Table 2-1 Summary of Predicted Hydrogeologic Impacts

Hydrogeologic Element	On-site Impacts[1]	Off-site Impacts[1]
Recharge[2,3]	▪ Short-term annual recharge will increase slightly due to removal of vegetation and till ▪ Long-term annual recharge will decrease slightly due to added vegetative cover in reclaimed condition ▪ Recharge will become more seasonal; higher amounts following wet season and lower amounts following dry season ▪ Perched flow systems may receive less recharge and may alter spatial distribution of recharge near the mine site[7]	▪ Minimal impact to off-site recharge patterns ▪ Spatial redistribution of recharge from perched water originating from the mine site may change[7]
Principal Aquifer[4]		
Water Levels	▪ Long-term average annual declines up to 0.6 feet ▪ Increased seasonal fluctuations of up to ± 2.4 feet ▪ Maximum total changes ranging from 3.0 feet below to 1.8 feet above pre-mining, average annual conditions at seasonal low and high water, respectively	▪ Long-term average annual declines up to 0.1 feet ▪ Increased seasonal fluctuations of up to ± 0.1 feet ▪ Maximum total changes ranging from 0.2 feet below to net-zero change from pre-mining, average annual conditions at seasonal low and high water, respectively
Flow Directions	▪ Locally small changes may occur due to long-term water level decline of up to 0.6 feet ▪ Small seasonal variability may occur but will average out over annual cycle to pre-project groundwater flow directions	▪ Flow directions will not change appreciably based on predicted water level changes
Spring Flow	<u>Spring E</u> ▪ Long-term average annual declines up to 0.7 gpm (about 2 percent of current total flow) ▪ Spring flow will change seasonally because on-site recharge schedule will be impacted ▪ Increased seasonal fluctuations of up to ± 20%, a range of about 6 gpm about the average annual flow rate	<u>Dockton and Ferguson Springs</u> ▪ Long-term average annual declines up to 0.5 gpm (about 1 to 2 percent of current flow) ▪ Increased seasonal fluctuations of between ± 0.1 and ± 0.5 gpm (no more than 2 percent of current total flow) ▪ Maximum total change ranging from about 1 gpm below to existing average flow conditions at seasonal low and high flow periods, respectively ▪ Spring owners should establish baseline monitoring programs to better assess existing spring yields
Infiltration Pond[5]	▪ Groundwater level to rise about 2 feet beneath pond at time of storm event ▪ Groundwater level to recover to near pre-storm conditions in 3 weeks of storm event ▪ At least 18 feet of separation will exist between water table and mine floor for modeled storm event ▪ Mine owner should analyze mounding using more detailed site design and testing parameters as part of final design process	▪ Water levels predicted to rise by up to 0.1 feet at mine boundaries ▪ No appreciable change in water levels at closest water supply wells
Deep Aquifer[4,6]	▪ Maximum seasonal reductions in vertical recharge rates are on the order of 1/2 percent of pre-mining, steady-state conditions ▪ A maximum seasonal reduction of about 600 to 900 cubic feet per day (cfd), or 3 to 5 gpm is predicted for the entire model area ▪ Recharge reductions will be smaller when water levels in mine are at seasonal high levels	

Notes:

1 Supporting details of predicted impacts are presented in Section 8.4.3.
2 Recharge occurring at land surface was assessed using PGG spreadsheet recharge model as presented in Section 7.1 and Appendix D.
3 Recharge dynamics in unsaturated zone were assessed using Hydrus-2D model as presented in Section 7.2 and Appendix E.
4 Principal and deep aquifer impacts assessed using MODFLOW groundwater flow simulation as presented in Section 8 and Appendix F.
5 Based on a 2-day storm event causing pond inflows of about 40 gpm as presented in Section 8.
6 Change in vertical recharge rates to deep aquifer is for *entire* model area during the season that local mine impacts are greatest.
7 Cannot be assessed quantitatively where detailed knowledge of perched flow system is lacking.

Table 3-1 Summary of Project Wells

Project Well ID Number	MW-1	MW-2	MW-3	MW-4	MW-5
Ecology Unique ID Number	AFG 349	AFG 348	AFG 347	AFG 345	AFG 346
Total Depth Drilled (feet, bgs)	205	72	76	178	157
Screen Depth (feet, bgs)	198 to 203	67 to 72	69 to 74	110 to 115	152 to 157
Screen Elevation (feet)	54 to 59	-29 to -34	19 to 24	45 to 50	34 to 39
Screen Slot Size (inches)	0.004	0.004	0.006	0.004	0.006
TOC Elevation (feet)	265.2	41.1	100.2	168.1	199.4
Location	On-site. next to OBW-5	On site. next to OBW-9	Off site. NE corner of SW 264th and 94th SW	Off site. SW 260th, E of Dockton Road SW	Off site. #25421 Dockton Road SW

Notes:

bgs = below ground surface
TOC = top of casing
Elevations are relative to NAVD 88 datum
Well locations shown on Figure 1-1

Table 3-2 Summary of Well Information

Project Well ID[1]	Owner's Name[2]	Northing[3]	Easting[3]	Reference Elevation (feet)[4]	Well Log Available[5]	Well Depth (feet, bgs)	Completion Interval	Depth to groundwater in 11/99 (feet, TOC)	Groundwater Elevation in 11/99 (NAVD 88, feet)	Depth to groundwater in 03/00 (feet, TOC)	Groundwater Elevation in 03/00 (NAVD 88, feet)
Domestic or Public Water Wells (existing)											
1	Williams, Ed	143,863.2	1,242,578.6	94.2	Yes	90	Qpvu	50.7	43.5	50.3	44.0
3	Cornutt	140,516.0	1,240,318.6	150.7	Yes	755	Qpvu	blocked at 130'	na	na	na
4	Hamilton	141,922.9	1,242,501.3	189.3	Yes	80	Qva, perched	54.7	134.6	55.5	133.8
4b	Williams, Jerry	141,944.2	1,242,383.4	187.8	Yes	122	Qva	91.7	96.2	91.9	95.9
5	Wolff	145,818.1	1,246,047.8	115.1	Yes	130	Qpvu	63.4	51.7	nm	nm
6	Silkett	145,487.7	1,245,808.2	101.6	Yes	162	Qpvu	44.2	57.5	nm	nm
8	Farcy	144,742.5	1,244,138.3	130.3	Yes	205	Qpvu	102.2	28.2	102.0	28.3
10	Williams, Edith	145,106.9	1,244,956.4	113.4	Yes	140	Qpvu	82.7	30.7	81.6	31.8
11	Bardeen	144,622.4	1,243,381.0	98.0	Yes	277	Qpvu	70.9	27.1	70.5	27.5
13	Vashon Golf-Upper	144,440.8	1,245,155.7	179.3	Yes	440	Qpvu	158.8	20.5	157.9	21.4
14	Vashon Golf-Lower	145,041.0	1,245,308.6	99.2	Yes	170	Qpvu	32.5	66.7	32.1	67.1
15	Saltarelli	145,031.2	1,247,045.2	196.9	Yes	138	Qpvu	111.2	85.8	nm	nm
16	Ridgeway	142,548.0	1,246,549.5	397.1	Yes	553	Qpvu	384.5	12.6	nm	nm
17	Ching	142,356.4	1,245,920.0	336.3	Yes	460	Qpvu	330 ATD	6	na	na
18	Turner	143,189.8	1,242,977.5	150.0	Yes	75	Qva	58.5	91.5	58.5	91.5
19	Weinshel	143,246.5	1,243,327.2	168.3	Yes	237	Qpvu	144.6	23.7	144.3	24.0
20	Iliad Water	141,438.4	1,245,260.9	387.8	Yes	520	Qpvu	300 ATD	88	na	na
21	Johnson	140,620.7	1,240,545.1	175.0	Yes	150	Qva	94.2	80.9	94.9	80.1
22	Vangolen	140,230.2	1,240,017.1	115.3	Yes	54	Qva	34.2	81.1	35.2	80.1
26	Bryant	not surveyed		60 est	Yes	200	Qpvu	nm (dry ATD)	nm (dry ATD)	nm	nm
30	Vashon Sand & Gravel	143,080.9	1,247,704.8	391.1	Yes	514	Qpvu	370 ATD	21	na	na
31	Sandy Shores	135,435.6	1,238,779.8	307.4	Yes	417	Qpvu	234.2	73.2	234.7	72.7
32	HillCrest	132,055.5	1,236,203.9	364.4	Yes	493	Qpvu	351.3	13.1	353.1	11.4
34	Gold Beach No. 1	140,289.9	1,246,331.4	105.5	Yes	113	Qva	81.1	24.4	77.5	28.1
35	Gold Beach No. 2	140,208.9	1,246,340.3	103.5	Yes	109	Qva	83.2	20.3	79.6	24.0
40	Rueter	144,087.6	1,243,070.5	110.0	Yes	473	Qpvu	89.3	20.7	89.3	20.8
41	Morris	not surveyed		390 est	Yes	422	Qpvu	332.0	58.0	nm	nm
42	Alton	142,558.2	1,247,402.5	410.2	Yes	577	Qpvu	405 ATD	5	na	na
44	Hartman	145,301.1	1,244,914.8	96.1	No	285	Qpvu	66.4	29.7	nm	nm
45	Woodman	145,615.5	1,247,120.9	169.7	Yes	235	Qpvu	128.4	41.4	nm	nm
46	Sheldon	143,597.6	1,242,337.7	99.8	No	500	Qpvu	66.4	33.4	nm	nm
47	Carhart	141,293.6	1,241,283.2	182.6	Yes	146	Qva	95.6	87.0	95.8	86.8
53	Skeffington	139,720.3	1,236,733.4	62.3	No	6	Qva or Qvt	0.6	61.7	0.8	61.5
55	Boise-Cascade Corp	not surveyed		280 est	Yes	422	Qpvu	203 ATD	77	na	na
Mine Site Observation Wells (see AESI, 1999a)											
OBW-1	Glacier Northwest	137,141.1	1,240,251.3	294.4	Yes	300	Qva	244.3	50.1	244.8	49.6
OBW-2	Glacier Northwest	138,062.2	1,241,104.7	351.7	Yes	340	Qva	305.2	46.5	305.5	46.2
OBW-3	Glacier Northwest	well not completed[6]		83 est	Yes	77	TD in Qva	na	na	na	na
OBW-4	Glacier Northwest	well not completed[6]		35 est	Yes	17	TD in Qva	na	na	na	na
OBW-5	Glacier Northwest	139,339.3	1,241,338.2	264.7	Yes	260	Qva	182.3	82.4	182.9	81.8
OBW-6	Glacier Northwest	138,128.6	1,239,859.8	271.9	Yes	250	Qva	214.5	57.4	217.3	54.7
OBW-7	Glacier Northwest	139,385.8	1,244,062.3	303.0	Yes	300	Qva	262.1	40.9	262.8	40.2
OBW-8	Glacier Northwest	138,078.8	1,243,241.9	83.3	Yes	100	Qva	66.6	16.7	66.8	16.6
OBW-9	Glacier Northwest	137,422.5	1,242,521.5	41.1	Yes	60	Qva	25.8	15.3	26.0	15.1
Project Observation Wells (installed this study, see Appendix A)											
MW-1	Dept. of Ecology	139,340.7	1,241,350.3	265.2	Yes	205	Qva	183.0	82.2	183.6	81.6
MW-2	Dept. of Ecology	137,403.8	1,242,510.6	41.1	Yes	76	Qva	33.4	7.7	34.0	7.1
MW-3	Dept. of Ecology	138,310.9	1,238,613.1	100.2	Yes	72	Qva	45.7	54.5	54.6	45.6
MW-4	Dept. of Ecology	139,497.7	1,239,997.8	168.1	Yes	178	Qva	101.7	66.4	101.8	66.3
MW-5	Dept. of Ecology	141,276.6	1,242,332.0	199.4	Yes	157	Qva	111.7	87.8	112.2	87.2

Notes:

bgs	below ground surface
TOC	measured from top of casing
ATD	Water level at time of drilling. Sounder access not possible in this study due to obstructions.
TD	Total depth
na	no well access, data not applicable or not available
nm	not measured
est	estimated value from USGS topographic map or mine site plan
Qva, perched	Completed in perched water in Vashon advance outwash (above *Principal Aquifer*)
Qva	Completed in Vashon advance outwash or upper transitional beds (*Principal Aquifer*)
Qpvu	Completed in pre-Vashon interglacial sediments (*Deep Aquifer*)
	Survey coordinates determined by W&H Pacific as part of this study (see Appendix C)
1	Project Well ID numbers are not sequential
2	Owner's name appearing on well log if available
3	Northing and easting are in NAD 83/91 coordinates
4	Reference elevation in NAVD 88 coodinates. TOC unless otherwise noted in Appendix C GPS survey report.
5	Available well logs presented in Appendix B
6	OBW-3 and OBW-4 are soil borings and do not include well completions.

Table 4-1 Summary of Spring Information

Project ID Number[1]	Spring Name[1]	Northing[2]	Easting[2]	Elevation (feet)[3]	Water Use	Collection System Used	Approximate Distance to Mine (feet)	Completion Interval	Flow Rate (gpm)	Groundwater Level (feet, TOC)	Groundwater Elevation (NAVD 88, feet)
Off-Site Springs											
48s	Ferguson Spring	139,157.0	1,238,939.4	47.8	domestic	buried lateral	1,300	Qva	25	10 ATI	38
49s	Hake Spring	not surveyed		180 est	public	buried lateral	3,900	Qva, perched	5	nm	na
50s	Park Spring, East	138,697.8	1,238,842.8	54.0	public	buried lateral	1,300	Qva	25	9.0	45.0
51s	Park Spring, West	138,658.3	1,238,564.0	46.4	public	drive points (10)	1,300	Qva	35	1.2	45.2
52s	Summerhurst Spring	133,520.2	1,239,652.0	97.8	unknown	unknown	2,000	Qva, perched	na	0	98
54s	Carol Spring	not surveyed		80 est	backup	unknown	2,200	Qva, perched	na	nm	na
On-Site Springs[4]											
A	na	not surveyed		10 est	none	none	200	Principal Aquifer	15 to 24	na	10 est
E	na	not surveyed		35 est	none	none	200	Qva, perched	30 to 33	na	35 est

Notes:

TOC	measured from top of casing
ATU	Water level reported at time of spring upgrade (personal communication, Bob Seabold, February 1999)
est	estimated elevation
na	data not applicable or not available
nm	not measured
Qva, perched	Completed in perched water in Vashon advance outwash (above *Principal Aquifer*)
Qva	Completed in Vashon advance outwash or upper transitional beds (*Principal Aquifer*)
1	Project ID number and spring name are assigned for purposes of this project only
2	Northings and eastings are in NAD 83/91 coordinates
3	Reference elevations in NAVD 88 coodinates
4	On-site springs characterized by Herrara (2000)

Table 6-1 Water Level Variations for AESI Observation Wells

Well ID[1]	One Year Water-Level Trend	Seasonal High[2]	Seasonal Low[2]	Magnitude of Fluctuation
OBW-1	+1.7 ft	July	February	1.0 ft
OBW-2	+1.6 ft	No Seasonal trend	No Seasonal Trend	0 ft
OBW-5	+0.7 ft	July	February	1.5 ft
OBW-6	+1.4 ft	July	February	1.2 ft
OBW-7	+3.3 ft	November	May	1.4 ft
OBW-8	No Annual Trend	February	October	1.4 ft
OBW-9	+0.2 ft	November	June	1.9 ft

Notes:

[1] Well IDs assigned to on-site wells by Associated Earth Sciences, Inc (AESI, 1999a)

[2] Seasonal highs and lows estimated relative to (assumed) linearly increasing 1999 water-level trend.

Table 7-1 Estimated Annual Recharge Values for Modeled Land Cover Classes

Land Cover Class	Annual Recharge (inches)	
	No Till	with Till
Grass (current condition and during excavation)	24.10	24.07
Forest (current condition)	25.85	25.57
Mine (current condition)	25.06	24.01
Barren (during excavation)	27.04	n/a
Coniferous Trees (after reclamation)	23.75	n/a

Notes:
n/a = not applicable. Land cover with till will not exist.

Table 8-1 Steady State Calibration Targets

Well ID	Easting[1]	Northing[1]	Model Layer	Water Level (feet)[2]
Well 4b	1,242,383	141,944	1	96.2
Well 18	1,242,978	143,190	1	91.5
Well 21	1,240,545	140,621	1	80.9
Well 22	1,240,017	140,230	1	81.1
Well 31	1,238,780	135,436	1	52.0
Well 34	1,246,331	140,290	1	24.4
Well 35	1,246,340	140,209	1	20.3
Well 47	1,241,283	141,294	1	87.0
OBW-1	1,240,251	137,141	1	50.1
OBW-2	1,241,105	138,062	1	46.5
OBW-5	1,241,338	139,339	1	82.4
OBW-6	1,239,860	138,129	1	57.4
OBW-7	1,244,062	139,386	1	40.9
OBW-8	1,243,242	138,079	1	16.7
OBW-9	1,242,522	137,423	1	15.3
MW-1*	1,241,350	139,341	1	82.2
MW-2	1,242,511	137,404	1	7.7
MW-3	1,238,613	138,311	1	54.5
MW-4	1,239,998	139,498	1	66.4
MW-5	1,242,332	141,277	1	87.8

Spring ID	Model Row	Model Column	Model Layer	Outlet Elevation (feet)[2]	Discharge (cfd)	Discharge (gpm)
West Dockton Springs	8	25	1	45	6740	35
East Dockton Springs	8	26	1	45	4810	25
Ferguson Springs	7	28	1	37	4810	25
Spring E	26	27	1	5-12	6310	33

Notes:

*	Well MW-1 was combined with Well OBW-5 as a single target during calibration, due to similarity of location and water-level elevation.
1	Northings and eastings are in NAD 83/91 coordinates
2	Reference elevations in NAVD 88 coodinates.
cfd	cubic feet per day
gpm	gallons per minute

Table 8-2 Summary of Steady-State Scenario Designs and Results

Parameter	Optimal	Scenario A	Scenario B	Scenario C
Layer 1 Kh (ft/d)	2.8 < Kh < 60 ft/d	11, 21[1]	11, 25, 2.8[2]	8.5, 11[1]
Layer 2 Kv (ft/d)	0.0003 < Kv < 0.03	0.0016	0.0016	0.0065
Layer 2 Kh (ft/d)	0.03 < Kh < 3 ft/d	0.16	0.16	0.65
Layer 3 Kv (ft/d)	n/a	0.1	0.1	0.1
Mean Water-Level Target Residual (ft)	0	0.46	0.18	-1.07
Sum-of-Squares WL Residual (ft^2) (19 targets)	0	623	256	869
Total Recharge to Model	n/a	938,171	938,171	1,079,669
Recharge Directly to Layer 1 (cfd)	n/a	879,349	878,228	877,648
Recharge Directly to Layer 2 (cfd)[3]	n/a	58,822	59,943	202,021
Recharge Rate to Exposed Qpvu Deposits (ft/d)	= L2 Kv	0.0016	0.0016	0.0058[4]
Flow to Layer 1 Constant Heads (cfd)	n/a	762,116	766,544	470,108
Flow to Layer 2 General Heads (cfd)	n/a	36,147	35,291	138,678
Flow to Layer 3 (cfd)	n/a	117,421	114,008	449,682
Flow to All Layer 1 Springs (cfd)	22,670	22,493	22,353	21,206
Flow / Elevation / Conductance of W. Dockton Springs (cfd / ft / ft^2/d)	6,741 / 45	6,775 / 45 / 2,500	6,326 / 45 / 4,000	6,140 / 44 / 6,000
Flow / Elevation / Conductance of E. Dockton Springs (cfd / ft / ft^2/d)	4,810 / 45	4,409 / 45 / 2,500	4,671 / 44 / 2,600	4,493 / 43 / 4,000
Flow / Elevation / Conductance of Ferguson Spring (cfd / ft / ft^2/d)	4,810[5] / 37[5]	4,715 / 37 / 1,000	4,789 / 37 / 1,000	4,427 / 37 / 1,600
Flow / Elevation / Conductance of Spring E (cfd / ft / ft^2/d)	6,310 / 5-12	6,594 / 5 / 2,500	6,567 / 5 / 3,000	6,145 / 5 / 6,000

Notes:

1 Lower Kh value pertains to the Qva trough, upper value pertains to adjacent flanks of Qva bottom surface.

2 Lowest Kh value pertains to heterogeneity in Qva trough which adjusts for anomalous (high) head at Well OBW-5.

3 Low-end recharge values to Layer 2 are direct recharge to Qpvu where Qva is absent and Layer 1 is inactive. High-end values are due to dry cells in Layer 1.

4 Specified recharge was not increased above the average island rate of 0.0058.

5 The referenced spring flow or elevation is considered very approximate and may contain significant error.

n/a not applicable

Figures

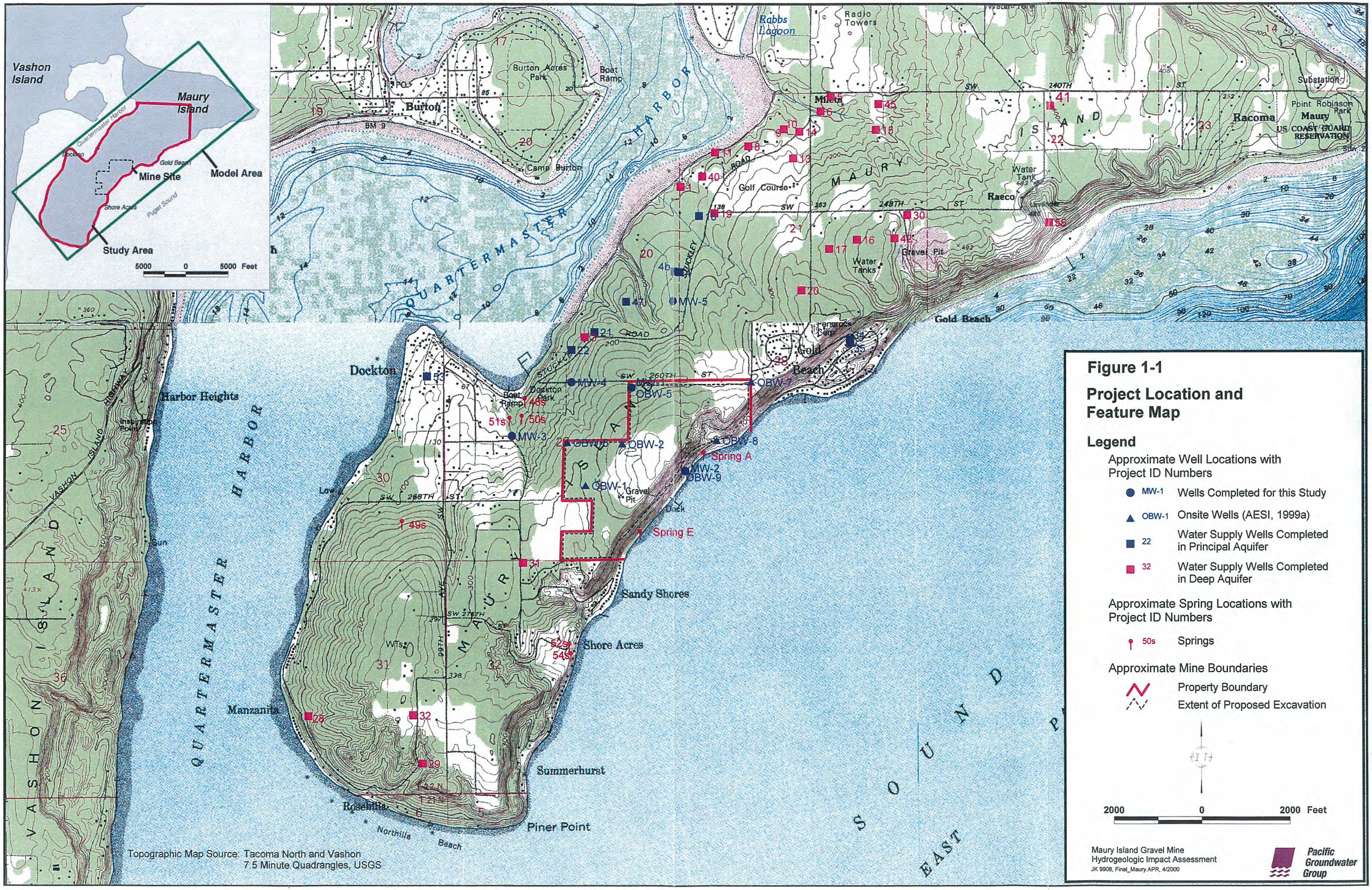
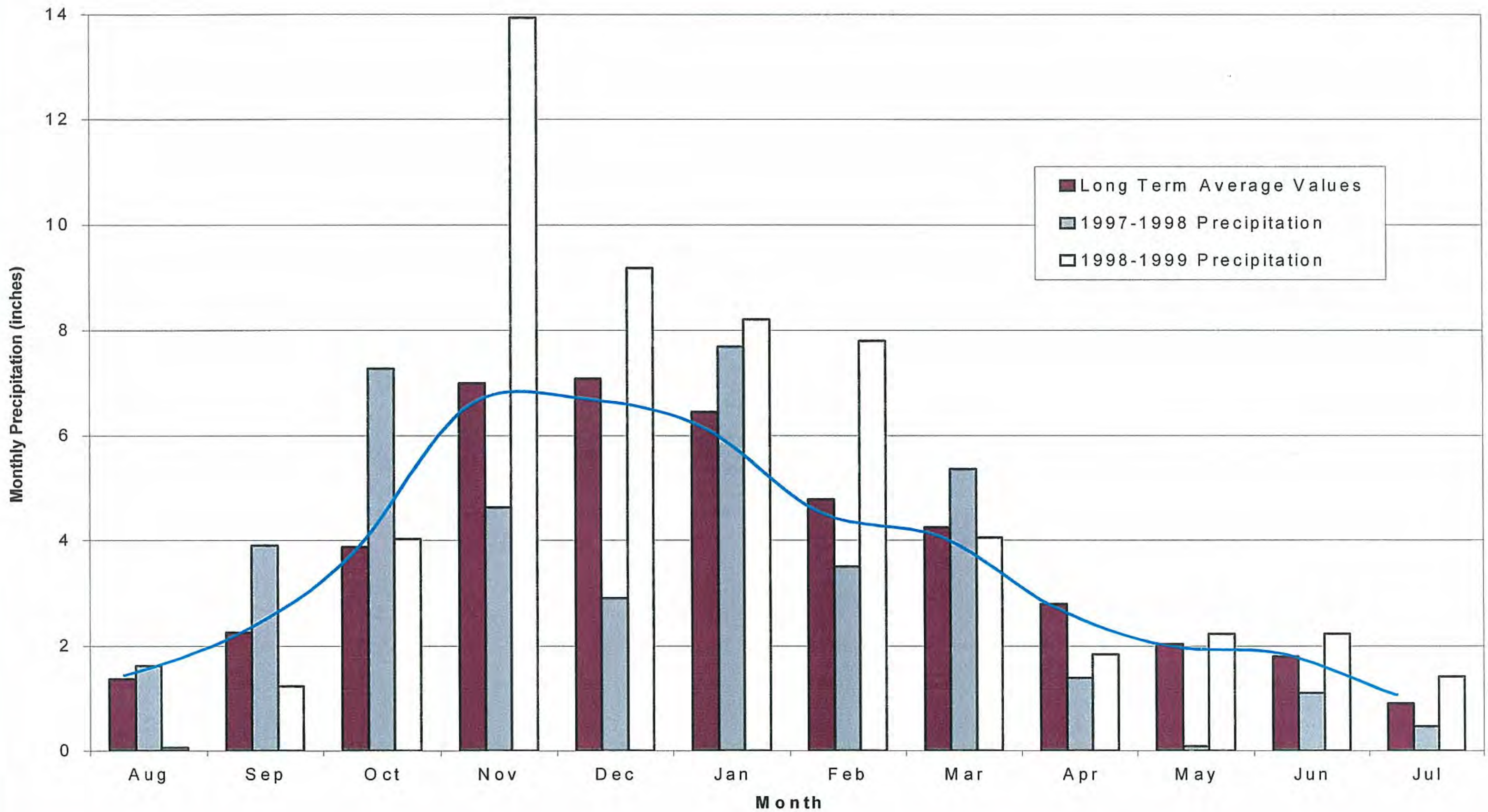


Figure 1-1
Project Location and Feature Map
Legend
Approximate Well Locations with Project ID Numbers
MW-1 Wells Completed for this Study
OBW-1 Onsite Wells (AESI, 1999a)
22 Water Supply Wells Completed in Principal Aquifer
32 Water Supply Wells Completed in Deep Aquifer
Approximate Spring Locations with Project ID Numbers
50s Springs
Approximate Mine Boundaries
Property Boundary
Extent of Proposed Excavation
2000 0 2000 Feet
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK 9908, Final_Maury.APR, 4/2000
Pacific Groundwater Group
Topographic Map Source: Tacoma North and Vashon
7.5 Minute Quadrangles, USGS
Vashon Island
Maury Island
Model Area
Mine Site
Study Area
5000 0 5000 Feet
Dockton
Harbor Heights
Burton
Burton Acres Park
Boat Ramp
Camp Burton
Rabbs Lagoon
Radio Towers
Golf Course
Water Tanks
Gravel Pit
Racoma
Point Robinson Park
US COAST GUARD RESERVATION
Substation
Raeco
Gold Beach
Sandy Shores
Shore Acres
Manzanita
Summerhurst
Piner Point
Rosehilla
Northilla Beach
QUARTERMASTER HARBOR
EAST PASSAGE
SOUND
VASHON ISLAND
MAURY ISLAND
MW-2
MW-3
MW-4
MW-5
OBW-1
OBW-2
OBW-5
OBW-7
OBW-8
OBW-9
Spring A
Spring E
49s
50s
51s
52s
54s



NOTES:

Period of record is from August of earlier year to July of later year.
Maury Island data derived by multiplying Seatac Airport data by 1.2.
Annual precip for LT period of record = 44.6 in
Annual precip for 1997-8 period of record = 39.9 in (11% low)
Annual precip for 1998-9 period of record = 56.2 in (26% high)

Figure 4-1
Long-Term and Recent Monthly Precipitation on Maury Island

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, Maury-precip.xls, 4/2000

Pacific Groundwater Group

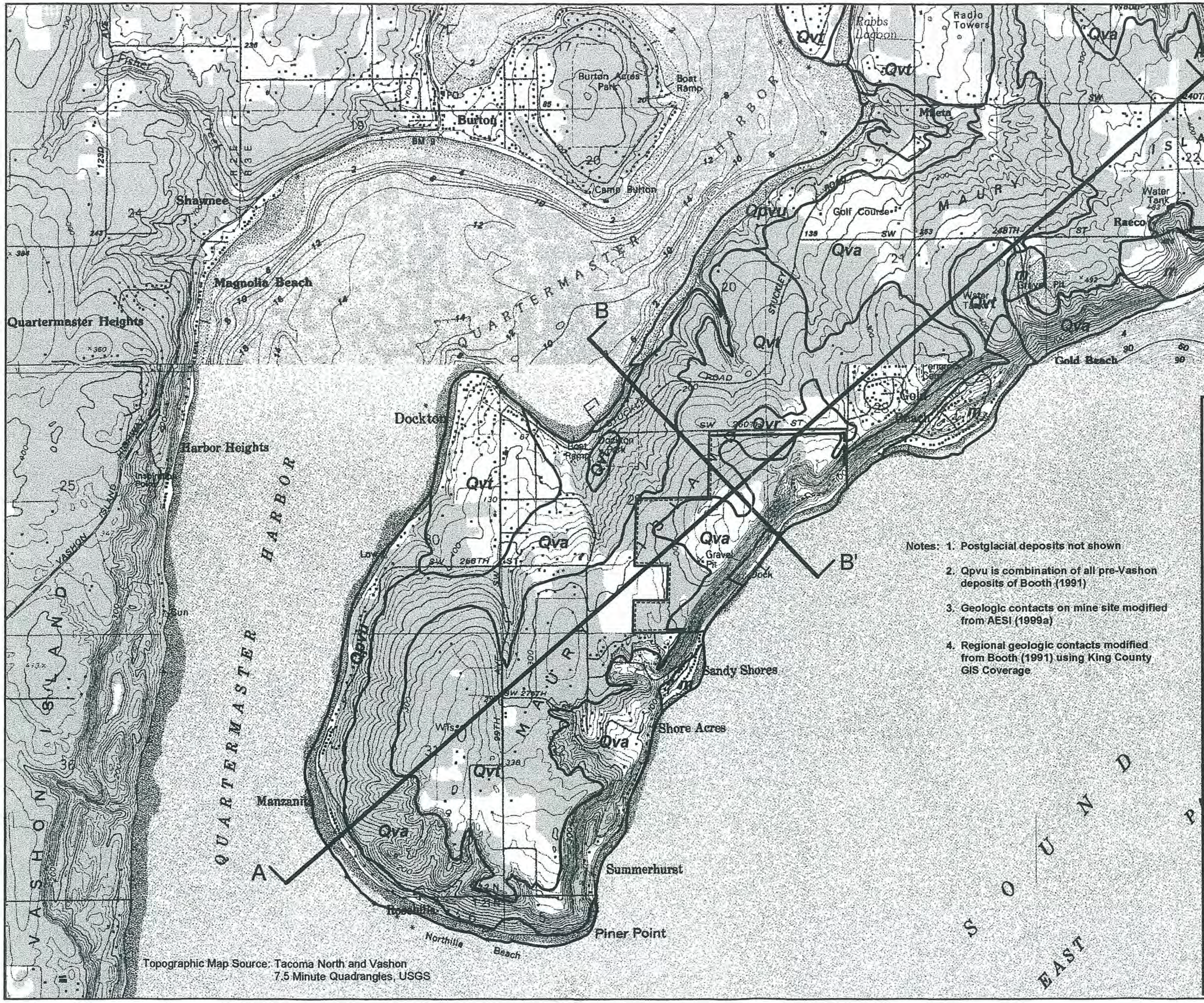


Figure 5-1
Simplified Surficial Geologic Map

Legend

Postglacial Deposits
- m - Modified Land (Sand & Gravel Fill)

Vashon Glacial Deposits
- Qvr - Recessional Outwash
- Qvt - Till
- Qva - Advance Outwash

Pre-Vashon Glacial Deposits
- Qpvu - Undifferentiated Interglacial Sediments

A A' Geologic Cross Section Alignment

Approximate Mine Boundaries
- Property Boundary
- Extent of Proposed Excavation

2000 0 2000 Feet

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK 9908, First_Maury.APR, 4/2000

Pacific Groundwater Group

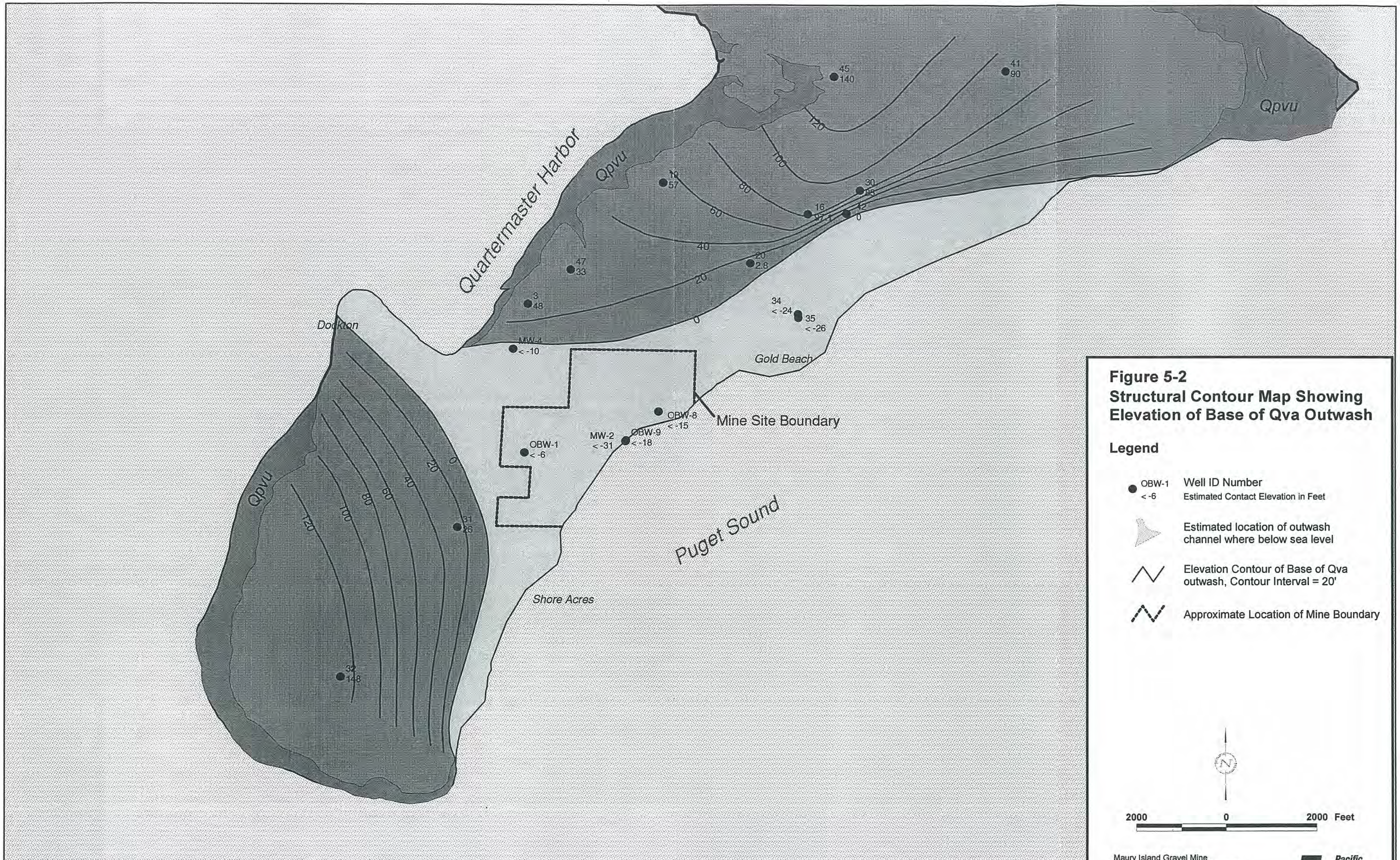


Figure 5-2
Structural Contour Map Showing Elevation of Base of Qva Outwash

Legend

- OBW-1 / < -6 — Well ID Number; Estimated Contact Elevation in Feet
- Estimated location of outwash channel where below sea level
- Elevation Contour of Base of Qva outwash, Contour Interval = 20'
- Approximate Location of Mine Boundary

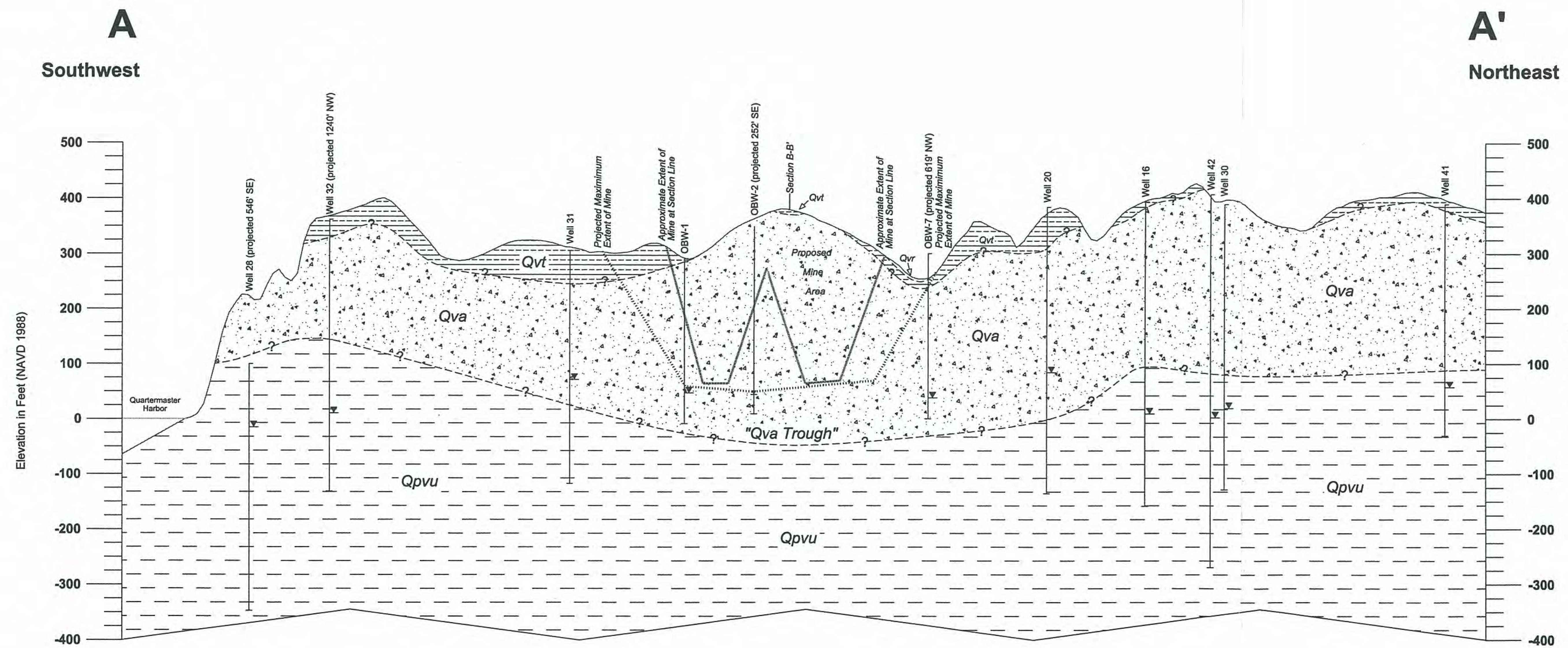
2000 0 2000 Feet

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK 9908, Final_Maury APR, 4/2000

Pacific Groundwater Group

Source: Modified from Figure 4 of Booth (1991) using wells shown

*Note: Shoreline Definition is Schematic



Legend

Qvr - Vashon Recessional Outwash

Qvt - Vashon Till

Qva - Vashon Advance Outwash

Qpvu - Undifferentiated Pre-Vashon Sediments

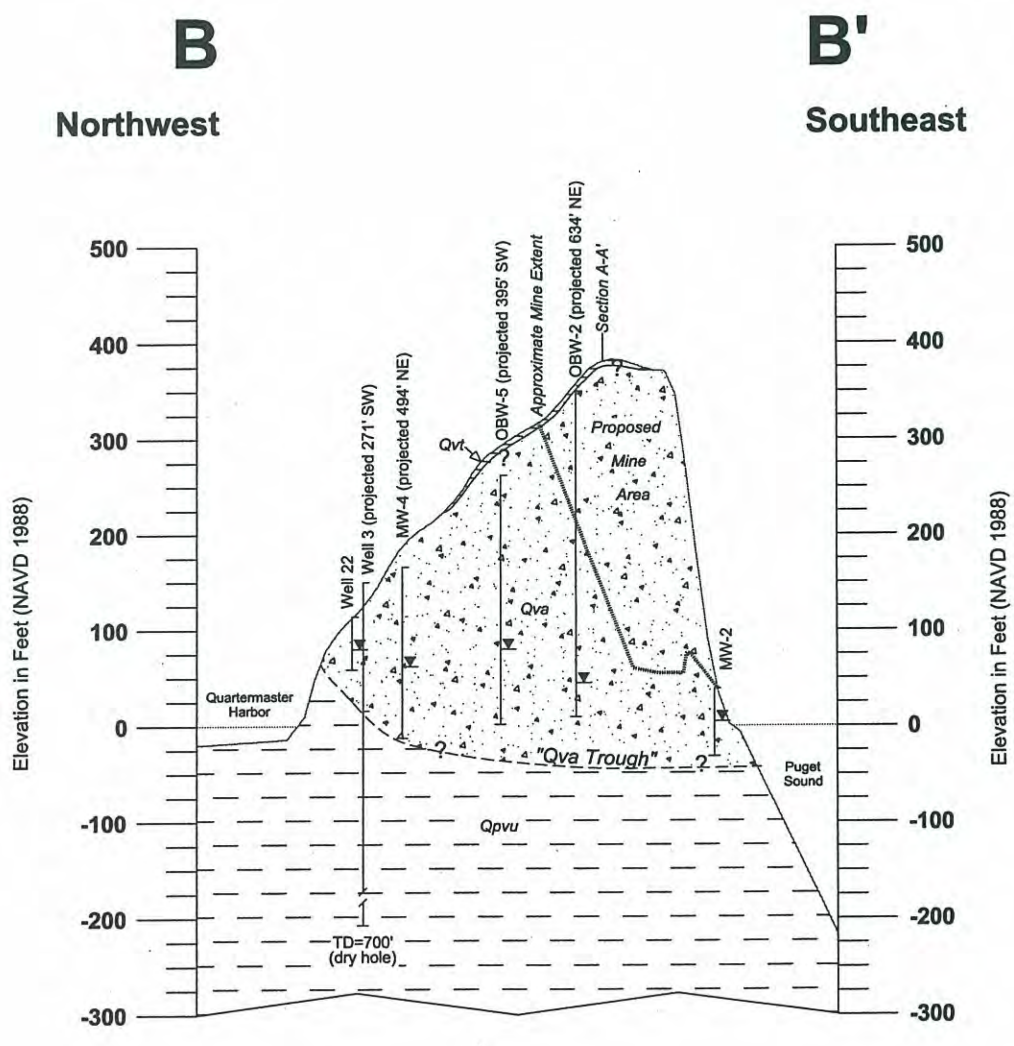
Horizontal Scale in Feet: 0, 1000, 2000

Vertical Scale in Feet: 0, 100, 200

Figure 5-3
Schematic Geologic Cross Section A-A'

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JOB JK9908, fig_xsect.DWG, 4/2000

Pacific Groundwater Group



Legend

Qvt - Vashon Till

Qva - Vashon Advance Outwash

Qpvu - Undifferentiated Pre-Vashon Sediments

Horizontal Scale in Feet

0 1000 2000

0 100 200

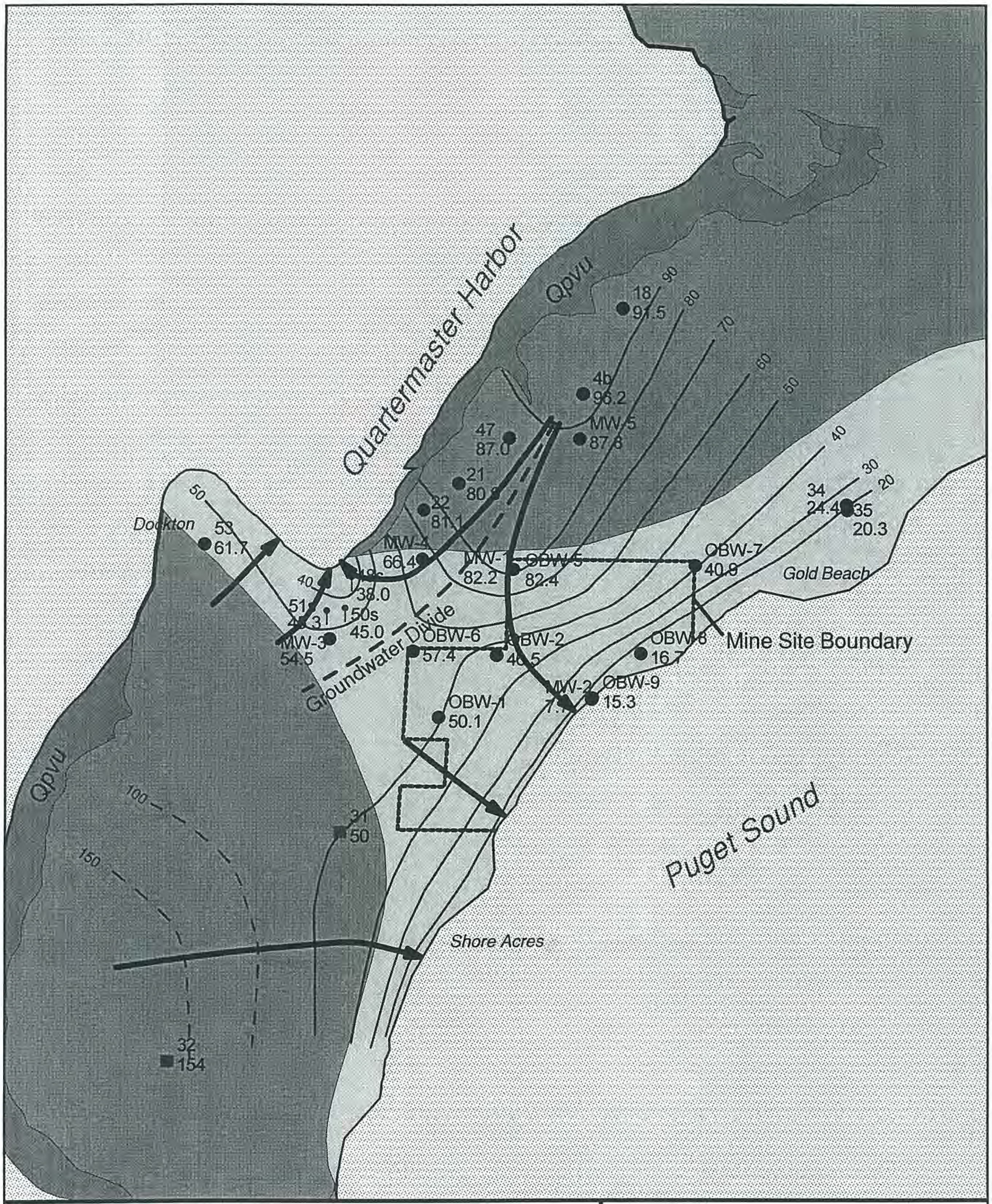
Vertical Scale in Feet

Figure 5-4

Schematic Geologic Cross Section B-B'

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JOB JK9908, fig_xsect.DWG, 4/2000

Pacific Groundwater Group



Principal Aquifer Completions

53 / 50.1 — Well ID Number, Water Level Elevation(ft)

51s / 45.3 — Well ID Number, Water Level Elevation(ft)

32 / 154 — Well ID Number, Estimated ATD Water Level Elevation(ft)

Water Level Contours in Principal Aquifer

Contour (10')

Inferred Contouring (CI = 50')

Groundwater flow direction in Principal Aquifer

Groundwater flow divide in Principal Aquifer

Estimated location of outwash channel where below sea level

Qpvu Interglacial Sediments

N

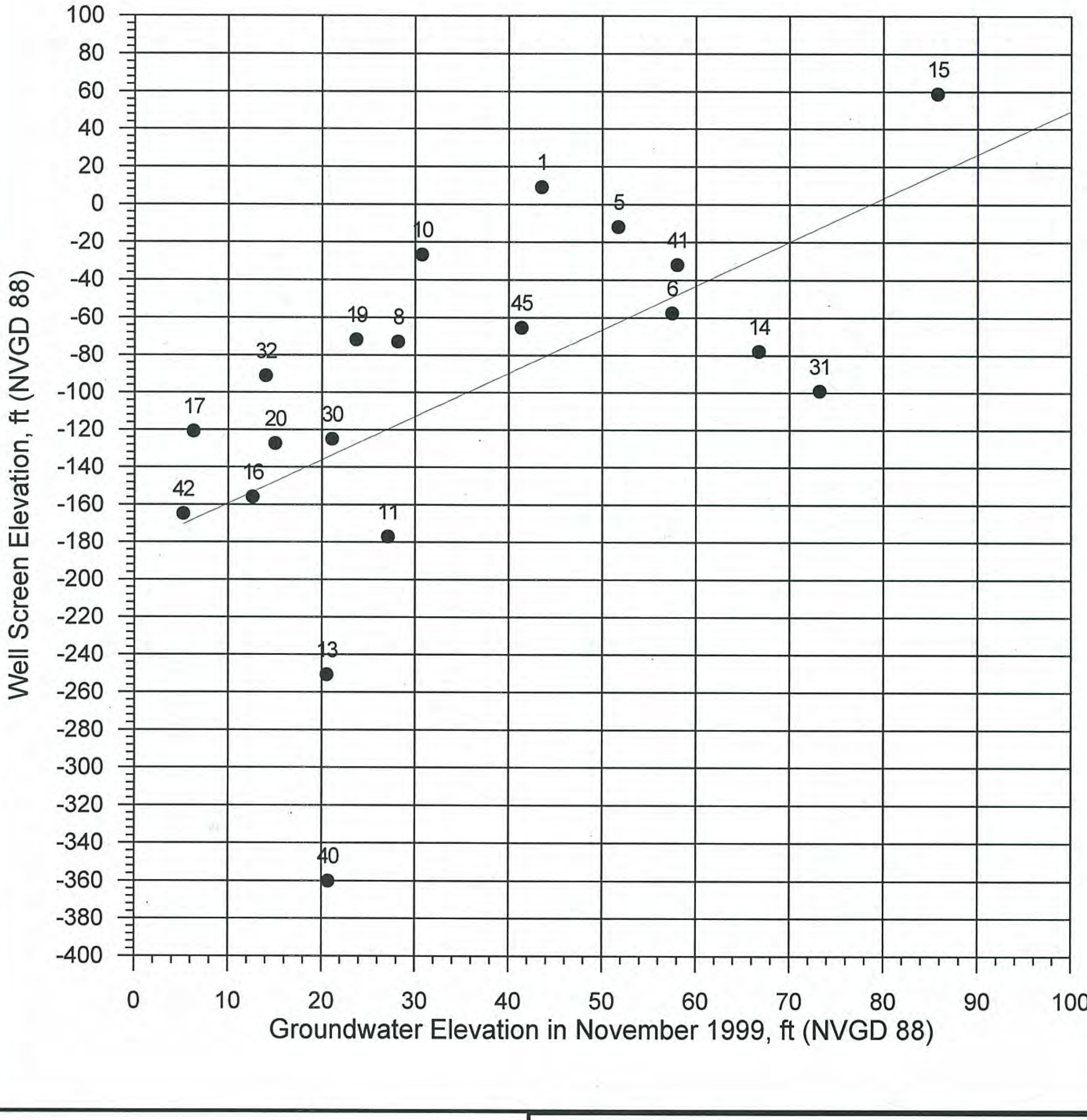
500 0 500 1000 Feet

Figure 6-1

Principal Aquifer Groundwater Contour Map for November 1999

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK 9908, Final_Maury.APR, 4/2000

Pacific Groundwater Group



Notes:

1) Project well ID numbers shown next to well symbol.
2) Screen elevation represents middle of screen or bottom of open-ended casing.
3) Water levels from November 1999.

Figure 6-2
Groundwater Elevation versus Screen Completion Elevation for Deep Aquifer (Qpvu) Wells

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK9908, DTW-DPTH.grf, 4/2000

Pacific Groundwater Group

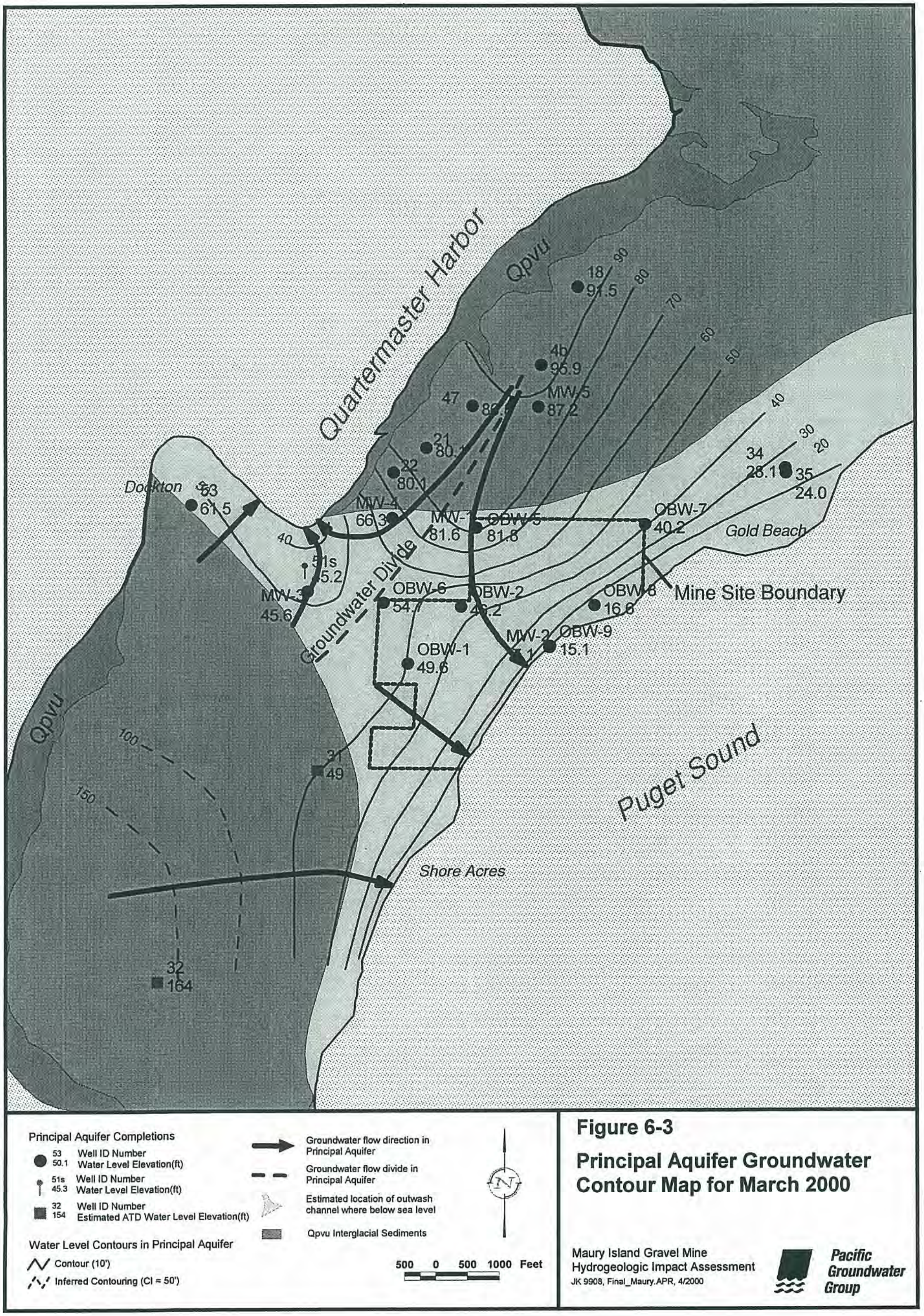
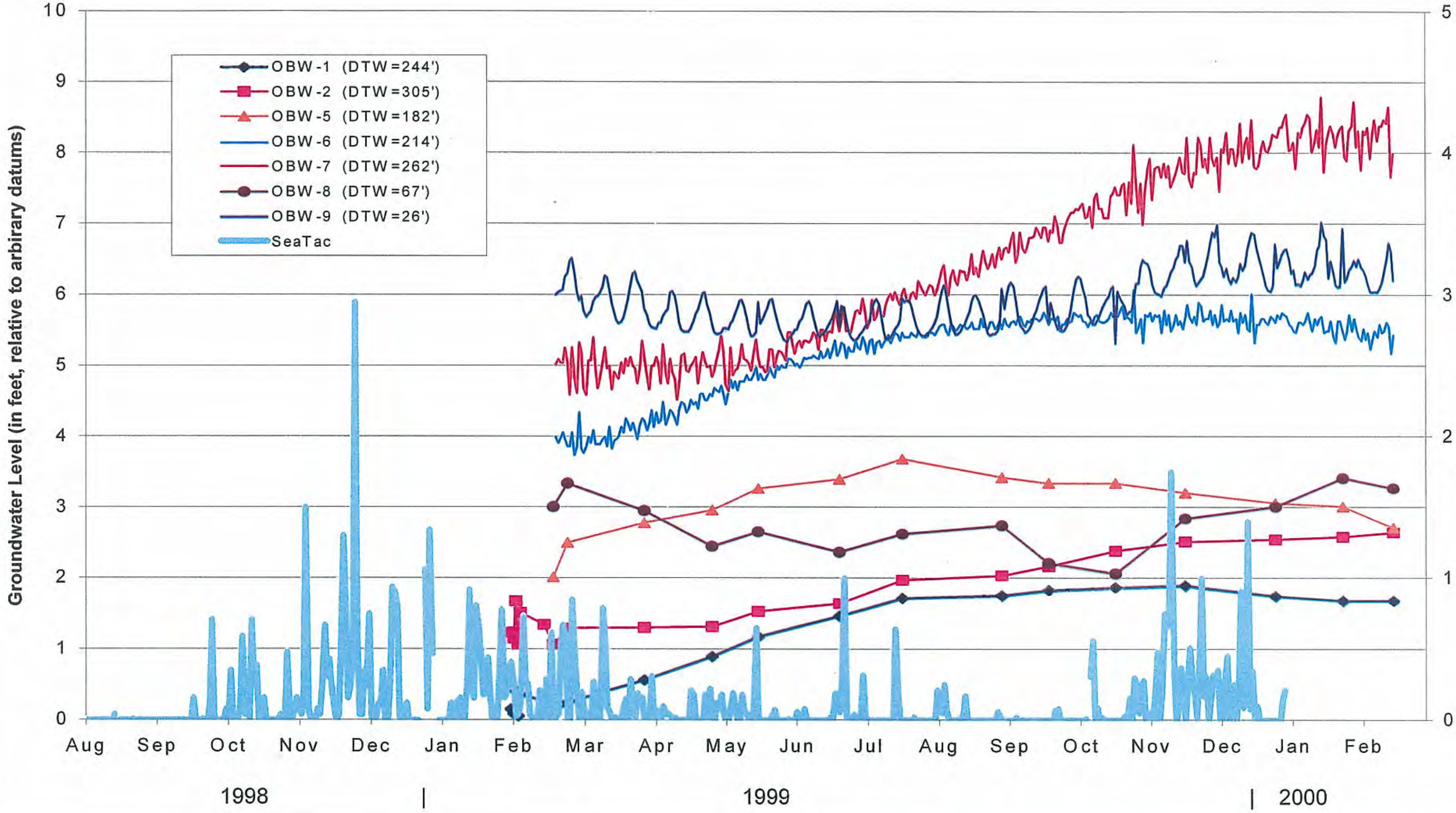


Figure 6-3

Principal Aquifer Groundwater Contour Map for March 2000

Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK 9908, Final_Maury.APR, 4/2000

Pacific Groundwater Group



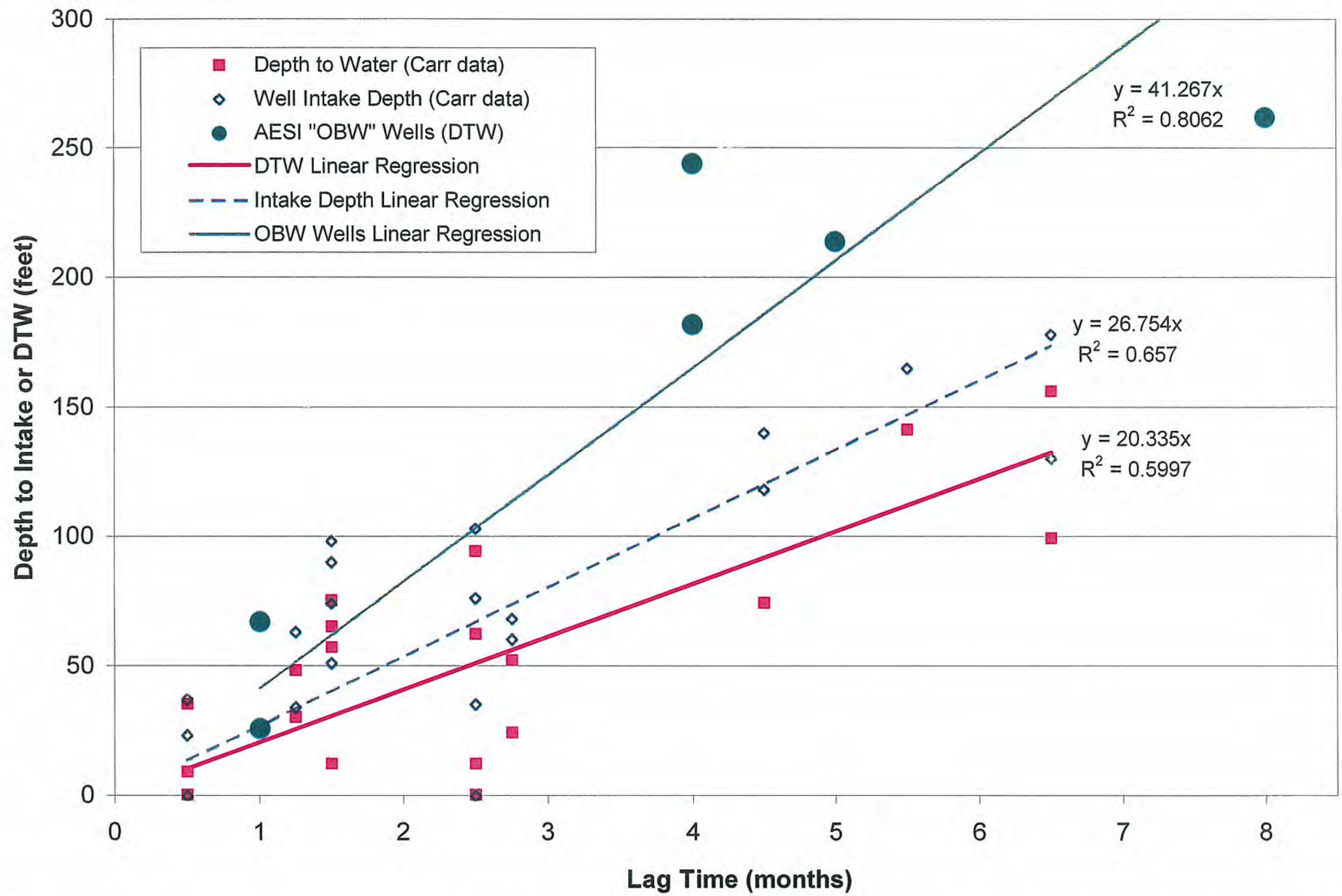
NOTE:
Water level data supplied by AESI in February, 2000.

Figure 6-4
Groundwater Level and Precipitation Trends

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, Maury-PNS-WL.xls, 4/2000

Pacific Groundwater Group



NOTES:

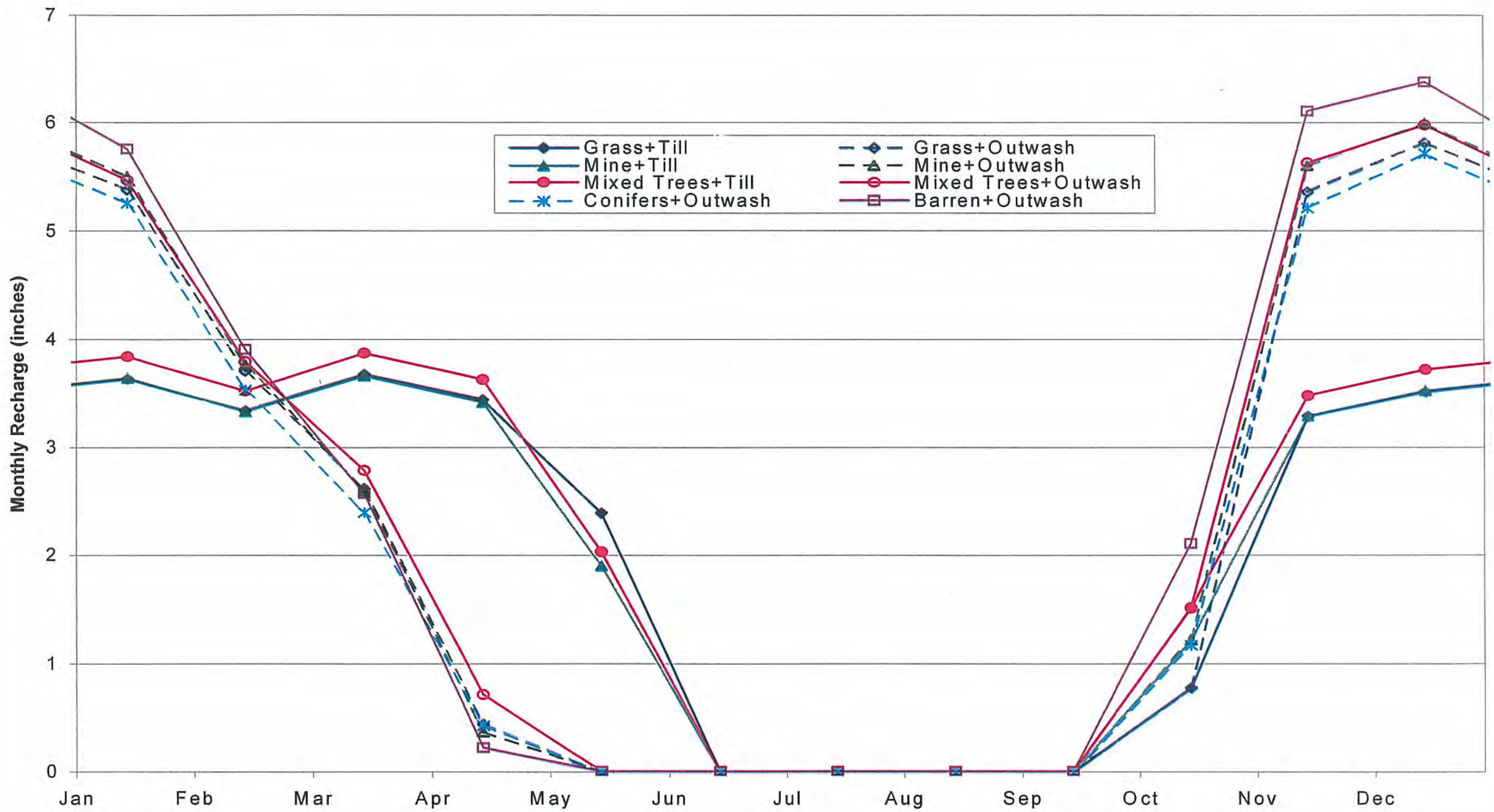
Original analysis (Carr, 1983) compared observed lag time and depth to well intake. PGG analysis compared observed time lag and depth to water. Documentation is unavailable to support independent evaluation of observed time lags.

Figure 7-2
Time Lag vs. Depth Observed on Vashon/Maury Island

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, Maury Lag 1.xls, 4/2000

Pacific Groundwater Group



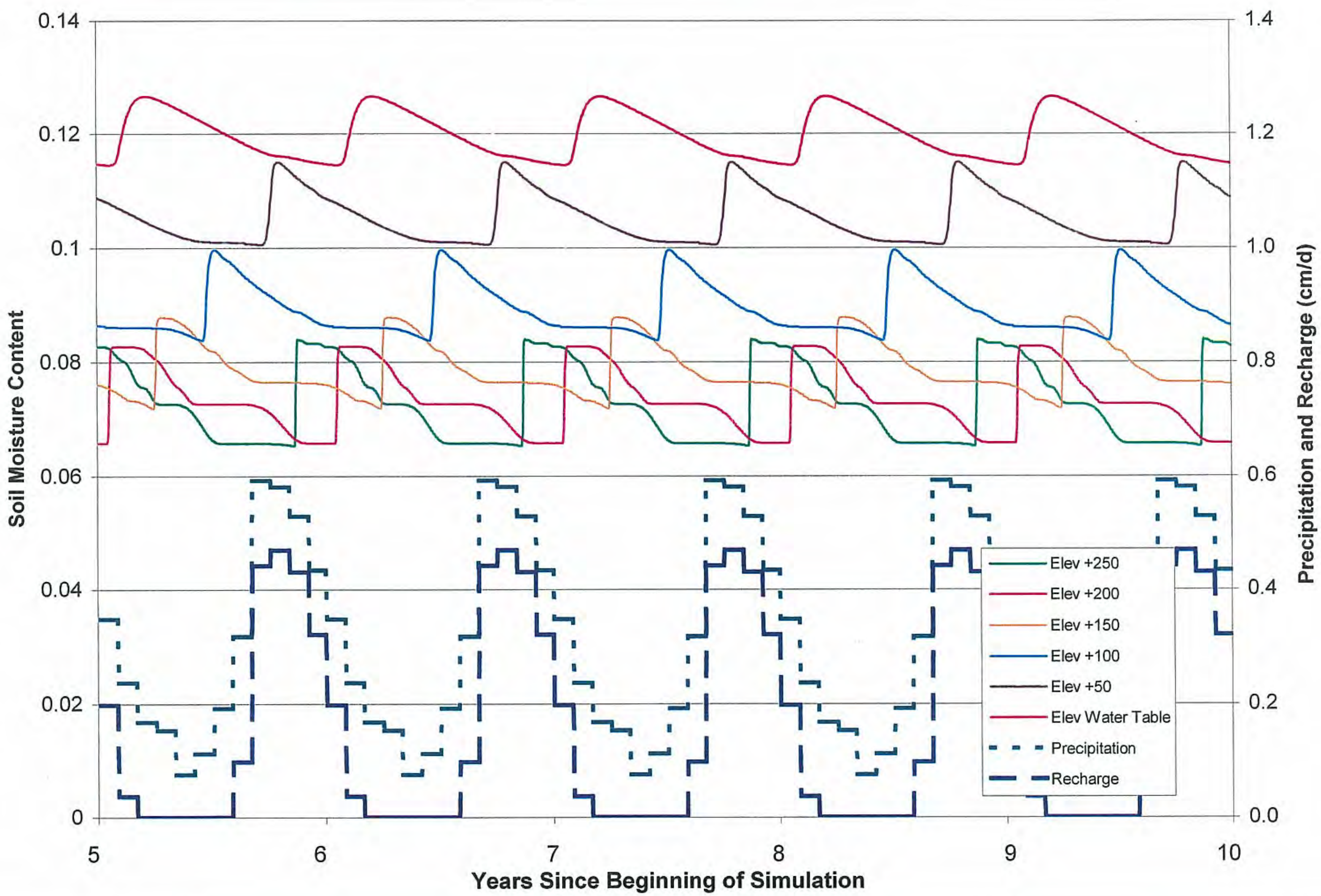
NOTE:
February values appear low due to the short duration of the month.

Figure 7-1
Monthly Recharge Estimates

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, PGG-DPM-Results.xls, 4/2000

Pacific Groundwater Group



NOTES:

Model simulations begin on March 1.

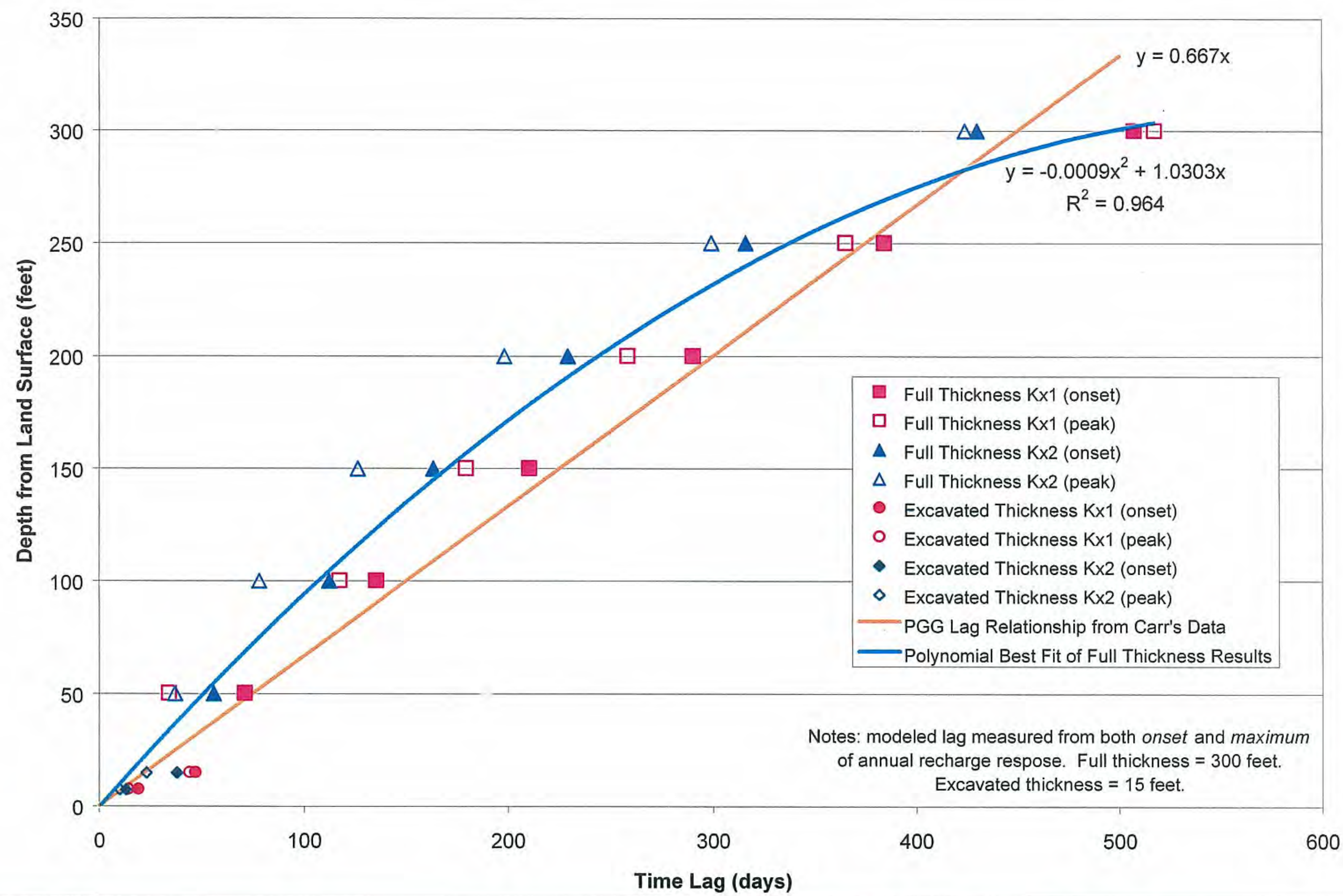
The timing of changes in soil moisture closely follows the timing of downward flux rates. However, the relative variation in the magnitude of soil moisture does not reflect the variation in the magnitude of flux rate.

Figure 7-3
Vadose Zone Predictions of Seasonal Water Content vs. Depth

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, Maury Lag 1.xls, 4/2000

Pacific Groundwater Group



NOTES:

Modeled lag measured from both onset and maximum of annual recharge response. Full thickness = 300 feet. Excavated thickness = 15 feet.

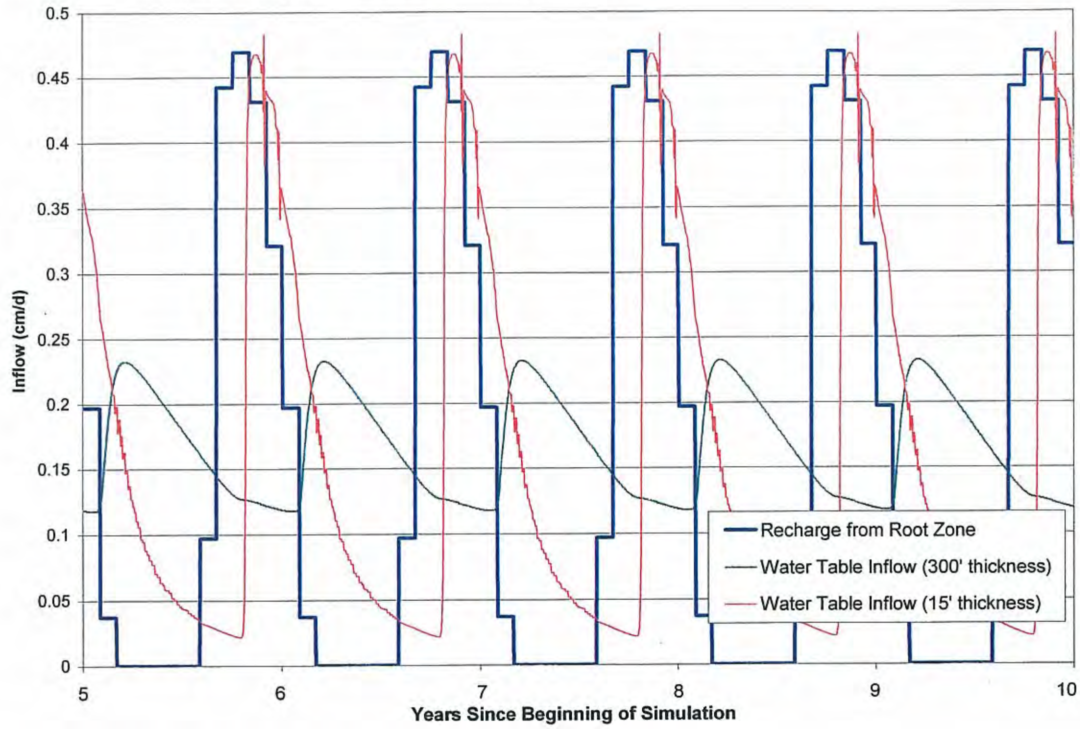
Figure 7-4
Time Lag vs. Depth Predicted with Hydrus-2D Vadose Zone Model

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

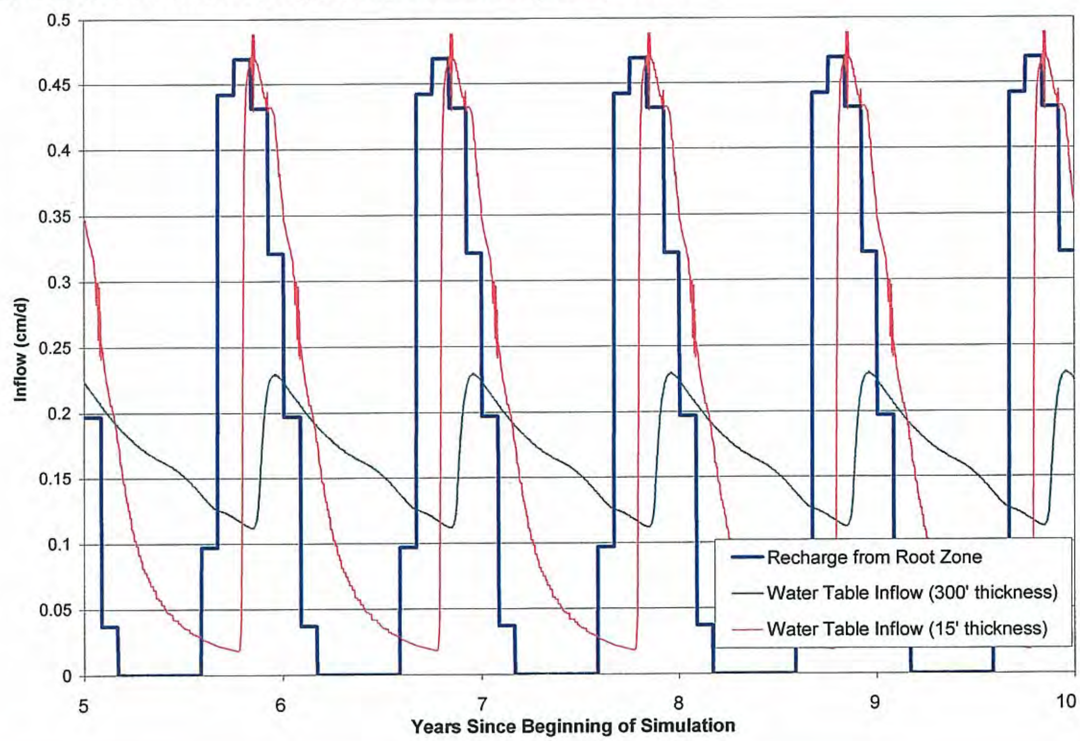
JK9908, Maury Lag 1.xls, 4/2000

Pacific Groundwater Group

A. Original Estimates of Hydraulic Conductivity Distribution



B. Doubled Estimates of Hydraulic Conductivity Distribution



NOTES:
Model simulations begin on March 1.

Annual average rate of recharge = 0.165 cm/day (23.7 inches/year).

Figure 7-5
Vadose Zone Predictions of Seasonal Recharge Flux vs. Depth

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, Maury Lag 1.xls, 4/2000

Pacific Groundwater Group

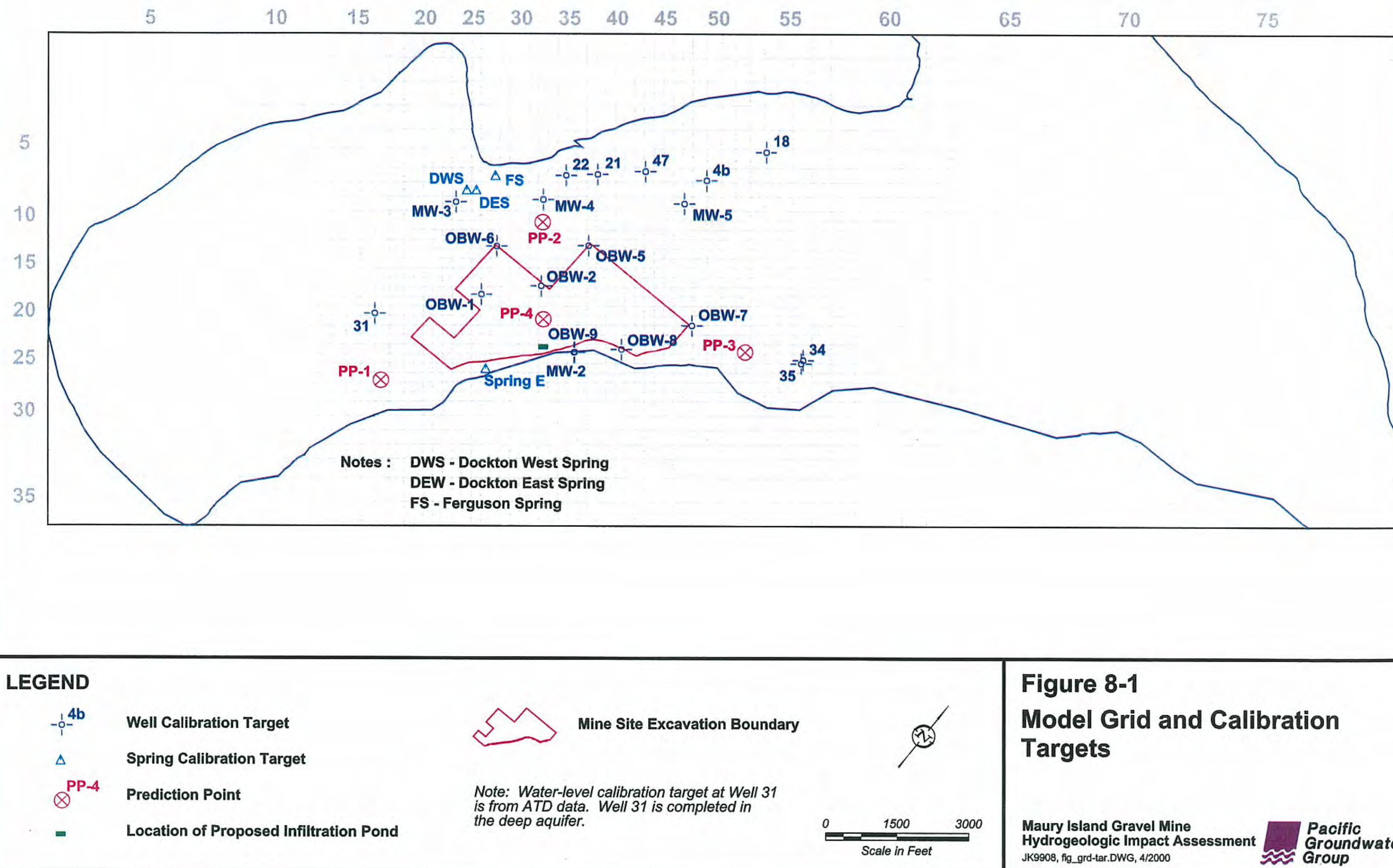
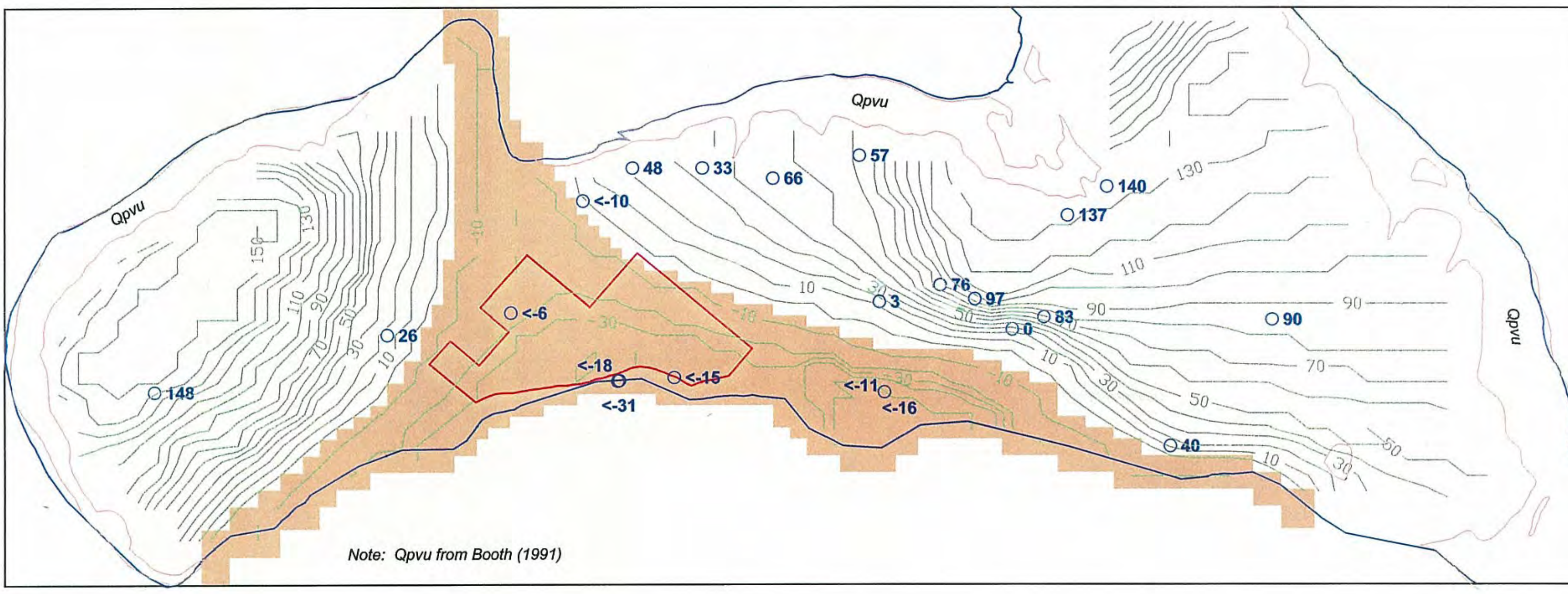


Figure 8-1
Model Grid and Calibration Targets

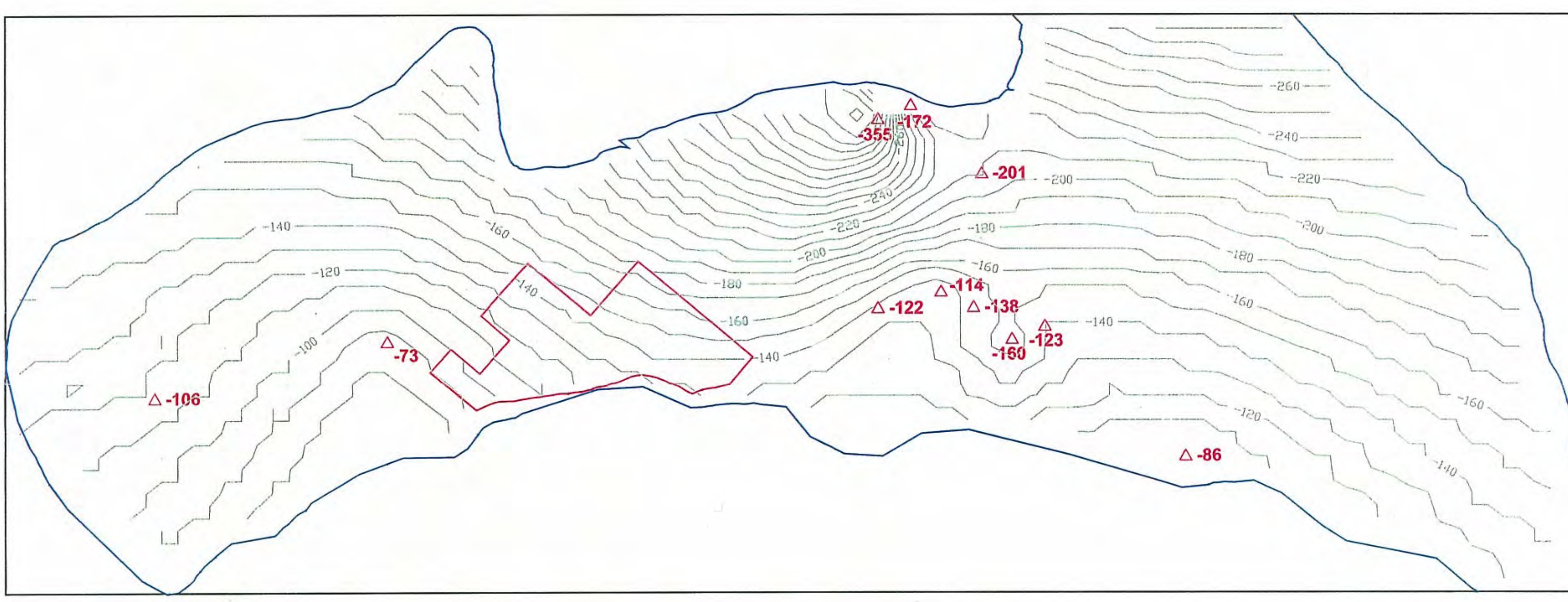
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK9908, fig_grd-tar.DWG, 4/2000

Pacific Groundwater Group

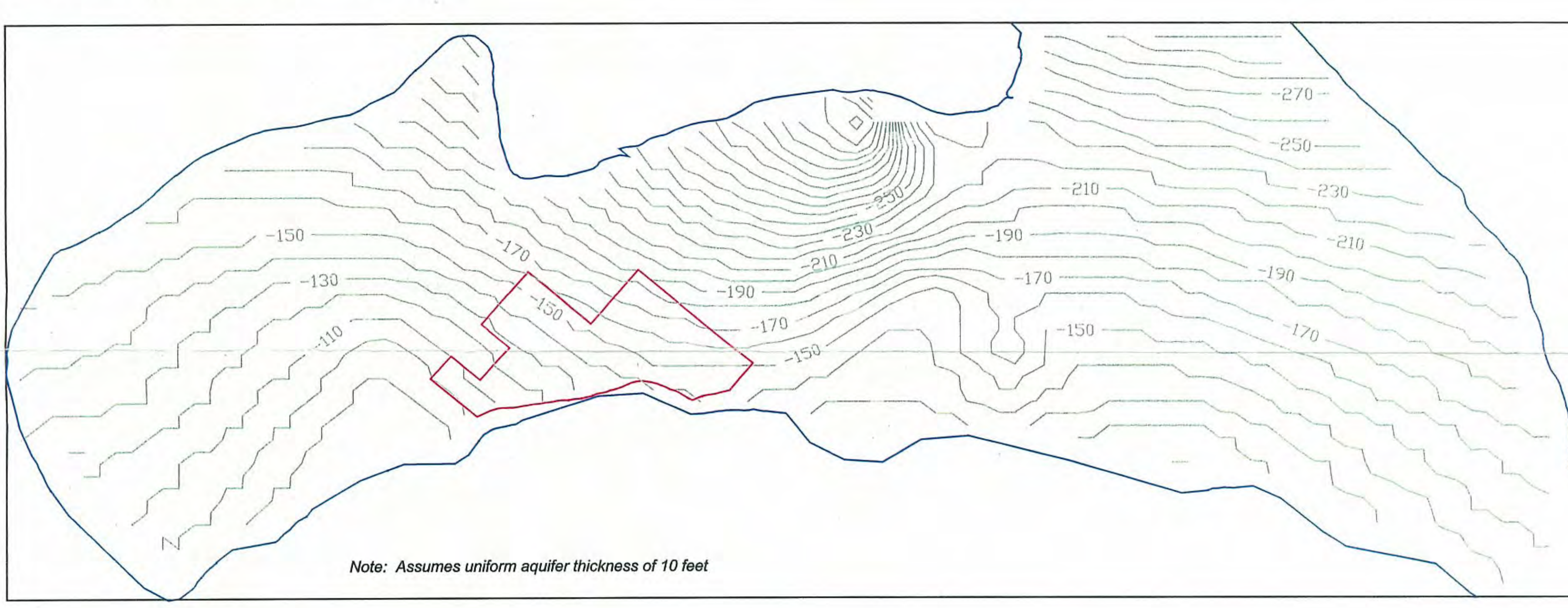
Bottom Elevation of Model Layer 1



Bottom Elevation of Model Layer 2



Bottom Elevation of Model Layer 3



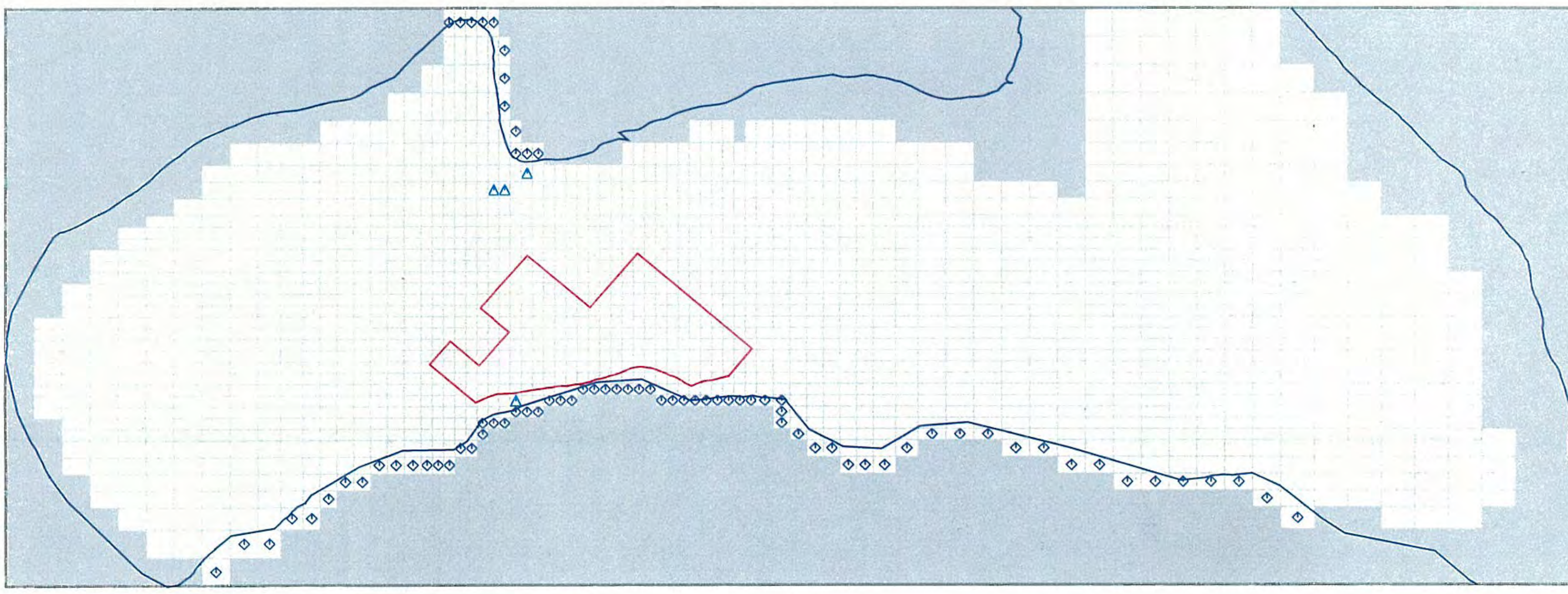
Legend

Figure 8-2
Layer-Bottom Elevations in Groundwater Flow Model

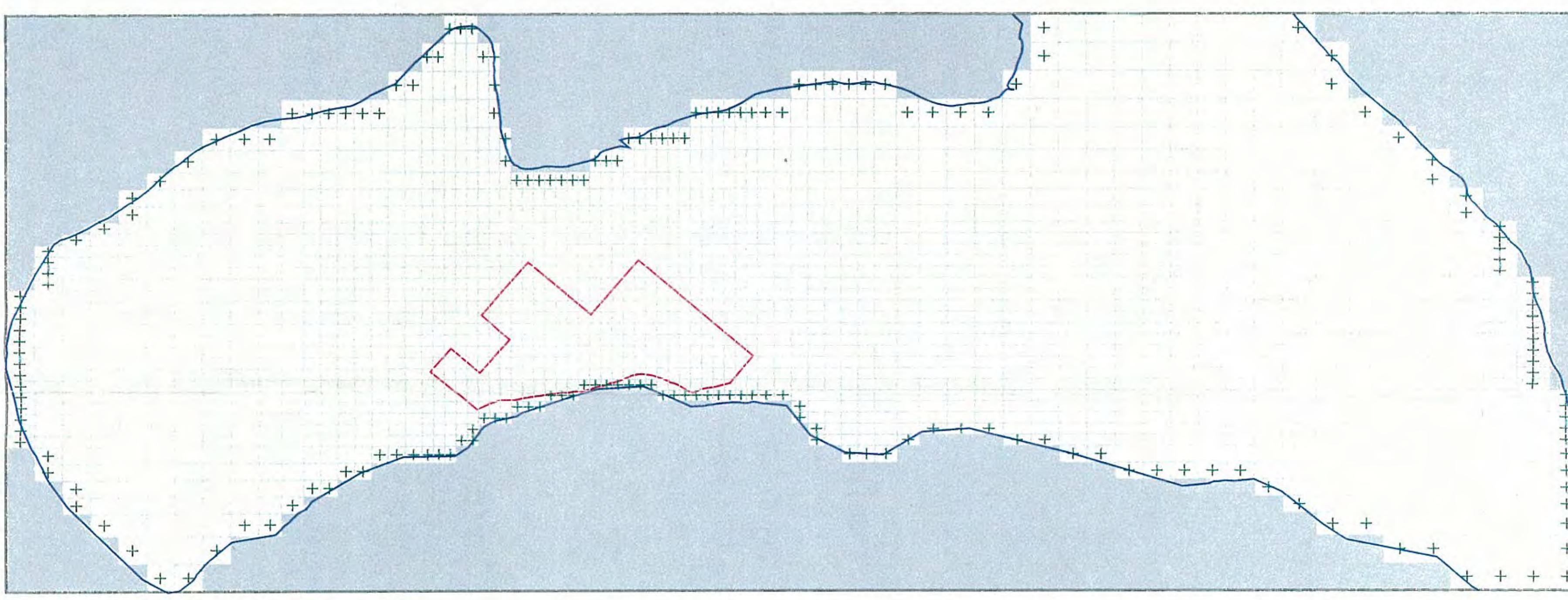
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JOB JK9908, fig-bottoms.DWG, 4/2000

Pacific Groundwater Group

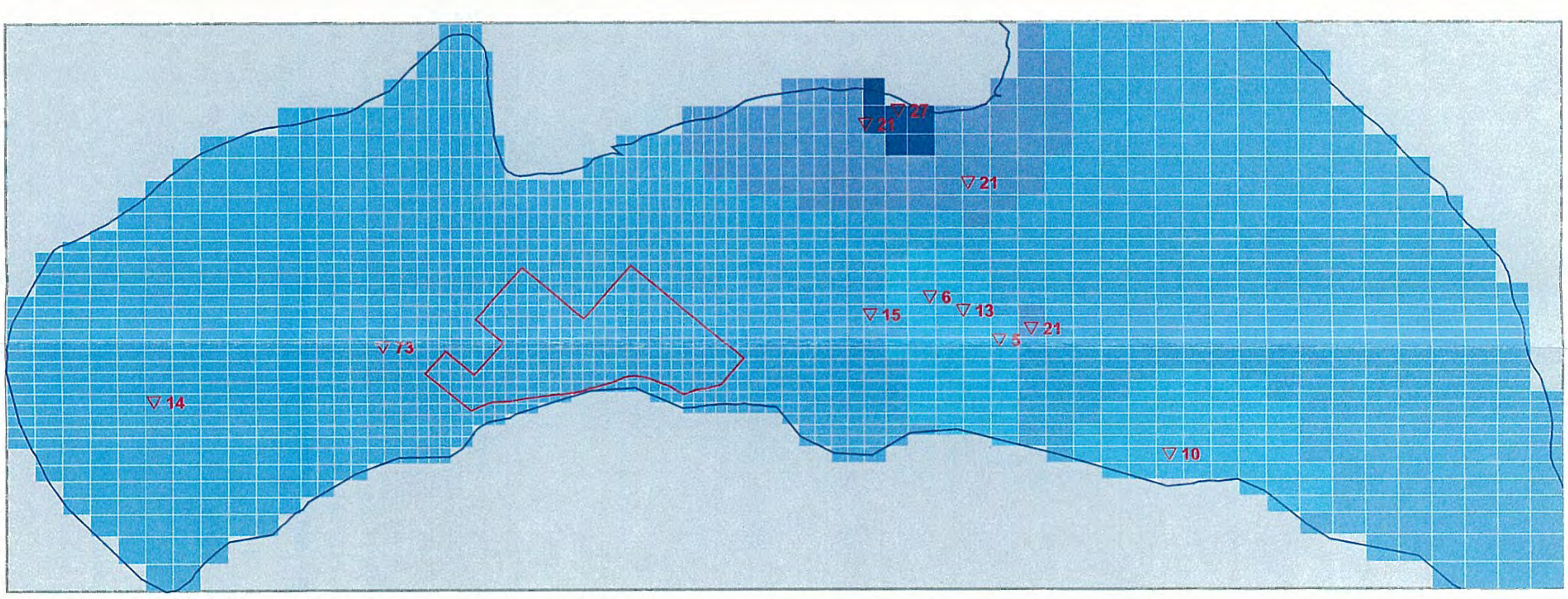
Boundary Conditions in Model Layer 1



Boundary Conditions in Model Layer 2



Boundary Conditions in Model Layer 3



Legend

- Constant Head Boundary
- Drain Boundary (Spring)
- General Head Boundary
- ▽ 14 Measured Water-Level Elevation in Deep Aquifer
- Inactive Model Cell

Mine Site Excavation Boundary

LAYER 3 CONSTANT HEAD VALUES

- 25 feet
- 20 feet
- 15 feet
- 10 feet

0 1500 3000

Scale in Feet

Figure 8-3
Boundary Conditions in Groundwater Flow Model

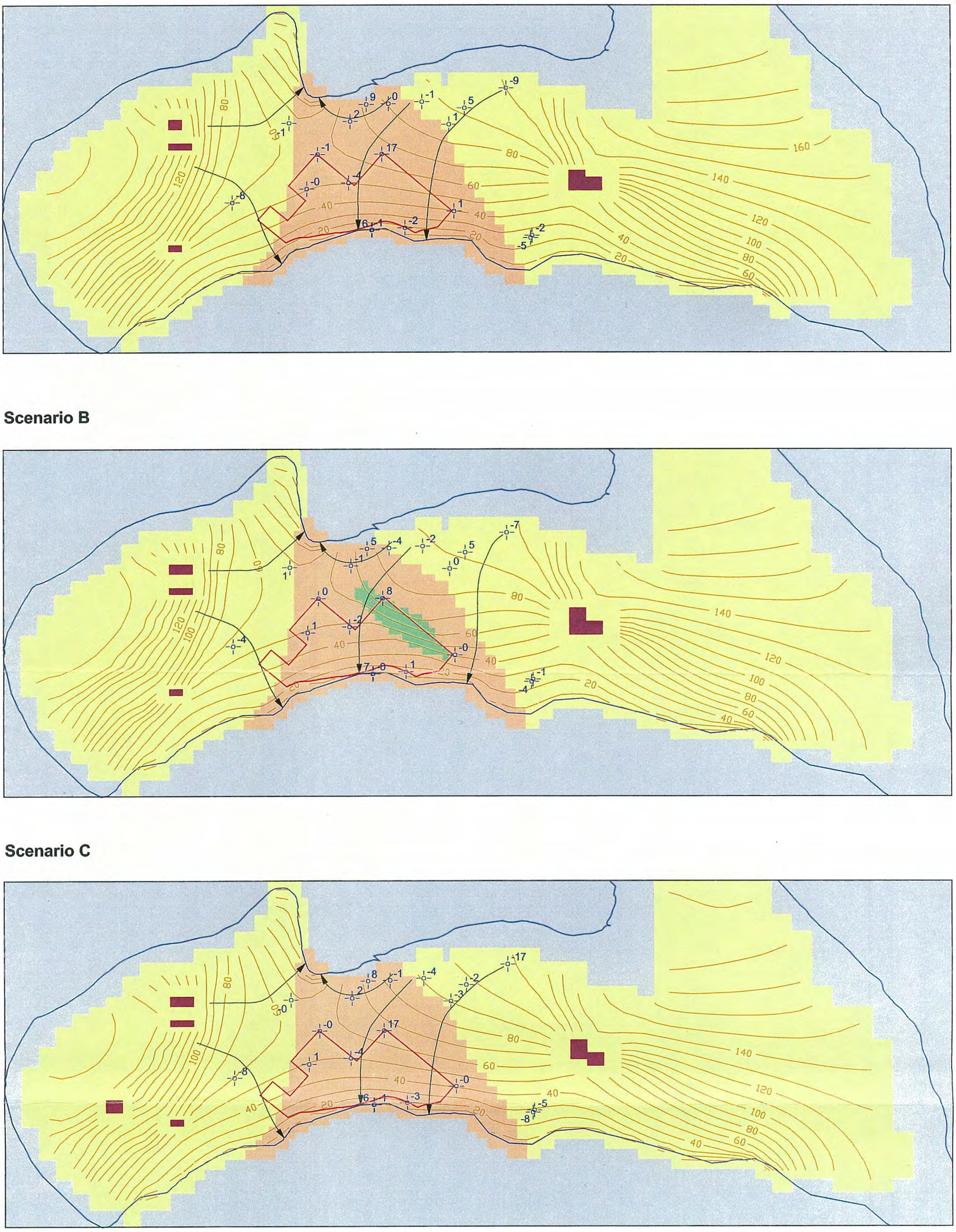
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JOB JK9906, fig_bndy.DWG, 4/2000

Pacific Groundwater Group

Scenario A

Scenario B

Scenario C



Legend

- 1 Calibration Target and Residual (feet)
- Dry Cell
- Inactive Cell
- Groundwater Flow Path

NOTES:
Contour Interval = 10 feet
Residual = Observed - Modeled Water Level
Vertical Hydraulic Conductivity (Kv) = Approximately 1/10 Horizontal Hydraulic Conductivity (Kh)

Mine Site Excavation Boundary

HYDRAULIC CONDUCTIVITY ZONES

- Kh = 21 ft/d (Scenario A); 25 ft/d (Scenario B); 11 ft/d (Scenario C)
- Kh = 11 ft/d (Scenarios A&B); 8.5 ft/d (Scenario C)
- Kh = 2.8 ft/d

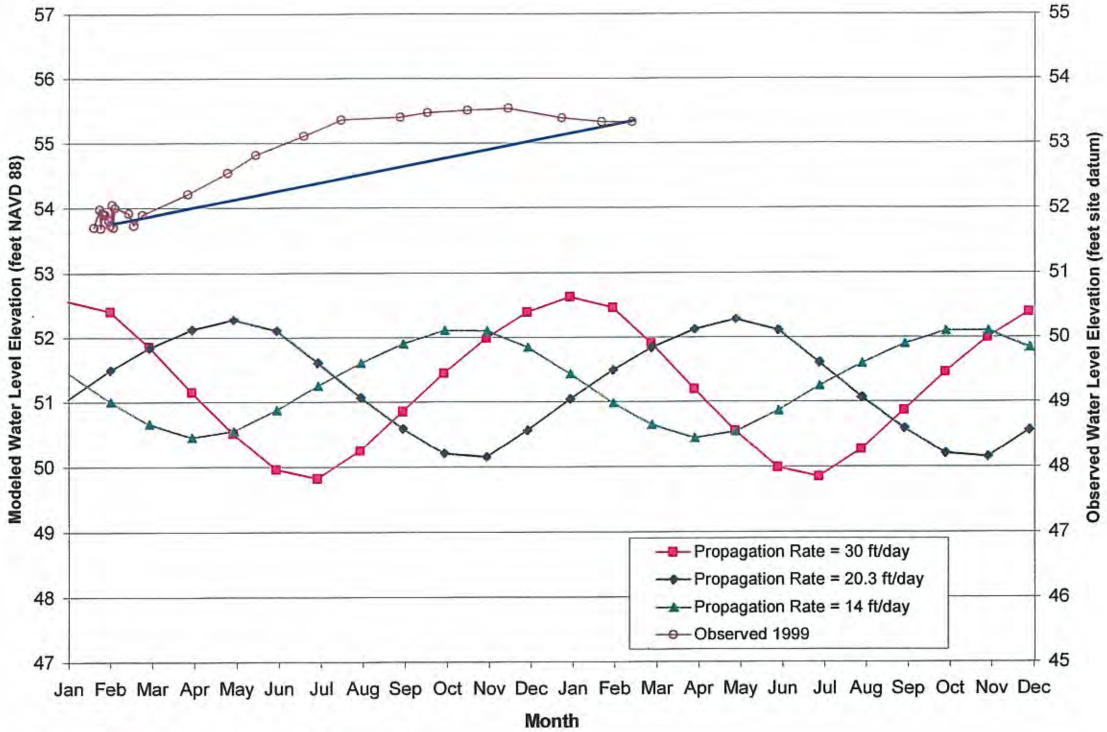
0 1500 3000
Scale in Feet

Figure 8-4
Steady State Groundwater Levels and Hydraulic Conductivity Distributions

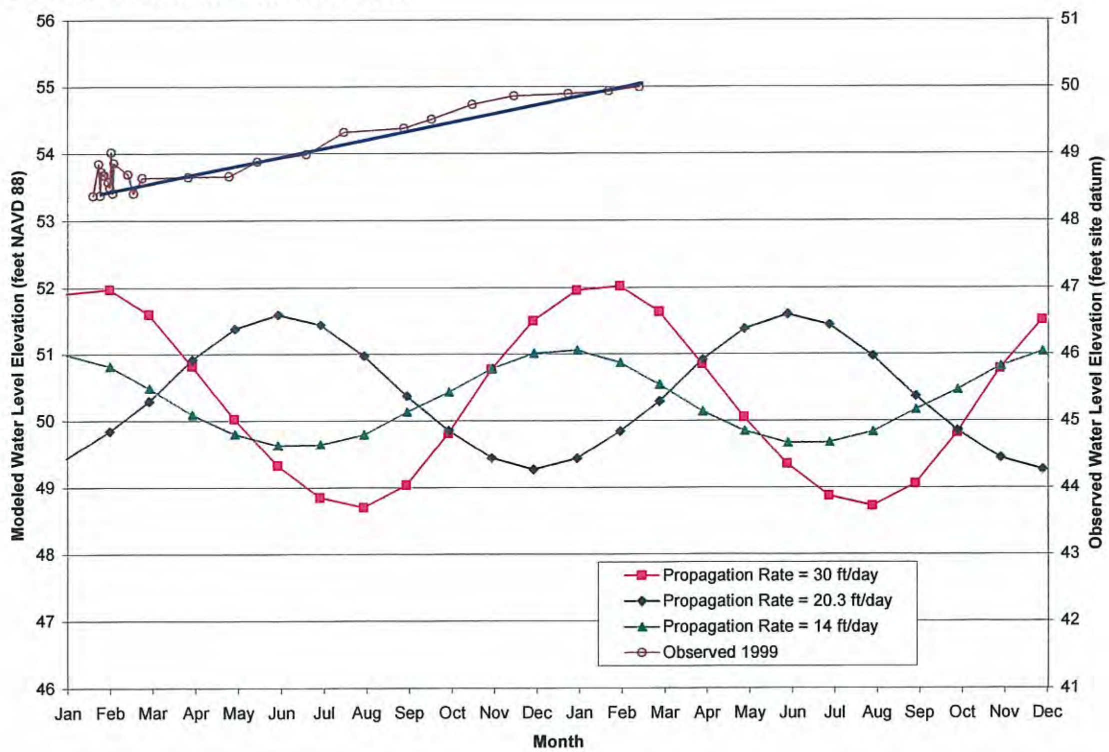
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JOB JK9908, fig_ss.DWG, 4/2000

Pacific Groundwater Group

A. Water Level Variations at OBW-1



B. Water Level Variations at OBW-2



NOTES:
Heavy blue line shows generalized 1999 groundwater level rise. Actual water-level variations are interpreted with respect to this trend.
Observed groundwater level elevations shown on these figures may differ slightly from those published in the report due to differences in vertical datum.

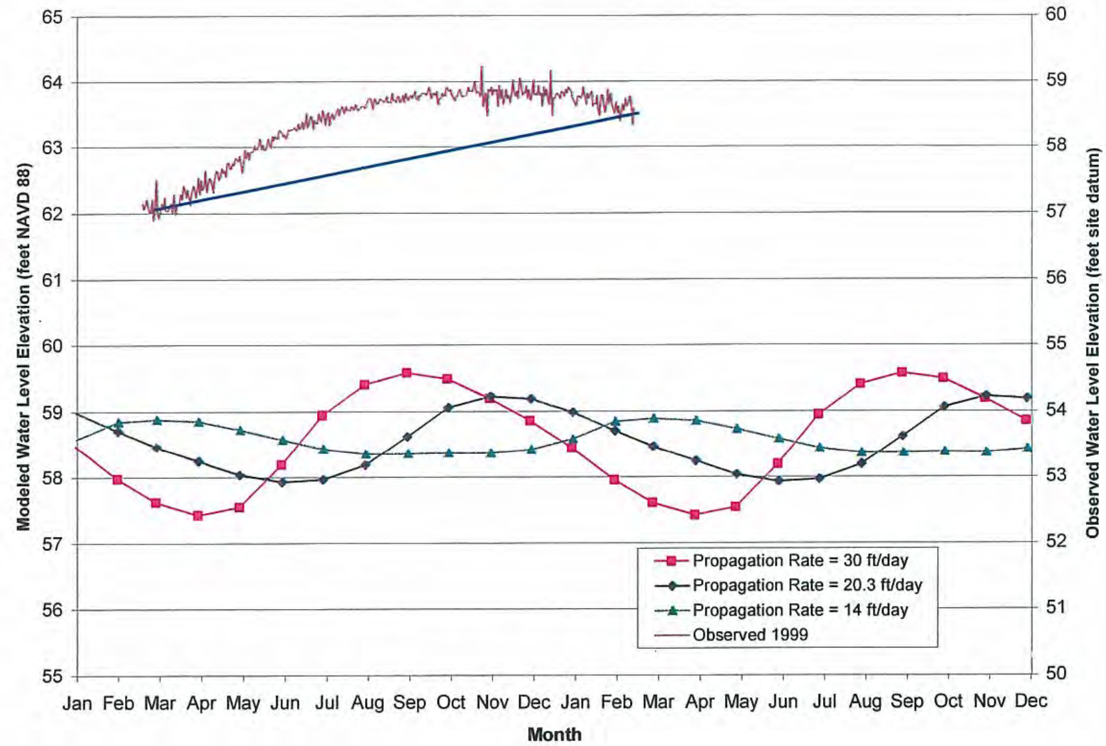
Figure 8-5
Transient Model of Current Condition Observed and Predicted Water-Level Trends

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

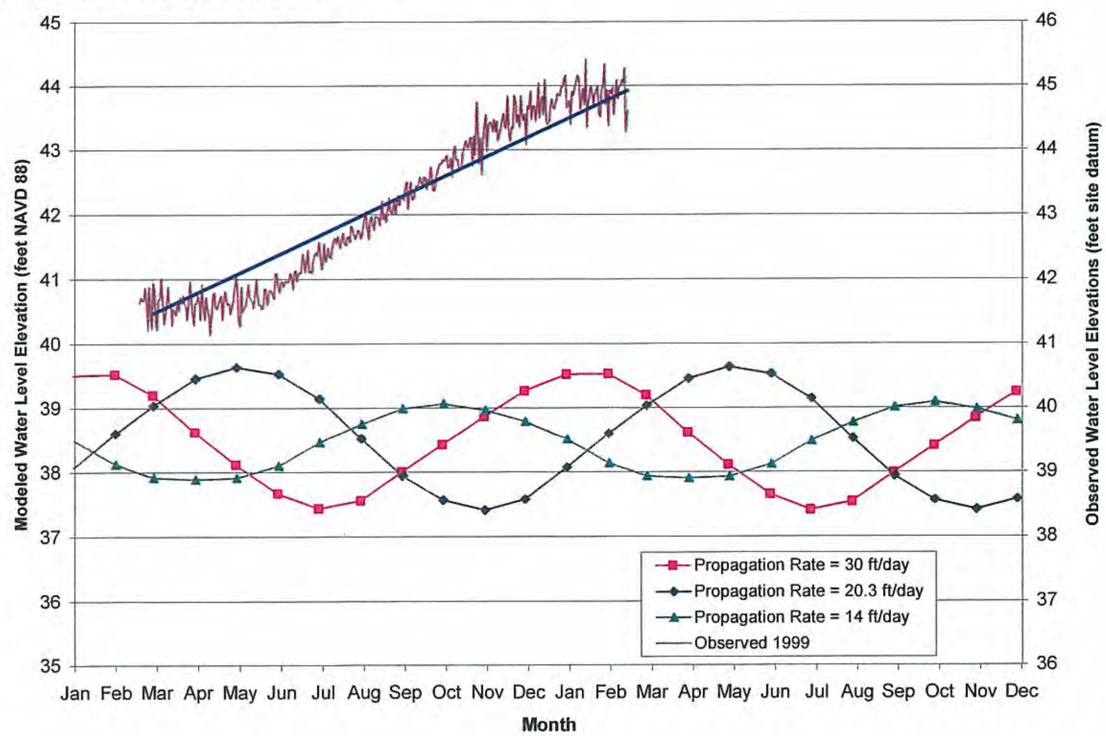
JK9908, LTA-MWs.xls, 4/2000

Pacific Groundwater Group

C. Water Level Variations at OBW-6



D. Water Level Variations at OBW-7



NOTES:
Heavy blue line shows generalized 1999 groundwater level rise. Actual water-level variations are interpreted with respect to this trend.
Observed groundwater level elevations shown on these figures may differ slightly from those published in the report due to differences in vertical datum.

Figure 8-6
Transient Model of Current Condition Observed and Predicted Water-Level Trends *(continued)*

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, LTA-MWs.xls, 4/2000

Pacific Groundwater Group

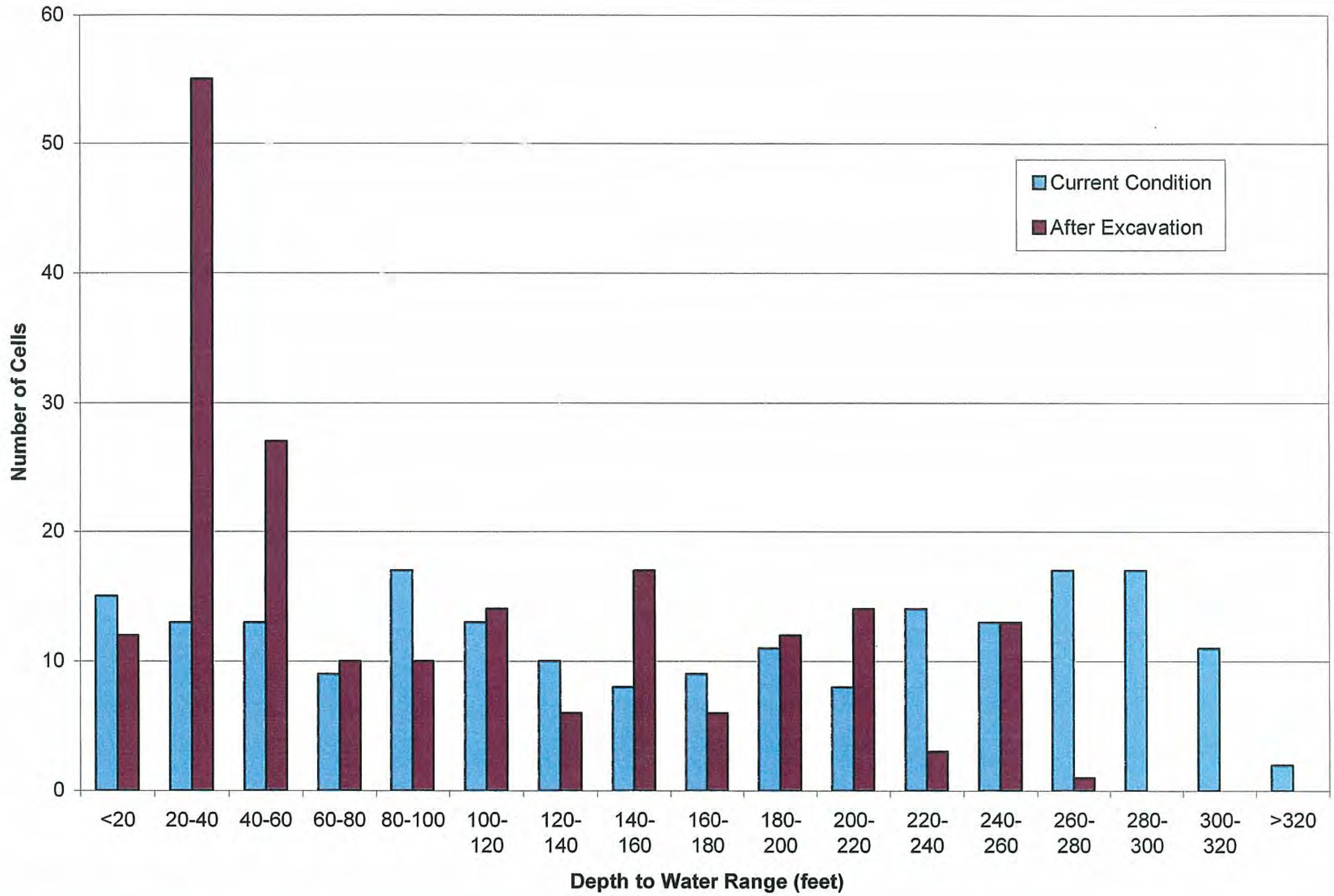
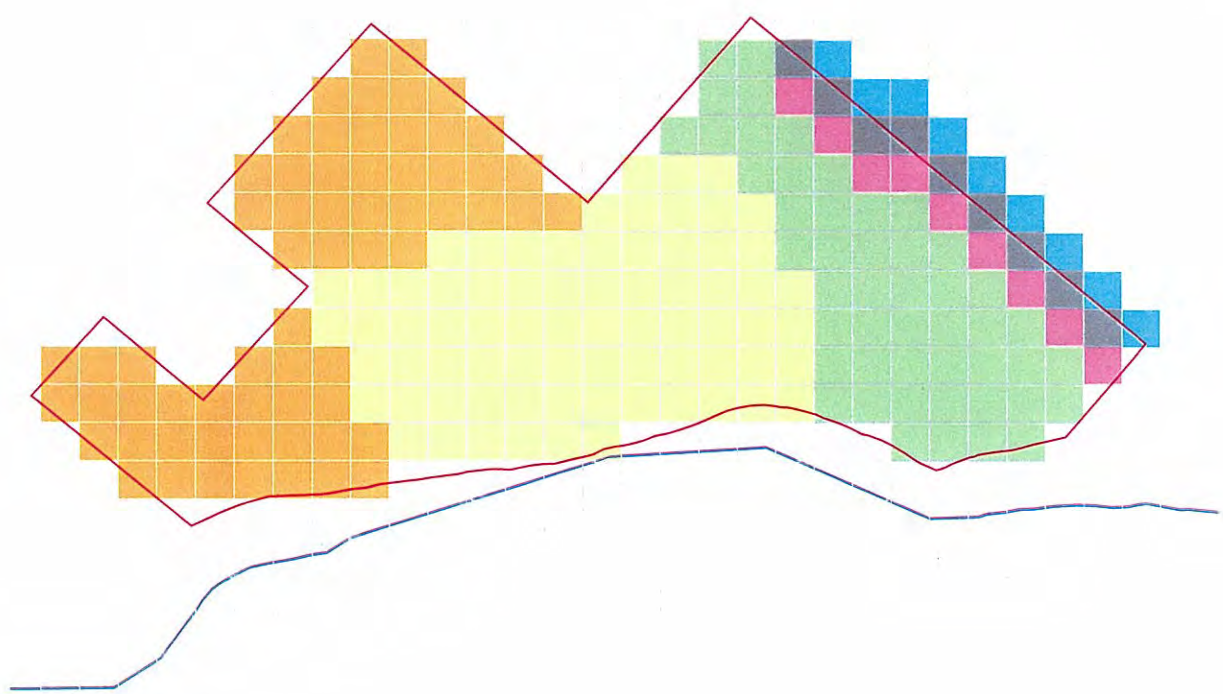


Figure 8-7
Modeled Depth to Water for Cells within the Mine Footprint

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, depth to water.xls, 4/2000

Pacific Groundwater Group



LEGEND

- Excavation Cell 1
- Excavation Cell 2
- Excavation Cell 3
- Imperveous Berm
- Receives 1/3 of Rejected Recharge from Berm
- Receives 2/3 of Rejected Recharge from Berm
- Mine Site Excavation Boundary

Note: Cells receiving 1/3 rejected recharge from berm are also included in excavation cell 3.

0 500 1000

Scale in Feet

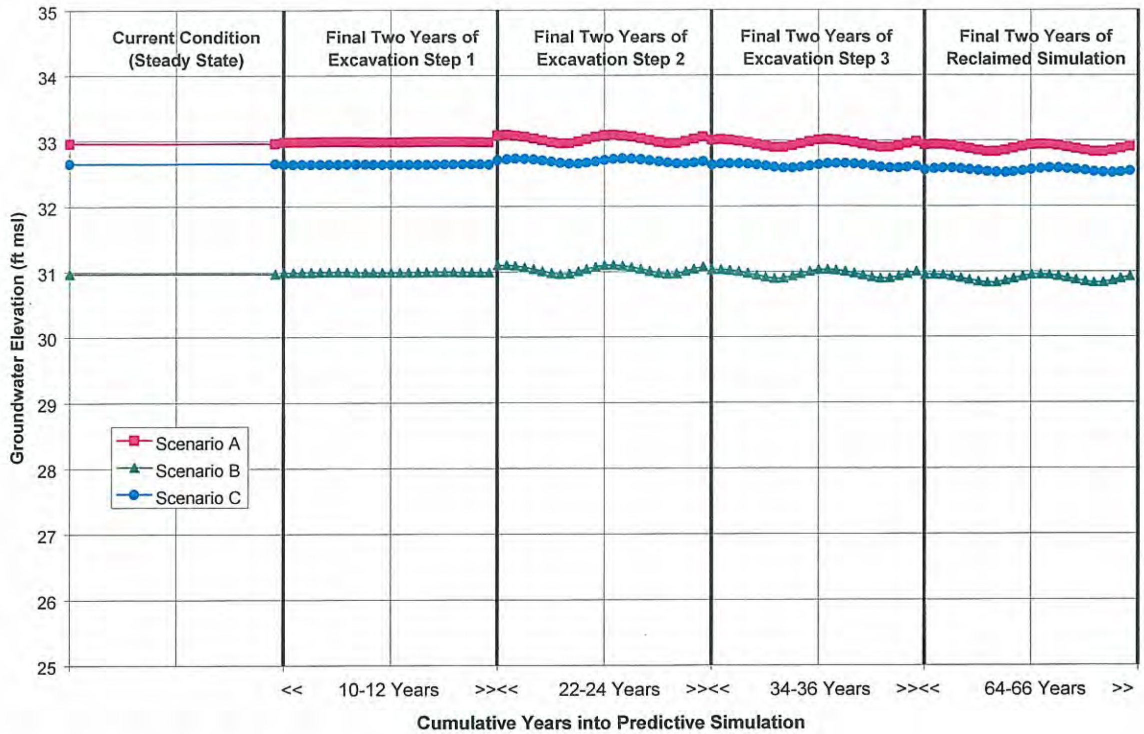
Figure 8-8

Excavation Cells Used in Predictive Model

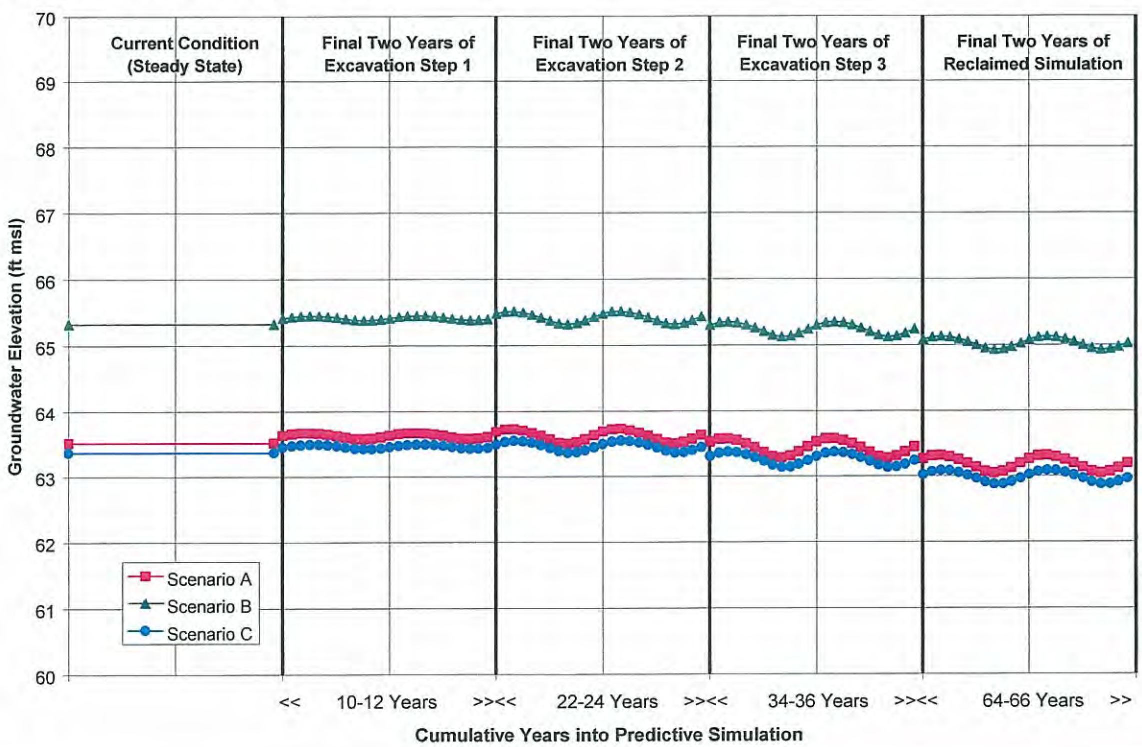
Maury Island Gravel Mine
Hydrogeologic Impact Assessment
JK9908, fig_excav.DWG, 4/2000

Pacific Groundwater Group

A. Impacts at Prediction Point 1



B. Impacts at Prediction Point 2



NOTES:
Graphed model years begin on May 1.

Graphs present modeled impacts of changing recharge from steady-state throughout the model domain to seasonally varying (zero time lag) in the excavated portions of the mine site. The final two years of each excavation step are presented. All three steps were modeled for 12 years, and reclamation was modeled for 30

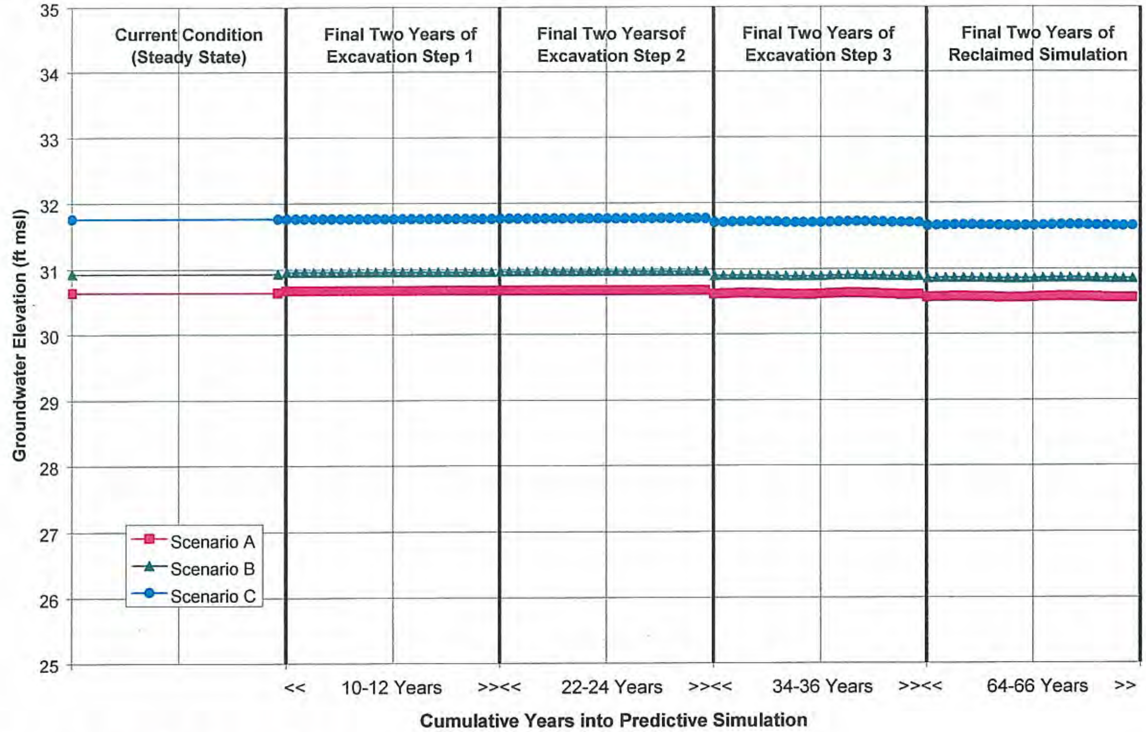
Figure 8-9
Predicted Impacts to Groundwater Levels at Model Prediction Points

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

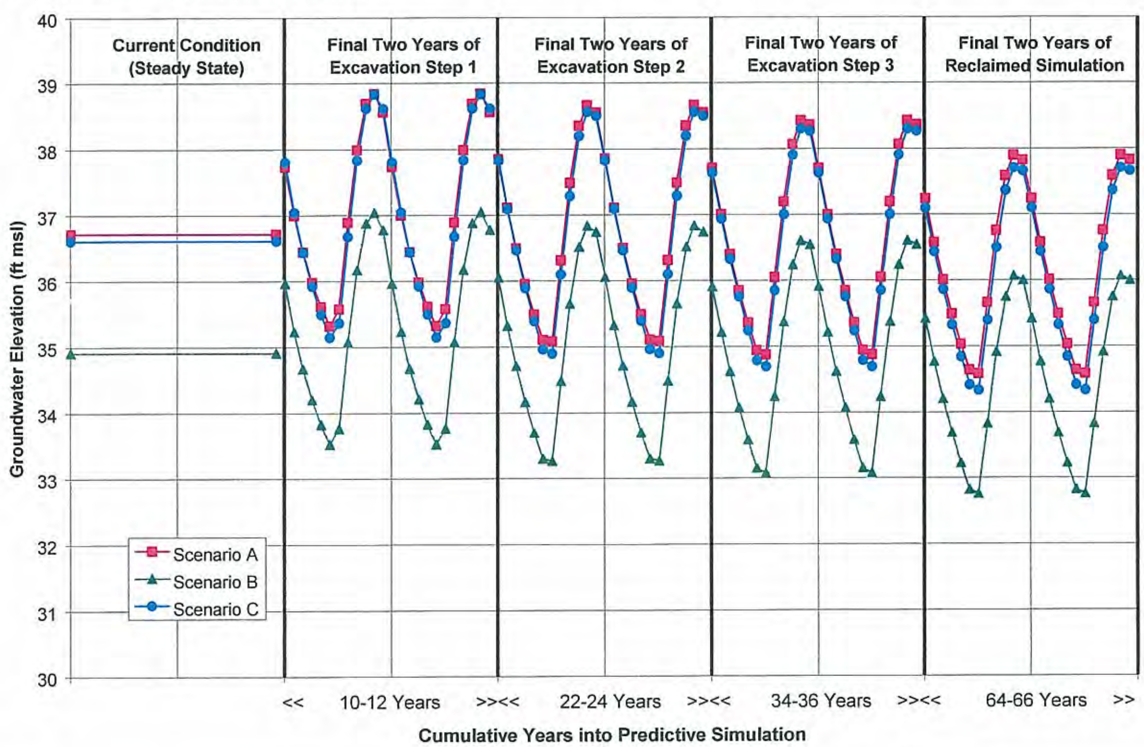
JK9908, New-Predict-MWs.xls, 4/2000

Pacific Groundwater Group

C. Impacts at Prediction Point 3



D. Impacts at Prediction Point 4



NOTES:
Graphed model years begin on May 1.

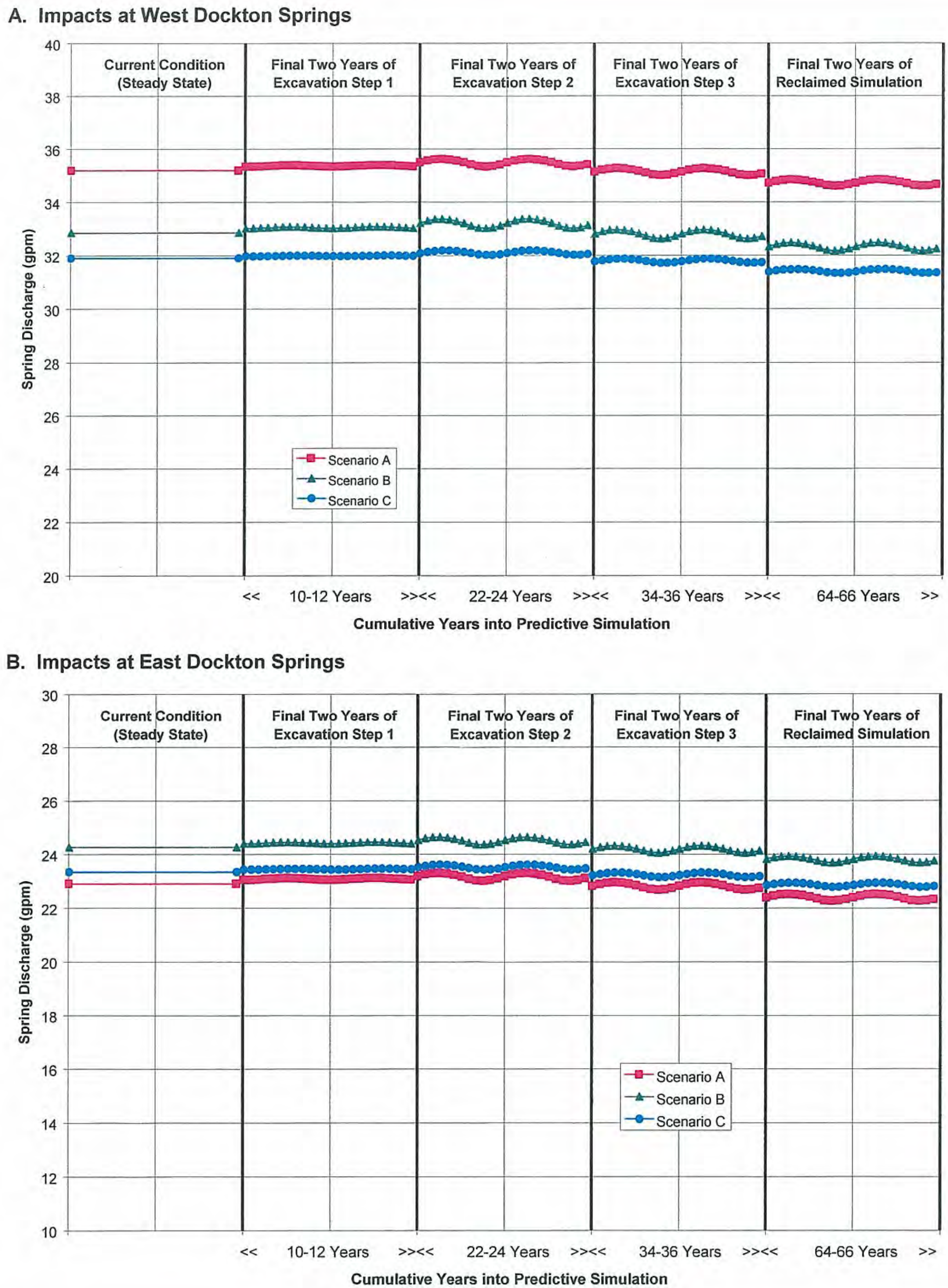
Graphs present modeled impacts of changing recharge from steady-state throughout the model domain to seasonally varying (zero time lag) in the excavated portions of the mine site. The final two years of each excavation step are presented. All three steps were modeled for 12 years, and reclamation was modeled for 30

Figure 8-10
Predicted Impacts to Groundwater Levels at Model Prediction Points *(continued)*

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, New-Predict-MWs.xls, 4/2000

Pacific Groundwater Group



NOTES:
Graphed model years begin on May 1.

Graphs present modeled impacts of changing recharge from steady-state throughout the model domain to seasonally varying (zero time lag) in the excavated portions of the mine site. The final two years of each excavation step are presented. All three steps were modeled for 12 years, and reclamation was modeled for 30

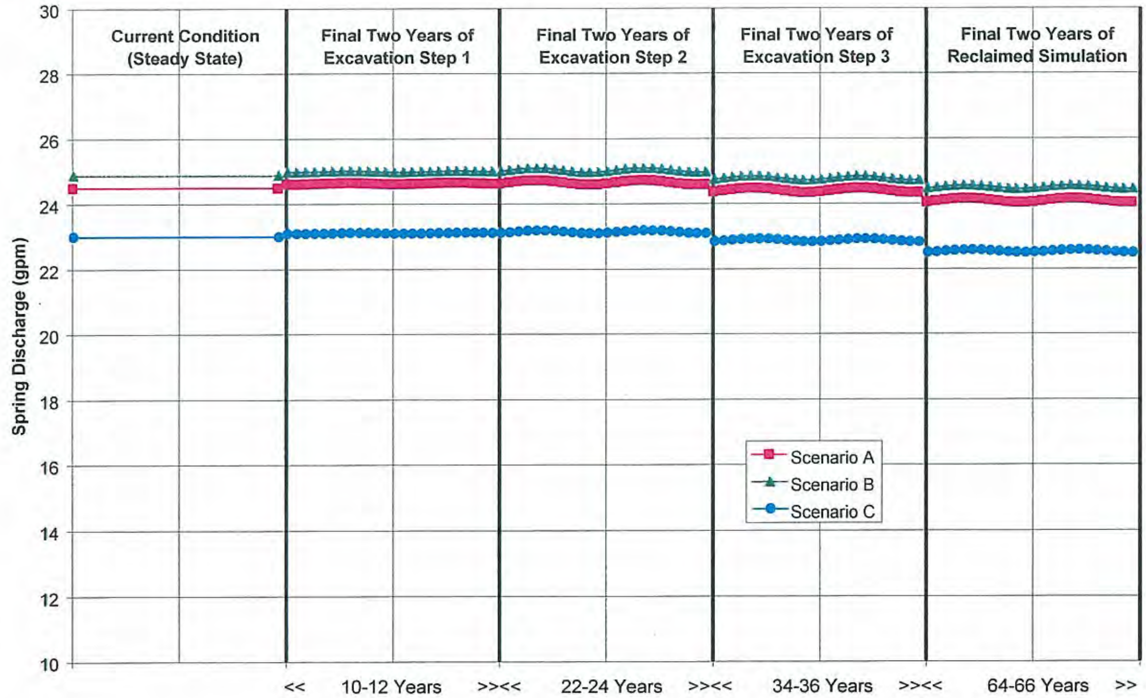
Figure 8-11
Predicted Impacts to Spring Discharge

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

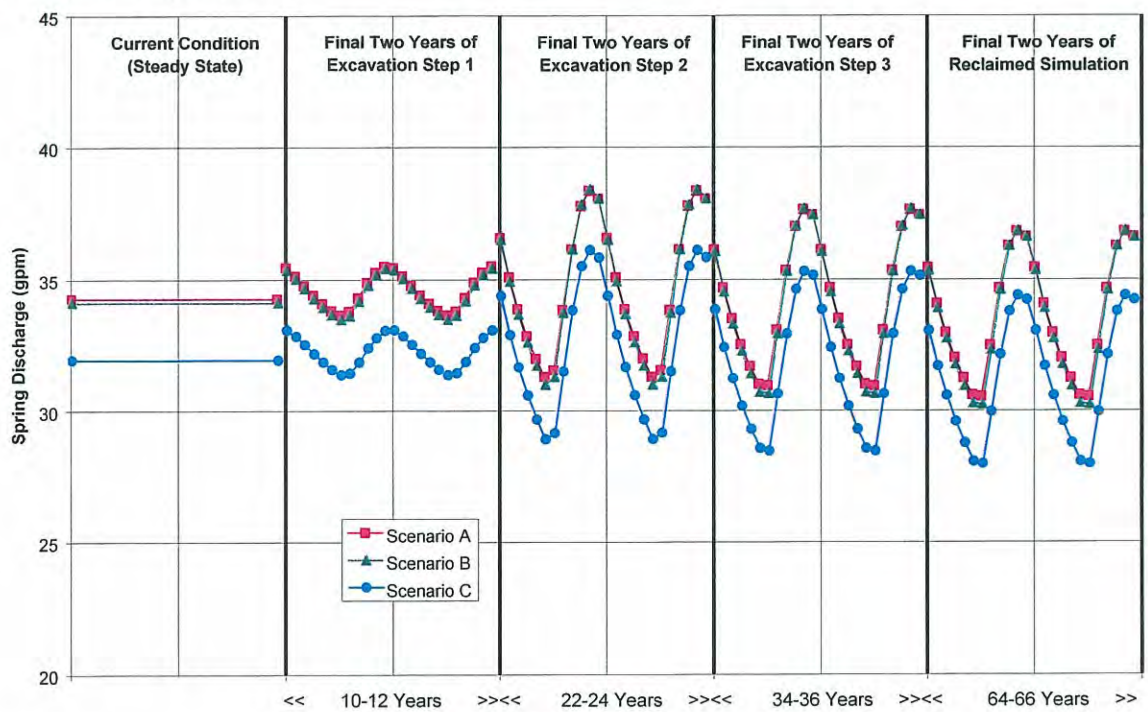
JK9908, New-Predict-SPRs.xls, 4/2000

Pacific Groundwater Group

C. Impacts at Ferguson Springs



D. Impacts at Spring E



NOTES:
Graphed model years begin on May 1.

Graphs present modeled impacts of changing recharge from steady-state throughout the model domain to seasonally varying (zero time lag) in the excavated portions of the mine site. The final two years of each excavation step are presented. All three steps were modeled for 12 years, and reclamation was modeled for 30

Figure 8-12
Predicted Impacts to Spring Discharge *(continued)*

Maury Island Gravel Mine
Hydrogeologic Impact Assessment

JK9908, New-Predict-SPRs.xls, 4/2000

Pacific Groundwater Group