BEFORE THE STATE OF WASHINGTON
ENERGY FACILITY SITE EVALUATION COUNCIL

In the Matter of: Application No. 2013-01 TESORO SAVAGE, LLC TESORO SAVAGE DISTRIBUTION TERMINAL	CASE NO. 15-001 SWORN PRE-FILED TESTIMONY OF MARK ROHRBACH

I, Mark Rohrbach, state as follows:

1. I swear under the penalty of perjury of the laws of Washington and the United States that the following testimony is true and correct.

2. I am over eighteen years of age and am otherwise competent to testify in this case. My testimony is based upon my education, training, experience, professional qualifications, and understanding of the matters herein.

3. Based on my professional experience and training, I have developed an expertise in Seismic – Ground Improvements. As the design engineer of record for all of the ground improvement in Areas 300 and 400 of the Terminal site, my testimony is intended to explain the static and seismic components of the design and to a limited extent the design objectives that were developed by others. Several other consultants are assisting with non-ground improvement design features throughout the various areas of the Terminal site, in Areas 300 and 400, and in other areas of the facility where Hayward Baker Inc.("HBI"). did not provide ground improvement design work. My testimony is intended only to address those portions of the project on which HBI did provide ground improvement design services. I collaborated with other members of the design team to fully ensure that the work done meets all applicable standards and codes, and that the work done by HBI is

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fully consistent with and compatible with work being done by others within Areas 300 and 400.

I. EDUCATION AND PROFESSIONAL BACKGROUND

4. I began my formal education while I was in the Army. While I was a full time soldier, I earned an Associate Degree in Technology from Pierce College, Steilacoom, WA (1997). After leaving the Army, I earned a Bachelor's of Science in Civil Engineering, University of Washington, Seattle (2000). I then began working full time for a regional consulting firm while working towards a Master of Science in Civil Engineering (MSCE), again from the University of Washington, Seattle. My MSCE was awarded in 2002. Following my MSCE, I completed some post graduate work in risk analysis and risk management, again at the University of Washington . Later I began working towards an MBA. The UW does not classify the civil engineering specialty (e.g. structural, environmental, geotechnical) associated with a MSCE degree, but my course of study was almost exclusively geotechnical.

5. I have 16 years of geotechnical engineering experience. Most of that time was spent as a consulting geotechnical engineer. I am a professional engineer in CA, OR, WA, AK, ID, NV, and HI. I am a registered professional geotechnical engineer in OR (the State of WA does not recognize "professional geotechnical engineer" as a specific specialty within civil engineering). In addition, I am a registered Professional Engineer (P.Eng.) in British Columbia, Alberta, and Saskatchewan. I have completed projects in each area where I am licensed. I have also been involved with large projects off Africa's west coast and in Mexico.

6. Professionally I have been quite active in the local geotechnical and civil engineering professional organizations. I am a Past President of the ASCE's Seattle section Geotechnical Group (now the Seattle Chapter of the Geo-Institute). I am a two-term

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president of the Tacoma/Olympia section of ASCE. I am currently the Public Relation's Chair of the Seattle Geo-Institute and a member of the Seattle Geo-Institute technical committee on Ground Improvement.

7. I have attached my Curricula Vitae as Attachment A to my testimony.

II. SCOPE OF ANALYSIS

A. Ground improvement design

8. As the ground improvement design engineer of record, I am very familiar with the site's soil, groundwater and seismic conditions. Ultimately, I am the individual responsible for ensuring that the ground improvement design will satisfy design expectations established by others and comply with (and more often than not exceed) the requirements of all applicable design guidelines, design standards and design specifications. My conclusions are based on the results of my analysis and the analysis of other specialists who were working on this project and under my charge.

9. I have reviewed and evaluated all of the ground improvement designs in the areas defined Areas 300 and 400 at the Terminal site, specifically the control of static tank settlement, seismic tank settlement, liquefaction predictions, and ground improvement below and in the vicinity of the 6 storage tanks. In addition, I am responsible for the ground improvement design to limit static and seismic settlement and movement of the pipeline which is proposed to run parallel to the river, the static and seismic settlement and movement of the dock abutment (and the peripheral buildings including emergency power and fire suppression facilities). This responsibility specifically includes evaluation and mitigation of seismic lateral spreading of the riverbank at the pipeline footing and dock abutment locations during design seismic loading.

B. Review background for design

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10. The primary documents I reviewed and which form the basis of my design are:

- **"Calculations for Flat Bottom Tank Ring Foundation", not dated, by R&M Engineering Consultants. This document appears to be a MathCAD file titled "13014 Savage POV, Typ. 350,000 bbl Crude Oil Tank Foundation";**
- **Design Concept Drawings "Area 300 Storage Tank Foundation, 0300-FD-004 REV HH", dated November 14, 2014, by R&M Engineering Consultants;**
- **Provided TSPT Site Plan CAD drawing by R&M, dated November 12, 2104, by R&M Engineering;**
- **Design Concept Drawings "Footing & Foundation Plot Plan Area 300, 0300-FD-001 REV HH", dated November 14, 2014, by R&M Engineering Consultants;**
- **"Ground Improvement Port of Vancouver", dated October 17, 2013, and prepared by R&M Engineering Consultants;**
- **"Tesoro Savage Vancouver Energy Distribution Terminal – Dock Facility, Port of Vancouver, USA", dated September 5, 2014, and prepared by GRI; and**
- **"Tesoro Savage Vancouver Energy Distribution Terminal – Upland Facility, Port of Vancouver, USA", dated December 20, 2013, and prepared by GRI (see below).**

I also consulted the International Building Code and ASCE 7-10 and other documents which address development of design conditions and derivation of loads to be resisted. However, these documents were used by others to derive the performance specifications for various design elements which my design satisfies.

11. HBI and my opinions and conclusions on the ground improvement design are contained in the report attached hereto as Attachment B (Hayward Baker Ground Improvement Design Report) which is incorporated herein by reference (hereafter "Design Report").

III. PURPOSE OF TESTIMONY

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12. The purpose of my testimony is to address how the Vancouver Energy Terminal project's Application for Site Certification (ASC) complies with the requirements of WAC 463-60-145 and Adjudication Issue 16 and 31, as identified in the Administrative Law Judge's Order Clarifying EFSEC's Process, Modifying Dispositive Motion Deadline, Summarizing Preliminary Issues, and Setting Hearing Dates (February 3, 2016). As explained below, based upon my review of the application and available information, the ground improvement design component of the ASC meets the requirements of WAC 463-60-145, all applicable codes and standards.

C. Analysis of soils reports, design criteria and design compliance

i. Incorporation of design criteria documents from GRI

13. As discussed in Sections 3 and 12 of the design report, a great deal of information was reviewed as a basis for the Design. Of particular importance were the design and performance requirements established by others as being appropriate for this project. These performance criteria are listed in Section 3.2 of the design report and reproduced below for completeness.

a. Performance Requirements for Area 300

14. The Performance Criteria for Area 300 are:

- Static settlement at the perimeter of the tanks:
  2" total settlement (post hydro-test), and
  1" differential settlement (post hydro-test).
- Seismic (Liquefaction) settlement at the perimeter of the tanks:
  2" total settlement, and
  1" differential settlement.
- Combined Seismic/Static Settlement at the center of the tanks:
  8 inches (post hydro-test).
- Design groundwater elevation:
  Elevation +12 Ft.

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- Design earthquake corresponding to IBC 2012 Site Class D/E:

  PGA=0.37g
  Mw=9.0

15. For convenience the most important design parameters are summarized in Table 1 (below):

Table 1. Summary of Ground Improvement Design Parameters for Area 300

Parameter	Value	Basis
Earthquake Magnitude	9	GRI
PGA	0.37	GRI
Groundwater Elevation in Area 300 (ft.)	12	GRI
Elevation of top of soil profile (ft.)	Varies (±27.5)	Based on survey data
Elevation of bottom of soil profile	Varies	Varies with top and tip of CPT*
Elevation of Installation	Ex. Grade - 4ft.	HBI Proposal Dated 11/26/13
Bottom of Tank Elevation (ft.)	31.75	Drawing 0300-FD-004
Thickness of soil profile to analyze	Length of CPT	Varies per CPT*
Critical Facility	NO	IBC 2012
Bearing Pressure (In Service)	2500 psf	GRI / R&M Calculations
Bearing Pressure (Hydro-test)	2882 psf	R&M Calculations
Tank Diameter	240 ft.	Drawing 0300-FD-004
Tank Shell Capacity	400,000 bbl	BergerABAM
Tank Maximum Fill Volume	360,000 bbl	BergerABAM
Tank Working Volume	340,000 bbl	BergerABAM
*All CPTs were advanced to practical refusal which occurred atop the gravel at about Elevation -24 ft. to -30 ft. The gravel is reported to have a low potential for static or seismic settlement.		

Design parameters represent the primary 'input' values used for evaluation of the existing site conditions and the post improvement site conditions. These input parameters represent the industries' best efforts to mathematically define the seismic and geologic environments in which the project exists. When there is some natural variation of a particular parameter (say depth to groundwater) a reasonably conservative value was selected. For example, when evaluating the potential for soil liquefaction assuming, a

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high groundwater level is conservative; however, when evaluating potential settlement a low groundwater level is conservative; thus, it is not appropriate to design a complex system using the largest or smallest possible depth to groundwater. As you can see from the table above, BergerABAM, GRI, and others established worked together to ensure the appropriate parameters were selected and to ensure that there is consistency across the various engineering specialties

b. Performance Requirements for Area 400

- The transfer pipeline is located about 80 ft. from top of bank
- Static displacement of pipe-rack foundations (both vertical and horizontal)
  - 2" total settlement (within 30 ft. pipe span)
  - 1" differential settlement (within 30 ft. pipe span)
- Seismic displacement of pipe-rack foundations (both vertical and horizontal)
  - 2" total settlement (within 30 ft. pipe span)
  - 1" differential settlement (within 30 ft. pipe span)
- Lateral Spreading (both vertical and horizontal)
  - 2" total
- Static settlements of structures in improved areas:
  - 1" total settlement
  - 0.5" differential settlement
- Seismic settlements of structures in improved areas:
  - 2" total settlement
  - 1" differential settlement

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- Design groundwater elevation along the shoreline:
  Elevation +7 ft.
- Design earthquake corresponding to IBC 2012 Site Class E:
  PGA=0.37g
  Mw=9.0

16. For convenience the most important design parameters are summarized in Table 2 (below):

Table 2. Summary of Ground Improvement Design Parameters for Area 400

Parameter	Value	Basis
Earthquake Magnitude, Mw	9	GRI
PGA	0.37g	GRI
Groundwater Elevation Area 400 (ft.)[1]	+ 7.5 ft.	GRI
Elevation of top of soil profile	Varies (±27.0 ft)	Based on survey data
Elevation of bottom of soil profile	Varies (-56 to -66 ft)	Varies with top and tip of CPT[2]
Thickness of Soil Profile to analyze	Length of CPT	Varies per CPT[2]
Critical Facility	NO	IBC 2012
Cross-section A-A' & A1-A1'	NA	GRI and project drawings
1. This is the groundwater elevation used for analysis and assumed to exist at the time of field explorations (SPT and S/CPT testing). **2. All CPTs were advanced to practical refusal which occurred atop the gravel at about Elevation -53ft.**		
The gravel is reported to have low potential for static or seismic settlement		

ii. Applicable regulations/codes

17. Selection of the appropriate design standards and loads was the responsibility of others. As part of my professional due diligence I compared the basis of design information provided to me for consistency with IBC 2012, ASCE 7-10, and other design guides. In each case I found the required loads and basis of design information to be consistent with or more conservative (safer) than required by the various design guides.

iii. Ground improvement design by area

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18. HBI analyzed the site conditions, applicable standards, and design criteria for development of our ground improvement design. In general, ground improvement is a designed and constructed system which changes the engineering properties of the site soils. There are many forms of ground improvement including, but not limited to: pre-inducing anticipated settlement, increasing the drainage rate of site soils, densifying site soils and reinforcing site soils. The appropriate method of ground improvement is related to the engineering properties of the soil, the loads and desired performance of the system, the time available for improvement, the cost of the ground improvement techniques and other factors. Ground improvement is often used in seismically active areas to change potentially unstable soil into stable soil and/or to prepare the ground for new construction projects, and/or reduce the potential for risks to the constructed system (i.e. structural and operational integrity) presented by seismic activity, rapidly changing groundwater conditions or static stability problems.

19. Before discussing the ground improvement design for the Terminal some discussion of the various techniques is appropriate. As discussed in the design report:

a. Stone Columns (also known as Vibro-Stone Columns)

20. Use of Stone Columns is a ground improvement technique that uses specialty purpose-built vibrating probes to densify and reinforce the soils while constructing a stone column. The installation process imparts energy by means of vibrations produced by a rotating eccentric weight mounted on a shaft near the tip of the probe. The vibrator is suspended from a crane and lowered into the ground under its own weight, vibrations, and air jetting. Upon reaching the design depth, the vibrator is lifted in stages as the stone is fed through a side pipe and expelled at the tip of the vibrator. Cohesionless soils are densified while cohesive soils are reinforced by the installation of the stone column. For this project,

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pre-auguring through the fine grained soils is necessary to ensure the installation process does not damage sensitive fine grained soils.

21. Installation of stone columns by the dry bottom feed method displaces the ground that was not removed by pre-auguring. Verification of improvement is undertaken by HBI using cone penetration testing after stone column installation.

b. DSM Columns

22. Deep Soil Mixing (DSM) is a ground improvement technique that improves the characteristics of weak soils by mechanically mixing them with cementitious binder slurry. To construct columns, a powerful drill advances drill steel with radial mixing paddles located near the bottom of the drill string. The binder slurry is pumped through the drill steel to the tool as it advances and additional soil mixing is achieved as the tool is withdrawn. The process constructs individual soilcrete columns, rows of overlapping columns or 100% mass stabilization, all with a designed strength and stiffness. The technique has been used to increase bearing capacity, decrease settlement, increase global stability, and mitigate liquefaction potential for planned structures, tanks, embankments and levees.

23. Wet soil mixing has also been used to construct in situ gravity retaining structures, and to facilitate tunnel construction or remediate the impact tunneling may have on nearby structures. Soil stabilization by wet soil mixing can provide structural support and/or it can greatly reduce lateral loads on bulkhead walls. Mixing shaft speed, penetration rate, batching, and pumping operations are typically adjusted after constructing one or more test columns in a convenient area on site. Pre-production laboratory testing is used to prescribe mix methodology, energy, and the grout slurry system.

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24. HBI has developed proprietary special equipment and software for the real-time monitoring of all mixing parameters during the wet soil mixing process (DAQ). Verification of improvement is undertaken by HBI using DAQ, wet-sampling, and coring.

c. Jet Grout

25. Jet grouting is a grouting technique that creates in situ geometries of soilcrete (grouted soil), using a grouting monitor attached to the end of a drill stem. The jet grout monitor is advanced to the maximum treatment depth, at which time high velocity grout jets (and sometimes water and air) are initiated from ports in the side of the monitor. The jets erode and mix the in situ soil as the drill stem and jet grout monitor are rotated and raised. The jet grouting process constructs soilcrete full columns designed strength and geometry. Since the geometry and physical properties of the soilcrete are engineered, the properties of the soilcrete are readily and accurately predictable.

26. Jet grouting's ability to construct soilcrete in confined spaces and around subsurface obstructions such as utilities, provides a unique degree of design flexibility. Verification of improvement is undertaken by HBI using DAQ, wet-sampling, and/or coring.

27. Jet grouting produces spoils which require proper field management/control and proper disposal. Field management and control of jet grout spoils to typically the responsibility of the project general contractor and is usually accomplished using a combination of ditches, collection/settling/curing ponds. In the state of Washington off-site disposal of jet grout spoils is typically necessary.

d. Area 300

28. The ground improvement in Area 300, the tank area, consists of stone columns three feet in diameter and spaced at 8.2 ft. on centers (square grid spacing) and a systematic first filling of each tank with water. The length and tip elevation for the stone

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columns is different for each tank. The tip elevations range from about Elevation -14 ft. to about Elevation -18.5 ft. Additional information is provided in the narrative of this report and on the Design Concept Drawings. At Tank 1, the base design is supplemented with two additional rings of stone columns to address potential differential settlement concerns in unusually poor soil conditions.

29. Also in Area 300, HBI's analysis indicates that ground improvement below the proposed transfer pipeline is also necessary. In general, ground improvement below the transfer pipeline consisting of stone columns three feet in diameter and spaced at about 7.7 ft. on centers will achieve the required static and seismic ground behavior. The length and tip elevations for the stone columns supporting the proposed transfer pipeline vary along the alignment of the transfer pipeline. Stone Column tip elevations range from about Elevation 5 ft. to about Elevation -16 ft. Additional information is provided in the narrative of this report and on the Design Concept Drawings.

30. In this area the substantive review comments in the DEIS state that the ground improvement in Area 300 do not extend all of the way through the liquefiable soil layers. This is true and acceptable because rigorous analysis has shown that the performance objectives can be satisfied without fully penetrating the liquefiable layers. In my opinion adding stone column length in Area 300 has the practical effect of increasing the carbon footprint of the project and the cost of the project with no benefit to environment or the project. The ground improvement design meets or exceeds all applicable standards, and takes a conservative approach to ground improvement for this area.

e. Area 400

31. With Regard to Area 400, the marine terminal, the transfer pipeline alignment is generally parallel with the river and about 94 ft. northeast of the ordinary high water line (OHWL). HBI's analysis has shown that ground improvement below the

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proposed transfer pipeline is necessary. In the transfer pipeline portion of Area 400 stone columns alone are not adequate to provide the required stability; therefore, the design includes a series of jet grout columns, DSM panels and stone columns. The DSM panels are used to limit the potential liquefaction below the pipe alignment. The jet grout column is used to provide the vertical support of the pipe-rack foundation. The stone columns form a nonliquifiable buttress that stabilizes the shoreline area. The DSM panels are spaced approximately 35 ft. apart, 55 ft. long, ±6 ft. wide and extend to Elevation -18 ft. The jet grout column below the DSM panel is 8 ft. in diameter and extends to Elevation -50 ft. The stone columns are located between the DSM panels and the top of the bank are 3 ft. in diameter and spaced at 8 ft. on centers. The stone columns extend to the nonliquefiable soils at approximately Elevation -50 ft. Additional information is provided in the narrative of this report and on the Design Concept Drawings.

32. Also in Area 400, HBI's analysis indicates that ground improvement in the vicinity of the proposed dock abutment is necessary. In this area, the transfer pipeline support transitions from foundations bearing on improved soils to pipe-racks supported by the proposed dock structure. This transition occurs at the dock abutment. At the dock abutment a block of ground improvement approximately ±160 ft. long (parallel to the river) and ±72 ft. long (perpendicular to the river) is necessary. This ground improvement block consists of three zones. The southern zone begins at the OHWM and extends ±40 ft. landward (northeast). The soil in this area is not adequate to support the abutment piles so jet grouting methods will be used to achieve full replacement (Ar = 100%) The central zone contains jet grout columns 6 ft. in diameter and spaced to achieve a 40% replacement ratio (Ar = 40%). The third (northern) zone contains the DSM/Jet Grout section described above for support of the pipe-rack foundations. Additional information is provided in the narrative of this report and on the Design Concept Drawings.

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33. There have been several questions about the functionality of the proposed improvements within Area 400. In very general terms during a very significant earthquake, the soil between the DSM panels could liquefy and displace laterally towards the river (this process in this context is known as 'extrusion'). The potential for this type of failure was evaluated using the method proposed by Kitazume & Terashi, 2013, a method that is accepted as an industry standard. HBI's analysis using this published and accepted method concluded that a post improvement extrusion failure is unlikely to occur and supports the use of commonly accepted and statistically valid estimates of lateral spreading for the seismic no-liquefaction case. In my opinion the ground improvement design for Area 400 meets or exceeds all applicable standards, and takes a conservative approach to ground improvement for this area. Further this not the first time this method has been used on a major project. HBI has previously used this analytical procedure during our design and subsequent construction of the projects listed in Table 3

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Table 3. Previous successful projects with similar analysis methods

Project Name	Location	Application	Owner/GC	Approval Agency
Lake Sherwood	Ventura County, CA	Soil mixing, DDC, wick drain, and surcharge	Sherwood Development	Ventura County, CA
Pardee Warehouse	Oakland, CA	DDC, wick drain and surcharge	Fullmer Construction	Alameda County, CA
Hynundai Site, Montague Expressway	San Jose, CA	Compaction grouting	Legacy Partners Residential, Inc	City of San Jose, CA
Neptune Marina	Marina Del Ray, CA	Vibro stone column and soil mixing	Johnstone Moyer, Inc	Los Angeles County, CA
79 Emerald Bay	Laguna Beach, CA	Soil Mixing	Scheckter	Orange County, CA

iv. Analysis regarding anticipated compliance

34. The system I designed is anticipated to comply, in every way, with the local standard of practice for similar structures/projects. I recognize that this is a major project constructed adjacent to valuable environmental and economic resources, that these resources are highly regulated and that the Terminal project is attracting attention from a large number of stakeholders.

35. I understand that some have suggested that more sophisticated analysis methods, such as finite element modeling (FLAC/Plaxis) methods should be used for portions of the analysis. These types of analysis are very complex and rely on many input variables and very complex analytical algorithms. While very sophisticated in appearance, functionality and quality of the output is, in my opinion, always limited by the quality of the information input and more importantly the various algorithms and analytical procedures used. In highly three dimensional systems, where the existing soil

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conditions/stresses have been modified by the construction of ground improvement, it is my considered opinion that these methods are less reliable than the method I used for my design.

D. DEIS review and responses.

36. I have reviewed the entire DEIS and I have prepared and/or reviewed language included in some of the Applicant's comment letters. In my opinion as an experienced licensed professional engineer, the design is appropriate as described in the design submittal as I have described above. The pipeline footing soil improvements within Area 300 and Area 400, in my opinion as an experienced licensed professional engineer are appropriate as described in the design submittal.

37. The following documents are attached to my testimony for reference:

Attachment A: CV of Mark Rohrbach

Attachment B: Hayward Baker Ground Improvement Design Report

[Signature on following page]

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DATED this 13th day of May, 2016.

Mark Rohrbach, Declarant

STATE OF WA)
)
COUNTY OF King)

Mark Rohrbach, being duly sworn upon oath, deposes and says: The foregoing testimony is true, correct and complete to the best of my knowledge, information and belief and is given subject to the laws of perjury in the State of Washington.

GIVEN under my hand and official seal this 13th day of May, 2016.

NOTARY PUBLIC in and for the State of: Washington

Residing at: Kent, WA

My Commission Expires: 8-31-2017

Dana Dye
Printed Name of Notary:

Notary Public
State of Washington
DANA DYE
My Appointment Expires Aug 31, 2017

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