Shadow Flicker Briefing

Subject:	Shadow-Flicker Modeling Kittitas Valley Wind Power Project, WA.
Customer:	Horizon Wind Energy 210 SW Morrison, Suite 310 Portland, OR 97204
Project type:	Modeling
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Distribution:	Valerie Schafer, Chris Taylor; Horizon
Revision:	3
Date:	Nov. 23, 2005

1. Introduction

This Project Briefing provides a brief explanation of the shadow-flicker phenomenon, the modeling approach employed and relevant explanations to the shadow-flicker reports. The corresponding shadow flicker reports are based on analysis of the layout submitted by the applicant September 30, 2005 and revised in November 2005. The analysis uses the same software modeling as the original analysis prepared for the EFSEC DEIS in December 2003.

2. Shadow-Flicker Background

Shadow flicker caused by wind turbines is defined as alternating changes in light intensity caused by the moving blade casting shadows on the ground and stationary objects, such as a window at a dwelling. No shadow will be cast when the sun is obscured by clouds/fog or when the turbine is not operating.

Shadow-flicker can occur in project area homes if the turbine is located near a home and is in a position where the blades interfere with very low-angle sunlight. The most typical effects are the visibility of an intermittent shadow in the rooms of the residence facing the wind turbines and subject to the shadow-flicker. Such locations are typically called shadow-flicker receptors. Obstacles such as terrain, trees, or buildings between the wind turbine and a potential shadow-flicker receptor significantly reduce or eliminate shadow-flicker effects.

The spatial relationships between a wind turbine and receptor, as well as wind direction are key factors related to shadow flicker duration. General industry practices place turbines at least 1000 ft from sensitive receptors. At these distances shadow flicker usually only occurs at sunrise or sunset when the cast shadows are sufficiently long. For situations where the rotor plane is in-line with the sun and receptor (as seen from the receptor), the cast shadows will be very narrow (blade thickness), of low intensity, and will move quickly past the stationary receptor. When the rotor plane is perpendicular to the sun-receptor "view line", the cast shadow of the blades will move within a circle equal to the turbine rotor diameter.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance and low visibility weather conditions, such as haze, or fog.

The analysis performed for this report does not evaluate the level of shadow flicker intensity, but rather focuses on the total amount of time (hours and minutes/year) that shadow flicker can potentially occur at receptors regardless of whether the shadow flicker is in the barely noticeable range or otherwise.

Consequently, it is likely that all receptors would experience less shadow flicker impact than is reported here. It is further likely that marginally affected receptors may not experience shadow-flicker at all.

The shadow-flicker frequency is related to the rotor speed and number of blades on the rotor. The modeling results presented are based on a wind turbine with a 3-bladed, 90 m diameter rotor, 80 meter hub height and a nominal rotor speed of 16 RPM which translates to a blade pass frequency of 0.8 Hz (less than 1 alternation per second). This is within the range of turbine sizes under consideration for the project and since the rotor diameter and hub heights are at the high end, the results represent what would be considered worst case in terms of the distance of the shadow flicker zone from the turbines.
Health wise, such low frequencies are harmless. Frequencies higher than 3 Hz but below 10 Hz are widely used in discotheques and the Epilepsy Foundation has made a statement that frequencies below 10 Hz are not likely to trigger epileptic seizures.

3. Modeling Approach

A near worst case approach has been adopted for reporting the shadow-flicker results. Additional general site and receptor-specific assessments such as obstacles, mountains outside of the range of the model and diurnal and seasonal cloud and fog patterns may further reduce the reported shadow flicker impacts. The analysis assumes windows are situated in direct alignment with the turbine to sun line of sight. Even when windows are so aligned, the analysis does not account for the difference between windows in rooms with primary use and enjoyment (e.g. living rooms) and other less frequently occupied rooms.

The shadow-flicker model uses the following input:

- Turbine locations (coordinates)
- Shadow Flicker receptor (residence) locations (coordinates)
- USGS 1:24,000 topographic and USGS DEM (height contours)
- Turbine rotor diameter
- Turbine hub height
- Joint wind speed and direction frequency distribution
- Sunshine hours (long term monthly reference data)

The model calculates detailed shadow-flicker results at each assessed receptor location and the amount of shadow-flicker time (hours/year) everywhere surrounding the project (on an iso-line plot). A receptor in the model is defined as a 1 m^2 area 1 meter above ground level. This omni-directional approach produces shadow-flicker results at a receptor regardless of the direction of windows and provides similar results as a model with windows on various sides of the receptor.

The sun's path with respect to each turbine location is calculated by the software to determine the cast shadow paths every 2 minutes, every day over a full year.

The turbine run-time and direction (seen from the receptor) are calculated from the site's long-term wind speed and direction distribution.

Finally, the effects of cloud cover are calculated using long term reference data (monthly average sunshine hours) to arrive at the projected annual flicker time at each receptor.

Output from the model includes the following information:

- Calculated shadow-flicker time at selected receptors
- Tabulated and plotted time of day with shadow flicker at selected receptors
- Map showing turbine locations, selected shadow-flicker receptors and iso-line contours indicating projected shadow-flicker time (hours per year).

4. Conclusion

The shadow-flicker model assumptions applied to this project are very conservative and as such, the analysis is expected to over-predict the impacts. Additionally, many of the modeled shadow flicker hours are expected to be of very low intensity.

The results are therefore prudent projections of the anticipated shadow flicker levels that would be experienced at the nearby residences.

The number of shadow-flicker hours calculated at the nearby residences is common and comparable to other wind power projects installed around the USA.

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Table 3.4-2: Kittitas Valley Wind Power Project Wind Turbine Shadow-Flicker Analysis

Residence	# Days/Year with Shadow Flicker	Max # Hours/Day with Shadow Flicker	Expected #Hour/Year with Shadow Flicker
Ackerson	186	0:52	26:28
Ahles	138	0:30	14:21
Andrew	297	1:44	84:07
Anthony	247	0:40	29:42
Archambeau	140	0:24	16:32
Brown	125	0:22	9:48
Burt (#084)	198	0:22	15:25
Burt (#670)	186	0:22	13:00
Burt (#690)	194	0:24	15:52
Campbell	233	0:42	22:29
Darrow	183	0:22	16:00
Engelstad	190	0:22	10:29
Franklin	113	0:14	4:10
Gaskill	247	0:38	28:55
Genson	257	1:06	30:54
Gerean, L	16	0:04	0:08
Hawley	34	0:14	2:22
Henley Group	173	0:30	19:13
Henry	50	0:22	3:14
Higginbotham (#740)	114	0:20	9:24
Higginbotham (#750)	141	0:20	9:52
Hink	138	0:22	15:08
Jackson	140	0:32	11:00
Jones	196	0:26	15:20
Millett	169	0:36	18:54
Nelson	220	1:30	41:10
North	120	0:20	10:48
Pearson (#047)	160	0:34	21:38
Pearson (#118)	75	0:28	8:46
Ptaszynski	108	0:26	10:50
Rainbow Valley Ranch	134	0:28	12:18
Robertson	149	0:26	17:06
Schwab	192	0:42	35:52
Shults (#710)	141	0:22	11:30
Shults (#720)	121	0:22	10:23
Tate	155	0:22	12:27
Taylor	240	0:40	39:44
Thayer (#450)	120	0:24	13:32
Thayer (#470)	119	0:24	14:35
Thayer (#480)	108	0:24	13:10
Thompson/Giesick	162	1:30	56:40
Wines/Snover	53	0:16	3:44
Yeager	191	0:28	24:28
Zellmer	273	0:50	25:24

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Pearson North (047flat), Brown (086flat), PTASZYNSKI (900flat), Pearson South (118flat), ENGELSTAD (810flat), JONES (850flat), TATE (820flat)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines A-04-07, B-03-07
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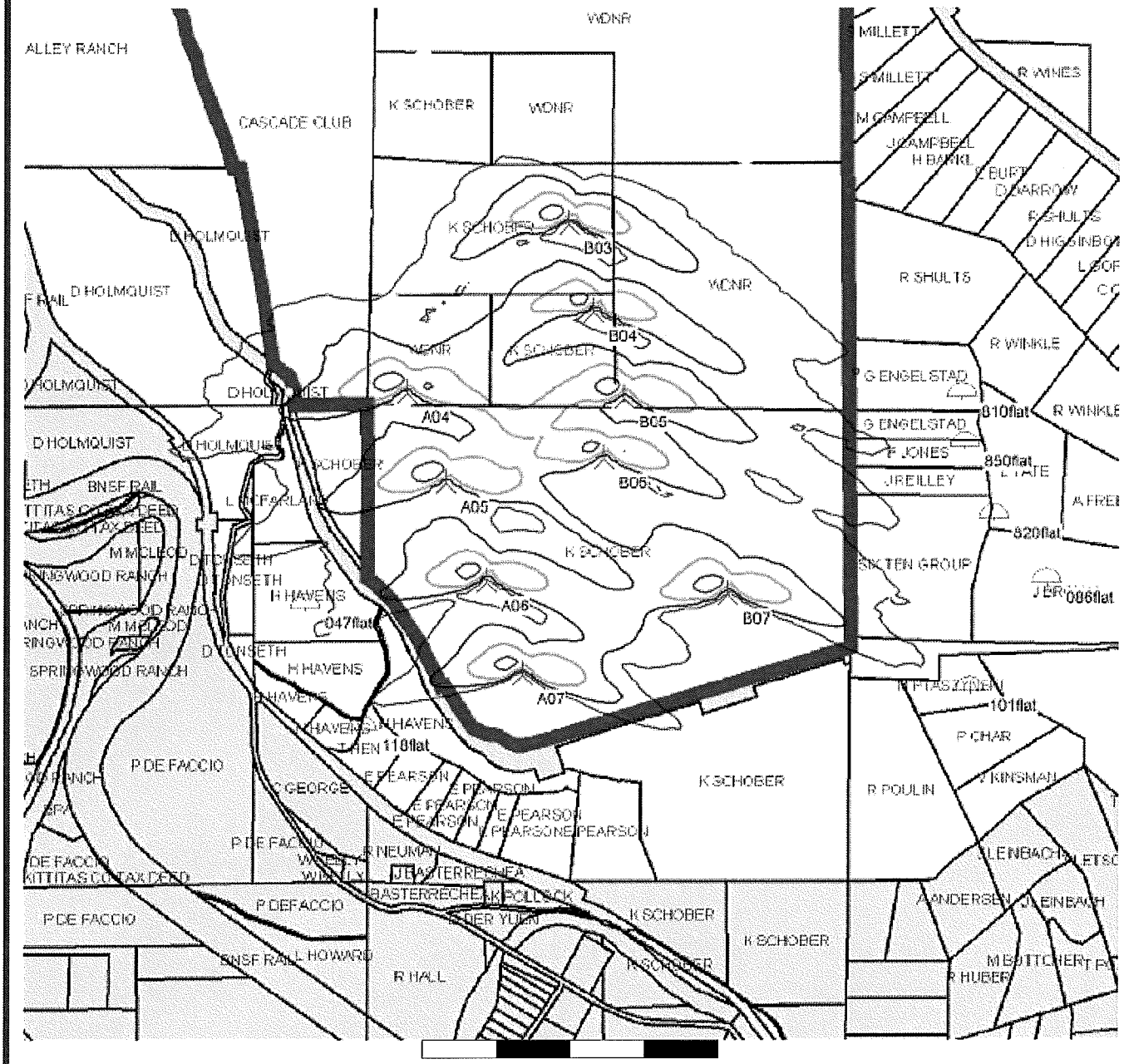

Map: kv simply parcels 110405, wt_2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 674,523 North: 5,220,112

New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Rainbow Valley Ranch (041flat), Archambeau (042flat), Ahles (370flat), Henley (380flat), Yeager (420flat), Hink (440flat), Thayer (470flat and 480flat)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines F-01, F-02, G-01 through G-04

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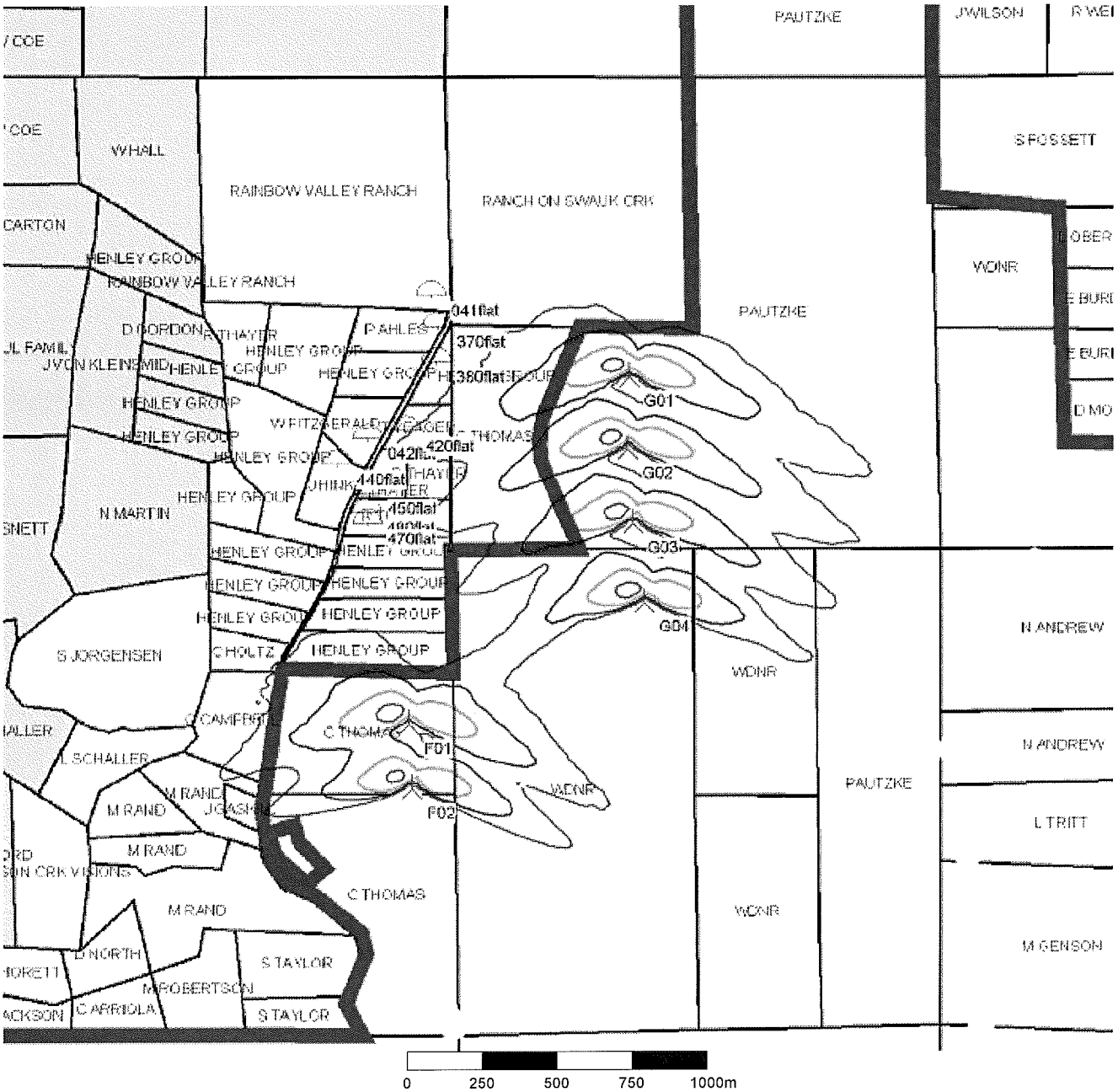

Map: kv simply parcels 110405, wt_2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 674,023 North: 5,225,412

New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Anthony (043flat), Gaskill (044flat), Taylor (045flat), Jackson (149flat), North (150flat), Robertson (555flat)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines E-02-05, F-01-06, G-01-04 (no E-01)

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Calculation: 051110 SF, E (-1), F and G, on 043-045, 149-150, 555 **File:** kv simply parcels 110405, wt_2.bmi

Map: kv simply parcels 110405, wt_2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 673,423 North: 5,224,112

New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Andrew N (510flat)
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Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines H-01-07, I-03-10
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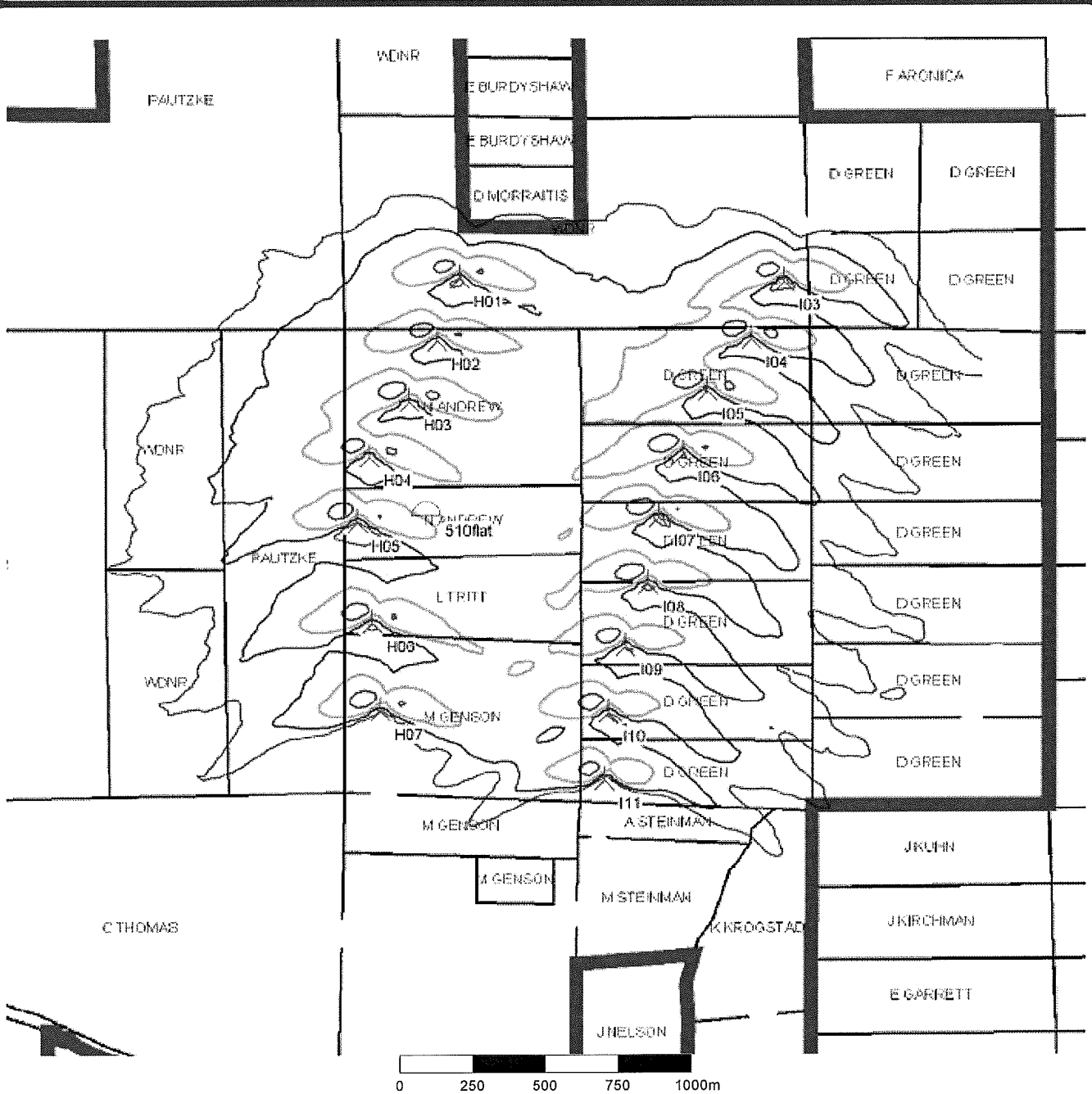

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New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor (216flat), STATR OF WASH DNR (270flat), STATR OF WASH DNR (930flat), GEREAN (340flat)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines H-01-03, I-01-05

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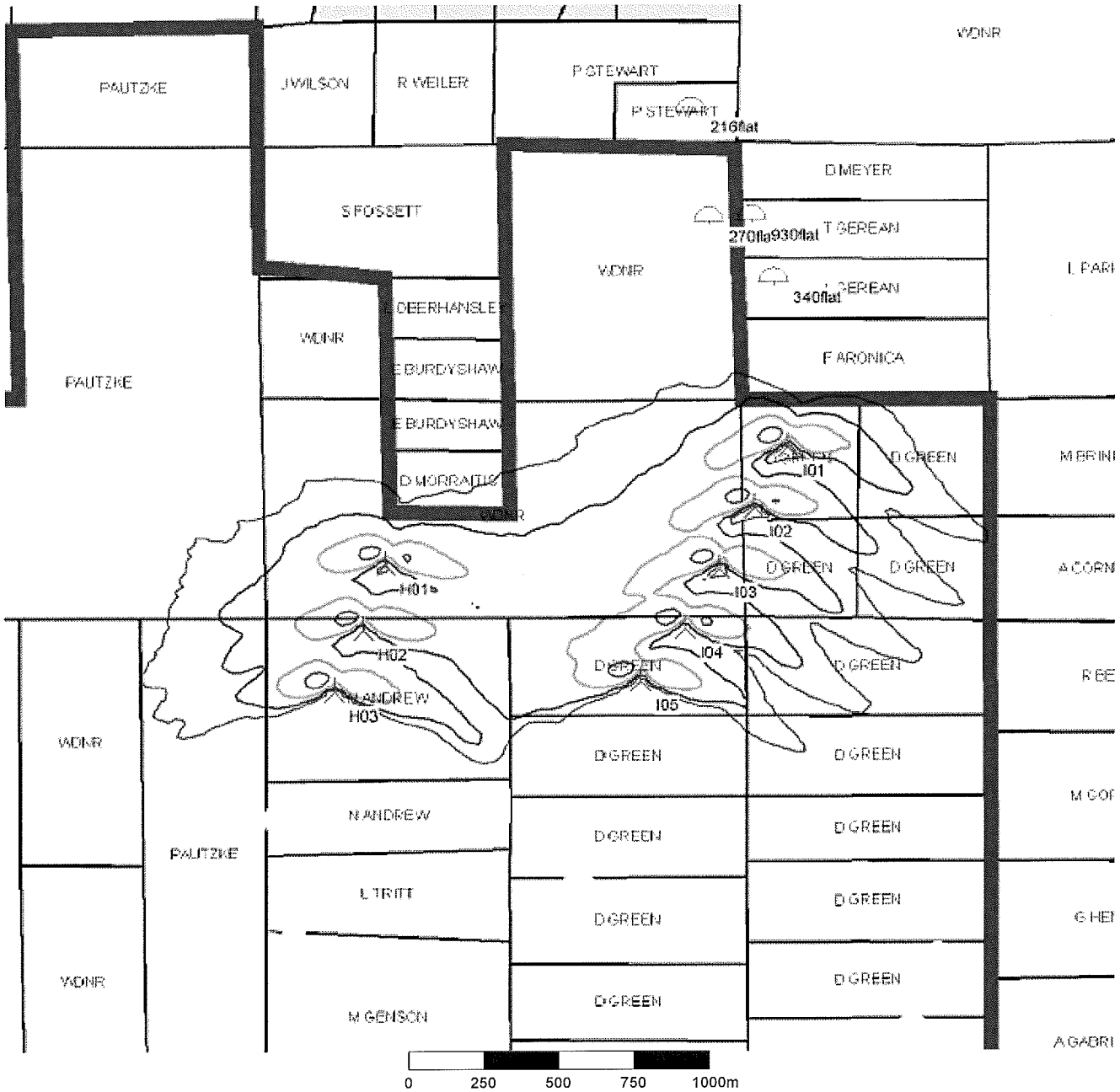

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New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor HENRY, GREG (530flat)
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Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines K-01-02
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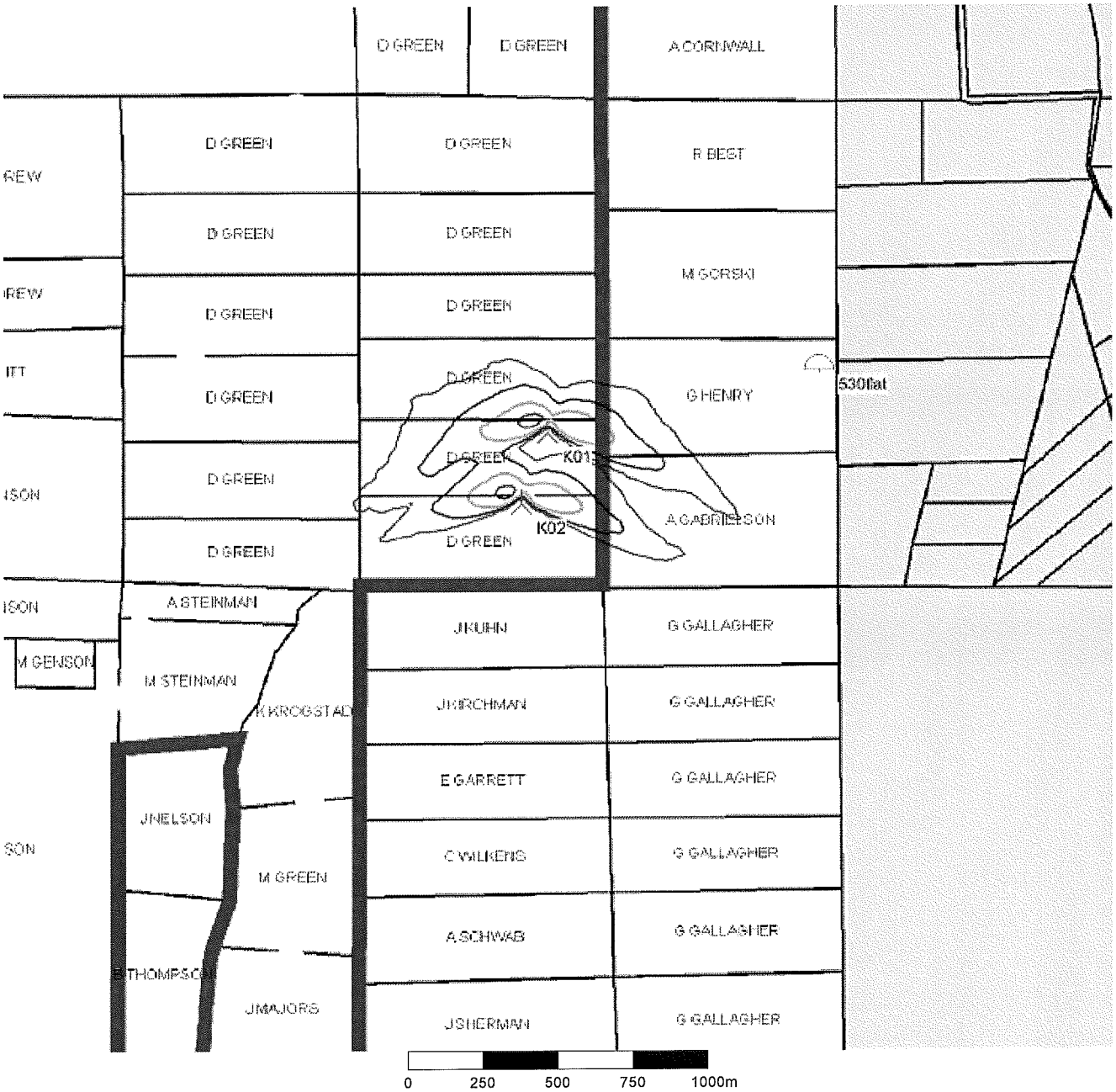
SHADOW - kv simply parcels 110405, wt_2

Calculation: 051109 SF, K, on 530 **File:** kv simply parcels 110405, wt_2.bmi



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New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor GENSON (570), NELSON (580), ACKERSON (590), THOMPSON (600)
SCHWAB (610) all flat
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines B-01-02, C, D, F-03-06, H-06-10, I-10-16, J, K

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SHADOW - kv simply parcels 110405, wt_2

Calculation: 051112 SF, B, C, D, F, H I, J, K on 570, 580, 590, 600, 610 **File:** kv simply parcels 110405, wt_2.bmi

Map: kv simply parcels 110405, wt_2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 676,000 North: 5,222,790

New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Pearson North (047flat), Brown (086flat), PTASZYNSKI (900flat), Pearson South (118flat), ENGELSTAD (810flat), JONES (850flat), TATE (820flat)
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines A-04-07, B-03-07

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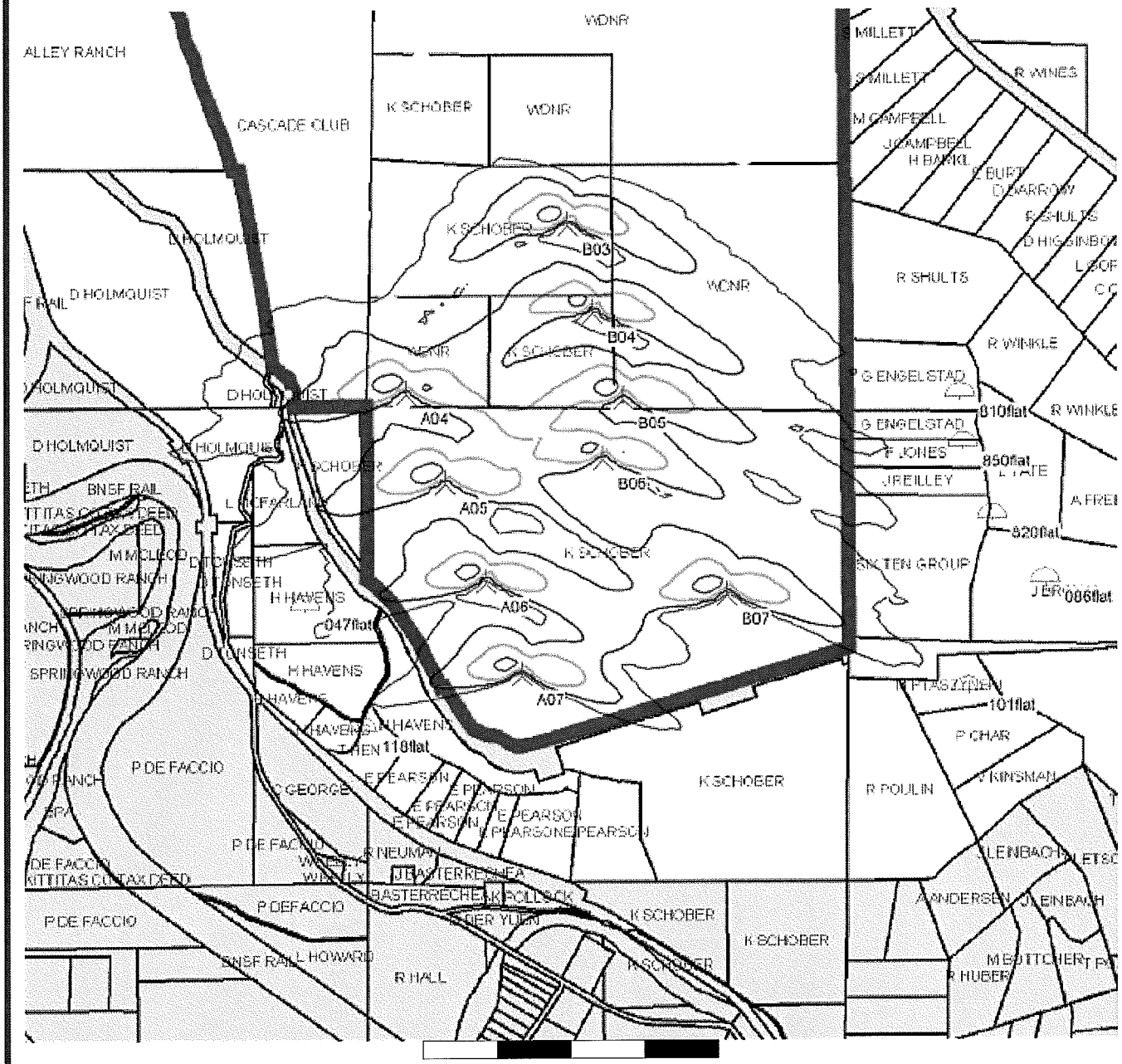
SHADOW - kv simply parcels 110405, wt_2

Calculation: 051111 SF, A, B and G, on 047, 086, 118, 810, 820, 850, 900 **File:** kv simply parcels 110405, wt_2.bmi



Map: kv simply parcels 110405, wt_2 , Print scale 1:20,000, Map center UTM NAD27 Zone: 10 East: 674,523 North: 5,220,112

New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Zellmar (048), MILLETT (650), Campbell (082), BURT (670, 084, 690), Darrow (086)
SHULTS (710, 720), HIGGINSBOTHAM (740, 750), FRANKLIN (780), HAWLEY (640)
WINES/SNOVER (630) all flat
Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines A01-07, B01-07, C-01-02, D-01-02, I-14-16, J-01-04 on 048
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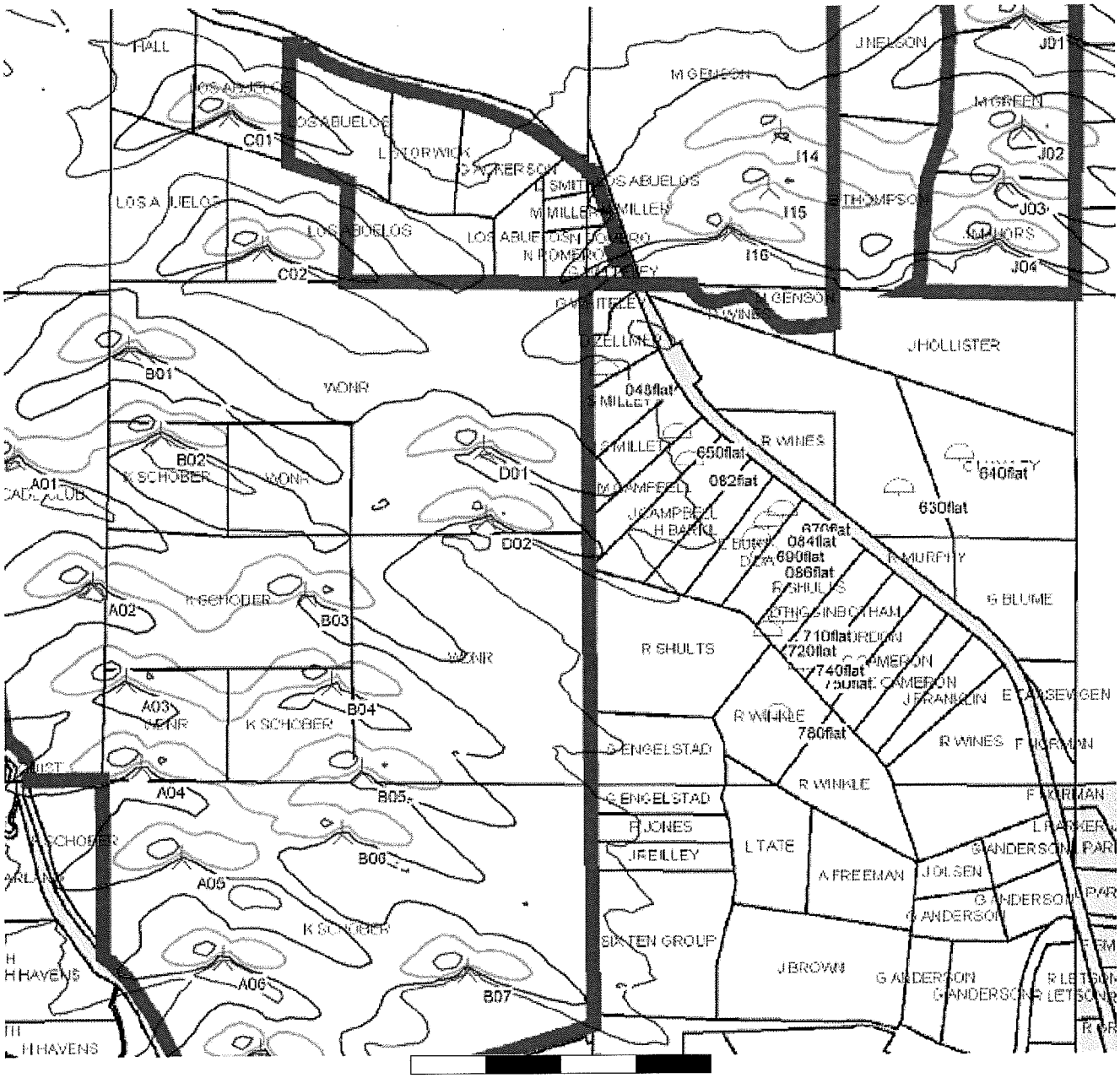
SHADOW - kv simply parcels 110405, wt_2

Calculation: 051110 SF, A, B, C, D, I, J on 048, 650, 082, 670, 084, 690, 086, 710, 720, 740, 750, 780, 630, 640 **File:** kv simply parcels 110405, wt_2.bmi



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New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200

Project:
030326 Kittitas

Description:
SIEMENS 90m 2.3 MW MkII at 80m hub height
Shadow receptor Morriatis (flat)

Monthly sunshine percentage applied
Joint frequency distribution applied (for run-hours and direction)
Turbines G-01-04, H-01-06, I-01-07

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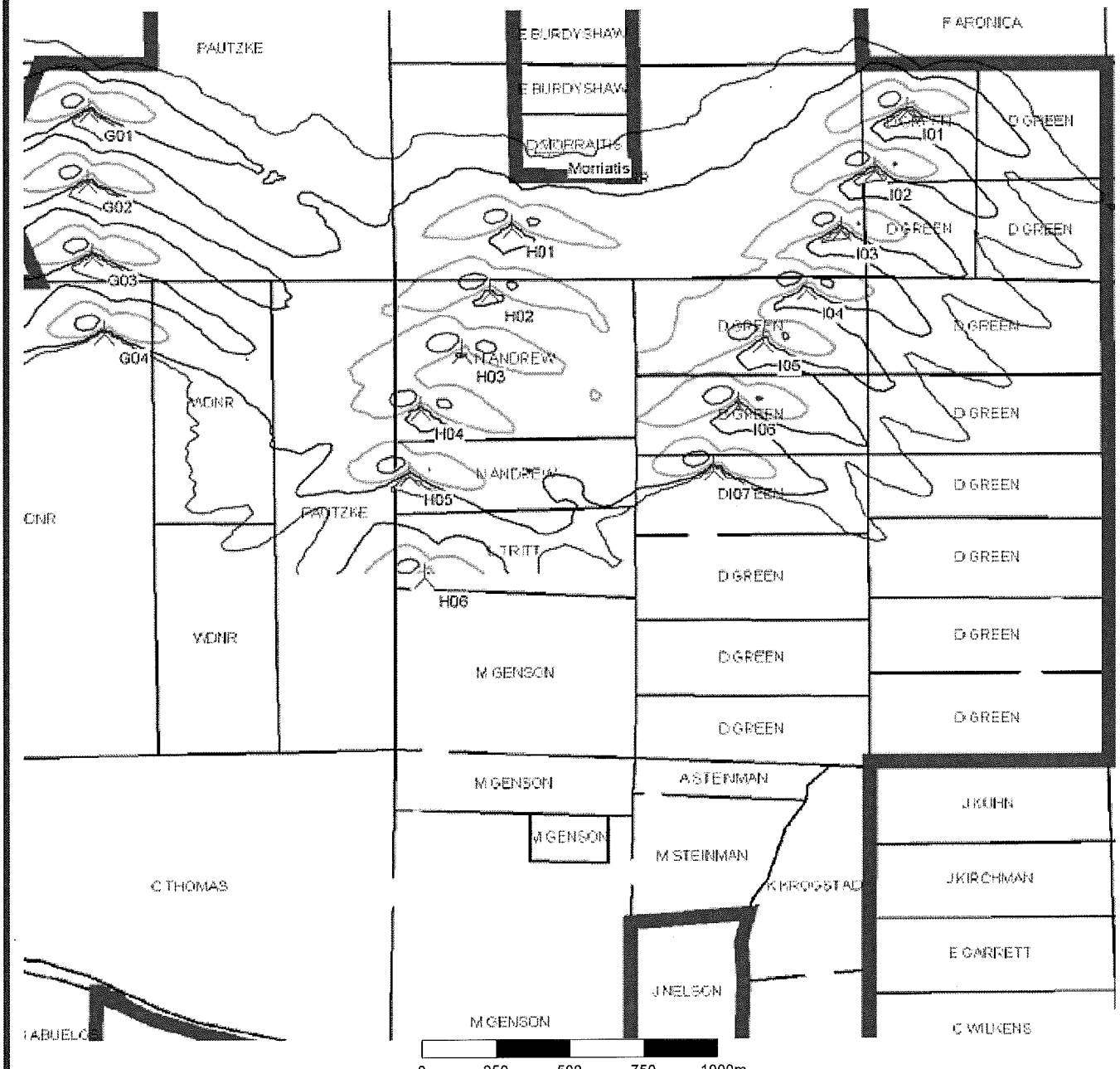

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New WTG Shadow receptor

Isolines showing shadow in Shadow hours|per year. Real value calculation.

25 50 100 200