundwater conveyance and storage and the condition and complexity of aquatic habitats (Knutson and Naef 1997; Murphy and Meehan 1991). Removal or disturbance of riparian/shoreline vegetation during construction or maintenance of overwater structures can have several potential impacts to habitat and species in each of these systems, including:

- Shading and water temperature regime
- Streambank/shoreline stability
- Altered allochthonous input
- Groundwater influence
- Habitat conditions

Each of these impact mechanisms is discussed below.

7.4.1 Shading and Water Temperature Regime

Riparian vegetation provides shade from solar radiation (Murphy and Meehan 1991). In general, the smaller the stream, the more closely water temperature will tend to track air temperature; exposure to the sun's energy (due to a lack of riparian vegetation) causes an increase in water temperature, while streams without an insulating canopy of riparian vegetation may also lose heat more rapidly when the air temperature is colder. Removal of trees can thus affect the water temperature in streams both by affecting local air temperatures and by increasing incident radiation[5] and heat loss (Quinn 2005; Bolton and Shellberg 2001; Poole and Berman 2001; Knutson and Naef 1997; Murphy and Meehan 1991). The influence of riparian vegetation on water temperature generally diminishes as the size of the stream increases, because of the proportionally reduced area in which riparian vegetation can insulate against solar radiation and trap air next to the water surface (Knutson and Naef 1997; Quinn 2005; Poole and Berman 2001; Murphy and Meehan 1991).

Water temperatures significantly affect the distribution, health, and survival of fish, especially salmonids. Because fish are ectothermic (cold-blooded), their survival is dependent upon external water temperatures, and they will experience adverse health effects when exposed to temperatures outside their optimal range (USEPA 2003).

In lentic (still-water) systems, water temperatures generally change gradually with the seasons, show less change from night to day, and are often stratified vertically. Water temperatures associated with lotic (flowing) systems often change on a diel cycle, and can affect water quality, specifically dissolved oxygen. Salmon, trout and other cold water fish, and many aquatic invertebrates require cool and well-oxygenated water, with a preferred temperature range of 40 to 58 degrees Fahrenheit (F) (5.5 to 14.4 degrees Celsius [C]), and dissolved oxygen levels of greater than 5 parts per million. As stream temperatures rise, dissolved oxygen content decreases. Temperature increases and consequent reductions in dissolved oxygen tend to have deleterious effects on fish and other aquatic organisms by (Knutson and Naef 1997):

- Inhibiting growth and altering metabolism

[5] Incident radiation is solar radiation (i.e., sunshine) that falls directly upon an object (from the sky), as distinguished from reflected or reradiated radiation.

- Amplifying effects of toxic substances
- Increasing susceptibility to disease and pathogens
- Increasing potential risk of eutrophication through increased growth of bacteria and algae

In marine and estuarine waters, shoreline vegetation is not likely to have much influence on marine water temperatures (Lemieux et al. 2004). However, solar radiation has long been recognized as one of the classic limiting factors for upper intertidal organisms and plays an important role in determining distribution, abundance and species composition. Although the influence and importance of shade derived from shoreline vegetation in the Puget Sound nearshore ecosystem is not well understood, it is recognized as a limiting factor to be considered and has prompted investigations to determine direct linkages between riparian vegetation and marine organisms. One such link is the relationship between shad and surf smelt. On the basis of a comparison of adjacent shaded and unshaded spawning sites sampled in northern Puget Sound, Penttila (2001, in Brennan and Culverwell 2004 and Lemieux et al. 2004) found significantly higher egg mortality on the unshaded beaches. Anthropogenic changes in shoreline microclimate will change the intertidal incubating environment, potentially altering developmental rates or increasing physiological stress in fish embryos (Rice 2006). Considering the influences of temperature, moisture, and exposure on the diversity, distribution, and abundance of organisms that use upper intertidal zones, additional benefits of natural shading likely will be discovered as further investigations continue (Brennan and Culverwell 2004).

7.4.2 Streambank/Shoreline Stability

The root structure of riparian/shoreline vegetation resists the shear stresses created by flowing water and thus retards bank cutting by streams, stabilizes streambanks and shorelines, maintains undercut banks along stream margins, and inhibits sediment from entering streams by dissipating the erosive energy of flood waters, wind, and rain (Knutson and Naef 1997). Removal of riparian/shoreline vegetation exposes streambanks and shorelines to the erosive effects of wind, rain, and current and increases the input of fine sediments to the aquatic system (Waters 1995). Much of the scientific literature discusses the potential impacts of increased sediment as it relates to

salmonids (Quinn 2005; Waters 1995; Furniss et al. 1991). Refer to Section 7.7 for further information on the impacts to potentially covered species associated with sediment regime changes.

For marine shorelines, and particularly those in areas with steep and eroding bluffs, native vegetation is usually the best tool for keeping the bluff intact and/or minimizing erosion (Brennan and Culverwell 2004). Disturbing the face or toe of a bluff or bank may cause destabilization, slides and cave-ins (Clark et al. 1980, in Brennan and Culverwell 2004). Removal of the vegetation that helps to stabilize the face, or excavation along the face, increases the chance of slumping, which results in imperiled structures, lost land, a disruption to the ecological edge-zone, and increased sedimentation to the aquatic environment (Brennan and Culverwell 2004).

7.4.3 Altered Allochthonous Input

Riparian/shoreline vegetation provides allochthonous input such as terrestrial macroinvertebrates, which supplement the diets of fishes, and detritus like leaves and branches, which provide food sources for benthic macroinvertebrates (Knutson and Naef 1997; Murphy and Meehan 1991). Additionally, riparian/shoreline vegetation supplies large woody debris (LWD) to the aquatic environment, which in streams influences channel morphology/habitat complexity, retains organic matter, and provides essential cover for fish (Quinn 2005; Naiman et al. 2002; Knutson and Naef 1997; Murphy and Meehan 1991), as discussed below with regard to altered habitat conditions (Section 7.4.5).

In lakes, estuaries, and marine environments, woody debris increases habitat complexity, affording cover for fish, protection from currents, and foraging opportunities (Quinn 2005).

Removal of riparian vegetation diminishes allochthonous input into the aquatic environment, which can affect the prey base available to fish, the forage detritus available for benthic macroinvertebrates, future LWD recruitment, and aquatic habitat complexity, diminishing the quality and complexity of habitat and species diversity of fish and benthic macroinvertebrates (Murphy and Meehan 1991).

One of the characteristics that make marine nearshore areas so productive is that they act as sinks for nutrients derived from upland and marine sources. The primary source of nutrients in the system is derived from primary producers (i.e. aquatic and terrestrial vegetation, phytoplankton), although terrestrial-derived organic contributions have not been well studied. Alterations of intertidal and subtidal areas by dredging, filling, diking, overwater structures, and shoreline armoring have dramatically affected marine wetland and other aquatic vegetation (i.e. eelgrass, algae) (Brennan and Culverwell 2004 and Lemieux et al. 2004). Similarly, upland development has greatly reduced the amount of vegetation and nutrients available to the marine system. Such modifications have resulted in decreased abundance and taxa richness in both benthic and infaunal invertebrate and insect assemblages (Brennan and Culverwell 2004).

7.4.4 Groundwater Influence

Riparian/shoreline vegetation acts as a filter for groundwater, filtering out sediments and taking up nutrients (Knutson and Naef 1997). Riparian vegetation, in conjunction with upland vegetation, also moderates stream flow by intercepting rainfall, contributing to water infiltration, and using water via evapotranspiration (Knutson and Naef 1997). Plant roots increase soil porosity, and vegetation helps to trap water flowing on the surface, thereby aiding in infiltration (Knutson and Naef 1997). Water stored in the soil is later released to streams through subsurface flows. Through these processes, riparian and upland vegetation help to moderate storm-related flows and reduce the magnitude of peak flows and the frequency of flooding (Knutson and Naef 1997). Riparian vegetation, the litter layer, and silty soils absorb and store water during wet periods and release it slowly over a period of months, maintaining stream flows during rainless periods (Knutson and Naef 1997).

The interface between flow within the hyporheic zone[6] and the stream channel is an important buffer for stream temperatures, so alteration of groundwater flow can affect stream temperature as well (Poole and Berman 2001). The magnitude of the influence depends on many factors, such as stream channel pattern, structure of the alluvial aquifer, and variability in the stream hydrograph (Poole and Berman 2001).

[6] The zone of hydrologic interchange between groundwater and surface water in stream channels.

7.4.5 Habitat Conditions

Habitat conditions within freshwater, estuarine, and marine environments are influenced by riparian/shoreline vegetation. Inputs of woody debris into these environments from riparian areas contribute significantly to habitat conditions within freshwater environments (Naiman et al. 2002). Woody debris input in streams is important in controlling channel morphology, regulating the storage and transport of sediment and particulate organic matter, and creating and maintaining fish habitat (Murphy and Meehan 1991). Within streams, approximately 70 percent of structural diversity is derived from root wads, trees, and limbs that fall into the stream as a result of bank undercutting, mass slope movement, normal tree mortality, or windthrow (Knutson and Naef 1997).

In small streams, LWD is a major factor influencing pool formation in plane-bed and step-pool channels. Bilby (1984, in Naiman et al. 2002) and Sedell et al. (1985, in Naiman et al. 2002) found that approximately 80 percent of the pools in several small streams in southwest Washington and Idaho are associated with wood. Additionally, juvenile salmonid abundance in winter, particularly juvenile coho salmon, is positively correlated to abundance of LWD (Hicks et al. 1991). In larger streams, the position of LWD strongly influences the size and location of pools (Naiman et al. 2002). In larger streams, LWD is typically oriented downstream due to powerful streamflow, which favors formation of backwater pools along margins of the mainstem (Naiman et al. 2002).

In lakes, estuaries, and marine waters, large woody debris provides cover and foraging opportunities for fish (Quinn 2005). Structurally, LWD provides foraging, refuge and spawning substrate for fishes; and foraging, refuge, spawning and attachment substrate for aquatic invertebrates and algae in the marine/estuarine environment (Brennan and Culverwell 2004). The removal of riparian/shoreline vegetation limits the future input of woody debris to the aquatic environment and can limit habitat complexity, foraging opportunities, and predator avoidance (Quinn 2005).

7.5 Noise

Underwater noise produced in association with the construction of overwater structures includes noise generated from pile driving (when applicable) and by construction vessels and equipment. An increase in underwater noise may also be attributed to the operation of the structure if it involves increased boating traffic. This section discusses potential impacts to fish and invertebrates from underwater noise produced by these activities.

7.5.1 Pile Driving

Pile driving within the water column is often necessary in the construction and retrofitting of overwater structures. Placing piles in the benthic substrate affects both the substrate directly beneath the piles and the physical attributes of the water column in the vicinity of the activity (Nightingale and Simenstad 2001b). One important physical attribute of the aquatic habitat affected by pile driving is sound pressure (noise) within the water column.

Hastings and Popper (2005) recently performed a comprehensive literature review to evaluate the current best available science regarding noise thresholds at which fish would be injured by the percussive sound generated by pile driving. Much of the information presented below has been extracted from that review.

Fish are sometimes injured or killed by the impact of sounds generated by percussive pile driving (Yelverton et al. 1975; Hastings 1995, in Hastings and Popper 2005). The specific effects of pile driving on fish depend on a wide range of factors, including the types of piles and hammer used, the fish species and life stages present, the environmental setting, and many other controlling factors (Hastings and Popper 2005; Popper et al. 2006; WSDOT 2006a). Noise generated by pile driving can cause physiological and/or behavioral impacts depending on the size of the fish relative to the wavelength of sound, the mass and anatomical structure of the fish (Hastings and Popper 2005), the received sound, and the level and duration of noise produced (Popper et al. 2006; Scholik and Yan 2002). Feist et al. (1992) found that pile driving impacted distributions and behaviors of juvenile pink and chum salmon relative to their location to the activity and to schooling behavior, although the consequences of these effects on the survivability or fitness of juvenile salmon are unknown.

Anatomical variations of the inner ear, swim bladder, esophagus, lateral line, and other structures determine how fish hear and feel sound pressure (Hastings and Popper 2005). All fish fall into two hearing categories: "hearing generalists" such as salmon and trout, and "hearing specialists" such as herring and eulachon (Hastings and Popper 2005).

Hearing specialists have particular adaptations that enhance their hearing bandwidth and sensitivity (Hastings and Popper 2005). Hearing specialists found on the Pacific coast include the sardine and related Clupeiforms such as herring, shad, menhaden, and anchovy (Hastings and Popper 2005).

The majority of fish on the Pacific coast are hearing generalists and do not have specialized hearing capabilities apart from their swim bladder, inner ear, and lateral line (Hastings and Popper 2005). Hearing generalists sense sound directly through the inner ear, and some use the inner ear coupled with the swim bladder to sense additional energy (Hastings and Popper 2005).

In using the existing scientific literature to address potential effects of underwater noise on potentially covered species, it is not sufficient to simply extrapolate information by comparing species that are taxonomically related, because hearing categories do not usually follow fish taxonomic groupings. Both hearing generalists and hearing specialists are found in many taxonomic groups (Hastings and Popper 2005). Ideally, fish should be compared based on biomechanical properties of their swim bladder and any other internal gas-filled chamber, hearing capabilities, and aspects of their behavior (Hastings and Popper 2005). However, when such data are not available, it is probably more appropriate to extrapolate between species that have somewhat similar auditory structures or pressure-detecting mechanisms (most notably the swim bladder) and species of similar size, mass, and anatomical variety (Hastings and Popper 2005). This would enable at least a first-order approximation of extrapolation to fishes such as salmonids and other teleost fishes that presumably do not have hearing specialization (e.g., rockfish). The results are less easily extrapolated to teleosts without a swim bladder, such as sand lance and lingcod, and to fish with very different ear structures, such as lamprey and sturgeon (Hastings and Popper 2005).

Table 5 outlines the known and presumed hearing categories of potentially covered fish species.

Table 5
Hearing Categories for Potentially Covered Fish Species

Common Name (Scientific Name)	Hearing Category	Notes and/or References
Trout and salmon (*Salvelinus, Onchorynchus* spp.)	Generalist	Popper and Carlson 1998
Sturgeon (*Acipenser* spp.)	Undetermined	Popper (2005) states that sturgeon can detect an extremely wide range of sounds, and several studies have found that some sturgeon produce sounds that may be used to facilitate breeding. However, further studies are necessary to determine how sturgeon vocalize, what levels of sound are produced in the natural environment, and how their vocalizations are used in their behavior.
Eulachon (*Thaleichthys pacificus*)	Specialist	Blaxter et al. 1981, in Scholik and Yan 2001a
Rockfish (*Sebastes* spp.)	Generalist	Hastings and Popper 2005
Lake chub (*Couesius plumbeus*)	Specialist	Hastings and Popper 2005; Popper et al. 2005
Dace (*Rhinicthys* spp.)	Unknown/ Presumed Generalist	Not a member of a family or grouping identified as containing hearing specialists (Fay and Popper 1999)
Lingcod (*Ophiodon elongates*)	Generalist	Does not have a swim bladder, which is generally an indication of poor hearing (Moyle and Cech 2004; Kapoor and Khanna 2004)
Surf smelt (*Hypomesus pretiosus*)	Generalist	Included in the taxonomic order Salmoniformes – hearing generalists (Hastings and Popper 2005)
Lamprey (*Lampetra* spp.)	Generalist	Popper 2005
Margined sculpin (*Cottus marginatus*)	Generalist	Closely related to the bullhead (*Cottus scorpius*), which is identified as a generalist (Fay and Popper 1999); also not a member of a family or grouping identified as containing hearing specialists (Fay and Popper 1999)
Mountain sucker (*Catostomus platyrhynchus*)	Unknown/ Presumed Specialist	*Catostomus* spp. are known to have weberian ossicles to assist with hearing (Krumholz 1943)
Olympic mudminnow (*Novumbra hubbsi*)	Unknown/ Presumed Specialist	May have weberian ossicles to assist with hearing (Moyle and Cech 2004). Many closely related fish (minnows, pikeminnow cyprinids) are specialists (Scholik and Yan 2001b; Popper 2005).
Pacific cod (*Gadus macrocephalus*)	Generalist	*Gadus* sp. more sensitive than most generalists (Astrup and Mohl 1998, in Scholik and Yan 2002; Hastings and Popper 2005)
Pacific hake (*Merluccius productus*)	Unknown/ Presumed Generalist	Not a member of a family or grouping identified as hearing specialists (Fay and Popper 1999)
Pacific herring (*Clupea harengus pallasi*)	Specialist	Hastings and Popper 2005
Pacific sand lance (*Ammodytes hexapterus*)	Generalist	Does not have a swim bladder, which is generally an indication of poor hearing (Moyle and Cech 2004; Kapoor and Khanna 2004)
Pygmy whitefish (*Prosopium coulteri*)	Generalist	Of the order Salmoniformes – hearing generalists (Hastings and Popper 2005)
Walleye pollock (*Theragra chalcogramma*)	Unknown/ Presumed Generalist	Not a member of a family or grouping identified as containing hearing specialists (Fay and Popper 1999)

Physical impacts to fish from intense noises may include temporary hearing loss (referred to as temporary threshold shift), permanent hearing loss (referred to as permanent threshold shift), damage or rupture to gas organs such as the swim bladder and the surrounding tissues, rupture of capillaries in the skin, neurotrauma, and eye hemorrhage (Hastings and Popper 2005). The more serious of these impacts could cause instantaneous death or later death from injuries (e.g., breakdown of tissues in some organs) (NMFS 2003a).

Behavioral and indirect effects may include movement of fish away from feeding grounds, reduced fitness to survive, increased vulnerability to predators, reduced success locating prey, effects on fish communications, effects on the fish's sense of the physical environment, and many other possible scenarios (Hastings and Popper 2005).

Not enough is known to provide discrete injury thresholds for different fish species, and even less is known regarding behavioral thresholds (Hastings and Popper 2005; Popper et al. 2006). The National Marine Fisheries Service (NMFS) and the USFWS have adopted injury and disturbance thresholds for threatened and endangered salmonids at 180 dB_{peak} (i.e., peak decibels during each pulse) for injury and 150 dB_{RMS} (i.e., decibels root mean square, the square root of sound energy divided by impulse duration) for behavioral disturbance (WSDOT 2006a and numerous biological opinions).

Recently, after extensive review of the existing literature (Hastings and Popper 2005), Popper et al. (2006) recommended using a combined, interim single-strike criterion as a threshold for pile driving injury to salmonids: 187dB_{SEL} and 208dB_{peak}, where SEL is the sound exposure level, which accounts for the accumulation of energy over a complete pile strike. These thresholds are considered conservative by the authors, but current science limits the extrapolation of the single-strike SEL to estimate the effects on fish due to accumulated energy from multiple pile strikes. Discussions on the use of these proposed dual criteria are currently in progress.

7.5.1.1 Impacts on Eggs and Larvae

Although it is possible that some (but not all) fish species would swim away from a sound source, thereby decreasing exposure to sound, larvae and eggs are often at the

mercy of currents, move slowly, or are sedentary (Hastings and Popper 2005). Data on the effects of sound on developing eggs and larvae are limited, although in a study by Banner and Hyatt (1973), increased mortality was found in eggs and embryos of sheepshead minnow (*Cyprinodon variegates*) exposed to broadband noise (100 to 1,000 hertz) that was about 15 dB above the ambient sound level. Hatched fry of sheepshead minnow and fry of longnose killifish (*Fundulus similes*) were not affected in this study.

7.5.1.2 Impacts on Invertebrates

Although studies of noise impacts on invertebrates have consistently shown that very high sound pressure levels (in excess of 217 dB) can cause serious injury, the information is sparse, is poorly reported, and was obtained without due experimental rigor (Turnpenny et al. 1994). The studies reported in Turnpenny et al. (1994) exposed mussels, periwinkles, amphipods, squid, scallops, and sea urchins to high airgun and slow-rise-time sounds at between 217 dB and 260 dB. Mussels, periwinkles, and amphipods showed no detectable effect at 229 dB (Kosheleva 1992, in Turnpenny et al. 1994), although one Iceland scallop suffered a split shell after being exposed to 217 dB from a single airgun strike (Matishov 1992, in Turnpenny et al. 1994).

7.5.2 Noise from Commercial and Recreational Boating Traffic

Motors, sonars, and depth sounders used on commercial vessels and recreational boats can produce high levels of continuous underwater noise that can impact fish behavior (Blaxter et al. 1981, Boussard 1981, both in Scholik and Yan 2001a; Pearson et al. 1992; Scholik and Yan 2001a) and result in temporary hearing loss (Scholik and Yan 2001b).

The potential impacts to fish from vessel noise are discussed in greater detail in Section 7.12.

7.5.3 Noise from Construction Vessels and Equipment

Equipment and vessels necessary to dig trenches, place riprap, support equipment over water, and perform other activities associated with the construction of overwater structures also produce underwater noise. Construction equipment tends to produce

the same type of slow-rise-time noise as do motor boats and ship engines. Jones and Stokes (2006) estimated that noise produced by a rather large ocean-cable-installation vessel is about 154 dB_{RMS}. JASCO (2005) estimated that noise produced by a rock-dumping vessel is approximately 177 dB (neither peak nor RMS identified) at 3.28 feet (1 m), and Richardson et al. (1995, in Jones and Stokes 2006) estimated that an equipment support vessel produces noise levels of 152 dB_{peak} at 3.28 feet (1 m). Sounds of this amplitude may affect the behavior or physiology of fishes, depending on their hearing sensitivity and proximity to the sound.

7.6 Water Quality

Placing constructed features in aquatic settings may adversely impact water quality in several different ways, mainly by causing increases in suspended solids concentrations, reducing dissolved oxygen levels, changing pH, or releasing toxic substances from treated wood products. Stormwater runoff from constructed surfaces also poses a threat to water quality from its often-associated nonpoint source pollutant load. These potential impact mechanisms may adversely impact potentially covered species.

7.6.1 Suspended Solids

Particulate matter suspended in the water column can have adverse impacts on aquatic life (Bash et al. 2001). Disturbance of instream sediment during instream work, such as dock construction, or stormwater runoff from upland portions of construction sites may increase suspended sediment levels (E. Molash, pers. comm., in Bash et al. 2001). Sediment disturbance can be further increased by instream operation of equipment or storage of excavated material within the floodplain (Reid et al. 2004), although the latter activity is commonly prohibited under the HPA authority.

Changes in stream profile and the presence of submersed structures often cause changes to hydraulic conditions that redistribute the energy of moving water, which may cause chronic increases in suspended sediment (NMFS 2005a). The effects of hydraulic alteration are discussed in Section 7.7. Similarly, vessel activities associated with construction or operation and maintenance of structures may also resuspend sediments and increase turbidity on a periodic to continuous basis, depending on nautical traffic

conditions (Simenstad et al. 1999). The effects of vessel activities are detailed in Section 7.12.

7.6.1.1 Measuring Suspended Solids

Suspended sediments are generally measured and reported in one of three ways: as turbidity, as total suspended solids (TSS), or as water clarity (Bash et al. 2001). These three measurement methods are not always well correlated and may yield different results for any single sample (Duchrow and Everhart 1971).

- Turbidity can be quantified by the degree to which light is scattered as it passes through water. Turbidity is reported in nephelometric turbidity units (NTUs), measured using a nephelometer, or in Jackson turbidity units (JTUs), measured using an older tool called a Jackson candle turbidimeter. NTUs and JTUs are roughly equivalent at higher values but measurement of JTUs below 25 relies on human judgment (USEPA 1999). NTUs are now the preferred turbidity unit (USEPA 1999).
- TSS concentration is measured by filtering the sample, weighing the dried, filtered residue, and reporting TSS as weight of dried residue per volume of water sample. Older literature sometimes refers to TSS as suspended sediment concentration. TSS and suspended sediment concentration are equivalent (Bash et al. 2001).
- Water clarity is a measure of sight distance through water and is affected by both suspended and dissolved loads.

7.6.1.2 Determining Background Suspended Solids Levels

Determining background suspended solids levels is a difficult process confounded by the inconsistency in measurement methods and natural environmental variation in factors contributing to turbidity levels (Bash et al. 2001). Turbidity often varies temporally with variations in precipitation, runoff, and discharge regimes as erosion and transport of suspended material varies. Turbidity may also vary spatially between watersheds or within watersheds as geology and water velocity vary. Widespread, continuous sampling would be required to determine a reasonable estimate of natural background turbidity levels (Bash et al. 2001).

7.6.2 Suspended Solids Impacts on Fish

Fine sediment has been recognized as detrimental to the reproductive success of salmonids since at least 1923 (Harrison 1923). Bash et al. (2001) exhaustively reviews 40 years of research on the physiological and behavioral effects of turbidity and suspended solids on salmonids, with findings as briefly summarized below:

Physiological effects of suspended sediment on salmonids include gill trauma and altered osmoregulation[7], blood chemistry, reproduction, and growth. Most research has entailed laboratory studies. Stress response is a result of the combination of duration, frequency, and magnitude of exposure and other environmental factors. Stress responses vary between salmonid species and life stages. Abrasive suspended sediments may irritate gills. Several laboratory studies have shown gill trauma and increased coughing frequency with increased turbidity. Other studies have shown impairment of osmoregulation during smolting in association with increases in suspended sediment (Bash et al. 2001).

The behavioral effects of suspended sediments on salmonids are described by laboratory and field studies in the categories of avoidance and changes in territoriality, foraging, predation, homing, and migration. Salmonids appear to avoid areas of increased turbidity in laboratory and field studies. Laboratory studies have shown alterations in social interactions and territoriality in response to increases in turbidity. It has been suggested that decreased territoriality and a breakdown in social structure can lead to secondary effects such as altered feeding and growth rates which may, in turn, lead to increased mortality. Some laboratory studies have shown a negative impact of increased turbidity on foraging, possibly due to reduced visibility, while other studies have shown a positive effect of increased turbidity on foraging, possibly due to reduced risk of predation. Laboratory and field studies have shown a link between increased turbidity and reduced primary production and prey availability. Field studies have indicated that increased turbidity may delay migration (Bash et al. 2001).

Additional studies have supported the assertion that water clarity affects fish behavior. Avoidance responses, changes in territorial behavior, feeding patterns and homing

[7] The act of regulating osmotic pressure to maintain water and mineral salt content in body fluids.

ability have been observed in association with increased turbidity levels (Sigler 1988). Avoidance responses of rainbow trout and Atlantic herring to suspended sediment have been observed at concentrations of 10 milligrams per liter (mg/L) and 20 mg/L, respectively (Wildish and Power 1985). Juvenile chum salmon, considered a species more tolerant of suspended sediment (Nightingale and Simenstad 2001a), have also exhibited avoidance behavior in response to elevated turbidity levels (Salo et al. 1979). However, turbidity plumes that do not extend from bank to bank are not expected to significantly impact the behavior of migrating fish, as they are able to avoid the areas of high turbidity (Nightingale and Simenstad 2001a).

Water clarity is important to fish during the development of visual acuity (Nightingale and Simenstad 2001a). Water clarity affects light transmission, which in turn is thought to play a role in the development of visual acuity in fish (Nightingale and Simenstad 2001a). Visual acuity adjustment in estuarine waters is part of the smolting process of salmonids (Beatty 1965; Folmar and Dickhoff 1981). Similar visual development has been reported in juveniles of other species, such as sand lance, kelp greenling, and lingcod (Britt 2001; Tribble 2000).

Recent literature maintains that water clarity is important to fish as visual feeders. Larval fish have little or no swimming capability, are visual feeders, and undergo high mortality rates due to starvation (Nightingale and Simenstad 2001a). Increased turbidity and reduced water clarity could negatively impact the already limited prey-catching ability of larval fish (Nightingale and Simenstad 2001a).

Several NMFS biological opinions on overwater structures and piling projects have been reviewed for their conclusions on potential water quality impacts to listed fish species. In all cases, sediment- and turbidity-related impacts comprised the overwhelming majority of discussion on water quality effects. In most cases, the magnitude, frequency, and duration of sediment pulses are expected to be similar to naturally occurring conditions during natural fluctuations in flow conditions, and few salmonids are predicted to be present during in-water work windows; therefore, NMFS concluded that potential increases in turbidity would have negligible impacts on salmonids and their habitats (NMFS 2006a; NMFS 2006f; NMFS 2006h; NMFS 2006i; NMFS 2006j; NMFS

2006k; NMFS 2006m; NMFS 2006n). However, NMFS found that elevated turbidity can cause direct mortality (NMFS 2006g), while sublethal threats include harassment, as feeding patterns may be affected and fish are likely to avoid areas of increased turbidity (NMFS 2006d).

7.6.3 Suspended Solids Impacts on Invertebrates

The limited mobility of many invertebrates prevents them from escaping even temporary pulses of increased suspended sediment loads. Suspended sediment levels of 188 and 1,000 mg/L have been observed to hinder egg development of eastern oyster (*Crassostrea virginica*) (Cake 1983) and hard clam (*Mercenaria mercenaria*) (Mullholland 1984). Comparable impacts could be expected in other benthic bivalves such as the California floater, Western ridged mussel, and Olympia oyster, which are all potentially covered species. There appears to be a break point at 750 mg/L between chronic and acute impacts of suspended sediment (Nightingale and Simenstad 2001a). At levels below 750 mg/L, development continues for both clams and oysters, but at levels above 750 mg/L that last for 10 to 12 days, effects become lethal (Nightingale and Simenstad 2001a). Evidence of physiological responses among shellfish to increased turbidity appears to be ambiguous; it has been hypothesized that at lower turbidity levels, resuspended chlorophyll may act as a food supplement enhancing growth, while at higher levels, planktonic food resources are diluted to the point of inhibiting growth (Nightingale and Simenstad 2001a). Increased suspended sediment has also been associated with behavioral changes among shellfish. Changes have been observed in siphons and mantles of soft-shelled clams (*Mya arenaria*) at suspended sediment concentrations of 100 to 200 mg/L (Grant and Thorpe 1991). Based on these studies, it appears likely that shellfish are generally less vulnerable to acute effects of suspended sediment than are fish, but have some risk from chronic exposure. Thus, there is a risk that potentially covered shellfish species could experience some level of incidental take due to increased suspended sediments. However, general minimization measures commonly required by HPAs will limit the dispersion of resuspended sediment and normally result in only temporary turbidity increases.

7.6.4 Contaminated Sediment Impacts

Sediment can be contaminated with chemicals known to have potential to cause adverse impacts to potentially covered species if resuspended in the water column. Sediment contamination and the potential for resuspension must be determined prior to construction on a site-by-site basis as part of a project-specific assessment. It is unlikely that a project with the potential to resuspend contaminated sediments would qualify under a programmatic evaluation of ESA-related impacts, because the range of potential impacts is extremely wide and the state of the science is rapidly evolving. There exist many scenarios under which the risk of incidental take is extremely high; site-specific analyses and conservation measures may be required to effectively reduce that risk. Because the potential impacts of resuspended contaminated sediment are site-specific, they are not further discussed in this paper.

7.6.5 Dissolved Oxygen Impacts

Juvenile salmon are highly sensitive to reductions in dissolved oxygen concentrations (USFWS 1986) and so are probably among the more vulnerable potentially covered species with regard to dissolved oxygen impairments. It has been hypothesized that resuspension of large quantities of anoxic sediments, an effect more commonly associated with dredging activities than with the construction of overwater structures, may reduce dissolved oxygen levels in surrounding water as a result of oxidation reactions (Nightingale and Simenstad 2001a). However, even with the potentially large amounts of resuspended, deep-water, anoxic sediments associated with dredging, little evidence supports the notion that associated dissolved oxygen reduction in surrounding water poses a risk to fish moving through the area (Nightingale and Simenstad 2001a). Given the low levels of organic material commonly mobilized during the construction and operation of overwater structures, the risk of adverse impacts to covered species is quite low.

7.6.6 pH Impacts

Structures constructed in aquatic settings can adversely impact the pH of surrounding water via contact between water and uncured concrete (Ecology 1999). Standard HPA provisions (Appendix A) prohibit fresh, uncured concrete from coming into contact with surrounding water or the bed of the water body.

7.6.7 Treated Wood-Related Impacts

Some overwater structures are supported by wood piles. Wood piles are also sometimes used to construct temporary trestles that support equipment during construction activities. Wood piles that have been chemically treated to resist rot and are in contact with water have the potential to leach chemical contaminants into the surrounding water (Poston 2001). In addition to this possible direct impact, indirect pathways of contamination also exist; for instance, stormwater runoff from surfaces elevated above the water body or splinters of treated material that are dislodged by activity above the water line and fall into the water body (Poston 2001). For this reason, creosote- and pentachlorophenol-treated wood products are not allowed in Washington lakes for applications that involve direct water contact (WACs 220-110-060(4), -170(6), -223(6), and –224(2)). However, wood that has been treated with other chemicals and is used in direct water contact applications may also pose a threat to water quality through the potential to leach toxic chemicals into surrounding water (Poston 2001). A common method for increasing the resistance of wood to rot is treatment with copper in the form of ammoniacal copper zinc arsenate (ACZA) or chromated copper arsenate (CCA Type C) (Poston 2001).

7.6.7.1 Creosote-Treated Wood

Poston (2001) reviews approximately 20 years of research on this topic with findings as summarized below:

- Creosote-treated wood poses a much greater risk to water quality from trace metals and polycyclic aromatic hydrocarbons (PAHs) in the immediate surrounding water over a relatively short period of time; toxic lighter-weight PAHs escape the wood, volatilize, and degrade rapidly, while higher-weight PAHs contribute to more chronic contamination as they incorporate into sediment. The greatest risk from creosote-treated wood in aquatic applications is to benthic organisms and organisms that directly colonize treated wood structures.
- Temporal and spatial impacts of creosote-treated wood on aquatic environments appear to be much greater than those of ACZA- or CCA-treated wood.

- The vast majority of research discussed in this review investigated the impacts of relatively small applications (<100 pilings) of treated wood. More investigation is needed into the potential impacts of larger projects.
- Impacts of treated wood projects alone may be difficult to assess in settings complicated by other ecological stressors.
- PAHs may continue to diffuse from creosote-treated wood for the life of the product, but diffusion from creosote-treated wood products that have been treated to fix or remove excess preservative may not be as great as previous studies have indicated. PAH releases from wood products may also reach equilibrium with PAH degradation in aerobic sediments over time; however, this may not be true for anaerobic sediments, where PAHs would likely persist for longer periods of time.
- Removal of creosote-treated wood structures may resuspend sediments contaminated with PAHs. Although no data were located regarding this, field data indicate higher degrees of PAH contamination in sediments immediately adjacent to creosote-treated structures.
- PAH contamination from both immersed and above-water structures appears to diminish with distance from the structure and, although PAHs are relatively mobile, PAH contamination of sediments is unpredictable in relation to water currents.
- Areas with less water circulation and lower pH are at greater risk for contamination, because leaching is faster and dilution occurs more slowly.
- Metals will not degrade but may mineralize or become physically or chemically sequestered as they are likely incorporated into sediment. However, long-term accumulation of metals at the bases of pilings has not been reported. The risk of sediment resuspension during the removal of pilings is not well understood at this time.
- The sediment content of fines and organic carbon plays a key role in the fate of metals contaminants in the sediment. The function of acid volatile sulfides in the bioavailability of metals contaminants is not understood at this time, but acid volatile sulfides likely also play a role in toxicity. Metals contamination of sediments appears to be localized, while sediment

disturbance will likely transport and redistribute metals, possibly diluting the contamination.

- The risk of potential impacts to salmonids from direct exposure to PAHs or metals leached from treated wood is low. Riverine spawning substrates for salmonids do not typically facilitate the accumulation of PAHs or metals, and juvenile salmonids are not likely to encounter high concentrations of such contamination in larger waterways when they begin their open-water, marine lifestage. However, salmonids are potentially at some risk of exposure from consumption of contaminated prey.

Some additional studies not described by Poston (2001) have been conducted to characterize PAH leaching rates associated with creosote-treated wood in aquatic applications. PAH leaching rates have been shown to increase with increased water circulation (Kang et al. 2003). PAH leaching rates also seem to increase with temperature, although water circulation appears to have a much greater effect on leaching rates than does water temperature, with the greatest leaching rates occurring in warm, turbulent water (Xiao et al. 2002). PAH leaching rates seem to vary with wood species (Cooper 1991; Rao and Kuppusamy 1992), decreasing as wood density increases as found in studies comparing loblolly pine and Douglas fir (Miller 1972, in Cooper 1991). PAH leaching rates also increase as treated wood surface area to volume ratios increase (Colley and Burch 1961, Stasse and Rogers 1965, Gjovik 1977, Miller 1977, all in Cooper 1991).

Table 6 summarizes several studies on biological effects thresholds for PAHs in surface water (from Stratus 2005a).

Table 6
Effects Thresholds for PAHs in Surface Water

Organism	Exposure Source	Toxicity Endpoint	Concentration in µg/L	Citation
Mysid, *Mysidopsis bahia*	Elizabeth River, Virginia, sediment extracts	24-hour LC50	180	Padma et al. 1999
Amphipod, *Rhepoxynius abronius*	Eagle Harbor, Washington, sediment extracts	96-hour LC50	100	Swartz et al. 1989
Pacific herring	PAHs leaching from ~ 40-year-old pilings	LC50 for hatching success	50	Vines et al. 2000
Zooplankton	PAHs leaching from pilings placed in microcosms	NOEC for communities	11.1	Sibley et al. 2004
Zooplankton	Commercial creosote added to microcosms	NOEC for communities	3.7	Sibley et al. 2001
Pacific herring	PAHs leaching from ~ 40-year-old pilings	Significant reduction in hatching success and increased abnormalities in surviving larvae	3	Vines et al. 2000
Zooplankton	Commercial creosote added to microcosms	EC50 for abundance	2.9	Sibley et al. 2001
Trout	Commercial creosote added to microcosms	LOEC for immune effects	0.6	Karrow et al. 1999

EC_{50} = Exposure concentration of a material that has a defined effect on 50 percent of the test population.
LC_{50} = Lethal concentration of a chemical within a medium that kills 50 percent of a sample population.
LOEC = Lowest observable effects concentration
NOEC = No observable effects concentration
µg/L = micrograms per liter
Source: Stratus 2005a

Many studies have investigated thresholds for biological effects of PAH concentrations in sediment. Several effects thresholds have been determined using NMFS' many years of data on the effects of PAH-contaminated sediments on benthic fish in Puget Sound (Stratus 2005a). Thresholds for effect on English sole were determined at 230 parts per billion (ppb) for proliferated liver lesions; 630 ppb for spawning inhibition, infertile eggs, and abnormal larvae; and 288 ppb for DNA damage, measured as PAH-DNA adducts (Johnson et al. 2002).

Several models have been developed to estimate PAH leaching rates from creosote-treated wood (Brooks 1997; Poston et al. 1996; Xiao et al. 2002). The models attempt to describe complex interactions and generally rely heavily on site-specific data and

assumptions (Stratus 2005a). Evaluations of the CREOSS model (Brooks 1997) and the box plume model (Poston et al. 1996) have shown that although they may not fully explain transient concentrations, such as those immediately following installation or severe disturbance such as abrasion, they are helpful in qualitatively describing the effect of many factors, such as salinity, temperature, wood density, water circulation, surface area to volume ratio, wood grain direction, time from treatment, and whether the wood was treated using BMPs to reduce leaching rate (Stratus 2005b).

7.6.7.2 ACZA- and CCA Type C-Treated Wood

Recent work on contaminant leaching from ACZA- and CCA Type C-treated wood not described by Poston (2001) includes a 2004 study of arsenic, copper, and zinc concentrations in sediment, water, and shellfish near four ACZA-treated wood structures on the Olympic Peninsula. In this study, there were insignificant increases in arsenic, copper, and zinc in sediment and water at three out of four sampling sites and minimal uptake by shellfish (Brooks 2004). Oysters growing on CCA-treated wood piles have been observed to have higher metals concentrations in soft tissues and a greater incidence of histopathological lesions than oysters collected from nearby rocks (Weis et al. 1993, in Stratus 2005b). Snails fed algae grown on CCA-treated docks showed mortality (Weis and Weis 1996, in Stratus 2005b). Significantly lower biomass and diversity of sessile epifaunal communities have been observed on treated wood panels than on untreated wood panels, but the response appeared to dissipate over time to negligible levels after three months of exposure (Weis et al. 1992a; Weis and Weis 1994, in Stratus 2005b).

Weis et al. (1998, in Stratus 2005b) measured metals concentrations in sediments and marine polychaete worms and diversity, abundance, and biomass in the benthic invertebrate community near five CCA-treated wood bulkheads ranging from one to eight years in age. It was found that concentrations of copper and arsenic in sediments were generally elevated within 3.3 feet (1 m) but diminished to background levels by 9.8 feet (3 m) from the bulkheads. Polychaete worms collected within 3.3 feet (1 m) of a one-year-old treated wood structure contained elevated copper and arsenic concentrations, and benthic community effects on abundance

and diversity were noted at all treated wood sites, diminishing with distance from the bulkheads. Effects were negligible at distances greater than 3.3 feet (1 m) from bulkheads (Weis et al. 1998, in Stratus 2005b).

A study on the leaching rate of arsenic from CCA Type C-treated lumber under simulated precipitation showed leaching rates of 0.0143, 0.0079, and 0.0062 micrograms per square centimeter per millimeter ($\mu g/cm^2/mm$) of simulated rainfall for the 0.1, 0.33 and 1.0 inch/hour (2.5, 8.0, and 25.4 mm/hour) rainfall rates, respectively (Lebow et al. 2004). This same study also found little reduction in arsenic leaching rates with the application of a water repellent (Lebow et al. 2004). In some cases, leaching rates seemed to increase with water repellent application (Lebow et al. 2004). Another study found that semi-transparent water-repellent stain, latex paint, or oil-based paint greatly reduces leaching rates of arsenic, chromium, and copper (Lebow et al. 2004).

The U.S. Environmental Protection Agency (USEPA) has established aquatic life criteria (ALC) (i.e., concentration criteria) for the constituent metals that may leach from ACZA- or CCA Type C-treated wood (USEPA 2002, in Stratus 2005b). The ALC have been established for criterion maximum concentrations (CMCs) for acute exposure and criterion chronic concentrations (CCCs) for chronic exposure for both salt water and fresh water (refer to Table 7). In both fresh water and salt water, invertebrates are the species most sensitive to copper, chromium VI, zinc, and arsenic (Stratus 2005b). These ALC appear to be appropriate for acute lethal impacts of copper and chromium VI (Stratus 2005b), but avoidance responses and olfactory neurotoxicity may occur in salmonids at sublethal copper concentrations, even with brief exposure (Hansen et al. 1999, Baldwin et al. 2003, Sandahl et al. 2004, all in Stratus 2005b), and there may be a risk of bioaccumulated toxicity in salmonid prey species at the chronic chromium VI criterion (Stratus 2005b).

Table 7
U.S. Water Quality Criteria for the Protection of Aquatic Life ("aquatic life criteria") for Water Soluble Chemicals Used in Treating Wood

Chemical	Freshwater CMC (µg/L)	Freshwater CCC (µg/L)	Saltwater CMC (µg/L)	Saltwater CCC (µg/L)
Arsenic	340	150	69	36
Copper[e]	7.0[a]	5.0[a]	4.8	3.1
Copper (2003)	BLM[b]	BLM[b]	3.1	1.9
Chromium III	323	42	None (850)[c]	None (88)[d]
Chromium VI	16	11	1,100	50
Zinc	65[a]	65[a]	90	81

a. Criteria are hardness-dependent. Criteria values calculated using site-specific hardness based on the equations presented in USEPA (2002). Hardness-dependent criteria values are presented for a hardness of 50 mg/L (as CaCO3).
b. Criteria developed using site-specific chemistry and the Biotic Ligand Model (BLM).
c. No saltwater CMC. As a proxy, we report the lowest reported LC50 from the USEPA database (Lussier et al. 1985) divided by a factor of two. See text for additional details.
d. No saltwater CCC. As a proxy, we report the lowest reported chronic value from the USEPA database (Lussier et al. 1985) divided by a factor of two. See text for additional details.
e. From USEPA 2002.

From draft ALC guidance on copper provided by USEPA in 2003 that relies on the BLM for calculating freshwater criteria based on site-specific water chemistry.
Notes: CMC = criterion maximum concentration
CCC = criterion chronic concentration
µg/L = micrograms per liter
Source: USEPA 2002, except as noted, as taken from Stratus 2005b

There does not appear to be a pattern of sensitivity among species with respect to chromium III, but the ALC, although established only for fresh water, appear to be protective of fish, particularly salmonids (Stratus 2005b). If chromium III toxicity is related to salinity (similar to chromium VI and copper), the application of the freshwater criteria to salt water would include a margin of safety. The ALC for zinc are water hardness-dependent and do not appear to be protective of salmonids in fresh water of low hardness (30 mg/L) (Hansen et al. 2002, in Stratus 2005b); however, the zinc ALC for salt water are likely protective of salmonids (Stratus 2005b).

Avoidance behavior has also been observed among salmonids at zinc concentrations below or slightly above the ALC (Sprague 1964, Sprague 1968, Black and Birge 1980, all in Stratus 2005b). The ALC for arsenic are likely to be protective of salmonids (Stratus 2005b). Overall, the ALC are suitable for assessing the impacts of ACZA-

and CCA Type C-treated wood on water quality and the potential risk to potentially covered species (Stratus 2005b).

Metals from treated wood in aquatic settings may contaminate sediment and affect benthic communities, in turn limiting food availability for fish and exposing fish to metals contamination through the consumption of contaminated prey (Stratus 2005b). However, site-specific sediment conditions such as particle size and organic content can dramatically influence metals toxicity, making sediment toxicity difficult to predict (Stratus 2005b). Tables 8 and 9 present some of the threshold effects concentrations (TECs) and probable effects concentrations (PECs) for arsenic, chromium, copper, and zinc in sediment as reported in recent literature (Stratus 2005b). In general, concentrations below the TEC are not expected to cause impacts, while concentrations above the PEC are expected to cause frequent impacts.

Table 8
Threshold Effects Concentrations (TECs) for Freshwater Sediment

Name	Definition	Concentration (mg/kg dry wt)					Reference
		Basis	As	Cr	Cu	Zn	
Lowest effects level	Level that can be tolerated by the majority of benthic organisms	Field data on benthic communities	6	26	16	120	Persaud et al. 1991
Biological threshold effects level	Concentration that is rarely associated with adverse biological effects	Compiled results of modeling, laboratory, and field studies on aquatic invertebrates and fish	5.9	37.3	35.7	123	Smith et al. 1996
Minimal effects threshold	Concentration at which minimal effects are observed on benthic organisms	Field data on benthic communities	7	55	28	150	Environment Canada 1992
Effects range low[a]	Concentration below which adverse effects would rarely be observed	Field data on benthic communities and spiked laboratory toxicity test data	33	80	70	120	Long and Morgan 1991
Survival and growth threshold effects level	Concentration below which adverse effects on survival or growth are expected to occur only rarely	Laboratory toxicity tests on the amphipod *Hyalella azteca* using field-collected sediment	11	36	28	98	Ingersoll et al. 1996; USEPA 1996
Consensus threshold effects concentration	Concentration below which adverse effects are expected to occur only rarely	Geometric mean of above published effect concentrations	9.79	43.4	31.6	121	MacDonald et al. 2000a

a. Based on data from both freshwater and marine sites.
Source: Taken from Stratus 2005b
mg/kg = milligrams per kilogram
As = arsenic; Cr = chromium; Cu = copper; Zn = zinc

Table 9
Probable Effects Concentrations (PECs) for Freshwater Sediment

Name	Definition	Basis	Concentration (mg/kg dry wt)				Reference
			As	Cr	Cu	Zn	
Severe effects level	Level at which pronounced disturbance of the sediment-dwelling community can be expected	Field data on benthic communities	33	110	110	820	Persaud et al. 1991
Probable effects level	Concentration that is frequently associated with adverse effects	Compiled results of modeling, laboratory, and field studies on aquatic invertebrates and fish	17	90	197	315	Smith et al. 1996
Toxic effects threshold	Critical concentration above which major damage is done to benthic organisms	Field data on benthic communities	17	100	86	540	Environment Canada 1992
Effects range median[a]	Concentration above which effects were frequently or always observed or predicted among most species	Field data on benthic communities and spiked laboratory toxicity test data	85	145	390	270	Long and Morgan 1991
Probable effects level	Concentration above which adverse effects on survival or growth are expected to occur frequently	Laboratory toxicity tests on the amphipod Hyalella azteca using field-collected sediment	48	120	100	540	Ingersoll et al.1996; USEPA 1996
Consensus probable effects concentration	Concentration above which harmful effects on sediment-dwelling organisms are expected to occur frequently	Geometric mean of above published effects concentrations	33.0	111	149	459	MacDonald et al. 2000a

a. Based on data from both freshwater and marine sites
Source: Taken from Stratus 2005b
mg/kg = milligrams per kilogram
As = arsenic; Cr = chromium; Cu = copper; Zn = zinc

7.6.8 Stormwater and Nonpoint Source Water Quality Impacts

Stormwater generated by above-water portions of structures may adversely impact potentially covered species by introducing nonpoint source pollution to waterways. Overwater structures provide a surface on which pollutants can accumulate, and those pollutants can become mobile with stormwater runoff. Overwater structures may also be associated with a variety of adjacent land uses, including roads and parking lots, and may act as conduits for stormwater delivery from those adjacent land uses to waterways. These stormwater impacts are mitigated by regulations promulgated by the Washington State Department of Ecology (Ecology) under the federal Clean Water Act

(33 USC §§ 1251-1387). The Ecology regulations are subject to USEPA review and Section 7 requirements of the ESA (16 USC 1531-1544).

7.7 Channel Hydraulics

7.7.1 Controlling Factors in Channels

Streams are dynamic systems that adjust to tectonic, climatic, and environmental changes (Dollar 2000). Environmental changes can be either human-induced or natural. A stream system adjusts to maintain a steady state, or dynamic equilibrium, between the driving mechanisms of flow and sediment transport and the resisting forces of bed and bank stability and resistance to flow (Soar and Thorne 2001). Alluvial channels (as opposed to channels incised into bedrock) have erodible bed and banks comprised of sediments. An alluvial stream adjusts the dimensions of its channel to the wide range of flows that mobilize its boundary sediments. For many rivers and streams, a single representative discharge may be used to determine a stable channel geometry. This representative channel-forming (dominant) discharge has been given several names by different researchers, including bankfull, specified recurrence interval, and effective discharge (Copeland et al. 2000).

Miller et al. (2001), a WDFW white paper, provides an overview of the geomorphic basis for and the principles of channel design and is incorporated herein by reference. Bolton and Shellberg (2001) also provides a literature review of geomorphic controls on streams and the ecological effects of stream channelization. As a WDFW white paper, Bolton and Shellberg (2001) is incorporated herein by reference. Additional useful sources of information on channel design include Watson et al. (1999), Papanicolaou and Maxwell (2000), Copeland et al. (2001), and Bates (2003).

Placement of structures within or beneath the stream channel can have the following primary effects on the channel (Brookes 1988, in Bolton and Shellberg 2001):

- Channel shortened by straightening
- Channel cross-sectional area reduced (by placing fill, pilings, and/or abutments in the channel)
- Channel bed and/or banks replaced with non-erodible artificial materials
- Channel loses the ability to migrate over time

Each of these effects constitutes an "impact" (Figure 1), but collectively these impacts affect channels primarily by altering only one controlling factor: stream power, which is in turn determined by water surface slope, flow volume, and channel roughness (Dunne and Leopold 1978). Structures placed in the channel have the potential to alter each of the factors identified in the above list.

Because the surface of a stream is roughly parallel to its bed (Dunne and Leopold 1978), water surface slope is mainly altered by changes in channel gradient. Overwater structures normally have little capacity to alter channel gradient.

Channel roughness elements affect stream velocity by increasing boundary shear stress, thereby increasing resistance to flow (Leopold et al. 1964). Structures can increase or decrease channel roughness in a variety of ways that alter habitat, such as changes in in-channel roughness elements, changes in channel perimeter roughness elements, or changes in the relationship between channel area and wetted perimeter. All materials in contact with the wetted channel constitute roughness elements. The principal in-channel roughness elements are artificial structures such as gratings or pilings, and natural structures such as large woody debris. An example of roughness effects on channels was encountered at a highway bridge reconstruction investigated by Barks and Funkhouser (2002), using a two-dimensional flow model to estimate conditions during the 100-year flood. Barks and Funkhouser (2002) found that relocating a bridge abutment from an area of dense vegetation to an agricultural area predicted a 67 percent decrease in channel roughness and a 29 percent increase in flow velocity, with associated high risk of scour and channel destabilization. They used the same model to show that planting trees and placing riprap in the area would alleviate the predicted flow increase and move the area of maximum flow back into the stream's thalweg (the line of steepest descent along the stream). This study identified some of the principal channel border roughness elements, such as sediment, vegetation, and artificial elements like riprap and bridge abutments. The fact that the investigated abutment supported a bridge is immaterial; the structure represented by the abutment could have supported any kind of overwater structure, such as a pier.

Because flow velocity is proportional to the product of roughness and wetted perimeter (Leopold et al. 1964), changes in the length of the wetted perimeter can also alter stream power. Structures in the channel alter the wetted perimeter directly, such as when flow is confined by a pier, or indirectly, such as when erosion or deposition causes changes in channel geometry. Structures such as docks and piers tend to confine the channel within artificial bounds and thus generally cause locally reduced channel roughness, potentially causing scour at the structure, with corresponding deposition downstream. Sturm (2004), modeling scour at bridge abutments in sandy sediments, found that scour could be significant enough to alter channel geometry, producing large excavations near bridge abutments and causing reduced water depths and sediment deposition immediately upstream. Sturm (2004) also found that this effect could be exacerbated in higher flows. The fact that the investigated abutment supported a bridge is immaterial; the structure represented by the abutment could have supported any kind of overwater structure, such a as pier. This study underscores the importance of using hydraulic modeling to avoid locally significant changes in channel structure.

Channels are dynamic landscape elements that integrate inputs from tributary channels and from valley and hillslope processes (Washington Forest Practices Board 1995). Thus, a structure placed in a channel is likely, over time, to experience the effects of altered stream power and an altered sediment transport regime caused by changes in the watershed upstream. For example, in areas subject to progressive urbanization, gradual increases in catchment impervious surface cause predictable hydrologic changes characterized by increased variance in the hydrograph (Booth et al. 2002). One consequence of this change is increased peak flows and correspondingly increased sediment transport capacity, which often cause streambank instability and channel downcutting (Dunne and Leopold 1978, pp. 693-695). The resulting increases in flow and sediment around and through in-water structures can exceed the structures' design capacity, leading to outcomes such as scour around abutments and pilings (discussed above).

To summarize, the placement of artificial structures in channels can, through a variety of mechanisms, cause increased erosion at or upstream of the structure, increased deposition downstream, and increased sediment transport past the structure. This

amounts to a change in channel structure and thus potentially affects habitat structural elements of the channel: channel type, substrate size distribution, channel cross section, channel migration, bed mobility, and bank structure. These potential changes, and their significance to potentially covered species, are described below.

7.7.2 Habitat Structure in Channels

Channels are defined by the transport of water and sediment confined between identifiable banks (Dietrich and Dunne 1993). Natural stream channels show great variety, reflecting differences in channel processes, disturbance regimes, structural controls, and geologic history (Washington Forest Practices Board 1995). One of the channel classification schemes most widely employed in Washington distinguishes channels primarily according to their roughness characteristics and their sediment transport regime (Montgomery and Buffington 1993, 1997). Some channel types addressed in this classification, i.e., bedrock and colluvial channels, are of little concern here because they seldom provide significant habitat for potentially covered species and because bedrock channels, in any event, are unlikely to experience appreciable process change due to placement of artificial structures. Alluvial channels, however, are channels in which bed and banks are primarily comprised of alluvium (i.e., material previously transported by the stream), and thus alluvial channels represent a linked water-sediment transport system in which a wide variety of channel types may develop. Montgomery and Buffington (1993) recognize six such channel types: cascade, step-pool, plane bed, pool-riffle, braided, and regime. They propose that these types are controlled primarily by channel gradient and also by sediment supply (the amount of material available for transport) and transport capacity (determined by shear stress, which is similar to stream power). The singular importance of LWD as a structural element is also recognized. Changes in channel gradient, sediment supply, and stream power, which can be altered by placement of instream structures, therefore have the potential to directly alter habitat conditions for potentially covered species.

The steepest channels described by Montgomery and Buffington (1993) are cascade channels. Because of their high gradient (typically steeper than 8 percent), these channels usually have high roughness caused by boulder or bedrock bedforms. They typically have high transport capacity, so little sediment is stored in the bed or banks.

The most common disturbance is debris flow. Cascade channels are predominant in small mountain tributaries in Washington, where they are often seasonal, non-fish-bearing streams. Some cascade channels, however, occur lower in the stream system, commonly where a stream transits a layer of relatively erosion-resistant rock; in such areas, they may link lower-gradient reaches having greater habitat value.

Step-pool channels commonly have a lower gradient of about 3 to 8 percent (Montgomery and Buffington 1993; Papanicolaou and Maxwell 2000). Many perennial, fish-bearing streams in hilly and mountainous parts of Washington have a step-pool morphology. Step-pool channels commonly provide the principal spawning habitat for resident salmonids, especially when lower-gradient habitats downstream are utilized by anadromous salmonids (Montgomery and Buffington 1993). Step-pool channels are highly sensitive to the amount of LWD in a stream and to the stream's sediment supply; if LWD is removed from a step-pool channel, the channel's sediment storage capacity is reduced, sediment is transported from the reach, and the channel commonly shifts to a plane bed or pool-riffle morphology (Montgomery and Buffington 1993). This is an adverse habitat change for organisms that require deep and persistent pools, for example as cover or habitat buffer during low-flow periods. Severe increases in sediment supply also tend to cause loss of pools, again by filling, but step-pool channels tend to be robust against such a change, because filling pools reduces channel roughness, in turn increasing transport capacity and allowing scour to reestablish the pools (Montgomery and Buffington 1993). However, the pool filling and subsequent scour associated with this equilibration process could be expected to have adverse impacts on stream organisms. More moderate changes in sediment supply would also be expected to alter these channels, primarily by causing a general coarsening or fining of bed material. Generally, step-pool channels have a high enough gradient and transport capacity that it should be feasible to place additional roughness elements, such as artificial structures that occupy a fraction of the channel, without substantially altering channel hydraulics and sediment transport.

At more moderate gradients (typically 1 to 3 percent), the principal channel types are pool-riffle and plane-bedded channels. These channel types are highly vulnerable with regard to hydraulic or sediment source changes, because they represent channels that

have low to moderate transport capacity; thus, relatively small changes in channel morphology can cause changes in net sediment accumulation or export, with associated changes in grain size and bedform (Montgomery and Buffington 1993, pg. 50).

Normally, plane-bed channels have well-defined bed and banks with a lack of bedforms. LWD plays a critical role in pool-riffle and plane-bed channels. Adding LWD to a system will often cause a plane-bed channel to become a pool-riffle channel, while removing LWD will often cause the reverse transformation (Montgomery and Buffington 1993, pp. 41, 53). This occurs because, since these channels lack the transport capacity to move boulders, LWD provides the principal sites for both scour (which forms pools) and sediment accumulation (which forms riffles). Artificial instream structures such as abutments and pilings are often local sites for scour in these channels. In larger rivers with plane-bed channels, significant scour can occur, particularly in response to channel structures such as LWD (Sedell et al. 1986; Collins et al. 2002). This has been described, for instance, as the historical condition on the South Fork Nooksack River (Maudlin et al. 2002; Sedell and Luchessa 1982) and the Willamette River (Sedell and Froggatt 1984) and in the general case for larger western Washington rivers (Abbé and Montgomery 1996).

Plane-bed and pool-riffle channels display a characteristic sensitivity to changes in sediment supply. Increases in fine sediment supply commonly lead to embedding, a process whereby fine sediments are incorporated to the bed of the stream and remain there after they become armored by a relatively thin surficial layer of coarse sediment. Embedding gives the stream a relatively hard, impervious bed that provides a poor substrate for salmonid spawning, impairs hyporheic exchange, and provides poor habitat for benthic invertebrate infauna. Typically, several years of peak flow events are required after the fine sediment inputs have ended for the bed to be sufficiently reworked that embedding abates.

Inputs of coarse sediment initially have little effect on pool-riffle channels, but as the inputs increase, the pools are filled, the channel aggrades, and the bedform changes from pool-riffle to plane bed (Montgomery and Buffington 1993). Continuing aggradation leads to channel widening and bar development (Montgomery and

Buffington 1993). With sufficiently large increases in coarse sediment supply, the channel may develop a braided form (Montgomery and Buffington 1993).

Plane-bed and pool-riffle channels are among the most important for salmonid spawning because they have a bed mobility and scour regime to which salmon are well adapted, providing spawning habitat for large numbers of fish (Montgomery et al. 1999). These channels are also a principal habitat for freshwater molluscs, such as the potentially covered mussels, limpets, and spire snails listed in Table 1.

The lowest-gradient channels, having gradients of less than 1 percent, are regime channels (Montgomery and Buffington 1993). These channels are abundant on floodplains and in tidewater areas of Washington. Regime channels are normally transport-limited and commonly have sand or silt beds. They are highly vulnerable to changes in sediment supply, alteration of bank vegetation, and artificial changes in gradient (Montgomery and Buffington 1993). Coarse sediment tends to fill the channel because the stream lacks the transport capacity to move it through the system. Finer sediment will be exported, but slowly; in the meantime, the channel tends to become wider and shallower (Montgomery and Buffington 1993). Because the bed and banks are comprised of relatively fine sediment, the roots of vegetation are particularly important to maintaining bank integrity; the loss of vegetation can trigger bank erosion, causing sediment inputs and channel widening/shallowing (Montgomery and Buffington 1993, p 53). Thus, preserving riparian vegetation is important when overwater structures are sited in regime channels.

7.8 Littoral Drift

Wave action striking shorelines at an angle causes littoral currents that move parallel to shore (Cox et al. 1994). While littoral processes are most conspicuous in marine waters, they can occur along lake shores as well, where fetch and wind speed combine to produce waves and subsequent longshore currents strong enough to move shoreline sediments. Shoreline features, including artificial structures, affect the velocity and direction of shoreline currents and sediment transport.

Washington State contains thousands of miles of shorelines, including about 2,000 miles in Puget Sound alone. Much of this shoreline consists of poorly consolidated bluffs of glacial sediments faced with cobble beaches in the upper intertidal zone and sandy sediments in the lower intertidal and subtidal areas. Erosion and occasional landslides on these bluffs provide a sediment source. The sediment moves from location to location through littoral drift and ultimately is deposited in deep water, where it no longer contributes to littoral processes. Local geomorphology, weather, fetch, and sediment sources determine the volume, timing, and direction of sediment transported past an individual beach. Each discrete unit of shoreline with sediment sources and sinks is considered a littoral drift cell (Cox et al. 1994). The direction of drift within a drift cell may reverse between winter and summer as prevailing wind and wave direction changes, causing sand to redistribute among beach areas (Cox et al. 1994). Littoral drift is estimated to transport volumes of 1,000 to 500,000 cubic feet (30 to 14,000 cubic meters) of sediment per year past Puget Sound beaches (Canning and Shipman 1994). Beaches along the Pacific coast of Washington have much greater wave energy and can experience annual littoral drift rates of 3.5 million to 10 million cubic feet (100,000 to 300,000 cubic meters) per year (MacDonald 1994).

The construction of overwater structures or non-structural piling may affect littoral drift when they alter wave action or littoral currents.

7.8.1 Wave Action

Overwater structures and piling can affect wave direction and intensity. The effects of piers and pilings on wave action depend on spacing, orientation, and number of pilings, as well as depth and proximity to shore (Fresh 1998, in Nightingale and Simenstad 2001b; Nightingale and Simenstad 2001b). Widely spaced piles in deep water have relatively little effect, as waves refract around them (Nightingale and Simenstad 2001b). In contrast, a series of pilings can reflect waves, resulting in reduced littoral currents (Nightingale and Simenstad 2001b). Floating structures can also attenuate waves and alter the intensity of wave action that cause and maintain littoral drift (Nightingale and Simenstad 2001b). The effectiveness of a floating structure as a wave attenuator depends on the shape, dimensions, and orientation of the structure (Cox et al. 1994).

Wave energy and water transport alterations imposed by docks, ramps, abutments, pilings, and associated structures often alter the size, distribution, and abundance of substrate and detrital materials required to maintain the nearshore detrital-based food web (Nightingale and Simenstad 2001b). Alteration of sediment transport patterns can present potential barriers to the natural processes that build spits and beaches and provide substrates required for plant propagation, fish and shellfish settlement and rearing, and forage fish spawning (Parametrix and Battelle 1996, Penttila 2000b, Thom et al. 1994, 1997, all in Nightingale and Simenstad 2001b; Thom and Shreffler 1996). For example, experimental investigations by Shteinman and Kamenir (1999, in Nightingale and Simenstad 2001b) demonstrate how the construction of jetties and other in-water structures can partially or completely disrupt the longshore transport process. In a natural hydraulic regime, size separation of sediments proceeds along the bottom slope with wave flow impact, and steep-sloped bottoms move larger sediments toward the shore, accumulating a thin nearshore strip along the shoreline. While smaller sediments were found to move toward deeper areas, where they accumulate or were further transported by currents, the opposite was found to occur on gentle bottom slopes, where smaller sediments accumulated near the shore and coarser sediments were moved toward the deeper areas (Shteinman and Kamenir 1999, in Nightingale and Simenstad 2001b).

Such changes in wave energy across substrates determine the size and distribution of sediments and associated detritus (Nightingale and Simenstad 2001b). Throughout Puget Sound, Hood Canal, and Washington's coastal estuaries, variations in the interface between bottom slopes, wave energy, and sediments build beaches, nearshore substrates, and habitats unique to the climate, currents, and conditions of specific sites (Nightingale and Simenstad 2001b). Although specific characteristics of the factors at play vary with the geology of each region or subsystem, changing the type and distribution of sediment will generally alter key plant and animal assemblages (Nightingale and Simenstad 2001b).

Wave and current interactions in shallow water (depths less than 3 feet) are particularly important to intertidal flora and fauna. For example, along the shallow edge of the tidal water, high suspended sediment concentrations may flow over a mudflat. This passage

across the intertidal area potentially deposits large quantities of sediment and nutrients on upper mudflat areas, particularly at slack water (Christie and Dyner 1998, in Nightingale and Simenstad 2001b). These are part of the sedimentation and water transport processes that shape the geomorphology and consequently the plant and animal communities that rely on the shallow, soft sediment habitats of mud and sandflats (Nightingale and Simenstad 2001b).

Depending on the geomorphology, current transport processes, and climatic conditions of a specific area, overwater structures have the potential to alter these important habitat-building processes (Nightingale and Simenstad 2001b).

7.8.2 Littoral Currents

In-water structures such as piers and pilings have the potential to block or divert littoral currents. Alteration of littoral currents can cause sediment deposition and reduce beach nourishment down-current from the structure (Thom et al. 1994). Changes in beach nourishment and sediment deposition can in turn alter benthic and epibenthic communities, as well as bank erosion rates (Thom et al. 1994). The significance of these effects depends on the location and orientation of the structures (Thom et al. 1994). Closely spaced pilings can collect sediment along the up-current side (Nightingale and Simenstad 2001b), but widely spaced pilings allow currents to flow freely and sediment transport is essentially unaffected (Nightingale and Simenstad 2001b). WDFW noted that miles of historical habitat have been permanently lost due to the placement of structures and fill, with commensurate permanent loss of riparian vegetation and large organic debris, as well as extensive intertidal habitat degradation from increased wave and current turbulence waterward of such structures (Canning and Shipman 1994).

Benthic habitat may be impacted by alterations in natural sediment movement. For instance, a structure that interferes with littoral drift cells poses the risk of interference with the deposition of fine sediments to adjacent beaches that support beach spawning forage fish, such as surf smelt and sand lance (Nightingale and Simenstad 2001b). Limiting the fine sediments deposited to adjacent beaches also poses the risk of limiting the establishment of rooted vegetation, such as eelgrass, along submerged areas of adjacent shorelines and therefore the risk of reducing the available habitat for fish and

shellfish species that rely on such vegetated habitats for spawning and rearing (Nightingale and Simenstad 2001b). The manner in which a structure is used by vessels will determine additional effects of wave energy from vessel traffic and other effects such as vessel pollutant distribution or impacts to other adjacent shoreline structures (Nightingale and Simenstad 2001b).

Alterations to littoral drift can also affect the beach profile (Thom et al. 1994). Changes in littoral drift that reduce sediment supply can make beach slopes steeper and increase erosional processes, especially in shorelines hardened by development resulting in a coarsening of the beach substrate, which can substantially interfere with the quality and quantity of intertidal forage fish spawning habitats (Thom et al. 1994).

7.9 Substrate Modifications

Modifications of substrate caused by channel hydraulic processes are discussed in Section 7.7, and modifications caused by the analogous shoreline process, littoral drift, are discussed in Section 7.8. These include most substrate modifications observed in association with construction and operation of overwater structures in stream channels and along shorelines. However, there are also substrate modifications that occur in conjunction with overwater structures (such as docks along many lakeshores or along rocky seacoasts) in waters where sediment transport is not a significant habitat-forming process. In such settings, the structure itself constitutes the substrate modification.

In the nearshore environment, dock pilings have been found to alter adjacent substrates with increased shellhash deposition from piling communities and changes to substrate bathymetry (Penttila 1990, Shreffler and Moursund 1999, both in Nightingale and Simenstad 2001b). The change in substrate type can also alter the nature of the flora and fauna native to a given site, and native dominant communities typically associated with sand, gravel, mud, and seagrass substrates are replaced by those communities associated with shellhash substrates (Nightingale and Simenstad 2001b).

WAC 220-110-300(1) does allow for the grounding of up to 20 percent of floats or rafts in marine waters that do not provide spawning for surf smelt, Pacific herring, Pacific sand lance or rock sole. Grounding of these structures can affect substrates and the aquatic

organisms occupying the substrates found beneath these structures by directly resting and grinding upon (during tidal fluctuations and wave action) the substrate and the organisms that occupy the substrate. Grounding of floats can also occur in freshwater systems that are managed, such as reservoirs, and have similar impacts, although the draw down of the water is not a natural occurrence and typically is of a longer duration (i.e. seasonal fluctuations).

7.10 Channel Dewatering

Channel dewatering occurs primarily in freshwater settings and is typically associated with the need to work "in the dry" during construction of overwater structures, such as when fabricating and pouring concrete supports. Basic requirements for channel dewatering are provided in WAC 220-110-120. Review of numerous biological opinions prepared by NMFS indicates that channel dewatering typically requires the installation of a cofferdam and a bypass system to divert flowing water around the construction site and allow work to occur in the dry.

The impacts associated with channel dewatering include:

- Fish removal and exclusion
- Fish entrainment in dewatering pump
- Alteration of flow
- Disturbance of the streambed
- Loss of invertebrates and undetected fish
- Elevated turbidity when the construction area is rewatered

Each of these impacts is discussed below.

7.10.1 Fish Removal and Exclusion

Fish removal and exclusion is performed using passive methods, such as the volitional movement of fish from the construction area during its slow dewatering, or through active methods, such as the use of hand nets, beach seining, or electrofishing equipment to capture and move fish from the construction area that will be dewatered (NMFS 2003b). Potentially covered invertebrate species are typically not removed, and potentially covered invertebrate species present within the area to be dewatered may be

subject to injury or mortality, depending on the duration of dewatering and the nature of the work that will be performed in the dewatered area.

Passive capture of fish typically involves installing an upstream block net (when a flowing water is dewatered) and a cofferdam (in flowing or lentic waters) and slowly dewatering the construction area. It has been suggested that reductions in streamflow of 80 percent result in the greatest number of fish volitionally moving out of the dewatered construction area (NMFS 2006a). This type of passive fish removal eliminates the need to capture and handle some fish.

More active methods of fish removal include the use of a beach seine to "herd" fish beyond the construction area, where dewatering will not occur. In streams, a block net is installed at the downstream-most point to exclude fish from moving back upstream and entering the construction and dewatering areas. Once the block nets are in place, several passes of the construction area may be made with the nets or beach seine to capture any fish that may remain within the construction area. Once fish are no longer being captured with the beach seine, a portable electrofishing unit can be employed to ensure that as many fish as possible have been removed from the construction area being dewatered (NMFS 2003b).

Captured fish are typically released downstream or outside of the construction area. Depending on the number of fish captured, the size of the stream, and whether flowing or lentic waters are dewatered, fish may be released at multiple sites to minimize overcrowding of available habitat (NMFS 2003b).

Beach seining can affect fish in several ways, including stress, scale loss, physical damage, suffocation, and desiccation. The amount of unintentional injury and mortality attributed to seining can vary widely depending on the seine used, the ambient conditions, and the expertise of the field crew (NMFS 2003b). Professional experience has shown that beach seining in areas of dense aquatic vegetation can also result in significant mortality of seined fish that become trapped in a mass of vegetation. However, adverse effects are often less for seining compared to electrofishing, and first

using a seine to remove fish will minimize the adverse effects of electrofishing (NMFS 2003b).

Electrofishing can kill both juvenile and adult fish if improperly conducted. Mortality can be immediate as a result of trauma or delayed as a result of disease or fungal attack. Researchers have also found that sublethal effects, such as spinal injury, occur (NMFS 2003b; Snyder 2003). Although fish may receive spinal injuries as a result of electrofishing, research indicates that few die of these injuries. However, severely injured fish grow at slower rates and sometimes show no measurable growth (NMFS 2006a).

7.10.2 Fish Entrainment

Dewatering a portion of a stream channel requires a flow bypass system and may rely on either gravity or a pump to convey the flow around the dewatered portion of the channel. This type of activity has the potential to entrain fish within the bypass system.

If pumps are used to bypass water around a work site, or to complete dewatering within a cofferdam, the hose or pipe pulling water from the channel is typically fitted with a mesh screen to prevent entrainment of aquatic life into the intake hose/pipe of the pump (WSDOT 2006b). Such measures are required for all pumped diversions (WAC 220-110-190). Screens should be placed approximately 2 to 4 feet from the end of the intake hose to reduce velocity at the screen as a measure to ensure that fish are not impinged upon the screen (WSDOT 2006b).

7.10.3 Alteration of Flow

Dewatering can temporarily alter the flow regime in the affected stream. Flow must be diverted around the construction area and discharged downstream. Generally, cofferdams are installed upstream and downstream of the construction area to assist with dewatering. This approach allows the work area to be completely dewatered so the work can be performed in the dry. The alteration of flow associated with dewatering a work area depends on the size of the area dewatered, but generally is only temporary.

In general, flow alteration associated with channel dewatering is of relatively short duration and affects a relatively small area. The hydraulic effects of overwater structures on stream channels are discussed in more detail in Section 7.7.

7.10.4 Disturbance of the Streambed

Disturbance of the streambed associated with channel dewatering can be extensive, depending on the purpose of the dewatering. If an overwater structure is being installed where one did not previously exist, a permanent loss of streambed and associated habitat components (e.g., riparian habitat, floodplain, and substrate) occurs, such as when a new dock or pier is constructed. The effects of such substrate disturbance are discussed in greater detail in Section 7.7.

7.10.5 Loss of Invertebrates

Channel dewatering may lead to loss of potentially covered invertebrate species within the portion of the channel being dewatered. Although no studies were located that specifically examined the impacts of construction related dewatering, several studies have looked at the influence of dam operations on freshwater mussel habitats, which provide insight to the potential impacts from construction dewatering (summarized in Watters 1999). Depending on the use of the dam, water levels may fluctuate at regular intervals (for hydroelectric purposes) or random intervals (for flood control). In some areas, water levels may become shallow enough that thermal buffering is lost, allowing extreme temperatures to occur (Watters 1999). Blinn et al. (1995, in Watters 1999) reported that substrate subjected to 2- to 12-hour exposures to air required more than four months for mussels to regain a biomass similar to that in unexposed habitat. Federally endangered mussel species were reported by Neck and Howells (1994, in Watters 1999) as casualties of scheduled dewatering processes, and Riggs and Webb (1956) reported that several thousand mussels died in the tailwaters of Lake Texoma, an impoundment of the Red River formed by Denison Dam, when water levels dropped, in turn allowing water temperatures to become excessively warm (exceeding 79 degrees F [26 degrees C]). This area was exposed for at least 20 days before being inundated again.

Exposure to cold air may be equally lethal (Watters 1999). Nagel (1987, in Watters 1999) believed mussels were more sensitive to cold water during frosts than to warm water during temporary droughts. Blinn et al. (1995) showed that a single overnight exposure to subzero temperatures resulted in at least a 90 percent loss of invertebrate biomass, and Valovirta (1990) reported that mussels were killed when water froze to the river bottom.

Benthic macroinvertebrates provide food for fish, and different species tend to be associated with different substrates. Chironomids of various species do well in silts and sands, but the larger ephemeropterans, trichopterans, and plecopterans prefer a mixture of coarse sands and gravels (Meehan 1991). The temporal and spatial impact of channel dewatering on macroinvertebrates depends on the amount of channel dewatered and the type of disturbance (temporary or permanent) to the channel.

Disturbance of the streambed from activities that generally result from channel dewatering also equates to direct disturbance of benthic macroinvertebrates. Loss of macroinvertebrates can result from excavation, installation of structures, and placement of fill material. Channel dewatering typically results in a localized loss of benthic macroinvertebrate abundance due to channel modifications.

Benthic macroinvertebrates are consumed by salmonids and other potentially covered species and may represent a substantial portion of their diet at various times of the year. The effect of macroinvertebrate loss on salmonids is generally temporary, unless construction has caused permanent loss of habitat (i.e., installation of a new structure). Once the dewatered area is rewatered, benthic macroinvertebrates from outside of the area affected by dewatering, and those which sought refuge in the hyporheic zone, will begin to recolonize the area. When the disturbance is temporary, a rapid recolonization of the disturbed area is anticipated. Reported rates of recolonization range from about one month to 45 days (NMFS 2003b), although some less motile species and species with long life cycles (e.g., freshwater mussels) would take longer to recolonize. NMFS (2003b) did not indicate the duration or area of the dewatering that corresponds to the one-month to 45-day time frame for recolonization.

7.10.6 Elevated Turbidity During Rewatering

To dewater a channel, a bypass system is needed to convey stream flow around the construction area. A typical bypass system consists of a pipe of adequate size to convey flows or a temporary channel built adjacent and parallel to the existing channel. The type of bypass system is determined by the size of the stream and other hydraulic or environmental factors.

Increased turbidity can result from the installation, operation, or removal of a stream bypass system. Installation of a stream bypass typically requires in-water work, which can disturb substrates and bank material and cause an increase in turbidity levels. Operation of a stream bypass generally will not result in disturbance to the streambed or cause an elevation in turbidity levels, unless the discharge of the pipe results in scouring of substrate material or erosion of streambanks. Removal of the stream bypass requires in-water work and will result in some disturbance to the streambed and banks as the cofferdam is removed and flow is returned to the channel. Generally, the downstream cofferdam is removed first to allow backwatering of a portion of the channel that was dewatered. Then the upstream cofferdam is removed, and flow is slowly returned to the channel to minimize resuspension of fine sediments and increases in turbidity.

7.11 Artificial Light

Artificial lighting may be used during the construction of overwater structures, and some kinds of structures also require nighttime lighting for security or operations. Nighttime artificial lighting has been shown to change fish species assemblages by:

- Attracting fish to lighted areas (Prinslow et al. 1979, in Nightingale and Simenstad 2001b; Simenstad et al. 1999; Nightingale and Simenstad 2001b)
- Delaying salmonid migrations (McDonald 1960, in Tabor et al. 1998; Prinslow et al. 1979, in Nightingale and Simenstad 2001b; Tabor et al. 1998)
- Increasing the risk of predation (Tabor et al. 1998; Kahler et al. 2000)
- Altering predator avoidance and detection (Tabor et al. 1998)
- Increasing prey capture success for some species of fish (Prinslow et al. 1979, in Nightingale and Simenstad 2001b; Nightingale and Simenstad 2001b)

Impacts to fish from artificial lighting are often the result of changes in nighttime behaviors such as migration, activity, and location (Nightingale and Simenstad 2001b) and potentially in schooling behavior in juvenile salmonids (Ali 1959, 1962, in Simenstad et al. 1999). Therefore, behavioral differences between species at differing life stages, life histories, and behaviors specific to the local environment must be considered when evaluating potential impacts from artificial light. For instance, different species of salmonids have different nighttime behaviors. Species that occupy and defend stream territories, such as coho salmon and steelhead trout, tend to be quiescent at night (Simenstad et al. 1999), while species that disperse to lakes and estuaries as juveniles, such as sockeye, Chinook, pink, and chum salmon, typically school and show nocturnal activity (Godin 1982, Hoar 1951, both in Nightingale and Simenstad 2001b). Behavioral differences in salmonid responses to artificial lighting have been observed by several authors. Ocean-type juvenile salmon, such as chum and summer and fall run Chinook, are attracted to lights at night (Simenstad et al. 1999). Pucket and Anderson (1988, in Simenstad et al. 1999) and Nemeth (1989, in Simenstad et al. 1999) found that different species of salmon react differently to strobe lights; Mork and Gulbrandsen (1994, in Simenstad et al. 1999) found differing activity levels in reaction to lights at surface and bottom depths in different species of salmon, trout, and char. Fields (1966, in Simenstad et al. 1999) found that spring migrant juvenile salmon were more repulsed by bright lights than were later migrants. Behavior patterns of different salmon species related to different light intensities and other details of artificial light impacts to juvenile salmonids are reviewed by Simenstad et al. (1999).

Impacts to fish also depend on the fish's ability to adapt to dark or lighted conditions and the intensity and type of light. Ali (1959, in Simenstad et al. 1999) found that the eyes of sockeye fry and smolts and coho smolts adapt to light more slowly than do the eyes of coho, Chinook, and pink fry. Other studies by Ali (1959, 1962, in Simenstad et al. 1999) reveal the threshold light intensities for different behaviors of juvenile salmon. For a description of fish vision, refer to the discussion of shading in Section 7.1. For a detailed discussion of salmonid vision and light adaptation, see Simenstad et al. (1999).

Impacts on predator-prey relationships resulting from artificial lighting include increased risk of predation (Tabor et al. 1998; Tabor, pers. comm. and Warner, pers. comm., both in Kahler et al. 2000), increased predator avoidance and detection (Tabor et al. 1998), and

increased prey capture success (Prinslow et al. 1979, in Nightingale and Simenstad 2001b; Nightingale and Simenstad 2001b).

The few studies that have examined predation rates on juvenile salmonids under varying light intensities have generally shown that within the natural range of light intensities (e.g., overcast skies, moonless nights, clear nights, moonlit nights), predation increases with increasing light (Patten 1971, Ginetz and Larkin 1976, Mace 1983, all in Tabor et al. 1998); however, this occurrence cannot be extrapolated to determine impacts of artificial night lighting and for all species and life stages of fish. Ali (1959, in Simenstad et al. 1999) found that the maximum prey capture success for coho fry and sockeye and coho smolts was at light intensities equivalent to levels found at dawn or dusk, whereas maximum prey capture success for sockeye and pink fry was found to be equivalent to a cloudy day. Tabor et al. (1998) showed that under freshwater laboratory conditions, sculpin capture success of sockeye fry decreased with increased light. The authors also found that sculpin can capture sockeye fry even in complete darkness. Although sculpin success at capturing sockeye decreased with increasing light in a circular tank, the increased light slowed emigration of sockeye fry in a simulated stream, and predation increased under the lighted conditions due to the slower migration rate. The light may have also caused the fry to migrate in areas of lower water velocity and closer to the bottom, leaving them more susceptible to predation by sculpin (Tabor et al. 1998).

Predation rates may also increase due to predator congregations in lighted areas. Prinslow et al. (1979, in Nightingale and Simenstad 2001b) observed chum congregating at night below security lights in Hood Canal and suggested that lighting may provide increased feeding opportunities for chum at night. Prinslow et al. (1979, in Nightingale and Simenstad 2001b) also observed that dogfish (an important predator of herring and an occasional predator of juvenile and adult salmonids) were attracted to the security lights. Grebes, blue herons, and other birds have been observed feeding at night on the Cedar River delta in an area lit by Boeing Company facilities (Warner, pers. comm., in Kahler et al. 2000), and Tabor (pers. comm., in Kahler et al. 2000) observed grebes foraging under lights at night on Lake Washington. Finally, Kahler et al. (2000) suggests that lighting attached to piers in Lake Washington where bass congregate may benefit bass by extending the duration of predation because it allows the visual predators to forage at night.

7.12 Vessel Activities

Vessel activities associated with the installation and operation of in-water and overwater structures may adversely impact potentially covered species. Projects involving the use of large vessels such as ferries, cargo ships, or cruise ships would likely present complex potential risks to potentially covered species and are more difficult to address under a programmatic analysis. However, vessels used during construction and commercial and recreational boats have more predictable impacts. Impact mechanisms include:

- Physical disturbance of sediment, organisms (Haas et al. 2002), and submerged vegetation through grounding or water turbulence caused by propeller wash, potentially resuspending sediment, physically dislodging vegetation and organisms, or damaging vegetation
- Noise from vessel activity
- Propeller-wash entrained air bubbles that combine with turbidity increases from disturbed sediment, leading to a temporary reduction in the availability of light

Each of these impact mechanisms is discussed below.

7.12.1 Sediment Disturbance

Vessel traffic can disturb and suspend sediment in the water column as a result of water currents moving under and around the vessel, pressure fluctuations as the vessel displaces water during movement, propeller wash, and waves generated by the bow and stern of a vessel that wash up on the bank (McAnally et al. 2004). Vessel traffic has been correlated with an increase in turbidity of up to 50 percent in shallow waters (average depth 10 feet [2.9 m]) (Anthony and Downing 2003). Correlations of vessel traffic with turbidity patterns and sediment particle settling velocities suggest that vessel traffic may increase turbidity levels on a daily as well as seasonal temporal scale (Garrad and Hey 1988). Recreational vessel traffic has been observed to induce levee erosion at rates of 0.0004 to 0.009 inch (0.01 to 0.22 mm) per boat pass (Bauer et al. 2002). Water depth appears to have less influence on vessel-induced turbidity than does vessel speed (Hill and Beachler 2002). Field measurements have shown that at very low speeds and very high speeds, planing hull vessels have little effect on turbidity, even in shallow water, but at transitional speeds, significant sediment resuspension can occur, even in relatively deep water (Hill and Beachler 2002).

7.12.2 Eelgrass and Macroalgae Disturbance

Simenstad et al. (1999) describes the potential effects of propeller wash on eelgrass. Flume studies have shown that current velocities of 20 to 31 inches per second (50 to 80 centimeters per second [cm/sec]) may be sufficient to cause sediment disturbance around eelgrass and that velocities of 71 inches per second (180 cm/sec) can cause severe erosion of eelgrass patch edges. However, eelgrass patches in Puget Sound thrive in currents of up to 79 inches per second (200 cm/sec) (Thom et al. 1996, in Nightingale and Simenstad 2001b). The effect of vessels used during installation of overwater structures on eelgrass and macroalgae depends on local current and sediment conditions, as well as on maximum current velocity at the sediment surface. In addition to the direct effects of propeller wash on submerged vegetation, propeller wash can entrain bubbles and suspend sediment, causing reduced light availability that can indirectly affect eelgrass and, to a lesser extent, macroalgae (Simenstad et al. 1999).

Thom et al. (1996), in studying the impacts of passenger-only ferries at the Vashon Island terminal, found that at 187 feet (57 meters) from the boat, it is likely that the propeller wash has little effect on existing eelgrass. Thom et al. (1996) also concluded that currents with a velocity above 2.46 feet/second (0.75 meters/second) damaged eelgrass by eroding away overlying sediment and that currents above 3.61 feet/second (1.1 meters/second) caused extensive damage to eelgrass rhizomes. The vertical and horizontal distance at which current velocity may affect eelgrass depends on the size and shape of the propeller. The U.S. Army Corps of Engineers' Regional General Permit No. 6 prohibits the construction or installation of floats or float support pilings within a 4-foot depth elevation between the top of the float stopper and the elevation of the landward-most edge of a macroalgae bed or eelgrass (USACE 2005). This restriction applies to a zone 25 feet wide on both sides of the float projecting waterward horizontally from the float (USACE 2005).

Studies in Florida related to the impacts of boating activity on seagrass indicate that the largest concentration of scarring occurs in waters less than 6.5 feet (2 meters) deep (Sargent et al. 1995, in Dawes et al. 2004). In Florida, many shallow flats and mud banks are severely eroded due to constant scarring, ship groundings, chronic wave action from boats, and water-current scouring (Kruer 1994, in Dawes et al. 2004). Removal of

seagrass roots and rhizomes due to prop scarring also destabilizes sediments and resuspension occurs, thereby lowering water transparency and retarding seagrass regrowth into the scar (Durako et al. 1992, in Dawes et al. 2004).

Studies in Florida have also found that fragmentation of seagrass beds caused by propeller scarring did not appear to have any consistent effects on some animal populations over a one-year period, as long as the seagrass patch sizes were greater than 3 square feet (1 square meter) (Bell et al. 2002, in Dawes et al. 2004). The numbers of pinfish (*L. rhomboides*), pipefish (*Syngnathus scovelli*), and eight species of epibenthic shrimp were similar in moderately scarred (6 percent to 31 percent loss of the beds) and non-scarred seagrass beds in Tampa Bay (Dawes et al. 2004). The results of these studies suggest that propeller scars that fragment seagrass beds may enhance certain faunal development caused by edge effects along the cuts, as long as they are not too severe (Dawes et al. 2004). Nevertheless, a recent study of scarring in a *T. testudinum* bed in Puerto Rico revealed a negative effect of scarring on crabs and molluscs up to 16 feet (5 m) from the scar. Also, shrimp species within the scar differed from those in the non-scarred seagrasses. Fish populations did not show an effect from the scarring (Dawes et al. 2004). Further studies are clearly needed to define the effects of moderate scarring compared to those of severe scarring on seagrass productivity (Dawes et al. 2004).

7.12.3 Freshwater Aquatic Vegetation Disturbance

Lagler et al. (1950, in Carrasquero 2001) reported that studies of the effects of outboard motor use have shown that outboard motor propellers clear a swath through aquatic vegetation when within 1 foot (30 centimeters [cm]) of the vegetation. When the installation, use, or maintenance of overwater structures will entail the use of outboard motors in shallow water, some loss of aquatic vegetation could occur.

7.12.4 Noise

The construction or expansion of docks, moorings, and piers can cause increased recreational and commercial boating traffic at the facility and in the general area. Motors, sonars, and depth sounders used on commercial vessels and recreational boats can produce high levels of continuous underwater noise (Scholik and Yan 2001a). Large tankers and naval engines produce up to 198 dB, depth sounders can produce up to 180

dB (Heathershaw et al. 2001, in WSDOT 2006a), and commercial sonar operates in a range of 150 to 215 dB (neither peak nor RMS identified) (Stocker 2002, in WSDOT 2006a). Even small boats with large outboard motors can produce sound pressure levels in excess of 175 dB (neither peak nor RMS identified) (Heathershaw et al. 2001, in WSDOT 2006a). Therefore, fish may experience high levels of underwater sound when boats are present. The impacts to fish from boat traffic noise depend on a variety of factors, including the level of sound generated, the fish species and life stage present, the sound received by fish, and the exposure time. The literature regarding boat motor noise (discussed below) suggests that impacts are most likely to result in behavioral disturbance or sublethal injury.

Scholik and Yan (2001b) exposed a hearing specialist (the fathead minnow) to 2 hours of boat engine noise at 142 dB, which resulted in temporary hearing loss to the fish. Schwarz and Greer (1984, in Scholik and Yan 2001a) examined the reactions of Pacific herring to boat noise and found that abrupt changes in the sound characteristics associated with changes in vessel speed elicited an alarm response. An alarm response to boat noise has also been observed in herring and rockfish (Blaxter et al. 1981, in Scholik and Yan 2001a; Pearson et al. 1992), and Boussard (1981, in Scholik and Yan 2001a) produced an alarm response in two cyprinid species (a roach, *Rutilus rutilus*, and a rudd, *Scardinius erythrophthalmus*) when he exposed them to noise from a 260-horsepower speedboat.

7.12.5 Artificial Light

Although it is reasonable to expect that the construction and operation of overwater structures have potential to add artificial light to the aquatic environment, no literature on the potential impacts of artificial light related to vessel activity was identified.

8 CUMULATIVE IMPACTS OF OVERWATER STRUCTURES AND NON-STRUCTURAL PILING

This section draws on available literature and the authors' professional experience concerning the possible cumulative impacts of the construction and operation of overwater structures and non-structural piling over time or at multiple sites in a limited area.

Only one study (Nightingale and Simenstad 2001b) specifically discusses the cumulative impacts of overwater structure construction. Because this study focused on overwater structures in Washington, its findings are particularly relevant. The authors note that "The bathymetry of Washington's inland waters, that of a fjord surrounded by a narrow strip of shallow vegetated habitat, magnifies the need to protect the integrity and continuity of this limited area of nearshore habitat because of the concentrated zone of potential impact" (Nightingale and Simenstad 2001b). This finding is directly relevant to an ESA analysis, because it identifies the area where cumulative impacts will have a concentrated expression on a limited habitat. The authors then discuss cumulative effects on "rural and natural" as opposed to "urban industrialized" shorelines. For rural shorelines, the authors find that:

> The habitat value of an environment that directly supports the recruitment of fish and shellfish stocks is magnified by its overall importance in stock recruitment. Its value is intrinsic to its location but its loss to stocks and the larger ecosystem reaches beyond its specific location. In short, protection of habitats critical to important survival and recruitment needs of fish and shellfish magnify the importance of controlling any adverse effects to them. Economically, it is far less expensive and more productive to protect existing critically important habitat than to restore lost or degraded habitats. The factors controlling habitat characteristics and the biologic assemblages that have evolved are endemic to the geologic and biologic history specific to a geographic location and region. Perhaps more significantly, the linkages among these ecosystem components are not fully understood (Nightingale and Simenstad 2001b).

This finding is relevant to an ESA analysis because it identifies how cumulative impacts potentially impair habitat essential to reproduction and thus directly affect a species' capacity to

sustain and increase its numbers. Such impacts, if sufficiently severe, may jeopardize a species' continued existence.

With regard to cumulative impacts along urban industrialized shorelines, Nightingale and Simenstad (2001b) identify three principal concerns:

- Reduced access to prey resources, compelling juvenile salmon to outmigrate farther and faster than they otherwise would, reducing their metabolic energy resources and potentially exposing them to other risks, such as predation. Although this finding is not directly transferable to other potentially covered species, it is plausible that they too would have to travel farther to access suitable habitat and would also suffer reduced metabolic energy resources and increased exposure to other stressors.
- Reduced autochthonous productivity due to limited light availability, an impact that could be reduced by incorporating design features to reduce shading by overwater structures.
- Landscape-scale effects (such as fragmentation) that could be minimized by landscape-scale habitat treatments, enhancing habitat in refuge areas such as beaches.

One cause of cumulative impacts that is generally not addressed in the literature but that applies to all overwater structures and non-structural piling regardless of impact mechanism is accidents. Accidental chemical spills, accidental concrete spills, accidental erosion of material stockpiles, and various other kinds of accidents that occur during use of structures constructed under the HPA authority all constitute impacts that likely would not have occurred but for the issuance of an HPA. Such accidents can be predicted only in a statistical sense, and WDFW would likely not have legal liability for these accidents, but the impacts could still occur and therefore could affect populations of potentially covered species. This impact would be considered by the federal agencies in their decision to issue an Incidental Take Permit.

8.1 Shading

The studies reviewed do not identify cumulative impacts of shading that differ from the direct and indirect impacts of single-structure shading, i.e., decreased primary productivity, loss of eelgrass beds with impacts to the associated food chain processes, and changes in the migration patterns of salmonids. There are data to suggest that the cumulative loss of habitat resulting from the shading of multiple structures can affect fish abundance and

species richness within a region (Carrasquero 2001; Kalher et al. 2000; Fayram 1996; Williams and Thom 2001).

The cumulative impacts of even narrow residential piers can be detrimental in a freshwater environment (Carrasquero 2001). It has been suggested that the cumulative impact of an increase in the number of docks around the Lake Washington shoreline, where approximately 4 percent of shallow-water habitats are covered by overwater structures (Kalher et al. 2000), might have caused the observed decrease in freshwater survival of juvenile sockeye salmon over time (Fayram 1996). Although individual shoreline structures may not impose significant impacts on salmon species, populations, or stocks, the cumulative impacts of dense, contiguous shoreline modifications are likely contributors to the present decline of several Puget Sound salmon species and may inhibit the success of recovery actions (Williams and Thom 2001).

The shading of eelgrass beds that serve as important nursery habitat for many species can also greatly affect numbers of marine biota within a region, including salmonids, crab, herring, and important epibenthic crustaceans. Given the strong association of important fish prey resources with eelgrass, the shading out of eelgrass by numerous overwater structures poses a potential risk of reduced prey resources for fish, affecting fish populations.

8.2 Littoral Vegetation

Installation of overwater structures in the nearshore has the potential to cause local losses of littoral vegetation. It logically follows that the cumulative impact of structures that shade littoral vegetation or otherwise inhibit growth would be a reduction in littoral vegetation cover, as can be seen in the case of eelgrass at individual piers (Nightingale and Simenstad 2001b). Large-scale eelgrass monitoring in the inland waters of Washington State (2001 through 2005) indicates that an equal number of sites appear to have increasing or decreasing eelgrass coverage (Dowty et al. 2005). However, because eelgrass coverage is affected by many variables in addition to the cumulative impacts of development, the results observed by Dowty et al. (2005) do not indicate a clear cause and effect of overwater structures or other development on overall patterns of eelgrass coverage. The real implications of cumulative changes in eelgrass distribution and cover are unclear, because it

is not known how dependent many potentially covered species are on eelgrass. For instance, herring spawn on eelgrass, but there are extensive areas of eelgrass where no herring spawn, so changes in eelgrass cover alone would be a poor predictor of future herring spawning success. Similarly, young salmon forage extensively in eelgrass, but foraging habitat may not be a limiting factor for juvenile salmon in Puget Sound (Haas et al. 2002). Much human impact on eelgrass and macroalgae takes the form of habitat fragmentation, but although such fragmentation is in principle an adverse impact, it remains unclear just how that impact is delivered to affected species (Haas et al. 2002). Thus, our understanding of cumulative impacts on eelgrass and macroalgae is limited by major data gaps.

8.3 Freshwater Aquatic Vegetation

Individual overwater structures can reduce the overall coverage and density of freshwater aquatic plants in lakes and ponds with developed shorelines (Radomski and Goeman 2001). This could be significant to the ecological functions of aquatic systems where human development occurs. For example, Radomski and Goeman (2001) found that because of reduced aquatic vegetation, the most highly developed lakes are lacking in physical habitat structure compared to less developed lakes, which was reflected in a correlation between the occurrence of floating leaved and emergent plants and (warm-water) fish biomass.

8.4 Riparian and Shoreline Vegetation

Although there have been numerous evaluations on the effects of large-scale removal of riparian habitat to aquatic habitats, few studies reviewed for this white paper specifically addressed cumulative impacts from the localized removal of riparian and shoreline vegetation (as could occur during installation of overwater structures). It is expected that permitting multiple activities within a watershed can have cumulative impacts on riparian/shoreline vegetation, including increased likelihood that the impacts will be measurable and thus more likely to have an adverse impact on aquatic species and habitat. Additionally, cumulative impacts are likely to be more significant in smaller watersheds. The threshold at which a group of activities will have an adverse impact on aquatic species and habitat at the watershed scale cannot be quantified, because each watershed has unique characteristics, such as riparian/shoreline vegetation and the contribution such habitat makes to the quality of specific aquatic habitat.

8.5 Noise

Cumulative noise impacts may result from the accumulation of exposure energy that fish receive from multiple pile drives (Popper et al. 2006), increased numbers of boats or boating use (Scholik and Yan 2001a), and increased use of construction equipment. In speaking of cumulative noise impacts to marine mammals, Dr. Sylvia Earle, former chief scientist at NOAA, has stated that "each sound by itself is probably not a matter of much concern," but taken together, "the high level of [ocean] noise is bound to have a hard, sweeping impact on life in the sea" (Holing 1994, in Radle 2005). However, the cumulative impacts of noise on fish physiology and behavior are unknown at this time.

8.6 Water Quality

Although natural turbidity-causing mechanisms may vary greatly in magnitude and duration, they are more likely to occur in an isolated fashion and affect different portions of the stream network at different times (Bash et al. 2001). This variation allows fish to use refuge areas that might otherwise be impacted by these events (Bash et al. 2001).

Professional experience has shown that anthropogenic sediment disturbance is often different; such events are more likely to occur simultaneously in many scattered areas or in overlapping time frames across a watershed, causing secondary impacts and lingering effects with greater potential to affect larger portions of a stream network at any given time. In addition, anthropogenic disturbances may more frequently result in temporary barriers to fish movement, which could reduce the existence of or limit accessibility to refugia (Bash et al. 2001).

Turbidity impacts may not be the only source of stress to aquatic life in a system (Bash et al. 2001). The potential of an activity to increase turbidity should be evaluated in the context of other environmental conditions present in the system, such as velocity, water depth or water temperature (Bash et al. 2001). It is also important to note that much of the research on turbidity impacts on salmonids has occurred in controlled laboratory settings and that extrapolation to complex natural systems may require consideration of other factors such as predator and prey abundances (Bash et al. 2001).

Much of the research has focused on smaller projects and little is known about the potential impacts of large projects (>100 pilings) involving the use of treated wood piles in aquatic settings (Poston 2001). It is conceivable that many smaller projects using ACZA- and CCA Type C-treated wood products, if close enough to one another both spatially (with respect to leachate dilution rates) and temporally (in terms of diminishing rates of leaching), could produce effects similar to those of larger projects (Poston 2001).

It is well known that PAHs and metals are significant components of urban stormwater. The risks of PAH and metals contamination from treated wood products should be considered in the context of background PAH and metals concentrations in the surrounding water and sediments, as well as in the context of potential PAH loads from other point and nonpoint sources, such as industrial outfalls and stormwater runoff (Menzie et al. 2002). This may be a difficult undertaking, given that little data are available on the background PAH and metals concentrations in most water bodies and their sediments (Poston 2001).

8.7 Channel Hydraulics

We found no studies specifically addressing the cumulative impacts of channel hydraulic changes on potentially covered species. Generally, the question of cumulative impacts emerges as a data gap. The HPA program itself offers the best means of measuring these impacts, because WDFW has authority to require monitoring of the impacts of authorized projects.

8.8 Littoral Drift

Artificial structures that change longshore drift can alter organic and sediment deposition on beaches and therefore alter biotic assemblages (Thom et al. 1994). However, the overall cumulative impacts of changes in littoral drift due to artificial structures on the system as a whole cannot be predicted at this time (Thom et al. 1994).

8.9 Substrate Modifications

No studies were found analyzing the cumulative impacts of substrate modifications in association with overwater structures or non-structural piling. However, certain changes can be anticipated. As noted in Section 7.10, both permanent and temporary losses of benthic macroinvertebrates are likely to occur as a result of new construction of overwater

structures or expansion of existing structures; changes in the representative species assemblages as a result of associated changes in hydraulics and habitat conditions within affected reaches are also likely. Benthic macroinvertebrates, by definition, inhabit the stream bottom; therefore, modification of the streambed will most likely have some effect on the benthic macroinvertebrate community (Waters 1995). It is difficult to ascertain the cumulative impact of changes to benthic macroinvertebrate populations or species diversity and subsequent changes to fish populations or habitat occupancy that may result. Permanent loss of benthic macroinvertebrate numbers or a decrease in species diversity due to permanent loss of habitat will affect foraging opportunities for fish and could affect the population numbers within stream reaches; this may be measurable over time at the watershed scale depending on the size of the watershed and amount of habitat permanently lost.

8.10 Channel Dewatering

No studies examining the cumulative impacts of channel dewatering were found during the literature review. The following discussion is therefore based on the authors' professional experience.

Cumulative impacts of channel dewatering will most likely be associated with fish removal/exclusion methods, disturbance of the bed, and modification of invertebrate habitat and consequent changes in species diversity. Alteration of flow and increased turbidity are temporary and are therefore not likely to have cumulative impacts to aquatic species or habitat.

Fish removal/exclusion will result in the capture and handling of fish, which can cause stress, harm, and mortality. Cumulatively, the impacts to fish populations resulting from multiple permitted activities within a watershed that require fish removal/exclusion could be measurable at the population scale depending on several factors, including watershed and population size. The threshold for watershed and population size and the number of activities that must occur within a particular watershed to have a measurable cumulative impact are not established in the literature, but it seems unlikely that HPA-authorized activities would result in measurable cumulative effects except in the case of rare species where a single project might affect a large fraction of the watershed's population.

Disturbance of the streambed associated with dewatering may result in temporary loss of habitat. The significance of the loss depends on the size of the watershed, the amount of habitat cumulatively lost, and the significance of the habitat lost to the population (i.e., spawning, rearing, or migration habitat). Again, it seems unlikely that HPA-authorized activities would result in measurable cumulative effects except in the case of rare species where a single project might affect habitat critical to a large fraction of the watershed's population.

8.11 Artificial Light

Although it has been shown that juvenile salmonid migrations can be delayed by artificial light in freshwater and marine environments (McDonald 1960, in Tabor et al. 1998; Prinslow et al. 1979, in Nightingale and Simenstad 2001b; Tabor et al. 1998), the implications of this delay are not known. The cumulative impacts of increased artificial light in the aquatic environment have not been investigated. It has been suggested (and, in the case of sockeye fry and sculpin, shown [Tabor et al. 1998]) that rates of predation on juvenile fish increase under artificial light because of changes in migration patterns, congregation of predators, or increased opportunity time for predation. Artificial lighting is often required both for construction and operation of overwater structures, cumulatively adding to light sources over water. However, it is unknown whether losses of threatened and endangered juvenile salmonids could occur due to regional-scale cumulative lighting impacts.

8.12 Vessel Activities

Little is known about the cumulative impacts of construction, commercial, and recreational vessel activities associated with overwater structures, but cumulative impacts from vessel activities have been reported with respect to turbidity. Vessel traffic may cause extended periods of elevated turbidity as boat traffic collectively churns the water, slowing the settling of suspended sediment (Garrad and Hey 1988). In addition, successive passes by vessels may accelerate shoreline erosion; recreational vessel traffic has been observed to cause boat wake-induced levee erosion at rates of 0.0004 to 0.009 inch (0.01 mm to 0.22 mm) per boat pass (Bauer et al. 2002).

Commercial shipping in the Northern Hemisphere has been implicated in a 10-fold to 100-fold increase in oceanic noise levels (Tyak 2000, in Scholik and Yan 2001a), and it has been

shown that fish exhibit behavioral and physical responses to vessel noise. However, the cumulative impact of vessel noise on fish has not been specifically studied.

9 POTENTIAL RISK OF TAKE

Table 10 summarizes the risk that potentially covered species may suffer incidental take resulting from the impact pathways discussed in Section 7; the potential that a species may experience incidental take is characterized in Table 10 as Y (yes; potential for take), N (no potential for take), or U (unknown potential for take). The magnitude of the risk is highly dependent on how the impact is expressed, which in turn is highly dependent on the suite of conservation measures employed to minimize the risk of causing take. For species for which there is no potential for take, no additional precautions would be required apart from compliance with existing regulations. For species for which the potential for take is unknown, the data gap precludes reaching a conclusion. The "unknown" category may be the most problematic from the standpoint of ESA compliance, because we lack information needed for the federal agencies to determine whether incidental take would be likely to jeopardize continued existence of affected populations.

Table 10
Summary of Potential for Incidental Take of Potentially Covered Species

		Impact Mechanisms											
Common Name	**Scientific Name**	**Shading**	**Eelgrass and Macroalgae**	**Freshwater Aquatic Vegetation**	**Riparian and Shoreline Vegetation**	**Noise**	**Water Quality**	**Channel Hydraulic Effects**	**Littoral Drift**	**Substrate Modifications**	**Channel Dewatering**	**Artificial Light**	**Vessel Activities**
Green sturgeon	*Acipenser medirostris*	U	U	Y	Y	U	Y	Y	Y	Y	Y	U	U
White sturgeon	*Acipenser transmontanus*	U	U	Y	Y	U	Y	Y	Y	Y	Y	U	U
Newcomb's littorine snail	*Algamorda subrotundata*	U	Y	N	Y	U	Y	N	Y	Y	N	U	U
Pacific sand lance	*Ammodytes hexapterus*	Y	Y	N	Y	U	Y	N	Y	Y	N	U	U
California floater mussel	*Anodonta californiensis*	U	N	Y	Y	U	Y	Y	Y	Y	Y	U	U
Mountain sucker	*Catostomus platyrhynchus*	U	N	U	Y	U	Y	Y	N	U	Y	U	U
Pacific herring	*Clupea harengus pallasi*	U	Y	N	Y	U	Y	N	Y	Y	N	U	U
Margined sculpin	*Cottus marginatus*	Y	N	Y	Y	U	U	Y	N	U	Y	U	U
Lake chub	*Couesius plumbeus*	U	N	Y	U	U	U	U	N	U	U	U	U

Common Name	Scientific Name	Impact Mechanisms											
		Shading	Eelgrass and Macroalgae	Freshwater Aquatic Vegetation	Riparian and Shoreline Vegetation	Noise	Water Quality	Channel Hydraulic Effects	Littoral Drift	Substrate Modifications	Channel Dewatering	Artificial Light	Vessel Activities
Giant Columbia River limpet	*Fisherola nuttalli*	U	N	U	U	U	Y	Y	N	Y	Y	U	U
Great Columbia River spire snail	*Fluminicola columbiana*	U	N	U	U	U	Y	Y	N	Y	Y	U	U
Pacific cod	*Gadus macrocephalus*	N	Y	N	N	U	Y	N	Y	Y	N	U	U
Western ridged mussel	*Gonidea angulata*	U	N	Y	Y	U	Y	Y	Y	Y	Y	U	U
Northern abalone	*Haliotis kamtschatkana*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Surf smelt	*Hypomesus pretiosus*	U	Y	N	Y	U	Y	N	Y	Y	N	U	U
River lamprey	*Lampetra ayresi*	U	N	N	Y	U	Y	Y	Y	Y	Y	U	U
Western brook lamprey	*Lampetra richardsoni*	U	N	N	Y	U	Y	Y	N	Y	Y	U	U
Pacific lamprey	*Lampetra tridentata*	U	N	N	Y	U	Y	Y	Y	Y	Y	U	U
Pacific hake	*Merluccius productus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Olympic mudminnow	*Novumbra hubbsi*	U	N	Y	Y	U	Y	Y	N	Y	Y	U	U
Coastal cutthroat trout	*Oncorhynchus clarki clarki*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U	U
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Y	N	Y	Y	Y	Y	Y	N	Y	Y	U	U
Pink salmon	*Oncorhynchus gorbuscha*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Chum salmon	*Oncorhynchus keta*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Coho salmon	*Oncorhynchus kisutch*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Redband trout	*Oncorhynchus mykiss*	Y	N	Y	Y	Y	Y	Y	N	Y	Y	U	U
Steelhead	*Oncorhynchus mykiss*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Sockeye salmon	*Oncorhynchus nerka*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Chinook salmon	*Oncorhynchus tschawytscha*	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Lingcod	*Ophiodon elongatus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Olympia oyster	*Ostrea lurida*	Y	Y	N	Y	U	Y	N	Y	Y	N	U	U
Pygmy whitefish	*Prosopium coulteri*	U	N	U	U	Y	U	Y	N	U	Y	U	U

Common Name	Scientific Name	Impact Mechanisms											
		Shading	Eelgrass and Macroalgae	Freshwater Aquatic Vegetation	Riparian and Shoreline Vegetation	Noise	Water Quality	Channel Hydraulic Effects	Littoral Drift	Substrate Modifications	Channel Dewatering	Artificial Light	Vessel Activities
Leopard dace	*Rhinichthys falcatus*	U	N	U	U	U	U	Y	N	U	Y	U	U
Umatilla dace	*Rhinichthys Umatilla*	U	N	U	U	U	U	Y	N	U	Y	U	U
Bull trout	*Salvelinus confluentus*	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Dolly Varden	*Salvelinus malma*	U	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	U
Brown rockfish	*Sebastes auriculatus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Copper rockfish	*Sebastes caurinus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Greenstriped rockfish	*Sebastes elongates*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Widow rockfish	*Sebastes entomelas*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Yellowtail rockfish	*Sebastes flavidus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Quillback rockfish	*Sebastes maliger*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Black rockfish	*Sebastes melanops*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
China rockfish	*Sebastes nebulosus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Tiger rockfish	*Sebastes nigrocinctus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Bocaccio rockfish	*Sebastes paucispinis*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Canary rockfish	*Sebastes pinniger*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Redstripe rockfish	*Sebastes proriger*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Yelloweye rockfish	*Sebastes ruberrimus*	U	Y	N	N	U	Y	N	Y	Y	N	U	U
Longfin smelt	*Spirinchus thaleichthys*	U	Y	N	Y	Y	Y	Y	Y	U	Y	U	U
Eulachon	*Thaleichthys pacificus*	U	Y	N	Y	Y	Y	N	Y	Y	N	U	U
Walleye pollock	*Theragra chalcogramma*	U	Y	N	N	U	Y	N	Y	Y	N	U	U

Note: Species listed in alphabetical order by scientific name.

The following decision rules explain most of the content of Table 10:

- Marine species are not at risk of take due to impacts to channel hydraulics, or freshwater aquatic vegetation.

- Species that spend all of their lives in freshwater are not at risk of take due to impacts to eelgrass and macroalgae.
- For most species except salmonids, the effects of noise, artificial light, shading, and vessel activities are largely unknown.

The risk of take of potentially covered species is discussed below by impact mechanism.

9.1 Shading

The evidence reviewed in Section 7.1 supports the following conclusions about impacts potentially amounting to incidental take of potentially covered species:

- The principal impact of shading is reduction in cover and productivity of underwater vegetation. These impacts are detailed in Sections 7.2 and 7.3.
- Most studies of shading are focused on juvenile salmonids. However, available data on light sensitivity suggest that those impacts may reasonably be extrapolated to other small fishes, particularly nearshore marine species. For all other potentially covered species, almost nothing is known about sensitivity to shading.
- In freshwater environments that support significant bass populations, bass are effective, high-level predators that forage from under shade-producing structures.
- Migration of juvenile salmonids is sometimes impeded by shade-producing structures.

WAC 220-110-300(3) states that overwater structures and associated moorings "shall be designed and located to avoid shading of eelgrass (Zoestra spp.)." WAC 220-110-300(5) states that mitigation measures for overwater structures and associated moorings "shall include, but not be limited to, restrictions on structure width and/or incorporation of materials that allow adequate light penetration (i.e. grating) for structures located landward of -10.0 feet MLLW." Additionally, WAC 220-110-300(6) states that overwater structures and associated moorings "shall be designed and located to avoid adverse impacts to Pacific herring spawning beds and rockfish and lingcod settlement and nursery areas," and WAC 220-110-300(7) states that overwater structures and associated moorings "shall be designed and located to avoid adverse impacts to juvenile salmonid migration routes and rearing habitats." The language in WAC 220-110-300 is vague in that the WAC does not provide any specific information regarding how to avoid shading of eelgrass, what adequate light

penetration is or how to achieve adequate light penetration, or how to avoid adverse impacts to Pacific herring spawning beds, rockfish and lingcod settlement and nursery areas or juvenile salmonid migration routes or rearing habitats. Thus, it is difficult for an applicant for an HPA to design and locate a structure to avoid such impacts and, therefore, there is a moderate potential risk for take of the potentially covered species.

NMFS (2005b) identified incidental take of juvenile Puget Sound Chinook resulting from shading by a wharf and moorage float in Swinomish Slough, which may impede longshore movement during certain times of the day, and from a reduction in primary productivity and consequent reduction in food resources. Based on the shading footprint, the extent of take (identified as harm in this biological opinion) was determined to be any juvenile Puget Sound Chinook rearing and outmigrating within less than 1 acre around the structure.

In a freshwater environment, NMFS (2006c) determined that the shading and structure resulting from the proposed expansion of a marina in the Columbia River will likely result in increased predation of listed juvenile salmon by a number of piscivorous fish species found in the area, although NMFS was unable to quantify the number of salmon expected to be killed.

9.2 Eelgrass and Macroalgae

Generally, the federal agencies have treated loss or reduced density of eelgrass as equivalent to loss of essential habitat for listed species known to occur in the area. As such, it constitutes a take of listed species such as salmon and bull trout. A similar perspective has been adopted by state jurisdictional agencies, including WDFW and the Washington Department of Natural Resources (WDNR). Overwater structures and non-structural piling can sometimes be sited to avoid eelgrass and macroalgae, but some structures must be sited within a narrowly defined area, and in some areas eelgrass and/or macroalgae are very common, thus some over water structures and/or non-structural piling are likely to directly impact eelgrass and/or macroalgae.

Accordingly, compensatory mitigation has been required, typically including consideration of temporal impacts related to the time between impact and full eelgrass recovery. An example of such a requirement is WAC 220-110-100(7) and WAC 220-110-300(4), “Kelp. . .

and intertidal wetland vascular plants. . . shall be replaced using proven methodology." Additionally, WAC 220-110-300(3) states that overwater structures and associated moorings "shall be designed and located to avoid shading of eelgrass (Zostera spp.)," but does not provide any guidance on design or locational parameters to accomplish this. Based on the regulatory background, the federal agencies are almost certain to evaluate eelgrass loss as resulting in incidental take of potentially covered species that use eelgrass. Those species include anadromous salmonids, anadromous and marine forage fishes, and certain larval pelagic fishes.

Notwithstanding WAC 220-110-100(7) and WAC 220-110-300(4), the federal agencies have generally not regarded impacts to macroalgae as amounting to incidental take. The macroalgae most critical to potentially covered species are kelps that chiefly occur in areas of rocky substrate, often in deep water, and will not often be permanently impacted by overwater structures and/or non-structural piling.

9.3 Freshwater Aquatic Vegetation

Based on the discussion in Section 7.3, overwater structures can impair the growth of freshwater aquatic vegetation by a variety of mechanisms. WAC 220-110-060(8) requires that "removal of aquatic vegetation shall be limited to that necessary to gain access to construct the project." This requirement provides some assurance that impacts are minimized, but makes no provision for recovery or restoration of the impacted vegetation. Moreover, WAC 220-110-331 through 338 provide extensive regulation of aquatic plant removal measures but provide no consideration of the ecological role of the affected vegetation. Since the specified measures do not exclusively apply to designated noxious aquatic weeds, it is entirely possible that they could be used to regulate activities impacting potentially covered species that are dependent on aquatic vegetation. Certain potentially covered species, including freshwater molluscs and an array of fishes, have a strong association with freshwater aquatic vegetation and would be at relatively high risk of incidental take from projects that remove or reduce such vegetation within their habitat. Sessile organisms and larval fishes would also be at high risk of mortality caused by vegetation-clearing operations.

The impacts of noxious aquatic weeds are indirect, deriving mainly from their accidental introduction during the construction and use of artificial structures. Noxious weed introductions have a high probability of causing incidental take of ESA listed fish species, because noxious weeds can potentially out-compete native vegetation and alter water quality and food web interactions (WNWCB 2006).

9.4 Riparian and Shoreline Vegetation

The hydraulic code includes provisions that minimize but do not avoid impacts to riparian and shoreline vegetation. For instance, WAC 220-110-070(1)(c) provides that in bridge construction, "disturbance of bank or bank vegetation shall be limited to that necessary to construct the project" and that "the banks shall be revegetated within one year with native or other approved woody species", except that "the requirement to plant woody vegetation may be waived." WAC 220-110-060(2) contains similar language for freshwater docks, piers, floats and the driving or removal of piling in freshwater environments. However, the ambiguous language and the lack of binding provisions regarding replacement of ecological function render the WAC provisions inadequate in that they do not provide assurance that loss of riparian and shoreline vegetation is effectively minimized, let alone compensated. Thus, there is a moderate to high risk that take of fish could occur. WAC 220-110-300 does not contain any language related to the disturbance of bank or bank vegetation.

In its biological opinion for a bridge replacement on an Oregon river, NMFS (2006a) determined that the take caused by habitat-related effects of a project could not be accurately quantified (i.e., as a number of fish) because the relationship between habitat conditions and the distribution and abundance of those individuals in the action area was imprecise, and nearshore areas damaged by construction would require years to recover characteristics favorable for rearing and migration.

In such instances, NMFS uses the causal link established between the activity and the change in habitat conditions affecting the listed species to describe the extent of take as a numerical level of habitat disturbance, rather than stating an expected amount of take (50 Code of Federal Regulations 402.14(i)). NMFS (2006a) found that the best available indicators for the extent of take is the area of riparian habitat that will be permanently modified by the action, because it is directly proportional to long-term harm attributable to

the project. In another instance, NMFS (2006b) indicated that the risk of take associated with the removal or disturbance of riparian/shoreline vegetation should be described in terms of acres of riparian/shoreline or miles of stream affected.

9.5 Noise

It is well established that impact pile driving can result in incidental take of fish. NMFS and USFWS biological opinions commonly identify such take and quantify it based on the area of habitat affected by sounds above the threshold levels cited in Section 7.5 and the duration of pile driving activities. However, the sound sensitivity of individual species is not well known. In addition, species that lack internal gas-filled voids (such as swim bladders) appear to be less vulnerable to noise impacts than are fish that have gas-filled voids, such as salmonids. These include potentially covered invertebrate species and certain fishes identified in Table 5. For such species, the risk of take is somewhat lower than it is for salmonids; however, species-specific studies would be required to quantify the difference in risk. Standard measures to minimize such take are discussed in Section 11.5. The WACs do not provide any avoidance or minimization measures related to underwater noise. WAC 220-110-270(12) does state that "if a fish kill occurs or fish are observed in distress, the project activity shall immediately cease and the department granting the HPA shall be notified immediately." However, this does not provide any avoidance of underwater noise related impacts for the covered species, and thus there is a high risk of take associated with underwater noise generated by pile driving activities.

Construction noise and activity associated with the La Conner Wharf and Float Project was thought to cause forage fish to temporarily leave the vicinity, which would temporarily reduce the prey base for Chinook and other fish species (NMFS 2005b); project effects on other predators, such as those eating young Chinook, were not addressed. However in the consultations reviewed, NMFS has not assigned quantifiable incidental take associated with construction noise other than pile driving.

9.6 Water Quality

Many aspects of water quality can be impacted by overwater structures, with varying degrees of impact on potentially covered species. With respect to suspended solids, the take risk to potentially covered fish species increases in proportion to the magnitude and

duration of the impact; vulnerability of the affected life-history stage; inability of the fish to avoid the impact through avoidance behavior; physiological, developmental, and behavioral impairments suffered by the fish; and indirect mechanisms such as exposure to predation. Fine sediment deposition also poses an incidental take risk to invertebrates, as discussed in Section 7.7.

Incidental take risk associated with dissolved oxygen impacts is probably quite low. Because the potential impact of pH change from uncured concrete is normally avoided via compliance with the hydraulic code (e.g., WAC 220-110-070(1)g and WAC 220-110-270(3)), the risk of incidental take from pH change is near zero.

Risk of incidental take of potentially covered species due to the use of treated wood appears to be related to factors that include proximity, dilution by the water body, and type of treatment. PAH releases from creosote pilings may pose a significant risk, given that many types of organisms have significant PAH sensitivities at low exposure levels (e.g., fishes studied by Incardona et al. 2004 and Incardona and Scholz 2006). Potentially vulnerable species include molluscs and mussels that may be sessile on the treated wood or in adjacent sediments, or to juvenile fish that consume epibenthic prey inhabiting those sediments. ACZA-treated wood appears to be somewhat less harmful, with most impacts expected during initial leaching (up to 10 days, per Poston 2001), although recent investigations (Baldwin et al. 2003; Linbo et al. 2006) indicate that juvenile salmonids may have substantially higher sensitivities to dissolved copper (the primary active ingredient of ACZA) than previously suspected. That sensitivity includes an impaired sense of smell with potential sublethal effects including reduced foraging efficiency and reduced predator avoidance ability. The hydraulic code provides for minimizing but not entirely avoiding this risk in salt water (WAC 220-110-060(4) and WAC 220-110-270(9)) by requiring that "materials treated with preservatives shall be sufficiently cured to minimize leaching into the water or bed" and by prohibiting creosote and pentachlorophenol-treated wood use in lakes.

There are few data on the stormwater vulnerability of potentially covered species other than salmonids. WAC provisions (WAC 220-110-070(1)(f), (2)(f) and (3)(i) and WAC 220-110-100(3)(b)) require avoidance of direct stormwater delivery to streams during construction,

but indirect effects arising during operation of bridges or commercial/industrial piers may still occur resulting in some potential risk for take.

Based on the discussion above, it can be concluded that activities that allow significant increases in suspended sediment have a high risk of causing incidental take of potentially covered fish species exposed to this condition. The risk of take increases in proportion to:

- The magnitude and duration of the impact
- The vulnerability of the affected life-history stage
- The inability of the organism to avoid the impact through avoidance behavior
- The physiological, developmental, and behavioral impairments suffered by the fish
- Indirect mechanisms such as exposure to predation

9.7 Channel Hydraulics

Impacts to potentially covered species may result when a vulnerable life-history stage of a species is exposed to an impact directly or indirectly caused by an overwater structure. In this context, a direct impact arises when an overwater structure alters the process of sediment transport, and an indirect impact arises when the change in sediment transport causes further habitat changes, such as bank erosion and loss of riparian vegetation. In the following discussion, indirect impacts are mentioned only briefly; they are detailed elsewhere in Section 7 where channel dewatering, water quality, and freshwater aquatic and riparian vegetation are evaluated.

Potential impacts of changes in channel hydraulics on potentially covered species are summarized in Table 11 and further discussed below (excepting riparian vegetation, which is discussed in Sections 7.4 and 9.4).

WAC 220-110 places great emphasis on minimizing impacts attributable to channel hydraulic changes. WAC 220-110-070 notes the benefits of avoiding impacts by placing bridges rather than culverts; WAC 220-110-070(1)(a) recommends placing bridge piers back of the OHWL; and WAC 220-110-070(1)(h) requires that bridge components have the least effect on channel hydraulics. Such provisions discourage, but do not prohibit construction of bridges that could have significant impacts on channel hydraulics, including the impacts discussed below. However, the use of qualifying language diminishes the effectiveness of

such provisions in avoiding incidental take. Examples of such language include "shall be avoided, where practicable" (WAC 220-110-070 preamble); "disturbance ... shall be limited to that necessary" (WAC 220-110-070(2)(d) and (3)(d)); and "the requirement ... may be waived" (WAC 220-110-070(2)(h) and (3)(d)). Some provisions, though, are not ambiguous and effectively avoid potential impacts; such provisions are noted below, where applicable.

Table 11
Potential Impacts of Changes in Channel Hydraulics on Potentially Covered Species

Impact	Potentially Affected Species
No impact identified	Marine species or marine life stages of estuarine and anadromous species
Habitat destruction due to siting of structure	Species potentially occupying the affected stream
Embedding due to reduced sediment transport capacity or indirectly as a result of bank erosion	Species potentially occupying the affected streambed: gravel spawners and benthos
Scour due to locally increased transport capacity	Species potentially occupying the affected streambed: gravel spawners and benthos
Deposition downstream of scour areas	Species potentially occupying the affected streambed: gravel spawners and benthos
Loss of riparian vegetation due to bank erosion	Species potentially occupying the affected stream. This impact is detailed in Section 7.4.

9.7.1 No Impact

Localized scour or deposition could occur around anchors or pilings. Such impacts would be minor, local, and not significantly different from similar impacts associated with natural structures on the seafloor, such as boulders or rock outcrops. Thus, there is a low risk of incidental take due to channel hydraulic effects in a marine setting.

There are also many sites in Washington where few, if any, of the potentially covered species are known to occur. Most of the freshwater-only species have very limited distributions (summarized in Table 2). Outside of those distribution areas and upstream of anadromous passage barriers, the western brook lamprey and freshwater-only varieties of the trout and char species are the principal species vulnerable to impact. These species, however, are vulnerable to almost all impacts detailed below. Thus, there are few HPA-jurisdictional waters in Washington where all potentially covered species can confidently be dismissed as absent.

9.7.2 Habitat Destruction

For the purpose of this white paper, habitat destruction is defined as the replacement of habitat with an artificial structure. Habitat destruction includes temporary and permanent elements. Temporary habitat destruction occurs when an area of habitat is inaccessible during or for a time following construction but becomes accessible within a reasonable time after construction, typically by the time work on the site concludes. Permanent habitat destruction occurs when an area of habitat remains inaccessible for the service life of the structure or longer. Permanent destruction of channel habitat occurs when fill is placed in the channel, usually to raise an area above the OHWL or to support an overwater structure (such as pilings or piers). Temporary channel habitat destruction includes both of these mechanisms when they are not permanent, as well as channel dewatering (Section 7.10) resulting from the diversion of flow or flow exclusion via structures such as cofferdams. Habitat destruction necessarily entails loss of habitat for any potentially covered species that utilize the affected habitat. As such, habitat destruction presents a high potential risk of incidental take; the risks are related to use of the habitat by potentially covered species, the area affected, the time frame during which the area is affected, and how potentially covered species respond to the loss or degradation of habitat.

Additionally, the process of placing fill may cause harm to individual animals. However, in-water placement of fill generally requires isolating and dewatering the work site, the impacts of which are discussed in Sections 7.10 and 9.10.

9.7.3 Embedding

Embedding is an issue principally in moderate-gradient channels that normally have a gravel or cobble bed, i.e., plane-bed and pool-riffle channels. Steeper channels have sufficient stream power that the "fines" consist of coarse sand and gravel, which do not substantially impair habitat quality. The less steep regime channels have fine-grained bed materials (generally defined as particles smaller than 0.04 inch [1 mm] in diameter) that are vulnerable to deposition (discussed below) rather than embedding. This circumstance is partly due to a research and management emphasis on gravel-bedded streams, which provide optimum spawning habitat for salmonids (Montgomery et al. 1999). There are fewer data on spawning habitat for other potentially covered fish

species. Salmonids chiefly spawn in beds with a substrate size between 0.8 and 4.7 inches (2 and 12 cm) in diameter (Raleigh et al. 1986, in Bjornn and Reiser 1991), and artificial spawning channels have generally employed gravels 0.8 to 1.5 inches (2 to 3.8 cm) in diameter (Bjornn and Reiser 1991). Lamprey, in contrast, spawn primarily in channels with fine gravel and sand substrates (Wydoski and Whitney 2003, pp. 33-39), and Olympic mudminnow spawn in submerged vegetation and primarily occur in regime channels (Mongillo and Hallock 1999).

Normally, spawning salmon winnow the fines from their redds, mobilizing fine sediment into the water column and in the process coarsening the bed in the immediate vicinity of the redd (Kondolf et al. 1993; Montgomery et al. 1999). In streams that support substantial populations of spawners, this process can be as effective as annual floods at mobilizing bed sediment and scouring fines from the bed, and thus significantly enhances hyporheic upwelling and downwelling (Gottesfeld et al. 2004). Hyporheic flows create a hydraulic gradient across redds that conveys waters having relatively high dissolved oxygen concentrations through the redd (Geist 2000a, 2000b). However, fine sediments can be deposited again after redd construction, filling pore spaces between gravel particles in and over the redd with fine sediment.

The probability of this phenomenon increases if the sediments are particularly fine, the sediment supply is large, and the streamflows are relatively low (Bjornn and Reiser 1991). The process may also be exacerbated by downwelling hyporheic flows, which often occur at salmonid spawning sites in Pacific Northwest rivers (Tonina and Buffington 2003, 2005). Consequences of this embedding include reduced water flow around the eggs, reduced dissolved oxygen uptake by developing embryos, and reduced flushing of metabolic waste, which can result in reduced embryo survival (Bjornn and Reiser 1991). Reduced survival occurs due to three mechanisms: reduced hydraulic conductivity through sediments, reduced intragravel oxygen concentrations due to the oxidation of organic particles in the gravel, and impaired oxygen exchange efficiency due to clay particles on the egg membrane (Greig et al. 2005). Redds of large salmonids are usually buried beneath at least 6 inches (15 cm) of gravel (DeVries 1997) and are often more than 12 inches (30 cm) deep (Bjornn and Reiser 1991). Fine sediment does not need to penetrate to that depth to impact eggs and alevins (fry that have not yet

emerged from the gravel); near-surface deposits of fine sediment may be sufficient to reduce water flow through the redd, causing mortality due to reduced dissolved oxygen, and the embedded surface layer may prevent alevin emergence (Everest et al. 1987; Bjornn and Reiser 1991). In addition to effects on redds, eggs, and alevins, embedding also reduces prey for foraging juveniles by promoting a shift from epibenthic to benthic infaunal macroinvertebrates, which are not easily preyed upon by young salmonids (Bash et al. 2001, pg. 25; Suttle et al. 2004). Thus, embedding has a high risk of causing incidental take if it affects sediments used for spawning.

9.7.4 Scour

Scour is potentially an issue in all channel types, although it is most often a concern in plane-bed and pool-riffle channels, which have a relatively mobile bed. The term "scour" is usually used to refer to flow-driven excavation of the streambed, but it can also occur along stream margins and result in bank erosion. Overwater structures, such as bridges can cause scour when the structure has not received correct hydraulic design, but such errors are unlikely in view of requirements that bridges "be aligned to cause the least effect on the hydraulics of the watercourse" (WAC 220-110-070(1)(h)). Thus, a bridge is only required to minimize such impacts. Since there are no guarantees that a bridge design or the installation will completely avoid scour, such activities implemented according to the WACs will have some associated low to moderate risk of scour, which could impact suitable habitat for potentially covered species. Non-structural piling and piling associated with other overwater structures (i.e., piers) could also potentially cause scour in marine or estuarine areas with strong tidal currents, or riverine environments with strong currents.

Scour chiefly occurs in conjunction with high-flow events that account for the largest fraction of annual sediment transport. Such flows can mobilize all spawning-sized substrates in step-pool and cascade channels, with the result that salmonids in such channels preferentially spawn in microsites with low scour potential (Montgomery et al. 1999). Conversely, the depth of bed mobilization is somewhat less in pool-riffle and plane-bed channels. In these sites, salmon normally excavate their redds deep enough to avoid scour during years with normal peak flows (Montgomery et al. 1999). However, scour that occurs in areas where it has previously been rare may result in the

loss of redds with eggs or of gravels containing fry or the benthic invertebrates that constitute part of the prey base for fish in the stream. Such scour events are particularly likely around hard structures placed in the channel (e.g., pilings), because shear stresses, and therefore energy available to mobilize sediments, are exceptionally high near such structures (Yager et al. 2004). The opposite effect is observed in the vicinity of aquatic vegetation (Bennett et al. 2002), raising the possibility that aquatic vegetation plantings may help to decrease scour around structures at some sites. Freshwater mussels are particularly vulnerable to scour because they are long-lived, sessile organisms. Mussels are commonly found on relatively coarse (gravel to boulder) substrates in microsites that constitute flow refugia with low risk of scour (Cuffey 2002; Brim-Box et al. 2004).

Scour can potentially result in incidental take via several mechanisms. Impacts to eggs and fry of potentially covered species (e.g. salmonids), or to sessile organisms such as mussels, constitute the potential for incidental take of animals. Impacts to the prey base can be interpreted as incidental take if the food supply is a limiting factor on fish productivity. The literature review did not specifically identify scour impacts on other potentially covered species, but such impacts are likely for sessile species and for species that spawn in benthic habitats.

The WACs do not provide specific guidance or measures to avoid or minimize impacts from scour associated with overwater structures or non-structural piling. WAC 220-110-070(1)(h) does require that bridges "be aligned to cause the least effect on the hydraulics of the watercourse" but does not necessarily require that bridges be designed appropriately or footings or other support structures be placed in such a way as to avoid or minimize impacts to hydraulic processes of a watercourse. The generally vague language presented in the WACs will minimize the potential risk for take of potentially covered species, but will not eliminate it.

9.7.5 Deposition

Deposition may occur in slackwater areas created downstream of an artificial structure, or it may occur farther downstream when sediment mobilized by scour is redeposited. Deposition can have a variety of effects, depending on the amount of sediment and its particle size distribution. Deposition of large quantities in a localized area results in the

creation of bedforms, discussed below. Deposition of somewhat smaller quantities that do not significantly modify bedforms may still result in burial of redds and benthic organisms such as mussels. Moderate deposition of a few centimeters of coarse-grained material may not harm redds and may even help to protect them from scouring flows (Montgomery et al. 1999), but deposition of greater thicknesses may result in reduced dissolved oxygen levels in redds, causing mortality of eggs or alevins, as detailed above in the discussion of embedding. As with scour, deposition impacts are most likely when an overwater structure and associated support structures and non-structural piling are installed and have not received proper hydraulic design. While significant amounts of deposition (i.e., amounts potentially causing measurable incidental take) are not likely to occur from the installation of an overwater structure or non-structural piling, some localized deposition may occur as a result of changes in hydraulics in the immediate vicinity of the structure. The same WAC provision cited above (WAC 220-110-070(1)(h)) as minimizing scour-related impacts, will also serve to minimize depositional impacts. Implementation of the WAC as written will likely minimize the risk of take but not eliminate it.

The potential risk of take from deposition related to hydraulic changes resulting from an overwater structure and non-structural piling is relatively minor. However, fine sediment deposition can impair the growth and feeding efficiency of filter feeders (Bash et al. 2001). For example, deposition of fine sediment can adversely impact freshwater mussels, but the mechanisms and quantities involved are not well understood, and different mussel species show varying responses to fine sediment inputs (Box and Mossa 1999). Deposition can affect mussels by burying them or altering their habitat. Burial under fine sediment (silt) can suffocate animals (Tucker and Theiling 1998). Ellis (1936, in Tucker and Theiling 1998) experimentally showed that as little as 0.25 inch (6.35 mm) of silt covering the substrate caused death in about 90 percent of the mussels examined. Siltation also is detrimental to young mussels and reduces their survival (Scruggs 1960, in Tucker and Theiling 1998). Habitat alteration harms mussels by filling interstitial spaces in gravel and cobble bed channels inhabited by mussels. Flow through the gravel is inhibited and algal and microbial communities change (Tucker and Theiling 1998). Juvenile survival (even of hardy species) may be reduced in silt-impacted mussel beds, which can limit recruitment in the entire bed (Tucker and Theiling 1998). Potential

impacts from deposition associated with installation of an overwater structure or non-structural piling would be localized and relatively minor with a low potential risk for take of the covered species.

Both coarse and fine sediment deposition can present potential for incidental take by burying animals living in the bed, such as eggs and alevins in redds and invertebrate infauna, and/or impairing habitat by reducing access to necessary resources such as prey and well-oxygenated water.

9.8 Littoral Drift

The littoral drift processes of wave action and littoral current affect benthic substrate and vegetation and therefore influence species assemblages (Thom et al. 1994). Primary productivity, organic matter flow, nutrient dynamics, benthic biota, and the entire local food web may also respond to alterations in littoral drift (Thom et al. 1994). The following discussion focuses on direct and indirect impacts to potentially covered finfish and shellfish species in response to these habitat alterations that may result from overwater structures and non-structural piling.

Pacific salmon, Pacific herring, surf smelt, sand lance, and a variety of other fish may be affected by habitat changes caused by structures that affect littoral drift (Thom et al. 1994). Suitable surf smelt spawning areas were adversely impacted by littoral drift alterations resulting from bulkheads along the Hood Canal (Penttila and Aguero 1978, in Nightingale and Simenstad 2001b). Typical spawning substrates consist of fine gravel and coarse sand, with broken shells intermixed in some cases (Thom et al. 1994). Surf smelt make no attempt to bury their demersal, adhesive eggs, but rely on wave action to cover the eggs with a fine layer of substrate (Thom et al. 1994). Therefore, altering substrate composition in surf smelt spawning areas can affect surf smelt spawning or reduce egg survival.

Pacific sand lance spawn in the high intertidal zone on substrates varying from sand to sandy gravel. Sand lance also rely on sandy substrates for burrowing at night. Like surf smelt, sand lance are susceptible to deleterious effects of littoral alterations because they rely on a certain beach profile and specific substrate compositions.

Any species that depends on eelgrass, such as Pacific salmon or Pacific herring, is susceptible to changes in littoral drift. Eelgrass typically grows in sand and mud substrates in sheltered or turbulent waters (Phillips 1984), and Pacific herring spawn on the blades of eelgrass and other macroalgae (WDNR 2006a). It is consistently documented that the vegetation assemblages associated with eelgrass support increased numbers of juvenile salmonid epibenthic prey species (Nightingale and Simenstad 2001b). Studies of eelgrass communities in Padilla Bay show that a specific group of copepods (*Harpacticus uniremis* and other copepods of the genera *Zaus* and *Tisbe*) is unique to the eelgrass epiphyte assemblage and the principal prey of juvenile chum salmon, Pacific herring, Pacific sand lance, and surf smelt (Nightingale and Simenstad 2001b). Pacific herring are also a direct food source of larger predators, including adult Chinook salmon, bull trout (Nightingale and Simenstad 2001b), Pacific hake (Bailey 1982; NMFS 1990; Quirollo 1992; McFarlane and Beamish 1986, in NRC 2001), Pacific lamprey, rockfish (WDNR 2006a), and many other species (WDNR 2006a).

Benthic communities, including invertebrate populations, are impacted by sediment alterations (Nightingale and Simenstad 2001b). For instance, the Olympia oyster is an epibenthic filter feeder found throughout the inland waters of Puget Sound, as well as in Willapa Bay and possibly Grays Harbor (WDNR 2006b). Olympia oysters occupy nearshore areas on mixed substrates with solid attachment surfaces and are found from approximately 1 foot (0.3 m) above MLLW to approximately 2 feet (0.6 m) below MLLW; their larvae settle onto hard substrate such as oyster shells and rocks (West 1997, Baker 1995, both in WDNR 2006b). Olympia oysters are adversely impacted by siltation and do best on firm substrates (WDNR 2006b). Therefore, it follows that local impacts to littoral drift can alter preferred substrate or smother oysters beneath silt.

The WACs do not address impacts to littoral drift from overwater structures or non-structural piling or provide any guidance or measures to avoid or minimize potential impacts associated with littoral drift.

To conclude, impacts to littoral drift may change beach substrate characteristics and sediment deposition. Changes to these processes can alter benthic and epibenthic communities, fish spawning and rearing habitat, and vegetation (Thom et al. 1994).

9.9 Substrate Modifications

Based on the studies cited in Section 7.9, it appears that the primary direct impact of placing structures is to create hard substrates in settings where such substrates did not previously occur, increasing habitat diversity. This change would likely benefit rockfish and any other potentially covered species that use hard or rocky substrates. However, the indirect impact of increased shellhash deposition can harm productive natural habitat types, specifically eelgrass and macroalgae communities. In that case, the risk of incidental take will be the risk of adversely impacting eelgrass and macroalgae, as discussed in Section 9.2.
WAC 220-110-300(1) states that "floats and rafts shall not ground on surf smelt, Pacific herring, Pacific sand lance and rock sole spawning beds. In all other areas, no more than twenty percent of the float or raft within the beach area shall ground at any time. Those portions of the float or raft that will ground shall be constructed to align parallel to the shore and provide a minimum of eight inches clearance between the beach area and nongrounding portions of the float." WAC 220-110-300(2) states that "floats, rafts, and associated anchoring systems shall be designed and deployed so that the bed is not damaged." WAC 220-110-060(2) states that "excavation for and placement of the footings and foundation shall be landward of the ordinary high water line unless the construction site is separated from state waters by use of an approved dike, cofferdam, or similar structure." The language in the WACs will avoid impacts to forage fish and rock sole spawning beds, but does provide for direct impacts to other areas, where twenty percent of a float or raft may ground at any time or where excavation may occur landward of the ordinary high water line, which will impact habitat that may be considered designated critical habitat under the ESA, or could be designated in the future, providing for a moderate to high potential risk for take of the potentially covered species. Additionally, installing a cofferdam or other similar structure may require fish handling in some situations, which has a high potential risk for take of the potentially covered species.

9.10 Channel Dewatering

The primary risks of incidental take associated with channel dewatering result from the capture and handling of fish, the loss of small fish (particularly salmonid fry) that seek refuge in the substrate of the dewatered bed, and the use of pumped bypass systems. This conclusion is based on a review of several biological opinions, specifically the take

calculations and the incidental take statements presented in these documents, as cited below.

The hydraulic code provides few assurances that incidental take will be minimized during dewatering activities. For construction of overwater structures and driving and removal of piling in freshwater, WAC 220-110-060(1) states that "excavation for and placement of the footings and foundation shall be landward of the ordinary high water line unless the construction site is separated from state waters by use of an approved dike, cofferdam, or similar structure." WAC 220-110-120 provides the most restrictive code language, but it only applies to "game and food fish" (implicitly excluding many potentially covered species) and only states that they must be captured or moved – there is no discussion of ways to manage the dewatered work area so as to minimize the need to handle fish. WAC 220-110-060(1) does not indicate whether the isolated work area must be dewatered or fish removal is required. Assuming the isolated work area must be dewatered and fish removal is required, there is no requirement that the operation be performed by trained personnel, nor that it comply with any recognized protocol. There is a relatively high risk of take for dewatering activities in fish-bearing waters because the WAC does not focus on "all fish," methodologies for removal could result in stranding fish, and fish could be harmed through mishandling. The efficiency of capturing fish is also strongly correlated to site conditions. Areas with large, complex substrate, deep pools, complex woody debris, overhanging and submerged vegetation and other features that provide hiding places and hinder visibility can decrease the efficiency of fish capture and removal efforts.

Capture-related take, such as injury or mortality from electrofishing, varies from 2 percent (no distinction between injury and mortality) (NMFS 2006a) to 30 percent (25 percent injury and 5 percent mortality) (NMFS 2006b) of fish captured using electrofishing equipment. Some biological opinions did not distinguish between methods of capture (e.g., volitional movement of fish from the project site during slow dewatering, capture by seining or dip-netting, capture by electrofishing). One biological opinion estimated take due to stranding (i.e., fish not captured and removed and thus remaining in the work area to be dewatered) at 8 percent (NMFS 2006b). All such injury and mortality represent incidental take directly attributable to a project.

NMFS biological opinions also routinely identify impacts attributable to increases in turbidity and suspended solids. These include indicators of major and minor physiological stress, habitat degradation, and impaired homing behavior. These effects are sublethal, but are still considered take under the ESA (NMFS 2006b). The effects of increased suspended solids concentrations are discussed in Sections 7.6 and 9.6.

9.11 Artificial Light

Incidental take of listed fish species as a result of artificial light during construction or operation of overwater structures has not been quantified in past biological opinions and corresponding incidental take statements. The studies cited above indicate that artificial light has mixed effects; many of these effects are detrimental, and all of them represent a change from natural patterns of behavior. This suggests that, although artificial light responses are unknown for most potentially covered species, there is a significant risk that nighttime illumination of the water surface may contribute to incidental take. However, such impacts can generally be minimized, as discussed in Section 11.11.

The WACs do not provide any guidance or specific requirements to avoid or minimize impacts relating to artificial light.

9.12 Vessel Activities

Vessel activities may result in incidental take of potentially covered species via several mechanisms, including:

- Physical disturbance of sediment, organisms (Haas et al. 2002), and submerged vegetation through grounding or water turbulence caused by propeller wash, potentially resuspending sediment, physically dislodging vegetation and organisms, or damaging vegetation
- Noise from vessel activity, which would most likely harm organisms by causing them to move from the affected area, potentially impairing foraging or reproductive activities or exposing them to increased risk of predation
- Propeller-wash entrained air bubbles that combine with turbidity increases from disturbed sediment, with the potential consequences resulting from increased turbidity discussed in Section 9.6 and the consequences resulting from decreased light availability discussed in Section 9.1.

The WACs do not provide any guidance on vessel operation during construction of an overwater structure or installation of non-structural piling. There are no provisions for avoiding or minimizing potential impacts to the potentially covered species relating to the grounding of vessels, propeller-wash, or noise associated with work vessels.

9.13 Risk Evaluation

Table 12 presents a brief summary of the incidental take risk analysis presented above. Given the uncertainties described above, this risk evaluation is at best a qualitative assessment and is based strongly on professional experience of the analysis team in the context of their work in ESA implementation. The risk evaluation summarized in Table 12 assumes that potentially covered species are present when the described impact occurs; thus, impacts may be avoided by performing the activities when or where covered species are absent.

Table 12
Conclusions of the Risk Evaluation

Activity	Low Risk	Moderate Risk	High Risk
Freshwater structures per WAC 220-110-060	• Structures located in areas lacking submerged aquatic vegetation; • Structures causing little increased shading, either due to size or incorporation of grating or other light penetrating features • Pile-driving activities with peak sound <150 dB; • Structures in areas with little sediment transport; • Structures not increasing the volume of untreated stormwater; • Placing small areas of non-conforming substrate; • Activities avoiding the impacts potentially causing "moderate" or "high" risk.	• Structures removing riparian vegetation; • Structures that require removing LWD in lentic waters; • Pile-driving activities with peak sound between 150 and 180 dB; • Structures increasing the volume of untreated stormwater due to increased impervious surface; • Structures comprised of CCA- or ACZA-treated wood; • Structures that measurably alter channel hydraulics or littoral drift; • Structures causing nighttime illumination of the water surface.	• Structures in areas of submerged aquatic vegetation that are used by dependent species (e.g., Olympic mudminnow); • Structures that require removing LWD in lotic waters; • Pile-driving activities requiring hammer pile driving with peak sound >180 dB; • Structures that substantially alter channel hydraulics; • Placing large areas of non-conforming substrate; • Activities that require dewatering of the work area; • Activities requiring substantial in-water operation of mechanized equipment. • Structures in riverine environments that use creosote treated wood;
Saltwater structures per WAC 220-110-300	• Structures located in areas lacking submerged aquatic vegetation; • Structures causing low shade; • Pile-driving activities with peak sound <150 dB; • Structures in areas with little sediment transport; • Placing small areas of non-conforming substrate; • Activities avoiding the impacts potentially causing "moderate" or "high" risk.	• Structures removing riparian vegetation; • Pile-driving activities with peak sound between 150 and 180 dB; • Structures discharging stormwater; • Structures requiring CCA- or ACZA-treated wood; • Structures measurably altering littoral drift; • Structures causing nighttime illumination of the water surface.	• Structures located in areas of eelgrass or macroalgae; • Structures shading large areas; • Structures requiring hammer pile driving with peak sound >180 dB; • Structures that require creosote-treated wood; • Placing large areas of non-conforming substrate; • Activities that require dewatering of the work area; • Activities requiring substantial in-water operation of mechanized equipment.
Non-structural or structural piling	• Pile-driving activities with peak sound <150 dB; • Structures that avoid the impacts potentially causing "moderate" or "high" risk.	• Pile-driving activities with peak sound between 150 and 180 dB • Structures requiring CCA- or ACZA-treated wood.	• Piling located in areas of eelgrass or macroalgae; • Structures requiring hammer pile driving with peak sound >180 dB. • Structures requiring creosote-treated wood.

10 DATA GAPS

This section identifies information gaps in the available literature about the 12 impact pathways (presented in Section 7) associated with the construction and operation of overwater structures and non-structural piling and describes the data needed to fill those gaps.

10.1 Shading

As stated in the WDFW white papers on overwater structures (Nightingale and Simenstad 2001b; Carrasquero 2001), significant gaps and uncertainties remain in the extent of scientific knowledge about the impacts of overwater structures and shading on the aquatic environment and biota. Some of these gaps are basic to understanding the ecology and life history of potentially impacted species, such as those defining the extent and ecological dependence of shoreline habitat use by certain biota. Since the publication of the two WDFW white papers cited above, a few studies have been completed regarding shoreline habitat use of aquatic biota. Toft et al. (2004) reported on fish distribution, abundance, and behavior in nearshore habitats along the marine shoreline of the City of Seattle, and Tabor et al. (2006) studied nearshore habitat use by juvenile Chinook salmon in the Lake Washington basin. One data gap identified by Nightingale and Simenstad (2001b), which is to determine the conditions for and the significance of avoidance of shoreline structures by migrating juvenile salmon, has been studied in greater detail since the publication of the white papers. Southard et al. (2006) studied conditions for, and the significance of, avoidance of shoreline structures by migrating juvenile salmon in *Impacts of Ferry Terminals on Juvenile Salmon Movement along Puget Sound Shorelines*. This study supported other findings that identified shading of overwater structures as the mechanism for salmonid avoidance (Weitkamp 1982, Pentec 1997, in Nightingale and Simenstad 2001b; Shreffler and Moursund 1999) and recommended ways to minimize impacts of ferry terminals on juvenile salmonids. Furthermore, Haas et al. (2002) suggest that additional research is necessary to determine the thresholds at which epibenthic biota become affected by the shading of vegetation.

Additional data gaps include the effects of temporary shading associated with vessel operations during construction of overwater structures or installation of non-structural piling. However, in general vessels required for the construction of overwater structures and installation of non-structural piling will operate during the approved in-water work window, which will minimize potential impacts associated with shading. Additional data

gaps relate to the operation of commercial and recreational vessels which may be moored at an overwater structure or non-structural piling, and may occur at various times of year and therefore affect covered species.

10.2 Littoral Vegetation

Numerous significant data gaps preclude a clear understanding of how human activities cumulatively impact littoral vegetation. Relatively little work has been done on macroalgae. For eelgrass, the following gaps are particularly significant:

- Factors governing the extent of eelgrass coverage, including local and large-scale changes in eelgrass coverage, are just beginning to be researched (Dowty et al. 2005).
- How large-scale changes in eelgrass cover resulting from overwater structures vary in conjunction with other large-scale changes, such as climate variability, has not been determined.
- More research is needed to determine the causes of local declines in eelgrass coverage observed in Washington State (Dowty et al. 2005).
- It is not known how strongly many potentially covered species depend on eelgrass. For instance, young salmon forage extensively in eelgrass, but foraging habitat may not be a limiting factor for juvenile salmon in Puget Sound (Haas et al. 2002).
- Much human impact on eelgrass and macroalgae takes the form of habitat fragmentation, but although such fragmentation is in principle an adverse impact, it remains unclear just how that impact is delivered to affected species (Haas et al. 2002).

10.3 Freshwater Aquatic Vegetation

It is not known at what point the cumulative impact of overwater structures on aquatic vegetation becomes significant to most potentially covered freshwater species. Most of these species are thought to be affected by the loss of aquatic vegetation through indirect impact pathways that could vary from one location to another. To assess the relative merits of aquatic plant conservation and mitigation measures, the importance of aquatic vegetation in different systems and for all of the potentially covered species needs to be better understood. Of the potentially covered species, current data have shown a clear and consistent dependence on freshwater aquatic vegetation only for the Olympic mudminnow,

although it is expected that freshwater aquatic vegetation is important for other potentially covered species as well, which is why this is identified as an important information gap.

10.4 Riparian and Shoreline Vegetation

Most of our understanding of the role of riparian and streamside vegetation as a mediator of instream habitat condition has grown out of concern over its role in providing salmonid habitat. Although the reviewed literature addresses many ecosystem functions affected by riparian vegetation, such as shading, LWD recruitment, and allochthonous nutrient inputs, there is little discussion of how these changes may affect species other than salmonids. Knutsen and Naef (1997) indicate that nutrient inputs from riparian vegetation are important for suckers, whitefish and minnows, which feed directly on such detritus. Riparian habitat is also important for terrestrial wildlife.

10.5 Noise

Data on the effects of exposure to sound from pile driving on specific fish or invertebrates are few, and although the few studies completed provide some information about exposures to pile-driving sounds, there is little that can be definitively concluded (Hastings and Popper 2005). Hastings and Popper (2005) stress that because monitoring data show that sound pressure levels do not necessarily decrease monotonically with increasing distance from the pile, it is important that received sound levels be measured in future experiments to develop exposure metrics that correlate with mortality and different types of damage observed in fish exposed to pile driving. Hastings and Popper (2005) conclude that it is important to initiate experimental studies that start with basic questions about the effects on fishes from exposure to pile-driving sounds. Recommended studies from Hastings and Popper (2005) are presented in Table 13. Two data gaps are particularly significant: the cumulative impact of sound to fish and the effects of noise on the behavior of fish and the consequent impact to species survival and recovery.

In addition to data gaps on the hearing capabilities of fish and how fish are injured by pile-driving noise, uncertainties also exist on how fish react to other anthropogenic noises caused by vessels, construction, and other sources. It is also important to develop information on ambient noise levels for particular areas, because ambient noise levels

influence the area of effect (attention to ambient), and fish reaction to sound likely varies depending on the "loudness" of ambient conditions.

Table 13
Research Questions on the Impact of Pile Driving on Fishes

Project Title	Project Objectives	Significance	Relationship to Other Studies	Relationship to Pile Driving Needs
Characterize Pile Driving Sounds				
Define acoustic dose for exposure to pile driving sound	Develop ways to express exposure to pile driving sounds in terms of total energy received and the degree of temporal variation in the waveform, and to define the acoustic particle velocity within the sound field	This will provide a series of "standard" pile driving sounds in water and substrate for use as the stimuli with which to do studies on representative species	This study is fundamental to investigations of effects on fishes because it provides laboratory signals that would be representative of the range of pile driving stimuli in different locations	Without this standardization it will be impossible to generalize between studies done in different locales and with different piles
Structural acoustic analysis of piles	Develop structural acoustics models of piles to investigate how modifications to piles and hammering could alter the sounds and potentially incur less damage to animals	This could result in potential modifications to the structure, hammer, and/or process that could reshape the temporal characteristics of the pile driving stimulus without changing structural integrity	Would need to test modified sounds on animal models	This analysis will help provide ways to mitigate some effects of pile driving on aquatic organisms
Define characteristics of the underwater sound field	Develop underwater sound propagation model and integrate with pile structural acoustics models to estimate received levels of sound pressure and particle velocity in the vicinity of pile driving operations and verify with field measurements of underwater sound pressure measurements	This is the only way to define zones of impact on fishes because the sound energy received by a fish depends on not only the pile-driving source, but also the size, shape, and properties of the underwater environment.	Would be able to map the impact of pile driving sounds on the underwater environment based on results of tests of pile driving sounds on animal models	Received levels of sound pressure and acoustic particle velocity must be known underwater in the region surrounding the pile to calculate appropriate metrics related to observed effects and define the zone of impact
Characterize injury of fish exposed to pile driving sounds				
Hearing capabilities of Pacific Coast fishes	Determine hearing capabilities (using Auditory Brainstem Response [ABR]) of representative species. Determine in terms of both pressure and particle motion.	Useful for prediction of detection range of pile driving sounds and potential effects on hearing capabilities	Previous behavioral studies did not use any Pacific Coast fishes or elasmobranches	Studies would be on species that are particularly germane to those affected by pile driving

Project Title	Project Objectives	Significance	Relationship to Other Studies	Relationship to Pile Driving Needs
Mortality of fishes exposed to pile driving	Determination of short and long term effects on mortality of representative species as a result of pile driving. Measure pathology (using necropsy studies) of the effects on fishes of received sounds representative of different distances from the source	Provide baseline data on effects of pile driving and the effects of such signals of different levels and spectral components	Studies of this type have, heretofore, not be done under controlled situations	Provide mortality data as well as pathology as to the effects of pile driving and determination of the cause of immediate and long-term mortality
Effects of pile driving on non-auditory tissues	Using the precise same paradigm as for effects on the ear, examine other tissues using standard fish necropsy techniques to asses gross, cellular, and molecular damage to fish. Furthermore, determine stress effects on fish using appropriate stress measures (e.g., hormone levels). Do for representative species.	Provide insight into how the sounds affect fish, even when there is no immediate mortality	The only comparable data are from blasts, which suggests significantly different effects depending on fish size and species.	Direct measure of potential long-term damage to fishes.
Effects of pile driving on hearing capabilities	Determine temporary threshold shifts and permanent threshold shifts on representative species.	Provide insight into hearing loss and possible recovery as a result of different sound levels and sound types	No studies of this type have been done using pile-driving sounds	Data that will help understand the sound levels and other parameters that could result in the loss of the ability of different species types to detect sounds, and thus detect biologically critical signals
Effects of pile driving on fish eggs and larvae	Determine mortality, growth rates, and pathological changes in developing fishes of representative species with exposure at different times during the development cycle	Since eggs and larvae do not move from the sites of spawning, determine if long-term pile driving could affect fish populations	No studies done on any fish system are relevant to this investigation	If fish spawn in the vicinity of pile driving sites, or cannot be kept from spawning during pile driving operations, effects on eggs and larvae could be considerable

Project Title	Project Objectives	Significance	Relationship to Other Studies	Relationship to Pile Driving Needs
Behavioral responses of fish to pile driving	Observe, in large-scale cages, the short-term behavioral responses of representative species to pile driving sounds. Do fish attempt to swim from the source? Do they react to the sounds? Do they "freeze" in place?	In knowing behavioral responses, it may be possible to predict which species would remain in an area of pile driving vs. species that could be expected to leave the area after the initial pile driving activity.	None have been done to date.	This may help limit the number of species that would need to be "protected."
Long-term behavioral effects of pile driving on fish	Attempt to do field studies that would provide insight into movement patterns of fishes and normal behaviors and how these might be affected, in the long-term, by the presence of continuous pile driving.	While there may be few or no apparent effects on immediate behavior (e.g., rapid swimming), physiology (e.g., hearing, effects on other organs), or mortality, there may be longer-term behavioral effects such as those from continual sounds from pile driving preventing fish from reaching breeding sites, finding food, hearing and finding mates, etc. This could result in long-term effects on reproduction and population survival.	None have been done to date.	Pile driving may not have an immediate impact on fishes, but continual pile driving may have longer-term effects that could significantly alter fish populations in the areas in which pile driving takes place.
Effects of pile driving on the ear and lateral line	Determine morphological changes over time for representative species on sensory cells of the ear and lateral line, and whether such changes are reversible	If there is loss of sensory cells there is a loss in hearing ability or the ability of the lateral line to be used in hydrodynamic reception. If there is recovery of these cells, fishes may be able to survive (assuming they did not die prior to recovery).	A few studies suggest that exposure to high sound pressure levels will affect the sensory cells of the ear, but almost nothing is known about the lateral line. However, no studies were done with sounds comparable to those from pile driving	Loss of hearing capabilities, even for a short period of time, could dramatically affect survival of fishes.
Effects of multiple pile driving exposures on fish	For the appropriate experiments cited above, determine effects of multiple exposures, over time, of pile driving	Some fishes may stay in the pile driving area, or go between areas that have different time tables for pile driving. Thus, there may be multiple exposures over time	No data in the literature.	If fish remain in an area over time, there may be cumulative effects that need to be understood

Source: Hastings and Popper 2005

10.6 Water Quality

There is still much work to be done to understand the impacts of suspended sediment and turbidity on potentially covered species. Most of the reviewed literature discussed impacts only with respect to salmonid species. Many of the studies were conducted in the laboratory in the absence of complex interactions that occur in natural systems. While the laboratory work is useful for describing interactions around which a study has been designed, additional field data would help to verify laboratory-derived conclusions. In addition, many data gaps identified by Bash et al. (2001) still appear to be gaps. For instance, a lack of background water quality data for most waters in Washington, exposure thresholds for sublethal effects, the effects of short-term sediment pulses, species responses to varying sediment particle sizes and shapes, the effect of fine sediment deposition on hyporheic mechanisms, and how these affect habitat quality and quantity. This information would help in estimating the potential impacts of aquatic projects by providing a more comprehensive impact analysis in the context of existing conditions and species response thresholds to suspended sediment exposure.

Similarly, many data gaps exist with respect to the potential for treated wood applied to aquatic settings to impact potentially covered species. Little work has been done to evaluate the potential impacts of treated wood applications in large projects on water quality and sediment and dose responses of potentially covered species to PAH and metals concentrations in water and sediment (Poston 2001). Poston (2001) reported a lack of knowledge on bioaccumulation and pathways of exposure of potentially covered species to PAHs and metals, as well as microbial and physical degradation processes of PAHs and metals. These processes are still not well described in the literature. Recent work has called into question the reduction in PAH leaching rates achieved by current BMPs for creosote treatment (Poston 2001). This information would allow for better estimates of take.

10.7 Channel Hydraulics

Relatively few studies specifically address questions about the effects of overwater structures on potentially covered species other than salmonids. Instead, this white paper relies on studies that address water crossing effects on habitat features, such as scour or sediment composition, and on studies that address the effects of changes in habitat features on potentially covered species. We have high confidence that this approach suffices to

identify potential impacts on potentially covered species, although there are few case studies demonstrating quantitative impacts on animals or their habitat. The existing studies are often of limited use because they focus on "legacy" effects, i.e., impacts that occurred because of practices that are rarely, if ever, authorized under current regulations.

Nearly all studies that specifically look at impacts to potentially covered species address only impacts on salmonids listed under the ESA (i.e., Pacific salmon and bull trout). Some studies address effects on resident salmonids, sturgeon, lamprey, or mussels, but the literature is largely barren for all other potentially covered species. For many potentially covered species, the literature does not provide sufficient information to estimate how a given alteration in physical habitat might affect the species, because their life histories and habitat requirements are imperfectly understood. For such species, which include most potentially covered warm-water fish and invertebrate species (except mussels), this lack of information makes it difficult to estimate take potential.

10.8 Littoral Drift

Littoral drift cells can change over time with natural and human-caused alterations in shoreline configuration, sediment sources, and other variables. Mapped shoreline sediment sources and the location and direction of littoral currents and drift cells should be updated periodically to help users avoid adversely affecting important aquatic habitat characteristics and the potentially covered species that depend on them.

10.9 Substrate Modifications

The literature on substrate modifications is limited. Most studies of substrate changes have examined changes in a hydraulically active environment, which in this white paper is treated in Sections 7.7 and 7.8 on channel hydraulics and littoral drift. Hydraulically passive environments are mainly deep marine and deep lake environments, where substrates are seldom altered except by point and linear structures such as pilings. Relevant studies focus on the marine environment. No data were identified as applicable to lake environments, where the potentially covered species include sturgeon and, to a lesser degree, suckers and mature salmonids. Conducting interviews and reviewing agency documents might provide further detail on the impacts of structures in hydraulically passive environments, but seems impracticable in view of the small risk of incidental take associated with such structures.

10.10 Channel Dewatering

No data that would allow quantification of the amount of habitat lost due to placement of footings located below the OHWL or MLLW associated with piers or ramps or temporarily disturbed each year as a result of the construction of overwater structures were identified. Such data would make it possible to improve estimates of take and cumulative impacts.

Relatively few studies have directly compared the susceptibility of different species to electrofishing-induced spinal injuries and muscular hemorrhages, especially within or among non-salmonids, including potentially covered species. However, injury frequencies reported for specific species are highly variable among and often within investigations and sometimes appear to be contradictory. Differences in rates and degree of injury, especially between investigations, are often difficult to attribute to species, fish size, fish condition, environment (including water conductivity and temperature), field intensity, or other current or field characteristics. Still, most existing data support Salmonidae as the fish taxon most susceptible to electrofishing injury (Snyder 2003).

10.11 Artificial Light

Extensive gaps exist in our understanding of how artificial light impacts aquatic organisms. As discussed in Section 7.11, impacts to fish resulting from artificial light are often related to changes in nighttime behaviors such as migration, activity, location (Nightingale and Simenstad 2001b), and potentially schooling behavior in juvenile salmonids (Ali 1959, 1962, in Simenstad et al. 1999). Further studies on the qualitative effects of predator/prey relationships associated with artificial light, and investigations focused on the consequences of behavioral changes in aquatic organisms in a natural environment, are necessary to better understand the impacts associated with nighttime artificial light.

10.12 Vessel Activities

Relatively little is known about the potential impacts of vessel activities on potentially covered species. Although some work has been done with respect to turbidity, much of the research to date has focused on freshwater environments. More work is needed with respect to impacts of smaller vessels on turbidity in estuarine and marine environments. Much work is also needed to assess the noise impacts of small vessels operating at varying speeds, so that noise levels specific to conditions created by a particular project can be

estimated. Similarly, potential impacts of small vessels on eelgrass and aquatic vegetation are not well known, and more work is needed to support impacts to these resources. Haas et al. (2002) recommends determining thresholds of disturbance for epibenthic communities affected by varying degrees of vessel activity. No literature was identified describing the potential impacts of vessel activities with respect to artificial light.

11 HABITAT PROTECTION, CONSERVATION, MITIGATION, AND MANAGEMENT STRATEGIES

If the impacts described in Section 7 occur within habitat used by a potentially covered species, the result may be incidental take of aquatic animals through either physical harm to the animals or reduced capacity of the habitat to serve essential life functions, such as reproduction, foraging, and migration. The ESA requires that such impacts be avoided or, if unavoidable, minimized to the maximum extent practicable. This analysis assumes that all overwater structures and non-structural piling are conditioned under the HPA authority in accordance with the Hydraulic Code rules (WAC 220-110) and other local, state, and federal regulations. Additional measures for further avoiding or minimizing the risk of incidental take are identified below. These measures include one that was not specified in any of the documents reviewed for this white paper: modifying in-water work windows to be protective of spawning and incubation by any potentially covered species that could be present in the area affected by a proposed project.

11.1 Shading

Nightingale and Simenstad (2001b), Carrasquero (2001), and Thom et al. (1995, in Haas et al. 2002) provide impact minimization measures for the design, construction, and revetment of a variety of overwater structures. WDFW might want to consider following the guidance provided by these authors, such as:

- Increasing the height of overwater structures to allow light transmission under the structures
- Decreasing structure width to decrease the shade footprint
- Aligning the structure in a north-south orientation to allow the arc of the sun to cross perpendicular to the structure, which reduces the duration of light limitation each day
- Using the smallest number of pilings possible, allowing more light beneath the structure
- Using grated surfaces or including openings in the deck surface to pass light, as opposed to prisms. Gayaldo and Nelson (2006) found that grating (with 37 to 58 percent open space) transmits 10 times more light under piers than do acrylic prisms. In addition, light that passes through open grating penetrates the water evenly under the pier, whereas light transmitted though prisms concentrates beams

of light that do not always reach the water surface. The U.S. Army Corps of Engineers Regional General Permit for residential overwater structures in inland marine waters within Washington State (USACE 2005) requires ramps to be grated, and floats are required to have grating account for a minimum of 30 percent of the surface area; the grating must have 60 percent open area and be oriented to maximize light penetration (USACE 2005). Additionally the Regional General Permit for residential overwater structures in inland marine waters prohibits pier widths greater than 6 feet, float widths greater than 8 feet and lengths greater than 20 feet, and the construction of new or the modification of existing fingers, "ells," and T structures onto floats (USACE 2005).

Southard et al. (2006) provides additional recommendations on minimization measures specific to shading impacts on juvenile salmonids, and Kahler et al. (2000) provides recommendations for lakes, as outlined below:

- To minimize the shade-related impacts to migrating juvenile salmonids created by ferry terminals, overwater structures should be designed and constructed to allow incidental light to penetrate as far under as possible, while still providing the necessary capacity and safety considerations necessary to support their intended function. The physical design (e.g., dock height and width, dock orientation, construction design materials, piling type and number) will influence whether the shadow cast on the nearshore covers a sufficient area and level of darkness to constitute an impediment. Construction of closely spaced terminal structures should be avoided to minimize the potential cumulative impacts of multiple overwater structures on juvenile salmonid migration (Nightingale and Simenstad 2001b).
- Experiment with technologies and designs that can soften the light-dark edge to minimize potential temporary inhibition of movement.
- The incorporation of light-enhancing technologies in the design of overwater structures is likely to maintain light levels under overwater structures greater than what is required by juvenile salmonids for feeding and schooling (i.e., estimated at between 0.0001 and 1 foot-candles, depending on age and species). To encourage daytime movement under terminals and other overwater structures, it would be beneficial to decrease the dark-edge effect as much as possible. Providing even a small amount of light in a regular pattern under a dock may encourage fish to swim

underneath. Natural lighting for fish could also be enhanced if the underside of the dock were reflective.

- Continued research is needed to improve our understanding of the relationship between overwater structures and the behavior of migrating juvenile salmonids. Acoustic tagging-tracking technology should be further used to address the data gaps in our knowledge.
- Fish feeding behavior during temporary delays of movement should be investigated. If prey resources and refuge habitat are adequate, fish may benefit from holding in an area adjacent to a terminal.

Kahler et al. (2000) recommends the following measures to mitigate or avoid the undesirable impacts of overwater structures on salmonids in lakes:

- No net increase in overwater coverage should occur in the Lake Washington system — permits for new construction should be contingent on permits for replacement structures. Only replacement structures that demonstrate a reduction in overwater coverage should be permitted. The amount of overwater coverage eliminated from the replacement pier could be held in a "surface area mitigation bank," which new piers would have to draw from. Gradually lower the total net coverage over local lakes.
- All piers, both new and replacement structures, should be restricted to a 3.5-foot-wide cantilever bridge that spans the nearshore area to a narrow moorage structure of the minimum size necessary to moor the applicant's boat.
- Cantilever bridge structures should be grated and as high off the water as practicable, and moorage structures should be no less than 24 inches above OHWL. Floating structures should have maximum light penetration and be removed annually after boating season.
- Prisms and grating should be studied to determine their efficacy at providing sufficient ambient light for macrophyte production under piers. The best products should be utilized in all new or replacement overwater structures to minimize losses of primary productivity.

11.2 Littoral Vegetation

Mitigation of impacts to littoral vegetation is best achieved through avoidance. If overwater structures are designed and located so that they do not reduce available light below approximately 325 $\mu M/m^2/sec$, then eelgrass impacts may be avoidable (Thom et al. 1996, in Simenstad et al. 1999). Where projects result in a direct loss of eelgrass during in-water construction, revegetation can be achieved through natural regrowth or transplanting (Thom et al. 2001); however, transplanting eelgrass is not always successful and the science is still developing. For one project in the San Juan Islands, post-disturbance monitoring of eelgrass beds indicates that where substrate, depth, light availability, and currents are suitable and adjacent eelgrass remains intact, natural revegetation can recolonize disturbed areas at a rate of greater than 1 foot per year (Jones and Stokes 2005).

In Washington, transplanting has been used with some success to revegetate eelgrass beds, although a review of eelgrass restoration projects concluded that eelgrass restoration is "possible, with difficulty" (Thom et al. 2001). New eelgrass beds can be established where conditions that prevent eelgrass from growing (e.g., shade, depth, substrate, or current velocity) are remedied (Thom et al. 2001).

Where conditions are suitable for eelgrass growth, impacts of overwater structures should be avoided or minimized by use of the following measures:

- Avoid impacts by locating structures away from eelgrass beds whenever possible.
- Minimize the area of impact by using the best available installation methods.
- Minimize shading by using the lowest possible number of pilings.
- Space pilings to minimize shade to areas suitable for eelgrass.
- Minimize dimensions of the structure to reduce shade.
- Incorporate design elements such as grated decks or deck openings to reduce shade.
- Whenever possible, orient structures to reduce the shade in habitat that is otherwise appropriate for eelgrass growth (e.g., structures oriented east-west cast a shadow on a single area for a longer period of the day than do structures oriented north-south).
- Locate the structure as high above the water as practical to reduce shade.
- Encourage shared-use docks to minimize cumulative impacts.
- Remove floats during off season and store at an upland location.

- Avoid vessel impacts to eelgrass by maximizing the vertical and horizontal distance between vessel propellers and eelgrass to the extent practicable, maintaining a minimum clearance of 1 foot below the propeller.

Adopting these measures would likely result in avoidance and minimization of eelgrass and macroalgae impacts to the greatest extent practicable. However, it is likely that some projects would still require compensatory mitigation to completely offset temporal loss of eelgrass function and site-specific and cumulative impacts on eelgrass.

11.3 Freshwater Aquatic Vegetation

Mitigation of impacts to aquatic vegetation should focus on ecosystem functions (Hruby et al. 1999). Although all non-noxious aquatic plants are considered beneficial, replacement of vegetation lost or disturbed during project installation may be less beneficial than other ecosystem renovation methods, depending on the plant coverage, density, species, and setting involved. For example, guidance on assessing the functions and values of riverine flow through wetlands in Western Washington (Hruby et al. 1999) does not include aquatic vegetation as a variable in evaluating the functions and values to anadromous or resident fish. Likewise, the matrices of ecosystem functions and pathways for making ESA determinations of effect at the watershed scale (NMFS 1996; USFWS 1998) do not include aquatic vegetation as an indicator of ecosystem function. However, this is partly because both of these evaluation systems are largely designed to address salmonid habitat requirements; re-evaluation is warranted for many potentially covered species having a stronger dependence on freshwater aquatic vegetation (e.g., Olympic mudminnow or California floater). In many settings, aquatic vegetation can recolonize through natural seeding and vegetative growth if conditions are suitable. Depth, substrate, shade, and competition among plant species are all factors that determine which species of plants colonize and survive (Chambers et al. 1999).

Using the functional approach to assessing potential impacts to aquatic vegetation (Hruby et al. 1999), which is an important habitat component for many of the potentially covered species (e.g., Olympic mudminnow and California floater), and determining appropriate mitigation for the loss of freshwater aquatic vegetation are likely to result in minimal potential for incidental take related to aquatic vegetation loss.

11.4 Riparian and Shoreline Vegetation

The following measures could help avoid and minimize incidental take arising from impacts to riparian and shoreline vegetation:

- Prepare revegetation plans for projects that temporarily disturb vegetation during construction. The revegetation plans should identify areas to be replanted with native riparian vegetation when construction is complete. Replanted vegetation should be monitored for a three-year period, and the project proponent should be required to ensure 100 percent survival of all plantings (considered viable and healthy) at the end of one year and 80 percent survival of all plantings (considered viable and healthy) by the end of the three-year monitoring period. These recommendations are based on provisions in WAC 220-110 and on general conditions provided by the Corps, NMFS, and USFWS for Corps ESA Section 7 programmatic consultations.
- Submit monitoring reports to WDFW as part of the revegetation plan. Similar to the requirement of the Corps for ESA Section 7 individual and programmatic consultations, two monitoring reports should be required, one to be submitted one year after project completion and the other to be submitted three or five years after project completion. The monitoring reports must include information on the percentage of plants replaced, by species and achieve specific performance standards related to survival rates (i.e., 100 percent at the end of year one and 80 percent at the end of the monitoring period). Monitoring reports should also state the cause of any plant failure, a provision generally required by the Corps, NMFS, and USFWS for Corps ESA Section 7 programmatic consultations.
- Recommend that vegetation (specifically large trees and root wads) removed for the project be saved for later use in restoration efforts. This condition has often been required in recent individual and programmatic Section 7 consultations. Even if the material is not specifically useful for the permitted action, a WDFW area habitat biologist will generally know of ongoing or pending restoration projects in need of LWD and root wads.
- To the extent practicable, do not permit removal or disturbance of riparian vegetation in areas with high erosion hazard (Knutson and Naef 1997). If such removal or disturbance is permitted, require replanting with native riparian vegetation or other appropriate erosion control measures.

- Require performance bonds for projects disturbing large areas of riparian vegetation.
- Projects that require extensive in-water work, which may require extensive access and which have high-quality riparian habitat, should have work performed entirely within the wetted channel to avoid impacts to riparian vegetation. The short-term impact to a stream channel may be of less consequence than the long-term impact that may be incurred to riparian vegetation, due to the respective rate of recovery.

Brennan and Culverwell (2004) recommend the following for consideration as part of any coastal management strategy and development of shoreline regulations associated with marine riparian habitat:

- Use the precautionary principle: "Do No Further Harm" — Preventing additional losses is both critical and cost-effective. Once riparian functions are lost, they are difficult and expensive to restore, if restoration is possible at all.
- Fill data gaps — The lack of empirical data for Northwest coastal ecosystems and limited recognition of riparian functions have led to poor management practices and protection standards for coastal resources. Research and documentation are critical to establish a scientific foundation for creating adequate policies and practices for protection and restoration.
- Establish appropriate buffers and setbacks — Buffers and setbacks are essential, functional, and cost-effective tools for preserving important processes and functions, preventing environmental degradation, and protecting valuable coastal resources.
- Maintain and/or restore riparian vegetation for human health and safety — Flooding, storm, and erosion hazards are common problems in coastal areas and become a greater threat when shoreline development does not consider the functions and values of maintaining riparian vegetation buffers.
- Identify, evaluate, and incorporate multiple functions into a management strategy — Any management strategy should be based on maintaining all natural processes and functions, determined by an evaluation of the specific requirements for maintaining individual and collective functions over space and time (e.g., LWD recruitment; life history requirements of multiple species of fishes and wildlife).
- Use a multidisciplinary approach in developing riparian management zones — Experts in a wide range of natural sciences should collaborate on an integrated and multidisciplinary assessment.

- Maintain and/or restore riparian vegetation for pollution abatement and soil stability — Vegetative buffers would likely be of benefit by reducing contaminants in runoff and reducing costly reactionary measures to clean up waterways.
- Maintain and/or restore riparian vegetation for fish and wildlife — It is clear that as vegetation is eliminated, the food supply, and thus the carrying capacity of the coastal ecosystem, is reduced.
- Protect marine riparian areas from loss and degradation — Riparian areas provide a wide range of functions that are beneficial to humans, fish, and wildlife. Every effort should be made to preserve remaining marine riparian areas from further degradation, fragmentation, and loss.
- Increase public education and outreach — It is critical that decision makers and the general public be educated about the outcomes of their actions, especially those who have the greatest influence on outcomes (i.e., those who live, work, and play along our shorelines).
- Develop and implement conservation programs — Use ecological principles to guide actions and incorporate multiple functions and processes in developing goals and objectives for conservation actions.
- Develop incentives for conservation programs — Land acquisition, tax incentives, regulatory incentives, and other measures have been used and should be considered in the development of conservation programs.

11.5 Noise

Several noise reduction devices have been developed for pile driving, including air bubble curtains, fabric barriers, pile caps, and cofferdams. Air bubble curtains infuse the area surrounding the pile with air bubbles, creating a bubble screen that reduces peak underwater sound pressure levels. Results on the effectiveness of bubble curtains for reducing sound pressure waves vary and range from 0 dB_{RMS} to 30 dB (neither peak nor RMS identified) (Reyff et al. 2003, Vagle 2003, both in WSDOT 2006a). Proper design and implementation of a bubble curtain are key factors in the effectiveness of this strategy (WSDOT 2006a). Based on the literature, NMFS and USFWS usually assume there will be a 15 dB_{peak} and RMS reduction in sound levels when using a bubble curtain (WSDOT 2006a). For steel piling 14 inches or less in diameter, as well as concrete and wooden piling, such a

reduction would reduce noise levels to below injury thresholds established by NMFS and USFWS (as described in Section 7) at a distance of 33 feet (10 meters).

Fabric barriers and cofferdams are also used to attenuate sound levels from pile driving by creating another interface through which sound travels. The concept is similar to that behind the use of bubble curtains (WSDOT 2006a).

Pile caps have also been shown to effectively reduce underwater sound levels. Laughlin (2006) reduced sound levels by 27 dB with a wood pile cap when driving a 12-inch-diameter steel pile, which would reduce noise levels to below those established for injury (at 33 feet [10 meters]) by NMFS and USFWS. Conbest, Micarta, and Nylon pile caps have also been shown to reduce sound levels (Laughlin 2006).

Under certain conditions, a vibratory hammer can be used to reduce noise impacts. Vibratory hammers vibrate the pile into the sediment by oscillating the pile into the substrate. The vibratory action of this hammer causes the sediment surrounding the pile to liquefy so that the pile can be driven (WSDOT 2006a). Peak sound levels for vibratory hammers can exceed 180 dB; however, the sound from these hammers has a relatively slow rise, produces sound energy that is spread out over time, and is generally 10 to 20 dB lower than pile driving using an impact hammer (WSDOT 2006a). However, it is frequently necessary to proof a piling driven with a vibratory hammer with an impact hammer to ensure the integrity of the piling.

In addition to the prevention measures discussed above, construction activities should be timed to occur when sensitive life stages (e.g., spawning, incubation, emergence) of potentially covered species are less likely to be present (NMFS 2003a).

11.6 Water Quality

The following mitigation measures regarding suspended sediment are based on those proposed by Bash et al. (2001):

- Prior to project construction, determine suspended sediment concentrations and collect information on particle size and shape as indicators of the nature of existing turbidity.

- When evaluating cumulative impacts from turbidity, consider information from existing assessments of watershed condition to account for point and nonpoint source pollution loads from watershed sources other than the project, as well as legacy impacts of the system.
- Once existing turbidity and sources have been determined, WDFW may be able to establish allowable/acceptable increases to background turbidity associated with project-related activities, similar to those established in the Implementing Agreement between the Washington State Department of Transportation (WSDOT) and Ecology (WSDOT and Ecology1998), which states that:

> All work in or near the water, and water discharged from the site shall meet the State's Water Quality Standards, WAC 173-201A. A mixing zone for turbidity is authorized within WAC 173.201A-030 during and immediately after necessary in-water or shoreline construction activities that result in the disturbance of in-place sediments. Use of a turbidity mixing zone is intended for brief periods of time (such as a few hours or days) and is not an authorization to exceed the turbidity standard for the entire duration of the construction. Use of the mixing zone is subject to the constraints of WAC 173-201A-100(4) and (6), requiring an applicant have supporting information that indicates the use of the mixing zone shall not result in the loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the water body, result in damage to the ecosystem, or adversely affect public health. The mixing zone is authorized only after the activity has received all other necessary local and state permits and approvals, and after the implementation of appropriate best management practices to avoid or minimize disturbance of in-place sediments and exceedances of the turbidity criteria. Within the mixing zone, the turbidity standard is waived, and all other applicable water quality standards shall remain in effect. The mixing zone is defined as follows:
>
> 1) For waters up to 10 cfs [cubic feet per second] flow at time of construction, the point of compliance shall be 100-feet downstream of project activities.

2) For waters above 10 cfs up to 100 cfs flow at time of construction, the point of compliance shall be 200-feet downstream of project activities.
3) For waters above 100 cfs flow at the time of construction, the point of compliance shall be 300 feet downstream of project activities.
4) For projects working within or along lakes, ponds, wetlands, estuaries, marine waters or other non-flowing waters, the point of compliance shall be at a radius of 150-feet from the activity causing the turbidity exceedance.

- Set stockpile areas back from the bank and include erosion prevention BMPs, such as silt fencing and tarp covers.

Many of the following mitigation measures regarding aquatic applications of treated wood are based on those suggested by Poston (2001).

- Use alternative materials such as metal, concrete, or composites, or for temporary projects use untreated wood.
- If possible, install immersed treated wood products when potentially covered species are not present near the site. This measure is based on information on rapidly diminishing leaching rates reported by Poston (2001).
- Pre-soak treated wood in confined water to reduce impacts by capturing the initial surge of most concentrated leachate, particularly in the case of ACZA- and CCA Type C-treated products, for which leaching rates appear to drop dramatically after a few days.
- Phase and stagger the installation of ACZA- and CCA Type C-treated structures by a few weeks or more, which may dramatically reduce the concentration of leached metals in surrounding water and the instantaneous extent of the area of impact. This measure is based on information on rapidly diminishing leaching rates reported by Poston (2001).
- Use semi-transparent, water-repellent stain, latex paint, or oil-based paint on above-water portions of treated wood structures, which may reduce leaching of arsenic, chromium, and copper into stormwater generated by that portion of the structure (Lebow et al. 2004).

Adopting these measures would greatly reduce, and in some cases eliminate, the risk of incidental take due to water quality impairments.

11.7 Channel Hydraulics

It is difficult to programmatically quantify the risk of incidental take attributable to any structure that modifies a stream channel because of the great variety of site-specific factors at work. However, the review performed for this white paper indicates that habitat impacts are approximately defined by the area of habitat affected, the number of species affected, and the importance of the habitat to each species.

The area of habitat affected is the area of habitat destruction, which can be determined from project plans, plus the area of habitat subject to embedding, scour, or deposition, which can be determined via hydraulic modeling of the structure using a common sediment transport model (appropriate models are described by Miller et al. 2001).

The number of species affected can be determined at the site scale via surveys or from an inventory database, such as the Streamnet database, the Priority Habitats and Species database, the distribution maps developed for the WDNR Aquatic Lands HCP effort, or the Forest Practices HCP. For certain species, these resources identify species use as well as presence, e.g., spawning, migration, or rearing habitat.

The importance of a habitat can be estimated by the principle of limiting factors: The resource that is most limiting to a population's growth will be the principal control on that population. For example, if the fish in a given stream are most limited by insufficient spawning habitat, then a project that destroys spawning habitat will result in greater harm than one that destroys an equivalent area of foraging habitat. Baseline data on limiting factors for some species are available from watershed councils and have been prepared for most WRIAs that contain habitat accessible to anadromous salmonids; a current inventory and summaries of limiting factors are available from the Washington State Conservation Commission website at http://salmon.scc.wa.gov. However, these summaries are rarely informative enough to make a determination about which habitat elements are directly limiting for fish production. For salmonids, quantitative analysis has estimated limiting

factors for most streams in Washington using the Ecosystem Diagnosis and Treatment model; further information is available at http://www.mobrand.com/edt/.

Additional measures that could minimize impacts from artificial structures include finding an alternative to building the structure; siting the structure as far as possible outside of the active channel; minimizing the structure's footprint; and generally designing the structure to have the least possible effect on channel hydraulics (Bates 2003).

WDFW could consider requiring that HPAs for any structure that will place fill within the OHWL include a hydraulic model of probable structure effects on sediment transport and channel hydraulics to ensure that impacts such as scour, deposition, and embedding due to fine sediment deposition are avoided or minimized to a quantitatively ascertainable degree. Such a requirement would ensure that effects of the structure on the channel, and by extension on potentially covered species, are as well understood as practicable. The results of such studies can be summarized to provide an indicator of the quantitative impact of authorized projects on channel hydraulics. Such results would be useful in estimating cumulative impacts of the HPA program, incidental take, and identifying appropriate compensatory mitigation measures.

11.8 Littoral Drift

Impacts to littoral drift can be avoided or minimized by avoiding or reducing those features that interfere with littoral transport processes (see Section 7.8) through the following measures:

- Design pile-supported structures with maximum open space between pilings to allow waves, currents, and sediment to pass beneath (MOEE 1995).
- Minimize certain impacts from floating structures placed perpendicular to shorelines, which dampen wave action and prohibit natural shoreline erosional processes, by minimizing the dimensions of these types of structures.
- Utilize floating breakwaters or ramps in place of breakwater walls to reduce effects on littoral drift (Nightingale and Simenstad 2001b).
- Do not allow floats to ground at low tide.

The effects of these measures are site-specific, and thorough study of the littoral drift cell and potential habitat affected should be conducted on projects that could affect the system's littoral currents and wave action. Avoiding or minimizing alterations in littoral processes would allow shoreline sediment conditions to change at the scales and rates that match those that potentially covered species have evolved to adapt to, minimizing the potential for incidental take through alterations in shoreline substrate distribution and consistency.

11.9 Substrate Modifications

In the nearshore environment, where overwater structures alter the benthic environment via shellhash deposition and establishment of invertebrate communities on pilings, use of fewer and more widely spaced pilings will help to reduce sea star and crab bioturbation of the benthos (Thom et al. 1995, in Haas et al. 2002).

Prohibiting overwater structures from grounding out during low tide events will avoid potential impacts such as affecting aquatic organisms by directly crushing the organisms or changing the character of the substrate. The U.S. Army Corps of Engineers prohibits the grounding of floats on tidal substrates at any time in their Regional General Permit No. 6 (USACE 2005).

11.10 Channel Dewatering

The following actions could be taken to minimize the impacts of channel dewatering on potentially covered species:

- Adopt guidance/protocols for fish removal and exclusion. Specifically, this refers to guidance/protocols for fish capture (including seining and electrofishing), fish handling, and reporting on the number and types of fish captured, fish injured, injuries observed, and mortality. An example protocol is provided by WSDOT (WSDOT 2006b).
- Develop guidelines for channel dewatering and stream bypasses. Adopt a protocol for review/approval of proposed dewatering and stream bypass plans.
- Define the qualifications of a "qualified fish biologist" or "qualified personnel" who can perform fish capture and handling activities or develop an appropriate training or qualification process for biologists. In addition, maintain a list of qualified fish biologists who can perform fish removal and exclusion activities.

- Initiate volitional fish removal activities before isolating and dewatering the work area and have qualified fish biologists present to oversee the fish removal activities.

In addition, Snyder (2003) recommends the following measures to minimize the harmful effects of electrofishing on fish:

- Use the lowest power output that still provides for effective electrofishing (sufficiently large field for taxis and narcosis).
- Use the least damaging current available (direct current; do not use alternating current). However, the occurrence of brands (i.e., burn-type marks caused by electrofishing) and extended tetany (tonic spasm of muscles) indicates harmful effects are still a problem, even when using currents designed to be less harmful.
- Use spherical electrodes and vary the number and size of spheres according to water conductivity and desired size and intensity of the field. Personal communications cited in Snyder (2003) suggest that while spherical electrodes are theoretically superior to cables, no significant difference in catch rate or the incidence of brands was observed between the two; that spherical anodes and cable cathodes appear to be the best combination; and that anodes should be kept high in the water to draw fish to the surface, where they can be easily netted.
- Minimize exposure to the field and specimen handling by rapidly netting fish before they get too close to the anode and quickly, but gently, placing them in oxygenated holding water.
- Change the holding water frequently to ensure adequate dissolved oxygen and to avoid excessive temperatures on hot days; process the fish frequently to reduce crowding.

11.11 Artificial Light

Kahler et al. (2000) recommends that to reduce impacts on salmonid predation, additional shoreline or pier lighting on lakes should not be permitted, and Tabor et al. (1998) suggests that reducing artificial light in the Cedar River would benefit emigrating sockeye salmon. Tabor et al. (1998) also observed that any reduction in artificial lighting must be balanced with safety and other public concerns.

11.12 Vessel Activities

Issues related to vessel activities include vessel grounding in sensitive habitats (such as eelgrass), the effects of propeller wash, the risk of accidental spills of fuel or other contaminants, and the risk of introducing noxious weeds. Vessel grounding impacts can be minimized by adopting WDFW's HPA provisions that prohibit the grounding of vessels in areas of eelgrass, macroalgae, or forage fish spawning (e.g., "Eelgrass and kelp shall not be adversely impacted due to project activities [e.g., vessels shall not ground, anchors and spuds shall not be deployed, equipment shall not operate, and other project activities shall not occur in eelgrass and kelp"]). It may also be appropriate to require construction vessel operation plans for larger projects or projects located in particularly sensitive habitat to ensure that the potential for vessel and construction activity impacts to sensitive habitats and species is minimized. To reduce vessel impacts to the nearshore environment at the Clinton ferry terminal, Thom et al. (1995, in Haas et al. 2002) recommended constructing a longer deck that keeps vessels in deeper water. HPA standard provisions should include provisions to clean propellers before putting boats into the water to reduce the spread of noxious weeds, file a spill prevention plan, and maintain the vessel on a routine basis as well as prior to its use on the construction site. Residential/recreational floats should be sited in deeper water to reduce the potential impacts associated with propeller wash.

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APPENDIX A

STANDARD HPA PROVISIONS

Chapter 220-110 WAC

Last Update: 6/22/05

Hydraulic code rules

Chapter Listing

WAC Sections

220-110-060 Construction of freshwater docks, piers, and floats and the driving or removal of piling.

220-110-300 Saltwater piers, pilings, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings.

220-110-060
Construction of freshwater docks, piers, and floats and the driving or removal of piling.

All pier, dock, float, and piling construction projects shall incorporate mitigation measures as necessary to achieve no-net-loss of productive capacity of fish and shellfish habitat. The following technical provisions shall apply to freshwater dock, pier, and float construction projects and the driving or removal of piling:

(1) Excavation for and placement of the footings and foundation shall be landward of the ordinary high water line unless the construction site is separated from state waters by use of an approved dike, cofferdam, or similar structure.

(2) Alteration or disturbance of the bank and bank vegetation shall be limited to that necessary to construct the project. All disturbed areas shall be protected from erosion, within seven days of completion of the project, using vegetation or other means. The banks shall be revegetated within one year with native or other approved woody species. Vegetative cuttings shall be planted at a maximum interval of three feet (on center), and maintained as necessary for three years to ensure eighty percent survival. Where proposed, planting densities and maintenance requirements for rooted stock will be determined on a site-specific basis. The requirement to plant woody vegetation may be waived for areas where the potential for natural revegetation is adequate, or where other engineering or safety factors preclude them.

(3) Removal of existing or temporary structures shall be accomplished so that the structure and associated material does not reenter the watercourse.

(4) All piling, lumber, or other materials treated with preservatives shall be sufficiently cured to minimize leaching into the water or bed. The use of wood treated with creosote or pentachlorophenol is not allowed in lakes.

(5) Skirting or other structures shall not be constructed around piers, docks, or floats unless specifically approved in the HPA.

(6) Floatation for the structure shall be enclosed and contained, when necessary, to prevent the breakup or loss of the floatation material into the water.

(7) All work operations shall be conducted in such a manner that causes little or no siltation to adjacent areas. If at any time, fish are observed in distress, a fish kill occurs, or water quality problems develop as a result of a pier, dock, float, or piling project, construction operations shall cease and the permittee or authorized agent shall immediately contact the department.

(8) Removal of aquatic vegetation shall be limited to that necessary to gain access to construct the project.

[Statutory Authority: RCW 75.08.080. 94-23-058 (Order 94-160), Â§ 220-110-060, filed 11/14/94, effective 12/15/94; 87-15-086 (Order 87-48), Â§ 220-110-060, filed 7/20/87. Statutory Authority: RCW 75.20.100 and 75.08.080. 83-09-019 (Order 83-25), Â§ 220-110-060, filed 4/13/83.]

220-110-300
Saltwater piers, pilings, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings.

Piers, pilings, docks, floats, rafts, ramps, boathouses, houseboats, and associated mooring projects shall incorporate mitigation measures as necessary to achieve no-net-loss of productive capacity of fish and shellfish habitat. The following technical provisions apply to piers, pilings, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings in saltwater areas. In addition, these projects shall comply with technical provisions and timing restrictions in WAC 220-110-240 through 220-110-271.

(1) Floats and rafts shall not ground on surf smelt, Pacific herring, Pacific sand lance, and rock sole spawning beds. In all other areas, no more than twenty percent of the float or raft within the beach area shall ground at any time. Those portions of the float or raft that will ground shall be constructed to align parallel to the shore and provide a minimum of eight inches clearance between the beach area and nongrounding portions of the float.

(2) Floats, rafts, and associated anchoring systems shall be designed and deployed so that the bed is not damaged.

(3) Piers, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings shall be designed and located to avoid shading of eelgrass (Zostera spp).

(4) Kelp (Order laminariales) and intertidal wetland vascular plants (except noxious weeds) adversely impacted due to construction of piers, docks, floats, rafts, ramps, boathouses, and houseboats shall be replaced using proven methodology.

(5) Mitigation measures for piers, docks, floats, rafts, ramps, and associated moorings shall include, but are not limited to, restrictions on structure width and/or incorporation of materials that allow adequate light penetration (i.e., grating) for structures located landward of -10.0 feet MLLW.

(6) Piers, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings shall be designed and located to avoid adverse impacts to Pacific herring spawning beds and rockfish and lingcod settlement and nursery areas.

(7) Piers, docks, floats, rafts, ramps, boathouses, houseboats, and associated moorings shall be designed and located to avoid adverse impacts to juvenile salmonid migration routes and rearing habitats.

(8) Floatation for the structure shall be fully enclosed and contained to prevent the breakup or loss of the floatation material into the water.

(9) Boathouses and houseboats and covered moorages shall not be located landward of -10.0 feet MLLW.

[Statutory Authority: RCW 75.08.080. 94-23-058 (Order 94-160), Â§ 220-110-300, filed 11/14/94, effective 12/15/94. Statutory Authority: RCW 75.08.012, 75.08.080 and 75.20.100. 84-04-047 (Order 84-04), Â§ 220-110-300, filed 1/30/84. Statutory Authority: RCW 75.20.100 and 75.08.080. 83-09-019 (Order 83-25), Â§ 220-110-300, filed 4/13/83.]

APPENDIX B

MAPS: TRAs AND WRIAs

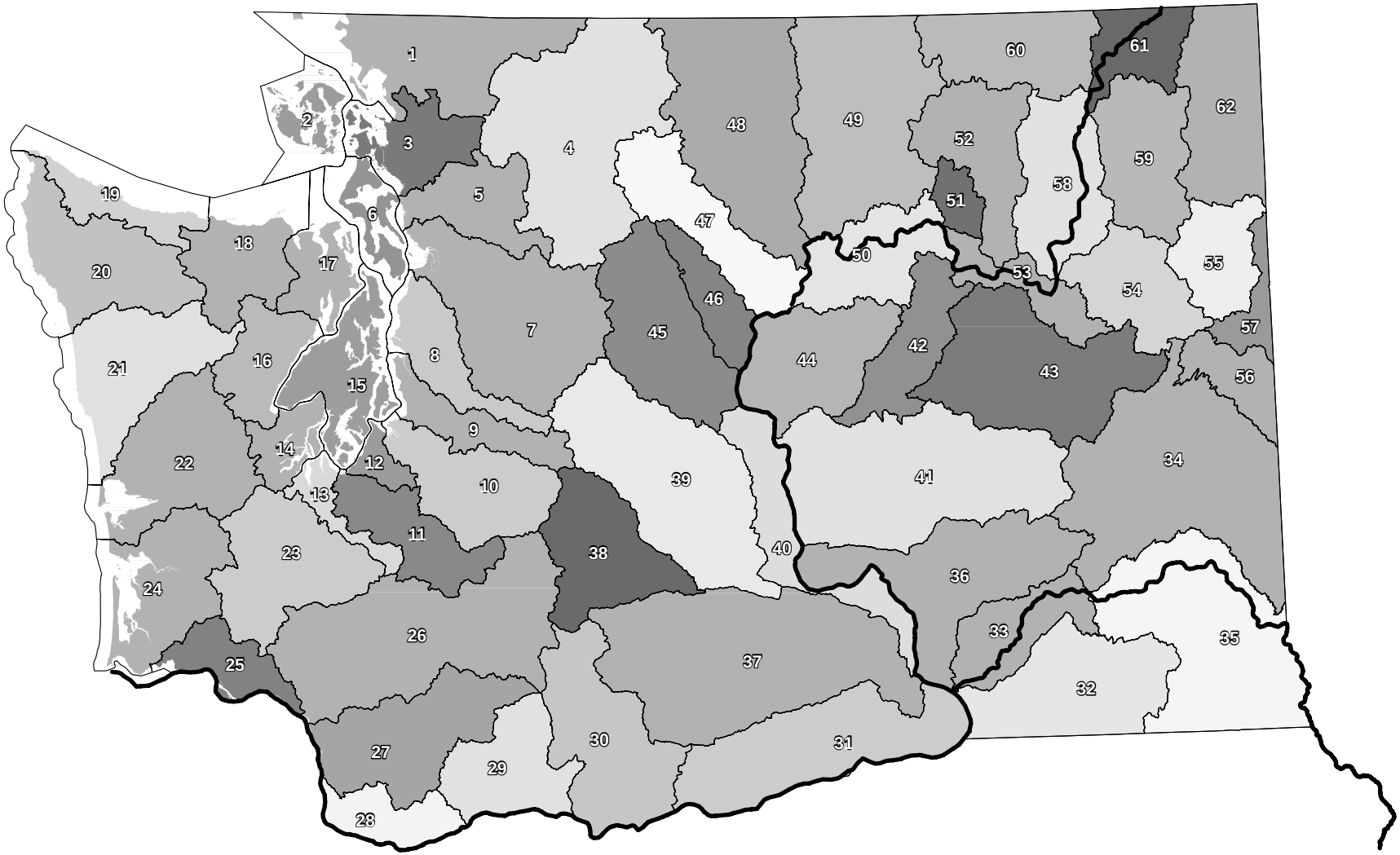

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Figure B-1
Water Resource Inventory Areas

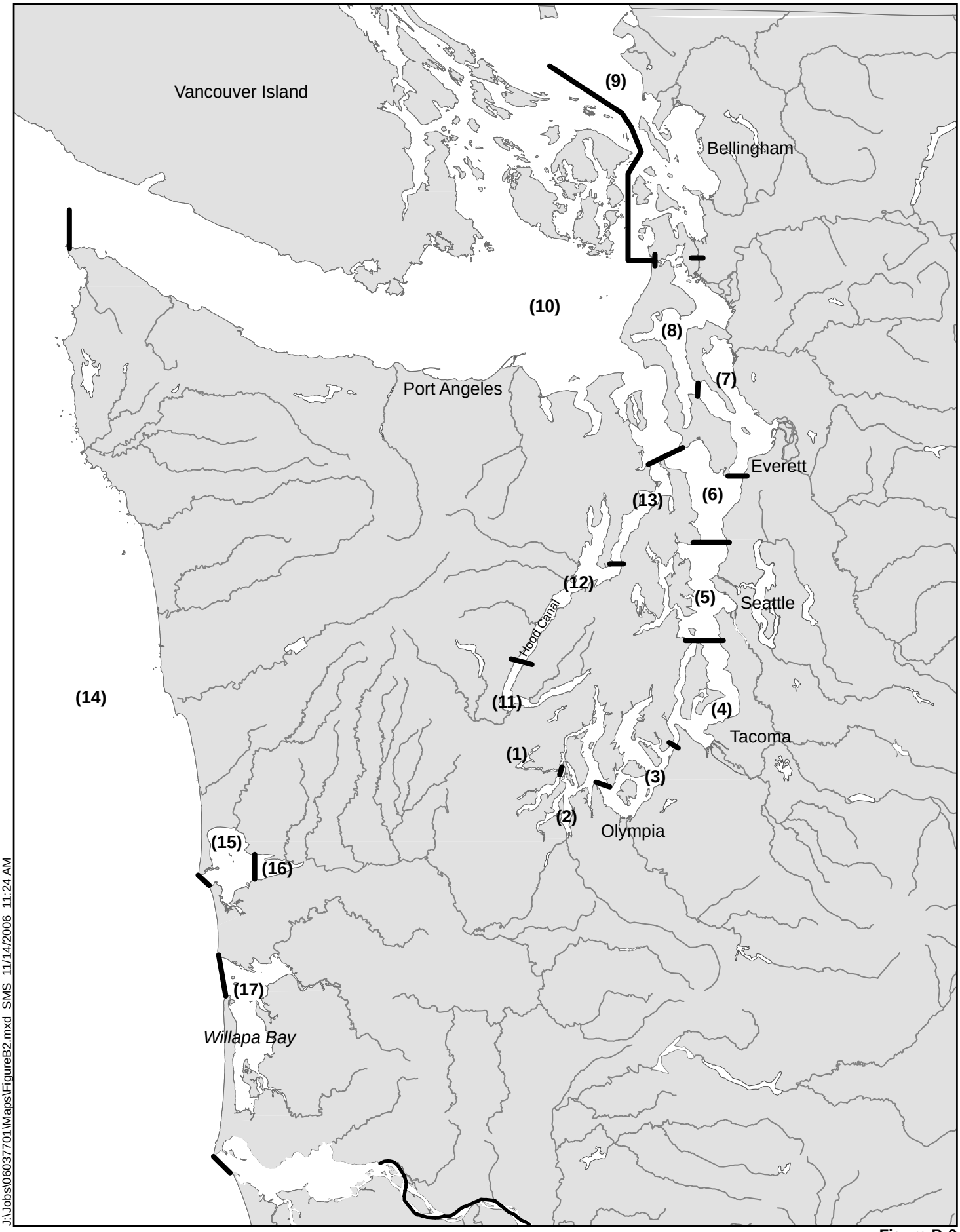

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Figure B-2
Tidal Reference Areas

Executive Summary: Overwater Structures: Freshwater Issues

Jose Carrasquero, Herrera Environmental Consultants

As part of the process outlined in Washington's *Statewide Strategy to Recover Salmon: Extinction is Not an Option* the Washington Departments of Fish and Wildlife, Ecology, and Transportation were charged to develop Aquatic Habitat Guidelines employing an integrated approach to marine, freshwater, and riparian habitat protection and restoration. Guidelines will be issued, as funding allows, in a series of manuals addressing many aspects of aquatic and riparian habitat protection and restoration.

This document is one of a series of white papers developed to provide a scientific and technical basis for developing Aquatic Habitat Guidelines. The white papers address the current understanding of impacts of development and land management activities on aquatic habitat, and potential mitigation for these impacts.

The scope of work for each white paper requested a "comprehensive but not exhaustive" review of the peer-reviewed scientific literature, symposia literature, and technical (gray) literature, with an emphasis on the peer-reviewed literature. The reader of this report can therefore expect a broad review of the literature, which is current through late 2000. Several of the white papers also contain similar elements including the following sections: overview of the guidelines project, overview of the subject white paper, assessment of the state of knowledge, summary of existing guidance, recommendations for future guidance documents, glossary of technical terms, and bibliography.

This white paper evaluates the state of knowledge of the effects of on-, in-, and over-water structures on the functioning of freshwater ecosystems and their relation to salmonids. Scientific and technical literature on the subject was compiled and examined, and input from experts on freshwater habitats and organism life histories was solicited and evaluated. Effects on an array of organisms and communities were considered.

In order to analyze and present the available data in a logical and easily referenced format, the information sources are divided into either direct or indirect mechanisms of impact, then categorized by the type of response observed.

Three direct mechanisms of impact associated with over-water structures were identified: shore-zone habitat structure changes, shading and ambient light changes, and disruption of water flow pattern and energy. One indirect mechanism of impact associated with construction activities and ongoing operation of over-water structures was identified: physical/chemical environmental disruption (e.g., water quality degradation and noise). Interrelated effects of over-water structure use and operation (i.e., boating activities) are also included under the discussion of this indirect mechanism of impact.

Over-water structures often induce simultaneous responses on predation, behavior, and habitat function, potentially confounding the assessment of any individual response. However, such structures may induce a response in an organism without eliciting a response from its habitat and without promoting a response to its predator-prey system. For this reason and in the interest of clarity, a simple three-part categorization is used here for the range of responses. Under each of the direct mechanisms of impact, available research is grouped into the following categories of response: predation, behavior, and habitat function.

A summary of findings of impacts resulting from changes induced by on-, in-, and over-water structures and associated construction and operation activities is presented under each mechanism of impacts and depicted in flow diagrams. In addition, information gaps are identified and summarized.

Habitat protection, restoration, and mitigation techniques pertaining to the over-water structures and associated activities are analyzed and presented. Also, a summary of the regulatory framework governing over-water structures is included.

Finally, this white paper presents recommendations intended for the development of future policy and guidance documents that address the environmental impacts of over-water structures and associated construction and operation activities.

Exhibit 3

WHITE PAPER

Over-Water Structures: Freshwater Issues

Submitted to

Washington Department of Fish and Wildlife
Washington Department of Ecology
Washington Department of Transportation

April 2001

WHITE PAPER

Over-Water Structures: Freshwater Issues

Submitted to

Washington Department of Fish and Wildlife
Washington Department of Ecology
Washington Department of Transportation

Prepared by

José Carrasquero
Herrera Environmental Consultants

April 12, 2001

Note:
Some pages in this document have been purposefully skipped or blank pages inserted so that this document will copy correctly when duplexed.

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Overview of Aquatic Habitat Guidelines Project

As part of the process outlined in Washington's *Statewide Strategy to Recover Salmon: Extinction is Not an Option* the Washington Departments of Fish and Wildlife, Ecology, and Transportation were charged to develop Aquatic Habitat Guidelines employing an integrated approach to marine, freshwater, and riparian habitat protection and restoration. Guidelines will be issued, as funding allows, in a series of manuals addressing many aspects of aquatic and riparian habitat protection and restoration.

This document is one of a series of white papers developed to provide a scientific and technical basis for developing Aquatic Habitat Guidelines. The white papers address the current understanding of impacts of development and land management activities on aquatic habitat, and potential mitigation for these impacts. The following topics are addressed in the white paper series:

- Over-water structures - marine
- Over-water structures - freshwater
- Over-water structures - treated wood issues
- Water crossings
- Channel design
- Marine and estuarine shoreline modification issues
- Ecological issues in floodplain and riparian corridors
- Dredging - marine
- Dredging and gravel removal - freshwater

Individual white papers will not necessarily result in a corresponding guidance document. Instead, guidance documents, addressing management and technical assistance, may incorporate information from one or more of the white papers. Opportunities to participate in guidelines development through scoping, workshops, and reviewing draft guidance materials will be available to all interested parties.

Principal investigators were selected for specific white paper topics based on their acknowledged expertise. The scope of work for their projects requested a "comprehensive but not exhaustive" review of the peer-reviewed literature, symposia literature, and technical (gray) literature, with an emphasis on the peer-reviewed literature. Readers of this report can therefore expect a broad review of the literature, which is current through late 2000. The coverage will vary among papers depending on research conducted on the subject and reported in the scientific and technical literature. Analysis of project specific monitoring, mitigation studies, and similar efforts are beyond the scope of this program.

Each white paper includes some or all of these elements: overview of the Aquatic Habitat Guidelines program, overview of the subject white paper, assessment of the state of the knowledge, summary of existing guidance, recommendations for future guidelines, glossary of technical terms, and bibliography.

The overarching goal of the Aquatic Habitat Guidelines program is to protect and promote fully functioning fish and wildlife habitat through comprehensive and effective management of activities affecting Washington's aquatic and riparian ecosystems. These aquatic and riparian habitats include, but are not limited to rearing, spawning, refuge, feeding, and migration habitat elements for fish and wildlife.

Assessment of the State of Knowledge

This white paper evaluates the state of knowledge of the effects of over-water structures on the functioning of freshwater ecosystems and their relation to salmonids. Scientific and technical literature on the subject was compiled and examined, and input from experts on freshwater habitats and organism life histories was solicited and evaluated. Effects on an array of organisms and communities are considered.

Although reference to a particular genus is made when appropriate within this paper, all seven native salmon and trout of the genus *Oncorhynchus* (i.e., chinook, coho, chum, sockeye, and pink salmon, and steelhead and cutthroat trout) that occur in Washington are collectively referred to as salmonids.

Predators of salmonids consist primarily of the following species. In lakes of western Washington (particularly Lake Washington and Lake Sammamish), largemouth (*Micropterus salmoides*) and smallmouth bass (*Micropterus dolomieui*) are the juvenile salmonid predators that use shore-zone structures more than other species. In eastern Washington, existing hydrological characteristics of river reservoirs (particularly in the Columbia and Snake rivers) favor the northern pikeminnow (*Ptychocheilus oregonensis*; formerly the northern squawfish) as the major predator of juvenile salmonids (Petersen et al. 1993; Poe et al. 1991; Ward et al. 1995). However, smallmouth bass also have a high potential as juvenile salmonid predators in river and reservoir systems of eastern Washington, particularly in the spring when they inhabit rocky shoreline areas also inhabited by juvenile salmonids (Gray and Rondorf 1986). In this discussion of effects of in-, on-, and over-water structures (hereafter, over-water structures) on predation, the emphasis is on predation of juvenile salmonids by these species.

Methods

Literature Sources

An extensive search of available literature was conducted, including but not limited to the following:

- University of Washington electronic library and commercial databases:
- University of Washington catalogs
- Aquatic Sciences and Fisheries Abstracts (ASFA)
- Water Resource Abstracts (WRA)
- National Technical Information Service (NTIS)
- BIOSIS previews.

The University of Washington catalogs contain over 1.9 million titles held by more than 20 branches of the University of Washington libraries. The ASFA database covers all aspects of marine, brackish, and freshwater environments including biology, ecology; fisheries, aquaculture, oceanography, limnology, resources and commerce, pollution, biotechnology, marine technology, and engineering. The WRA database contains abstracts of journal articles,

monographs, and reports covering the development, management, and research of water resources. The NTIS Government Reports is an index produced by the U.S. Department of Commerce, which is a central source for public sale of U.S. government-sponsored research, development, and engineering reports. The BIOSIS previews databases and supplies comprehensive coverage of international life science journals, including references found in biological abstracts.

This review of literature on over-water structures incorporates analysis of existing data available on freshwater organism responses to over-water structures. More specifically, it focuses on the review of studies that address direct and indirect effects of over-water structures and associated construction activities on juvenile salmonids and their habitats. The literature sources include (but are not limited to) peer-reviewed journal articles, theses and dissertations, books, technical documents, previous over-water impact studies in the state of Washington, previous over-water structure impact literature searches, and regulatory documentation. When available, internet web sites that contain information reviewed in this paper are provided. In addition, personal communications with local scientists have been included where related research has yielded pertinent results.

For the purpose of this white paper, sources referring to the ecological effects of over-water structures (i.e., direct sources) are distinguished from literature sources not referring directly to such effects (i.e., indirect sources). Direct sources, then, comprise those references that directly address the mechanism of impacts of over-water structures, as well as those that directly address the response of an organism (particularly juvenile salmonids) to over-water structures (Appendix C). Indirect sources comprise those that address organism predation, behavior, and habitat function without reference to the presence of over-water structures.

During the development of this white paper, a literature review prepared for the City of Bellevue (i.e., Kahler et al. 2000) became available. This literature review was prepared with the collaboration of researchers of the Washington Department of Fish and Wildlife. Also during the development of this white paper, a conference was held to present current and ongoing research on chinook salmon in Lake Washington (i.e., King County 2000). This conference, coordinated by King County, presented research by state and federal agencies. There was some duplication among these three endeavors (i.e., the literature review by Kahler et al. 2000, the conference by King County 2000, and this white paper). Due to time constraints and in the interest of avoiding further duplication, Kahler et al. (2000) and King County (2000) are not fully reviewed in this white paper.

Categorizing Information

In this white paper, unless otherwise stated, only research on over-water structures known to occur in freshwater environments is considered in the literature survey, and the analysis focuses on freshwater environment studies. Appendix B provides a matrix of data availability. A literature review and analysis of the effects of over-water structures in estuarine and marine environments is included elsewhere in the series of white papers and therefore is not discussed here.

Pertinent information on ecological effects of over-water structures (and associated structures and activities) in freshwater environments was found only for the following:

- Docks, piers, boathouses, and floats
- Marinas
- Wharves and pilings
- Log booms and log rafts
- Riprap and retaining walls
- Pile driving and removal
- Construction and operational activities.

This white paper assesses the ecological effects of over-water structures based on the current state of knowledge. In order to analyze and present the available data in a logical and easily referenced format, the information sources are divided into either direct or indirect mechanisms of impact, then categorized by the type of response observed.

For the purpose of this white paper, three direct mechanisms of impact associated with over-water structures have been identified: shore-zone habitat structure changes, shading and ambient light changes, and disruption of water flow pattern and energy. One indirect mechanism of impact associated with construction activities and ongoing operation of over-water structures has been identified: physical/chemical environmental disruption (e.g., water quality degradation and noise). Interrelated effects of over-water structure use and operation (i.e., boating activities) are also included under the discussion of this indirect mechanism of impact.

Over-water structures often induce simultaneous responses on predation, behavior, and habitat function, potentially confounding the assessment of any individual response. However, such structures may induce a response in an organism without eliciting a response from its habitat and without promoting a response to its predator-prey system. For this reason and in the interest of clarity, a simple three-part categorization is used here for the range of responses. Under each of the direct mechanisms of impact, available research is grouped into the following categories of response:

- Shore-zone habitat structure changes
  - Predation
  - Behavior
  - Habitat function

- Shading and ambient light changes
  - Predation
  - Behavior
  - Habitat function

- Disruption of water flow pattern and energy
  - Habitat function.

Objective

The objective of this paper is to evaluate the state of knowledge of the effects of over-water structures on the functioning of freshwater ecosystems within the context of salmonid protection. For this purpose, the following fundamental question is the focus of the review: What are the effects of over-water structures on the ecosystem, measured both by mechanism of impact and by type of response?

Overview of Ecological and Habitat Issues

In general, modification of riparian areas and near-shore littoral zone habitat (i.e., shoreline development) degrades freshwater aquatic communities. Local habitat modification (e.g., construction of individual residential docks) leads to changes in fish assemblages, particularly "when many diverse incremental changes have accumulated within a basin over time" (Jennings et al. 1999).

Cumulative effects of incremental shoreline development on fish assemblages are typically not considered during the construction of a single over-water structure. Years of shoreline development (i.e., construction of over-water structures and associated activities) along lakes, rivers, and reservoirs around the state are now showing the accumulated effects on habitat and fish species. This passage of time has increased the awareness and conviction that cumulative effect analysis is essential to effectively manage the consequences of human activities on the environment (Council on Environmental Quality 1997). However, only recently has the issue of cumulative effects of incremental shoreline habitat modification in freshwater environments been studied (Bryan and Scarnecchia 1992; Beauchamp et al. 1994; Ward et al. 1994; Christensen et al. 1996; Jennings et al. 1999; Lange 1999).

More studies have been conducted on the effects of a range of human activities that alter structural elements of aquatic systems such as size and uniformity of substrate particles (Jennings et al. 1999), quantity and composition of shoreline habitat (Christensen et al. 1996), artificial habitat structures (Beauchamp et al. 1994; Ward et al. 1994), and composition and density of macrophytes (Bryan and Scarnecchia 1992). Among these activities, a high level of concern exists with regard to over-water structures, associated in-water structures, and their related construction activities. This is due to the great potential of these activities to affect, both directly and indirectly, ecological and habitat functions, and thereby individual species.

Jennings et al. (1999) studied the cumulative effect of incremental shoreline habitat modification on fish assemblages in northern temperate lakes. They found that "fish do not respond to shoreline structures: rather, fish respond to various habitat characteristics that are the result of the structures." In addition, fish respond to habitat changes resulting from alterations in the riparian zone (e.g., vegetation and woody structure removal) associated with the placement of the in-water structure (Jennings et al. 1999).

Direct Mechanisms of Impact

Shore-Zone Habitat Structure Changes

Docks, Piers, Boathouses, and Floats

Docks, piers (and pier skirting), boathouses, and floats alter the shore-zone habitat structure, promoting changes in fauna and flora assemblages. These over-water structures can thereby affect the biological community and the environment by altering predator–prey relationships, fish behavior, or habitat function.

Docks and piers are typically structures of open construction that extend into the water from shore (Mulvihill et al. 1980). They come in various shapes, heights, and sizes. They occur in lakes, rivers, and reservoirs throughout Washington and are used for recreational and commercial purposes. They can be pile-supported or supported by a solid base.

A boathouse typically is a building that houses and protects boats. A houseboat is a watercraft with a broad beam, usually a shallow draft, and a large superstructure resembling a house. Houseboats can be either free-floating, anchored on moorages, or supported by pilings. In this regard, one would expect houseboats supported by pilings to have the greatest potential for habitat disruption, because they not only shade the underwater environment but also permanently disrupt the bottom sediments and modify the habitat structure, potentially creating habitat for predatory fishes.

Only two papers were found that address environmental effects of boathouses on aquatic animals and plants (i.e., Brown 1998 and Lange 1999). No literature sources were found addressing the environmental effects of houseboats.

Floats occur in a variety of sizes and shapes, including small moored floating objects (buoys), and larger floating flat objects, known as platforms. Typically, buoys are used for a variety of purposes, for instance, as aid to navigation or for attachment of vessels or instrumentation (Mulvihill et al. 1980). Floating platforms are used for recreational or commercial purposes.

Predation

Predator–prey relations in this section focus on the potential influence of docks, piers, and floats on predation of juvenile salmonids by bass, northern pikeminnow, and piscivorous birds, and by salmonids on their prey. The effects of over-water structures on predator–prey interactions are widely recognized but have not been extensively examined. The literature reviewed does not provide any quantitative or qualitative evidence that docks, piers, boathouses, or floats either increase or decrease predation on juvenile salmonids. No literature source was found addressing pier skirting. No studies have been found examining mortality due to predation specifically associated with over-water structures.

The literature reviewed presents the following observations and inferences:

- Smallmouth bass and largemouth bass have a strong affinity to structures, including piers, docks, and associated pilings.
- Bass have been observed foraging and spawning in the vicinity of docks, piers, and pilings.
- Smallmouth bass are opportunistic predators that consume prey items as they are encountered.
- Smallmouth bass are major juvenile salmonid predators, likely due to the overlap in rearing habitat.

- In the Colombia and Snake river reservoirs, northern pikeminnow is an important predator of juvenile salmonids because of their in-shore preferences and preference for low-velocity microhabitats, which are created by in-water structures.

In western Washington, largemouth bass and smallmouth bass are common predators of juvenile salmonids. Several authors have documented the use of over-water structures by bass in western Washington waters. Stein (1970), examining the types of largemouth bass cover in Lake Washington, found that they prefer areas of heavy log and brush cover over other habitat types (including docks). However, largemouth bass are commonly found under docks in early spring and are thought to be present there until late summer (Stein 1970).

White (1975) studied the influence of piers in Lake Washington and found that fish species (including largemouth bass) are not significantly more abundant (based on catch-per-unit-effort) beneath these over-water structures than at adjacent sites lacking artificial structures. White's (1975) findings led him to suggest that piers provide neither shelter nor habitat for predatory species that prey upon salmonids. However, his sampling method had two major flaws. First, he employed variable-mesh horizontal gill nets as sampling gear, which are more effective for sampling peamouth (*Mylocheilus caurinus*), northern squawfish, and yellow perch (*Perca flavescens*) than for sampling bass. Second, the sampling gear was placed adjacent to the pier rather than beneath it, precluding the characterization of fish composition under the structure. Consequently, the data obtained by White (1975) do not provide information of predatory fish abundance under the piers. In addition, the study sampling gear was ineffective in sampling some fish species, including bass, and therefore, the results do not accurately reflect use of over-water structures by all fish species.

Additional supporting evidence on bass utilization of docks and piers associated with over-water structures comes from unpublished data. Biologists with the Washington Department of Fish and Wildlife found that in local lakes, bass preferentially utilize natural structures, but are also found associated with docks (Kahler et al. 2000). Also, biologists with the Muckleshoot Indian Tribe found that in Lake Sammamish, smallmouth bass preferentially locate their nests near residential piers and associated in-water structures (Kahler et al. 2000). These findings are consistent with the findings of Stein (1970), who observed a largemouth bass affinity for dock, piers, and associated pilings.

Interactions of smallmouth bass and juvenile salmonids depends on factors such as timing of salmonid out-migration, salmonid species, and residence of the juvenile salmonids in lentic or lotic environments (Warner 1972; Pflug and Pauley 1984; Gray et al. 1984; Gray and Rondorf 1986; Poe et al. 1991; Shively et al. 1991; Tabor et al. 1993 and 2000; Fayram and Sibley 2000).

Although substrate type often determines the acceptability of an area for bass spawning, adjacent cover and structural complexity are also necessary for protection while the fish are concentrated in shallow water (Stein 1970; Cooper and Crowder 1979; Helfman 1981b; Pflug and Pauley 1984). Therefore, one would expect that an increase in numbers of docks, piers, boathouses, and floats could be beneficial to the bass population by increasing spawning habitat utilization. Increases in the concentration of bass in spawning sites, where there is an occurrence of juvenile

salmonids, may increase the predation on juvenile salmonids. However, researchers have indicated that structural complexity can moderate predator–prey interactions by providing more refuges for prey species as well as reducing the foraging efficiency of the predator (Cooper and Crowder 1979). This moderation may apply to naturally occurring structural habitat complexity, as well as habitat complexity due to the presence of docks, piers, boathouses, and associated pilings. In such a case, fish may adapt to the use of artificial structures in lieu of natural habitats. Prey such as juvenile salmonids, in the absence of natural hiding cover, may use artificial structures as refuge. However, snorkel observations conducted by Roger Tabor in Lake Washington indicate that although they may migrate along the shoreline, passing under docks, the juvenile chinook salmon prefer open areas rather than areas covered by docks (King County 2000). Moreover, although manmade structures can serve as refuge for prey, they may also provide refuge for predators (Cooper and Crowder 1979).

It has been suggested that the increase in the number of docks around the shoreline of Lake Washington might have caused the observed decrease in freshwater survival of juvenile sockeye salmon (Fayram 1996). Studying the spatial location and temporal duration of predation by bass on juvenile sockeye salmon, Fayram (1996) speculates that the increase in docks potentially provides increased locations for bass to ambush prey such as juvenile sockeye salmon while they are in the littoral zone. Fayram (1996) also suggests that the cumulative effect of an increase in predation due to the increase in number of docks may have been great enough to cause the decline in sockeye salmon freshwater survival.

One would expect that the temporal duration of sockeye salmon predation by bass depends on the extent of the overlap of these two species in littoral zones. This overlap may be strongly affected by temperature because, in subyearling fall chinook, temperature appears to control the duration of shoreline residence in Lower Granite Reservoir (Curet 1993). In Lake Washington, the overlap is typically restricted to late April and most of May because juvenile sockeye normally leave the system by the end of May. It is possible that warming of the lake water over time has increased the period of habitat overlap between these two species (Fresh 2000 personal communication). In addition, Vigg et al. (1991) suggests that among the factors influencing consumption rates of smallmouth bass, water temperature is the single most important factor.

The presence of docks and piers may adversely affect existing macrophyte vegetation, potentially altering predator–prey interactions, particularly those in which largemouth bass plays a role. In Lake Baldwin, Florida, largemouth bass showed a significant preference for piers only where aquatic vegetation was absent (Colle et al. 1989). In Lake Sammamish, largemouth bass have been shown to prefer moderate to dense vegetation and silt and sand substrate (Pflug 1981). The preference of largemouth bass for aquatic vegetation habitat may increase their foraging success on passing schools of salmonids, compared with the lesser success of smallmouth bass that occupy habitat with little concealment (Pflug 1981; Helfman 1981b).

Consistent with these findings, Fayram (1996) found that in Lake Washington, largemouth bass are more structurally oriented than smallmouth bass. Floats have been reported to influence the distribution of fish (Crossman 1959; Helfman 1979). Helfman (1979), studying shade-producing experimental floats in Cazenovia Lake, New York, found that several species of predator fishes are particularly attracted to the area under the floats. The author suggests that the large

aggregation of prey fishes under floats may also attract predator species, although this is inconclusive in his study. In this study, largemouth bass showed little response, positive or negative, to the presence of floats (Helfman 1979). However, Helfman (1979) observed that largemouth bass occasionally hovered near and below the floats but usually moved away as the diver approached. He speculates that this response to the diver might have biased the data collection process and hence the study results by reducing the numbers of largemouth bass observed at the floats. He also attributes this response to a largemouth affinity for "more massive structure than was provided by the experimental floats." Helfman (1979) did not observe smallmouth bass beneath or near floats, although this species was common in the lake.

The northern pikeminnow (formerly known as the northern squawfish), and to a lesser extent the smallmouth bass, are primary predators of juvenile salmonids in eastern Washington. Existing hydrological characteristics of major river systems have favored the northern pikeminnow as a predator of juvenile salmonids. These hydrological characteristics are the result of a substantial habitat modification, mostly due to the construction of dams. The following quotation from Gray and Rondorf (1989) better illustrates this: "Man has significantly altered the aquatic habitat and fish species complex in the Columbia River, and its alteration has created substantial changes in the dynamics of predator-juvenile salmonid relationships . . ."

During this literature survey, numerous studies of the effects of dams on the ecology and biology of the Columbia basin reservoirs were found, in particular, studies of the effects of dams on salmonid predation. Those studies are beyond the scope of this white paper and therefore are not discussed here. In contrast, only a few studies of ecological effects of in-water and over-water structures in eastern Washington systems were found (Beamesderfer and Rieman 1988; Knutsen and Ward 1991; and Petersen et al. 1993). Such studies show some inconsistencies in the evidence of predatory fish aggregation associated with such structures, and study results show no direct evidence of an increased predation rate on juvenile salmonids. This inconsistency may be due to characteristics of each study site (e.g., fast, free-flowing areas or slow-flowing protected areas) and the species targeted (e.g., northern pikeminnow or smallmouth bass) in each particular study.

Although only a few direct sources have been identified, the following characteristics are all reported to be related to fish predator behavior and distribution in the context of juvenile salmonid predation:

- Degree of habitat overlap (i.e., potential for predator–prey interaction)
- Location in relation to the river mile
- Location in relation to the river stem
- Location in relation to the river flow (i.e., free-flowing or backwater)
- Degree of shore-zone development
- Characteristics of the shoreline (i.e., slope and substrate type)
- Presence of manmade in-water structures (i.e., flow obstructions)
- Species of predatory fishes.

Beamesderfer and Rieman (1988) studied juvenile salmonid predation by northern squawfish and smallmouth bass in a main stem Columbia River reservoir. Beamesderfer and Rieman (19898

conclude that northern squawfish have the greatest potential for predation of juvenile salmonids because of their preference for in-shore low-velocity microhabitat. Low-velocity microhabitat can be created by in-water structures such as jetty pilings (Petersen et al. 1993), but can also be created by dock and pier pilings located along the banks of narrow, fast-flowing sections of the Columbia River reservoirs (Carrasquero 2000 unpublished observation). Therefore, one would expect that resulting low-velocity microhabitats could potentially increase juvenile salmonid predation by providing aggregating habitat for northern pikeminnow and perhaps juvenile salmonids as well.

Additional evidence of predation by squawfish was found by Petersen et al. (1993), who, in a study of the systemwide significance of predation on juvenile salmonids in Columbia and Snake river reservoirs, found that northern squawfish feed primarily on juvenile salmonids. The authors speculate that northern squawfish as well as juvenile salmonids might congregate near flow shears (i.e., back-eddies) created by in-water structures (i.e., jetty pilings), to avoid high-velocity water (Petersen et al. 1993). This preference of northern squawfish for back-eddies has been reported elsewhere (Faler et al. 1988). Consequently, in the Columbia and Snake river reservoirs, in-river obstructions associated with over-water structures such as jetty pilings can make salmonids more vulnerable to predation.

In contrast, Ward et al. (1994) found that developed sites (i.e., sites having floating platforms and pile-supported piers) do not increase predation by northern squawfish. Studying the effect of harbor development on juvenile salmon predation by northern squawfish in the lower Willamette River, Ward et al. (1994) found more northern squawfish in areas without development (i.e., where floating platforms and pile-supported piers are not present).

In terms of understanding the contrasting results, it is noteworthy that the hydrological conditions and shoreline configurations of the sites studied by Petersen et al. (1993) greatly differ from those of Ward et al. (1994). The study sites of Petersen et al. (1993) include free-flowing and high water velocity areas in eastern Washington, with the presence of in-water obstructions and gently sloping littoral terrain. On the other hand, the western Oregon study area of Ward et al. (1994) includes protected harbor areas with low water velocity and steeply sloped bottoms caused by dredging. This difference in study site conditions may help to explain the different results found.

Smallmouth predation on subyearling fall chinook salmon may also be significant in eastern Washington. For example, smallmouth bass accounted for 7 percent of the loss of late-migrating subyearling fall chinook salmon in Lower Granite Reservoir on the Snake River (Anglea 1997). Other research in the Columbia River basin also suggests that smallmouth bass may be a substantial predator of subyearling fall chinook salmon because both species rear in littoral habitat with low water velocities and therefore have a high potential for habitat overlap (Garland and Tiffan 1999; Curet 1993; Tabor et al. 1993).

Shallow near-shore water with a low gradient is an important habitat element for subyearling fall chinook salmon rearing in free-flowing areas of the Snake River. Bennett et al. (1992) reported that areas with low gradients were characteristic of juvenile chinook salmon rearing areas in

Little Goose Reservoir. Similarly, Dauble et al. (1989) found that shallow near-shore areas were preferred by subyearling fall chinook.

Juvenile chinook salmon use of the littoral zone is not unique to eastern Washington systems. In Lake Washington, chinook fry reportedly use shallow shoreline habitat characterized by a sandy bottom and no aquatic vegetation, with an absence of large woody debris (King County 2000).

Tabor et al. (1993), studying smallmouth bass and squawfish predation in the Columbia River, found that juvenile salmonids are the dominant prey item of smallmouth bass, and that crayfish are the dominant prey of northern squawfish. Tabor et al. (1993) also found a habitat overlap (i.e., a near-shore area where current velocities are reduced) between salmonids and smallmouth bass and suggested this as the factor that, when combined with the small size and high abundance of prey, may have contributed to the high salmonid predation rate observed. Smallmouth predation on juvenile salmonids due to habitat overlap has been reported previously (Poe et al. 1991).

Interestingly, Tabor et al. (1993) speculates that "predation on juvenile salmonids may be quite different in free-flowing and adjacent areas from predation in main-stem reservoir areas." If experimentally verified, one may expect this speculation to be consistent with the findings of Petersen et al. (1993). In fact, low incidence of predation on juvenile fall chinook salmon by smallmouth bass in all areas of the free-flowing Snake River already has been reported (Garland and Tiffan 1999).

Also supporting the conclusion of Tabor et al. (1993), Beamesderfer and Rieman (1988) found smallmouth bass more abundant in embayments. This is consistent with previous findings in the Columbia and Snake river reservoirs indicating that smallmouth bass are most abundant in protected embayments (Hjort et al. 1981; Palmer 1982, both as cited by Beamesderfer and Rieman 1988).

Hence, in river reservoirs of eastern Washington, smallmouth bass and northern pikeminnow predatory systems may operate at two different spatial scales, determined by the relative position occupied in reservoirs. These two spatial scales seem to consist of near-shore areas where current velocities are reduced, for smallmouth bass (Tabor et al. 1993), and free-flowing areas with low-velocity microhabitats produced by in-water-obstructions, for northern pikeminnow (Faler et al. 1988; Beamesderfer and Rieman 1988; and Petersen et al. 1993).

As stated earlier, the degree of habitat overlap may affect the rate of predation of smallmouth bass on juvenile salmonids. Studies of habitat use by subyearling fall chinook salmon conducted in reservoirs of the Snake River have shown a subyearling fall chinook salmon preference for littoral habitats. These results have been consistent regardless of the gear type and sampling technique employed (i.e., beach seining [Bennett et al. 1992; Curet 1993] and electrofishing [Garland and Tiffan 1999]).

In terms of avian predation on salmonids, no published data directly pertaining to the effect of over-water structures in freshwater environments were found. (See Phinney [1999] for an overview of avian predation throughout the Yakima River basin and a reference list of Columbia

River studies of avian predation on salmonids.) Nonetheless, a few indirect sources produced some related unpublished data.

Although common in Lake Washington, double-crested cormorants (*Phalacrocorax auritus*) rarely use docks or bulkheads for perching. On the other hand, gulls, also common in Lake Washington, perch on low decks (unpublished data cited by Kahler et al. 2000). Both double-crested cormorants and gulls are known predators of juvenile salmonids.

Cederholm et al. (2000) report that in 1997, a colony of 14,000 Caspian terns (*Sterna caspia*) used Rice Island (a dredge material disposal island) in the lower Columbia River for nesting and roosting, constituting the largest known colony in North America. Their data suggest that in 1997, the terns appeared to be largely dependent on juvenile salmonids for their dietary sustenance (mostly hatchery-originated). Cederholm et al. (2000) also found that although salmon is not their primary diet item, common murre (*Uria aalge*) would use salmon resources during food-stress conditions. In this regard, piscivorous birds are believed to be opportunistic feeders that use the available prey in a system (Modde et al. 1996). No information was found on the use of over-water structures by the Caspian tern or common murre.

Habitat type and location used by fish may determine bird predation success and thereby fish survival. Hence, fish that inhabit pelagic waters (e.g., rainbow trout) are more vulnerable to birds than substrate-oriented fish (e.g., brook trout; Matkowski 1989), because bird predation strategies may be limited by physical characteristics of the habitat such as amount of cover, depth, etc. In this regard, Wood and Hand (1985) found that cover reduces success of capture by one species of bird, the merganser (*Mergus merganser*). Therefore, over-water structures and related construction activities that modify the shoreline configuration (e.g., increasing the shoreline slope and eliminating shallow-water habitat refugia) could potentially affect predation rates on salmonids. This may occur, for example, if the shore-zone habitat and shallow habitat refugia are eliminated, forcing juvenile fish to venture into deeper waters where predator diving birds may have increased success. This hypothetical situation is of particular importance to juvenile chinook salmon, which have the greatest affinity to shore-zone shallow-water habitats (King County 2000; Garland and Tiffan 1999; Fresh 1999 personal communication; Curet 1993; Bennett et al. 1992; Healey 1991; Rondorf et al. 1990; Wydoski and Whitney 1979).

The presence of over-water structures may also influence the distribution of prey items for juvenile salmonids. In Lake Washington, benthic fish food organisms for salmonids, such as insect larvae, amphipods, and mollusks, have been suggested to prefer docks and piers in the absence of aquatic vegetation (White 1975). The presence of benthic organisms, while providing an increased source of food for juvenile salmonids, may also expose the salmonids to increased predation through increased aggregation. This is yet to be demonstrated.

Behavior

No evidence was found to indicate whether docks, piers, boathouses, or floats disrupt the migration of salmonids or cause a delay in migration in riverine systems or in lakes, and no literature sources were found addressing pier skirting. Numerous studies present data suggesting that docks, piers, and floats attract fish, and that this is the main effect of these over-water

structures on fish behavior. Anecdotal information from sport fishermen is consistent with these data. Also, it consistently emerged that where vegetation is lacking within a system, largemouth bass populations seek other forms of structures such as dock pilings. Alterations of predator–prey interactions associated with fish behavior that has been modified by human activities are discussed above in the predation section.

Knutsen and Ward (1991) studied waterway development factors (including floating platforms, piers, and associated pilings) and in-river activities (i.e., dredging and construction) with the potential to affect migration rate and distribution of juvenile salmonids migrating through the Portland harbor section of the Willamette River. They found that subyearling chinook salmon occur closer to shore at developed sites than at undeveloped sites. Although Knutsen and Ward (1991) found no evidence that waterway development directly attracts juvenile salmonids or slows migration, they argue that development that causes loss of preferred habitat may have subtle and indirect adverse effects. However, even relatively subtle anthropogenic changes are of concern because of their implications for cumulative effects (see habitat function section below).

Knutsen and Ward (1991) speculate that the amount of time that a particular race of juvenile salmonids spends migrating through Portland harbor might determine the effects of waterway development on their behavior. As juvenile steelhead migrate faster than yearling chinook salmon through Portland harbor, they are exposed to waterway development or activities over shorter time periods (Knutsen and Ward 1991). In addition, because subyearling chinook may be present in Portland harbor during most times of year, in-river activities have more potential to affect this portion of the salmon population (Knutsen and Ward 1991).

Ward et al. (1994) also studied the effects of waterway development on juvenile migration in the lower Willamette River, finding that floating platforms (on a riprap and sand shoreline) and pile-supported piers (on a clay shoreline) have no effect on juvenile salmonid migration. Although Ward et al. (1994) conclude that waterway development presents few risks to migrating salmonids, they recommend that dredging and construction be avoided in the spring when fish are out-migrating, in order to avoid potential construction-related adverse effects.

Several studies indicate that in both eastern and western Washington, juvenile chinook salmon prefer habitats that exhibit the following characteristics (Bennett et al. 1992; Curet 1993; Garland and Tiffan 1999; King County 2000):

- Shallow near-shore habitats with sandy bottom and no aquatic vegetation
- Near-shore shallow water with a low gradient in free-flowing areas
- Littoral habitat with low water velocities.

Hence, juvenile chinook salmon generally are adversely affected wherever these characteristics are modified by shoreline development.

Data from studies conducted in other systems indicate that shoreline development induces behavioral responses in fish. Beauchamp et al. (1994) studied the effect of shore-zone structures (i.e., piling-supported piers and rock-crib piers) on littoral fishes in Lake Tahoe. The piling-

supported piers consisted of 20- to 30-centimeter-diameter steel or wood, sunk into the substrate at approximately 5-meter intervals, with a solid deck on top. Piers of this construction provide simple submerged structures lacking complexity. The rock-crib piers consisted of a timber framework, filled with boulders and cobbles, providing habitat complexity in three dimensions (Beauchamp et al. 1994).

Beauchamp et al. (1994) found that piling-supported piers have no significant effect on the densities of any littoral fishes, whereas rock-cribs piers enhance both the density and diversity of fishes in the immediate area. However, this research was conducted at a time when the pier walkways were 2 to 3 meters above water surface and thus provided little or no shade (Beauchamp et al. 1994). The lack of shaded area may have been responsible in part for the low density of fish found, as other authors have shown that fish (particularly prey fish) use shaded areas under docks (Helfman 1979, 1981a).

With regard to fish attraction to shaded areas, Helfman (1979) studied fish attraction to shade-producing experimental floats in Cazenovia Lake, New York. These floats were placed in 3-meter deep water, among dense macrophyte vegetation, although the vegetation was cleared from the area below the floats. Helfman (1979) found that snorkeled-estimated fish densities were significantly higher under the floats than at the control and in adjacent areas, and the densities under floats were positively correlated with the float surface area. In his study, adult golden shiner (*Notemigonus crysoleucas)* and black crappie (*Promoxis nigromaculatus*) were observed near the float, whereas bluegill (*Lepomis macrochirus)* and pumpkinseed *L. gibbosus* were found beneath the float. Although fish were present under the floats during daytime and nighttime, their densities were lower at night and highest at midday, and little feeding activity was seen (Helfman 1979).

In a related study also in Cazenovia Lake, Helfman (1981a) found that the number of fish aggregating beneath shade-producing objects is directly proportional to the size of the objects (i.e., larger floats attract more fishes as more shade is produced). Helfman (1981a) speculates that "the amount (or depth) of shade produced was a determinant of the attraction phenomenon," which in general may significantly influence the advantage to fish of hovering under such structures. Helfman (1981a) deduces that tactile attraction to the physical structure of the floats is not involved, because fish were not attracted to control floats that consisted of wood frame only. He further indicates that because large numbers of fish were commonly found under docks and under overhanging trees that were supported above the water (i.e., objects located at a fixed height that provide shade without the tactile stimulus), the observed behavior cannot be attributed to tactile attraction.

Consistent with the hypothesis that fish are attracted to the shade produced by on- and over-water structures are recent research data presented during a conference titled *Selected Ongoing and Recent Research on Chinook Salmon in the Greater lake Washington Watershed*, November 8–9, 2000 (King County 2000). The synopsis of findings included data on the factors influencing the decline in all life stages of chinook salmon. These data indicate that migrating adult salmon hold at various locations within the Sammamish River, and that most of these locations are in the shaded area underneath bridges.

The findings discussed in the preceding two paragraphs suggest that the attraction of fish (including chinook salmon and largemouth bass) to floating or overhanging objects is linked to the shade produced by the object rather than to the tactile stimulus. Also, these data suggest that the larger the floating object, the greater the shaded area, and thus the greater the number of fish attracted to such objects, potentially altering fish distribution and aggregation.

An alternative explanation of fish attraction to on- and over-water structures is that both the structures and the shade they cast may provide fishes with physical reference points for orientation (Fresh 2000 personal communication).

In terms of bass habitat preferences in relation to docks and piers, Bryan and Scarnecchia (1992) compared the abundance of juvenile fish assemblages between naturally vegetated sites and developed sites (i.e., with residential structures, boat docks, and manmade beaches) in Spirit Lake, Iowa. Bryan and Scarnecchia (1992) found species richness and total fish abundance (including largemouth bass abundance) consistently greater in natural sites than in developed sites. In contrast, smallmouth bass were consistently found in greater abundance in developed sites.

Studies conducted in Lake Sammamish by Pflug and Pauley (1984) found that smallmouth bass nest sites (located in 1.5 to 2.5 meters of water) were typically situated next to benthic structures such as isolated boulders, logs or dock pilings. Similar results were found by Helfman (1981b) in Cazenovia Lake and Skaneateles Lake, New York, and Mirror Lake, New Hampshire.

Stein (1970) found that in Lake Washington, largemouth bass prefer areas of heavy log and brush cover to all other habitat types, including docks, but often occur under docks in early spring. In Lake Sammamish, largemouth prefer moderate to dense vegetation and silt or sand substrate, and nests are constructed at depths from 0.6 to 1.5 meters, in vegetated areas with soft sediment or gravel substrate on moderate to steep slopes (Pflug 1981). In Cazenovia Lake and Skaneateles Lake, New York, and Mirror Lake, New Hampshire, juvenile largemouth bass also use macrophytes (in depths less than 1 meter) for protection against predators (Helfman 1981b).

The preceding discussion clearly indicates a largemouth bass affinity for aquatic macrophytes, thus posing a question of the implications of removing such vegetation for the construction of over-water structures. The studies discussed below provide some insight into this question.

Colle et al. (1989) studied the distribution of largemouth bass in Lake Balding, Florida after all submerged aquatic vegetation was eradicated by grass carp. Movements of 16 largemouth bass were monitored using radio telemetry from April 11, 1986 to April 4, 1987. A distinct depth segregation was evident for the radio-tagged largemouth bass, which were divided into three groups for purposes of analysis: in-shore (water depth 0–2.0 meters), mid-depth (0–3.5 meters), and offshore (more than 3.5 meters). Colle et al. (1989) found that six largemouth bass had home ranges in the in-shore zone extending 15 to 70 meters from shore. Five largemouth bass used both the in-shore region and the mid-depth region, coinciding with the maximum depth of the blue-green algae in the lake (*Lyngbya* sp). Five largemouth bass used the offshore region. In-shore largemouth bass preferred habitat near a water tupelo (*Nyssa aquatica*) area and avoided bare sand areas. In-shore fish had home ranges averaging 4.1 hectares, whereas offshore fish had

home ranges averaging 21 hectares. Largemouth bass that used the entire area out to the 3.5-meter contour preferred the 11 piers in the lake, especially the mid-depth group. Largemouth bass associated with piers moved more than other fish and were associated with multiple piers. Adult largemouth bass using an in-shore fringe of water tupelo as an underwater structure were relatively sedentary (Colle et al. 1989).

Based on these data, Colle et al. (1989) conclude that a component of the largemouth bass population preferred the artificial habitat provided by piers. Colle et al. (1989) suggest that the fact that offshore largemouth bass had a greater home range (i.e., 21 hectares) than the in-shore largemouth bass may be explained by a difference in prey density and structure abundance. That is, prey density was probably lower in the offshore region than in the in-shore region, thereby forcing largemouth bass to shift from ambush to active hunting, because of the absence of underwater structures offshore (Colle et al. 1989).

Both largemouth and smallmouth bass are structurally oriented for both foraging and spawning (Colle et al. 1989; Helfman 1981b; Pflug 1981; Pflug and Pauley 1984; and Stein 1970). They will use docks, piers, and associated pilings in the absence of natural structures. It is not clear which elements of these structures attract them. Additional evidence from published and unpublished data on the behavioral response of bass to docks, piers, and associated pilings can be found in Kahler et al. (2000).

A possible attracting feature of docks, piers, and associated pilings is related to food-web interactions of prey fishes. Chmura and Ross (1978) address the environmental impacts of several in-water and over-water structures, suggesting that as fouling communities grow on docks and piers, they add to the biological productivity of the area (also suggested by Mulvihill et al. 1980). In various rivers and lakes of Washington, it is not uncommon to see fish (including juvenile salmonids) feeding upon periphyton, insects, and macroinvertebrates adhered to dock and pier pilings (Carrasquero 2000 unpublished observation). Thus, associated in-water dock and pier structures that provide substrate for growth of fish food organisms can alter the behavior of both prey and predator species. This is further discussed in the following sections.

Habitat Function

With regard to habitat function, one might argue that the impact of over-water structures is not attributed exclusively to the structure but rather to the resulting changes induced by the structure and associated activities. Within this context it has been proposed that “fish do not respond to shoreline structures; rather, they respond to a suite of habitat characteristics that are the result of the structure, changes to the riparian zone associated with its placement (vegetation and woody structure removal), and often, intensive riparian zone management that occurs on developed properties” (Jennings et al. 1999).

In this white paper, habitat function is defined as the attributes of the ecosystem that are created and maintained by biological, chemical, and physical processes through the interaction of the various ecosystem components (e.g., shore-zone, shoreline, and riparian). Individual habitat modifications may lead to only small changes in local fish species richness, but the fish

assemblage structures respond to the incremental changes that accumulate over time within a given basin (Jennings et al. 1999).

In this regard, shoreline development (e.g., construction of docks and piers) in Lake Washington has increasingly eliminated shallow-water habitat (Kahler et al. 2000), particularly affecting juvenile chinook salmon. Once the shoreline is developed, docks and associated pilings may provide shallow-water cover for juvenile salmon, although they may also provide cover for predators (see Cooper and Crowder 1979). Thus, this type of shoreline modification may affect not only the physical habitat but also the various elements of the biological community and the habitat function.

Lange (1999) studied the effects of shoreline residential development on littoral fish abundance (i.e., fish catches) and species richness at different scales of observation (i.e., sampling site distances of 122, 244, and 488 meters) in Lake Simcoe, Ontario, Canada. He found that fish aggregated near permanent rock-crib-supported docks and avoided shoreline areas with bank stabilization structures (i.e., retaining walls built above the ordinary high water line). He also found that in shorelines where multiple features such as docks and break walls were present, fish abundance was positively correlated and species richness negatively correlated with these structures. Features such as docks and break walls combined with boathouses were generally associated with a decrease in both abundance and richness of fish species (Lange 1999).

In addition, Lange (1999) found that shoreline development was associated with sites having hard substrate (i.e., boulder, rubble, and gravel) and an absence of aquatic vegetation. Abundance and richness of fish had a significant positive correlation with both submerged vegetation and the presence of soft substrate types such sand, mud, and detritus, but were negatively correlated with hard substrate types.

Interestingly, Lange (1999) also found reduced fish abundance and species richness with increased density and diversity of shoreline residential development. He found that the specific development features associated with this pattern changed with the scale of observation, indicating that fish respond to both proximally and distantly located habitat alteration.

These results suggest that the cumulative effects of shoreline development might influence fish abundance and species richness. The results also suggest that shoreline alteration can affect fish abundance and species richness regardless of the relative distance of the development from the study site. This clearly illustrates the importance of considering the cumulative effects of even small new residential over-water structures that may be proposed in systems where numerous over-water structures already exist.

Some studies suggest that in the absence of certain predatory species such as bass, piers constructed in shore-zones may have a minimal influence on fish. For example, Beauchamp et al. (1994) studied the effect of shore-zone structures on the density of littoral-zone fishes in Lake Tahoe, California/Nevada. They found that piling-supported piers have no significant effect on the densities of any littoral fish, in contrast to rock-crib piers (i.e., timber framework filled with boulders and cobbles), which actually enhance both the density and diversity of fishes. Beauchamp et al. (1994) suggest that the difference in fish density associated with these two

types of piers might be attributed to the greater habitat complexity of rock-crib piers due to the interstitial spaces within the boulders.

Similarly, Lange (1999), studying the effect of shoreline residential development on littoral fishes, found that fish abundance and species richness were higher in rock-crib-supported docks (i.e., permanent docks) than in docks supported by pillars (i.e., seasonal docks).

One may argue that this response should be seen as an adverse effect, because it promotes anthropogenically induced fish aggregation. It is not known whether artificial structures used for habitat restoration in streams actually contribute to the enhancement of the targeted fish species, or whether such structures merely provide a focal point for fish distribution (King County 2000; Beschta et al. 1994; Everest and Sedell 1984; Kauffman et al. 1993; Reeves and Roelofs 1982). A high incidence of failure of artificial habitat structures has been reported for streams of the Pacific Northwest (Fissell and Nawa 1992). Artificial structures that alter fish distribution may increase salmonid predation rates by also aggregating predatory fish. Indeed, to be effective, artificial habitat structures used in restoration projects must be designed with attention to the needs of resident and desired species and consideration of the prevailing physical factors in a particular river or stream (Howe 1997). For example, recent snorkel observations at restoration sites in slow-flowing areas of the Sammamish River indicate that added large woody debris is providing habitat for predatory species rather than for salmon (King County 2000).

Based on qualitative observations of piscivorous fishes in Lake Joseph, Ontario, Canada, Brown (1998) suggested that the presence of predators around crib structures is a response to the abundance of forage fishes. She also studied the influences of shoreline residential development (i.e., docks and boathouses) and physical habitat on fish density in the Lake Joseph littoral fringe zone (i.e., 0–2.5 meters offshore with average depth of 0.53 meters). She found that coarse woody debris (CWD) was the most important habitat variable predicting density of total forage fishes. Sites with the higher number of shoreline structures had the lower densities of coarse woody debris. She also found that crib structures increased densities of forage fishes (<100 millimeters) in the littoral fringe on exposed shorelines or in areas where coarse woody debris had been removed.

Brown (1998) also found that forage fish density in the fringe zone and around shoreline structures increased with the addition of shoreline structures. She attributes this result to the added structural complexity that these structures provide, suggesting that this may increase protection from predators and from physical elements such as wave energy. She speculates that interstitial spaces within crib structures provided refuge from waves and predation for small fish along exposed shorelines.

As noted previously, shoreline development, with its suite of associated human activities and presence of artificial structures, degrades aquatic communities. In the review of habitat function above, individual over-water structures and overall shoreline development are discussed. Bryan and Scarnecchia (1992) studied species richness and juvenile fish abundance (young-of-the-year, YOY) in developed areas (i.e., with docks present) versus undeveloped areas (i.e., naturally vegetated), in Spirit Lake, Iowa. Bryan and Scarnecchia (1992) consistently found greater species richness and total juvenile fish abundance in natural sites than in developed sites in both

near-shore and intermediate depth zones (0–1 meters and 1–2 meters, respectively). However, they found little difference between natural and developed sites in the offshore depth zones (2–3 meters). Throughout this study, juvenile fishes were more abundant where macrophyte abundance was greater (i.e., where vegetation was not removed for development). Smallmouth bass was the only species consistently found in equal or greater abundance in developed sites, which Bryan and Scarnecchia (1992) attribute to its lack of reliance on vegetative cover.

Hence, one might expect that if shore-zone development (in particular, construction of docks and associated in-water structures) eliminates the macrophyte vegetation, it might adversely affect fish species assemblages and young-of-the-year survival, particularly of vegetation-dependent species. In this regard, DiCostanzo (1957, as cited by Bryan and Scarnecchia 1992) speculate that insofar as juvenile fish use vegetation beds to avoid predation and to feed during their first summer of life, human activities that eliminate such habitat may reduce juvenile survival.

Collins et al. (1995) compare fish use of fringe zones adjacent to lawns with their use of undeveloped shorelines in Lake Rosseau, Ontario. They found that fish exhibit much less rearing and feeding activity in lawn-edge zones, where wave disturbance is greater, than in undeveloped habitats. Based on their results, Collins et al. (1995) identify shallow water as critical for foraging, refuge, and migration of small fishes (i.e., less than 100 centimeters total length).

Loss of riparian and wetland vegetation resulting from the construction of over-water structures and activities associated with shore-zone development has an adverse effect on water temperature. An increase in water temperature can promote temperature barriers, thus limiting the range and survival of certain fish species (Donald and Alger 1993). Indeed, results of field studies conducted in streams, rivers, and lakes suggest that the distribution and survival of certain species of trout, including bull trout (*Salvelinus confluentus*), are limited by water temperature (Fraley and Shepard 1989; Goetz 1989; Donald and Alger 1993; Rieman and McIntyre 1993; Ratliff et al. 1996; McPhail and Baxter 1996). In general, bull trout are uncommon where water temperature exceeds 15°C for more than a few days per year. In fact, a study of distribution of juvenile bull trout in the upper Cedar River and upper Yakima River drainages found that this species was absent in streams where summer water temperatures exceeded 14°C (Goetz 1997).

Only one source was found addressing benthic communities in the context of the effects of over-water structures. White (1975) studied the influence of shoreline development on fish and benthic fish food organisms in Lake Washington. He found that during the fall, population densities for insect larvae, mollusks, and amphipods were significantly higher outside the piers than under the piers. Conversely, in spring, population densities for mollusks, amphipods, and insects other than Chironomidae larvae (and presumably other grazing insects) were all significantly higher under the piers.

White (1975) suggests that the observed seasonal difference may be due to a combination of factors, including food availability, light, and life histories. The organisms whose partial or complete life cycles are related to aquatic vegetation did not avoid docks during the fall, but rather, responded to the available vegetation outside the docks (White 1975). He attributed the

spring preference (for protection, food, and shelter) of areas under docks and piers to the spring vegetation lacking the heavy growth observed during the fall. Therefore, during the spring, the docks offered a viable alternative type of structure to that provided by the vegetation during the fall (White 1975).

In White's (1975) study, chironomids, an important food item for juvenile salmonids, showed no difference between population densities under and outside the piers. White (1975) did not discuss the potential implication of his results on the survival of juvenile salmonids, particularly juvenile chinook salmon. Interestingly, the samples he obtained from sites without docks ("natural zones") indicated that chironomids were the most abundant organism at these sites. Clearly, his suggestion that docks offer an alternative type of structure to that provided by vegetation does not seem to apply for Chironomidae larvae.

Chmura and Ross (1978) state that "piers, docks, and wharves can have detrimental effects on both salt and freshwater marshes by blocking light and water flow . . . especially if piers are supported by closed (solid) bases." The associated problem of use of treated wood is also mentioned by Chmura and Ross (1978).

Marinas

As defined by Mulvihill et al. (1980), "a harbor is a protected water area offering a place for safety to vessels. Small craft harbors are protected areas whose depth and maneuvering area limit usage to small craft. 'Marina' is used synonymously with small craft harbor, but generally refers to harbors for pleasure crafts." Although marinas might be seen as over-water structures typical of marine environments, in Washington there are marinas in freshwater environments as well.

During the preparation of this white paper, Kahler et al. (2000) published *A Summary of the Effects of Bulkheads, Piers, and Other Artificial Structures on ESA-Listed Salmonids in Lakes*. This summary provides a comprehensive literature review of published and unpublished data primarily focused on Lake Washington and Lake Sammamish. Although marinas are not explicitly addressed in this review, there is a discussion of the effects of piers, bulkheads, lighting, chemical contaminants, and recreational and construction activities on fish and their habitat, which relates to the potential environmental effect.

Only two papers, both literature reviews, were found that directly address the environmental impact of marinas on freshwater environments (Chmura and Ross 1978; Mulvihill et al. 1980). The Chmura and Ross (1978) paper includes 66 literature citations and is organized by structure type, type of effect, and management considerations. The Mulvihill et al. (1980) paper includes 555 information sources, provides a summary of the literature, and is organized by coastal region case history studies. This review includes environmental impacts and biological impacts, the latter divided by construction, chronic, and cumulative effects. The Mulvihill et al. (1980) review is focused on the impact on the coastal environment and is somewhat outdated, particularly from an environmental viewpoint. Both the Chmura and Ross (1978) and Mulvihill et al. (1980) reviews address issues related to marinas in freshwater, estuarine, and marine environments.

Chmura and Ross (1978) identify both adverse and beneficial impacts caused by marinas. Among the adverse effects, the primary impacts cited are habitat loss, pollution resulting from stormwater runoff, and aesthetic (visual) pollution. Among beneficial impacts, the authors mention concentration of shoreline development ("as opposed to many scattered private docks"), and increased habitat diversity generated where substrate is provided for fouling organisms. Although habitat loss is seen as a primary adverse impact, the authors state that marinas also "provide an artificial habitat with its own unique environment," and that associated in-water structures "can add to the biological productivity of the area and attract fish." While documentation for this statement is not provided, an examination of the Chmura and Ross (1978) reference list suggests that marine or estuarine studies may be the source of this information. Nonetheless, the fish attraction noted by Chmura and Ross (1978) is consistent with the supporting evidence found elsewhere for docks, piers, and floats (see discussion above). However, the Chmura and Ross (1978) review provides no discussion of the potential adverse effect of such fish attraction (i.e., an increase in predation rate).

Dredging is addressed elsewhere in this series of white papers. Therefore, although dredging issues are discussed by Chmura and Ross (1978), only the general adverse effects of dredging associated with over-water structures are listed here:

- Promotion of water turbidity
- Promotion of onsite and offsite pollution
- Reduced oxygen content
- Induced burial of organisms
- Disruption and removal of bottom sediment, and alteration of benthic communities.

The Mulvihill et al. (1980) review provides an examination of the biological and physical impacts of marina placement. Harbors cause loss of benthic succession and impoverishment of substrate and water quality. Furthermore, elimination of wetland areas as productive habitat may result from cumulative effects of harbors constructed in wetland areas (Mulvihill et al.1980).

Wharves and Pilings

Although usually associated with docks, piers, and marinas, wharves and pilings possess their own mechanism of impact on the shore-zone habitat function and structure. Because their effects have been studied for the same categories of response as for docks and piers, some pertinent information discussed in the docks, piers, and floats section above is omitted here.

Empirical indirect evidence indicates predatory fish attraction to pilings and wharves by the following two mechanisms:

- Modification of the underwater habitat complexity, in which case predatory fish are attracted to the physical structure itself (i.e., pilings)

- Physical disruption of the water flow (i.e., back-eddies, backwater, or shear flow), resulting from flow obstruction by such structures.

These two mechanisms seem to be controlled by the shoreline configuration and its degree of natural protection, and also by the hydrological characteristics of the system. The empirical data also indicate a species-specific response of the involved predatory fish. For example, northern pikeminnow is attracted to back-eddies, backwater, or shear flow created by piling structures in free-flowing areas; whereas smallmouth bass is attracted to the piling structure. Some pertinent information in this regard is included above in the discussion of docks and piers and therefore is not discussed here.

Predation

Petersen et al. (1993) found that in the Colombia and Snake river reservoirs, northern squawfish feed primarily on juvenile salmonids and are associated with back-eddies created by jetty pilings. In this regard, Petersen et al. (1993) suggest that in the Columbia River, in-river obstructions below the Bonneville Dam (e.g., pilings) might make salmonids more vulnerable to predation because of the potential for aggregation in back-eddies they create. It is unknown whether this aggregation affects the out-migration rate of juvenile salmonids. Nevertheless, the implication of this behavioral response in terms of increased predation rates on juvenile salmonids may have even more profound consequences on their freshwater survival. This is because juvenile salmonids whose migratory behavior is delayed by aggregating structures may experience increased exposure to predators.

In contrast, Ward et al. (1994), studying the effect of harbor development on juvenile salmon migration and predation by northern squawfish in the lower Willamette River, found that offshore wharves supported by pilings do not have an effect on juvenile salmonid migration. The difference in location between the studies of Petersen et al. (1993) and Ward et al. (1994) may explain these contrasting results. Petersen et al. (1993) focused their study in the Columbia River in an area of free-flowing water in which jetty pilings constitute flow obstructions and create back-eddies. Conversely, the study sites of Ward et al. (1994) are located within a protected area of Portland Harbor in the Willamette River.

As with docks, piers, floats, and marinas, no studies on the effect of pilings and wharves on avian predation were found. Some unpublished data indicate that in Lake Washington, double-crested cormorants perch on individual piles (Kahler et al. 2000).

Habitat Function

Knutsen and Ward (1991) studied the behavior of juvenile salmonids (chinook and steelhead) migrating through the Willamette River at developed sites (i.e., with presence of wharves, pilings, floating platforms, riprap, and vertical walls) and undeveloped sites (i.e., no structure present, and mostly clay, silt, or sand bottoms, steeply sloped from dredging). They report that although there appears to be a species-specific difference between habitat occupied by migrating juveniles at undeveloped sites versus that at developed sites, variables that characterize such habitats seem to have a temporal variation.

To explain, subyearling chinook salmon were found closer to the shore in developed sites than in undeveloped sites, particularly in one site containing a wharf supported by closely spaced pilings

(i.e., less than 10 feet apart; Knutsen and Ward 1991). This site had a completely riprapped shoreline and a shallow backwater, with a soft bottom at the downstream end of the wharf. The authors do not specify whether this backwater might have formed as a result of the existing in-water obstructions. However, the downstream location of the wharf and the bottom characteristics suggest that this backwater and associated deposition area (i.e., soft bottom) were at least partially related to the presence of the wharf. Therefore, this, and the fact that at this site the shoreline was completely riprapped, preclude possible inference of the (sole) effect of the wharf.

In general, Knutsen and Ward (1991) found that yearling chinook salmon were closer to the surface than were subyearling chinook salmon at developed sites. Subyearling chinook salmon were found closer to the shore in developed sites than in undeveloped sites. However, results from this study are inconclusive, because the authors are not able to infer whether the observed distribution is related to increased water depth at developed sites or to the presence of developments themselves (Knutsen and Ward 1991).

Nonetheless, one may argue that for future construction, at least the potential physical effect (such as creation of backwater and associated deposition areas) should be considered when placing this type of in-water structure. Increased fine sediments and detritus loading expected to occur in deposition areas such as this could adversely affect bottom-dwelling communities by embedding organisms and promoting anoxic microzones, making bottom habitats unsuitable for benthic organisms.

Although effects of treated wood piling are not addressed within the scope of this white paper, a few of the sources reviewed address this issue as an associated problem of wharves and piling structures. Within this context, two studies are of particular interest: Chmura and Ross (1978) and White (1975).

In their literature review regarding effects of marinas, Chmura and Ross (1978) found that wharves have been reported to be potentially detrimental, through blockage of light and through adverse impacts on water quality (and thereby habitat conditions) due to the treated wood pilings. Also, pilings have been reported to provide suitable substrate for periphyton and some macroalgae species growth (Chmura and Ross 1978; White 1975) and therefore have potential for habitat structure modification.

White (1975) used five experimental pilings (one control, one treated with creosote, one with ammoniacal copper arsenate, and two with pentachlorophenol) to study periphyton attachment in Lake Washington. After one month, diatoms occurred more frequently than other periphyton on all the pilings. The alga, *Cymbella* sp, was the only algal species common to all pilings. The creosote-treated piling had the greatest number of algal species growing on its surface. After one year, all but the ammoniacal copper arsenate-treated piling had extensive algal encrustment, along with many amphipods, limpets, and watermites.

This research suggests that periphyton, algae, and eventually macroinvertebrate species can colonize even treated pilings. Juvenile salmonids as well as other fish species can feed upon these macroinvertebrates species. Therefore, the presence of this source of food on piling

surfaces may be a contributing element of distribution of fish prey and thereby fish predators around piling structures.

Log Booms and Log Rafts

The number and body sizes of organisms using the area influenced by a floating object are directly related to the surface area of the object (Helfman 1979, 1981a). Log booms and log rafts are capable of producing a shaded area beneath their surfaces with the consequent potential for altering ecosystem functions. Therefore one would expect a relationship corresponding to that reported by Helfman (1979, 1981a) in relation to the dimensions of log booms and log rafts found in lakes and rivers of Washington. If such a relationship exists, then it is plausible that fish predator–prey interactions similar to those suggested for docks and piers may also exist in response to log booms and log rafts. Unfortunately, no published data were found directly addressing the effects of these two types of on-water structures on fish predation or behavior.

Regarding avian predation, no empirical data were found indicating a relationship between log booms or rafts and predation on fish (nor were data found showing a relationship between these structures and modification of fish behavior [e.g., migration] in freshwater environments). However, log booms have been suggested as potentially linked to avian predation on salmonids by providing perch sites for predatory birds in Lake Washington and Lake Union. In Lake Union, double-crested cormorants perch on the log booms rather than docks, bulkheads, or pilings along the lakeshore (Warner 2000 personal communication, as cited by Kahler et al. 2000).

Habitat Function

Three reports were found addressing the effects of log booms or log rafts in freshwater. Schuytema and Shankland (1976) studied the effects of log handling and storage on water quality and on bottom-dwelling communities at five log-rafting areas. The bottom-dwelling community included “animals” (i.e., insects, macroinvertebrates, and mollusks), “attached algae” (i.e., periphyton), and “slime growth” (i.e., bacteria of the genus *Sphaerotilus*). The study area included Steamboat and Elochoman sloughs on the north side of the Columbia River, about 4 miles downstream of Cathlamet, Washington; Coal Creek Slough on the northern edge of the Columbia River downstream of Longview, Washington; and the western edge of the Multnomah channel, which is part of the Willamette River near Scappose, Oregon.

Schuytema and Shankland (1976) found loss of bark to be the most significant problem associated with log rafting, with effects dependent on the intensity of the activity and the flushing action of the holding water body (i.e., slough, lake, or river). Sludgeworms, which are common inhabitants of areas subjected to organic enrichment or pollution, were consistently present in areas where a high volume of bark occurred (Schuytema and Shankland 1976). In general, they found that the biologically degraded sites identified in the study had fewer kinds of organisms, higher population density, and more bark and detritus.

Schuytema and Shankland (1976) speculate that rafting activities have an adverse effect upon bottom-dwelling organisms in some reaches where log rafts have been present. The

decomposition of the log detrital material will "probably produce a habitat more conducive to the establishment of animal populations tolerant to organically enriched conditions" (Schuytema and Shankland 1976). They also found that dissolved oxygen varies with the location depending on the amount of water flow and detritus, and speculate that in areas without adequate water flow (e.g., sloughs), log rafts could adversely affect the population of bottom-dwelling organisms (Schuytema and Shankland 1976).

Schuytema and Shankland (1976) found that dredging to remove the bark was a regularly associated activity of the log rafting sites, and although not discussed in their report, it should be considered as an associated environmental problem of log rafting practices. The implication of dredging in freshwater environments is discussed in a separate white paper within this series.

Similar results have been reported for logs stored in water. Schaumburg (1973) found loss of bark from water-stored logs to be the most significant problem, as benthic depositions exert oxygen demand and may influence the biology of the benthic zone. He also found that leachates from logs held in water storage contained mostly organic substances, and that these substances exerted both chemical and biological oxygen demand. In relatively stagnant areas, the leaching rate continually decreased due to the increased levels of dissolved organic substances, whereas in flowing water the leaching rate was nearly constant for at least 80 days (Schaumburg 1973).

In terms of toxicity, Schaumburg (1973), conducting laboratory toxicity tests, found that leachate from ponderosa pine, hemlock, and older Douglas fir produced no toxicity to chinook salmon or rainbow trout fry during 96-hour bioassay studies. However, log sections without bark were found to be more toxic than comparable sections with bark intact. The 96-hour toxicity test values ranged from 20 to 93 percent (volume/volume) for leachate from young Douglas fir logs. The author speculates that the slight toxicity for young Douglas fir logs may be due to a much greater release of soluble substances into the holding water (i.e., where the fish were held during the test). No information was found addressing bioaccumulation of toxicants and their possible adverse impacts on salmonids.

Based on his findings, Schaumburg (1973) concludes that leachates from logs held in water storage do not represent a significant water quality problem. However he states that "the severity of pollution problems associated with the storage of logs depends upon the quantity of logs stored, the age, and the species of the log and flow rate of the holding water." Unfortunately, this author did not conduct toxicity tests in the field, thereby limiting the applicability of his results to laboratory settings. For example, in storage sites, and under certain physical/chemical conditions of temperature, pH, and dissolved oxygen, log leachate in interaction with naturally occurring substances (e.g., sulfurous compounds) may have additive effects, resulting in a higher toxicity to fish.

Pacific Northwest Pollution Control Council (1971) prepared a literature review of the physical influences of log rafts and their effects on water quality. They found that bark originating from rafting and storage of logs (about 5 percent of each log's bark layer) is a concern because of its potential to increase organic material in the water (see Pacific Northwest Pollution Control Council [1971] for the complete review of related literature and for proposed guidelines and recommendations). A further concern is the long-lasting adverse effects of bark residue in lakes

due to the time it may take for its complete biodegradation. For example, within a lake on the Oregon coast that was used for log handling in the early 1900s, the remaining bark residue made habitat unsuitable for several decades thereafter (Pacific Northwest Pollution Control Council 1971).

The primary problems cited by Pacific Northwest Pollution Control Council (1971) associated with bark debris in water are consistent with those cited in the two studies previously discussed. The identified problems related to the accumulation of bark on the bottom are 1) a consequent reduction in dissolved oxygen in the overlying water, and corresponding creation of an anaerobic layer near the bottom, resulting in the generation of toxic sulfide compounds; and 2) burial of benthic communities.

The secondary problem cited by Pacific Northwest Pollution Control Council (1971) is associated with leachates (i.e., release of soluble organic compounds). These leachates are reported to substantially decrease the dissolved oxygen.

Riprap and Retaining Walls

The effects of riprap and retaining walls (i.e., bulkheads) have been broadly studied in marine environments, particularly when used as the means to armor the shoreline for protection against wave-induced erosion (from ambient waves and boat wakes). In contrast, very few sources were found directly addressing the environmental effect of these structures in freshwater environments.

In general, bulkheads are constructed to hold fill and to protect the upland by taking the brunt of wave energy (Chmura and Ross 1978). In doing so, bulkheads prevent natural seepage of groundwater into local waters and create reflection waves which disturb sediments, and encourage scouring at the base of the bulkheads (Chmura and Ross 1978).

The construction of bulkheads promotes loss of terrestrial, shallow-water, and benthic habitat. Such construction involves the use of heavy equipment that causes physical disturbance, noise, and air pollution at the site.

The physical disturbance and damage to fish and wildlife habitat caused by the construction of bulkheads depends upon 1) the type of habitat in the area before construction, 2) the shoreline location where the structure is placed, 3) the size of the structure, and 4) the construction methods. In addition, the bulkhead and associated backfilling bury established terrestrial and shallow-water flora and fauna (Mulvihill et al. 1980).

The construction of bulkheads and associated activities also cause local erosion, new sediment deposits in the vicinity of the structure, turbidity, and hence water quality degradation. New sediment deposits are often silty and thus can destroy spawning areas, smother benthic organisms, and reduce bottom habitat diversity and food supply (Mulvihill et al. 1980).

Bulkheads also promote erosion of the foreshore because of an increase in wave energy due to waves reflecting off the face of the structure. Bulkheads can also promote erosion of adjacent beaches and interfere with sand recruitment processes (Mulvihill et al. 1980).

Bulkheads constructed in wetland areas can cause extensive damage to fishes and wildlife by the following mechanisms: 1) covering narrow fringe marshes, 2) covering the waterfront edge, and 3) altering water circulation in larger shore-front marshes (Mulvihill et al. 1980).

Riprap and retaining walls are typically associated elements of over-water structures that exert a direct mechanism of impact on marine environments. These associated elements are commonly incorporated into dock and pier design as mitigation measures providing permanent erosion control of shoreline areas disturbed by the project construction. However, the empirical data found in this literature review suggest that riprap and retaining walls may produce adverse responses in aquatic organisms.

The following quotation from Jennings et al. (1999) best illustrates the ecological significance of the use of riprap and retaining walls in lakes:

> *Although riprap may increase structure complexity at the scale of the individual site, when viewed at the scale of the whole lake, conversion of the entire shoreline to this one habitat type does not increase overall habitat diversity; rather, it causes a reduction. Because of this reduction of habitat diversity, conversion of unaltered shoreline to riprap should not be viewed as enhancement. However, when erosion control is necessary, riprap appears to provide beneficial fish habitat compared with retaining walls.*

Scientific information on juvenile salmonid ecology from ongoing research indicates that in both western and eastern Washington, shallow-water near-shore habitats are important sites for migration of juvenile salmonids, particularly chinook (King County 2000; Garland and Tiffan 1999; Curet 1993; Fresh 1999 personal communication; Bennett et al. 1992; Healey 1991; Rondorf et al. 1990; Dauble et al. 1989; Wydoski and Whitney 1979). These sites are important because of the abundance of prey resources and refuge from predators. Consequently, loss of rearing and foraging habitat in the shore-zone lentic and lotic freshwater environments may increase juvenile salmonid exposure to potential predators, particularly in freshwater systems such as the reservoirs of the Columbia and Snake rivers, which are used by juvenile salmonids as migratory corridors.

In the context of the effects of shoreline armoring, and comparing retaining wall versus riprap bulkheads, sites next to retaining walls tend to be deeper, primarily because the structures are usually placed below the ordinary high water mark and then backfilled. This effectively pushes the shoreline out from its original location resulting in a corresponding increase in water depth of the littoral zone. Given that, as discussed above, out-migrating juvenile salmonids (particularly chinook) use shallow-water habitats for rearing, foraging, and migration, one may argue that retaining walls may disrupt juvenile salmonid migration. In turn, the cumulative impact of this migration disruption may be an overall reduction in survival rate, as forcing juveniles into deeper water potentially affects their survival by limiting prey resource availability, thereby decreasing

their growth rate, and also by increasing their exposure to predators, thereby increasing the predation rate.

Although riprap bulkheads may cause less loss of shallow water habitats than retaining walls, because of the interstitial spaces of their more complex three-dimensional structures, they also may provide concealing habitat to salmonid predators, such as some species of sculpin (Kahler et al. 2000).

Habitat Function

Jennings et al. (1999), studying the relationship between habitat modification and fish assemblage, compared three types of sites in 17 Wisconsin lakes: shoreline modified by the addition of riprap; shoreline modified by the construction of a vertical retaining wall; and unarmored sites. They found that sites with riprap contained more fish species than sites in which retaining walls were constructed and, than unarmored sites. This is because riprap provides more habitat complexity (i.e., interstitial spaces for cover and food production) than retaining walls (Jennings et al. 1999). However, the authors cautioned that their results may have been an artifact of confounding variables (scale of the investigation, heterogeneity of the unarmored sites, and the increased effort required to assess species richness at unarmored sites). Beauchamp et al. (1994) also observed fish preferences for complex habitats in the context of rock-crib piers.

It should be emphasized that although shoreline armored with riprap may provide more habitat complexity than retaining walls, riprap and most manmade structures are not comparable substitutes for naturally occurring structures and aquatic vegetation. The reason may be that from the habitat viewpoint, manmade structures only simulate physical attributes at best, but lack the chemical and biological attributes of, for example, natural wood. Naturally occurring structures such as small and coarse woody debris, as well as aquatic vegetation, possess not only unique physical characteristics contributing to habitat complexity, but also chemical and biological characteristics necessary for healthy food web and predator–prey interactions (e.g., nutrients and substrate for microinvertebrates and food for prey species).

With regard to salmonids, avoidance of armored shorelines rather than aggregation has been reported (Garland and Tiffan 1999). Garland and Tiffan (1999), studying near-shore habitat use by subyearling fall chinook salmon in the Snake River, found that this species avoided bedrock cliffs and manmade boulder (riprap) areas, and was more abundant at sites where sand was the dominant substrate. Key et al. (1996) reported little use of boulders and riprap in a study conducted in the Hanford reach of the Columbia River. Bennett et al. (1992) found most subyearling chinook over sandy substrates in Little Goose Reservoir. Also, Curet (1993) reported that subyearling chinook rearing in Lower Granite and Little Goose reservoirs exhibited a strong preference for sandy areas and showed a moderate avoidance of areas containing cobble. Curet (1993) did not report capture effort over different substrate types. However, because Bennett et al. (1992) and Curet (1993) used beach seine as sampling gear, results from their studies are limited to the areas where beach seining techniques were effective.

As the preceding discussion shows, fish response to riprap varies with the species and geographical area. For example, fish assemblages like those studied by Jennings et al. (1999) in Wisconsin lakes respond to riprap and retaining walls in a different manner than subyearling chinook salmon respond to these structures in eastern Washington reservoirs.

The effect of habitat modification on macroinvertebrate abundance resulting from the addition of riprap and retaining walls has also been studied (Schmude et al. 1998). Using simulated riprap and retaining walls in three Wisconsin lakes, they found that simulated riprap supported greater macroinvertebrate abundance and species richness than did simulated retaining walls, regardless of the shoreline conditions where the simulated structures were placed (i.e., riprap, vertical retaining wall, or natural shoreline). As in other studies discussed above, Schmude et al. (1998) attribute the greater abundance of organisms found in the simulated riprap to the greater habitat complexity that this type of structure provides. They conclude that more complex, three-dimensional artificial substrate associated with riprap, with its greater substrate heterogeneity, surface complexity, and interstitial space, supports a more diverse and abundant macroinvertebrate community in lakes than does the less complex, two-dimensional artificial substrate of the retaining wall. They also speculate that the complexity of erosion control structures (i.e., bulkheads) affects the type and abundance of colonizing macroinvertebrates (i.e., riprap bulkheads support greater abundance).

From the preceding discussion, it becomes apparent that replacement of natural shorelines with simple artificial structures such as retaining walls may reduce the quality of habitat and change the community structure, through the removal of wetland and riparian vegetation and the introduction of changes to physical attributes such as shoreline slope. Removal of wetland and riparian vegetation eliminates fish and wildlife habitat, contributes to the impoverishment of water quality and quantity, and precludes future recruitment of woody debris. In this regard, Ward et al. (1994) found that in the Willamette River, the habitat type used by salmonids at an undeveloped site was unavailable at developed sites, especially at a site where the shoreline had been armored with a vertical retaining wall. They found differences in bottom slopes, water depths, and water current velocities when comparing developed and undeveloped sites.

The simplification of the shoreline (i.e., removal of structure) during the construction of retaining walls further reduces salmonid habitat. This thesis is supported by Christensen et al. (1996), who found that removal of coarse woody debris and shoreline vegetation as a result of bulkhead construction reduced refuge habitat. Christensen et al. (1996), studying 16 lakes in Northern Wisconsin, found a strong negative correlation between riparian snag density and coarse woody debris density and the shoreline cabin density at the whole lake scale. Their results demonstrate that there are substantial impacts of shoreline residential development on littoral riparian snag and coarse woody debris abundance, and that this impact is additive. Christensen et al. (1996) speculate that humans reduce coarse woody debris in lakes, apparently through direct removal as well as by altering riparian vegetation.

However, although most data found during this literature review seem to consistently show the adverse effects of bulkheads, not all of the research results are conclusive. For example, Knutsen and Ward (1991) found that in the Willamette River, physical characteristics of the near-shore zone area did not vary greatly, except when altered by structures. Shorelines associated with

structures had steeply placed riprap or vertical walls, and alteration of water depth was commonly associated with waterway developments. The authors found evidence that suggested that water depth might influence the horizontal distribution of yearling chinook salmon and juvenile steelhead. However, the results were inconclusive, and Knutsen and Ward (1991) were unable to find any significant pattern in such distribution for these fish species.

Another inconclusive study is that conducted by White (1975) in Lake Washington. He compared benthic macroinvertebrate abundance at various depths in front of different types of bulkheads, and found that reflected wave action associated with the bulkhead did not displace organisms. However, clear trends of macroinvertebrate abundance were not found, as benthic populations at similar bulkheads often varied, thus precluding any conclusive evidence (White 1975).

Shore-Zone Habitat Structure Changes – Summary of Findings and Data Gaps

Summary

Figure 1 schematically depicts the relationships among impacts resulting from changes induced by on-, in-, and over-water structures and associated construction and operational activities. As illustrated in this figure, on- and over-water structures alter the shore-zone habitat structure, resulting in changes to fauna and flora. Changes in the habitat structure may result in salmonid behavior disruption, which may then affect predation rate. Pile driving and removal and other construction and operational activities cause short- and long-term habitat impacts. Short-term impacts are associated with noise disturbance and water quality impairment during construction. Long-term impacts associated with the presence and operation of the structure may include physical damage to aquatic organisms and a reduction in primary production. Both the presence of structures and the impacts arising from the associated construction and operational activities can disrupt the food web and thereby affect the ecosystem.

The following is a summary of findings of this review pertaining to shore-zone habitat structure changes, organized by the observed type of response.

Predation

- Bass are major juvenile salmonid predators, likely due to the overlap in rearing habitat.

- In reservoir systems of eastern Washington, juvenile salmonid predation is specific to the behavior and distribution of each salmonid species and of its predator. The behavior and distribution of predator and prey species reportedly depend on temperature, the degree of shore-zone development, slope and substrate of the shoreline, and the presence of manmade in-water structures.

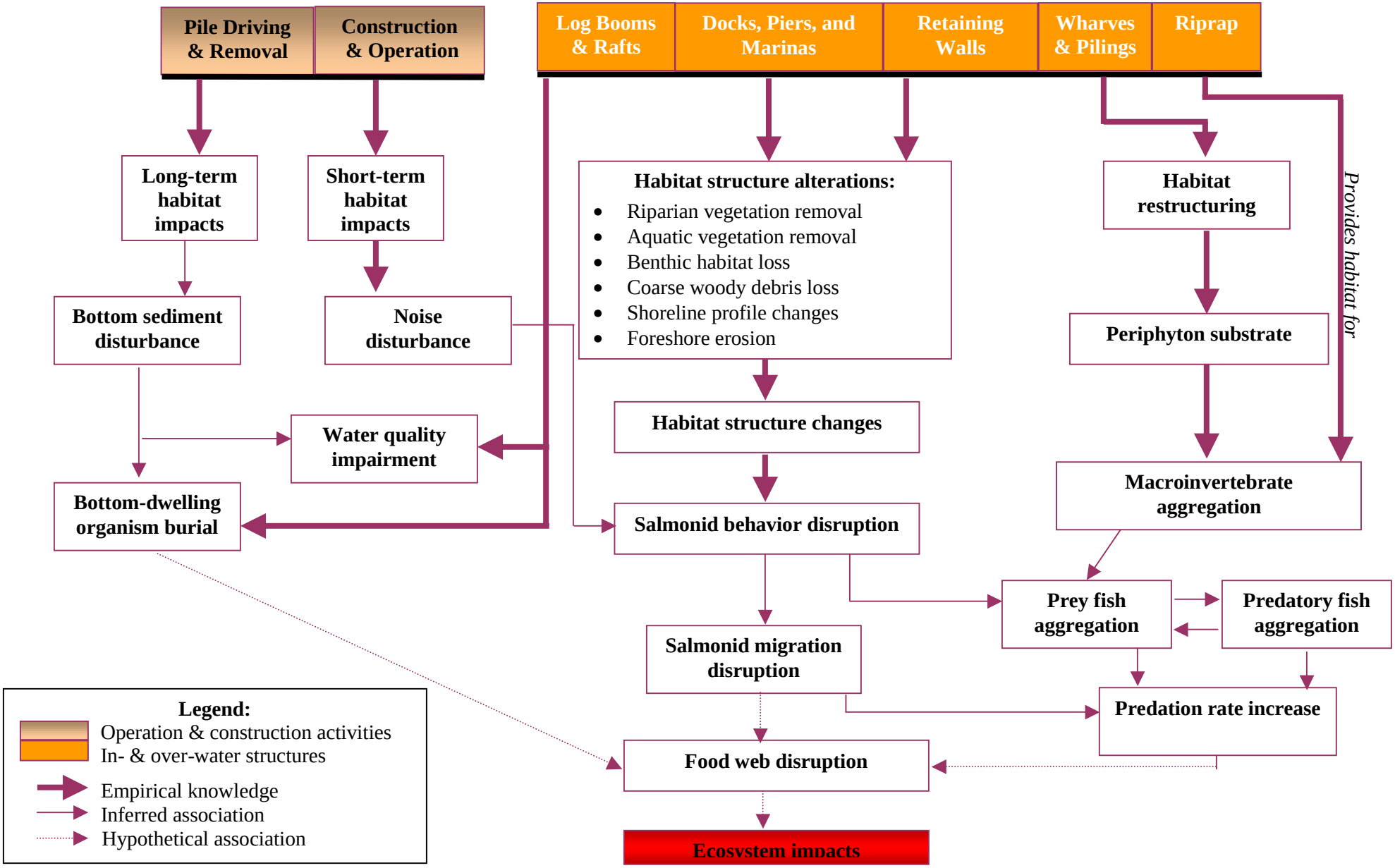

Figure 1. Impacts resulting from changes induced by on-, in-, and over-water structures and associated construction and operation activities.

- In the Colombia and Snake river reservoirs, northern pikeminnow is an important predator of juvenile salmonids because of their inshore preferences and preference for low velocity microhabitats, which are created by in-water structures.

- Habitat used by fish may influence bird prey selection, and in general, cover reduces success of their capture by predatory birds.

Behavior

- Docks, piers, and floats reportedly attract fish, this being the main effect of these over-water structures on fish behavior.

- Over-water structures may affect the survival of organisms (particularly juvenile salmonids) by providing a focal point for predatory fish aggregation, effectively altering predator-prey interactions.

- Although it is not clear which features (e.g., shade, tactile stimuli) of over-water structures attract bass, bass have been observed foraging and spawning in the vicinity of docks, piers, and pilings.

- The shade produced by houseboats and floats versus the shade produced by fixed-height structures may induce different responses in fish.

- Different fish species respond differently to the shade produced by over-water structures.

- Smallmouth bass and largemouth bass have a strong affinity to habitat structures including piers, docks, and associated pilings.

- Fish, particularly largemouth bass, rather than being attracted to the physical structure of experimental floats, seem to be attracted to the shade they produce. In contrast, smallmouth bass do not seem to be attracted to the shade produced by such structures.

- In free-flowing systems, pilings can create back-eddy microhabitats due to the physical disruption of the water flow, thereby attracting northern pikeminnow and perhaps juvenile salmonids to such habitats.

- Bulkheads adversely affect the migration and thereby the survival of juvenile salmonids by diverting them into deeper waters along armored shorelines.

- In the Snake River, subyearling fall chinook salmon avoid bedrock cliffs and manmade boulder (riprap) areas.

- The fish response to riprap and retaining walls varies with the region and the species.

Habitat Function

- The cumulative effects of shoreline development that accompany the construction of over-water structures, may be the main determinant of adverse effects on fish assemblages at the basin level.

- Over-water structures and associated construction and operation activities adversely affect juvenile salmonids by providing habitat for predators adjacent to natural refugia for migratory juvenile salmonids, such as coarse woody debris. Construction and placement of the over-water structures also affect juvenile salmonids by reducing refugia such as coarse woody debris.

- To be effective, artificial habitat structures used in restoration projects must be designed with attention to the needs of resident and desired species and consideration of the prevailing physical factors in a particular river or stream.

- In streams, rivers, and lakes, survival and distribution of salmonids is limited at least partially by water temperature.

- The number and body size of organisms using an area influenced by a floating object are directly related to the surface area of the object.

- Bark originating from log booms and rafts is reportedly the most significant problem associated with log rafting. This is because when bark accumulates on the bottom it may promote 1) a reduction in dissolved oxygen in the overlying water and a corresponding anaerobic layer near the bottom, resulting in the generation of toxic sulfide compounds; and 2) burial of benthic communities.

- The construction of bulkheads causes loss of terrestrial, shallow water, and benthic habitat, and thereby, loss of organisms.

- Bulkheads promote erosion of the foreshore and adjacent beaches, and interfere with sand recruitment processes.

- Due to its greater complexity, riprap reportedly has a greater potential than do vertical walls for maintaining the density and diversity of fishes and macroinvertebrates. However, armoring in general is detrimental to the environment and to organisms.

Data Gaps

No empirical data were found to support several of the processes depicted in Figure 1. Where empirical data are lacking, inferred and hypothetical associations have been drawn. The matrix of data availability in Appendix B shows where data exist for each of the categories of response studied in this white paper (i.e., predation, behavior, and habitat function).

Through this literature review, the following information needs have been identified (organized by the observed type of response):

Predation

- What are the effects of in-, on-, and over-water structures on predator-prey interactions?
- What are the predator-prey behavioral responses to each type of over-water structure and to shore-zone development in general?
- Do the over-water structures affect the predation rate on salmonids or other species? Would changes in design eliminate or minimize the effect?
- Does temperature affect the sockeye salmon and bass habitat overlap in Lake Washington?
- In reservoirs of eastern Washington, does temperature control the duration of shoreline residence of subyearling fall chinook, thereby affecting their habitat overlap with bass?
- What is the effect of over-water structures and shoreline development in general on avian predation?

Behavior

- Are bass attracted to the shade or to the physical structures (or both) of piers, dock, and floats?
- Is the food-web interaction of prey fishes an attracting feature of docks, piers, and associated pilings?
- In free-flowing areas of rivers and reservoirs of eastern Washington, do low-velocity microhabitats increase juvenile salmonid predation by providing aggregating habitat for northern pikeminnow and perhaps juvenile salmonids as well?
- Do on-water structures (e.g., boathouses and log rafts) induce the same effect on the behavior of organisms as over-water structures?

- Why do subyearling fall chinook salmon avoid bedrock cliffs and manmade boulder (riprap) areas in the Snake River? Does this avoidance expose them to increased predation?

Habitat Function

- Do fish respond to the actual shoreline structures, or to the habitat characteristics resulting from riparian zone alterations (e.g., vegetation and woody debris removal) associated with placement of the structures?

- What is the relationship between the cumulative effects of increased number of docks in Lake Washington and the decline in sockeye salmon freshwater survival?

- Can the effects of shoreline development be fully mitigated? How?

- Can habitat function in highly developed shore-zone areas be restored? How?

- In lakes and slow-flowing rivers and reservoirs, does large woody debris enhance salmon habitat or provide habitat for salmon predators?

Shading and Ambient Light Changes

Light is very important in the life of organisms. For juvenile salmonids, light is necessary for orientation, prey capture, schooling, predator avoidance, and migration navigation (Simenstad et al. 1999). Docks, piers, pier skirting, floats, houseboats, boathouses, barges, marinas, pilings, wharves, log booms, and log rafts all shade aquatic habitat and limit ambient light, affecting macrophyte and phytoplankton primary production. This shading could result in a decreased survival rate, or at least promote behavioral changes in various components of the biological community. Lighting associated with these structures may possibly alter fish species behavior, posing increased risk of predation and causing disruption of fish migration patterns. Empirical evidence exists (see discussion below) that indicates that changes in the underwater light environment may have an impact on juvenile salmonid physiology and behavior (Simenstad et al. 1999).

Predation

No data were found supporting a direct link between lighting and an increase in predation of fishes. Research results found were inconsistent, however may provide insight into the effects of lighting associated with over-water structures with regard to increased predation.

For example, under varying light intensities, within the natural range of light intensities occurring at night, it has been shown that predation rates on juvenile salmonids increase with

increasing light (Patten 1971; Ginetz and Larkin 1976; Mace 1983, as cited by Tabor et al. 1998).

In contrast, Tabor et al. (1998) in conducting freshwater laboratory experiments found decreased predation rates at higher light intensity. These researchers speculated that rather than increased inhibition of sculpin predatory behavior, the light may have actually influenced salmon behavior, by enhancing the ability of the fry to detect and avoid sculpin, which resulted in reduced predation. Tabor et al. (1998) proposed that differences in study components (such as salmonid species, environment) between their work and earlier studies of Patten (1971) and Mace (1983, as cited by Tabor et al. 1998) may explain the difference in the results they found.

Tabor et al. (1998) in the analysis of their research results, speculated that the reason increased predation did not occur may have been a result of the predator being sculpin, a non-obligated visual fish. In the darkness, sculpin may use some other sensory mechanism besides vision (i.e., their lateral line) to detect prey and therefore, the increase in light intensity may not have enhanced its foraging ability. However, these researches suggested that in the case of visual predatory fish such as cutthroat trout, rainbow trout, juvenile coho salmon, as well as some bird species, increased light intensity might result in an increased predation rate on juvenile salmonids. Consequently, studies using any of these visual species might find an increased predation rate correlated with increased light intensity. The speculation of Tabor et al. (1998) regarding their research results may not be accurate, as other research shows. For example, Petersen and Gadomski (1994) found in laboratory experiments with increasing light intensity a decreasing predation rate between northern squawfish (a visual predator) and juvenile chinook salmon.

In addition to differences in experimental condition, the reason for the lack of consistency in the aforementioned research results may be that simultaneous variables contribute to the effect of potential light-mediated predation rates on juvenile salmonids. In the field, physical/chemical and biological variables may have confounding, interrelated, and simultaneous interactions on fish responses to artificial light associated with over-water structures. To better interpret research results providing indirect evidence of the adverse effect of lighting on fish, such variables need to be studied and further understood. Unfortunately, this is usually difficult, particularly when field experiments are performed.

One example of a physical variable confounding the results of experiments on the effects of light on fish is a study conducted by Vogel and Beauchamp (1999) regarding the effects of light, prey size, and turbidity on reaction distance of lake trout (*Salvelinus namaycush*) and salmonids. They found that with increasing light, reaction distances increased rapidly (i.e., from less than 25 centimeters at 0.17 lux to about 100 centimeters at a light threshold of 17.8 lux). Above this threshold, increasing light contributed no further advantage for prey detection and therefore no further risk to prey. Vogel and Beauchamp (1999) also found that the “reaction distance declined as a decaying power function of turbidity.”

Artificial light associated with shoreline development can also have an effect on predation of juvenile salmonids through the alteration of their migratory behavior. It has been proposed that in the Cedar River, increased artificial light intensity levels may delay fry emigration and cause

fry to move to areas of lower water velocity where most predation appears to occur (Tabor et al. 1998). Therefore, one might expect that a delay in emigration due to the increasing incidence of nighttime lighting associated with shoreline development or over-water structures could lead to increased predation on emigrating fry. However, this has yet to be researched.

Behavior

Regarding fish attraction to shade and its potential effect on predation, Helfman (1979) found that in Cazenovia Lake, New York, experimental floats attracted prey fishes (small bluegill and adult golden shiner) and suggested that this aggregation may attract predatory fish species. However, this conjecture was inconclusive in this study. Helfman (1979) speculates that largemouth or smallmouth bass would gain an element of surprise by hovering in shaded regions. Conversely, prey fish would have an advantage by being able to see approaching predators before the predator sees them. This is because floats are shade-producing objects, which reduce the conspicuousness of fish in shade while enhancing their ability to view predators approaching from sunlit surroundings.

As juveniles, predator fish might also seek protection from their own predators by occupying shaded areas. Helfman (1979) speculates that attraction of predatory fish to floats might be because of predator-protection-seeking behavior imprinted as juveniles. Consistent with this, Haines and Butler (1969) show that structures that provide darkness are most often selected by yearling smallmouth bass.

Shade from over-water structures may have effects other than those reported by Helfman (1979) that promote fish aggregation under shade-casting structures. On a species-specific basis, those effects may vary with fish physiology. For example, in their review, Simenstad et al. (1999) analyzed empirical data pertaining to the juvenile salmonid light perception in the context of behavior and physiology. Their review indicates that 1) ambient and artificial light have been reported to induce behavioral responses consistently different between species and ontogenetic stage, and the responses vary with the dispersal patterns of the species; 2) upon a stimulus, the progression of changes the fish eye must undergo from one state to another is influenced by the intensity of the introduced light to which the fish has been exposed; and 3) there are threshold light intensities for different behaviors of juvenile salmonids.

Thus, one may argue that the shade cast by over-water structures that occur over juvenile salmonid migratory corridors may disrupt their migration by creating visual barriers and promoting disorientation. Over-water structures such as docks can create sharp underwater light contrasts by both casting shade and casting light (from lighting) under ambient daylight and nighttime conditions respectively (Simenstad et al. 1999). In this regard, there is empirical evidence which indicates that changes in the underwater light environment will have an impact on juvenile salmonid physiology and behavior, and these changes may pose a risk of affecting fish migration behavior and increasing mortality risk. (See Simenstad et al. 1999; a full review is beyond the scope of this white paper.)

Similarly, it has been suggested that changes in light intensity may modify the behavior of sockeye salmon fry (Tabor et al. 1998). Tabor et al. (1998), conducting simulated stream

experiments, found that increased light, especially that above natural levels, appears to slow or stop emigration of fry, which makes them more vulnerable to predation by sculpin. Tabor et al. (1998) found that as light level increased, and in the absence of sculpin, fry emigrated downstream at a slower rate. In the presence of sculpin, fewer fish emigrated but did so at a faster rate than in the absence of sculpin (Tabor et al.1998). Similarly, McDonald (1960) found that the downstream migration of sockeye and coho salmon fry was closely related to light intensity. He found the presence of artificial lights over experimental stream channels at night inhibited the downstream migration of sockeye and coho salmon fry in these channels until the lights were extinguished. Consistent with this finding, Godin (1981), based on a literature review of diel timing of salmon fry migration, indicates that natural light intensity appears to be the major environmental factor controlling the daily onset and termination of the downstream and upstream migrations of salmonid fry. His findings indicate the physiology of these organisms is involved in the process. As changes in the underwater light environment will have an impact on juvenile salmonid physiology (Simenstad et al. 1999), it follows that both the artificial light associated with over-water structures and the shade that these structures produce have a potential for disrupting salmon fry migration and thereby increasing exposure to predators.

In terms of fish attraction to lighting generally, the only data found during this literature review comes from an indirect source (Collis et al. 1995). While conducting an unrelated study on northern squawfish predation on salmonids, Collis et al. (1995) observed that juvenile salmonids were attracted (i.e., surfaced) to work lights in a Columbia River reservoir. However, such attraction may not hold in all systems and for all different ontogenetic stages (Simenstad et al. 1999). In many different second and third order creeks on the Olympic peninsula, night snorkel surveys of juvenile salmonids indicated no attraction to the light produced by flashlights when shined from under the water or from the surface (Carrasquero 1997 unpublished observations). Instead, fry and presmolt salmonids held position, at times even regardless of the proximity of the surveyor.

Habitat Function

In terms of the effects of on-and over-water structures on the light environment, another concern of shading and ambient light changes relates to the potential effects on habitat function. This includes reduction of the ambient light beneath a structure due to light obstruction by an over-water structure (shading), as well as changes of the ambient light (increase in intensity) due to lighting associated with the structure.

As noted previously, shading can affect habitat function by creating visual barriers to migrating fish. The physical design and elements of the over-water structure (i.e., deck height and width, piling numbers and type, pier skirting and batter boards, etc.) can influence whether the shadow cast on the near shore covers a sufficient area and has sufficient intensity to constitute an underwater visual barrier for fish (Simenstad et al. 1999). Also, to the extent that phytoplankton and aquatic macrophytes require light during photosynthesis, over-water structures that reduce or modulate the amount of light will ultimately affect macrophytes beds and reduce phytoplankton primary production, with corresponding effects on habitat function, the food web, and consequently the ecosystem.

Because epibenthic communities depend on light (of certain intensity) to persist, artifacts that may diminish light intensity beneath a structure will affect such communities and their habitat. For example, shading from pile-supported structures may modify wetland habitat, and depending on the amount of shading, algae and aquatic vegetation that occur beneath the structure may be reduced or absent (Mulvihill et al. 1980). However, piling and piers offer substrate for algae to grow in areas where bottom depth is below the photic zone or presents unstable sediment conditions (Mulvihill et al. 1980). A loss of phytoplankton primary production due to shading may be compensated by the primary production of algae that grow on pilings, particularly in areas with bottom conditions as described above.

In this regard, White (1975) studied the light intensity under and outside over-water structures to determine whether structures significantly reduced the amount of light available for primary production of phytoplankton. Not surprisingly, he found that light intensity was higher outside over-water structures compared with intensities beneath the structures, as a result of shading from the structures. However, surface phytoplankton production at the edge of a large over-water apartment complex and under narrow residential piers, exceeded those measured outside over-water structures. White (1975) explains these results as a natural inhibition of production that occurs at the surface of water due to light conditions, which are higher than those in which algae thrive. He suggests that under narrow residential piers, at approximately one meter beneath the over-water apartment complex, light intensity may be reduced to "optimal," resulting in higher primary production. White (1975) did not study the abundance or distribution of macrophytes under or outside the docks and piers, nor did he investigate the loss of primary production due to the reduction of macrophyte vegetation. Clearly, the loss of macrophyte vegetation due to the placement of over-water structures drastically affects primary production.

In terms of the surface area covered by piers, although suggesting that narrow residential piers do not significantly reduce phytoplankton primary production, White (1975) concludes that there is an inversely proportional reduction in such production due to the reduction of light. White's (1975) findings that there were no significant reductions of phytoplankton primary production, do not take into consideration the cumulative effects of individual piers. Analysis of alterations occurs primarily at the spatial scale of individual, recreational, and residential properties, the effects are incremental and cumulative in nature (Jennings et al. 1999).

One may argue that a shaded underwater area beneath an over-water structure is essentially a new and different habitat from that which previously existed. This shaded habitat possesses intrinsic physical characteristic that will promote changes in various interrelated parameters such as light intensity, temperature, primary production and consequently, dissolved oxygen (Simenstad et al. 1999). It is expected that the design (i.e., dimensions, materials, and location in relation to the sun path) and flow conditions at the selected site will influence how much such parameters change, due to the shade cast by the over-water structures. In turn, these changes may induce responses in the biological community with ecological consequences, which are still poorly known and much less well understood.

Shade-producing structures can introduce changes to fish assemblages and distributions, which in turn may affect the local communities, and therefore the systems they inhabit. Helfman (1979, 1981a) studied fish attraction to shade producing objects and to experimental floats in Cazenovia

Lake, New York. The experiments were conducted using underwater human observers and cameras. He found the number of fish aggregating beneath shade-producing objects is directly proportional to the size of the objects. Helfman (1981a) suggests that the amount (or depth) of shade produced is a determinant of the observed attraction phenomenon. Helfman (1979, 1981a) concludes that shade, interacting with water clarity, sunlight, and vision, is an important factor in attracting temperate lake fishes to overhead structures. In this regard, the major determinant of the apparent attraction of shade producing objects to fish is the relative visual advantage of a shade versus a sunlit observer (Helfman 1979, 1981a; Helfman et al. 1997). For example, during the day, largemouth bass are typically found near cover, which shields them from high light intensities and may provide a concealed vantage point for the occasional ambush of prey (Helfman 1981a).

The associated problems of shading are not exclusive to docks, piers, or associated piling structures. Floats can also shade the underwater environment in a fashion directly proportional to the site and shape of the structure. However, shaded areas caused by floats are usually small, and therefore a measurable effect is not expected (Mulvihill et al. 1980). No published empirical evidence of the specific effect of floats on habitat function was found.

Shading and Ambient Light Changes – Findings Summary and Data Gaps

Summary

Figure 2 schematically depicts the relationships among impacts resulting from changes induced by on-, in-, and over-water structures and associated construction and operational activities. As illustrated in Figure 2, these structures shade the underwater environment and limit the daylight available for photosynthesis, thus restructuring communities. Construction and operational activities associated with these structures impair water quality and promote algal blooms, thus reducing light penetration and disrupting salmonid behavior. Ultimately, these impacts disrupt the food web and in turn the ecosystem.

The following is a summary of findings of this literature review pertaining to shading and ambient light changes, organized by the observed type of response.

Predation

- In different species and under different environmental conditions, predation rates in juvenile salmonids have been shown to both increase and decrease with increasing light.

- With increasing light, reaction distances increase rapidly but only within a threshold, above which increasing light contributes no further advantage for prey detection. The reaction distance declines as a decaying power function of turbidity.

- Large or smallmouth bass may gain an element of surprise by hovering in shaded regions.

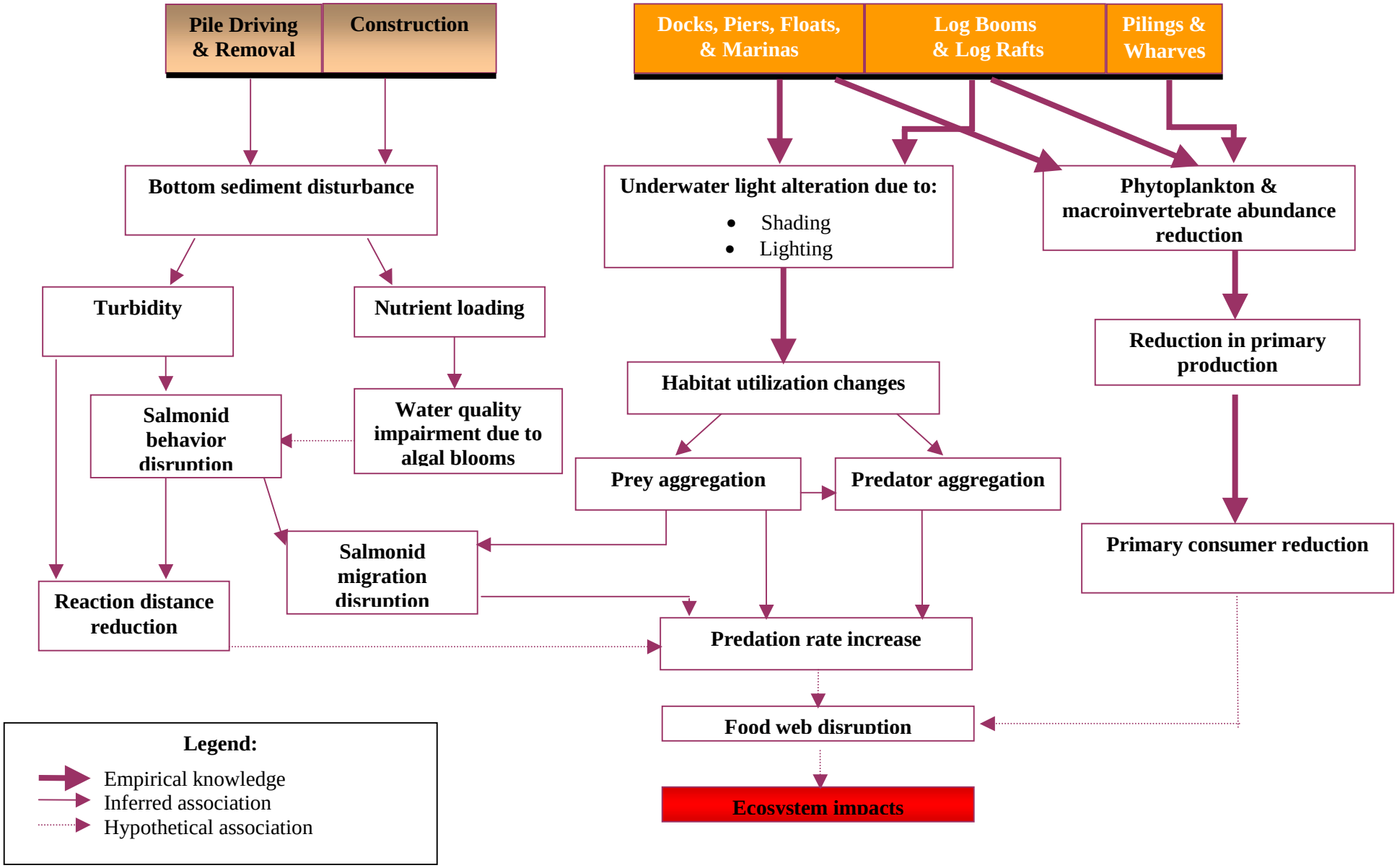

Figure 2. Impacts resulting from changes induced by on-, in-, and over-water structures and associated construction activities.

Behavior

- Ambient and artificial light have been reported to induce consistently different behavioral responses between species and ontogenetic stage, and the responses vary with the dispersal patterns of the species.

- Upon a stimulus, the progression of changes the fish eye must undergo from one state to another is influenced by the intensity of the introduced light to which the fish has been exposed.

- Changes in light in the underwater environment affect juvenile salmonid physiology and behavior. This is because there are threshold light intensities at which different juvenile salmonid behaviors occur.

Habitat Function

- Shading affects habitat function by creating visual barriers to migrating fish.

- Shading from pile-supported structures modifies the water temperature and wetland habitat, and depending on the amount of shading, algae and aquatic vegetation that occur beneath the structure are reduced or eliminated.

- The shade produced by a piling-supported pier promotes a loss of phytoplankton primary production. However, this may be compensated by the primary production of algae that grow on pilings, particularly in areas where the bottom depth is below the photic zone or presents unstable sediment conditions.

- Narrow residential piers may not significantly reduce phytoplankton primary production, but there is an inversely proportional reduction in production due to the reduction of light.

- The cumulative effects of even narrow residential piers are detrimental to the environment.

- Shade interacting with water clarity, sunlight, and fish vision is reportedly an important factor in attracting temperate lake fishes to overhead structures.

Data Gaps

No empirical data were found to support several of the processes depicted in Figure 2. Where empirical data are lacking, inferred and hypothetical associations have been drawn. The matrix

of data availability in Appendix B shows where data exist under each of the categories of response studied in this white paper (i.e., predation, behavior, and habitat function).

Through this literature review, the following information needs have been identified (organized by the observed type of response).

Predation

- Is there a relationship between lighting and predation on juvenile salmonids?
- Do large or smallmouth bass gain an element of surprise by hovering in shaded areas under over-water structures?
- What is the relationship between reaction distance decline (due to turbidity) and fish predation rate?

Behavior

- Does lighting from shoreline development and associated over-water structures disrupt or delay juvenile salmonid migration? Would this disruption have an effect on predation on juvenile salmonids?
- What is the relationship between impacts on juvenile salmonid behavior resulting from light changes in the underwater environment and changes in predation rates?
- Do changes in light intensity modify the behavior of sockeye salmon fry? Would this behavior modification make them more vulnerable to predation?
- Do algal blooms originating from nutrient loading disrupt salmonid migration?

Habitat Function

- What are the cumulative impacts of over-water coverage on primary production in various lakes and reservoirs of eastern and western Washington?
- How does the design of structures (i.e., dimensions, materials, and location in relation to the sun path) influence organism responses? Do these responses vary among species or systems?

Water Flow Pattern and Energy Disruption

Docks, piers, marinas, pilings, wharves, riprap, and retaining walls all have the potential to disrupt water flow patterns and energy. This disruption can lead to alteration of the distribution and abundance of sediment, vegetation, and detritus. In turn, alteration of these elements can restructure important habitat features, thereby affecting the biological community.

Docks, Piers, and Floats

Habitat Function

Lorang et al. (1993) studied the effects of lake level regulation and over-water structures on shoreline changes in Flathead Lake, Montana. They characterize two types of systems: 1) reflective systems characterized by dynamic gravel beach faces and steep in-shore shelves armored by wave-washed cobble, and 2) dissipative systems characterized by sand-sized substratum, broad in-shore flat shelves, and the presence of multiple linear bars approximately 350 meters offshore. They also found that piers, which intercept gravel transport, accelerated beach (backshore) erosion on "the downdrift side, and heavy aggregation of migrating gravels occurred on the updrift side." Erosion on reflective beaches was induced by continuous wave action during the much longer full-pool period (due to lake level regulation), resulting in fore- and back-shore erosion and loss of riparian vegetation (Lorang et al. 1993).

Kahler et al. (2000) speculate that in Lake Washington, which experiences a water level regime similar to that of Flathead Lake, similar processes may occur, with the corresponding effect on riparian and emergent vegetation. They further speculate that gravel interception around shore-zone structures could potentially increase the availability of suitable spawning habitat for smallmouth bass in Lake Washington (Kahler et al. 2000).

Similar processes also occur in reservoir systems of eastern Washington (e.g., the Columbia and Snake river reservoirs; Independent Scientific Group 1996). The fluctuating water levels in those regulated reservoirs prevent the establishment of riparian vegetation. This zone in which riparian vegetation does not become established, called the "varial zone," includes all the shallow, low-velocity habitats within the river channel of all regulated river segments in the Columbia basin (Independent Scientific Group 1996). Because of such a pattern of water level regulation, one might expect the gravel accumulation process to occur around shore-zone structures, with the corresponding effect on smallmouth bass habitat.

In areas with exposed banks, boat-induced waves moving along the exposed bank at the speed of the boat can erode the slopes, suspending sediments and removing aquatic plants and benthos (Warrington 1999a). Although armoring of the shoreline may be seen as a potential solution, retaining walls, groins, or riprap are not acceptable solutions because these methods often destroy as much habitat as the problems they are designed to treat (Warrington 1999a).

In general, loss of emergent vegetation can promote erosive cycles that preclude the recovery and reestablishment of such vegetation. Erosion of shorelines that cause a decrease in emergent vegetation will also promote changes in sediment transport patterns. This further increases emergent vegetation loss and, in turn, will promote more shoreline erosion (Rolletschek and Kuhl 1997).

Water Flow Pattern and Energy Disruption – Findings Summary and Data Gaps

Summary

Figure 3 schematically depicts the relationships among impacts resulting from changes induced by in- and over-water structures. As illustrated in this figure, over-water structure impacts alter habitat function directly through the loss of riparian and emergent vegetation, and indirectly through shoreline erosion. The loss of riparian and emergent vegetation results in further shoreline erosion, creating an erosive cycle that further increases vegetation loss, with a resultant adverse effect on nutrient cycles. In-water structures alter the water flow pattern, create microhabitats, and disrupt fish behavior, which may affect predator–prey relationships. Both in- and over-water structures can thereby disrupt the food web and thus adversely affect the ecosystem.

The following is a summary of findings of this literature review pertaining to water flow pattern and energy disruption.

- Piers, which intercept gravel transport, may accelerate beach erosion and promote heavy aggregation of migrating gravel. This gravel aggregation, if around shore-zone structures, may increase the availability of suitable spawning habitat for smallmouth bass in such water bodies as Lake Washington.
- In areas with exposed banks, boat waves can erode the slopes, suspend sediments and remove aquatic plants and benthos.
- Loss of emergent vegetation promotes erosive cycles that preclude the recovery and reestablishment of such vegetation.
- Retaining walls and riprap are not acceptable solutions to shoreline erosion, because these methods are often as damaging to habitat as the conditions they are designed to treat.

Data Gaps

No empirical data were found to support several of the processes depicted in Figure 3. Where empirical data are lacking, inferred and hypothetical associations have been drawn. The matrix of data availability in Appendix B shows where data exist under each of the categories of response addressed in this white paper (i.e., predation, behavior, and habitat function).

Through this literature review, the following information needs have been identified (organized by the observed type of response).

Predation

- Does disruption of flow pattern and energy have any influence on predator-prey interactions?
- Do in-water structures that promote fish aggregation by creating slow-flowing-water microhabitats have an effect on the food web?

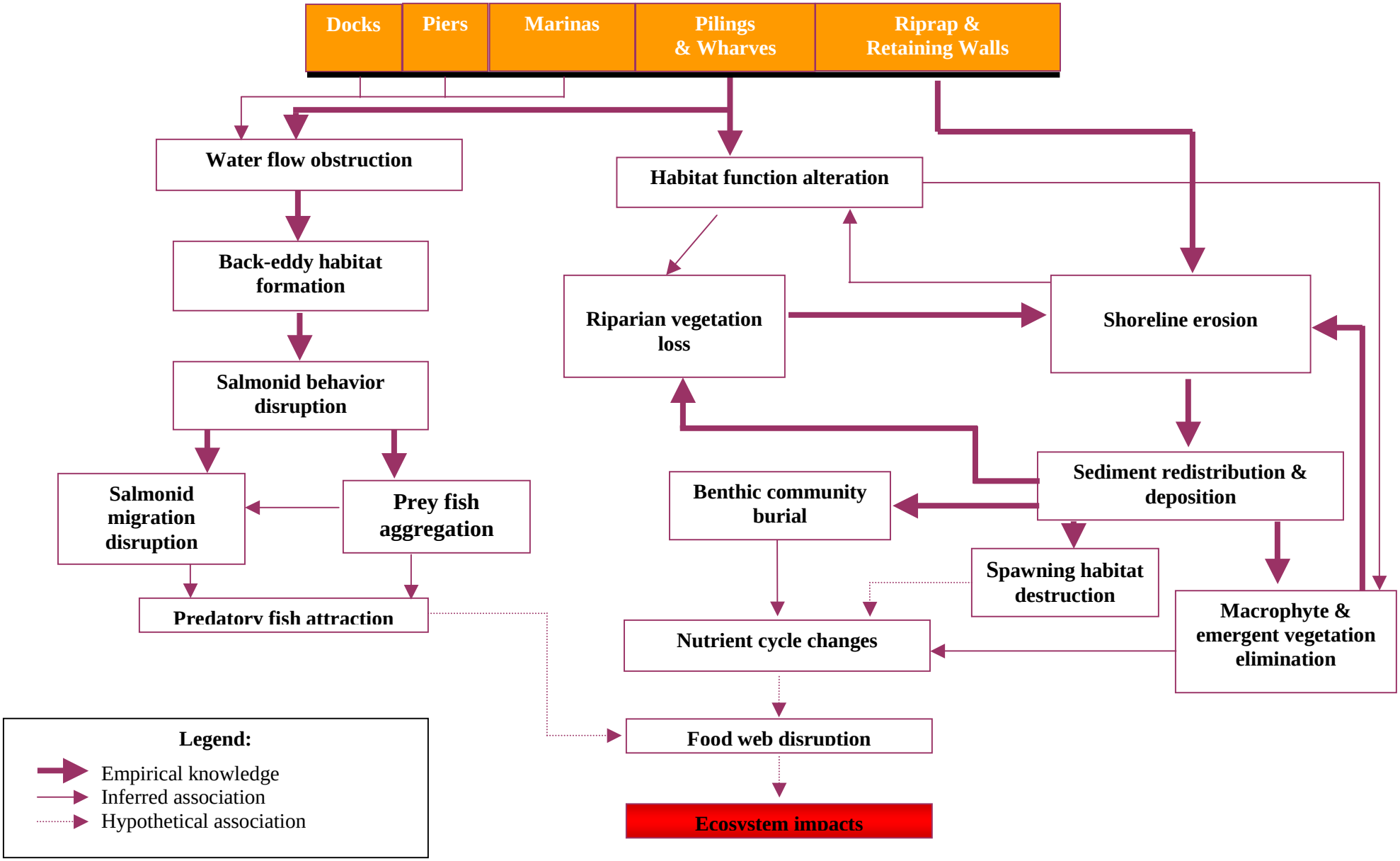

Figure 3. Impacts resulting from changes induced by in- on-, and over-water structures.

Behavior

- What effect does disruption of water flow pattern and energy have on behavior of various aquatic organisms, particularly salmonid fishes and their predators?

- Do in-water structures that disrupt fish behavior affect predator-prey interactions?

Habitat Function

- Does gravel aggregation around shore-zone structures affect bass population density and distribution?

- Are erosive cycles that preclude the recovery and reestablishment of emergent vegetation at work in eastern and western Washington systems? How could they be prevented?

Indirect Mechanisms of Impact

Physical/Chemical Environmental Disruption: Construction and Operation Activities

Although little studied in freshwater environments, the indirect effects of the physical/chemical processes associated with the construction and operation of over-water structures are widely recognized. Chmura and Ross (1978), Mulvihill et al. (1980) and Kahler et al. (2000) all provide literature reviews of direct and indirect effects of over-water structures documented in studies of marine estuarine and freshwater environments. A more comprehensive literature review of the impact of over-water structures on the physical environment can be found in the *Over-Water Structures: Marine Issues* white paper.

Physical/chemical environmental disruption due to construction and operation activities of over-water structures can have both temporary and permanent effects, and are related to noise disturbance and water quality degradation (Chmura and Ross 1978; Mulvihill et al. 1980; Kahler et al. 2000). For example, building an over-water structure involves pulse phenomena during the period of construction (e.g., pile driving, movement of sediments, release of chemicals from building materials), but these stop as soon as, or shortly after, the construction is complete (Underwood 1991). The over-water structure may, however, also cause long-term, possibly permanent adverse changes in such variables as water circulation (flow) and release of sewage or oil from boats. Any of these may cause an adverse environmental response (Underwood 1991).

Pile Driving and Removal

A major cause of disruption during construction of over-water structures is related to pile driving and removal. The effects of pile driving and removal on the habitat and its biological community typically result in localized sedimentation problems, disturbance of pollution-laden

sediments, and disruption of normal organism behavior, particularly that of fishes. This can occur through two mechanisms. First, shock waves generated by pile driving may disrupt spawning, rearing, and migratory fish behavior temporarily. Second, pile removal may promote burial of bottom-dwelling organisms and affect water quality by reincorporating pollutants into the water column, making them more readily bioavailable. The latter mechanism can have both temporary and permanent effects.

In general, construction activities (such as pile driving) that disturb the bottom sediments also increase turbidity and can affect bottom-dwelling aquatic organisms, remove submerged aquatic vegetation, drive away fish and other mobile organisms, and alter existing habitat at the structure site (Mulvihill et al. 1980). Turbidity can clog gills of fish and other organisms, and toxic material and silt suspended by construction activities can have a detrimental effect on the biota of the immediate area (Mulvihill et al. 1980). Turbidity effects are most significant for juvenile stages and sessile organisms. In addition, dislodging of organisms can cause spree (i.e., feeding frenzy behavior) by predators during construction periods (Mulvihill et al. 1980).

No freshwater studies showing field data on the effects of pile driving on fishes were found. One published marine study (in Puget Sound) on the effects of pile driving on salmonids was located. However, because underwater sound attenuation due to salinity (i.e., water density) is negligible over the distances of interest at the infrasound frequencies important for salmonid avoidance response, empirical species-specific data from studies conducted in marine and estuarine environments can be extrapolated to freshwater environments (Carlson 2000 personal communication). However, direct extrapolation of data from one species of fish to another is not practicable, because there is a high level of inter-specific variation in hearing capabilities of fishes (Popper 1997). Therefore, results obtained in marine environment studies should be applied to freshwater systems only on a species-specific basis.

For a better understanding of the effects of pile driving on fishes, the paragraphs below summarize the basic principles of underwater acoustics and the structures and function of the fish ear and lateral line, as well as known fish responses to sound. This brief presentation is followed by a review of the published literature on the effects of pile driving.

Sound is defined as a density disturbance that propagates energy through a medium (Popper and Carlson 1998). In water, the energy in a sound wave is contained in the oscillatory movement of water particles and in the pressure that a sound wave originates. Diminution of sound, which results from a decrease in its amplitude due to geometric spreading and attenuation, is a function of distance. Diminution of sound through attenuation is induced by mechanical and chemical factors (e.g., salinity); hence it is also a function of the oscillatory movement of water particles as well as water density (Popper and Carlson 1998).

Fishes detect both the particle motion and pressure components of sound fields using two sensory systems, the ear and the lateral line. Both sensory systems use similar mechanosensory hair cells as transducing structures for signal detection, and both sensory systems respond to similar types of signals (Popper and Carlson 1998). The ear responds to position and acceleration of the body. The lateral line responds to differences between motion of the body and motion of the surrounding water, including stimuli (ranging from less than 1 hertz to several

hundred hertz) produced by other swimming fish and other organisms (Popper and Carlson 1998). The ability of fishes to detect the pressure components of sound is species-specific.

Because the body of a fish is about the same density as the surrounding water, density discontinuities are needed within the body for sound detection to occur. These discontinuities consist of the otoliths (in the inner ear) and the swim bladder. The otoliths are at least three times more dense than the rest of the body. The swim bladder undergoes volume changes in a pressure field because it is filled with a compressible medium, thus acting as a secondary sound source in close proximity to hearing structures (Popper and Carlson 1998). This volume change generates a secondary sound field that enables a fish to detect pressure signals with the ear, either through direct coupling with the inner ear or by generating water particle movement (Popper and Carlson 1998; Fay 1997; Sand 1997). However, the efficacy of the swim bladder in exciting the fish ear depends upon the swim bladder's proximity to the ear or direct mechanical connections by fluid-filled ducts, arrangements of bones, or other means. For example, in hearing generalist species such as salmonids, the swim bladder is relatively far from the ear, and enhancement of hearing by the swim bladder appears to be insignificant (Fay 1997; Popper and Carlson 1998). Consequently, salmonids are poorly equipped to detect sound unless they are close to a source where most of the energy in the sound field is carried by pressure.

Wild and hatchery fry and smolts of Pacific salmon and steelhead exhibit an innate avoidance response to infrasound within the frequency range of 8 to 30 hertz (Carlson 1996). The level at which a fish can detect a sound depends upon the level of background noise. The sound must be at least 10 decibels more intense than background noise to be detected; otherwise it is masked by the background noise (Popper and Carlson 1998). Salmonids have a rather poor hearing capability; hence the background noise of the environment (and thereby the masking effect) is not as important in salmonids as in other fish species (Popper and Carlson 1998).

Intense sound (180 to 200 decibels referenced to 1 μPa) can damage the mechanosensory hair cells of fishes. The effect of intense sounds may be more injurious to fish species with highly sensitive hearing (i.e., hearing specialists) such as the northern pikeminnow, and less so to fishes with poor hearing capabilities (i.e., hearing generalists) such as salmonids.

Short-term exposure (for a few minutes) to intense sound may not damage inner ear or lateral line sensory receptors. Consequently, if fishes are able to leave the ensonified area (i.e., the area immediately adjacent to the sound source), their receptors may not be mechanically damaged. Conversely, if fishes remain in the area exposed to strong sounds for extended periods, their receptors may be damaged or some other component of the hearing system may be affected. Nonetheless, sound in general may result in other stress effects, such as decreased growth, increased susceptibility to disease, and impaired reproduction, even in hearing generalist fishes (Popper and Carlson 1998). The effects of intense sound that do not result in easily observed changes in fish behavior or mechanical injury to fishes, such as shearing of hair cells, have not been studied to any extent.

Given that fish eggs and embryos cannot leave the ensonified area, these developmental stages may be adversely affected by sound energy generated by pile driving activities; this has not been studied, however. In this regard, the Washington Department of Fisheries, in a memorandum

dated January 13, 1981, recommends a minimum distance needed to protect the eggs of lakeshore spawning sockeye in Lake Washington (WDF 1981). The recommendation consists of establishing a protection area of 300 feet around sockeye spawning sites. This recommendation is based on the analysis of peak energy release and duration data for sound originating from the detonation of explosives during demolition activities.

The energy release during pile driving and detonation of explosives has a short peak period of discharge at which maximum energy release occurs. For pile driving, WDF (1981) estimates that this energy would be measurable within 100 feet of the source. However, pile driving has a relatively longer peak period of discharge than detonation of explosives. Therefore, because the distance at which the energy is felt increases in proportion to the length of the peak discharge, WDF (1981) suggests that the estimate of 100 feet be tripled, and that this new value (i.e., 300 feet) be used to establish the protection area.

It is worth noting that at present sockeye is not the only lakeshore spawner that occurs in Lake Washington. In recent years, chinook salmon have been observed spawning in lakeshore areas of Mercer Island and Lake Union (Fisher 2000 personal communication; Quinn 1999 personal communication; Kinnison 1999 personal communication). Therefore, in Lake Washington, the concern regarding potential pile driving impacts on fish eggs and embryos also applies to this species.

Carlson (1997) characterizes the underwater sound generated by impact pile driving within the context of the response of salmonids to impulse sound, and concludes that the sound thus produced is unlikely to significantly affect the migratory behavior of salmonids. These studies were conducted over a two-day period at a pile dike repair where 15 piles were replaced on the Washington shore of the Columbia River upstream of Altoona, Washington. All underwater sound measurements were made within 30 feet of the piles being driven and at one of four depths (i.e., 5, 10, 15, or 20 feet). Sound measurements were obtained near the surface, at mid-depth, and at the bottom.

Based on his findings, Carlson (1996) concludes that impact pile driving does not produce adequate stimuli for sustained avoidance responses in salmonids. The reason is that in salmonids, the effective stimulus for avoidance response is the local flow (i.e., particle displacement) component of infrasound in the range of 5 to 30 hertz where water particle acceleration is less than 0.01 ms^{-2} (meters per second per second). At this sound level, water particle motion is found only in the near-field of volume displacement sources capable of generating an intense local flow field (Carlson 1996). In short, salmonids would have to be very close to the noise source to be disturbed and express an avoidance response. The threshold distance for an avoidance response by salmonids has been experimentally determined to be approximately 10 feet.

In another study, Carlson (1996) characterizes the underwater sound generated by vibratory pile driving within the context of the characteristics of sound known to result in avoidance response by juvenile salmonids. His experiments consisted of the comparison of data collected during vibratory pile driving operations against model data obtained from a volume–displacement–

infrasound source. The study was conducted during vibratory driving of six piles along the outer perimeter of a pier at the Hatfield Marine Science Center in Oregon.

Carlson (1996) found that infrasound generated by vibratory pile driving is not continuous and has a short life span but is probably dependent upon various aspects of the pile driving activity. Such aspects include the design and mode of operation of the vibratory hammer, the characteristics of the piles being driven, and characteristics of the substrate into which the piles are driven. For all of the piles observed, most of the energy in the sound field was located at frequencies below 50 hertz, with approximately half at infrasound frequencies. Results showed that vibratory pile driving generates a sound field with considerable energy in the frequency range where salmonid avoidance has been observed (Carlson 1996).

Carlson (1996) concludes that the vibratory pile is unlikely to cause an avoidance response by juvenile salmonids beyond the immediate vicinity of the pile driving activity. In addition, this type of construction activity is, in general, unlikely to have a significant impact on migrating salmonid behavior, because "generation of water particle motion levels in excess of fish behavioral response thresholds appears unlikely at ranges over 20 to 30 feet from the pile being driven" (Carlson 1996).

Regarding the published marine study on the effects of pile driving on salmonids, Feist et al. (1996) studied the effects of impact and vibratory pile driving on the behavior of juvenile chum and pink salmon in Puget Sound. They determined that salmonids could detect the sound of impact pile driving within a radius of at least 600 meters, and that the sound was at least 20 decibels above ambient levels at 593 meters. The pile driving did not cause juvenile chum and pink salmon to change their distance from shore or to cease foraging activities. However, Feist et al. (1996) found that the distribution and sizes of fish schools, and behavior within schools, on pile driving days significantly differed from that on non-pile-driving days.

It should be noted that this study was based on visual measurements of distribution and behavior changes, mostly using human observations, and therefore has its limitations and biases. Moreover, it is based on a small sample size and highly variable data.

Interrelated Effects of Construction and Operations – Boating

The operation and use of over-water structures can also promote interrelated effects such as those originating from boating activities. In this regard, Warrington (1999a,b) reports on the increasing use of freshwaters in British Columbia for recreational boating. Warrington (1999a,b) divides the aquatic environment into bottom sediment, bulk water column, surface microlayer, and shoreline habitat compartments, within which the effects of recreational boating may occur. In each of these compartments, plant or animal tissue, non-living particulate matter, and water subcompartments may exist. A number of different kinds of effects may also occur and can be categorized as either physical disturbances or behavioral effects, which also include reproductive failure (Warrington 1999a).

With regard to physical disturbances, recreational boating can cause shoreline (i.e., bank) erosion, sediment resuspension, and destruction of shallow-water and marginal vegetation (see

Warrington 1999b for a discussion of chemical pollution associated with outboard motors). In several river systems it has been observed that the physical effects of boating traffic are more pronounced in narrow, shallow river channels than in deeper channels (Warrington 1999a).

In the Illinois River, the bed sediments (i.e., silts and clays) were easily resuspended. Small pleasure craft produced waves of less than a foot and caused the least amount of shoreline wave wash. Large pleasure craft produced short, steep waves of brief duration, causing bank erosion and turbidity increases. Towboats raised the water level at first, then water was drawn down, exposing the bottom, followed by successive waves rushing back in, with the resulting turbulence causing high turbidity. The turbidity trail extended several miles behind a towboat and took several hours to return to normal (Warrington 1999a).

Turbidity increases can be attributed in part to algal growth, which may result from the increased availability of nutrients (particularly phosphorus) originating from disturbed bottom sediments (Warrington 1999a). This condition occurs when propeller-induced mixing and resuspension of sediments makes phosphorus more bioavailable to phytoplankton, resulting in greater algal growth and thereby higher turbidities (Hilton and Phillips 1982; Yousef 1974 as cited by Warrington 1999a). In addition, a significant quantitative relationship has been observed between plant community structure, submerged plant abundance, and recreational boat traffic. In this regard, it is hypothesized that turbidity and its effect on light are the cause of a decreased abundance of submerged vegetation (Warrington 1999a). In addition to increasing nutrient availability, resuspension of sediments also incorporates metals and other toxic materials that may have been precipitated and thus previously removed from biological activity (Warrington 1999a).

Aquatic plants have variable susceptibility to being uprooted or eroded from the banks or from shallow water by wave action, and this is a function of both their root structure and the type of sediments in which they normally grow (see Warrington [1999a] for a list of British Columbia freshwater submerged aquatic plants ranked in order of their relative resistance to wave action). Uprooting of submerged aquatic vegetation was observed in the pathways of outboard engines where the propellers came within 30 centimeters of the substrate (Lagler et al. 1950).

Behavioral effects of boating operations are also a concern because amphibians, fishes, and other aquatic organisms can be affected. For example, noise produced by motorboats disturbs fishes and wildlife (Warrington 1999a). In this regard, it has been shown that boats traveling at slow speeds near sunfish nesting areas usually drive the males off the nest, thereby affecting their reproductive success (Mueller 1980; Lagler et al. 1950).

In general, water turbidity can have several deleterious effects on fishes (Warrington 1999a). Turbidity can cause decreased growth due to a reduction in the primary production (Buck 1959), promote mortality through gill damage, disrupt feeding behavior and migration (Noggle 1978), and decrease egg and fry survival (Campbell 1954; McNeil and Ahnell 1964, both as cited by Warrington 1999a).

A reduction in macroinvertebrate abundance due to boating operations has also been reported. Lagler et al. (1950) found that the invertebrate abundance in the path of an outboard motorboat operated over a prolonged period in shallow water was substantially reduced.

In the context of boating operations, interdependent effects of over-water structures can also be observed. For example, human activities such as wading and swimming that involve the intense use of the shallow, vegetated areas of lakes and streams can disturb feeding and nesting waterfowl (Warrington 1999a).

Construction activities have a concomitant and inevitable degree of water pollution. Petroleum products in minor quantities may seep into the water from construction equipment, and the exhaust emissions add hydrocarbons to the air (Mulvihill et al. 1980). In general, the resultant chemical processes potentially include water quality degradation due to 1) pollution originating from the structural material (i.e., treated wood); 2) temporary reduction of oxygen content associated with oxidation of resuspended organic matter during dredging operations; and 3) temporary changes in pH due to water contact with or leakage from concrete structures. Chmura and Ross (1978), Mulvihill et al. (1980), and Kahler et al. (2000) address all but the pH issue.

Physical/Chemical Environmental Disruption: Construction and Operations – Findings Summary and Data Gaps

Summary

Figure 4 schematically depicts the relationships among impacts resulting from changes induced by construction and operation of over-water structures and by pile removal activities. As illustrated in this figure, there may be temporary, permanent, and interrelated impacts. Temporary impacts are associated with noise disturbance and water turbidity, and consequently salmonid behavior disruption. Permanent impacts are related to bottom sediment disturbance, burial of benthic communities, nutrient load changes, and resulting alterations of habitat function. Interrelated effects such as those resulting from boating activity cause shoreline erosion and turbidity-induced light reduction, with the consequent elimination of aquatic vegetation. All of these processes could disrupt the food web and thus affect the ecosystem.

The following is a summary of findings of this literature review pertaining to disruptions induced by construction and operational activities.

- Physical/chemical environmental disruption due to construction and operation of over-water structures has both temporary and permanent effects on aquatic organisms, related to noise disturbance and water quality degradation.
- Physical processes include construction activities that disturb the bottom sediment, increase turbidity, adversely affect bottom-dwelling aquatic organisms, remove submerged aquatic vegetation, drive away fish and other mobile organisms, and alter existing habitat at the over-water structure site.
- Chemical processes include water quality degradation due to pollution, and temporary reduction of oxygen concentrations associated with oxidation of resuspended organic matter.
- Underwater impact-pile-driving noise is unlikely to significantly affect the migratory behavior of salmonids.

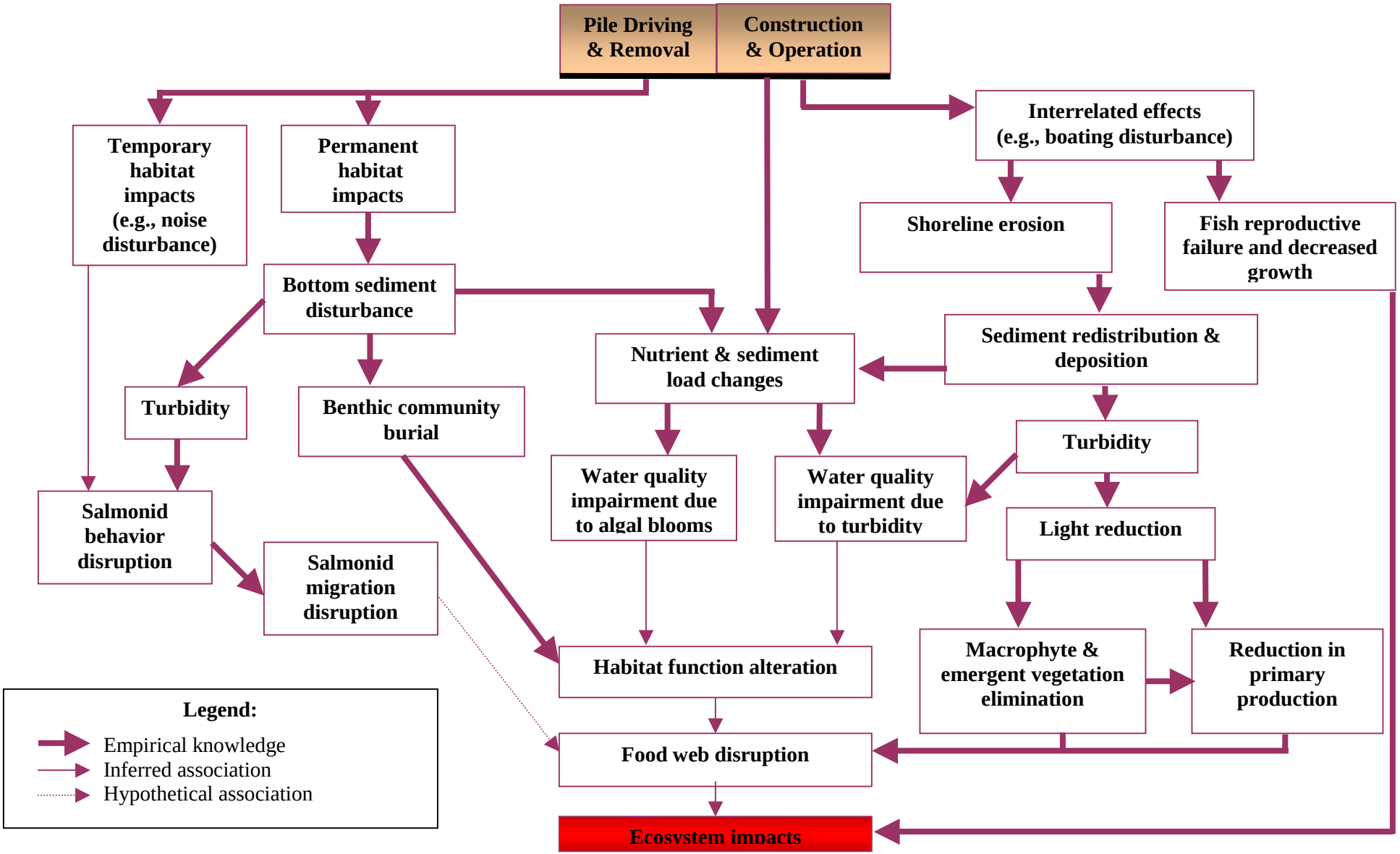

Figure 4. Impacts resulting from changes induced by pile driving and removal and other construction and operation activities.

- With regard to noise generated by pile driving, the threshold distance for an avoidance response has been experimentally determined to be approximately 10 feet.
- Infrasound generated by vibratory pile driving is not continuous, it has a short life span, and it is unlikely to have a significant impact on migrating salmonid behavior.
- Pile driving energy may affect salmonid eggs and embryos if they are located within 100 feet of the source.
- Operation of over-water structures can also have interrelated effects such as those caused by boating activities. These effects include physical disturbances and behavioral effects including reproductive failure.
- The interrelated physical effects include shoreline erosion, sediment resuspension (and resultant turbidity), and destruction of marginal aquatic vegetation and associated macroinvertebrate communities.
- Sediment resuspension creates turbidity that affects primary production, decreases bird fish-capture rate, damages fish gills,, decreases fish egg and fry survival, and can disrupt fish migration.
- Operational activities such as boating can have interdependent effects from the potential intense use of shallow, vegetated areas of lakes and streams by humans.

Data Gaps

No empirical data were found to support several of the processes depicted in Figure 4. Where empirical data are lacking, inferred and hypothetical associations have been drawn. The matrix of data availability in Appendix B shows where data exist under each of the categories of response addressed in this white paper (i.e., predation, behavior, and habitat function).

Through this literature review, the following information needs have been identified (organized by the observed type of response).

Predation

- Is there any relationship between physical/chemical environmental disruption and predator–prey interactions?

Behavior

- Would field studies corroborate or reject the experimentally determined threshold for fish response to impact pile driving (i.e., 10 feet)?
- Does avoidance response in fishes vary with the time of year, the system affected, or the species of fish?

- What are the effects of vibratory and impact pile driving on early stages (i.e., eggs and embryos) of aquatic organisms, particularly salmon?

- Does vibratory pile driving cause an avoidance response in juvenile salmonids at distances ranging beyond 20 to 30 feet from the pile driving activity? What would be the effect of this response on salmonid migration?

- What are the effects of boating on juvenile and adult salmonids? Can the reported effects on warm-water species be extrapolated to salmonids?

- Does turbidity disrupt migration of juvenile and adult salmonids?

- What are the effects of human activities such as wading and swimming, which involve the intense use of the shallow, vegetated areas of lakes and streams on aquatic organisms?

Habitat Function

- Does the energy from pile driving activities adversely affect salmonid eggs and embryos?

- Do 300 feet exclusion zones for pile driving activities provide adequate protection for eggs and embryos of salmonid species?

Habitat Protection, Restoration, and Mitigation Techniques

State of Knowledge

Shoreline development projects and interrelated activities can lead to habitat loss, which is one of the greatest threats to fisheries resources. Thomas (1994) considers the major causes of extinction of freshwater fishes in North America to be the loss or alteration of habitat (50 percent), the introduction of exotic species (37 percent), and over-exploitation of fisheries (8 percent).

Habitat alteration may lead to loss of habitat function and thereby to habitat loss. In recent years, several federal and state agencies, including U.S. Army Corps of Engineers, National Marine Fisheries Service, and Washington Department of Fish and Wildlife, have been implementing a policy of no-net-loss of certain critical habitats such as wetlands and eelgrass beds. Similarly, these agencies are implementing policies intended to prevent the introduction or spread of exotic species and the over-exploitation of fishery resources.

As outlined in Washington's *Statewide Strategy to Recover Salmon: Extinction Is Not an Option*, development projects occurring in or around water can replace damaged or lost habitat through the use of adequate and properly monitored mitigation techniques. Restoration of habitat in combination with strict controls to prevent exploitation of resources can contribute to the recovery of imperiled species. Strict controls to eliminate or minimize the access of exotic species can effectively restrict the continued spread of such organisms.

During the course of this review, literature was found addressing wetland protection, restoration, and mitigation, as well as stream bank protection and restoration. No documents were found specifically addressing lake and reservoir protection, restoration, or mitigation within the context of shore-zone development and construction of over-water structures. However, the information obtained regarding both wetlands and stream banks may be adapted for application to lakes and reservoirs, based on appropriate site-specific conditions and project-specific requirements.

For mitigation and restoration projects, the selection of adequate measures depends on project goals, objectives, and performance standards. There are clear criteria for mitigation projects: the habitat created and the functional value of the replacement habitat must be greater than values of the habitat replaced (Ecology 1998; Ecology et al. 1994). In contrast, for restoration projects, one must first ask to which historical condition a particular habitat must be restored. Unfortunately, this question does not always have a clear scientific answer and requires historical data that may not be readily available. Nonetheless, one can see that most of the general objectives of mitigation plans may apply to restoration projects.

Some of the objectives used in selecting wetland mitigation measures include the following (Ecology 1998; Ecology et al. 1994):

- The mitigation should be located in the same watershed and as close as possible to the affected area, and should provide the best possible contribution of functional values to the particular watershed system.

- Offsite mitigation efforts consolidated on one site are preferred to multiple offsite locations.

- Mitigation should provide better functional value than that provided by the wetland being replaced.

- Wetland mitigation in the form of wetland creation or enhancement must result in an overall net gain of wetland area over the wetland area being replaced.

- Mitigation sites must be of appropriate size and hydrologic condition in order to satisfy local, state, and federal requirements for wetland replacement (e.g., the wetland area lost must be replaced with a greater area of wetland created, and the functional value of the replacement wetland must be greater than the value of wetland replaced.

In addition, a monitoring plan should be implemented to evaluate the success of the created and enhanced wetland mitigation areas. For this purpose, quantifiable criteria included in the performance standards should be used as the basis for monitoring the success of the mitigation sites. Adequate mitigation techniques and timely implementation of best management practices (BMPs) can help to avoid, minimize, or compensate for impacts of proposed over-water structure projects. The basic goal of mitigation is to achieve no-net-loss of habitat functions by offsetting losses at the impact site (Washington 2000). These mitigation techniques must provide habitat protection and stability while achieving a range of parallel objectives, including terrestrial and aquatic habitat enhancement, water quality improvement, and ecosystem diversification (Schollen 1995).

Despite extensive expenditures under state and federal programs, there is little evidence in the literature to show that habitat restoration has actually improved the productive capacity of freshwater systems for salmonids. A reason for this is perhaps the lack of a clear understanding of the specific biophysical conditions that exemplify quality habitat. Although it is generally assumed that the use of BMPs has improved freshwater habitats (Independent Scientific Group 1996), empirical demonstration of the influences and benefits of BMPs on habitat is limited.

Therefore, designing to avoid environmental impacts should be a goal of all over-water structure projects. The structures should incorporate design elements that provide for fish habitat while preventing damage to the environment. However, when impacts cannot be avoided, mitigation techniques must be incorporated into the design and integrated into the operation of the structure. Thus, habitat restoration measures (either onsite or offsite, and either in-kind or out-of-kind) should be used to compensate for unavoidable habitat impacts. The site selection criteria for restoration activities should emphasize habitat connectivity, species occurrence and use, and ecological significance of the selected site from a holistic perspective (i.e., the ecosystem).

A crucial element to obtain a continued success of habitat protection and mitigation techniques is the inclusion of biological/environmental monitoring and evaluation of such techniques in programs and plans (Independent Scientific Group 1996). The importance of monitoring and evaluation is to ensure feedback to the state and federal agencies so that they can modify programs as needed to achieve their desired goals. In fact, effective observation and monitoring of the performance of mitigation plans is key to their success (Schollen 1995).

Monitoring data and general information from restoration sites can be used as the basis of watershed adaptative management plans, as well as to implement corrective actions in mitigated sites and to plan future restoration projects. For example, in a state listing of restoration projects, USEPA (2000) provides monitoring information ("lessons learned") from river corridor and wetland restoration projects. Among the elements contributing to the success of various projects, availability of monitoring information from other projects and follow-up to assure implementation and corrective actions when needed were among the most commonly cited attributes USEPA (2000).

This section of the white paper focuses on findings from the literature reviewed. Regulatory practices are described under the existing guidance summary section later in this paper. A few published sources provide information on habitat protection and mitigation techniques in the context of the over-water structures addressed in this white paper. Some of the information from early publications is outdated, and although it is discussed here, it should be used with caution. Mulvihill et al. (1980) provide regional considerations and information on function, site characteristics, environmental conditions, and placement constraints of over-water structures. Kahler et al. (2000) provide a series of conclusions and recommendations on effects of bulkheads, piers, and other artificial structures and shore-zone development on Endangered Species Act protected salmonids in lakes.

An important habitat mitigation tool is the use of bioengineering techniques. The draft *Integrated Streambank Protection Guidelines* (WDFW 2000) provides information on habitat impacts resulting from bank protection projects and describes several appropriate fish habitat mitigation measures, some involving bioengineering techniques. The guidelines are intended for streams, although some of the concepts and design criteria have applicability in lacustrine environments.

Similarly, *Streambank Revegetation and Protection: A Guide for Alaska* (ADFG 1996) provides information on bioengineering techniques developed to protect and restore stream banks. This guide also has applicability in lacustrine environments. In addition, *Soil Bioengineering, an Alternative for Roadside Management—A Practical Guide* (USDA-FS 2000) provides valuable techniques for stabilizing areas of soil instability, some of which are applicable to shorelines. However, soil bioengineering has unique requirements and therefore is not appropriate for all sites and situations (USDA-FS 2000).

Preservation and protection of shorelines and stream banks can be attained through a variety of approaches (USEPA 1993). However, based on the findings reviewed and presented in this white paper, preference should be given to nonstructural practices such as soil bioengineering, marsh creation, establishment and enforcement of no-wake zones, and establishment of setbacks.

Soil Bioengineering

Soil bioengineering refers to the installation of living plant material as a main structural component in controlling problems of land instability where erosion and sedimentation are occurring (USDA-FS 2000; USDA-SCS 1992). Native plants are used in order to ensure that the plant material will be well adapted to site conditions. Although a few selected species can be installed for immediate soil protection, it is expected that the natural invasion of a diverse plant community will stabilize the site through development of vegetative cover and a reinforcing root matrix (USDA-SCS 1992). Thus, adapted types of woody vegetation (i.e., shrubs and trees) are initially installed to offer immediate soil protection and reinforcement.

Soil bioengineering methods include an array of applied technologies that are effective not only for prevention but also for mitigation. These applied technologies combine mechanical, biological, and ecological principles to construct protective systems for the prevention of slope failure and erosion (USEPA 1993).

Soil bioengineering systems normally use rooted plants or cut, unrooted plant parts in the form of branches. As the systems establish themselves, resistance to sliding or shear displacement increases on shorelines, stream banks, and upland slopes. Examples of specific soil bioengineering practices include the following (USDA-FS 2000; USDA-SCS 1992):

- Native plant cutting and seed collection
- Salvaging and transplanting native plants
- Planting containerized and bare-root plants
- Distributing seed, fertilizer, and certified noxious weed-free straw or hay
- Live staking
- Installing erosion control blankets
- Installing live fascines
- Brush-layering
- Brush mattressing
- Branch-packing
- Live gully repair
- Installing vegetated geotextile
- Log terracing
- Joint planting
- Constructing live crib walls.

Information provided by USDA-FS (2000) and USDA-SCS (1992) on each of these techniques includes a description of required plant material, mechanism of action, advantages and disadvantages, tools needed, procedure for implementation, and applicability of the technique, as well as schematic cross-sections showing important design elements. While all of these techniques can be used for protection, restoration, and mitigation, they should be used on a project-specific and site-specific basis.

Marsh Creation

Another important technique that can be used to address shoreline erosion problems involves marsh creation and restoration. Plant marshes perform two functions in controlling shore erosion: dissipation of energy and stabilization of shoreline sediments. Energy dissipation is achieved through the exposed stems of plants (e.g., emergent vegetation), which form flexible masses that dissipate energy. Shoreline stability is achieved through dense stands of marsh vegetation, which create depositional areas that cause sediment accretion along the shoreline (USEPA 1993). Although most marsh creation techniques have been described for coastal areas (Knutson 1987, 1988; Lewis 1982), they also have great potential for application in freshwater environments (i.e., lakes, reservoirs, and sloughs).

Establishing and Enforcing No-Wake Zones

No-wake zones are useful tools for the prevention of shoreline and stream bank erosion and should be given preference over posted speed limits in shallow waters. The rationale is that, in theory, the boat speed that produces the maximum wake varies with the depth of the water (USEPA 1993). In shallow water, motorboats traveling even within speed limits produce wakes whose heights are equal to or near the maximum size that can be produced by the boats (USEPA 1993).

Establishing Setbacks

Another tool for the prevention of shoreline and stream bank erosion is the establishment of setbacks. Although a setback most often restricts the siting and construction of new structures along the shoreline, it can include requirements for the relocation of existing structures within the designated setback. In addition, setbacks can include restrictions on uses of waterfront and shore-zone areas that are not related to the construction of new structures (USEPA 1993). Finally, because setbacks effectively restrict the actual number of structures that can be placed on a given shoreline, they help to minimize the cumulative environmental effects of the structures.

Docks, Piers, and Floats

Because of increasing concern over the cumulative effect of over-water structures and, in response to the recent Endangered Species Act listing of several fish species, the Washington Department of Fish and Wildlife (WDFW) and the National Marine Fisheries Service (NMFS) are currently developing a series of documents establishing criteria for the construction of these structures. These documents provide recommendations and potential mitigation measures for implementation across the state. Many of these recommendations are not yet published and are available only through WDFW area habitat biologists and NMFS staff. Although not all the recommendations are yet supported by published scientific research (i.e., empirical data), these recommendations are intended to lessen or mitigate potential cumulative effects, as well as to protect fishes. Some of the documents containing criteria and mitigation measures currently

recommended by WDFW (undated[a,b,c,d]) and the NMFS (2000) for eastern Washington are presented below.

- *WDFW Salmonid Predation Reduction Measures and Dock Specifications for North Central Washington Water Inhabited by Federally Listed Fish Species* (WDFW undated[a]). This document includes some typical WDFW salmonid predation reduction requirements for dock-associated structures, specifically for piers, floats, ramps, piling, and anchors. These requirement include regulation of the following elements: 1) pier size and shape; 2) ambient light grid requirements; 3) piling size, number, and surface characteristics; 4) minimum distance waterward of the ordinary high water mark; 5) characteristics of anchors when used in lieu of pilings.

- *Some Typical WDFW Salmonid Predation Reduction Measures and/or HPA Dock Requirements on North Central Washington Waters Inhabited by Listed Fish Species Protected Under the Federal Endangered Species Act*. (WDFW undated[b]). This document includes criteria addressing the structure dimensions, avoidance of both light penetration reduction and creation of shaded areas, avoidance of predatory fish habitat creation, damage avoidance of near-shore shallow water habitats, and minimization of pile usage. The document includes the following eight criteria: 1) dock and float size and shape; 2) ambient light grid requirement; 3) minimum open water zone and distance from shoreline for floats; 4) ramp grating for light penetration and minimum ramp length; 5) dock and float anchoring; 6) piling surface characteristics; 7) reflective surface finish on flotation devices; and 8) minimum vertical distance between the ramp and float and the stream or lake bed.

- *Recommendations for Siting Marinas and Other Overwater Structures in the Lower Columbia River* (WDFW undated[c]). This document is intended to provide recommendations and mitigation measures necessary to achieve no-net-loss of productive capacity of fish and shellfish habitat. The document includes three levels of mitigation: avoidance of impacts, minimization of impacts, and compensation for impacts. Under avoidance of impacts, the following criteria are included: 1) dock and float size and shape; 2) minimum distance waterward of the ordinary high water mark; 3) maximum number of piling landward of Columbia River datum; 4) float characteristics and location; 5) treated piling restriction; 6) over-water structure siting in relation to water depth; 7) characteristics of breakwaters; and 8) preservation of a buffer along the shoreline. Under minimization of impacts, the following criteria are included: 1) size, number, siting location, and ambient light grid requirement of over-water structures; 2) bioengineering approach to shoreline protection; 3) location for boat mooring; and 4) dredging requirements. Under the compensation for impact section, the following criteria are included: 1) restoration of

filled, armored, or otherwise modified shorelines; and 2) restoration of salmonid habitat covered by over-water structures.

- *Conditions for Siting of Marinas and Boat Docks in Water Containing Anadromous Fish* (WDFW undated[d]). This document includes conditions and measures to minimize or avoid adverse effects of a proposed action on listed species and minimize or avoid adverse modification of critical habitat in freshwater. The document is intended for eastern Washington and has an appendix that includes approved in-water work windows for that region.

With regard to the recommended use of bright white PVC and paint and reflective metals for the construction of docks and associated structures referred to in the second bullet point above, empirical data obtained from the literature survey for this paper show that prey and predator fishes are attracted to white-painted floats to the same degree that they are attracted to non-white or reflective materials (Helfman 1979). Anecdotal evidence from sport fisherman and recreational scuba divers supports such empirical data. Therefore, this recommendation bears further research.

The NMFS is preparing an incidental *take statement* document, which contains "reasonable and prudent measures" necessary to minimize the take of Endangered Species Act listed and proposed species (NMFS 2000). The document addresses the upper Columbia River steelhead and spring chinook populations. The basis of this incidental take statement is that over-water structures provide an incremental enhancement to predator habitat that is directly related to the surface area of the over-water structure (NMFS 2000).

Criteria and mitigation measures specific to the construction of over-water structures in western Washington are also being developed by the NMFS. In addition, guidelines for the biological assessment of such structures have recently become available for use by project proponents. The NMFS (2000) criteria outlined below were adapted from *Guidance for ESA Section 7 Consultation—Effect Determinations for New and Replacement Piers and Bulkheads in Lake Washington* (NMFS 2000).

The safest months for construction, considering all life stages of the chinook, are November and December. In non-delta areas, August, September, and October should be construction windows with appropriate sedimentation controls. Projects that may qualify as "not likely to adversely affect" are those that fall under the following criteria:

- Replacement pier on existing footprint with materials that do not further degrade baseline conditions

- Replacement pier area and number and diameter of pilings significantly reduced

- New minimum-sized pier with narrow, elevated walkway and minimal number and diameter of pilings, providing for a shallow near-shore

migration and feeding zone, and including aquatic and riparian vegetation rehabilitation

- Shoreline rehabilitation directed toward providing complex in-water habitat (e.g., emergent plants; some woody debris with branches) and riparian vegetation with mixture of native trees, shrubs, vegetation overhanging the water, and ground covers.

Within the context of habitat protection and mitigation, both direct and indirect modifications of structural complexity of the aquatic environment have been used to protect and improve habitat. Direct or indirect manipulation of aquatic vegetation alters a wide variety of variables simultaneously (Cooper and Crowder 1979). For example, manipulation of brush shelter, rock rubble, and other artificial stream and lake improvement technologies can directly alter substrate areas, light penetration, and prey refuges. These same manipulations can also indirectly alter nutrient cycles, water chemistry, and food resources (Cooper and Crowder 1979).

The effects of docks, piers, and wharves can be minimized if these structures are constructed high enough above marshes to allow light to reach the water surface (Chmura and Ross 1978). In this regard, light-penetrating elevated walkways can be used for preventing stream bank damage where access to a sensitive or critical area is required (ADFG 1996). These structures prevent erosion and protect underlying vegetation, allowing vegetation recovery while providing access. Floating docks can be connected to elevated walkways to provide boating access (ADFG 1996). In addition, it is recommended that docks and piers extend out far enough to reach depths in which dredging will not be required (Chmura and Ross 1978). In a literature review of the effect of marinas, Chmura and Ross (1978) found that floating docks and pile-supported piers have the least effect on water circulation and therefore are preferred to solid structures. It should be pointed out, however, that Chmura and Ross' (1978) recommendation on floating docks does not take into consideration the shade avoidance criteria set forth by the revised WAC 220-110-60, which requires maximum height to minimize shading of the area under the structure.

Chmura and Ross (1978) also recommend avoiding painting underwater surfaces. The basis for this recommendation is that over-water structures such as docks and piers "provide additional substrate for the growth of fouling communities." Painting of the wood surfaces discourages such growth. Other researchers (Mulvihill et al. 1980) recommend that if structures are painted or otherwise covered, all coatings must be dry before placing floats in the water to avoid contamination.

Marinas

Mulvihill et al. (1980) provides a review of biological impacts of minor shoreline structures, but mostly in marine environments (see Mulvihill et al.1980 for study review and recommendations beyond the scope of this white paper). Site selection and corresponding site-specific engineering design are the first steps in environmental impact avoidance. For example, a site with maximum natural protection will minimize alterations and the concomitant adverse impacts of construction of marinas (Mulvihill et al. 1980).

In general, attention to selection of sites with the "maximum natural physical benefits" can help to avoid alterations and continual maintenance associated with dredging (Mulvihill et al. 1980). To minimize impacts, it is recommended that marinas be located "…at the end of, or between drift sectors, or on self-contained pocket beaches…" (Bauer 1973 as cited by Mulvihill et al. 1980).

Warrington (2000) provides comprehensive recommendations for best management practices (BMPs) to be employed during the construction and operation of marinas. The recommended BMPs are grouped by activities, including choice of location; construction; management of liquid waste, fuel, and solvents; sewage disposal; boat cleaning; boat coating; generation and disposal of solid waste; and protection of upland areas. However, these BMPs, which are proposed for construction activities in British Columbia, Canada, may not all apply in the state of Washington because of differences in laws and regulations, or they may not provide a sufficient level of environmental protection.

Quoted below are selected recommendations proposed by Warrington (2000) that apply to marinas in freshwater environments. These recommendations are in essence BMPs that should be incorporated as permit conditions for individual projects, in order to ensure that these BMPs are implemented (Fresh 2000 personal communication):

Choice of Location

- *Avoiding construction of mooring basins in blind channels or sloughs where there is insufficient tidal current or natural flow to ensure adequate and regular flushing*
- *Providing two entrances to provide for maximum flushing action*
- *Orienting the basin entrance to provide for maximum tidal flushing and prevailing current water exchange*
- *Orienting marina floats with currents or prevailing winds to prevent trapping surface debris and oily residue*
- *Designing marinas to retain as much existing natural aquatic and marginal vegetation as possible*

Construction

- *Constructing dredged basins with more than one water depth; the depth must decrease with distance from the entrance; to avoid internal deeper pockets which act as un-flushed holding basins*
- *Timing construction and dredging to periods when use of the site by fish is minimal*

- *Using floating or pile breakwaters rather than rubble mounds to minimize site impacts*
- *Using bubble curtains or padding to disrupt the shock wave when blasting*
- *Cutting boat or float plane ramps out of the upland rather than building them on intertidal foreshore*
- *Constructing gradual slopes which can be stabilized by natural vegetation rather than rip rap or walls*

Liquid Waste, Fuel, and Solvent Management

- *Providing fueling equipment with automatic shut-off nozzles to reduce spillage during fueling operations*
- *Providing impervious pavement, berms, curbs or other means of spill containment, spill control equipment and connection to spill collection sumps for fuel and storage tank areas*
- *Avoiding the use of underground storage tanks which lead to very expensive clean up costs when they eventually corrode and leak and cause extensive ground and water pollution*
- *Storing fuels and other highly inflammable fluids in a separate area to meet local fire department regulations*
- *Providing fluid storage containers with level indicators to prevent overfilling and spillage*
- *Keeping an accurate and up-to-date inventory of everything in storage for use by spill cleanup crews and fire fighters so that potentially hazardous combinations can be anticipated*
- *Avoiding discharge of on-site oil/water separator waste water to sewers or to ground unless it is demonstrated to contain less than 15 mg/L of oil*
- *Preventing discharge of any waste liquids down floor, sink or storm drains; signing all drains*
- *Establishing site-specific spill contingency plans, including reporting, and training employees in use of the required equipment*

Sewage Disposal

- *Providing fixed point pump-out facilities consisting of one or more centrally located sewage pump-out stations, generally situated at the end of a pier and often on a fueling pier for convenience; pumps or a vacuum system with flexible hose attachment draw wastewater from a docked plane's or boat's pump-out fitting and move it to an onshore holding tank, a pubic sewer system, a private treatment facility, or another approved disposal facility; for boats with small, removable toilets, a similarly connected dump station should be provided*

- *Providing portable pump-out facilities which function the same as the fixed-point system with the advantage of mobility for servicing different docks; wastes are drawn from a docked boat's pump-out fitting via vacuum or pump setup and hose attachment into a storage tank; the full tank is discharged into the marina's disposal facilities; these are thought by many to be the most economical and logistically feasible means of ensuring proper disposal of boat sewage*

- *Providing continuous wastewater collection at the slip where live-aboard vessels are situated, this would involve fixed force main piping, pumping, and sewage disposal means on the part of the marina; language should be included in slip leasing agreements mandating the use of pump-out facilities and specifying penalties for failure to comply*

- *Discharging sanitary wastes, black water and grey-water, to the municipal sewer, having it trucked/shipped out or pumped to a septic system or shore*

Boat Cleaning

- *Removing boats from the water to perform cleaning where feasible*

- *Cleaning boats in the water by hand*

- *Using detergents and cleaning compounds that are phosphate-free and biodegradable*

- *Avoiding use of detergents containing ammonia, sodium hypochlorite, chlorinated solvents, petroleum distillates, or lye*

- *Collecting hull wash water and removing solids before discharge to sewers or ambient waters*

- *Cleaning dock floors, lift platforms and yard surfaces before high pressure washing hulls*

- *Avoiding pressure washing on tidal grids, docks, planked and grated surfaces or other areas where the wash water can not be contained*

- *Pumping collected wastewater which contains low concentrations of pollutants directly into the sanitary sewer*

- *Treating small volumes of wastewater volume with high pollutant concentration directly by a mechanical filter system with the filtrate going to the sewer system and the sludge to an approved disposal facility*

- *Monitoring the quality of the water discharged to sewers or ambient waters*

- *Avoiding pressure washing on tidal grids or when beached unless there is a collection system and sump to collect all wash water; cleaning out the sump before tidal flooding; sump contents may be special waste*

- *Covering or installing filters on floor drains to prevent entry of spent grit into sumps and sewers*

- *Avoiding discharge of dry-dock flood water, cooling water, condenser water, boiler blow-down water and steam cleaning water to ambient waters if oil and grease exceeds 10 mg/L, turbidity exceeds 5 NTU over background or pH is outside the range 6.0 to 8.0*

Boat Coating (Painting and Anti-Fouling)

- *Avoiding spraying coatings while a vessel is on a tide grid or beached*

- *Using soft anti-fouling paint where cleaning is infrequent and hard paint where cleaning is needed frequently*

- *Applying anti-fouling coatings well away from sensitive fish habitat, shellfish beds, fish farms, shallow estuarine areas and surface storm drains*

- *Using tarps while vessel is on a tide grid, beached or on planked or grated docks and removing the tarps before the grid floods, it rains or washing occurs*

- *Using airless or high volume low pressure spray guns and monitoring wind drift*

- *Using brushes or rollers when vessel is afloat except when tops are fully shrouded*

- *Permitting use of tributyl tin paints only by licensed operators*
- *Avoiding use of tributyl tin paints on non-aluminum hulls under 25 m long*
- *Avoiding painting under high wind conditions when drift is evident*

Solid Waste Generation and Disposal

- *Ensuring that solid waste from boat operation and maintenance at marinas is properly disposed of or recycled regularly*
- *Prohibiting in-the-water hull scraping or any process for removing paint from the boat hull that occurs underwater*
- *Providing proper waste disposal facilities including recycling facilities where possible*
- *Providing filters on all drains to keep debris from entering stormwater or sewers*
- *Providing sufficient area above the high water line, for boat repair and maintenance; such work should not be allowed outside of designated areas*

Protection of Upland Areas

- *Providing a paved upland area for cleaning and painting*
- *Providing proper waste disposal facilities including recycling facilities where possible*
- *Collecting all surface runoff from paved upland areas in a storm water collection system*
- *Passing all the collected storm water through a sediment and oil separation treatment prior to discharge*
- *Collecting all paint and cleaning residues and storing in a covered container prior to off-site disposal*
- *Collecting all oil and filters for recycling or off-site disposal*
- *Using submerged outfalls which extend beyond tidal or seasonal low water levels*

Riprap and Retaining Walls

As with any structure, the design and material choice for the construction of bulkheads can be altered to minimize their impact. Nonetheless, regardless of the design, these structures will modify the environment and thereby adversely affect aquatic organisms, in a cumulative fashion.

The NMFS (2000) has recently released a document with guidelines for the determination of effect of piers and bulkheads that may be constructed or replaced in Lake Washington. In the context of bulkheads, the NMFS has proposed as "not likely to adversely affect" those projects that fall under the following criteria:

- Replacement bulkhead on existing footprint with materials that do not further degrade baseline conditions.
- Replacement bulkhead footprint set back from the ordinary high water mark, with shoreline rehabilitation including overhanging vegetation.
- Replacing bulkheads with bioengineered bank protection and significant shoreline vegetation rehabilitation including overhanging native plants.

In general, when planning armoring structures (i.e., bulkheads), the total effect of the structure on the environment should be considered (Mulvihill et al. 1980). In their review, Mulvihill et al. (1980) present biological considerations for the construction of bulkheads. Although most of these considerations were obtained from studies conducted in marine and estuarine environments, the general principles of habitat conservation should apply to projects in the freshwater environment. Some of the recommendations include using designs that minimize damage to fish and shellfish habitat, avoiding the disturbance of shoreline vegetation, enhancing existing vegetation to provide shoreline stabilization, setting bulkheads landward of the mean high waterline, and restricting amounts of suspended sediments during construction (Mulvihill et al. 1980).

Bonham (1983) field-tested whether emergent vegetation could attenuate wave energy in large canals and rivers in Britain (see Bonham 1983 for details of the bioengineering design). The emergent vegetation (four species tested) was capable of dissipating approximately two-thirds of boat wake energy and inhibiting wave break. Based on his results, Bonham (1983) proposed the use of emergent vegetation for shoreline wave-energy attenuation and scour prevention.

Once anthropogenic processes are initiated, and physical responses such as erosion-induced habitat alteration are observed, corrective measures may have profound repercussions on the ecosystem and therefore should be used with caution. For example, Rolletschek and Kuhl (1997) investigated the impacts of reed-protecting structures on shorelines in the lower Havel River and Great Müggel Lake, Berlin. The purpose was to address an existing cycle of reed destruction due to erosion. Faggots and palisades successfully protected reeds by acting as wave breakers and reducing erosion in the reedy areas of the shoreline. However, depending on the type of reed-protecting structure used (i.e., gester faggots, reisig faggots, or palisades), increased

sedimentation, increased nutrient concentration, and enrichment in fine sulfide-containing detritus occurred, with a corresponding decrease in water quality.

Pile Driving and Removal

No literature on mitigation techniques for pile driving and removal in freshwater was found. However, one recent study conducted in a marine environment addresses the use of bubble curtains to minimize the impact of noise produced during underwater construction (Würsig et al. 2000).

Würsig et al. (2000) conducted experiments near Hong Kong on the use of bubble curtains to minimize the impacts on Indo-Pacific hump-backed dolphins from noise produced during underwater construction. Percussive pile-driving techniques were used from a barge, and a bubble curtain was used as a mitigation measure to protect wildlife, in particular the hump-backed dolphins. These researchers found that when barges were not in the sound-propagation path, the bubble curtain provided a reduction of 3 to 5 decibels in the overall broadband sound level. Conversely, when the barge was in the sound propagation path measured by the receiver systems, bubble screening was much less effective. This was probably due to the vibrations of the barge with every percussive blow, which transmitted the piling noise over the curtain. Bubble screening of entire sound-emitting structures could reduce sound even more.

Some dolphins stayed in the vicinity during construction activities, but many appeared to temporarily abandon the construction area (possibly due to other factors). However, dolphins were observed during construction or pile driving periods traveling at speeds over twice those observed during non-pile-driving periods. It is not certain whether increased speeds were a result of increased stress related to construction (Würsig et al. 2000).

Construction and Operational Activities

With regard to construction-specific activities aimed at protection and mitigation during the construction of over-water structures, only a few published reports were located. One of those reports is the literature review prepared by Mulvihill et al. (1980), which provides general construction recommendations. Two of the relevant recommendations are presented below.

- The placement of the structure relative to the sun, as well as the height and width of the deck of over-water structures, are important factors to consider. The structure should be placed high enough above the water to prevent shading. A narrow pier extending from north to south will not produce as much shade as a wide pier running from east to west (Mulvihill et al. 1980).

- The size, number, and placement of pilings should be evaluated in relation to the various biological zones over which the pier will extend.

Warrington (1999a) compiled and reported data concerning best management practices for construction, specific to surface stabilization. Quoted below are selected recommendations presented in the report that apply to activities associated with the construction of over-water structures. As stated previously, these recommendations are in essence BMPs that should be incorporated as permit conditions for individual projects, in order to ensure that these BMPs are implemented (Fresh 2000 personal communication):

Scheduling

- *Coordinating the timing of land disturbing activities and installation of erosion and sedimentation control measures to minimize water quality impacts*
- *Scheduling (in-water) construction to avoid the period when either fall or spring spawning fish or their eggs and larvae are present*
- *Designing and planning the development of roads, utilities, and building sites with as little excavation and disturbance as possible*
- *Planning construction activities during the dry season to minimize erosion*
- *Staging development so that parts are being re-vegetated and parts have not been stripped yet to minimize the proportion which is actively bared and easily eroded*

Surface Protection

- *Carrying out watering, mulching, sprigging, or applying geotextile materials to a construction area to prevent soil loss as dust*
- *Mulching, a protective blanket of straw or other plant residue, gravel or synthetic material applied to the soil surface, to minimize raindrop impact energy and runoff, foster vegetative establishment, reduce evaporation, insulate the soil and suppress weed growth*
- *Seeding (permanent) to establish a perennial vegetative cover to minimize runoff, erosion and sediment yield on disturbed areas; disturbed soils typically require amendment with lime, fertilizer and roughening; seeding should be done together with mulching; mixtures are typically most effective and species vary with preferences, site conditions, climate and season*
- *Sodding to give permanent stabilization of exposed areas by laying a continuous cover of grass sod*
- *Seeding (temporary), planting rapid-growing annual grasses, small grains or legumes, to provide initial, temporary stabilization for erosion control on disturbed soils that will not be brought to final grade for more than approximately one month; seeding is facilitated by fertilizing and surface*

roughening; broadcast seeds must be covered by raking or chain dragging, while hydro-seed mixtures are spread in a mulch matrix

- *Treating disturbed soil with polyacrylamide (PAM) to increase infiltration and reduce suspension of soil particles*
- *Top-soiling, preserving and subsequently re-using the upper, biologically active layer of soil, to enhance final site stabilization with vegetation*

Runoff Control

- *Grading surfaces to redirect sheet flow*
- *Using diversion dikes or berms force sheet flow around a protected area*
- *Covering temporary stockpiles and backfill materials to prevent erosion and sedimentation*
- *Using silt fences to contain runoff from easily eroded slopes*

Sediment Traps

- *Constructing sediment traps, small, temporary ponding basins formed by an embankment or excavation to capture sediment from runoff; traps are most commonly used at the outlets of diversions, channels, slope drains or other runoff conveyances that discharge sediment-laden water; it is important to consider provisions to protect the embankment from failure from runoff events that exceed the design capacity; plan for non-erosive emergency bypass areas; make traps readily accessible for periodic maintenance; high length-to-width ratios minimize the potential for short-circuiting; the pond outlet should be a stone section designed as the low point*
- *Constructing sod drop inlet protection which consists of a permanent grass sod sediment filter area around a storm drain drop inlet for use once the contributing area soils are stabilized; this is well-suited for lawns adjacent to large buildings*
- *Constructing vegetated filter strips (VFSs) as a low-gradient vegetated area that filters solids from overland sheet flow; they can be natural or planted, should have relatively flat slopes, and should be vegetated with dense-culmed, herbaceous, erosion-resistant plant species; the main factors influencing removal efficiency are the vegetation type and condition, soil infiltration rate and flow depth and travel time, which are affected by size of contributing area, and slope and length of strip; channelized flows decrease their effectiveness; they are often used as buffers bordering on construction areas; level spreaders are often used to distribute runoff evenly across the strip*

The operation and use of over-water structures also cause interrelated effects associated with boating activities. Warrington (1999a) compiled and reported data concerning the impact of recreational boating in freshwater environments (see also Warrington 1999b for water pollution associated with boating activities). Quoted below are a summary of selected recommendations presented in the report:

- *To minimize bottom erosion, sediment suspension, vegetation loss and effects on wildlife, normal use of motorized boats should be restricted to water depths where the propeller or jet drive is at least 2 and preferably 3 meters above the sediment or vegetation surface, except at carefully selected boat launch sites. Also, in narrow channels (up to 3 boat lengths wide) boat speeds should be restricted to 'no wake.'*
- *Heavy planting of floating and emergent native vegetation will help to protect the shoreline from wave-caused erosion.*
- *A minimal number of specified access channels between shallow and deeper water should be marked and used exclusively. These should be as short and direct as possible and should have wake limits imposed.*
- *Boats should not be permitted to operate in an area where they would be considered confined (boat cross-sectional area exceeds 5% of the cross-sectional area of the waterway). This is necessary to prevent bank erosion, sediment resuspension and destruction of marginal and shallow water vegetation.*
- *To preserve viable waterfowl and fish populations, all boating, fishing and other human activities need to be excluded from breeding and overwintering habitats during the critical seasons.*

Habitat Protection, Restoration, and Mitigation Techniques—Data Gaps

A number of data gaps were identified during the review of literature pertaining to habitat protection and mitigation techniques for the construction of over-water structures. Further research to answer the following questions would serve to fill these data gaps.

- Which mitigation techniques are most effective in minimizing the loss of habitat or ecological function?
- Are the project goals, objectives, and performance standards used for wetland mitigation applicable to lakes and reservoirs?
- For restoration projects, how should project goals, objectives, and performance standards define targeted 'historical conditions'?)

- What is the best means of preventing erosive cycles that preclude the recovery and reestablishment of emergent vegetation?

- Does the use of bright white PVC and paint or reflective metals for the construction of in-water structures tend to prevent or decrease predator fish use of the structures?

- Which design features of docks and piers are most effective in preventing or minimizing the environmental effects of these structures? Which features are most effective in minimizing their cumulative effects?

Summary of Existing Guidance

Regulatory Framework Governing Over-Water Structures in Freshwater

The regulatory framework governing construction and maintenance of over-water structures consists of federal, state, and local laws and administrative rules and guidelines. Following is a description of each of the applicable laws, codes, regulations, and other documents that make up the current regulatory framework.

Federal Laws and Regulations

National Environmental Policy Act (NEPA) *(42 United States Code [USC] 4321 et seq.)*

Federal agencies making funding decisions or issuing permits for over-water structures are required to comply with the National Environmental Policy Act. If the impacts of the over-water structure are determined to be environmentally significant, an environmental impact statement (EIS) is required. If the NEPA lead agency determines that the over-water structure will not significantly impact the environment, that agency issues a *finding of no significant impact* (FONSI).

Clean Water Act Section 404 *(33 USC 1344 et seq.; USC 1251 et seq.)*

Construction of over-water structures that would result in discharge or excavation of dredged or fill material in United States waters, including wetlands, requires a Clean Water Act section 404 permit issued by the U.S. Army Corps of Engineers and/or the U.S. Environmental Protection Agency. The U.S. Fish and Wildlife Service, National Marine Fisheries Service, and Washington Department of Fish and Wildlife also play significant roles in the implementation of the section 404 permitting process (as authorized by the Fish and Wildlife Coordination Act).

River and Harbors Act Section 10 *(USC 403 et seq.)*

Any work affecting navigable waters of the United States that extends to the ordinary high water mark in freshwater areas (including the construction of piers, docks, and floats) requires a section 10 permit issued by the U.S. Army Corps of Engineers. Navigable waters as defined in the River and Harbors Act include all presently, historically, and reasonably potential navigable waters, and all waters subject to the ebb and flow of the tide, up to mean higher high water in tidal waters and up to ordinary high water in freshwater areas.

Endangered Species Act *(16 USC 1531 et seq.)*

Because of the recent listing of several anadromous fish species for protection under the Endangered Species Act, and because many of the freshwaters of the state of Washington provide habitat for those protected species, construction of over-water structures and shoreline

development in general must comply with the requirements of the statute. The Endangered Species Act provides broad protection for fish, wildlife, and plant species that are listed as threatened or endangered. Provisions are made for listing species and designating critical habitat for listed species, as well as for recovery plans. The statute outlines procedures for federal agencies to follow when taking actions that may jeopardize listed species, and contains exceptions and exemptions. The shoreline development activities that have federal nexus (i.e., federal funds or federal permits) are subject to review under the statute. Among these activities, construction, replacement, or repair of piers, docks, mooring buoys, boat canopies, boathouses, pilings, and bulkheads require a U.S. Army Corps of Engineers permit and thereby are subject to review under the Endangered Species Act.

State Laws and Regulations

State Environmental Policy Act (SEPA) *(Revised Code of Washington [RCW] 43.21C)*

An over-water project proposal that requires a state or local agency permit is first required to undergo a SEPA review. In accordance with SEPA rules, one agency is identified as the lead agency for this review. This agency may determine that a project proposal is categorically exempt, or is clearly in compliance with the provisions of SEPA, in which case the SEPA review process is satisfied. If further clarification is needed, the lead agency can ask an applicant to fill out an environmental checklist, answering a standard series of questions to determine whether the project would have a significant adverse impact on the environment. If it is determined not to pose this threat, then the proposal is granted a *determination of nonsignificance* (DNS) and is considered to be in compliance with SEPA. If the proposed project is considered to pose significant adverse impacts to the environment, then an environmental impact statement (EIS) must be drafted, publicly reviewed, and finalized.

Shoreline Management Act (SMA) *(RCW 90.58)*

Construction of any type (including over-water structures) in waters of the state or in the adjacent regulated shoreline area, if it is valued at $2,500 or more ($10,000 if the project is a pier), requires a shoreline management substantial development permit issued by the city or county and reviewed by the Washington Department of Ecology. Shorelines in freshwater areas include all lake and reservoirs greater than 20 acres and their associated wetlands, and all streams and river segments with a mean annual flow greater than 20 cubic feet per second and their associated wetlands. The shoreline designation extends horizontally 200 feet from the ordinary high water mark.

Other activities in the water or shoreline area may require conditional use permits or variances also issued by the Department of Ecology. All permit activities are subject to appeal by citizens, applicants, and government agencies. Appeals are heard by the Shoreline Hearings Board.

The Shoreline Management Act requires local governments to write *shoreline master programs* that regulate streams, lakes over 20 acres, and marine waterfronts. There are 247 city and county master programs currently in effect that were written based on state guidelines. These guidelines are being revised (WAC 173-16). Cities and counties regulate projects in or adjacent to state

waters with their comprehensive plans, shoreline master programs, and other development regulations. The local laws and regulations that affect development activities (more specifically on- and over-water structures) in waters of the state vary from one jurisdiction to another, but include critical area development regulations (adopted under the state Growth Management Act) and environmental designations under shoreline master programs (adopted under the state Shoreline Management Act).

Clean Water Act Section 401 *(33 USC 1251 et seq.)*
and Coastal Zone Management Act *(16 USC 601 et seq.)*

These federal laws are administered by the Washington Department of Ecology. Application for a federal permit under section 404 of the Clean Water Act to discharge dredge or fill material into state waters or wetlands, or to excavate in water or wetlands, triggers review under these laws. Section 401 certification and coastal zone consistency certification are issued by the Washington Department of Ecology.

National Pollutant Discharge Elimination System (NPDES)

The federal NPDES program is administered in Washington by the Department of Ecology. If a project disturbs more than 5 acres at one time, an construction permit must be issued by the Department of Ecology to ensure that state and federal water pollution provisions are upheld.

Hydraulic Project Approval Code *(RCW 75.20 and Washington Administrative Code [WAC] 220-110)*

Construction or operation of an over-water structure that would use, divert, obstruct, or change the natural flow or bed of any freshwater or saltwater of the state requires a hydraulic project approval issued by the Washington Department of Fish and Wildlife.

The Washington Administrative Code **(**WAC 220-110-060) regulates the construction of freshwater docks, piers, and floats and the driving and removal of pilings. As a result of the recent listing of fish species under the federal Endangered Species Act, state regulations are currently being revised to include all in-, on-, and over-water structures, and to grant a greater level of protection to endangered species and the environment, based on the best scientific data available. Similarly, WAC 220-110-224, which regulates freshwater boat hoists, ramps, and launches, is being revised to address the issue of cumulative effects of the siting of these structures, and to provide more specific regulatory language regarding the uses of these structures within the context of habitat and species protection.

In addition, under the state hydraulic code, WAC 220-110-223 regulates the construction of bulkheads, and WAC 220-110-050 addresses bank protection.

A memorandum of agreement between the Washington Department of Fish and Wildlife, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service was signed on April 4, 2000 to develop an Endangered Species Act compliance agreement for hydraulic project approvals, which are issued by the Department of Fish and Wildlife under RCW 75.20. This

memorandum of agreement provides language that addresses freshwater projects, including in-, on-, and over-water structures (section 5.C(3)(f)), oversight and monitoring (section 7), and adaptive management (section 10).

Forest Practices Act *(RCW 76.09)*

Any timber harvest or roadwork in a riparian management zone or riparian area associated with construction of an over-water structure requires a forest practices permit issued by the Washington Department of Natural Resources. This permit may require that forest landowners undertake corrective and remedial actions to reduce the impact of any forest practice that may be associated with a proposed project. The goal is to afford protection to forest soils, fisheries, wildlife, water quantity and quality, air quality, recreation, and scenic beauty.

Aquatic Lands Act *(RCW 79.90)*

Use of state-owned aquatic lands, including tidelands, shorelands, and beds of navigable waters, requires an aquatic use authorization (aquatic lease) issued by the Washington Department of Natural Resources.

Water Pollution Control Act *(RCW 90.48)*

A temporary exceedance of state water quality standards established by WAC 173-201A for in-water work (e.g., change in pH or turbidity) requires a Washington water quality standards modification issued by the Washington Department of Ecology.

Aquatic Resource Mitigation Act *(RCW 90.74)*

This law establishes a state policy to authorize innovative mitigation measures, by requiring state regulatory agencies to consider mitigation proposals for infrastructure projects that are timed, designed, and located in a manner to provide equal or better biological functions and values compared to traditional onsite, in-kind mitigation proposals. When making a regulatory decision, the agencies must consider whether the mitigation plan provides equal or better biological functions, compared to the existing conditions, for the target resources or species. The factors that agencies must consider in making this decision are identified in the state hydraulic code, the state Water Pollution Act, and the Aquatic Resource Mitigation Act.

Salmon Recovery Act *(RCW 75.46/ESHB 2496)*

In 1998 the Washington State Legislature passed the Salmon Recovery Act, in response to the state's need for a coordinated approach to respond to the listing of salmon and steelhead runs as threatened or endangered under the federal Endangered Species Act.

Wetland Mitigation Banking *(RCW 90.84)*

In 1998 the Washington State Legislature passed legislation establishing wetland mitigation banking as one element of compensatory mitigation. The law directs consistency with federal

guidance on mitigation banking, and defines a wetland mitigation site as a site where wetlands are restored, created, or enhanced, or in exceptional circumstances preserved expressly for the purpose of providing compensatory mitigation in advance of authorized impacts on similar resources.

Mitigation policy guidance (RCW 75.46) states that the guidance shall create procedures that provide for alternative mitigation measures that have a low risk to the environment, yet have a high net environmental, social, and economic benefit compared to status quo options.

Local Laws and Regulations

Counties and local jurisdictions in Washington regulate the construction of over-water structures through shoreline management codes, such as the King County Shoreline Management Code (*http://www.metrokc.gov/mkcc/Code/*) or the City of Bellevue Land Use Code (*http://www.ci.bellevue.wa.us/cobasp/lucindex.asp*). These codes are drafted in the spirit of and enacted in conformance with the Washington Administrative Code.

Available Guidance Materials for Construction and Operation of Over-Water Structures in Freshwater

In response to the recent Endangered Species Act listing of species, the Washington Department of Fish and Wildlife (WDFW), the Washington Department of Ecology (Ecology), the Washington Department of Transportation (WSDOT), the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS) have begun to update existing guidance and develop new guidance for activities with the potential to adversely affect the environment. This guidance is intended to provide a holistic approach to aquatic resources, and is expected to have the flexibility needed to address watershed activities and salmon recovery efforts while operating within the existing regulatory framework.

The following list of available guidance for construction and operation of over-water structures is not comprehensive. Rather it is limited to the most recent guidelines or those currently under revision.

- *Guidance for Endangered Species Act Section 7 Consultation—Effect Determinations for New and Replacement Piers and Bulkheads in Lake Washington*, July 24, 2000. This document was prepared by the NMFS and provides background and guidance for effect determinations for new and replacement piers and bulkheads proposed for urbanized lakes, with emphasis on Lake Washington. The effect determination guidance used in this document is addressed in two separate documents: *A Guide to Biological Assessments*, March 23, 1999, and *The Habitat Approach*, August 26, 1999

- *Alternative Mitigation Policy Guidance*, February 10, 2000. This guidance was cooperatively developed by Ecology, WDFW, and WSDOT under the auspices of the Salmon Recovery Act (RCW 75.46), in order to improve the ecological benefits of compensatory mitigation for project impacts on wetlands, water quality, and fish and wildlife.

- *A Citizen's Guide to the 4(d) Rule for Threatened Salmon and Steelhead on the West Coast*, June 2000. This guide introduces and explains the rule and provides a user-friendly description of why the rule is needed, what it contains, how it will affect citizens, and how to obtain more information: (*http://www.nwr.noaa.gov/1salmon/salmesa/4ddocs/citguide.htm#Take%20Guidance*).

- *Best Management Practices to Protect Water Quality from Non-Point Source Pollution*, March, 2000. This document was prepared by Warrington (2000). It is an open-ended document produced as a web site so that it can be readily updated and expanded. The document provides recommendations that have been compiled from readily available published documents and internet sites and from some gray literature that may not be as readily available. Citations, references, and web links are provided. The document is organized by sectors. Under the service industries sector, guidelines for best management practices for the construction of wharves, docks, piers, and floats are provided (*http://www.nalms.org/bclss/bmphome.html*).

Recommendations for Guidance Document

Shore-zone development in general modifies and degrades the environment, thereby adversely affecting wildlife and fish species. The observed responses discussed in this paper (i.e., predation, behavior, and habitat structures) confirm this fact. The resultant modification and degradation of the environment occur through the following mechanisms: shore-zone habitat structure changes, shading and ambient light changes, disruption of water flow pattern and energy, and physical-chemical environmental disruptions. However, some site-specific and species-specific responses still require further research. This research is needed to obtain information required to close existing data gaps, thereby gaining a better understanding of the mechanisms of disruption associated with all over-water structures. The following recommendations are intended for the development of future policy and guidance documents that address the environmental impacts of over-water structures and associated construction and operation activities.

General Policies

- A greater statewide level of coordination among local jurisdictions, state agencies, and federal agencies is needed in the preparation of guidelines for the maintenance, construction, and operation of over-water structures.

- Statewide guidelines are needed to protect ecosystem functions and direct habitat impact mitigation, resource management, and project planning. However, because of the hydrological characteristics of the systems and differences in fish habitat utilization, two separate sets of guidelines should be developed for eastern and western Washington.

- All new rules, regulations, and guidelines for over-water structures should be supported with scientific data.

- Future research should be focused on areas where gaps and ambiguities have been identified, and resources should be allocated for this purpose.

- Existing shoreline conditions (e.g., riparian and shallow-water) should be documented by videotaping to facilitate detection of unpermitted development activities. More intensive supervision and enforcement of shoreline use and inspection of proposed projects during construction should be implemented.

- In highly developed systems, such as Lake Washington in western Washington and Lake Chelan in eastern Washington, no net increase in over-water coverage should be allowed. In such systems, offsite mitigation alternatives (e.g., in areas with the lowest development density)

should be favored over onsite mitigation whenever the expected benefit is more cost-effective and yields greater ecological benefit.

- Preference should be given to offsite mitigation efforts consolidated on one site versus multiple offsite locations.

- All mitigation should provide better functional value than that provided by the habitat being replaced.

- If new over-water structures are to be allowed, the mitigation measures required to compensate for the construction of such structures should include site- and project-specific research to verify "not likely to adversely affect" situations prior to project implementation.

- For new and retrofitting projects, strict monitoring and evaluation programs should be required and included in the project plans. Third-party groups should conduct the monitoring and evaluation programs to preclude bias in the process.

- During the evaluation of proposed projects, a policy allowing no new over-water structures should first be considered. Because of their smaller surface area and correspondingly smaller shade effect, buoys should be selected rather than piers and docks for recreational mooring.

- There should be a greater level of regulation for activities such as boating that have interrelated effects. Funds from taxation imposed on such activities should be directed to shoreline restoration and enhancement programs.

Shore-Zone Development

- To provide maximum protection to juvenile chinook salmon in eastern and western Washington, further development in existing undeveloped shore-zone areas should be restricted, particularly in those areas having the characteristics preferred by this species (i.e., low-gradient habitats with sandy bottom and no aquatic vegetation).

- The goals and objectives of shore-zone restoration projects should include habitat characteristics, functionality, and values consistent with the preferred habitat for chinook salmon.

- New research should be initiated to investigate the preferred habitat characteristics for other salmonid species and their prey.

- Minimum setbacks should be established to help prevent shoreline and stream bank erosion and to help minimize the cumulative effects of shore-zone development. These required setbacks could include requirements for the relocation of existing structures that may already exist within designated setbacks.

- Additional research should be conducted to study the effectiveness of salmon habitat restoration projects in lakes and slow-flowing rivers and reservoirs.

Structure Size

- To minimize the cumulative effects of over-water structures, in particular the loss of habitat and the potential creation of refuge for predators, all structures should be as narrow as possible to achieve the project purpose. In addition, the multifamily use of individual docks should be encouraged, and only one dock per multi-lot development should be allowed.

- The number and body size of organisms using an area influenced by a floating object are directly related to the surface area of the object. Therefore, if a new over-water structure is to be allowed, the minimum possible size should be used to minimize the attraction of salmonid predators such as bass.

On-Water Structures

- Guidelines specifically addressing the storage and operation of on-water structures (i.e., log booms and rafts, trash-booms and trash-racks, work barges, and houseboats) should be prepared. Until structure-specific data become available, the responses observed from over-water structures should be extrapolated, particularly regarding changes in ambient light and in habitat function.

Pilings

- Smallmouth bass and largemouth bass have a strong affinity to pilings. Therefore, for all new projects, and for retrofitting projects when feasible from an engineering perspective, a downgrade in size and number of pilings should be required in order to minimize potential predation on juvenile salmonids.

- Pier and dock pilings, which intercept gravel transport, may accelerate beach erosion. Therefore, the use of buoy and anchor systems should be preferred over pilings to prevent beach erosion.

- In order to minimize the potential for predation on juvenile salmonids in free-flowing areas of systems where northern pikeminnow occur, the placement of in-water structures that create back-eddies and low-velocity microhabitat should not be allowed.

- Pile-driving activities should be regulated, not because of potential noise impact, which seems to be negligible for salmonids, but for the potential to disturb bottom sediments.

- The 300-foot protection zone restricting pile-driving activities in the vicinity of known sockeye spawning areas also should be required for chinook salmon in known beach spawning areas of Lake Washington.

Bulkheads and Riprap

- New bulkheads should not be permitted under any circumstance; instead, bioengineering solutions should be required.

- For retrofitting projects, bulkheads should be completely eliminated when possible or relocated shoreward of ordinary high water, and shorelines should be restored with emergent and riparian plant species.

- Riprap should not be allowed as an erosion control measure. Instead, site-specific bioengineering techniques should be required when alteration of the natural shoreline conditions is unavoidable, or for retrofitting projects.

Shoreline Vegetation

- If the over-water structure is permitted, onsite, in-kind, offsite, or out-of-kind mitigation (or any combination of these) should be required to achieve no-net-loss of habitat. This mitigation should include the establishment of native vegetation on any disturbed and adjacent shoreline areas, to minimize the adverse effects associated with cumulative loss of shoreline vegetation.

- A buffer should be preserved between new upland developments associated with over-water structures and the shoreline, to protect foraging and rearing habitat for fish and wildlife.

- Shoreline development associated with the construction of an over-water structure should not include the alteration of natural stable shorelines or the creation of manicured land that extends to the river or lake edge. In already altered shoreline areas, bioengineering techniques should be used to protect altered shorelines.

Ambient Light and Shading

- Given that shading can affect habitat function by creating visual barriers to migrating fish, new and retrofitted over-water structures should be required to incorporate design elements to minimize the shaded area under the structure.

- New dock design elements currently required in eastern Washington (e.g., ambient light grids, white PVC sleeves for pilings, bright reflective aluminum, and bright white materials for flotation) should be investigated to determine their efficacy in reducing salmonid predation and in allowing adequate light penetration for macrophyte production. If found to be effective, these elements also should be required for projects in western Washington.

- Accessory dock structures such as pier skirting and batter boards that increase shading impacts on aquatic vegetation should not be permitted in the design or construction of new docks.

Water Quality

- Because the reaction distance declines as a decaying power function of turbidity, maintenance of background turbidity levels should be required during construction, to avoid potential adverse effects on salmonid predation. This can be achieved, for example, by the use of silt curtains or cofferdams.

- Because leachate from treated wood is toxic to aquatic organisms, the use of treated wood should not be allowed in construction of over-water structures.

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APPENDIX A

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Literature Consulted and Other Sources of Information

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APPENDIX B

Matrix of Data Availability

ECOLOGICAL IMPACTS OF IN-, ON-, AND OVER-WATER STRUCTURES AND ASSOCIATED ACTIVITIES

- MATRIX OF DATA AVAILABILITY -

		In-, On-, and Over-Water Structures										Associated Activities	
MECHANISM OF IMPACT	***RESPONSE***	Docks, Piers, & Floats	Marinas	Boat hoists, Boat Lunches, & Boat Ramps	Boathouses	Trash-booms & trash-racks	Work barges	Floating Breakwaters	Log Booms & Log Rafts	Pilings, Wharves, & Dolphins	Riprap & Retaining Walls	Pile Driving & Removal	Construction & Operation
Shore-Zone Habitat Structure Changes	*Predation*												
	Behavior	X	X		X					X	X		
	Habitat Function	X	X		X				X	X	X		
Shading and Ambient Light Changes	*Predation*												X
	Behavior	X											X
	Habitat Function	X								X			
Water Flow Pattern and Energy Disruption	*Predation*												
	Behavior	X								X	X		
	Habitat Function	X								X	X		
Physical-Chemical Disruption (Noise and Water Quality)	*Predation*												
	Behavior											X	X
	Habitat Function	X	X						X		X		X

APPENDIX C

Matrix of Direct Literature Sources

Ecological Impacts of In-, On-, and Over-Water Structures and Associated Activities: Matrix of Direct Literature Sources[a]

Mechanism of Impact & Response	In-, On-, or Over-Water Structure										Associated Activities	
	Docks, Piers, & Floats	Marinas	Boat hoists, Boat launches, & Boat ramps	Boathouses	Trash-booms & Trash-racks	Work Barges	Floating Breakwaters	Log booms & Log rafts	Pilings, Wharves, & Dolphins	Riprap & Retaining Walls	Pile driving & Removal	Construction & Operation
Shore-Zone Habitat Structure Changes												
Predation												
Behavior	[4][5][10][21][26][34][53][54][55][62][65][67][87][89][90][108][121][135]	[19][81]		[9][71]					[62][87][121]	[5][9]		
Habitat Function	[5][9][18][19][22][24][29][50][61][71][81][135]	[19][81]		[9][71]				[84][102][105]	[19][67][135]	[5][9][19][20][61][67][81][103][121]		[40][59][65]
Shading & Ambient Light Changes												
Predation												
Behavior	[53][54][107][120]											[125]
Habitat Function	[19][81][107][135]								[81]			[125][126]
Water Flow Pattern & Energy Disruption												
Predation												
Behavior									[67][87][121]	[67][121]		
Habitat Function	[60][62][73][99][125]								[87][121]	[67][81][121]		
Physical-Chemical Disruption (Noise & Water Quality)												
Predation												
Behavior											[13][14][38]	[11][70][80][81][83][125]
Habitat Function			[19][81]					[84][102][105]		[81]		[19][57][70][77][81][125][126][139]

[a]Numbers in brackets are keyed to entries in the list of references.

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Northwest Region
7600 Sand Point Way N.E., Bldg. 1
Seattle, WA 98115

Refer to NMFS No.:
NWR-2012-9480

December 27, 2012

Shawn Zinszer
Chief, Regulatory Branch
Portland District, Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946

Re: Request for Additional Information to Initiate Endangered Species Act Section 7 Consultation and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation for the Coyote Island Terminals Construction of a New Coal Exportation Dock Facility in the Columbia River (6th field HUC 170701010904), Morrow County, Oregon (Corps No.: NWP-2012-56)

Dear Mr. Zinszer:

This letter acknowledges National Marine Fisheries Service's (NMFS) receipt of your November 23, 2012 letter, requesting formal consultation under section 7 of the Endangered Species Act (ESA) and section 305 of the Magnuson-Stevens Fishery Conservation and Management Act (MSA). The request concerns the possible effects of the proposed issuance of Corps of Engineers (Corps) permits under section 10 of the Rivers and Harbors Act. The applicant, Coyote Island Terminal LLC, proposes to construct a new barge loading dock and upland coal receiving and storage facility. The project is located in the Port of Morrow at Columbia River mile 271, near the City of Boardman, Oregon. The facility would allow for the loading of coal that would be barged down the Columbia River and transshipped at an existing dock structure at the Port of St. Helens, Oregon. The intent of this letter is to obtain additional information to begin the consultation process.

The Corps has determined that 13 ecologically significant units (ESUs) of salmonids, 7 species of marine mammals, 4 species of sea turtles, the southern distinct population segment (DPS) of green sturgeon and the southern DPS of eulachon listed under the Endangered Species Act (ESA) may be affected by the proposed project as outlined in Table 1. The Corps also believes that the proposed action may adversely affect essential fish habitat (EFH) for salmonids, coastal pelagic species, and Pacific Coast groundfish.

Table 1. ESA listed species considered in the Corps request for consultation for the Coyote Island Terminal project at the Port of Morrow, Morrow County, Oregon

Species	**ESU/DPS**[1]
Steelhead (*Oncorhynchus mykiss)*	Upper Columbia River DPS
	Middle Columbia River DPS
	Lower Columbia River DPS
	Upper Willamette River DPS
	Snake River Basin DPS
Chinook salmon (*O. tshawytscha*)	Upper Columbia River spring run ESU
	Lower Columbia River ESU
	Snake River fall run ESU
	Snake River spring/summer ESU
	Upper Willamette River ESU
Chum salmon (*O. keta*)	Columbia River ESU
Coho salmon (*O. kisutch*)	Lower Columbia River ESU
Sockeye salmon (*O. nerka*)	Snake River ESU
Green sturgeon (*Acipenser medirostris*)	Southern DPS
Eulachon (*Thaleichthys pacificus*)	Southern DPS
Steller sea lion (*Eumetopias jubatus*)	Eastern DPS
Killer whale (*Orcinus orca*)	Southern resident DPS
Humpback whale (*Megaptera novaeangliae*)	
Fin whale (*Balaenoptera physalus*)	
Sei whale (*B. borealis*)	
Blue whale *(B. musculus*)	
Sperm whale *(Physeter catodon*)	
Leatherback turtle (*Dermachelys coriacea*)	
Green turtle (*Chelonia mydas*)	
Loggerhead turtle (*Caretta caretta*)	North Pacific Ocean DPS
Olive ridley turtle (*Lepidochelys olivacea*)	

Due to the public controversy surrounding this project and the potential for substantial impacts to NMFS' trust species, we recommend that the Corps prepare a draft environmental impact statement (EIS) for the project instead of the environmental assessment that we understand is currently proposed. An EIS would provide a platform to more thoroughly evaluate the effects of the proposed action as well as to consider less damaging alternatives. It would also provide an opportunity for the Corps to do a comparative analysis of the relative effects of several other coal transshipping projects being proposed at various sites in the Pacific Northwest. Such a comparative analysis should be structured to determine whether a project at one of one of the other sites would result in fewer impacts to NMFS trust species than the proposed action at the Port of Morrow.

If the Corps decides to prepare an EIS, it would be appropriate to postpone the ESA and MSA consultation process until after a preferred alternative is selected at the FEIS stage In the event that the Corps decides to proceed with the current NEPA approach and not prepare an EIS, the NMFS has identified additional information necessary to initiate this consultation as outlined in

[1] ESU = Ecologically significant unit. DPS = distinct population segment

the regulations governing interagency consultations for ESA at 50 CFR section 402.14(c) (initiation of formal consultation) and for EFH at 50 CFR 600.920(g) (EFH assessments).

To complete the initiation package, please provide the following:

- The BA provides no information on a stormwater plan for the 23 acres of newly created impervious surface for the coal storage facility in the uplands at the Port of Morrow. Please provide a description of how and to what extent stormwater will be treated on site and where any discharges may be located.
- The reasons that existing facilities cannot be used for coal loading should be discussed. For example, there is a loading facility immediately east of the proposed project site. Describe what alternatives (if any) are available in the surrounding area that would suffice in lieu of construction of a new facility.
- Details are needed on the water depth(s) where permanent piles will be driven and what will be covered by over water structures.
- Specify the location and number of derelict pilings proposed for removal as mitigation for the new facility. Also discuss the methods that will be used to remove the piles.
- A planting plan for areas disturbed by construction at the Port of Morrow should be provided.
- A more in-depth analysis of the contaminants at the sites where vessels will be disturbing contaminated sediment (through prop wash) and the contaminant effects on species is needed.
- Please provide information on what measures will be implemented to mitigate impacts from shoreline erosion and juvenile fish wake strandings resulting from the increase in barge and vessel traffic due to the proposed action throughout the Columbia River action area.
- The BA acknowledges an increased risk of ship strikes from additional vessel and barge traffic could result in take of marine mammals and turtles, so the determination of not likely to adversely affect marine mammals and turtles is not valid. A Marine Mammal Protection Act permit may be needed. We are coordinating with NMFS marine mammal experts on this issue. Further information may be necessary.
- Effects to NMFS trust resources, such as potential marine mammal strikes from increased shipping traffic, should be analyzed at least out to the edge of the Exclusive Economic Zone (EEZ), not just to the mouth of the Columbia River.
- Effects on species and critical habitat from invasive species in ballast water and on the hulls of ocean going vessels coming from Asia should be analyzed, as well as effects from water withdrawals and return from these vessels.
- The BA acknowledges that transportation of the coal by rail to the Port of Morrow could be considered an interrelated and interdependent action, but provides no description or analysis of the effects. This should be provided. A discussion as to the extent of coal dust lost during transportation, the fate of that dust, what streams containing NMFS trust resources could be impacted and the extent of that impact needs to be provided.
- Methyl mercury has been identified as one of the threats to listed Lake Ozette sockeye salmon. Burning of coal in Asia has been linked to the increase in methyl mercury in the atmosphere. The project's contribution to the deposition of methyl mercury in Lake Ozette should be analyzed.

- There is no analysis in the BA of the effects of burning the coal in Asia (acid deposition, global climate change). Global climate change and resultant impacts to ESA listed salmonids has been shown and is a growing concern. An analysis of the extent to which the increase of coal being exported to Asia with subsequent burning affects climate change is necessary.
- The BA indicates that construction of the upland portion of the site will begin in May 2013. The applicant should be made aware of the potential problem of irretrievable and irreversible commitment of resources prior to issuance of a permit if construction is completed before a permit is issued.
- As part of our Tribal Trust responsibilities, NMFS will also be consulting with Tribal representatives regarding this project. Columbia River Tribes may have additional concerns not identified in this letter

The NMFS requests the above information to evaluate fully the potential adverse effects from the proposed action. If desired, NMFS is available to discuss conservation measures that may minimize adverse effects to listed species and could be adopted as part of the proposed action.

Until these information needs are addressed, consultation will not proceed. Consultation on the proposed action will resume upon receipt of the requested information if it is determined that the information is sufficient to complete consultation. If the additional information necessary to evaluate the effects of the proposed action on ESA-listed species and EFH is unavailable, the Corps has two options: (1) With your agreement, the consultation may be discontinued until sufficient information is available for a complete analysis; or (2) the NMFS can complete its analysis with the available information, giving the benefit of the doubt to the species. The consequence of completing consultation while giving the benefit of the doubt to the species depends on the significance of the missing data. Moreover, if additional data become available that differs from what was considered during consultation, re-initiation of consultation might be necessary.

We will notify you when we receive this additional information. Our notification letter will also outline the dates within which consultation should be completed.

If you have questions regarding this letter, or how to continue with the consultation process, please contact Ben Meyer, Chief, Willamette/Lower Columbia Habitat Branch of the Oregon State Habitat Office, at 503-230-5425.

Sincerely,

Michael P. Tehan
Assistant Regional Administrator
Habitat Conservation Division