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QUARRY INTERCEPTOR TRENCH FIELD STUDY - FIRST YEAR SUMMARY

WELDON SPRING SITE REMEDIAL ACTION PROJECT
WELDON SPRING, MISSOURI

AUGUST 2001 **REV. 0**

U.S. Department of Energy
Oak Ridge Operations Office
Weldon Spring Site Remedial Action Project

Prepared by MK-Ferguson Company and Jacobs Engineering Group

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Weldon Spring Site Remedial Action Project

Quarry Interceptor Trench Field Study - First Year Summary

Revision 0

August 2001

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U.S. DEPARTMENT OF ENERGY
Oak Ridge Operations Office
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ABSTRACT

The Quarry Residuals Operable Unit (QROU) is the second of two operable units established for the quarry area of the Weldon Spring site. The QROU addresses residual conditions at the quarry, primarily contaminated groundwater located north of the Femme Osage Slough. The selected action stipulates long-term monitoring of groundwater to ensure continued protection of human health and the environment. Institutional controls will be implemented to prevent groundwater usage inconsistent with recreational uses or uses that would adversely affect contaminant migration. Because of the presence of significant levels of uranium in the groundwater north of the slough, the effectiveness of efforts to reduce the levels of uranium in the groundwater in the quarry area continue to be conducted through field studies. Current available data support the conclusion that site contaminants will not measurably affect the aquifer of the Missouri River alluvium south of the slough. The conceptual model of uranium fate and transport establishes sorption and precipitation as the primary processes responsible for the notable decrease of uranium in groundwater north of the slough. This field study is being performed to support the evaluation presented in the *Feasibility Study* regarding the need for and effectiveness of groundwater remediation.

The objective of the quarry interceptor trench field study is to confirm the model for uranium removal from the shallow aquifer using actual field data. If the performance of the trench is less effective or not within the specified goals (≤ 10% of the mass of uranium is removed within the 2-year testing period), further evaluation of groundwater treatment will not be necessary. If the performance of the trench exceeds the specified goals (> 10% of the mass of uranium is removed within the 2-year testing period), the effectiveness of groundwater extraction will be reevaluated. This report summarizes the first year of sampling performed to monitor and evaluate the performance of the quarry interceptor trench system.

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1. INTRODUCTION

The Quarry Residuals Operable Unit (QROU) is the second of two operable units established for the quarry area of the Weldon Spring site. The QROU addresses residual conditions at the quarry, primarily contaminated groundwater north of the Femme Osage Slough. The *Record of Decision for Remedial Action for the Quarry Residuals Operable Unit at the Weldon Spring Site* (Ref. 1) was signed by the U.S. Environmental Protection Agency and the U.S. Department of Energy on September 30, 1998. This *Record of Decision* presents the selected remedial action for the QROU following the requirements of the *Comprehensive Environmental Restoration, Compensation, and Liabilities Act* (CERCLA). The selected action stipulates long-term monitoring of groundwater to ensure continued protection of human health and the environment. Institutional controls will be implemented to prevent groundwater usage inconsistent with recreational uses or uses that would adversely affect contaminant migration. Field studies are also being performed to collect data to verify the existing conceptual fate and transport model for the quarry area.

The present conceptual model is that sorption of uranium onto the aquifer matrix and organics and precipitation of dissolved uranium from groundwater is responsible for the notable decrease of uranium (from 3,000 pCi/l to less than 1 pCi/l) over a short distance (100 to 300 ft) north of the slough. The sharp decrease in uranium levels indicates that dispersion and dilution, which typically generate more diffuse boundaries, are not the only processes attenuating the uranium in groundwater.

Because the bulk wastes in the quarry proper have been removed, no additional contaminants are expected to be introduced to the groundwater system. However, because significant levels of uranium remain in the groundwater north of the slough, it was considered prudent to continue evaluating the effectiveness of the effort to reduce uranium levels. The available hydrological and geochemical information, as well as water quality data, support the conclusion that site contaminants will not measurably affect the aquifer in the Missouri River alluvium south of the slough. The following field studies will be conducted to support the action in the *Record of Decision* (Ref. 1):

- Studies to support evaluations in the *Feasibility Study* regarding the need for, and effectiveness of, groundwater remediation, which includes an interceptor trench.

- Field sampling to further characterize the conditions controlling the fate and transport of uranium in the shallow aquifer.

The objective of this quarry interceptor trench field study is to confirm the model for uranium removal from the shallow aquifer on the basis of field data. If the performance of the trench is less effective or within the specified performance goals (< 10% of the total mass of uranium is removed within the 2-year testing period), further evaluation of groundwater treatment will not be necessary. If the performance of the trench exceeds the specified goals

(> 10% of the mass of uranium removed within the 2-year testing period), the effectiveness of groundwater extraction will be reevaluated.

1.1 Purpose and Scope

This report summarizes the first year of sampling to monitor and evaluate the performance of the quarry interceptor trench system. Data presented include:

- The initial mass of uranium present at the start of the field study.
- The mass of uranium removed during the first year of the study.
- The volume of water extracted during the first year of the study.
- A summary of the analytical data for uranium and nitroaromatic compounds from the interceptor trench and monitoring wells sampled in support of the study.
- A summary of the geochemical data from the monitoring wells sampled in support of the study.
- Static water level data and potentiometric surfaces from the study area.
- Conclusions regarding the performance of the interceptor trench system during the first year of the study.
- Proposed changes to the study based on the results of the first year of operation.

1.2 Deviations from the Sampling Plan

Several deviations from the sampling approach (Ref. 2) were made during the field study. These changes included:

- Less frequent sampling of well MW-1047.
- More frequent sampling of the OW-series wells for on-site uranium analysis.
- Change in the laboratory method for sulfate analysis.

Monthly collection of samples for on-site analysis of uranium from MW-1047 was deleted from the sampling schedule due to the slow recharge of this bedrock well. This location has historically exhibited low uranium values, and evaluation of the water levels indicated that this location is not influenced by the extraction of groundwater by the interceptor trench.

Monitoring wells were scheduled for monthly sampling for on-site uranium analysis after the first 3 months of the field study. This frequency was increased to biweekly for the OW-series wells to better monitor the groundwater quality in close proximity to the interceptor trench.

Sulfate was initially analyzed on site using the Hach DR2000 analyzer. Starting in January 2001, sulfate samples were sent to off-site contract laboratories for analysis to obtain more reliable data.

2. URANIUM MASS DETERMINATION

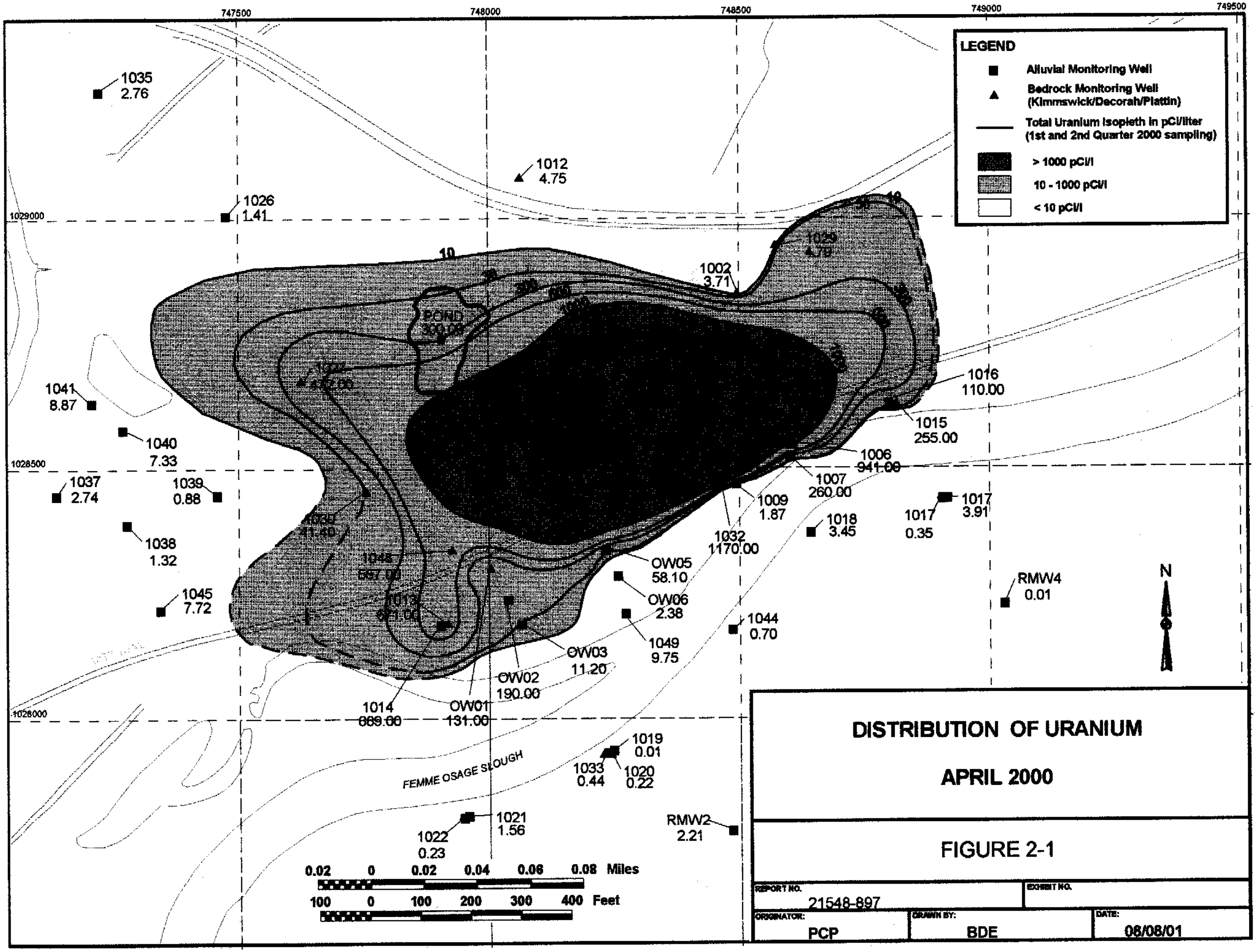
The objective of this field study is to confirm the predictive model for uranium removal from the shallow aquifer using actual field data. Performance will be based on the mass of uranium removed by trench compared to the mass of uranium present in the shallow aquifer south of the quarry. Modeling indicated that this extraction system had the potential to reduce the mass of uranium in groundwater north of the slough by no more than 10% over a two-year operating period (Ref. 3). Removal of 10% or less of the mass of uranium present would indicate that the analysis in the *Feasibility Study* correctly predicted the performance of this system in the quarry area and no further evaluation and/or treatment will be necessary. If the performance of the trench exceeds the specified goals (>10% of the mass of uranium removed within the 2-year testing period), the effectiveness of groundwater extraction will be reevaluated.

2.1 Initial Uranium Mass Determination

The mass of uranium used in the evaluation of Alternative 6 in the *Feasibility Study* (Ref. 3) was 1200 kg. Calculations were performed in the *Remedial Investigation* (Ref. 4) to determine if the uranium contamination in the alluvium north of the slough could have been precipitated or adsorbed from groundwater moving south from the quarry. The 1200-kg number represents an estimate of the mass of uranium that has moved in groundwater from the wastes in the quarry into the area of contaminated alluvium north of the slough (Ref. 4). This number was derived using an average concentration of uranium in a cross-section through the plume (2,829 pCi/l), volumetric flow of 7,500 gallons per day of impacted groundwater, and duration of 27 years.

During the development of the field study, it was determined that a more accurate method of estimating the mass of uranium could be developed using uranium levels measured prior to the start of the study. The mass of dissolved uranium could be determined by modeling the distribution of uranium in the groundwater using analytical data. The mass of uranium sorbed on the aquifer materials could be estimated using the uranium distribution in groundwater and equilibrium partitioning coefficients.

The uranium concentrations from January through April 2000 were modeled to determine the distribution of uranium in groundwater at the quarry area (Figure 2-1). The initial mass of uranium present prior to the field study is estimated to be 528 kg. The mass of uranium dissolved in the groundwater north of the Femme Osage slough is 158 kg and the mass of uranium sorbed onto the alluvial silts and clays and limestone bedrock is 370 kg. The estimation of the dissolved uranium mass in groundwater was done by multiplying the aquifer volume, effective porosity, and average concentration of uranium between adjacent mapped contours. The total mass of uranium sorbed to the aquifer material was estimated by multiplying the aquifer volume, the distribution coefficient for uranium, the dry bulk density of the aquifer material, and the average aqueous concentration between adjacent mapped contours. A more detailed approach for determining the mass is presented in Appendix A.



DISTRIBUTION OF URANIUM

APRIL 2000

FIGURE 2-1

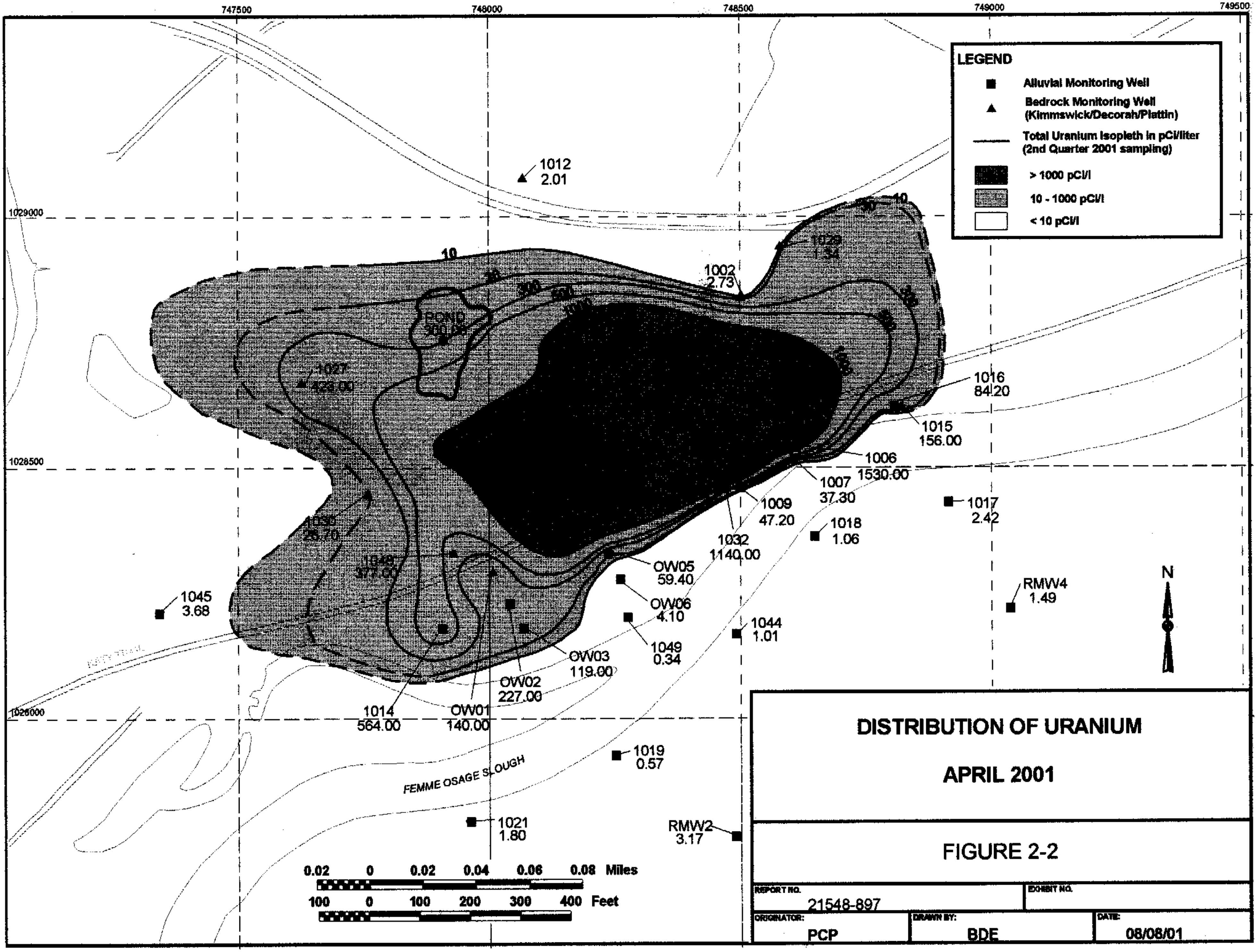
The uranium mass of 1200 kg did not account for the subsequent remediation of vicinity property 9 (VP9), which was located along the Femme Osage slough. A total of 4450 cubic yards of soil was removed from VP9 (Ref. 5). Using a weighted average concentration of 22.4 pCi/g (Ref. 4), the estimated mass of uranium removed by excavating contaminated soil was approximately 645 kg. The removal of uranium sorbed on the soil seems to account for the difference calculated using the 2000 data and that presented in the *Feasibility Study*.

Evaluation of these approaches indicates there is still some uncertainty associated with the amount of uranium sorbed and/or precipitated in the area of groundwater impact. A better understanding of the attenuation of uranium in the shallow aquifer north of the slough will be obtained after completion of the geochemical sampling to be performed later this year. At that time, this calculation may be revised to better reflect actual field conditions.

2.2 Uranium Mass Determination after Completion of Year 1

Another method of evaluating the efficiency of the trench system is periodic determination of the mass of uranium present in the groundwater during the field study. In order to reduce the uncertainties associated with determining the amount of uranium sorbed and/or precipitated on the aquifer materials, a comparison of the uranium dissolved in the groundwater could be made at different intervals during the study.

The mass of uranium present in the groundwater north of the slough after the first year of the field study was determined using data from samples collected in April 2001 (Figure 2-2). The mass of uranium dissolved in the groundwater north of the Femme Osage slough is 148 kg. This mass was calculated in the same manner as presented in Section 2.1.


747500
748000
748500
749000
749500
1029000
1028500
1028000
LEGEND
Alluvial Monitoring Well
Bedrock Monitoring Well
(Kimmswick/Decorah/Plattin)
Total Uranium Isopleth in pCi/liter
(2nd Quarter 2001 sampling)
> 1000 pCi/l
10 - 1000 pCi/l
< 10 pCi/l
1012
2.01
POND
1027
1002
2.73
1016
84.20
1015
156.00
1006
1530.00
1007
37.30
1009
47.20
1032
1140.00
1017
2.42
1018
1.06
OW05
59.40
OW06
4.10
1049
0.34
1044
1.01
RMW4
1.49
OW03
119.00
OW02
227.00
OW01
140.00
1014
564.00
1045
3.68
1019
0.57
1021
1.80
RMW2
3.17
FEMME OSAGE SLOUGH
N
0.02 0 0.02 0.04 0.06 0.08 Miles
100 0 100 200 300 400 Feet
DISTRIBUTION OF URANIUM
APRIL 2001
FIGURE 2-2
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21548-897
EXHIBIT NO.
ORIGINATOR:
PCP
DRAWN BY:
BDE
DATE:
08/08/01

3. OBSERVATION WELL INSTALLATION

Six observation wells were installed in support of this field study. Drilling began on March 31, 2000 and well development was completed on April 24, 2000. All work was performed in accordance with the *Sampling Plan for the QROU Interceptor Trench Field Study* (Ref.2). Well installation and development were performed under Work Package 487A.

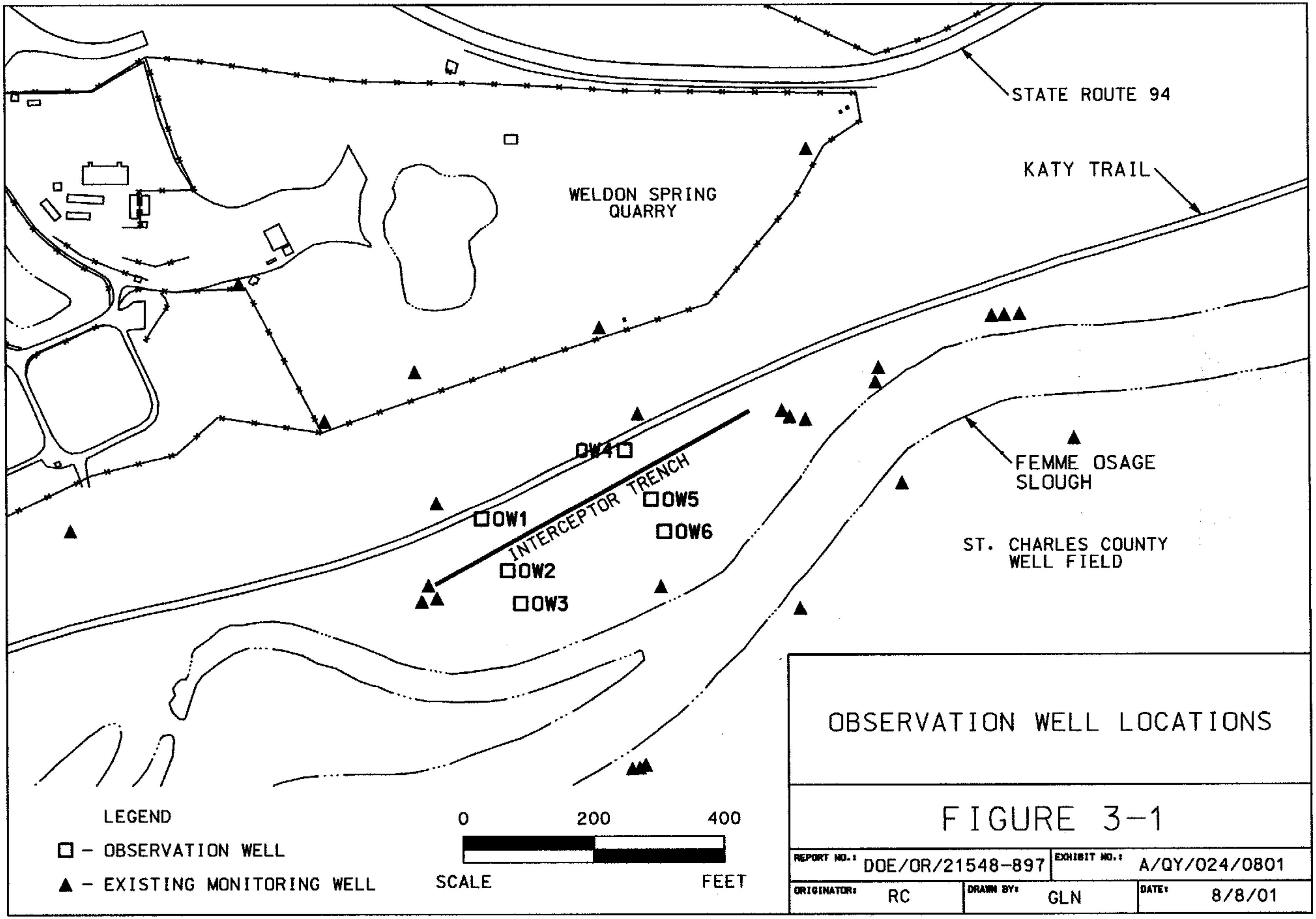
3.1 Drilling and Sampling

The observation wells were installed at the locations identified in the *Sampling Plan* (Figure 3-1). The locations were chosen to supplement the existing monitoring wells in close proximity to the quarry interceptor trench and were placed in two lines perpendicular to the trench to monitor water levels and groundwater quality both upgradient and downgradient of the trench. The locations of the lines were selected to assess the influence of groundwater extraction on uranium removal and groundwater flows from the differing aquifer materials (coarser grained and finer grained) that the trench intersects. The wells were screened at intervals to simulate the thickness of the aquifer that the interceptor trench influences.

All drilling and coring was performed using an all-terrain CME-750 drill rig. Hollow stem augers with an inside diameter (ID) of 4-1/4 inches and outside diameter (OD) of 7-1/4 inches were used to drill the alluvial wells. Larger augers with an ID of 6" and OD of 10" were used to drill the overburden material in the bedrock wells to allow a 6" roller bit to ream the bedrock through the augers and place the well. Soil samples were collected continuously using a split spoon sampler. Soils were described using the Unified Soil Classification System in accordance with procedure ES&H 4.4.7, *Soil, Rock Core, and Rock Chip Borehole Logging*

Core drilling was performed in the two bedrock monitoring wells, OW-1 and OW-4. Top of rock was determined by auger and/or sampler refusal. The rock core (NQ) was obtained by using wireline-drilling methods. Coring at each location was continued until the field geologist determined that the depth was sufficient to place the observation well. Following the coring, the bedrock portion of the hole was reamed using a 6-inch roller bit to allow installation of the observation well. Geologic logs for each location are included in Appendix B.

Geologic conditions were similar to those observed during previous hydrogeologic investigations. A distinct oxidation/reduction geochemical contact was observed in OW02, OW03, OW05, and OW06, located south of the trench. This contact was observed during the previous hydrogeological characterization activities performed in support of the interceptor trench construction (Ref. 6). This contact is indicated by a color change in the alluvial materials from browns to grays. The contact was not observed in OW01 and OW04, located north of the interceptor trench. Organic material was common in all of the borings and was found in all soil types. The organic material was commonly replaced with iron oxides (limonite and hematite) in the oxidized zone and was either unaltered or coalified in the reduced zone.



OBSERVATION WELL LOCATIONS

FIGURE 3-1

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ORIGINATOR:	RC	DRAWN BY:	GLN	DATE:	8/8/01

A very high plastic clay unit was logged in OW02, OW03, OW05, and OW06. This unit was also observed during the previous hydrogeological characterization activities performed in support of the interceptor trench construction (Ref. 6). This unit is the most distinct and correlatable unit observed in the area north of the slough. It is relatively continuous across the area, although its thickness varies considerably. The unit was not observed in OW01 and OW04, located north of the interceptor trench.

3.2 Packer Testing

Packer testing was performed in the bedrock interval at locations OW01 and OW04 to measure the hydraulic conductivity in the upper portion of the bedrock (Decorah Group). One packer test was performed at each location at depths representing the screened interval. A single packer assembly was used for this testing. Four individual tests ranging from 6 to 10 minutes in duration were performed at various water pressures.

The results from these two locations are consistent with earlier packer tests in the Decorah Group. The results from the testing are provided in Table 3-1

Table 3-1 Summary of Packer Testing Results

Well ID	Test Interval	Test Number	Test Pressure (psi)	K (cm/s)	Average K (cm/s)
OW01	18.0 – 25.0	1	5	9.3×10^{-5}	1.3×10^{-4}
		2	10	1.2×10^{-4}	
		3	15	1.6×10^{-4}	
		4	5	1.4×10^{-4}	
OW04	16.2 – 24.0	1	5	5.9×10^{-5}	2.8×10^{-4}
		2	10	2.7×10^{-4}	
		3	15	3.8×10^{-4}	
		4	5	4.2×10^{-4}	

3.3 Well Installation and Development

Wells were constructed using 2-inch PVC (Schedule 40) casings and screens (0.010-in. slot) with 20/40 silica sand filter packs. Table 3-2 summarizes the survey coordinates and construction details for the observation wells. Well completion diagrams for the six observation wells are included in Appendix B.

Table 3-2 Observation Well Construction Details

Well ID	Coordinates		Elevation		Screened Interval	Total Depth
	Northing	Easting	Ground	Top of Casing		
OW01	1028307.37	748007.25	464.11	467.56	14.2	25.4
OW02	1028243.04	748041.64	457.59	461.46	9.0	24.3
OW03	1028193.88	748068.50	456.08	459.48	9.6	20.0
OW04	1028409.51	748192.40	462.79	466.34	13.7	24.9
OW05	1028341.32	748236.02	454.67	458.36	5.7	21.0
OW06	1028290.91	748260.61	454.74	458.45	9.7	20.0

Following a minimum of 24 hours after well completion, all wells were developed using a pump and surge technique combined with over-pumping. Development was accomplished by initially surging the well with a PVC surge block to break down skin effects on the borehole caused by the drilling process. After completion of surging, the well was pumped using a peristaltic pump to remove sediment-laden groundwater. Physical parameters such as temperature, conductivity, and pH were measured after each well volume until all were stable and turbidity-free water was noted.

4. FIELD STUDY RESULTS

Operation of the interceptor trench started on April 27, 2000. Sampling of the trench and nearby monitoring wells has been performed as outlined in the *Sampling Plan for the QROU Interceptor Trench Field Study* (Ref. 2). The following is a summary of the first year of the study, April 27, 2000 through April 30, 2001.

4.1 Interceptor Trench Monitoring Results

As of April 30, 2001, a total of 407,644 gal of water was pumped from the interceptor trench. A summary of the production from each sump is provided in Table 4-1. A graph of the daily volume extracted by the trench and the cumulative volume is provided in Figure 4-1.

Table 4-1 Quarry Interceptor Trench Production Summary

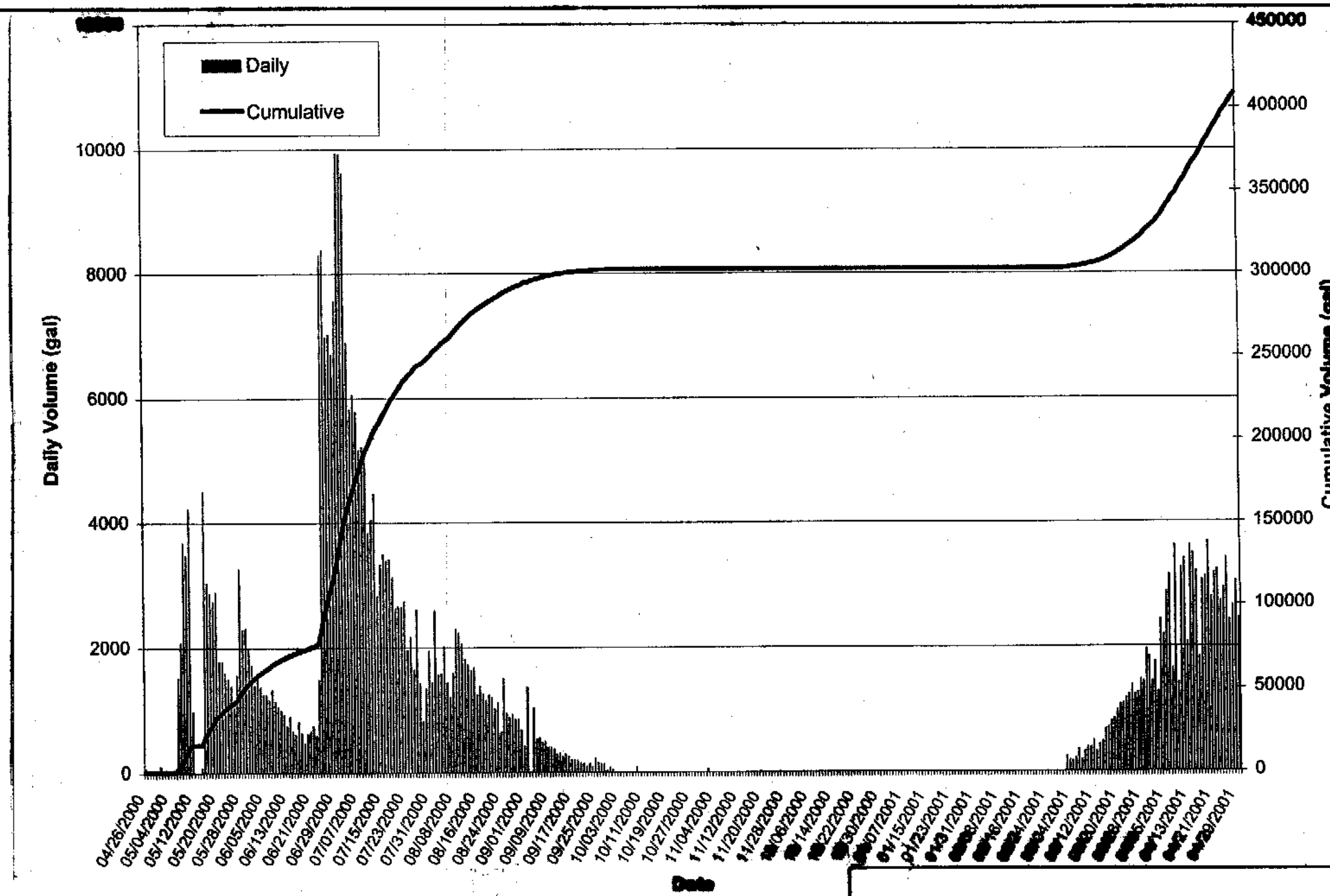
Sump	Production (gal)	Days of Operation
3004	220	1
3104	36,882	24
3204	25,532	18
3304	345,010	228
Total	407,644	228

Samples were collected from the operating pumps on a daily basis for on-site analysis of uranium and weekly for off-site analysis of uranium and nitroaromatic compounds. Analytical data for the trench are summarized in Tables 4-2 and 4-3.

Table 4-2 Summary of Uranium Data[(a)] from the Interceptor Trench

Sump	Uranium (pCi/l)		
	Average	Maximum	Minimum
3004	—	1309	—
3104	2768	3100	1690
3204	2268	2920	1889
3304	1227	5173	45.5

(a) Unfiltered data



QUARRY INTERCEPTOR TRENCH
VOLUME REMOVED
THROUGH 4/30/01

FIGURE 4-1

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ORIGINATOR:	RC	DRAWN BY:	GLN	DATE:	8/8/01

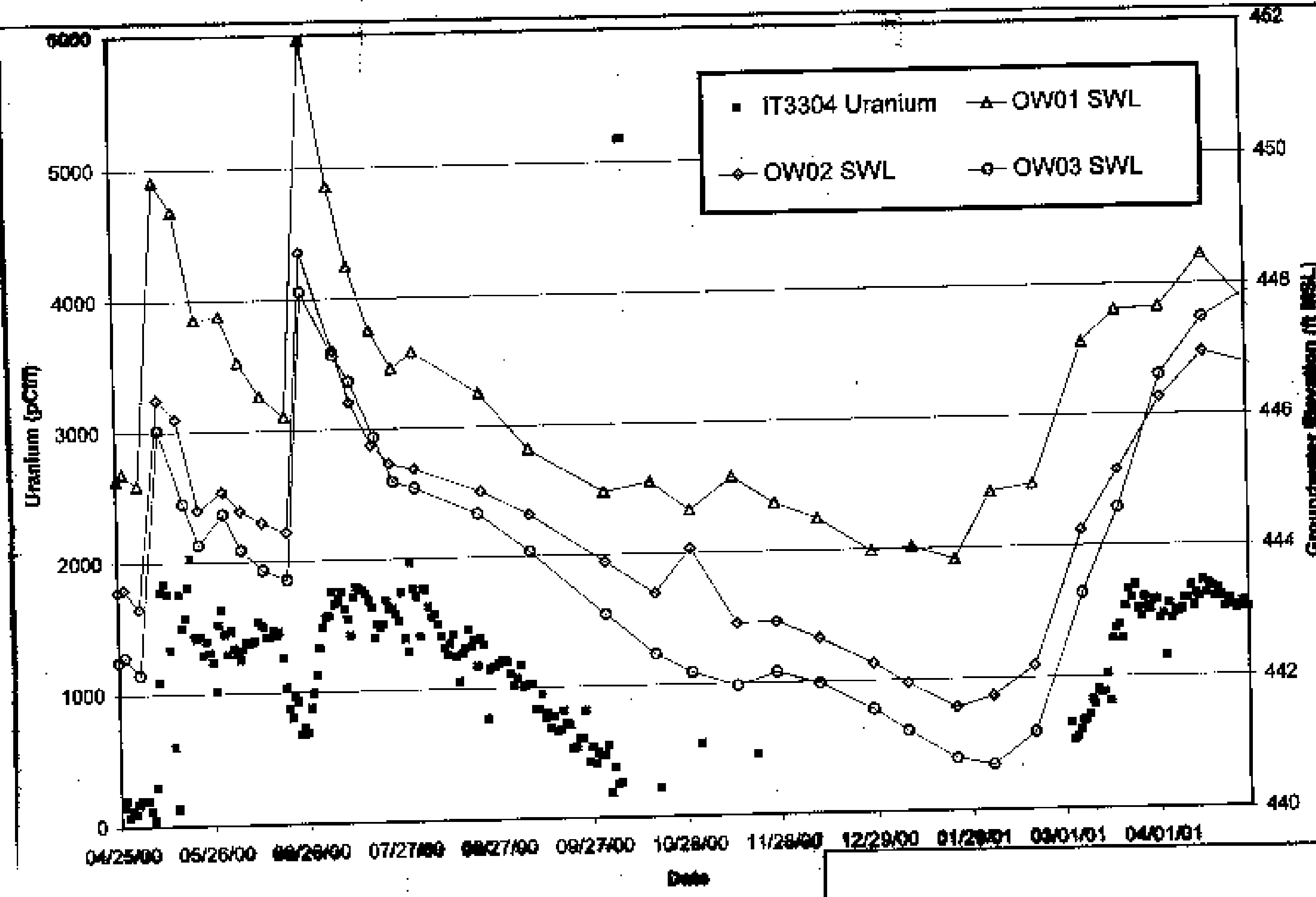
Table 4-3 Summary of Nitroaromatic Compound Data from the Interceptor Trench

Nitroaromatic Compounds		Sump			
		3004	3104	3204	3304
1,3,5-TNB	#Detects/# Samples	0	2 / 4	1 / 3	11 / 23
	Average (µg/l)	NS [a]	7.6	1.30	0.36
	Maximum (µg/l)	NS	12.0	—	2.7
	Minimum (µg/l)	NS	3.2	—	< 0.03
1,3-DNB	#Detects/# Samples	0	2 / 4	1 / 3	2 / 23
	Average (µg/l)	NS	0.85	0.47	0.06
	Maximum (µg/l)	NS	1.60	—	0.42
	Minimum (µg/l)	NS	0.095	—	< 0.09
2,4,6-TNT	#Detects/# Samples	0	2 / 4	1 / 3	13 / 23
	Average (µg/l)	NS	1.66	0.28	0.13
	Maximum (µg/l)	NS	2.70	—	0.48
	Minimum (µg/l)	NS	0.62	—	< 0.03
2,4-DNT	#Detects/# Samples	0	2 / 4	1 / 3	15 / 23
	Average (µg/l)	NS	0.30	ND (< 0.2)	0.10
	Maximum (µg/l)	NS	0.55	—	0.25
	Minimum (µg/l)	NS	0.053	—	< 0.03
2,6-DNT	#Detects/# Samples	0	2 / 4	1 / 3	15 / 23
	Average (µg/l)	NS	0.40	ND (< 0.2)	0.17
	Maximum (µg/l)	NS	0.64	—	0.55
	Minimum (µg/l)	NS	0.15	—	< 0.01

(a) NS – not sampled

Uranium concentrations in water extracted from the interceptor trench were within the typical ranges for the area north of the slough as determined from nearby monitoring wells. Comparison of the concentrations of uranium to the groundwater elevation in the OW-series wells indicates that the uranium is relatively dependent on the groundwater elevation (Figure 4-2). Increasing and decreasing trends in the uranium concentrations from sump 3304 follow trends in the water level in the area north of the slough. Only data from this sump was evaluated since the other three sumps have limited data.

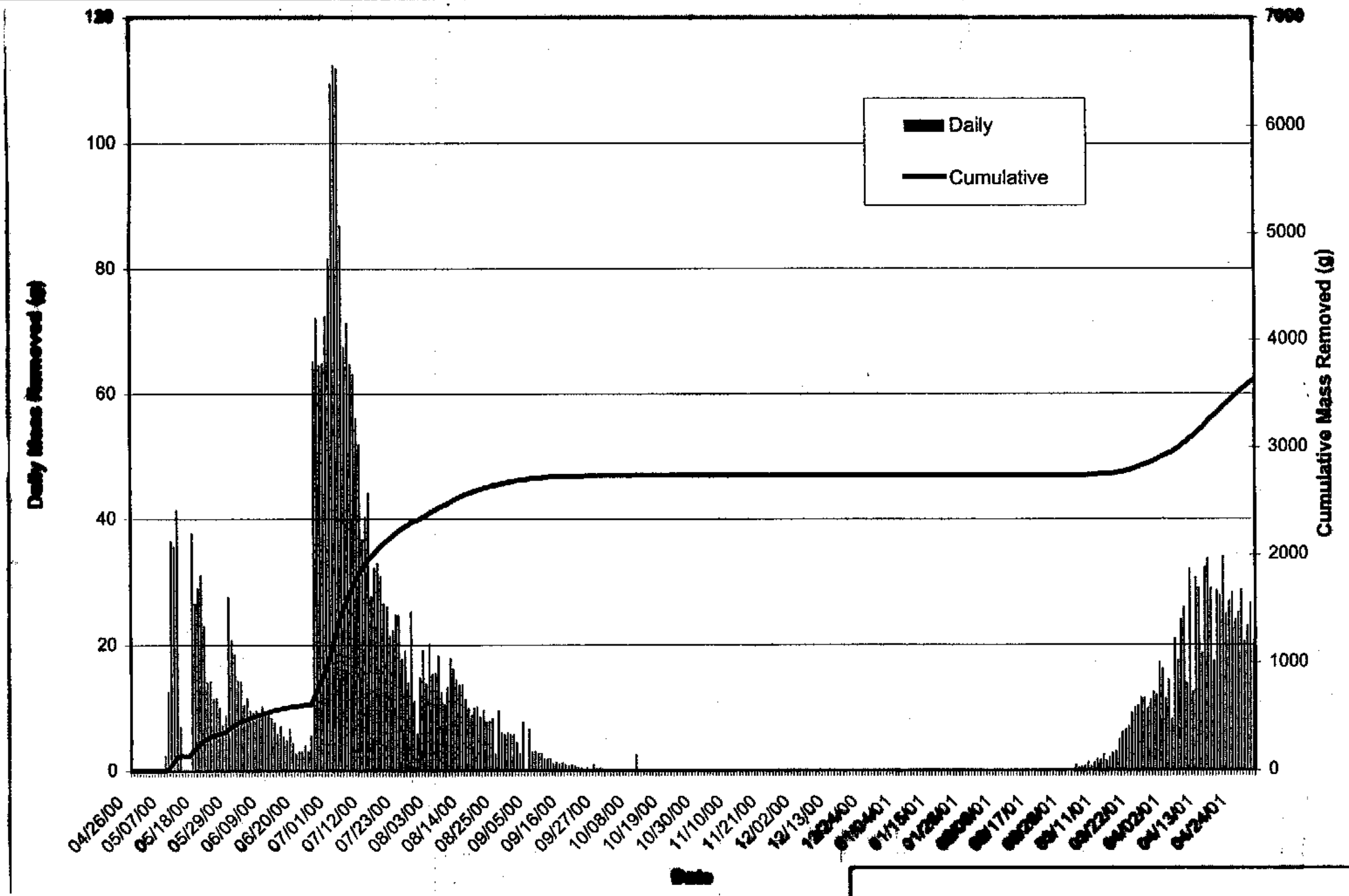
The total mass of uranium removed from the shallow aquifer during the first year is 3.6 kg. A summary of the mass removed in each sump is provided in Table 4-4. A graph of the mass removed each day and the cumulative mass removed is provided in Figure 4-3.



URANIUM CONCENTRATIONS
IN SUMP 3304

FIGURE 4-2

REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/P1/039/0801
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01



QUARRY INTERCEPTOR TRENCH
MASS OF URANIUM REMOVED
THROUGH 4/30/01

FIGURE 4-3

REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/PI/029/0601	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01	

Table 4-4 Quarry Interceptor Trench Uranium Mass Removal Summary

Sump	Mass (g) Removed to Date
3004	1.4
3104	558
3204	245
3304	2,824
Total	3,628

4.2 Groundwater Quality Monitoring Results

Nearby monitoring wells were sampled weekly for the first three months of the field study for uranium, nitroaromatic compounds, and geochemical parameters. After the first three months, the six OW-series monitoring wells were sampled biweekly for on-site analysis of uranium and monthly for off-site analysis of uranium, nitroaromatic compounds, and geochemical parameters. The remainder of the nearby monitoring wells were on the monthly sampling frequency. Summaries of the data are provided in Tables 4-5 and 4-6.

Table 4-5 Summary of Uranium Data for Monitoring Wells

Location	Uranium (pCi/l)		
	Average	Maximum	Minimum
OW01	196	255	91
OW02	207	511	45
OW03	531	1300	17
OW04	2220	2740	1490
OW05	57	1040	0.77
OW06	135	630	0.75
1008	2470	4490	960
1009	5.7	75	0.21
1013	556	718	449
1014	628	812	371
1031	43	61	27
1032	1190	1520	982
1047	4.6	35	(0.27)
1048	466	672	385
1049	1.6	12	(0.03)

( ) denotes estimated value

Table 4-6 Summary of Nitroaromatic Compound (µg/l) Data for Monitoring Wells

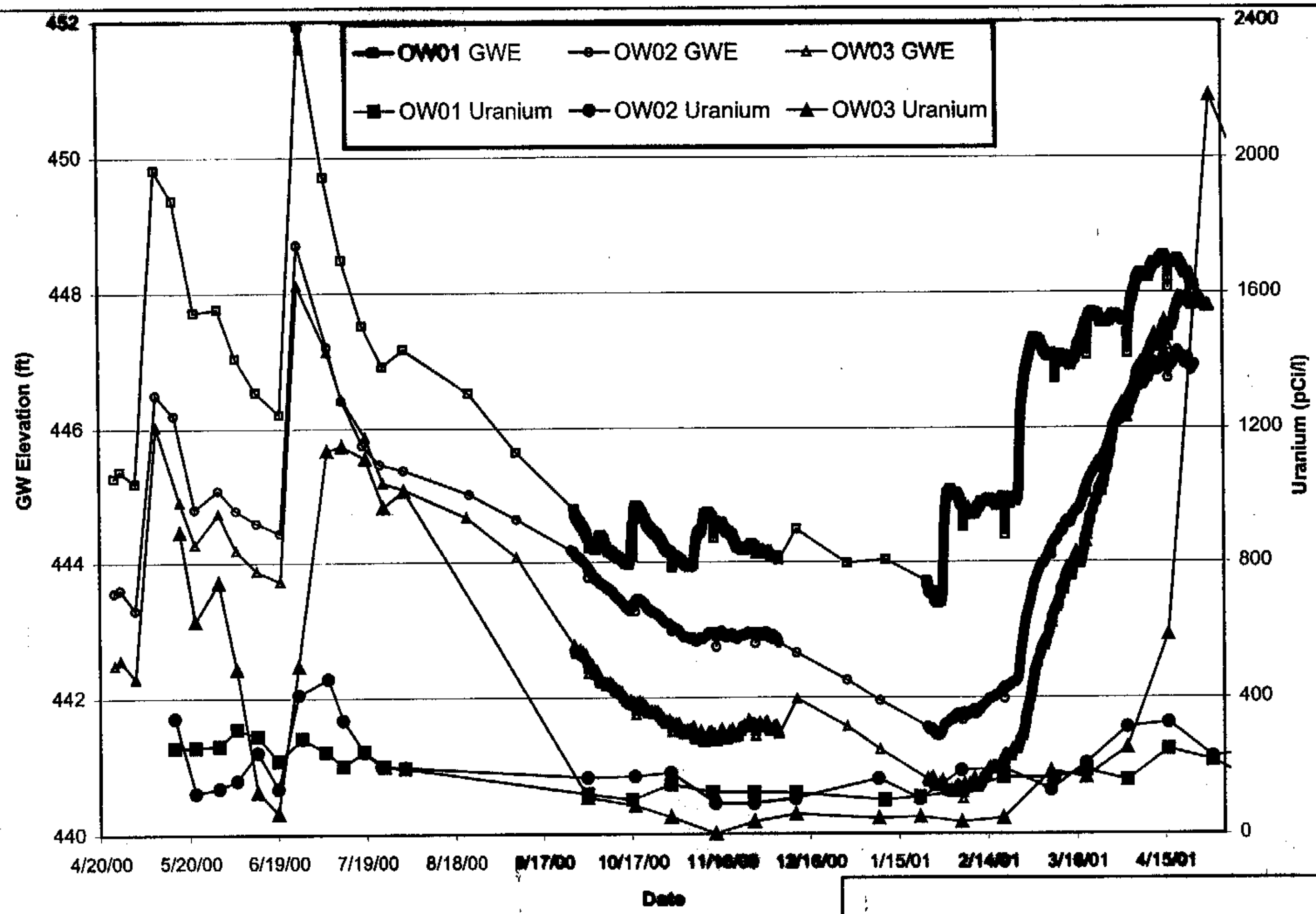
Location		1,3,5-TNB	1,3-DNB	2,4,6-TNT	2,4-DNT	2,6-DNT
OW01	# Detects/# Samples	0 / 6	0 / 6	1 / 6	1 / 6	0 / 6
	Average	---	---	---	---	---
	Maximum	---	---	0.052	0.053	---
	Minimum	---	---	---	---	---
OW02	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
OW03	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
OW04	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
OW05	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
OW06	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	0 / 6
1008	# Detects/# Samples	0 / 6	0 / 6	0 / 6	0 / 6	1 / 6
	Average	---	---	---	---	---
	Maximum	---	---	---	---	(0.0024)
	Minimum	---	---	---	---	---
1009	# Detects/# Samples	0 / 7	0 / 7	0 / 7	0 / 7	0 / 7
1013	# Detects/# Samples	0 / 7	0 / 7	0 / 7	1 / 7	0 / 7
	Average	---	---	---	---	---
	Maximum	---	---	---	0.052	---
	Minimum	---	---	---	---	---
1014	# Detects/# Samples	0 / 7	0 / 7	0 / 7	0 / 7	0 / 7
1031	# Detects/# Samples	0 / 1	0 / 1	0 / 1	0 / 1	0 / 1
1032	# Detects/# Samples	0 / 7	0 / 7	0 / 7	2 / 7	0 / 7
	Average	---	---	---	0.03	---
	Maximum	---	---	---	0.09	---
	Minimum	---	---	---	< 0.03	---
1047	# Detects/# Samples	0 / 4	0 / 4	0 / 4	0 / 4	0 / 4
1048	# Detects/# Samples	0 / 7	0 / 7	0 / 7	0 / 7	0 / 7
1049	# Detects/# Samples	0 / 7	0 / 7	0 / 7	0 / 7	0 / 7

Uranium concentrations in the monitoring wells were within typical ranges. Comparison of the concentrations of uranium to the groundwater elevation in the OW-series wells indicates that uranium is to some extent dependent on the groundwater elevation (Figures 4-4 and 4-5). This is best illustrated in wells OW03 and OW06. When the groundwater elevation is above elevation 445 ft, the uranium levels show significant increases. These increases were not as noteworthy in the remainder of the OW-series wells.

4.3 Geochemical Monitoring Results

Continuous measurement of field parameters was initiated in September of 2000 in the 6 OW-series monitoring wells. Pressure, temperature, dissolved oxygen, and oxidation-reduction potential are measured every 30 minutes. A data gap is present from December 12, 2000 through January 24, 2001 due to difficulty in calibration of the transducers. Graphs of the dissolved oxygen and oxidation-reduction potential are provided in Appendix C.

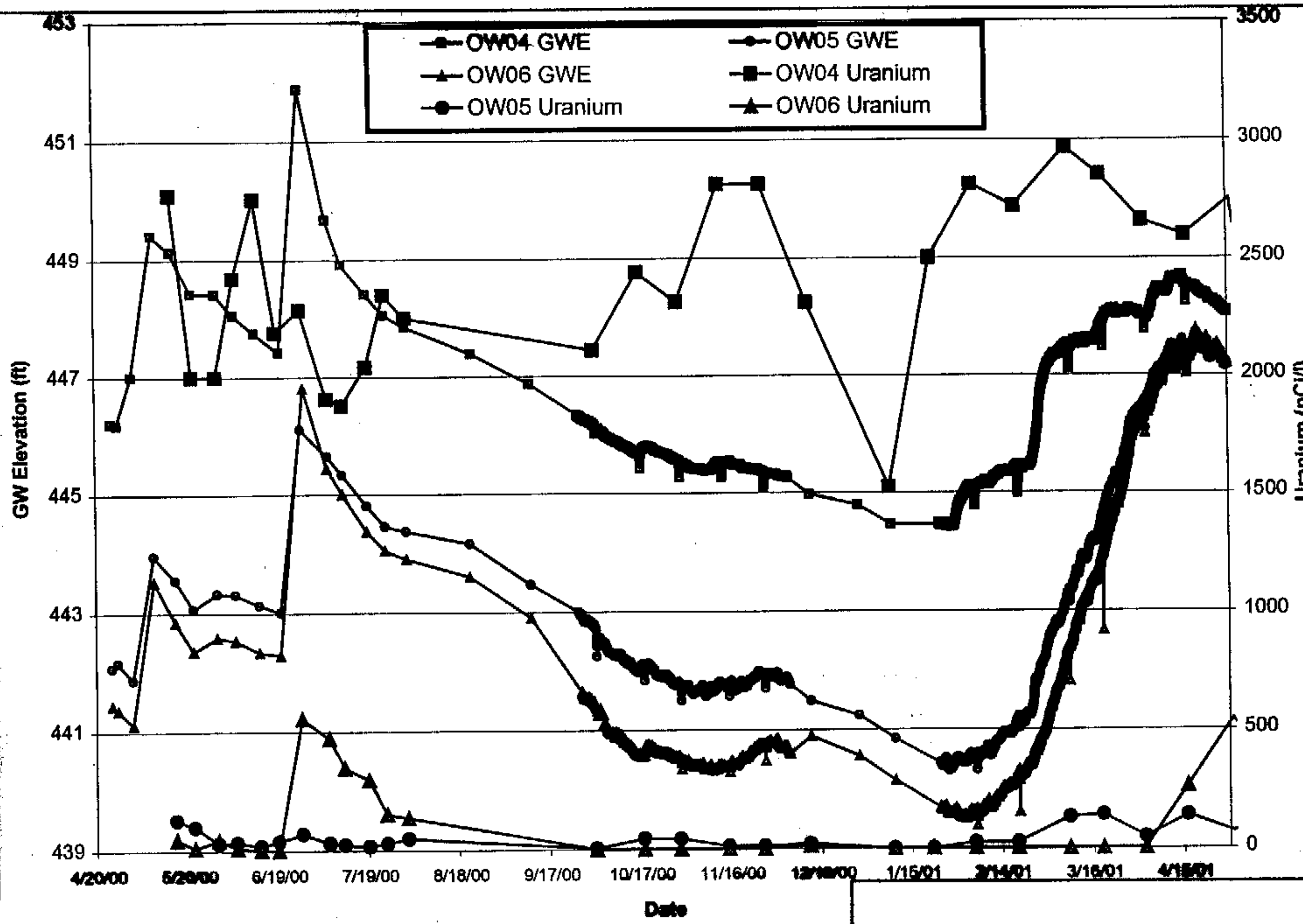
In general, the oxidation-potential measurements in the 6 wells range from –0.3 to –0.5 volts. The Eh measured with a platinum electrode can be used qualitatively to evaluate the



URANIUM CONCENTRATIONS IN OW01, OW02, AND OW03

FIGURE 4-4

REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/PI/040/0801
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01



URANIUM CONCENTRATIONS IN OW04, OW05, AND OW06

FIGURE 4-5

REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/PI/041/0801
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01

groundwater system but cannot be related to a specific redox pair (Ref. 7). The pH, as determined from measurements taken at sampling events, averages at 7.0. This would classify the water in the vicinity of the interceptor trench as neutral to reducing and slightly basic (Ref. 8). The dissolved oxygen content is highest (>10 mg/l) in OW01 and OW04. Wells OW02 and OW03 indicate levels at or below 1 mg/l. Wells OW05 and OW06 indicate variable results ranging from 0 to 10 mg/l. The Eh of the groundwater should be higher in the presence of dissolved oxygen.

Groundwater collected from wells in close proximity to the trench (OW01 through OW06, 1008, 1009, 1013, 1014, 1031, 1032, 1047, 1048, and 1049) were sampled for the following geochemical parameters: sulfate, sulfide, ferrous iron (Fe^{2+}), and total dissolved iron. Geochemical samples were collected monthly during the first 3 months of operations and then quarterly for the remainder of the study. Summaries of the data are provided in Tables 4-7 and 4-8.

Table 4-7 Average Total Dissolved Iron and Ferrous Iron Data

Location	Total Dissolved Iron (µg/l)	Ferrous Iron (µg/l)
OW01	1469	310
OW02	12151	2430
OW03	3841	1917
OW04	58.4	48.6
OW05	25163	3304
OW06	37584	3040
1008	55.0	31.3
1009	16150	2570
1013	3013	2552
1014	1839	1350
1031	139	ND
1032	308	142
1047	729	50
1048	588	498
1049	29840	3177

A preliminary evaluation of the geochemical data indicates a large variation in iron concentrations in the shallow aquifer north of the slough. The lowest total iron concentrations are observed in OW04, 1008, 1031, 1032, 1027, and 1048. All of the locations are shallow bedrock wells with the exception of 1008. The highest total iron concentrations are observed in OW02, OW05, OW06, 1009, and 1049. Assuming that the only components to total dissolved iron are ferrous (Fe^{2+}) and ferric (Fe^{3+}), ferric iron is the predominant cation in wells OW02, OW03, OW05, OW06, 1009, and 1049. Ferrous iron is the predominant cation in wells OW04, 1008, 1013, 1014, and 1048.

Table 4-8 Average Sulfate and Sulfide Data

Location	Sulfate (mg/l)	Sulfide (µg/l)
OW01	88.1	1.4
OW02	57.6	7.6
OW03	33.8	12.8
OW04	162	2.0
OW05	5.1	11.8
OW06	0.4	5.0
1008	82.1	3.3
1009	35.0	19.6
1013	88.0	7.8
1014	104	6.8
1031	38.6	ND
1032	144	36.0
1047	114	63.7
1048	73.6	11.1
1049	12.4	18.8

Sulfate data indicates variations in its distribution in the shallow aquifer, although not as dramatic as that of iron. The highest sulfate concentrations are observed in OW04, 1014, 1032, and 1047. The lowest sulfate concentrations are observed in OW05, OW06, and 1049. Sulfide is observed at negligible levels compared to sulfate.

The iron and sulfate data collected during the field study compared to historical data show similar concentrations in the area north of the slough. This indicates that the operation of the trench during this field study has not altered geochemistry of the shallow aquifer north of the slough.

In oxygenated waters, it would be expected that dissolved iron concentrations should be low under neutral and alkaline conditions, which are similar to those in the quarry area. Over the normal pH ranges for natural waters (5 to 9), as redox conditions become reducing, iron concentrations increase (Ref 7). The following sequence would be expected as oxygenated groundwater flows through an aquifer containing organic matter, similar to the aquifer in the area north of the slough. Initial iron concentrations will be low and then increase progressively until the onset of sulfate reduction. Iron concentrations should drop to a low value. If all sulfate is consumed making iron sulfides, the iron concentrations will again increase to a value corresponding to equilibrium with $FeCO_3$ (Ref. 7). The conversion of iron oxides to sulfides generally causes a color change from red or brown to black or gray, which has been observed in soils from the area north of the slough (Ref. 7)

If reduced species of iron (ferrous) and sulfur (sulfide) are present, they could reduce uranium from U (6+) to U (4+) and precipitate. This reduction could occur by oxidation of ferrous iron (2+) to ferric iron (3+) or HS^- to $SO4^{2-}$. Because sulfur and iron are common in groundwater systems, under reducing conditions it would be expected that uranium would precipitate to an insoluble form (UO_2) and be removed from solution (Ref. 8). The attenuation of uranium by precipitation and adsorption will be better evaluated during the geochemical studies to be performed later this year.

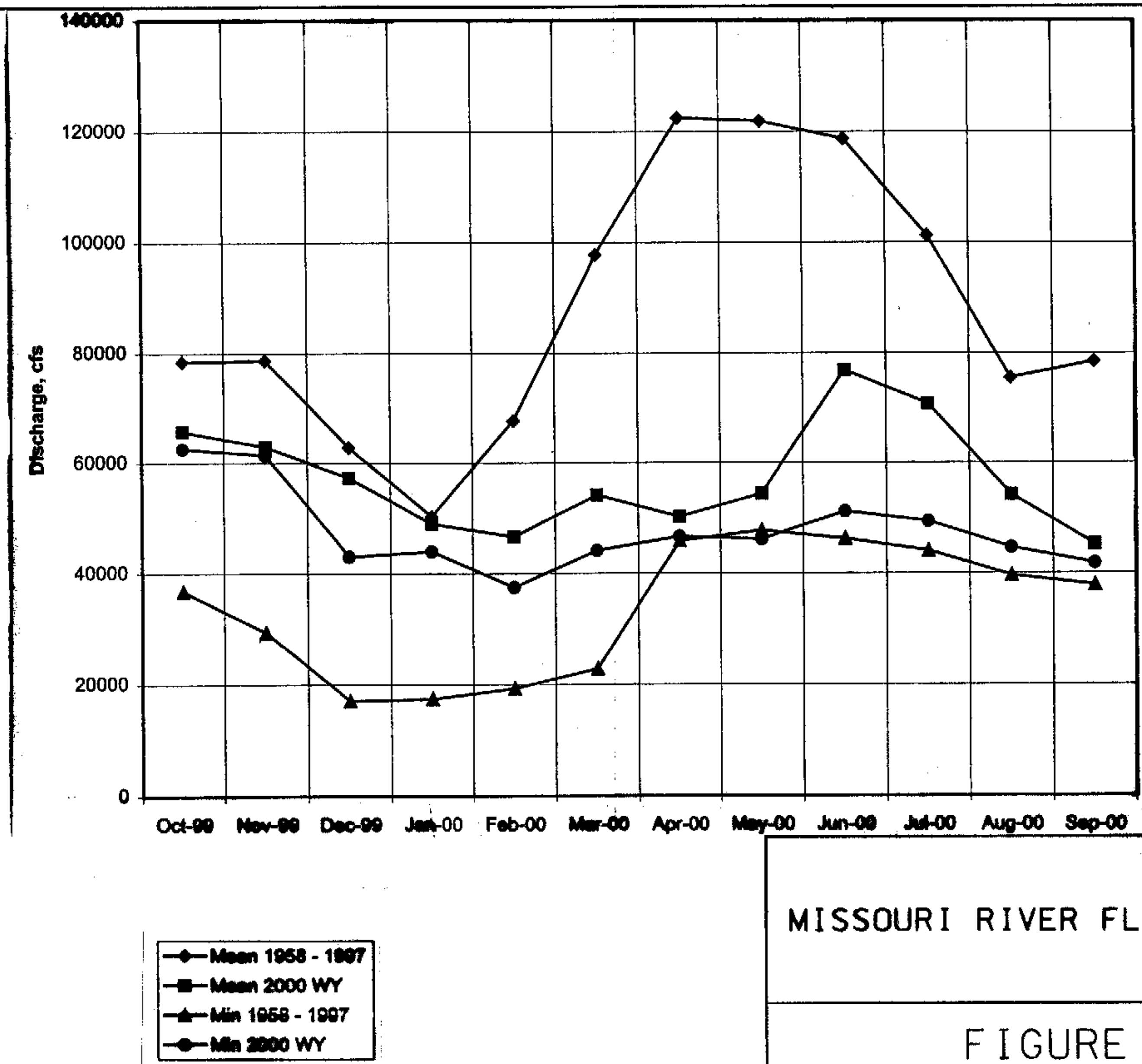
4.4 Water Level Monitoring Results

Static water level measurements have been collected on a biweekly basis from the nearby monitoring wells. Continuous measurement of water level measurements was initiated in September of 2000 in the 6 OW-series monitoring wells. Static water levels have been low during the first year of field study. An evaluation of the flow conditions in the Missouri River, which has a large influence on the water levels in the alluvial aquifer, indicates flow was below normal conditions during 2000 (Ref. 9). The mean and minimum monthly flows for 2000 were compared to the historical (1958 to 1999) mean and minimum monthly flows to evaluated the flow conditions in the Missouri River. The Hermann, Missouri river gage, located upgradient of the quarry, was used for this comparison. The comparison indicates that the mean flow was significantly below that of the historical data starting in January 2000 (Figure 4-6). For the months of April and May, the minimum flows were approximately equal to the historical minimums. Minimum flows for June through September were slightly greater than the historical minimum.

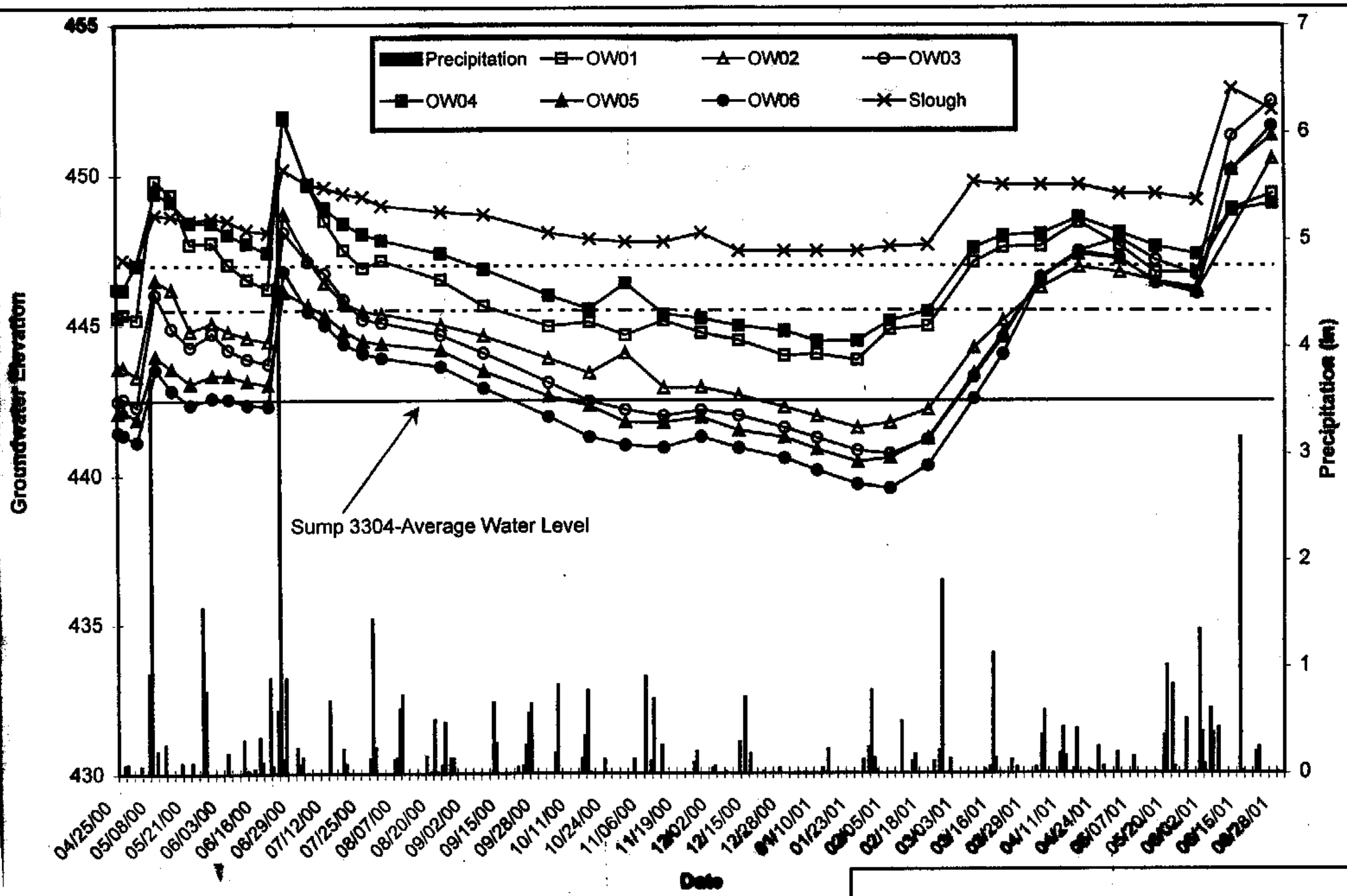
A graph of the static water levels during this period is provided in Figure 4-7. The water levels in the area north of the slough for the most part do not correlate to the precipitation events. However, early in the study two large increases in the static water levels are a result of large precipitation events.

A baseline groundwater surface was mapped using data collected in April, prior to the start of the field study (Figure 4-8). Groundwater flow direction is to the south and southeast through the study area. At the slough, the direction of groundwater flow has an increasing eastward component due to the influence of the Missouri River.

Mapping of the groundwater elevations in the study area indicates that when the trench is operational, flow centers on the western end of the interceptor trench, which is the lowest end of the trench (Figures 4-9 through 4-11). The centering of flow around the western end of the trench is attributed to several factors. The western sump (3304) has operated the most during the study. This is because it is in the lowest portion of the trench and when operating creates a steep drawdown within the granular materials in the trench (Figure 4-12). The consequence is that the water levels for the remainder of the trench are consistently below the level to trigger operation.



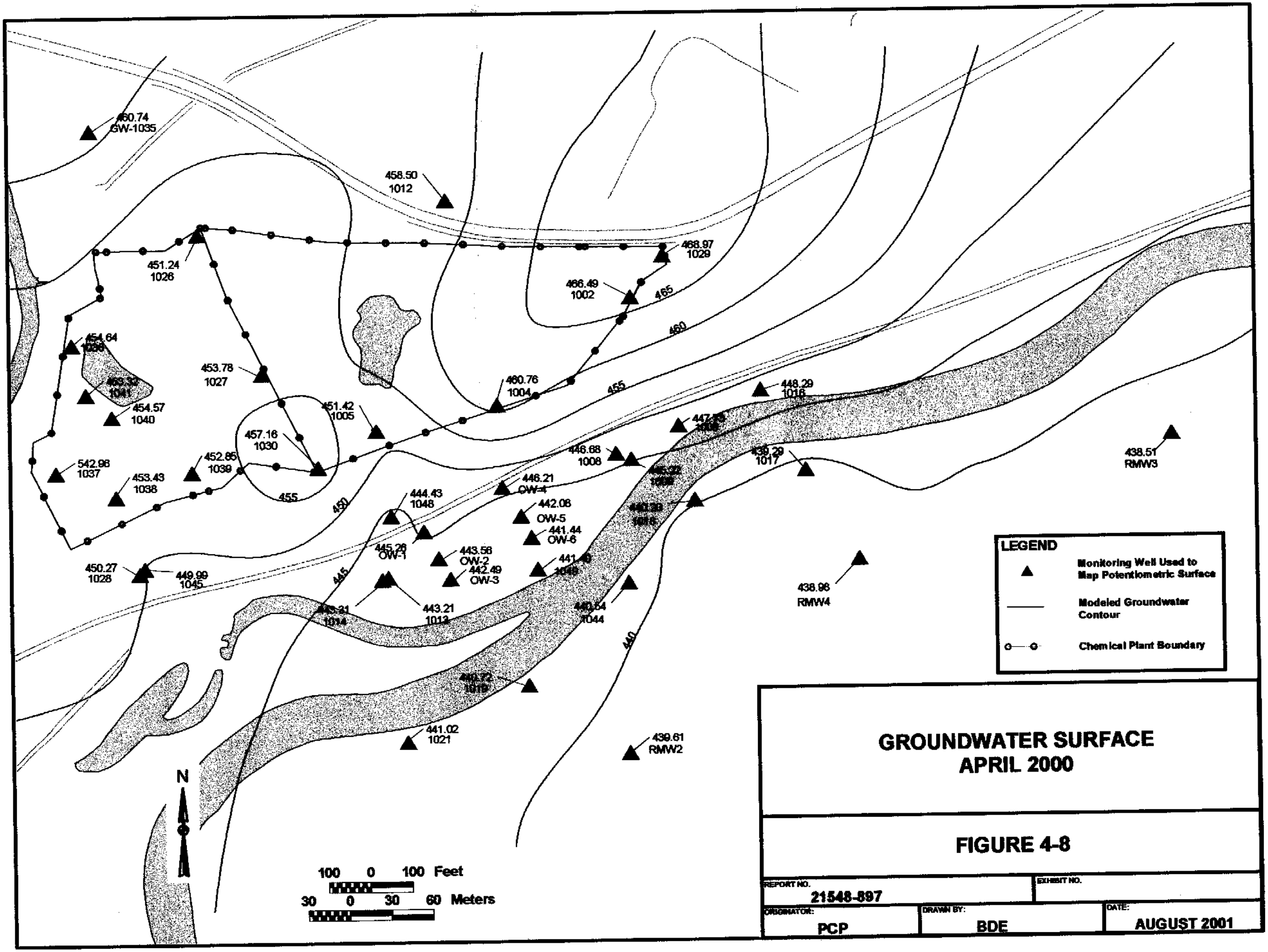
MISSOURI RIVER FLOW EVALUATION			
FIGURE 4-6			
REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/PI/042/0801	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01	

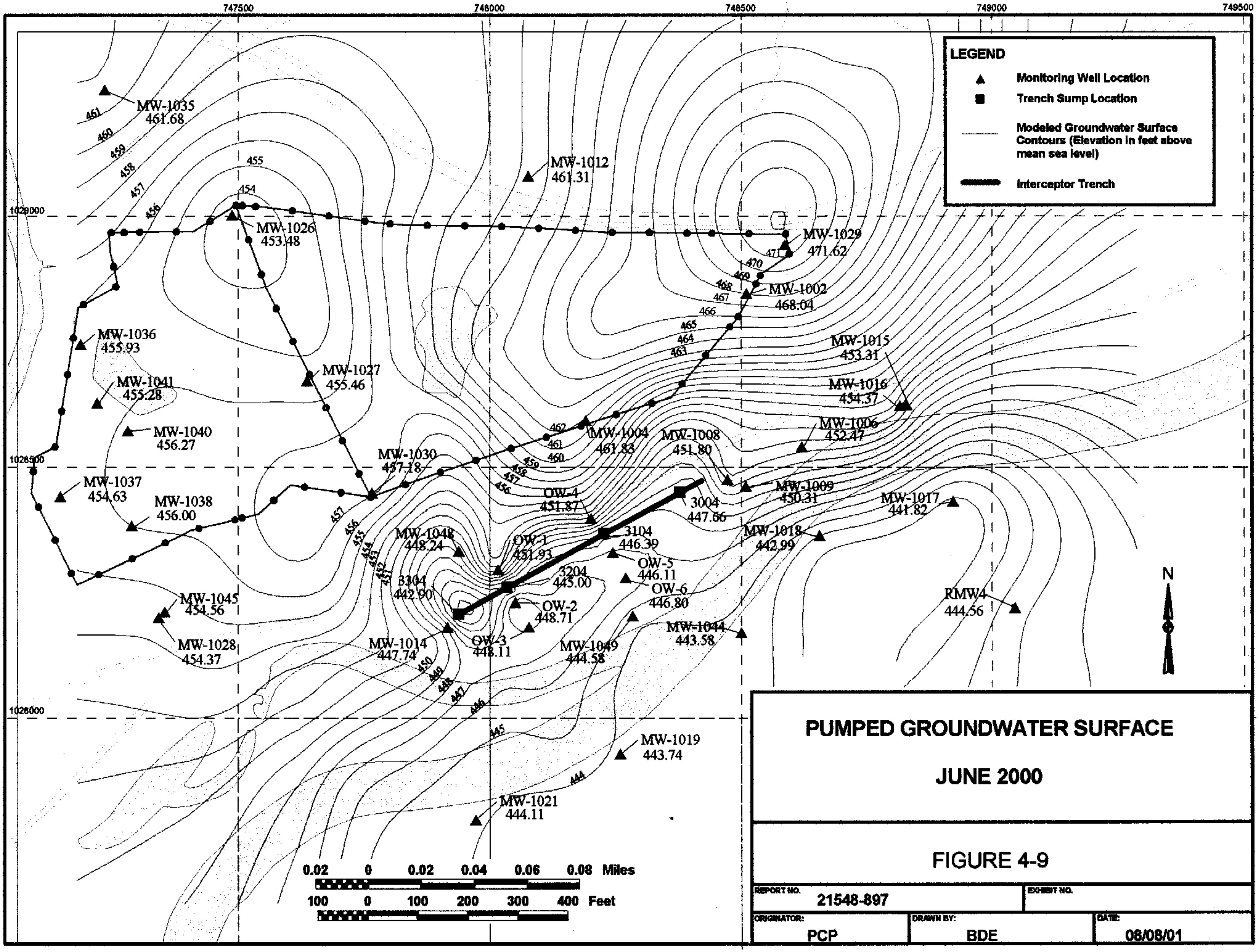


STATIC WATER LEVEL COMPARISONS FOR THE OW SERIES WELLS

FIGURE 4-7

REPORT NO.: DOE/OR/21548-897		EXHIBIT NO.: A/PI/043/0801	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 8/8/01	


460.74
GW-1035
458.50
1012
468.97
1029
466.49
1002
451.24
1026
454.64
1039
454.57
1040
453.78
1027
451.42
1005
457.16
1030
460.76
1004
448.29
1016
542.96
1037
452.85
1039
453.43
1038
446.68
1008
439.29
1017
438.51
RMW3
446.21
OW-4
444.43
1048
442.08
OW-5
441.44
OW-6
445.26
OW-1
443.56
OW-2
442.49
OW-3
450.27
1028
449.99
1045
443.21
1013
1014
1044
438.96
RMW4
441.02
1021
439.61
RMW2
465
460
455
450
445
440
N
100 0 100 Feet
30 0 30 60 Meters
LEGEND
Monitoring Well Used to Map Potentiometric Surface
Modeled Groundwater Contour
Chemical Plant Boundary
GROUNDWATER SURFACE
APRIL 2000
FIGURE 4-8
REPORT NO.
21548-897
EXHIBIT NO.
ORIGINATOR:
PCP
DRAWN BY:
BDE
DATE:
AUGUST 2001

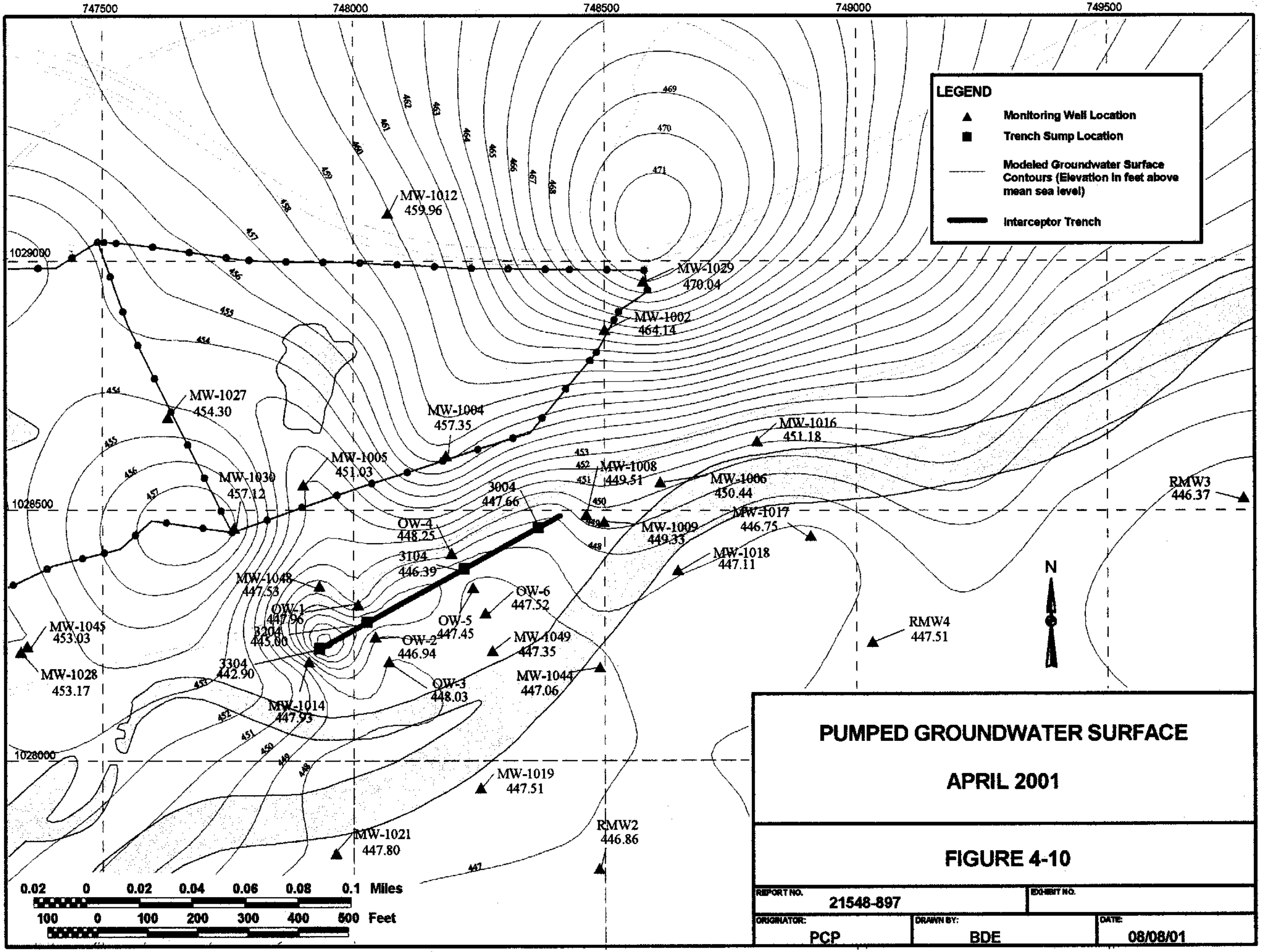


PUMPED GROUNDWATER SURFACE

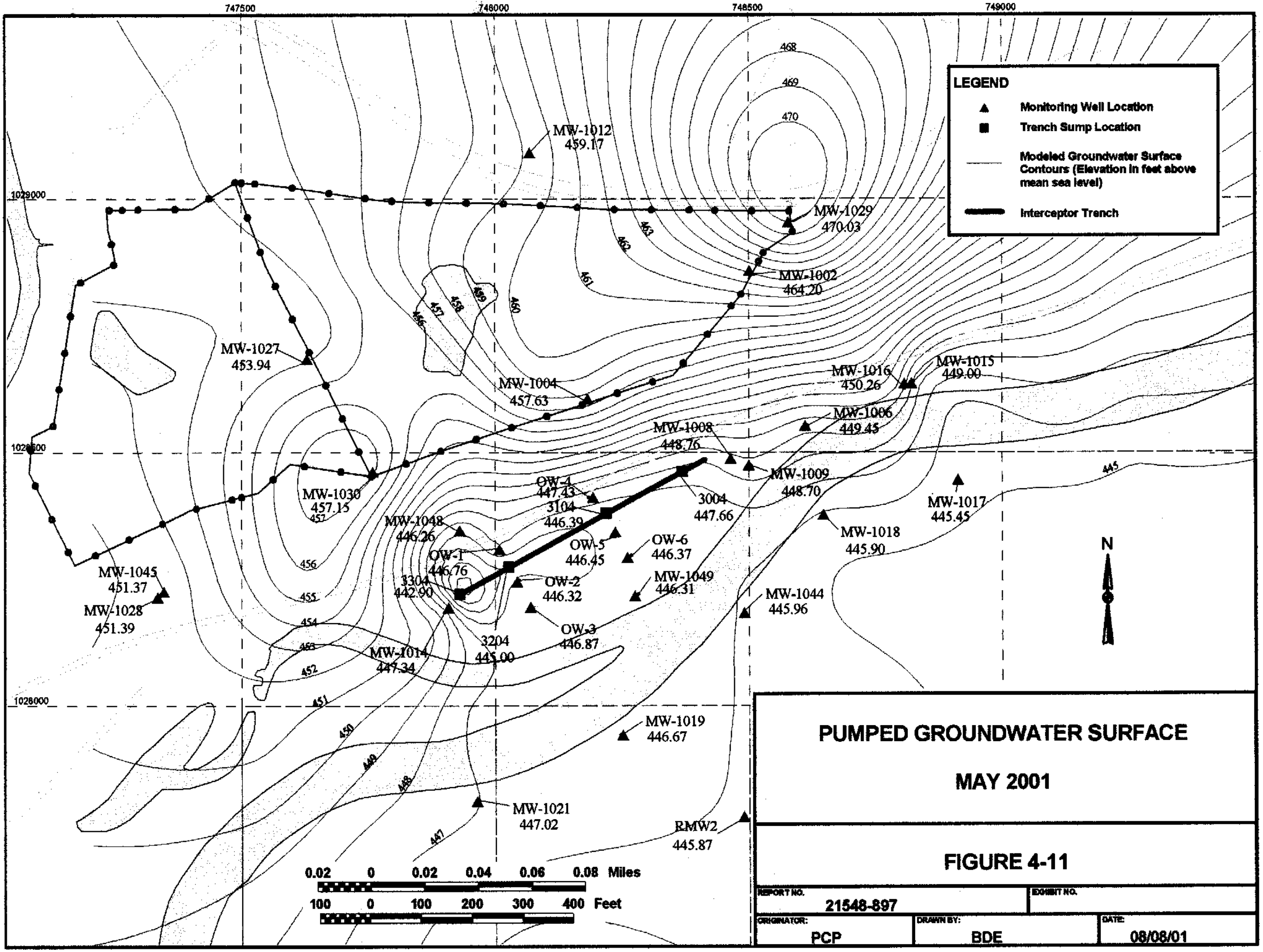
JUNE 2000

FIGURE 4-9

REPORT NO.	EXHIBIT NO.	
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01



747500
748000
748500
749000
749500
1029000
1028500
1028000
LEGEND
Monitoring Well Location
Trench Sump Location
Modeled Groundwater Surface Contours (Elevation in feet above mean sea level)
Interceptor Trench
MW-1012 459.96
MW-1029 470.04
MW-1002 464.14
MW-1027 454.30
MW-1004 457.35
MW-1016 451.18
MW-1005 451.03
MW-1030 457.12
MW-1008 449.51
MW-1006 450.44
RMW3 446.37
3004 447.66
MW-1017 446.75
OW-4 448.25
MW-1009 449.33
3104 446.39
MW-1018 447.11
MW-1048 447.53
OW-6 447.52
OW-1 447.96
OW-5 447.45
3204 445.00
OW-2 446.94
MW-1049 447.35
RMW4 447.51
MW-1045 453.03
MW-1028 453.17
3304 442.90
OW-3 448.03
MW-1044 447.06
MW-1014 447.93
MW-1019 447.51
MW-1021 447.80
RMW2 446.86
N
0.02 0 0.02 0.04 0.06 0.08 0.1 Miles
100 0 100 200 300 400 500 Feet
PUMPED GROUNDWATER SURFACE
APRIL 2001
FIGURE 4-10
REPORT NO. 21548-897
EXHIBIT NO.
ORIGINATOR: PCP
DRAWN BY: BDE
DATE: 08/08/01

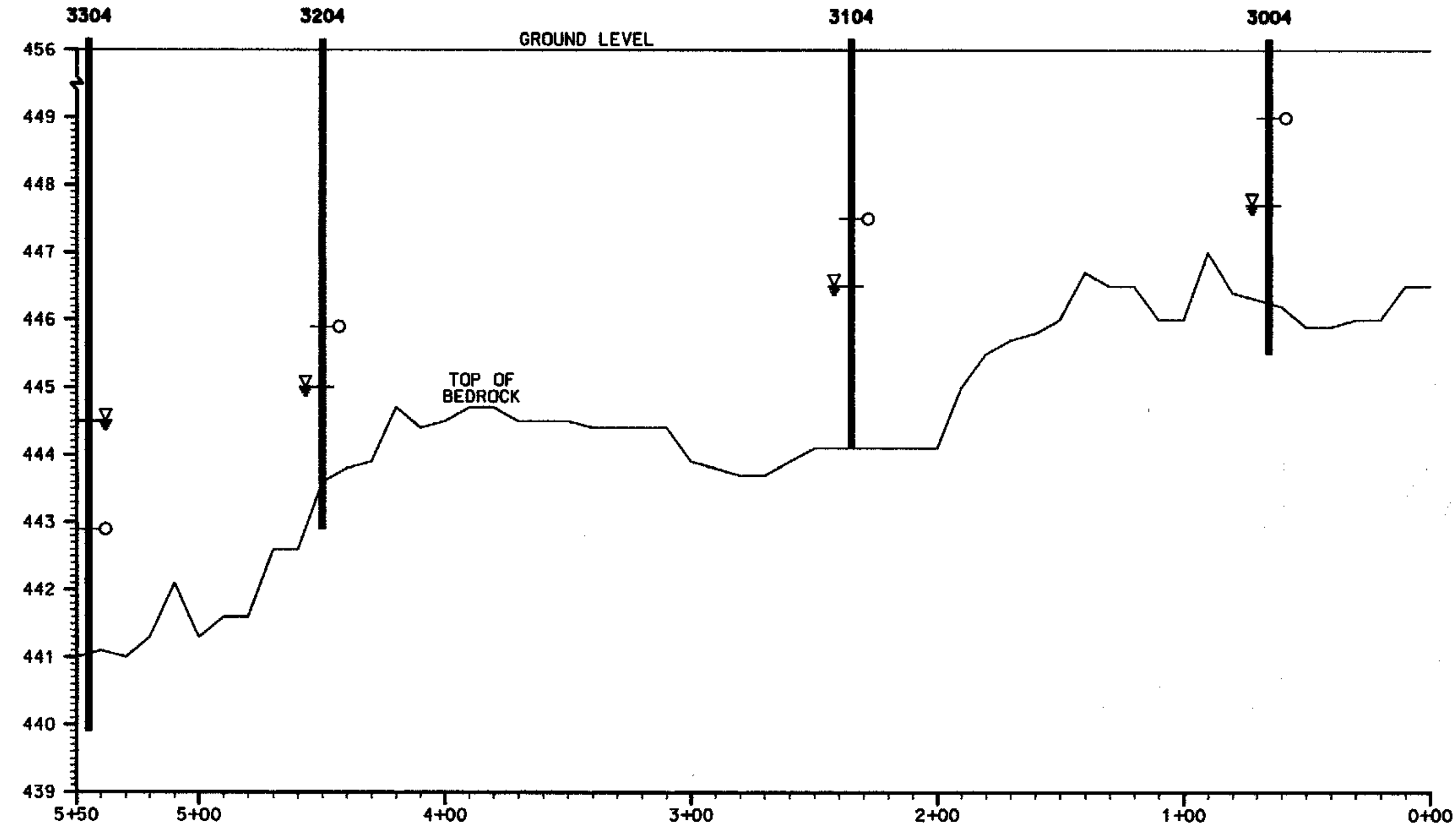


PUMPED GROUNDWATER SURFACE

MAY 2001

FIGURE 4-11

REPORT NO.	EXHIBIT NO.	
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01



LEGEND

▽— – WATER LEVEL

—○ – PUMP SWITCH

NOT TO SCALE

WATER LEVELS IN THE INTERCEPTOR TRENCH

FIGURE 4-12

REPORT NO.:	DOE/OR/21548-897		EXHIBIT NO.:	A/QY/025/0801	
ORIGINATOR:	RC	DRAWN BY:	GLN	DATE:	8/8/01

5. CONCLUSIONS

The efficiency of the interceptor trench system is defined as the ratio of the cumulative mass of uranium removed to the initial total mass present. The interceptor trench does not have an influence over the entire area of impacted groundwater. The percentage of the plume under the influence of the interceptor trench has been determined from static water level measurements obtained during the study.

5.1 Capture Zone of the Interceptor Trench

Although only one pump in the interceptor trench was operating consistently, the trench has an influence over a large portion of the area of groundwater impact. The hydraulic capture zone of the trench varies based on pumping rates and water levels (Figures 5-1 through 5-3). On average, the hydraulic capture zone encompasses approximately 57.4% of the area of uranium impact in the groundwater as depicted by the April 2000 uranium distribution map (Figure 5-4 through 5-6).

5.2 Trench Efficiency

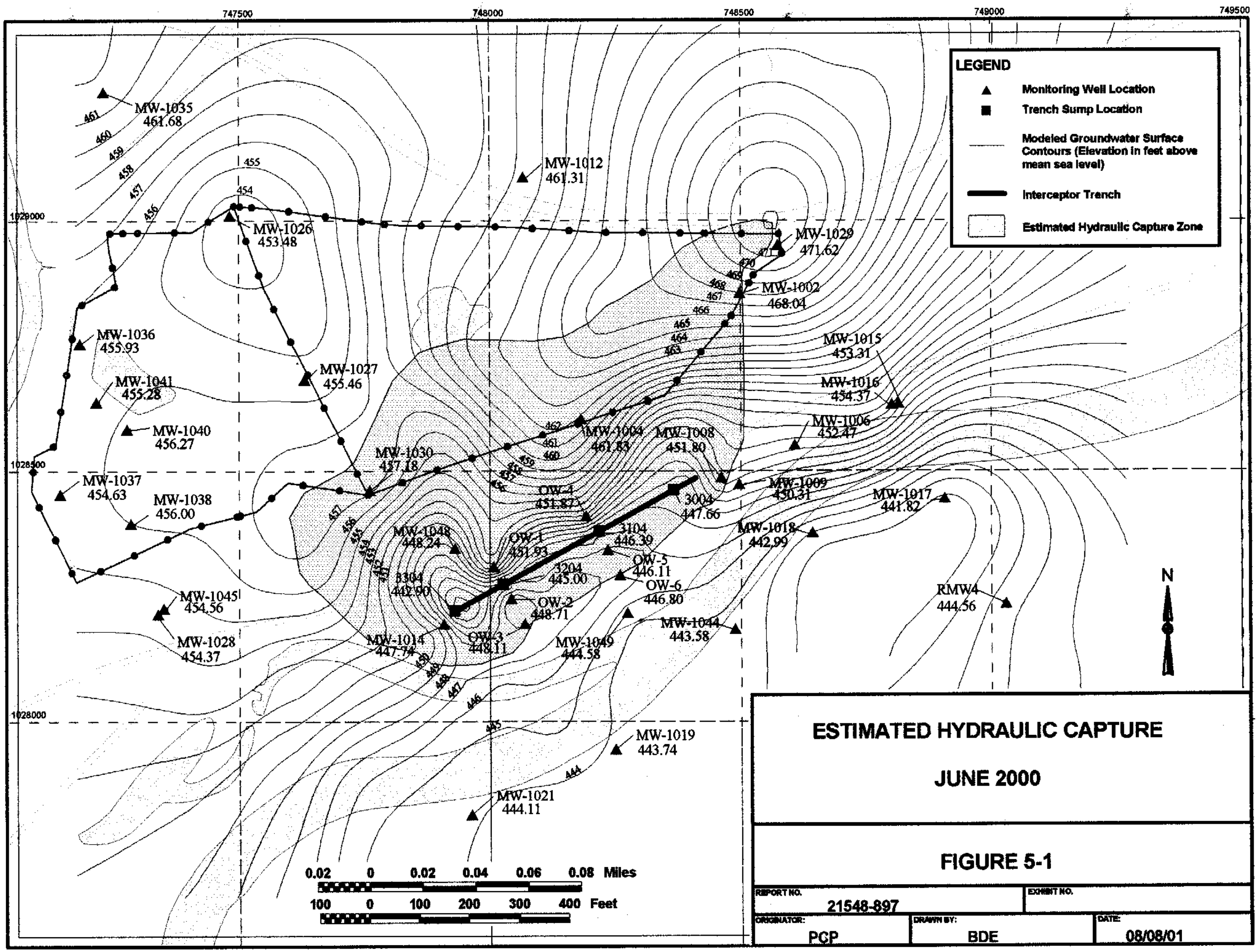
During the first year of the study, the interceptor trench removed 3.6 kg of uranium. The total mass of uranium present prior to starting the study was 528 kg. A total of 303 kg of uranium was within the average capture zone of the trench. Thus, the removal of 3.6 kg of uranium accounts for 1.2% of the total mass of uranium that could be captured by the interceptor trench.

The estimated mass of uranium dissolved in the groundwater prior to the start of the study was 158 kg. Based on the uranium levels measured in April 2001, the estimated mass of uranium in groundwater is 148 kg. This indicates a slight decrease in the mass of uranium over the past year.

The value of 3.6 kg of uranium removed by the interceptor trench is considered a reliable number since it is based on frequent (daily) volume measurements and uranium analyses. The decrease in the mass of uranium (10 kg), as estimated from uranium levels in the monitoring wells in the area of impact, is consistent with the mass removed by the trench (3.6 kg) as it is well within the error of the calculation as presented in Section 2. The similarity of these numbers provides credence to the total mass estimation used for this study. If these numbers were significantly different, the estimation method would have to be reevaluated.

5.3 Changes to the Interceptor Trench Field Study

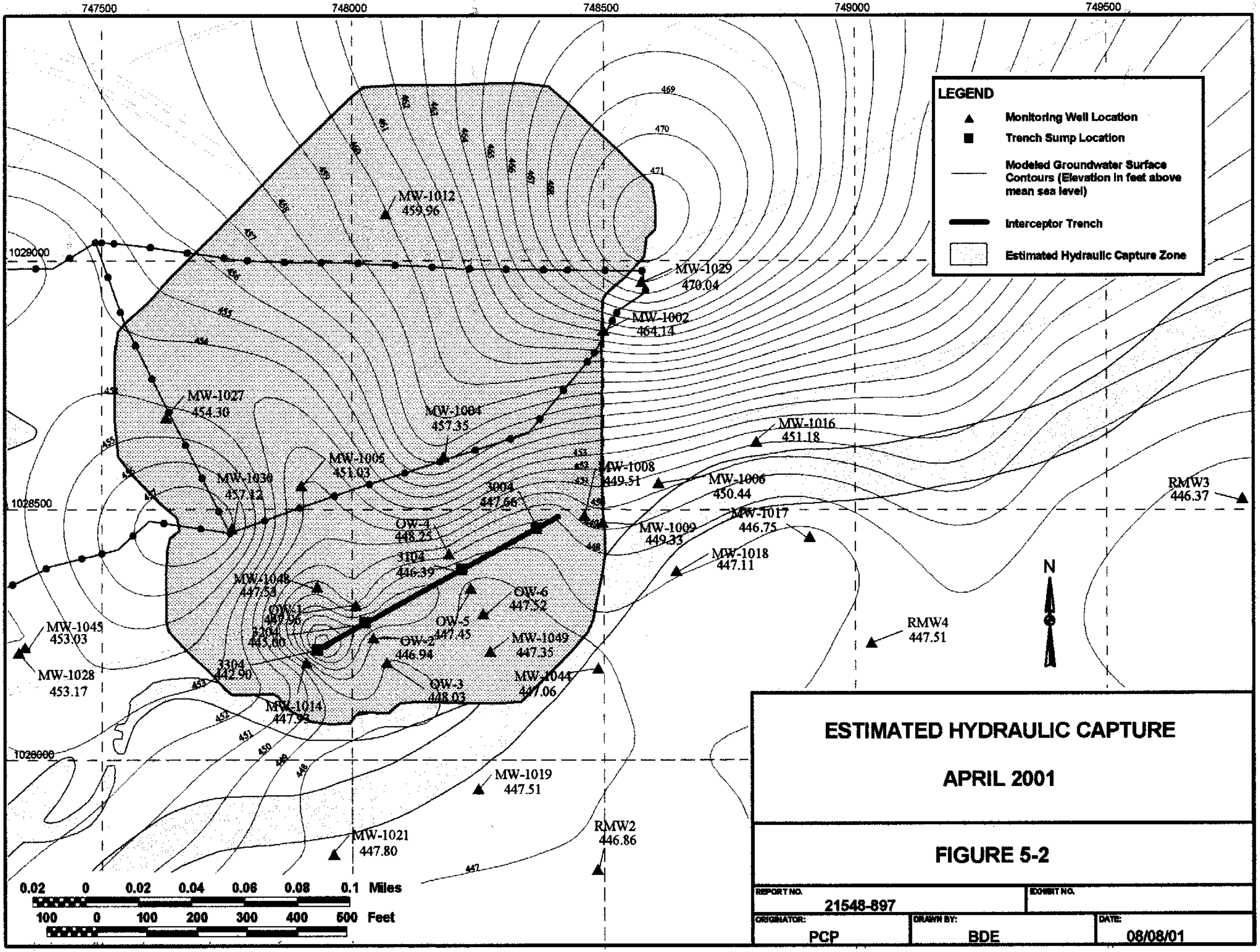
It is recommended that the sulfate/sulfide redox pair analysis for the geochemical sampling portion of this field study be discontinued. Sulfide is typically not a major constituent in groundwater since it forms insoluble sulfides with many heavy-metal ions (Ref. 11). A



ESTIMATED HYDRAULIC CAPTURE

JUNE 2000

FIGURE 5-1

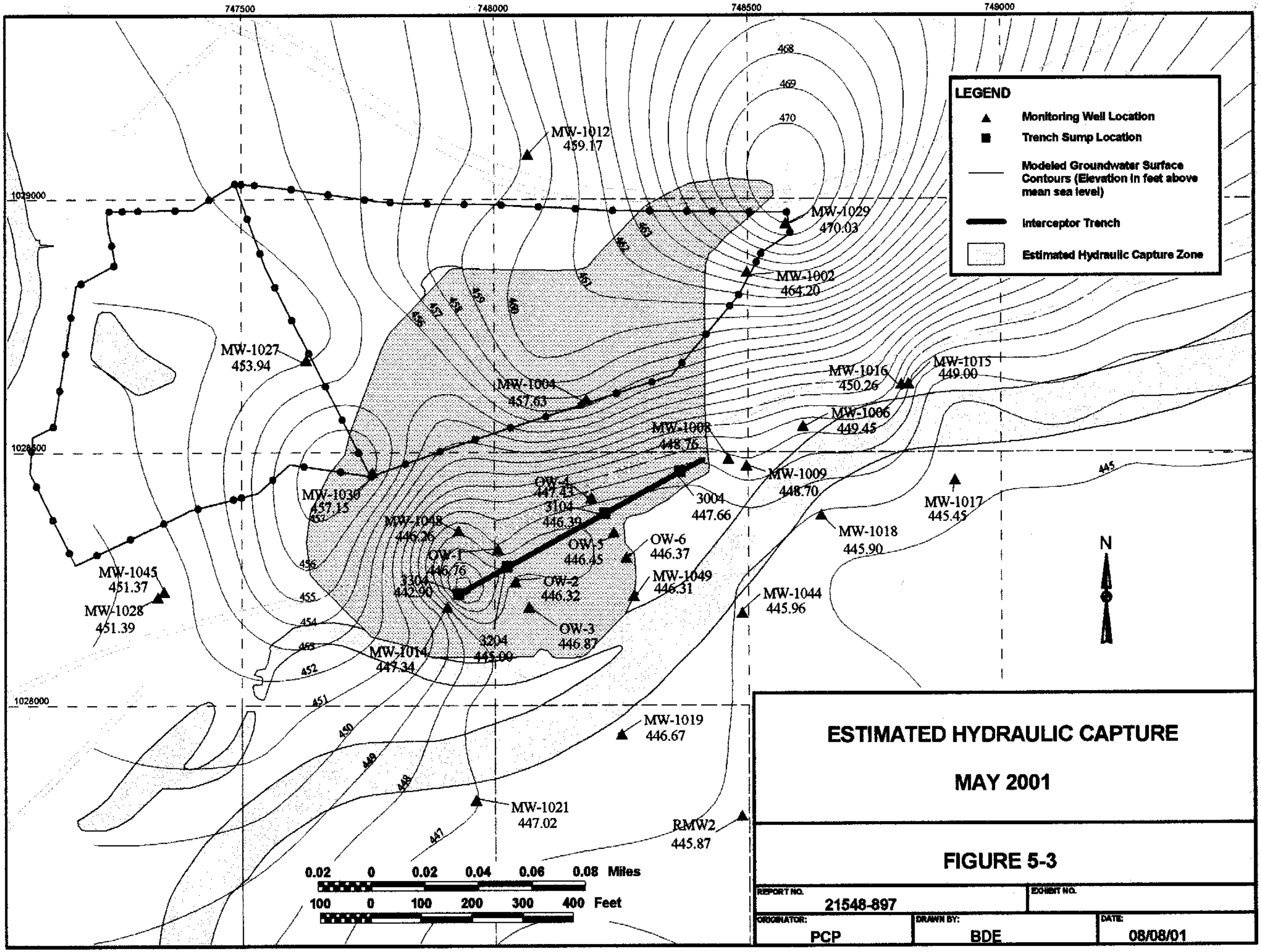


ESTIMATED HYDRAULIC CAPTURE

APRIL 2001

FIGURE 5-2

REPORT NO.		EXHIBIT NO.
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01

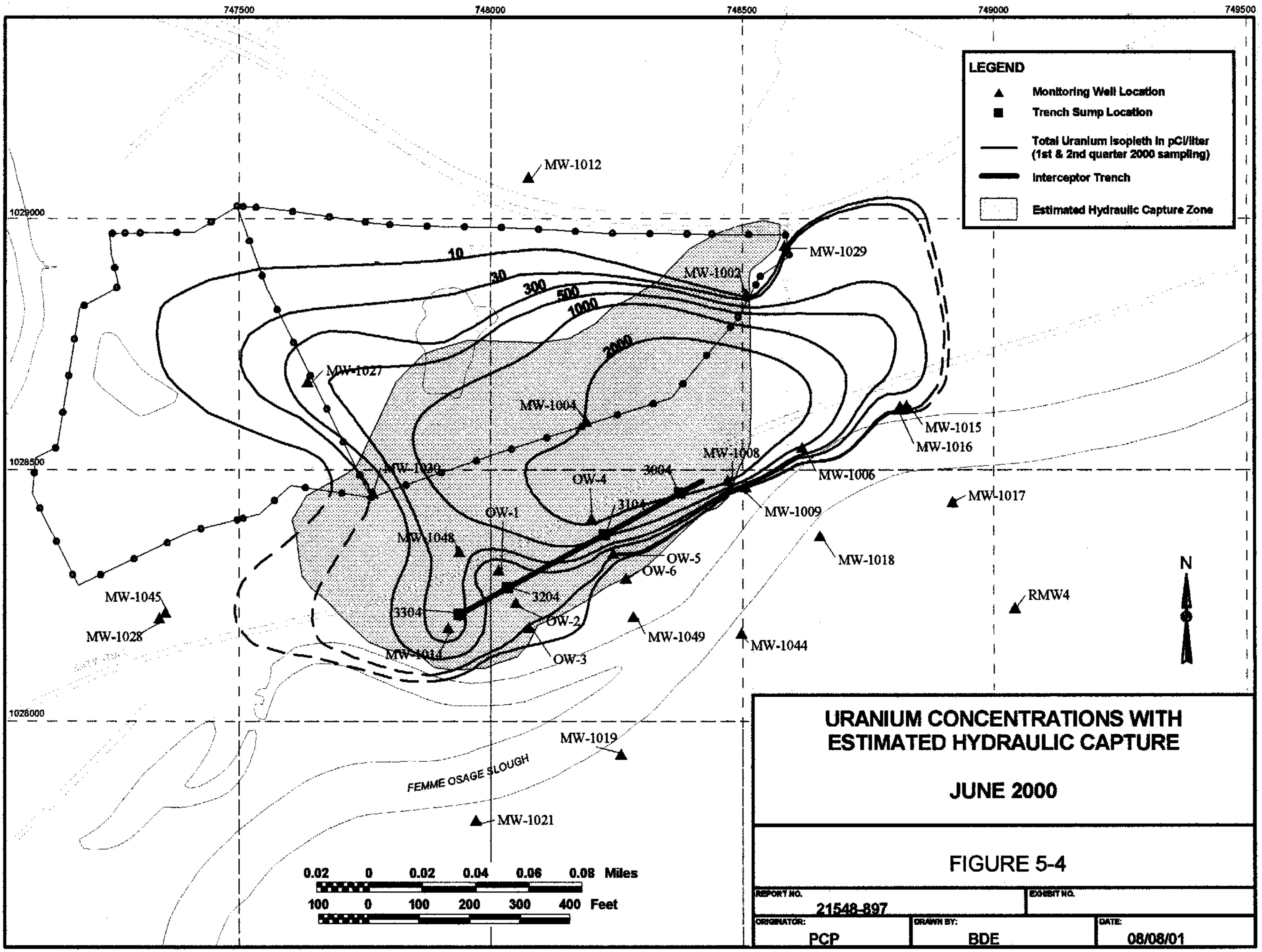


ESTIMATED HYDRAULIC CAPTURE

MAY 2001

FIGURE 5-3

REPORT NO.		EXHIBIT NO.
21548-897		
ORIGINATOR:	DRAWN BY:	DATE:
PCP	BDE	08/08/01

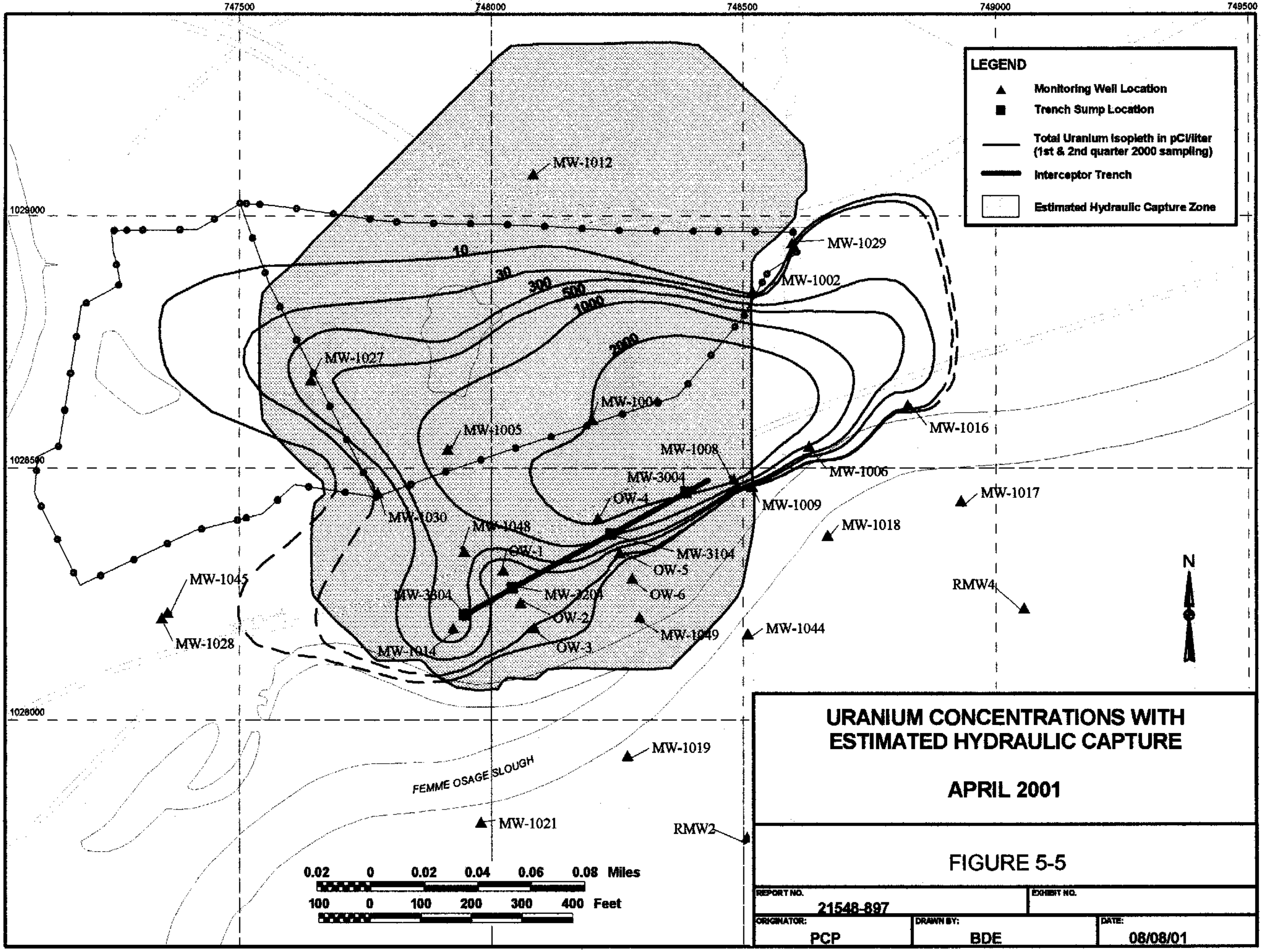


URANIUM CONCENTRATIONS WITH ESTIMATED HYDRAULIC CAPTURE

JUNE 2000

FIGURE 5-4

REPORT NO.		EXHIBIT NO.
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01

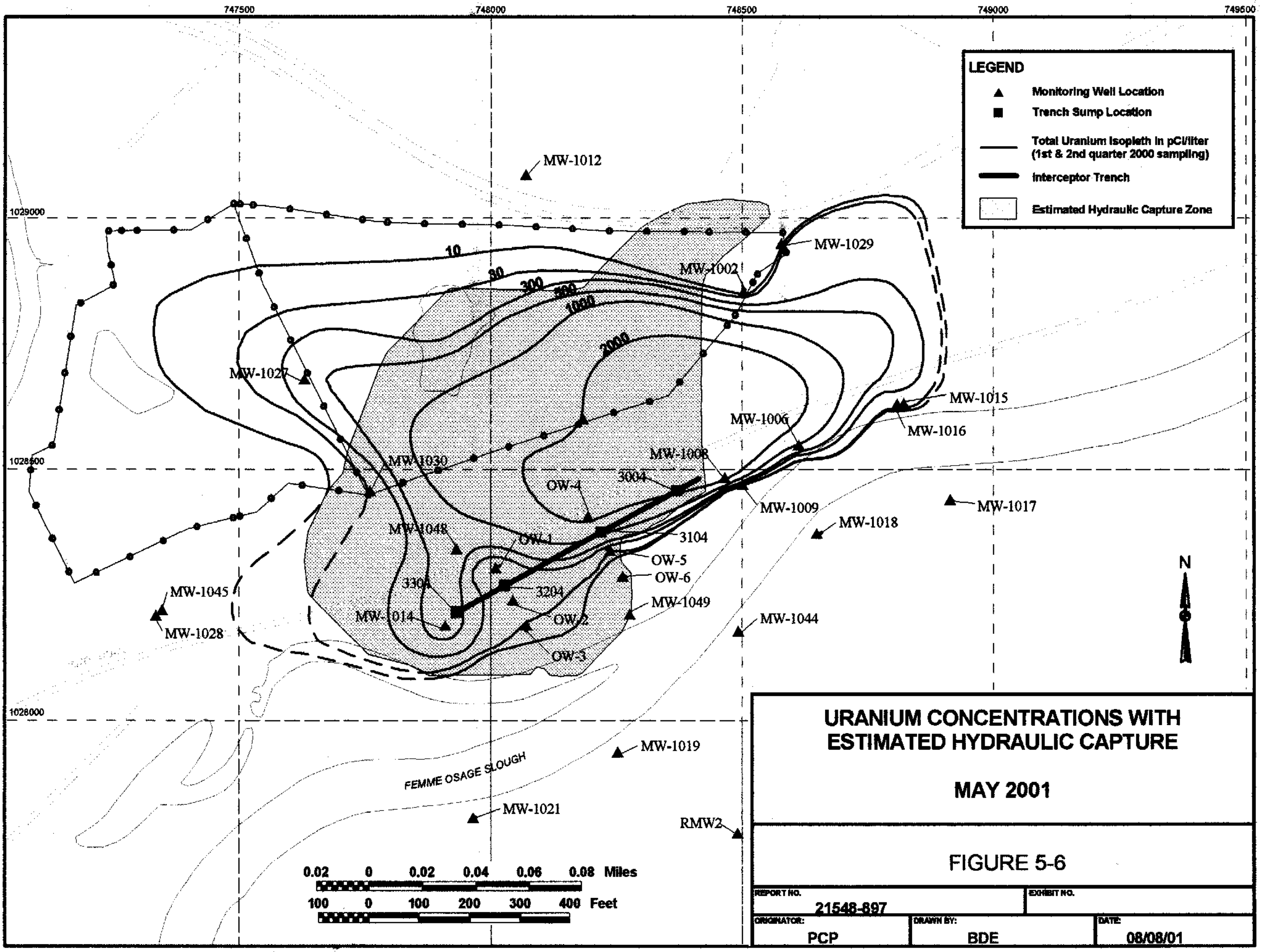


URANIUM CONCENTRATIONS WITH ESTIMATED HYDRAULIC CAPTURE

APRIL 2001

FIGURE 5-5

REPORT NO.		EXHIBIT NO.
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01



URANIUM CONCENTRATIONS WITH ESTIMATED HYDRAULIC CAPTURE

MAY 2001

FIGURE 5-6

REPORT NO.	EXHIBIT NO.	
21548-897		
ORIGINATOR: PCP	DRAWN BY: BDE	DATE: 08/08/01

comparison of these redox pairs is not providing a useful indicator for changes in the shallow aquifer. Also, more readily available data can be obtained from the transducer measurements for the OW-series wells.

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APPENDIX A
Uranium Mass in Groundwater (Rev. 1)

MORRISON KNUDSEN CORPORATION
GOVERNMENT GROUP
FEDERAL PROJECTS DIVISION

WSSRAP

INTER-OFFICE CORRESPONDENCE

FILE NUMBER: 3840-Q:HG-I-05- 5733-01

DATE: August 8, 2001

TO: M. Oaks/R.Cato

FROM: R.Rager/P. Patchin/ S. Vincent

LOCATION: Weldon Spring Site

LOCATION: MK - Boise

SUBJECT: **WSSRAP -QUARRY - TASK 962**
QROU RD/RA Document Support
Interceptor Trench Field Study – Uranium Mass in Groundwater (Rev.1)

The primary purpose of this revision is to add an estimate of the mass of sorbed and dissolved uranium for the 2nd quarter 2001. In addition, the following revisions were also made to the initial uranium mass estimate (1st and 2nd quarter 2000) since the Rev. 0 version:

- An average water level for each well in the quarry area (averaged from their installation to the present) was used to create the potentiometric surface that constitutes the top of the aquifer. This changed the aquifer thickness used in the Rev. 0 uranium mass calculation.

- The distribution coefficient (Kd) was revised after another review of the Berkeley Geosciences report (1984) which establishes the Kd for the limestone bedrock. There was a misread on this value in the QROU RI report.

The first step in this estimation was to contour the uranium concentrations in groundwater using monitoring well data (provided by PMC) from 1st and 2nd Quarter 2000, and 2nd Quarter 2001. Figure 1 shows the uranium distribution in 2000 and Figure 2 shows the 2001 distribution, both using data from offsite and onsite KPA analyses. The majority of the samples (particularly within the uranium plume) were analyzed offsite. Samples analyzed onsite were added to each data set as needed to provide plume definition on the edges of the quarry area and south of the Femme Osage Slough.

Following the mapping, the areas between the contours were calculated using a GIS. A simple arithmetic average of the bounding contour values was then calculated and used for the uranium concentration value for that area. For example, the area between the 300pCi/L and 500pCi/L contours was assigned an average value of 400pCi/L and so on. Once the areas and their assigned concentrations were determined, they were divided north and south of the Katy Trail to take into account the porosity and sorption coefficient (Kd) differences present in the shallow aquifer north of the trail, which is primarily bedrock, and south of the trail, which is primarily alluvium.

Once the contour areas were determined, the saturated aquifer thickness was established. First, a potentiometric surface for the quarry area was created in GIS using the average water levels from the quarry monitoring well network. The average water elevations for the period beginning with initial measurements up to August 2000 were used to more accurately represent the saturated aquifer thickness in the quarry area rather than using any single measurement. For the purposes of this calculation, this "historical average" water table surface constitutes the top of the saturated aquifer for the entire quarry area.

The bottom of the aquifer was determined separately for north and south of the Katy Trail. North of the Katy Trail, the bottom of the saturated aquifer was determined to be the contact between the Decorah Formation and Plattin Limestone. The average elevation of this contact was calculated using borehole intercepts from previous drilling. A surface was then constructed in GIS using this average elevation (429.8 ft.) to represent the bottom of the saturated aquifer north of the Katy Trail.

South of the Katy Trail where the alluvial aquifer is predominant, the bedrock surface beneath the alluvium minus an additional 5 feet was used as the bottom of the alluvial aquifer. The upper 5 feet of the bedrock beneath the alluvial material was included to represent the weathered portion, which likely contributes water to the system.

The following inputs and assumptions were used for this uranium mass calculation:

- Conversion factor from pCi/L to ug/L of 1.47 based on the ratio of uranium isotopes at WSSRAP of 20µg/L per 13.6 pCi/L (MK-Ferguson and Jacobs Engineering Group 1998a).
- Effective porosity in the bedrock portion of the shallow aquifer (north of the Katy Trail) of 20% (McCracken, 1997).
- Effective porosity in the alluvial portion of the shallow aquifer (south of the Katy Trail) of 27% (MK-Ferguson and Jacobs Engineering Group 1998b, p. B-5).
- Uranium distribution coefficient (Kd) of 0.0088 L/kg for the bedrock aquifer material north of the Katy Trail (Berkeley Geosciences 1984).
- Uranium distribution coefficient (Kd) of 5L/kg for the alluvial aquifer material (south of the Katy Trail) (MK-Ferguson and Jacobs Engineering Group 1998b, p. B-6).
- Bulk density of limestone bedrock aquifer material of 2.18 g/cm^3 (Lambe and Whitman, 1969).
- Bulk density of quarry alluvium aquifer material of 1.44g/cm^3 (MK-Ferguson and Jacobs Engineering Group, 1990, Table B-1)

Estimation of Uranium Mass in Groundwater

Estimation of the dissolved uranium mass in groundwater between adjacent mapped contours was performed by multiplying: *(aquifer volume between successive contours) x (effective porosity) x (average concentration for the area) x (pCi/L to ug/L conversion factor).* The calculation was performed using MathCAD® and is attached as Calculation QY-3006-01.

Estimation of Uranium Mass Sorbed to Aquifer Material

The total mass of uranium sorbed to the aquifer material between adjacent mapped contours was estimated by multiplying: *(aquifer volume between successive contours) x (average aqueous concentration for the area) x (pCi/L to ug/L conversion factor) x (uranium distribution coefficient [Kd]) x (dry bulk density of the soil/rock).* This calculation was also performed using MathCAD® (Calculation QY-3006-01 attached).

Equivalent calculations were also prepared using an Excel® spreadsheet (also attached) which shows a more detailed breakdown of the areas, volumes, and uranium mass. An electronic version of this spreadsheet will be e-mailed to you, which will allow you to manipulate the input parameters for the calculation should they change in the future based on new information.

References

Berkeley Geosciences, 1984. *Characterization and Assessment for The Weldon Spring Quarry Low-Level Radioactive Waste Storage Site,* prepared for the U.S. Department of Energy, Oak Ridge Operations Office, September.

Lambe, William T. and Robert V. Whitman, 1969. *Soil Mechanics* published by JohnWiley & Sons, Inc.

McCracken, 1997. Written correspondence from Mr. Steven McCracken (DOE Weldon Spring Site) to Mr. Glen Carlson (MDNR), Nov 4th.

MK-Ferguson Company and Jacobs Engineering Group, 1990, *Quarry Geotechnical Report for the Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri,* Rev. 0, (average of in-place dry densities for Quarry area geotechnical boring samples given in Table B-1), prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-147, November.

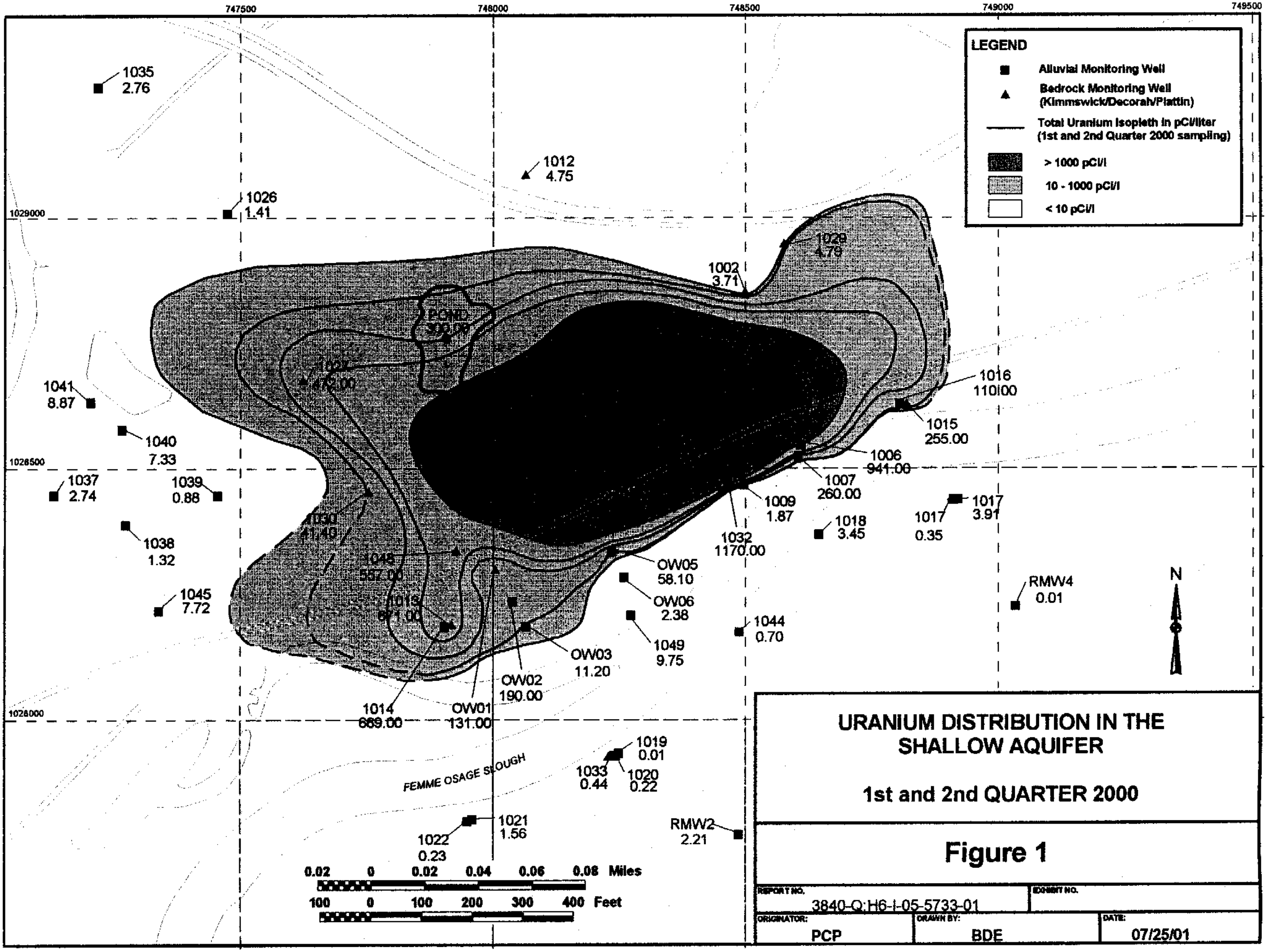
MK-Ferguson Company and Jacobs Engineering Group, 1998a, *Remedial Investigation for the Quarry Residuals Operable Unit: Weldon Spring Site, Weldon Spring, Missouri,* Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-587, Rev. 2, February.

MK-Ferguson Company and Jacobs Engineering Group, 1998b, *Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit: Weldon Spring Site, Weldon Spring, Missouri,* Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-595, March.

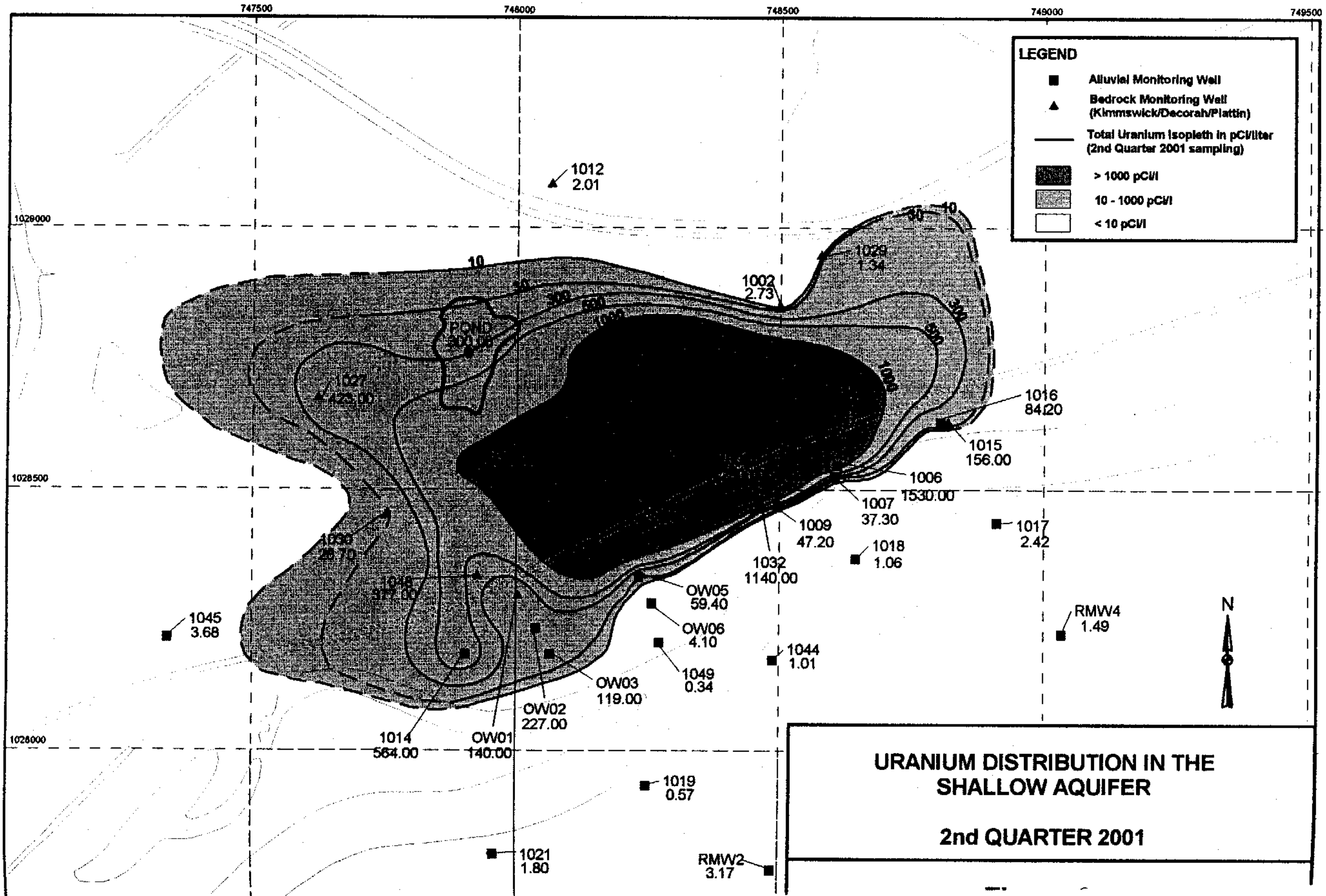
cc:

G. Valett
S. Vincent
R. Raymondi
Task File 392

Attachments



747500
748000
748500
749000
749500
1029000
1028500
1028000
LEGEND
Alluvial Monitoring Well
Bedrock Monitoring Well (Kimmswick/Decorah/Plattin)
Total Uranium Isopleth in pCi/liter (1st and 2nd Quarter 2000 sampling)
> 1000 pCi/l
10 - 1000 pCi/l
< 10 pCi/l
1035 2.76
1012 4.75
1026 1.41
1029 4.79
1002 3.71
POND
1041 8.87
1040 7.33
1037 2.74
1039 0.88
1038 1.32
1045 7.72
1030 41.40
1048 557.00
1016 110100
1015 255.00
1006 941.00
1007 260.00
1009 1.87
1032 1170.00
1018 3.45
1017 0.35
1017 3.91
OW05 58.10
OW06 2.38
OW03 11.20
OW02 190.00
OW01 131.00
1014 669.00
1049 9.75
1044 0.70
RMW4 0.01
N
1019 0.01
1033 0.44
1020 0.22
FEMME OSAGE SLOUGH
1021 1.56
1022 0.23
RMW2 2.21
0.02 0 0.02 0.04 0.06 0.08 Miles
100 0 100 200 300 400 Feet
URANIUM DISTRIBUTION IN THE SHALLOW AQUIFER
1st and 2nd QUARTER 2000
Figure 1
REPORT NO. 3840-Q:H6-I-05-5733-01
EXHIBIT NO.
ORIGINATOR: PCP
DRAWN BY: BDE
DATE: 07/25/01



URANIUM DISTRIBUTION IN THE SHALLOW AQUIFER

2nd QUARTER 2001

MORRISON KNUDSEN CORPORATION
GOVERNMENT GROUP
FEDERAL PROGRAMS DIVISION

WSSRA PROJECT

CALCULATION COVER SHEET

WK. PKG. ________ MKES DOC. NO. 3840-HG-C-05-5734-01 CALC. NO QY-3006-01

TASK NO. 962 DISCIPLINE Hydrogeology PAGE 1 OF 5

PROJECT:
WELDON SPRING SITE REMEDIAL ACTION PROJECT

FEATURE:
QUARRY RESIDUAL OPERABLE UNIT

ITEM:
Quarry Interceptor Trench – Uranium Mass Determination – 1st and 2nd Quarter 2000 and 2nd Quarter 2001

SOURCES OF DATA:

1. MK-Ferguson Company and Jacobs Engineering Group, 1998a, *Remedial Investigation for the Quarry Residuals Operable Unit: Weldon Spring Site, Weldon Spring, Missouri,* Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-587, Rev. 2, February.
2. McCracken, 1997. Written correspondence from Steve McCracken (USDOE Weldon Spring Site) to Mr. Glen Carlson (MDNR), November 4.
3. Lambe, William T. and Whitman, Robert V., 1969, *Soil Mechanics* published by John Wiley and Sons, Inc.
4. Berkeley Geosciences, 1984. *Characterization and Assessment for The Weldon Spring Quarry Low-Level Radioactive Waste Storage Site,* prepared for the U.S. Department of Energy, Oak Ridge Operations Office, September.
5. MK-Ferguson Company and Jacobs Engineering Group, 1998b, *Feasibility Study for Remedial Action for the Quarry Residuals Operable Unit: Weldon Spring Site, Weldon Spring, Missouri,* Prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-595, March.
6. MK-Ferguson Company and Jacobs Engineering Group, 1990, *Quarry Geotechnical Report for the Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri,* Rev. 0, (average of in-place dry densities for Quarry area geotechnical boring samples given in Table B-1), prepared for the U.S. Department of Energy, Oak Ridge Operations Office, DOE/OR/21548-147, November.

SOURCES OF FORMULA & REFERENCES:

PRELIMINARY CALC. ____ FINAL CALC. X SUPERSEDES CALC. NO. QY-3006-00

REV. NO.	REVISION	CALCULATION BY	DATE	CHECKED BY	DATE	APPROVED BY	DATE
01	Rev. 1 Final	S. Vincent SV	08/08/01	P. Patchin PP	08/08/01	P. Patchin PCP	08/08/01
00	Rev. 0 Final	S. Vincent	12/15/00	P. Patchin	12/15/00	P. Patchin	12/15/00
A	Rev. A Draft	P. Patchin	8/15/00	S. Vincent	8/16/00	P. Patchin	8/16/00

MORRISON KNUDSEN CORPORATION
GOVERNMENT GROUP - FEDERAL PROGRAMS DIVISION

Project WSSRAP	Contract No. 3840	File No. 962	
Feature Quarry Residuals Operable Unit	Designed S. Vincent	Date 08/08/01	
Item. Quarry Interceptor Trench – Uranium Mass Determination	Checked P. Patchin	Date 08/08/01	
	Calculation No. QY-3006-01		

For all calculations:

$\mu g \equiv 10^{-6} \cdot gm$ $\quad pCi \equiv \frac{20}{13.6} \cdot \mu g$ *...pCi to* μg conversion (Ref. 1)

Shallow Aquifer North of Katy Trail - Dissolved Uranium 1st and 2nd Quarter 2000

$C_{diss\_N} := \begin{bmatrix} 20 \\ 165 \\ 400 \\ 750 \\ 1500 \\ 2200 \end{bmatrix} \frac{pCi}{liter}$ *...average aqueous concentrations between contours on 8/00 uranium distribution map.*

$Vol_N := \begin{bmatrix} 117851.57 \\ 119233.17 \\ 64854.73 \\ 87427.00 \\ 113131.13 \\ 94872.03 \end{bmatrix} \cdot m^3$ *...corresponding aquifer volume between contours*

$\phi_B := 0.2$ *...Bedrock Effective Porosity = 20% (Ref. 2)*

$Mass_{diss\_N} := \overrightarrow{\left(Vol_N \cdot \phi_B \cdot C_{diss\_N}\right)}$ $\quad Mass_{diss\_N} = \begin{bmatrix} 0.69 \\ 5.79 \\ 7.63 \\ 19.29 \\ 49.91 \\ 61.39 \end{bmatrix} \cdot kg$ $\quad \Sigma Mass_{diss\_N} = 144.69 \cdot kg$ *...total dissolved uranium mass north of Katy Trail*

Shallow Aquifer North of Katy Trail - Sorbed Uranium 1st and 2nd Quarter 2000

$sg_{CaCO3} := 2.72 \cdot \frac{gm}{cm^3}$ *...specific gravity of calcite (Ref. 3)* $\quad a_{B\_N} := 0.024$ *..."linear sorption coefficient" for uranium in bedrock aquifer (Ref. 4, p. 6-31 and 6-76)*

$\rho_{B\_N} := (1 - \phi_B) \cdot sg_{CaCO3}$ $\quad \rho_{B\_N} = 2.18 \cdot \frac{gm}{cm^3}$ *...dry bulk density of limestone bedrock*

$Kd_{UB} := \frac{a_{B\_N}}{\rho_{B\_N}} \cdot (1 - \phi_B)$ $\quad Kd_{UB} = 0.0088 \cdot \frac{mL}{gm}$ *...distribution coefficient (K_d - Ref. 4, p. 6-6)*

$C_{sorb\_N} := \overrightarrow{\left(Kd_{UB} \cdot C_{diss\_N}\right)}$ *...mass of solute sorbed on solid phase per unit mass of solid*

$Mass_{sorbed\_N} := \overrightarrow{\left(C_{sorb\_N} \cdot Vol_N \cdot \rho_{B\_N}\right)}$

$Mass_{sorbed\_N} = \begin{bmatrix} 0.067 \\ 0.555 \\ 0.732 \\ 1.851 \\ 4.791 \\ 5.893 \end{bmatrix} \cdot kg$ $\quad \Sigma Mass_{sorbed\_N} = 13.89 \cdot kg$ *...total sorbed uranium mass north of Katy Trail*

Shallow Aquifer South of Katy Trail - Dissolved Uranium1st and 2nd Quarter 2000

$$C_{diss\_S} := \begin{bmatrix} 20 \\ 165 \\ 400 \\ 750 \\ 1500 \\ 2200 \end{bmatrix} \cdot \frac{pCi}{liter}$$

...average aqueous concentrations between contours on 8/00 uranium distribution map.

$$Vol_S := \begin{bmatrix} 13661.63 \\ 26059.27 \\ 9582.03 \\ 7748.71 \\ 5810.66 \\ 4798.28 \end{bmatrix} \cdot m^3$$

...corresponding aquifer volume between contours

$\phi_A := 0.27$ *...Alluvium Porosity = 27% (Ref. 5)*

$$Mass_{diss\_S} := \overrightarrow{\left(Vol_S \cdot \phi_A \cdot C_{diss\_S}\right)} \qquad Mass_{diss\_S} = \begin{bmatrix} 0.11 \\ 1.71 \\ 1.52 \\ 2.31 \\ 3.46 \\ 4.19 \end{bmatrix} \cdot kg \qquad \Sigma Mass_{diss\_S} = 13.3 \cdot kg$$

...total dissolved uranium mass south of Katy Trail

Shallow Aquifer South of Katy Trail - Sorbed Uranium 1st and 2nd Quarter 2000

$\rho_{A\_S} := 90.17 \frac{lb}{ft^3}$ $\rho_{A\_S} = 1.44 \cdot \frac{gm}{cm^3}$ *...average dry bulk density of alluvium (Ref. 6)*

$Kd_{UA} := 5 \cdot \frac{mL}{gm}$ *...distribution coefficient for uranium in alluvial aquifer (Ref. 5)*

$C_{sorb\_S} := \overrightarrow{\left(Kd_{UA} \cdot C_{diss\_S}\right)}$ *...mass of solute sorbed on solid phase per unit mass of solid*

$$Mass_{sorbed\_S} := \overrightarrow{\left(C_{sorb\_S} \cdot Vol_S \cdot \rho_{A\_S}\right)}$$

$$Mass_{sorbed\_S} = \begin{bmatrix} 2.902 \\ 45.666 \\ 40.706 \\ 61.721 \\ 92.568 \\ 112.112 \end{bmatrix} \cdot kg \qquad \Sigma Mass_{sorbed\_S} = 355.68 \cdot kg$$

...total sorbed uranium mass south of Katy Trail

Project	WSSRAP	Contract No. 3840	Sheet
Feature	Quarry Residuals Operable Unit	Designed S. Vincent	File No
Item.	Quarry Interceptor Trench – Uranium Mass Determination	Checked P. Patchin	Date
		Calculation No. QY-3006-01	Date

For all calculations:

$\mu g \equiv 10^{-6} \cdot gm$ $\quad pCi \equiv \frac{20}{13.6} \cdot \mu g$ ...*pCi to* µg conversion (Ref. 1)

Shallow Aquifer North of Katy Trail - Dissolved Uranium 2nd Quarter 2001

$$C_{diss\_N} := \begin{bmatrix} 20 \\ 165 \\ 400 \\ 750 \\ 1500 \\ 2200 \end{bmatrix} \cdot \frac{pCi}{liter}$$

...*average aqueous concentrations between contours on 8/00 uranium distribution map.*

$$Vol_N := \begin{bmatrix} 117097.14 \\ 123665.72 \\ 76220.13 \\ 94342.64 \\ 91506.68 \\ 87875.54 \end{bmatrix} \cdot m^3$$

...*corresponding aquifer volume between contours*

$\phi_B := 0.2$ ...*Bedrock Effective Porosity = 20% (Ref. 2)*

$$Mass_{diss\_N} := \overrightarrow{\left(Vol_N \cdot \phi_B \cdot C_{diss\_N}\right)} \qquad Mass_{diss\_N} = \begin{bmatrix} 0.69 \\ 6 \\ 8.97 \\ 20.81 \\ 40.37 \\ 56.86 \end{bmatrix} \cdot kg \qquad \Sigma Mass_{diss\_N} = 133.7 \cdot kg$$

...*total dissolved uranium mass north Katy Trail*

Shallow Aquifer North of Katy Trail - Sorbed Uranium 2nd Quarter 2001

$sg_{CaCO3} := 2.72 \cdot \frac{gm}{cm^3}$ ...*specific gravity of calcite (Ref. 3)*

$a_{B\_N} := 0.024$ ...*"linear sorption coefficient" for uranium in bedrock aquifer (Ref. 4, p. 6-31 and 6-76)*

$\rho_{B\_N} := \left(1 - \phi_B\right) \cdot sg_{CaCO3} \qquad \rho_{B\_N} = 2.18 \cdot \frac{gm}{cm^3}$ ...*dry bulk density of limestone bedrock*

$Kd_{UB} := \frac{a_{B\_N}}{\rho_{B\_N}} \cdot \left(1 - \phi_B\right) \qquad Kd_{UB} = 0.0088 \cdot \frac{mL}{gm}$ ...*distribution coefficient (K_d - Ref. 4, p. 6-6)*

$C_{sorb\_N} := \overrightarrow{\left(Kd_{UB} \cdot C_{diss\_N}\right)}$ ...*mass of solute sorbed on solid phase per unit mass of solid*

$$Mass_{sorbed\_N} := \overrightarrow{\left(C_{sorb\_N} \cdot Vol_N \cdot \rho_{B\_N}\right)}$$

$$Mass_{sorbed\_N} = \begin{bmatrix} 0.066 \\ 0.576 \\ 0.861 \\ 1.998 \\ 3.876 \\ 5.459 \end{bmatrix} \cdot kg \qquad \Sigma Mass_{sorbed\_N} = 12.84 \cdot kg$$

...*total sorbed uranium mass north of Katy Trail*

Project WSSRAP	Contract No. 3840	File No. 962	
Feature Quarry Residuals Operable Unit	Designed S. Vincent	Date 08/08/01	
Item. Quarry Interceptor Trench – Uranium Mass Determination	Checked P. Patchin	Date 08/08/01	
	Calculation No. QY-3006-01		

Shallow Aquifer South of Katy Trail - Dissolved Uranium 2nd Quarter 2001

$C_{diss\_S} := \begin{bmatrix} 20 \\ 165 \\ 400 \\ 750 \\ 1500 \\ 2200 \end{bmatrix} \frac{pCi}{liter}$ *...average aqueous concentrations between contours on 8/00 uranium distribution map.*

$Vol_S := \begin{bmatrix} 13027.15 \\ 28940.37 \\ 10046.33 \\ 8227.68 \\ 6552.85 \\ 5127.81 \end{bmatrix} \cdot m^3$ *...corresponding aquifer volume between contours*

$\phi_A := 0.27$ *...Alluvium Porosity = 27% (Ref. 5)*

$Mass_{diss\_S} := \overrightarrow{\left(Vol_S \cdot \phi_A \cdot C_{diss\_S}\right)}$ $Mass_{diss\_S} = \begin{bmatrix} 0.1 \\ 1.9 \\ 1.6 \\ 2.45 \\ 3.9 \\ 4.48 \end{bmatrix} \cdot kg$ $\Sigma Mass_{diss\_S} = 14.43 \cdot kg$ *...total dissolved uranium mass south of Katy Trail*

Shallow Aquifer South of Katy Trail - Sorbed Uranium 2nd Quarter 2001

$\rho_{A\_S} := 90.17 \frac{lb}{ft^3}$ $\rho_{A\_S} = 1.44 \cdot \frac{gm}{cm^3}$ *...average dry bulk density of alluvium (Ref. 6)*

$Kd_{UA} := 5 \cdot \frac{mL}{gm}$ *...distribution coefficient for uranium in alluvial aquifer (Ref. 5)*

$C_{sorb\_S} := \overrightarrow{\left(Kd_{UA} \cdot C_{diss\_S}\right)}$ *...mass of solute sorbed on solid phase per unit mass of solid*

$Mass_{sorbed\_S} := \overrightarrow{\left(C_{sorb\_S} \cdot Vol_S \cdot \rho_{A\_S}\right)}$

$Mass_{sorbed\_S} = \begin{bmatrix} 2.767 \\ 50.714 \\ 42.679 \\ 65.536 \\ 104.392 \\ 119.812 \end{bmatrix} \cdot kg$ $\Sigma Mass_{sorbed\_S} = 385.9 \cdot kg$ *...total sorbed uranium mass south of Katy Trail*

QROU Shallow Aquifer: Determination of Uranium Mass Sorbed to Aquifer Material - 1st and 2nd Quarter 2000

Area	Range (pCi/L)	Area (sq ft.)	Area (sq meter)	Average Uranium Conc. (pCi/L)[1]	Aquifer Volume (cu. meters)[2]	Mass of Sorbed Uranium (kg)	
NORTH	10 - 30	152,127	14,137	20	117851.57	0.07	
NORTH	30 - 300	139,829	12,993	165	119233.17	0.56	
NORTH	300 - 500	78,348	7,282	400	64854.73	0.73	
NORTH	500 - 1000	102,142	9,490	750	87427	1.85	
NORTH	1000 - 2000	124,127	11,534	1500	113131.13	4.79	
NORTH	> 2000	112,005	10,409	2200	94872.03	5.89	
Total North Area Within Plume		**708,578**	**65,845**			**13.89**	**kg Sorbed Uranium Mass North of Katy Trail[2]**
SOUTH	10 - 30	24,908	2,314	20	13661.63	2.90	
SOUTH	30 - 300	58,355	5,422	165	26059.27	45.67	
SOUTH	300 - 500	25,512	2,372	400	9582.03	40.71	
SOUTH	500 - 1000	23,652	2,195	750	7748.71	61.72	
SOUTH	1000 - 2000	19,174	1,781	1500	5810.66	92.57	
SOUTH	> 2000	19,879	1,847	2200	4798.28	112.11	
Total South Area Within Plume		**171,480**	**15,931**			**355.68**	**kg Sorbed Uranium Mass South of Katy Trail[2]**
Total Area Within U Plume		**880,058**	**81,776**				
Input Parameters/Conversions							
Kd for aquifer north of Katy Trail:				0.008824	L/kg	**369.566**	**kg Total Uranium Mass Sorbed to Aquifer Material**
Kd for aquifer south of Katy Trail:				5	L/kg		
Dry bulk density of aquifer material north of Katy Trail				2.176	g/cm^3		
Dry bulk density of aquifer material south of the Katy Trail				1.4443848	g/cm^3		
Conversion for pCi/L to ug/L (20ug/L = 13.6pCi/L) :				1.470588235	ug/pCi		
Conversion for cu.meter to Liter:				1000	L/m^3		
Conversion from ug to kg				0.000000001	ug/kg		

Notes

[1] Average concentration between isoconcentration contours.

[2] The Katy Trail is used as the dividing line between the primarily bedrock portion of the shallow aquifer north of the trail (NORTH), and the primarily alluvial portion of the shallow aquifer south of the trail (SOUTH).

Note: The saturated aquifer thickness is the interval from the average water table to (1) the average borehole intercept elevation of the top of Plattin Limestone (429.8 ft), north of the Katy Trail (bedrock portion) and (2) the top of bedrock beneath the alluvium minus 5 feet to represent the weathered portion, south of the Katy Trail (alluvial portion).

QROU Shallow Aquifer: Determination of Uranium Mass Dissolved in Groundwater - 1st and 2nd Quarter 2000

Area	Range (pCi/L)	Area (sq ft.)	Area (sq meter)	Average Uranium Conc. (pCi/L)[1]	Aquifer Volume (cu. meter)	Water Volume (Liters)[2]	Dissolved Uranium (kg)	
NORTH	10 - 30	152,127	14,137	20	117851.57	23570314	0.69	
NORTH	30 - 300	139,829	12,993	165	119233.17	23846634	5.79	
NORTH	300 - 500	78,348	7,282	400	64854.73	12970946	7.63	
NORTH	500 - 1000	102,142	9,490	750	87427	17485400	19.29	
NORTH	1000 - 2000	124,127	11,534	1500	113131.13	22626226	49.91	
NORTH	> 2000	112,005	10,409	2200	94872.03	18974406	61.39	
							144.69	**kg Dissolved Uranium Mass North of Katy Trail[3]**
Total North Area Within Plume		**708,578**	**65,845**					
SOUTH	10 - 30	24,908	2,314	20	13661.63	3688640.1	0.11	
SOUTH	30 - 300	58,355	5,422	165	26059.27	7036002.9	1.71	
SOUTH	300 - 500	25,512	2,372	400	9582.03	2587148.1	1.52	
SOUTH	500 - 1000	23,652	2,195	750	7748.71	2092151.7	2.31	
SOUTH	1000 - 2000	19,174	1,781	1500	5810.66	1568878.2	3.46	
SOUTH	> 2000	19,879	1,847	2200	4798.28	1295535.6	4.19	
							13.30	**kg Dissolved Uranium Mass South of Katy Trail[3]**
Total South Area Within Plume		**171,480**	**15,931**					
Total Area Within U Plume		**880,058**	**81,776**					

Input Parameters/Conversions

Conversion for pCi/L to ug/L (20ug/L = 13.6pCi/L) :	1.47058824	ug/pCi
Conversion for cu.meter to Liter:	1000	L/cu.meter
Aquifer porosity north of Katy Trail:	0.2	
Aquifer porosity south of Katy Trail:	0.27	
Conversion from ug to kg	1E-09	ug/kg

157.991 **kg Total Dissolved Uranium mass in Groundwater**

Notes

[1] Average concentration between isoconcentration contours.

[2] Based on an aquifer effective porosity of 20% north of the Katy Trail (bedrock) and 27% south of the Katy Trail (alluvium).

[3] The Katy Trail is used as the dividing line between the primarily bedrock portion of the shallow aquifer north of the trail (NORTH), and the primarily alluvial portion of the shallow aquifer south of the trail (SOUTH).

Note: The saturated aquifer thickness is the interval from the average water table to (1) the average borehole intercept elevation of the top of Plattin Limestone (429.8 ft). north of the Katy Trail (bedrock portion) and (2) the top of bedrock beneath the alluvium minus 5 feet to represent the weathered portion, south of the Katy Trail (alluvial portion).

QROU Shallow Aquifer: Determination of Uranium Mass Sorbed to Aquifer Material - 2nd Quarter 2001

Area	Range (pCi/L)	Area (sq ft.)	Area (sq meter)	Average Uranium Conc. (pCi/L)[1]	Aquifer Volume (cu. meters)[2]	Mass of Sorbed Uranium (kg)	
NORTH	10 - 30	150,988	14,027	20	117097.14	0.07	
NORTH	30 - 300	145,321	13,501	165	123665.72	0.58	
NORTH	300 - 500	91,578	8,508	400	76220.13	0.86	
NORTH	500 - 1000	107,769	10,012	750	94342.64	2.00	
NORTH	1000 - 2000	99,325	9,228	1500	91506.68	3.88	
NORTH	> 2000	103,727	9,637	2200	87875.54	5.46	
Total North Area Within Plume		**698,708**	**64,912**			**12.84**	**kg Sorbed Uranium Mass North of Katy Trail[2]**
SOUTH	10 - 30	24,881	2,311	20	13027.15	2.77	
SOUTH	30 - 300	63,406	5,891	165	28940.37	50.71	
SOUTH	300 - 500	26,142	2,429	400	10046.33	42.68	
SOUTH	500 - 1000	24,232	2,251	750	8227.68	65.54	
SOUTH	1000 - 2000	22,688	2,108	1500	6552.85	104.39	
SOUTH	> 2000	22,846	2,122	2200	5127.81	119.81	
Total South Area Within Plume		**184,194**	**17,112**			**385.90**	**kg Sorbed Uranium Mass South of Katy Trail[2]**
Total Area Within U Plume		**882,901**	**82,024**				
Input Parameters/Conversions							
Kd for aquifer north of Katy Trail:				0.008824	L/kg		
Kd for aquifer south of Katy Trail:				5	L/kg	**398.736**	**kg Total Uranium Mass Sorbed to Aquifer Material**
Dry bulk density of aquifer material north of Katy Trail				2.176	g/cm^3		
Dry bulk density of aquifer material south of the Katy Trail				1.4443848	g/cm^3		
Conversion for pCi/L to ug/L (20ug/L = 13.6pCi/L) :				1.470588235	ug/pCi		
Conversion for cu.meter to Liter:				1000	L/m^3		
Conversion from ug to kg				0.000000001	ug/kg		

Notes

[1] Average concentration between isoconcentration contours.

[2] The Katy Trail is used as the dividing line between the primarily bedrock portion of the shallow aquifer north of the trail (NORTH), and the primarily alluvial portion of the shallow aquifer south of the trail (SOUTH).

Note: The saturated aquifer thickness is the interval from the average water table to (1) the average borehole intercept elevation of the top of Plattin Limestone (429.8 ft), north of the Katy Trail (bedrock portion) and (2) the top of bedrock beneath the alluvium minus 5 feet to represent the weathered portion, south of the Katy Trail (alluvial portion).

QROU Shallow Aquifer: Determination of Uranium Mass Dissolved in Groundwater - 2nd Quarter 2001

Area	Range (pCi/L)	Area (sq ft.)	Area (sq meter)	Average Uranium Conc. (pCi/L)[1]	Aquifer Volume (cu. meter)	Water Volume (Liters)[2]	Dissolved Uranium (kg)	
NORTH	10 - 30	150,988	14,027	20	117097.14	23419428	0.69	
NORTH	30 - 300	145,321	13,501	165	123665.72	24733144	6.00	
NORTH	300 - 500	91,578	8,508	400	76220.13	15244026	8.97	
NORTH	500 - 1000	107,769	10,012	750	94342.64	18868528	20.81	
NORTH	1000 - 2000	99,325	9,228	1500	91506.68	18301336	40.37	
NORTH	> 2000	103,727	9,637	2200	87875.54	17575108	56.86	
Total North Area Within Plume		**698,708**	**64,912**				**133.70**	**kg Dissolved Uranium Mass North of Katy Trail[3]**
SOUTH	10 - 30	24,881	2,311	20	13027.15	3517330.5	0.10	
SOUTH	30 - 300	63,406	5,891	165	28940.37	7813899.9	1.90	
SOUTH	300 - 500	26,142	2,429	400	10046.33	2712509.1	1.60	
SOUTH	500 - 1000	24,232	2,251	750	8227.68	2221473.6	2.45	
SOUTH	1000 - 2000	22,688	2,108	1500	6552.85	1769269.5	3.90	
SOUTH	> 2000	22,846	2,122	2200	5127.81	1384508.7	4.48	
Total South Area Within Plume		**184,194**	**17,112**				**14.43**	**kg Dissolved Uranium Mass South of Katy Trail[3]**
Total Area Within U Plume		**882,901**	**82,024**					

Input Parameters/Conversions

Conversion for pCi/L to ug/L (20ug/L = 13.6pCi/L) :	1.47058824	ug/pCi
Conversion for cu.meter to Liter:	1000	L/cu.meter
Aquifer porosity north of Katy Trail:	0.2	
Aquifer porosity south of Katy Trail:	0.27	
Conversion from ug to kg	1E-09	ug/kg

148.127 kg Total Dissolved Uranium mass in Groundwater

Notes

[1] Average concentration between isoconcentration contours.

[2] Based on an aquifer effective porosity of 20% north of the Katy Trail (bedrock) and 27% south of the Katy Trail (alluvium).

[3] The Katy Trail is used as the dividing line between the primarily bedrock portion of the shallow aquifer north of the trail (NORTH), and the primarily alluvial portion of the shallow aquifer south of the trail (SOUTH).

Note: The saturated aquifer thickness is the interval from the average quarry area water table to (1) the average borehole intercept elevation of the top of Plattin Limestone (429.8 ft). north of the Katy Trail (bedrock portion) and (2) the top of bedrock beneath the alluvium minus 5 feet to represent the weathered portion, south of the Katy Trail (alluvial portion).

APPENDIX B
Borehole Diagrams and Well Completion Logs

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

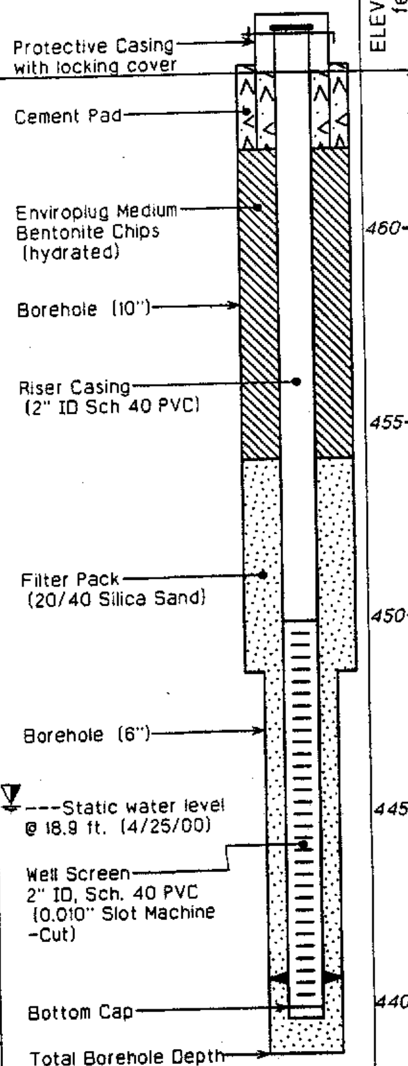
WSWL06-C

Field	Value
HOLE NUMBER	OW-1
SHEET	1 OF 1
NORTH (Y)	1028307.32
EAST (X)	748007.25
TOC ELEVATION	467.56
GROUND ELEVATION	464.11
STICKUP	3.45
HYDR CONDUCTIVITY (cm/sec)	$K= 1.27x10^{-4}$ (Packer Test)
WELL STATUS/COMMENTS	QUARRY INTERCEPTOR TRENCH OBSERV. WELL
LOCATION	QUARRY-NORTH OF SLOUGH
DRILLING CONTRACTOR	LAYNE WESTERN INC.
DRILL RIG MAKE & MODEL	CME-750 ALL-TERRAIN
HOLE SIZE & METHOD	10" HSA to 15.5', then 6" rotary
ANGLE FROM HORIZONTAL & BEARING	90
DRILL FLUIDS & ADDITIVES	Water
CASING TYPE, DEPTH, SIZE	N/A
DATE START	04/06/00
DATE FINISH	04/11/00
BOTTOM OF HOLE (TD) (DEPTH (FT.) FROM GROUND ELEV. TO:)	25.4'
BEDROCK	15.5'
WATER LEVELS & DATES	

LITHOLOGY BY Paul Patchin

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0	Auger			CL	0.0 - 5.5' **FILL**, gravelly clay, approx. 30% limestone gravel to cobble size, medium plasticity, dry to slightly moist, organics, CL.	Fill
5	SS-1		5	SM	5.5 - 6.5' **SILTY SAND**, (possible fill), very fine to fine- grained, approx. 30% silt, minor clay, medium dense, dry to slightly moist, low plasticity, minor FeOx, brown (10YR4/3), some roots, SM.	NO Alluvium
	SS-2	20/24"	9	CL	6.5 - 8.0' **SANDY CLAY**, approx. 20% v. fine sand and silt, soft, (pp=1.0), dry to slightly moist, low plasticity, minor FeOx, CL.	NO Alluvium
	SS-3	9/24"	3	CL	8.0 - 10.3' **SILTY CLAY**, dark grayish brown (10YR4/2) with reddish brown (5YR4/4) FeOx mottling and as blebs, some MnOx, damp, medium plasticity, firm (pp=1.5), increasing sand content with depth, CL.	NO Alluvium
10	SS-4		4	SC	10.3 - 13.2' **CLAYEY SAND**, brown (10YR4/3), approx. 40% clay and silt, medium dense, fine to very fine-grained, poorly graded, SC.	NO Alluvium
	SS-5	24/24"	4	CL	13.2 - 15.5' **SANDY CLAY**, dark grayish brown (10YR4/2), approx. 10-20% (increases with depth) fine sand in matrix, moist (very moist at 15.0'), low plasticity, minor chert gravel at 15.3-15.5' some silt, CL.	NO Alluvium
15	SS-6	6/6"	50	ls	15.5 - 15.7' **LIMESTONE**, medium crystalline, pinkish gray, (5YR8/1), moderately weathered, hard, vugs, [POSSIBLE KIMMSWICK].	Odg
	Run-1	105/114"	43	ls shl	15.7 - 23.3' **INTERBEDDED LIMESTONE AND SHALE**, 80/20%. Limestone is light olive gray (5Y6/1), very finely crystalline (to lithographic), fossiliferous (in bands), very thin-bedded with some waving bedding, closely fractured, moderately hard, moderate to low porosity, FeOx and clay-filling common in fractures. Shale is olive gray (5Y4/1) to minor olive black (5Y2/1), minor alteration, very thin to extreme bedded, wavy bedded, stringer-like bedding, fossiliferous, with small carbonaceous shale bed from 21.2-21.3', [DECORAH GROUP]	Odg
25				shl	23.3 - 24.6' **LIMESTONE AND SHALE**, interbedded as above but the limestone is medium light gray (N6), and very fossiliferous.	
				ls shl	24.7 - 24.9' **SHALE**, dark greenish gray, (5G4/1), soft, fissile, moderately weathered, abundant FeOx on partings, very thin-bedded, some fossils [DECORAH GROUP]	
					24.9 - 25.0' **LIMESTONE AND SHALE**, as in 23.3 - 24.6' [DECORAH GROUP]	
30					Total cored depth 25.0 feet. Reamed hole to 6" to 25.4' and installed 2" monitoring well.	
					Note: Soil color is indexed on the Muncell soil color chart. Rock color is from the GSA rock color chart.	
					Note: All soil samples were scanned with a Ludlum Model 44-9 scinillometer. No samples were above background.	
35					CONSTANT HEAD SINGLE PACKER TEST RESULTS: 17.9 - 25.0 ft. K=1.27E-4 cm/sec	

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▽average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	OW-2
SHEET 1 OF 1	
NORTH (Y):	1028243.04
EAST (X):	748041.64
TOC ELEVATION	461.46
GROUND ELEVATION	457.59
STICKUP	3.87
HYDR CONDUCTIVITY (cm/sec)	$K = 1.27 \times 10^{-4}$ (Packer Test)

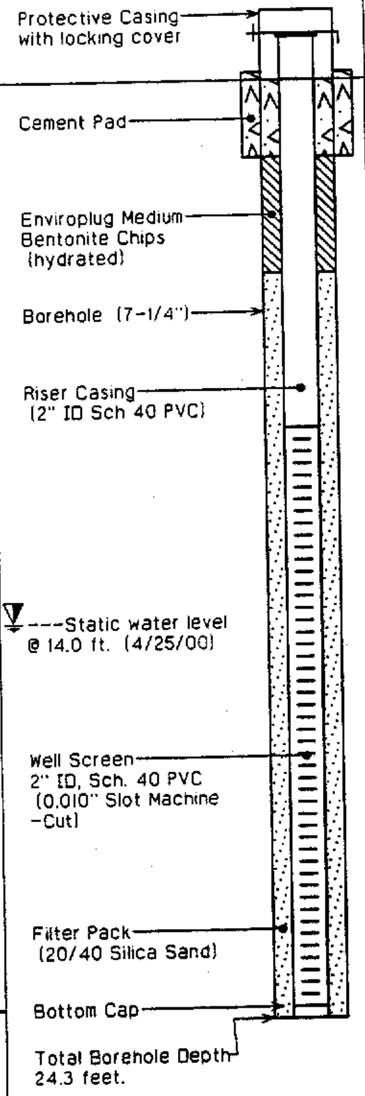
WELL STATUS/COMMENTS: QUARRY INTERCEPTOR TRENCH OBSERV. WELL	LOCATION: QUARRY-NORTH OF SLOUGH
DRILLING CONTRACTOR: LAYNE WESTERN INC.	DRILL RIG MAKE & MODEL: CME-750 ALL-TERRAIN
HOLE SIZE & METHOD: 7-1/4" HSA, 2" SS Sampler	ANGLE FROM HORIZONTAL & BEARING: 90
DRILL FLUIDS & ADDITIVES: None	CASING TYPE, DEPTH, SIZE: N/A
DATE START: 04/03/00	DATE FINISH: 04/03/00

DEPTH (FT.) FROM GROUND ELEV. TO:
- BOTTOM OF HOLE (TD): 24.3'
- BEDROCK: 24.3'
- WATER LEVELS & DATES: ∇ ▼

LITHOLOGY BY: Paul Patchin

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
0	Auger			FILL	0 - 2.5' Fill. (clayey soil and chert gravel)	FILL	
	SS-1	14/24"	3	CL	2.5 - 3.0' SILTY CLAY, very dark grayish brown (10YR3/2), medium plasticity, moist, firm (pp=1.0), rootlets, CL.	NO ALLV.	455
5	SS-2	15/24"	2		3.0 - 8.0' SILTY CLAY, increased silt (to~40%) brown (10YR4/3), slightly moist to moist, soft (pp=.5), rootlets, MnOx & FeOx blebs, silt as light-colored pockets and interbeds, CL.		
	SS-3	2/24"	2				450
	SS-4	9/24"	0	CL	8.0 - 12.3' CLAY, as above but less silt, possible minor chert gravel (5%) to 1/2" (subrounded), very moist to wet at 9.0', very soft (pp<.25), CL.		
10	SS-5	17/24"	1				
	SS-6	17/24"	0	CL	12.3 - 13.0' SANDY CLAY, approx. 30% fine to very fine sand, some silt, color to very dark gray (10YR3/1) at 12.5', wet, low plasticity, coalified wood chips at 13.0', reducing zone at 12.3', CL.		445
	SS-7	1/24"	1	SC	13.0 - 14.1' CLAYEY SAND, color as above, greater sand content than clay, lenses of clay common, wet SC.		
15				LOSS	14.1 - 16.0' LOSS, probable clayey sand as above.		
	SS-8	24/24"	0	CH	16.0 - 21.6' CLAY, high plasticity (putty-like), dark gray (5Y4/1), very soft (pp<.25) very moist to wet, concoidal fracturing, sand pockets (5%), silty interbeds to .5" CH.		440
	SS-9	24/24"	0				
20	SS-10	24/24"	0				
	SS-11	18/24"	58	SC	21.6 - 22.3' CLAYEY SAND, color as above, approx. 40% clay, fine grained, poorly graded, wet, SC.		435
				GC	22.3 - 24.0" CLAYEY GRAVEL, (bedrock residuum), dark gray (N4/), with white (N8/) limestone pieces, some black organic fracture filling, GC.		
25					Auger Refusal and Total Depth @ 24.3 feet (top of rock). Installed 2" monitoring well.		
					Note: Soil color is indexed on the Muncell soil color chart.		430
					Note: All soil samples were scanned with a Ludlum Model 44-9 scinillometer. No samples were above background.		
30							
							425
35							

WELL DIAGRAM



Sample Interval · No Sample Taken · ∇ minimum · ▼ maximum · ∇ average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	OW-3
SHEET	1 OF 1
NORTH (Y):	1028193.88
EAST (X):	748068.50
TOC ELEVATION	459.48
GROUND ELEVATION	456.08
STICKUP	3.40
HYDR CONDUCTIVITY (cm/sec)	

WELL STATUS/COMMENTS	QUARRY INTERCEPTOR TRENCH OBSERV. WELL
LOCATION	QUARRY-NORTH OF SLOUGH
DRILLING CONTRACTOR	LAYNE WESTERN INC.
DRILL RIG MAKE & MODEL	CME-750 ALL-TERRAIN
HOLE SIZE & METHOD	7-1/4" HSA, 2" SS Sampler
ANGLE FROM HORIZONTAL & BEARING	90
DEPTH (FT.) FROM / GROUND ELEV. TO: BOTTOM OF HOLE (TD)	20.0
DRILL FLUIDS & ADDITIVES	None
CASING TYPE, DEPTH, SIZE	N/A
BEDROCK	Not Encountered
DATE START	04/05/00
DATE FINISH	04/05/00
WATER LEVELS & DATES	

LITHOLOGY BY Paul Patchin

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class
SS-1	11/23"	5	CL
SS-2	3/24"	2	
SS-3	21/24"	2	CL
SS-4	15/24"	2	
SS-5	21/24"	1	CL
SS-6	19/24"	0	SC, ML, CL
SS-7	24/24"	0	ML, SP, CL
SS-8	13/24"	0	
SS-9	24/24"	0	SP, CL
SS-10	24/24"	0	CH, CH

DEPTH feet: 5, 10, 15, 20, 25

ELEVATION feet: 455, 450, 445, 440, 435, 430

STRAT. UNIT: MO Alluvium

DESCRIPTION AND REMARKS

0.0 - 3.0'? **SILTY CLAY**, brown (10YR4/3), approx. 15% silt througout and as lenses, minor FeOx, medium plasticity, slightly moist, firm (pp=1.75), rootlets, abundant wood chips at 1.0 ft., CL.

3.0 - 7.0' **SILTY CLAY**, approximate equal amounts of clay and silt , slightly more clay, color as above, moist, low to medium plasticity, soft (pp=.25), abundant FeOx (strong brown) in silty pockets with clayey sand lenses to .5", CL.

7.0 - 9.6' **SANDY SILTY CLAY**, approx. 20% v. fine to fine sand in clay matrix and as lenses, silty (20%), low plasticity, moist, dark grayish brown (10YR4/2), abundant FeOx (strong brown 7.5YR4/2) and MnOx, soft (pp=.25), CL.

9.6 - 10.0' **CLAYEY SAND**, color as above, fine grained, 30% fines, loose, moist, poorly graded, SC.

10.0 - 10.5' **CLAYEY SILT**, color as above grading to color below, sandy lenses (20%), and some clay lenses, FeOx common, ML.

10.5 - 11.3' **SILTY SANDY CLAY**, very dark gray (2.5Y3/1), (reduced zone at 10.5'), sand lenses with organics (slightly coalified wood chips), abundant other organics throughout, very soft (pp<.25), very moist to wet, CL.

11.3 - 11.5' **CLAYEY SILT**, color as above, minor very fine sand, very soft (pp<.25), trace organics, ML.

11.5 - 12.2' **SAND**, very fine grained with minor silt, quartzitic, subrounded, trace clay, trace dark minerals, poorly graded, SP.

12.2 - 15.0' **SILTY CLAY**, organic, approx. 40% silt and v. fine sand in matrix and as lenses, abundant organics (coalified wood pieces, twigs), very dark gray (2.5Y3/1), thin-bedded, lignitic from 13.5 to 14.0', very moist to wet, very soft (pp<.25), CL.

15.0 - 16.0' **SAND?**, (lost portion of the sample, description from top of 16.0' sample), fine grained, quartzitic, minor silt SP.

16.0 - 18.8' **SILTY CLAY**, organic as before, but less silt (20%), and sand (10%), sand to medium grained and as lenses to .7". Large slightly coalified wood chips, translucent amber-like mineral near the wood chips, medium to low plasticity, thin-bedded CL.

18.8 - 19.5' **CLAY**, color as above, moderate to high plasticity, less organics, sandy pockets, (clay is not quite moldable), CH.

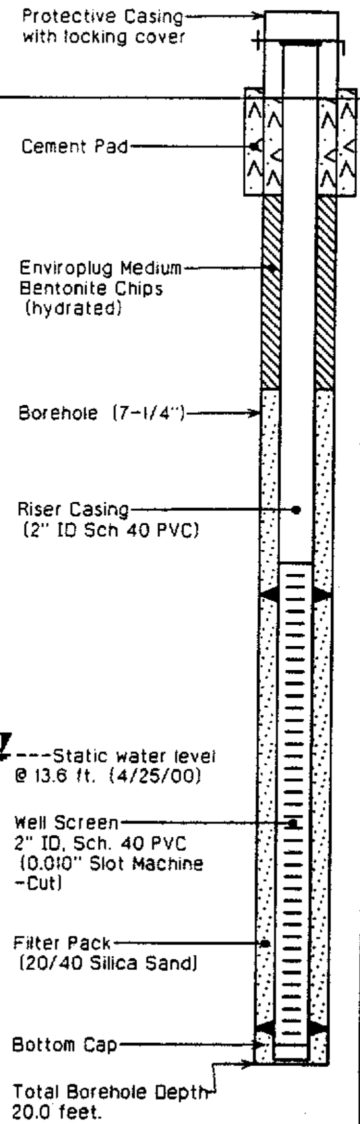
19.5 - 20.0' **CLAY**, high plasticity (moldable), very dark gray (5Y3/1), very moist, minor dark blebs and sand pockets, soft (pp=.75), CH.

Total Depth @ 20.0 feet (bedrock not encountered). Installed 2" monitoring well.

Note: Soil color is indexed on the Muncell soil color chart.

Note: All soil samples were scanned with a Ludlum Model 44-9 scintillometer. No samples were above background.

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

192.40

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSHLOG-C

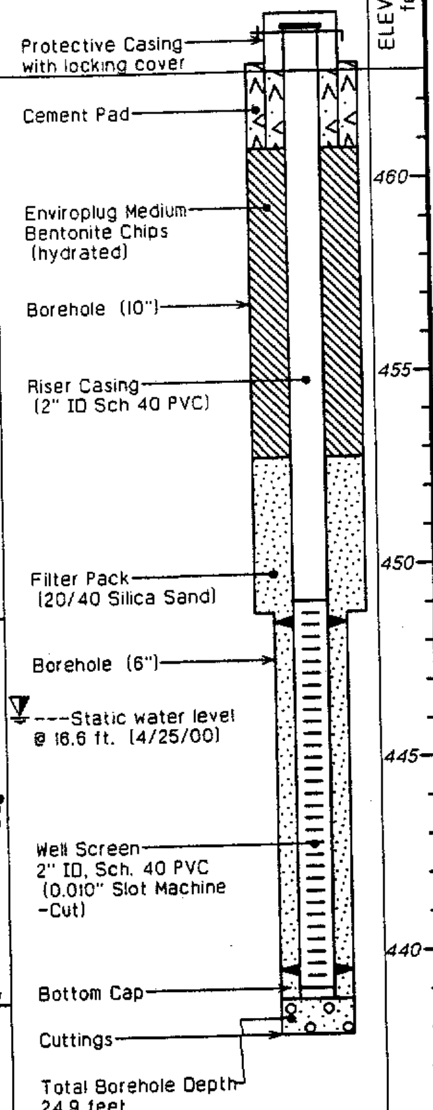
HOLE NUMBER	OW-4
SHEET 1 OF 1	
NORTH (Y):	1028409.5
EAST (X):	748235.77 (struck through)
TOC ELEVATION	466.34
GROUND ELEVATION	462.79
STICKUP	3.55
HYDR CONDUCTIVITY (cm/sec)	K= 2.81x10^{-4} (Packer Test)

WELL STATUS/COMMENTS	QUARRY INTERCEPTOR TRENCH OBSERV. WELL
LOCATION	QUARRY-N. OF SLOUGH/S. OF KATY TRAIL
DRILLING CONTRACTOR	LAYNE WESTERN INC.
DRILL RIG MAKE & MODEL	CME-750 HSA/NQ CORE/WATER ROTARY
HOLE SIZE & METHOD	10" HSA to 14.0', then 6" rotary
ANGLE FROM HORIZONTAL & BEARING	90
DRILL FLUIDS & ADDITIVES	water
CASING TYPE, DEPTH, SIZE	N/A
DATE START	04/12/00
DATE FINISH	04/14/00
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	24.9'
BEDROCK	14.0'
WATER LEVELS & DATES	

LITHOLOGY BY: Paul Patchin

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0.0	Auger			CL	0.0 - 4.5' SILTY CLAY, (possible fill) very silty (40%), dark brown (7.5YR3/2) low plasticity, moist, roots, very soft, (pp<.25), CL.	Fill?
	SS-1	17/24"	3			
	SS-2	17/24"	5			
5				CL	4.5 - 6.0' CLAY, slightly silty (15%), medium to high plasticity, color as above, firm (pp=1.75), occasional FeOx blebs, slightly moist, CL.	MO Alluvium
	SS-3	15/24"	16	CH	6.0 - 7.6' CLAY, high plasticity, slightly moist, hard (pp=3.5), very dark grayish brown (10YR3/2), with abundant FeOx blebs which are brown (7.5YR4/4), CH.	
	SS-4	23/24"	4	CL	7.6 - 11.0' SANDY CLAY, approx. 35% very fine to fine sand and silt, color as above, less FeOx blebs, minor angular chert gravel to 15mm, minor silty clay/clayey silt interbedding, moist, soft (pp=1.0), low plasticity, CL.	
10	SS-5	18/24"	3			
				CH	11.0 - 12.0' CLAY, high plasticity, color as above, no sand, trace silt, moist, firm (pp=1.75), minor FeOx mottling, CaCO3 stringers (white), CH.	
	SS-6	22/24"	2	CL	12.0 - 13.0' SANDY CLAY, very dark gray (2.5Y3/1), approx. 40% very fine to fine sand, very moist to wet, very soft (pp<.25), little FeOx, CL.	
				SC	13.0 - 13.8' CLAYEY SAND, dark grayish brown (2.5Y4/2), very fine to fine-grained, wet, abundant FeOx blebs, very loose, approx. 35% fines, poorly graded, SC.	
				CL	13.8 - 14.0' CLAY, medium plasticity, color as above, very moist, some sand and silt, very soft (pp<.25), CL.	
15	Run-1	120/120"	77	ls shl	14.0 - 23.99' INTERBEDDED LIMESTONE AND SHALE, approx 80% LS and 20% Shale. Limestone is light olive gray (5Y6/1), very finely crystalline very fossiliferous, very thin to thin-bedded (some squeeze-type bedding), closely fractured (2.5-8"), slightly weathered with some FeOx staining on fractures and clay coatings, hard. Shale is olive gray (5Y4/1) with occas. olive black (5Y2/1) carbonaceous beds, very thin bedded (stringer to 25mm) wavy bedded, fossiliferous bands included into shale, hard, slightly weathered, [DECORAH GROUP]	Odg
20						
				shl	23.99 - 24.0' SHALE, dark greenish gray, (5G4/1), soft, fissile, moderately weathered, [DECORAH GROUP]	
25					Total cored depth 24.0 feet. Reamed hole to 6" to 24.9' and installed 2" monitoring well.	
					Note: Soil color is indexed on the Muncell soil color chart. Rock color is from the GSA rock color chart.	
30					Note: All soil samples were scanned with a Ludlum Model 44-9 scinillometer. No samples were above background.	
					CONSTANT HEAD SINGLE PACKER TEST RESULTS: 16.2 - 24.0 ft. K=2.81E-4 cm/sec	
35						

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▽average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BORKEHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	OW-5
SHEET 1 OF 1	
NORTH (Y):	1028341.32
EAST (X):	748236.02
TOC ELEVATION	458.36
GROUND ELEVATION	454.67
STICKUP	3.69
HYDR CONDUCTIVITY (cm/sec)	

WELL STATUS/COMMENTS: QUARRY INTERCEPTOR TRENCH OBSERV. WELL	LOCATION: QUARRY-NORTH OF SLOUGH
DRILLING CONTRACTOR: LAYNE WESTERN INC.	DRILL RIG MAKE & MODEL: CME-750 ALL-TERRAIN
HOLE SIZE & METHOD: 7-1/4" HSA, 2" SS Sampler	ANGLE FROM HORIZONTAL & BEARING: 90
DRILL FLUIDS & ADDITIVES: None	CASING TYPE, DEPTH, SIZE: N/A
DATE START: 03/31/00	DATE FINISH: 03/31/00

DEPTH (FT.) FROM GROUND ELEV. TO:

- BOTTOM OF HOLE (TD): 21.0
- BEDROCK: 21.0
- WATER LEVELS & DATES: ▽ ▼

LITHOLOGY BY: Paul Patchin

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class
SS-1	15/23"	3	CL
SS-2	14/24"	2	
SS-3	19/24"	2	CL, ML
SS-4	24/24"	1	CL
SS-5	24/24"	0	ML, SM, CL/CH, ML
SS-6	22/24"	0	CL, CH
SS-7	24/24"	0	CL
SS-8	24/24"	0	CH
SS-9	19/24"	2	
SS-10	24/24"	0	
SS-11	11/12"	72	ML, SC/CL, GC

STRAT. UNIT: NO Alluvium

DESCRIPTION AND REMARKS

0.0 - 3.0' **SILTY CLAY**, dark grayish brown (10YR4/2), ~20% silt, medium plasticity, moist, soft, rootlets with FeOx replacement of roots, **CL**.

3.0 - 4.2' **SILTY CLAY**, increased silt (to~45%) brown (10YR4/3), moist, very soft (pp=<.25), rootlets, MnOx & FeOx blebs, silt as light-colored pockets and interbeds, **CL**.

4.2 - 5.3' **CLAYEY SILT**, brown (10YR4/3), low plasticity, very soft (pp<.25), very moist, FeOx mottling, minor v. fine sand, **ML**.

5.3 - 7.5' **SILTY CLAY**, as in 3.0 - 4.2 ft., **CL**.

7.5 - 7.7' **CLAYEY SILT**, as in 4.2 - 5.3 ft., **ML**.

7.7 - 7.9' **SILTY SAND**, very fine grained, poorly graded, wet, very loose, abundant FeOx, **SM**.

7.9 - 8.3' **CLAY**, medium plasticity, very dark grayish brown (2.5Y3/2), black organics, very soft (pp<.25), very moist to wet, sand pockets (very fine), reduced zone at 7.9', **CL/CH**.

8.3 - 8.7' **CLAYEY SILT**, color as above, minor sand, wet, very soft (pp<.25), **ML**.

8.7 - 10.3' **SILTY CLAY**, very dark grayish brown (10YR3/2), approx. 30% silt, minor sand lenses (2mm), with lignitic bands, very moist, to wet, **CL**.

10.3 - 11.1' **CLAY**, high plasticity, very soft (pp<.25), 20% silt, very moist to wet, **CH**.

11.1 - 14.4' **SILTY CLAY**, low to medium plasticity, soft (pp=.5), very dark grayish brown (2.5Y3/2), sand pockets/lenses to .3', approx. 20% silt and 20% fine sand as lenses and interbeds, very moist to wet, **CL**.

14.4 - 20.0' **HIGH PLASTICITY CLAY**, dark gray (2.5Y4/1), moldable, pockets (to 1") of clean, very fine sand, wet, silty sandy clay from 16.9 - 17.3' and 18.0 - 18.5', very soft (pp<.25), minor organic bands, **CH**.

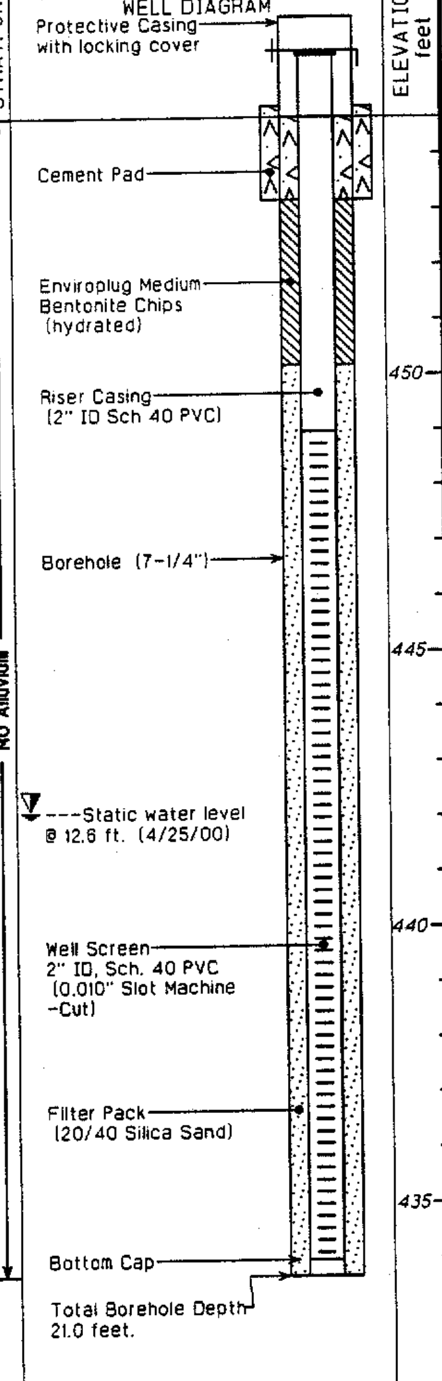
20.0 - 20.5' **SANDY SILT**, very soft, **ML**.

20.5 - 20.8' **CLAYEY SAND/SANDY CLAY**, dark gray (2.5Y4/1), approx. 50/50 sand and clay, poorly sorted very fine sand, **SC/CL**.

20.8 - 21.0" **CLAYEY GRAVEL**, (bedrock residuum), limestone gravel in clay, **GC**.

Auger Refusal and Total Depth @ 21.0 feet (top of rock). Installed 2" monitoring well.

Note: Soil color is indexed on the Muncell soil color chart.



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT
BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	OW-6
SHEET 1 OF 1	
NORTH (Y):	1028290.91
EAST (X):	748260.61
TOC ELEVATION	458.45
GROUND ELEVATION	454.74
STICKUP	3.71
HYDR CONDUCTIVITY (cm/sec)	

WELL STATUS/COMMENTS	QUARRY INTERCEPTOR TRENCH OBSERV. WELL
LOCATION	QUARRY-NORTH OF SLOUGH
DRILLING CONTRACTOR	LAYNE WESTERN INC.
DRILL RIG MAKE & MODEL	CME-750 ALL-TERRAIN
HOLE SIZE & METHOD	7-1/4" HSA, 2" SS Sampler
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD)	20.0
DRILL FLUIDS & ADDITIVES	None
CASING TYPE, DEPTH, SIZE	N/A
BEDROCK	Not Encountered
DATE START	04/04/00
DATE FINISH	04/04/00
WATER LEVELS & DATES	
LITHOLOGY BY	Paul Patchin

DEPTH (FT.) FROM GROUND ELEV. TO:

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class
SS-1	21/23"	0	CL
SS-2	17/24"	0	
SS-3	24/24"	0	CL/ML
SS-4	12/24"	1	
SS-5	13/24"	5	SP
SS-6	17/24"	2	CH, CL, SP
SS-7	24/24"	0	CH, CL, CH
SS-8	24/24"	1	CL, CH
SS-9	24/24"	1	SW, CH
SS-10	22/24"	5	SP

STRAT. UNIT: NO ALLUVIUM

DESCRIPTION AND REMARKS

0.0 - 4.3' **SILTY CLAY**, brown (10YR4/3), approx. 40% silt in matrix and as interbeds, low plasticity, moist, soft (pp=.5), FeOx and MnOx blebs, silt lenses are lighter color, **CL**.

4.3 - 7.0' **SILTY CLAY/SILT**, approx. equal amounts of each with approx. 20% fine sand throughout, dark grayish brown (10YR4/2), very moist, wet from 4.5-5.5', lenses of fine grained sand at approx. 4.3-4.3', 5.7-5.8', and 6.6-6.8', FeOx stain and blebs, minor organics, low plasticity, soft (pp=.5), **CL/ML**.

7.0 - 10.0' **POORLY GRADED SAND**, fine grained, very loose, moist, with occasional (10%) clay-rich lenses, olive brown (2.5Y4/3), poorly graded, 5% dark organics, subrounded to rounded grains, quartzitic, **SP**.

10.0 - 10.5' **CLAY**, highly plastic (moldable), dark gray (10YR4/1), soft (pp=.5), CaCO3 concretions, moist, concoidal fracts, occasional dark organics, reduced zone @approx. 10', **CH**.

10.5 - 11.0' **SANDY CLAY**, grading from CH to increased sand content, color as above **CL**.

11.0 - 12.0' **POORLY GRADED SAND**, fine to minor very fine grained, very dark gray (10YR3/1), some clay/fines, quartzitic, rounded, minor black minerals/organics, **SP**.

12.0 - 12.4' **CLAY**, high plasticity as in 10.0-10.5', **CH**.

12.4 - 12.7' **SILTY SANDY CLAY**, (approx. equal amounts of clay/silt/sand very thinly-bedded together) with abundant organics (coalified wood),**CL**.

12.7 - 14.1' **CLAY**, high plasticity, dark gray (2.5Y4/1), occasional sand lenses and silty zones up to 1", moist, soft (pp=.5), sand lenses are medium-grained to coarse, with coalified wood chips, **CH**.

14.1 - 14.4' **SANDY CLAY**, color as above, fine to coarse sand (40%), and organics **CL**.

14.4 - 16.2' **CLAY**, high plasticity (moldable), dark gray (5Y4/1), soft (pp=.5), little to no silty zones, **CH**.

16.2 - 16.9' **SAND**, medium to minor coarse-grained, loose, rounded, quartzitic, trace of organics, **SW**.

16.9 - 18.2' **CLAY**, high plasticity as in 14.4-16.2", **CH**.

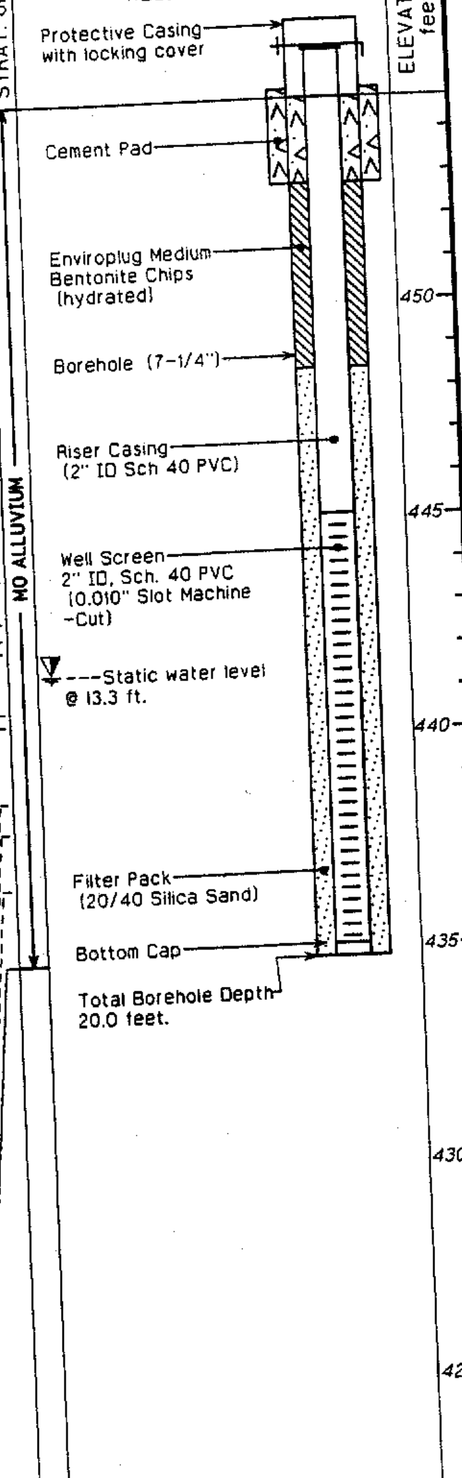
18.2 - 20.0' **SAND**, very fine to minor fine-grained, dark gray (5Y4/1), wet, loose, abundant black organics, (~15%), flowing sand heaved up to 6 ft. below ground surface, **SP**.

Total Depth @ 20.0 feet (bedrock not encountered). Installed monitoring well.

Note: Soil color is indexed on the Muncell soil color chart.

Note: All soil samples were scanned with a Ludlum Model 44-9 scinillometer. No samples were above background.

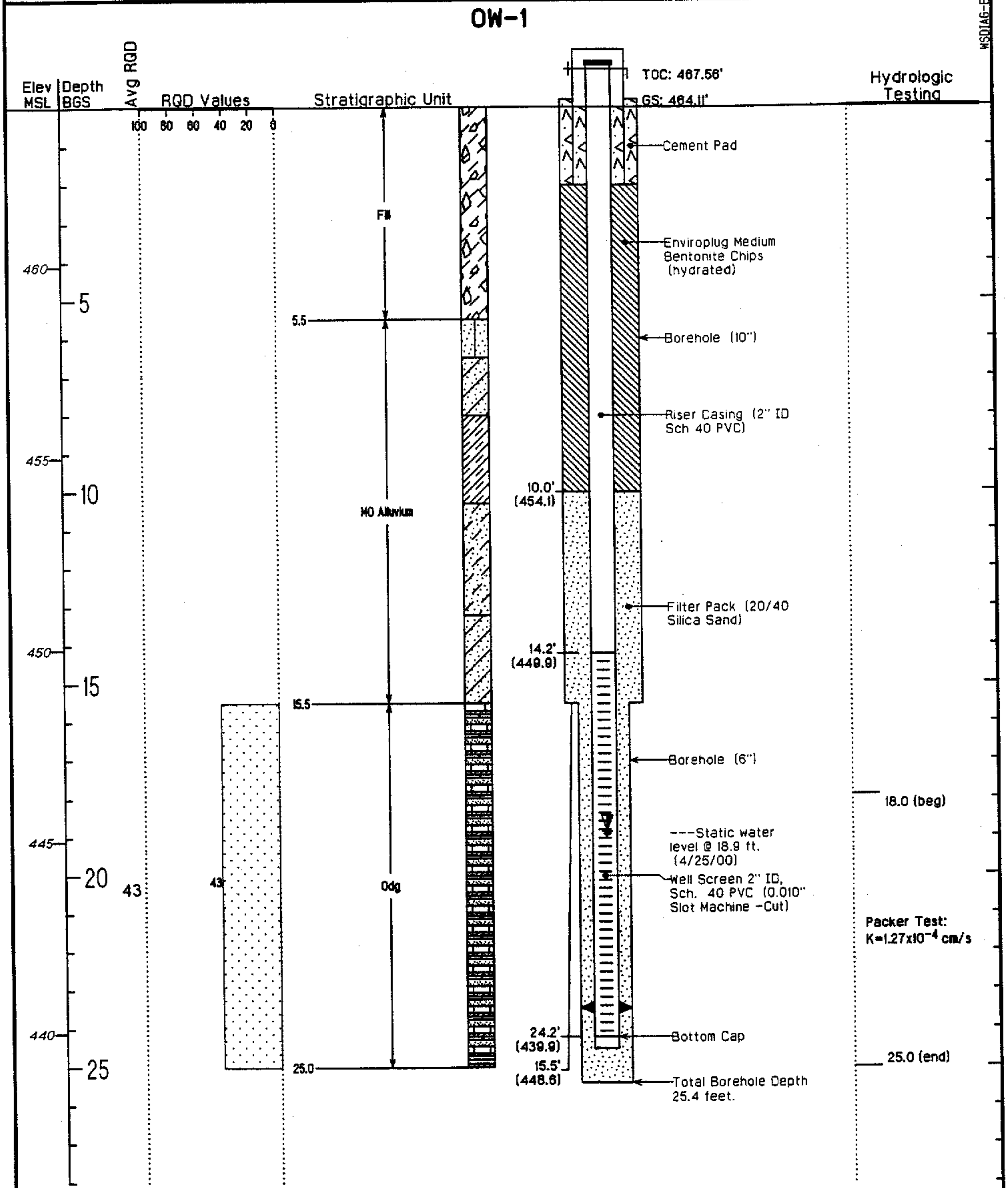
WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▽average

BOREHOLE DIAGRAM

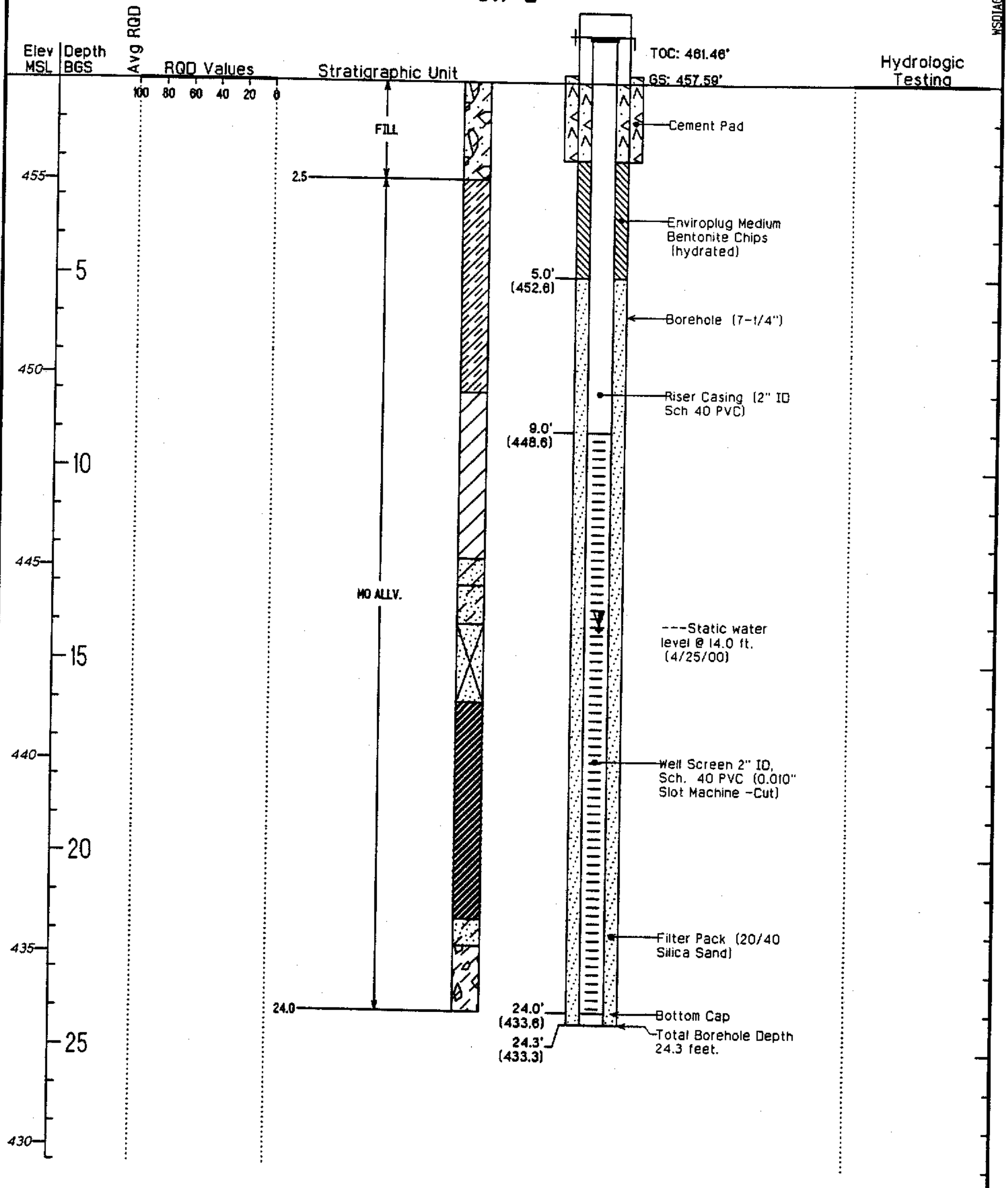
OW-1



▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

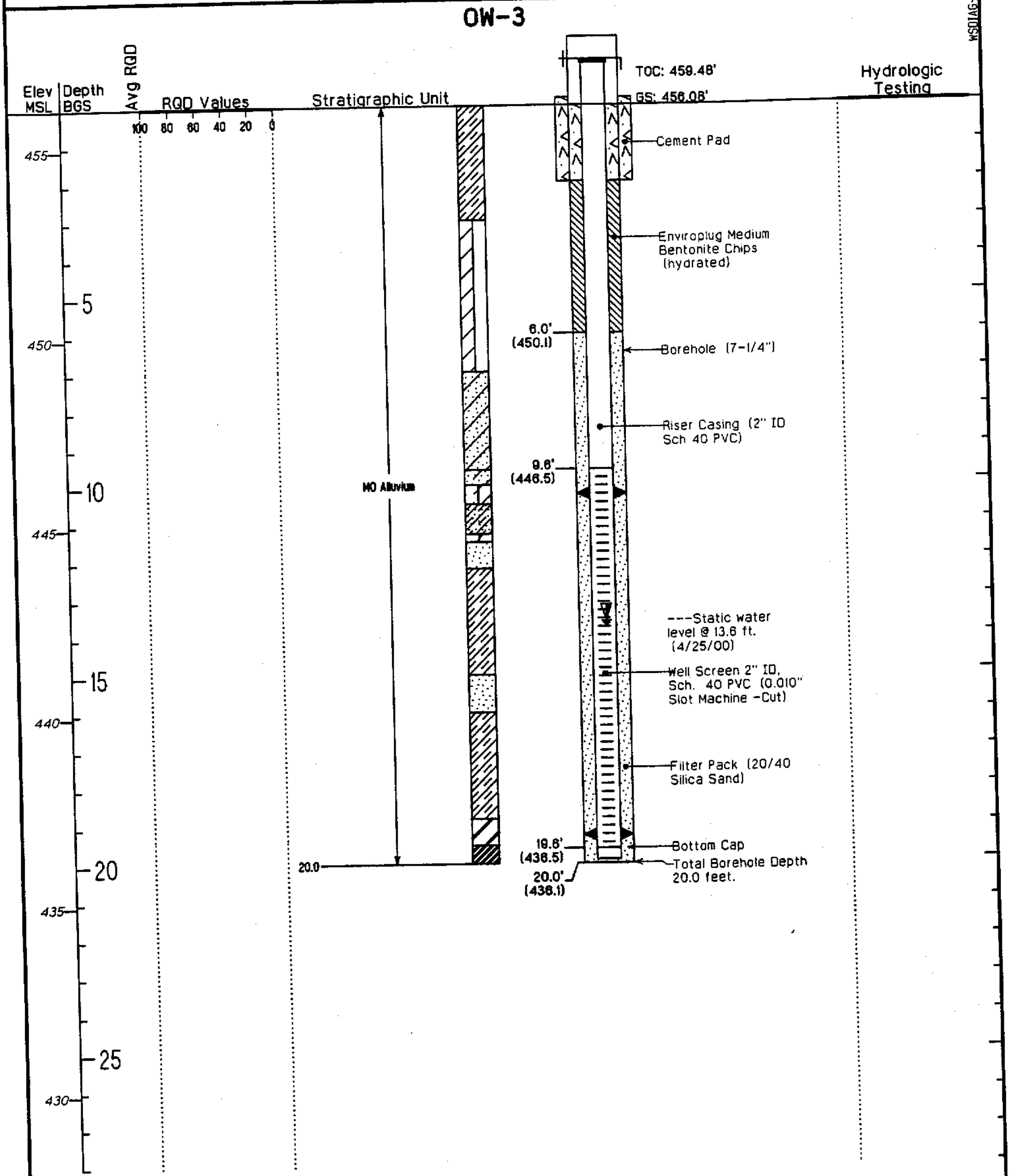
OW-2



▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

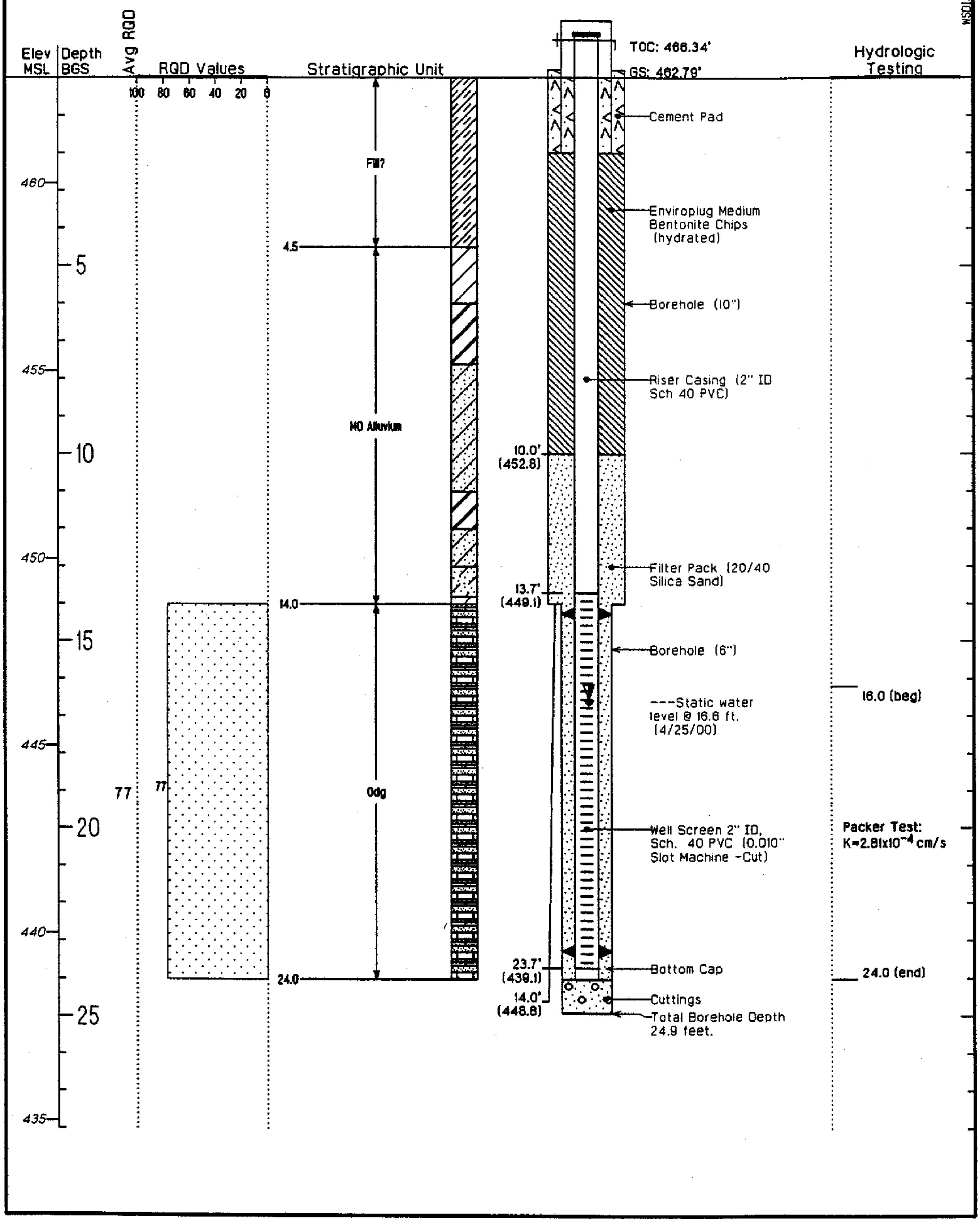
OW-3



▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

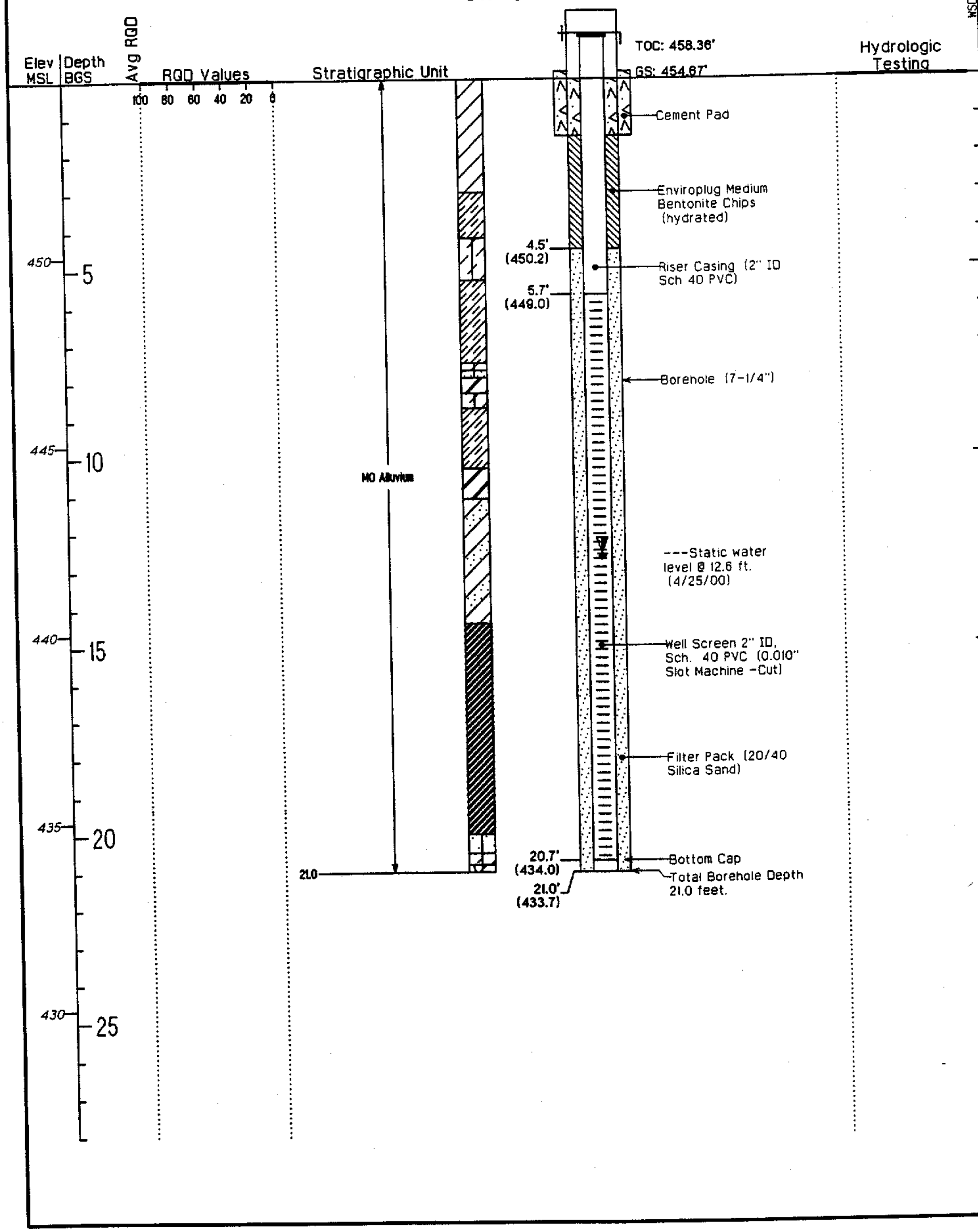
OW-4



▽minimum ▼maximum ▼average

BOREHOLE DIAGRAM

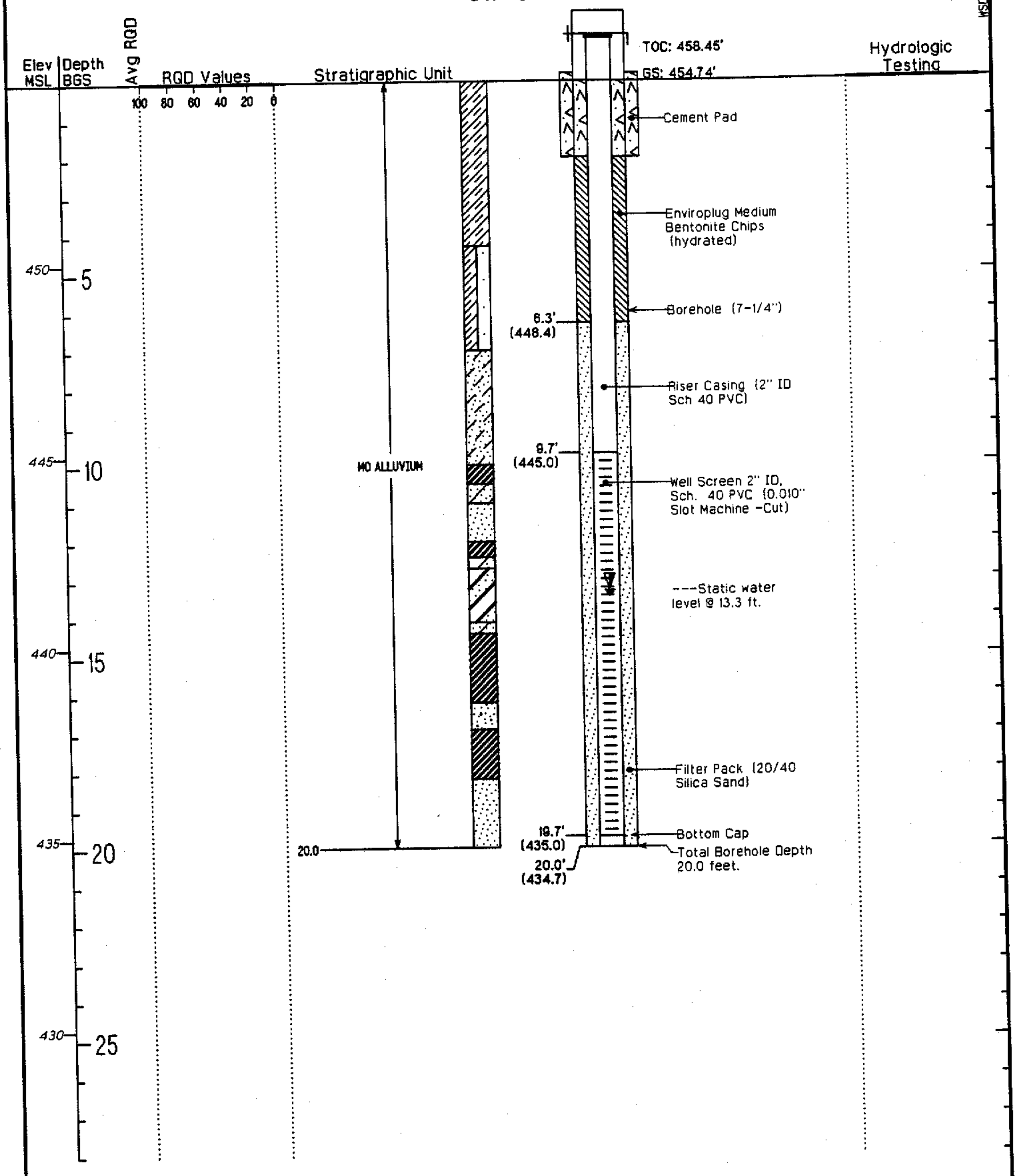
OW-5



▽minimum ▼maximum ▼average

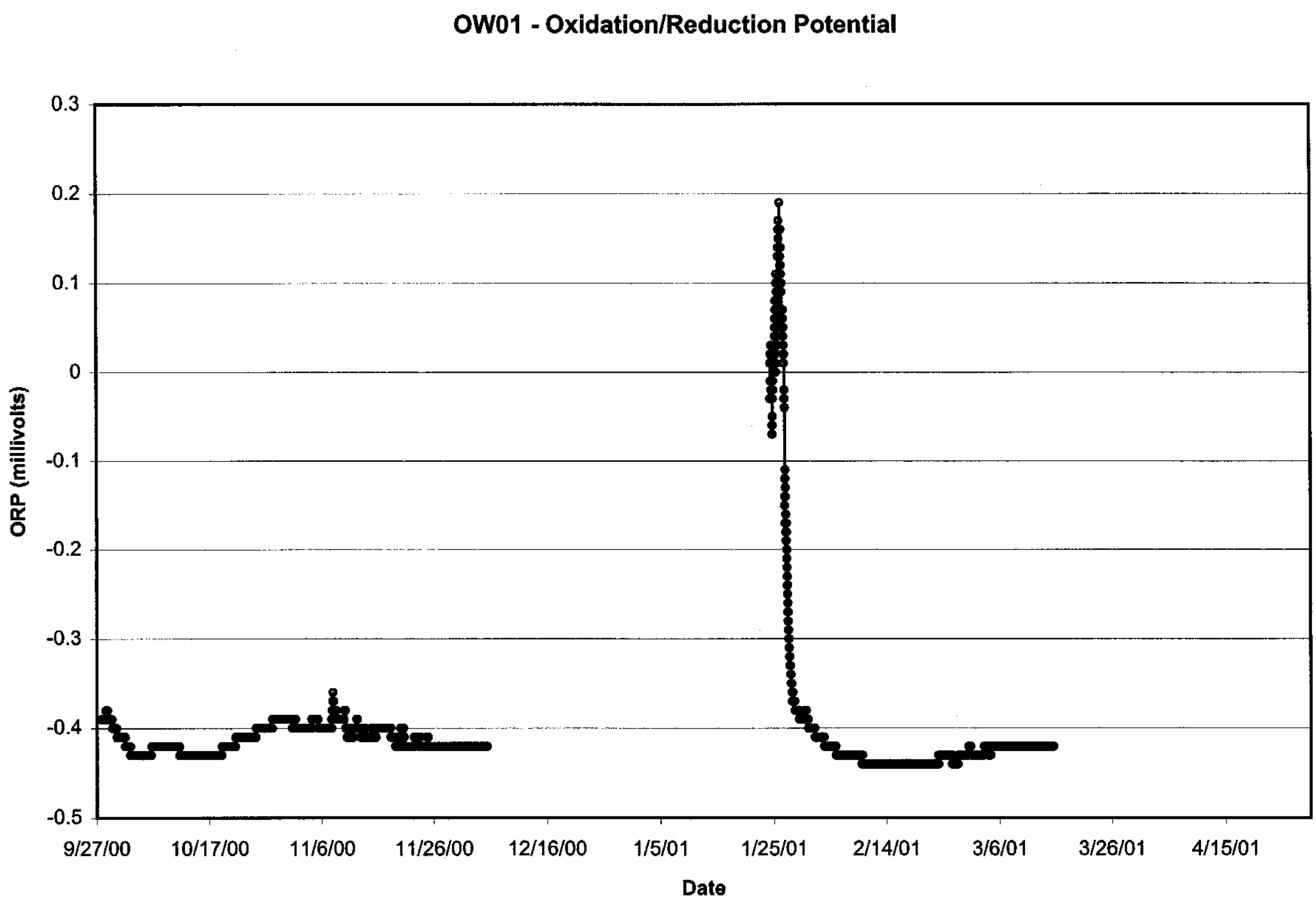
BOREHOLE DIAGRAM

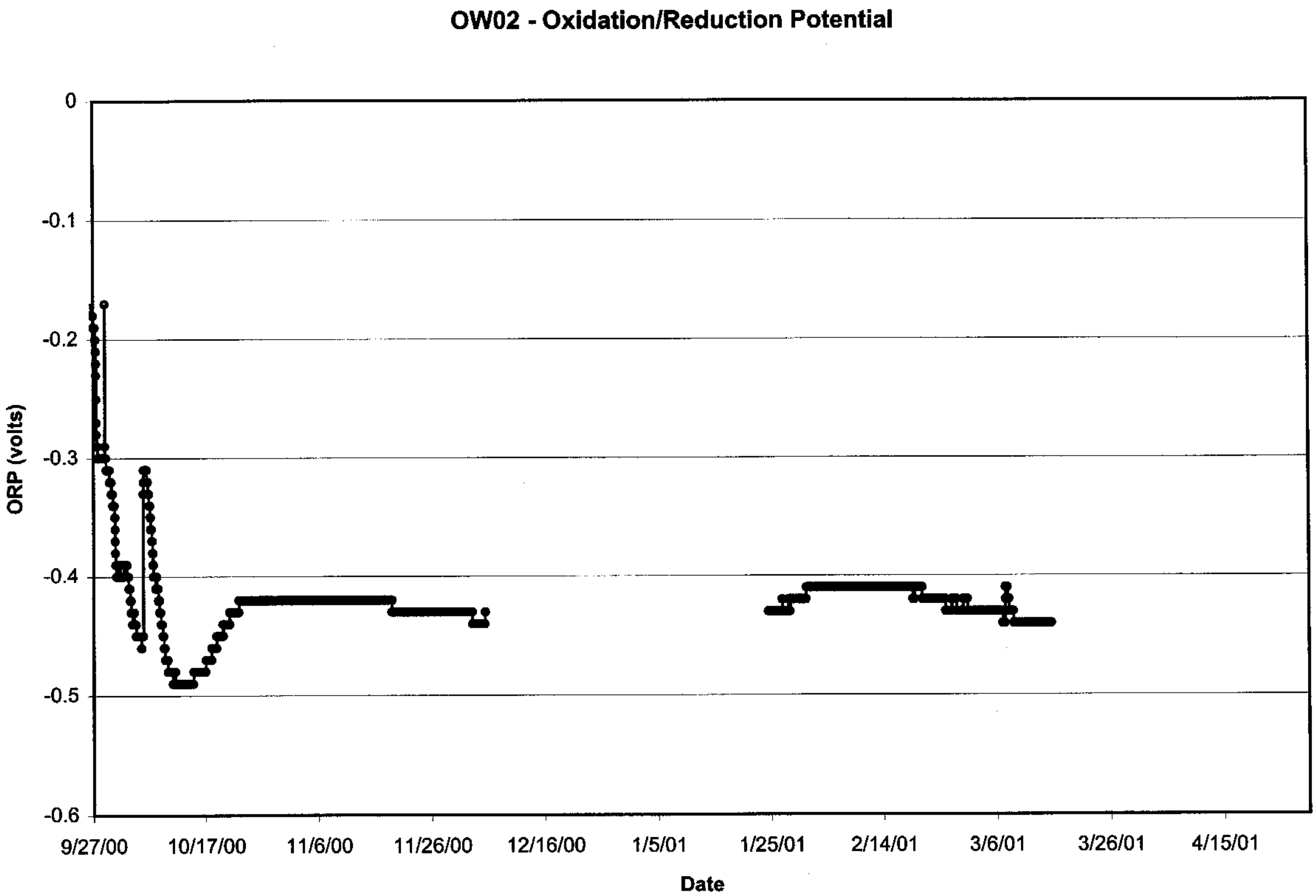
OW-6

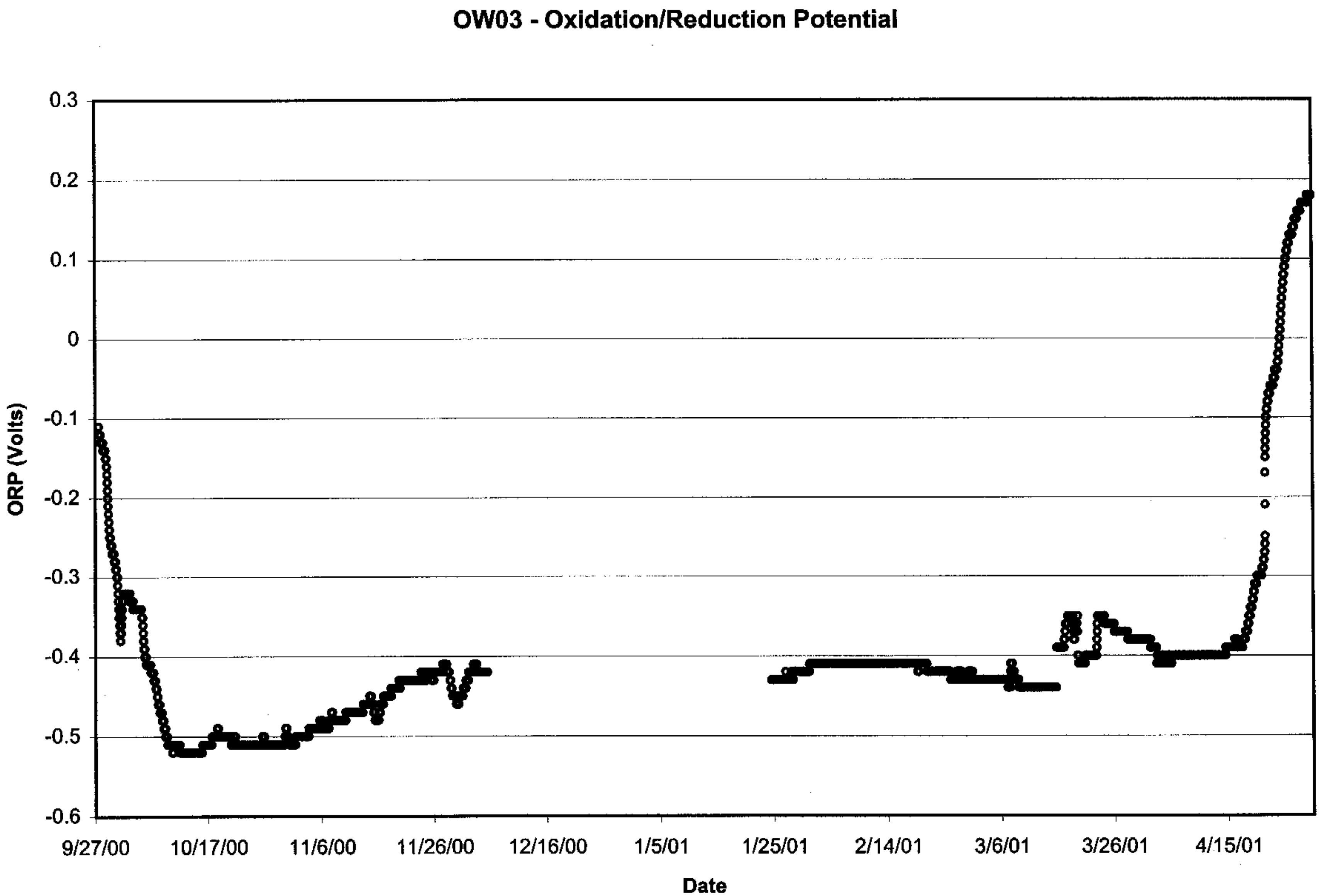


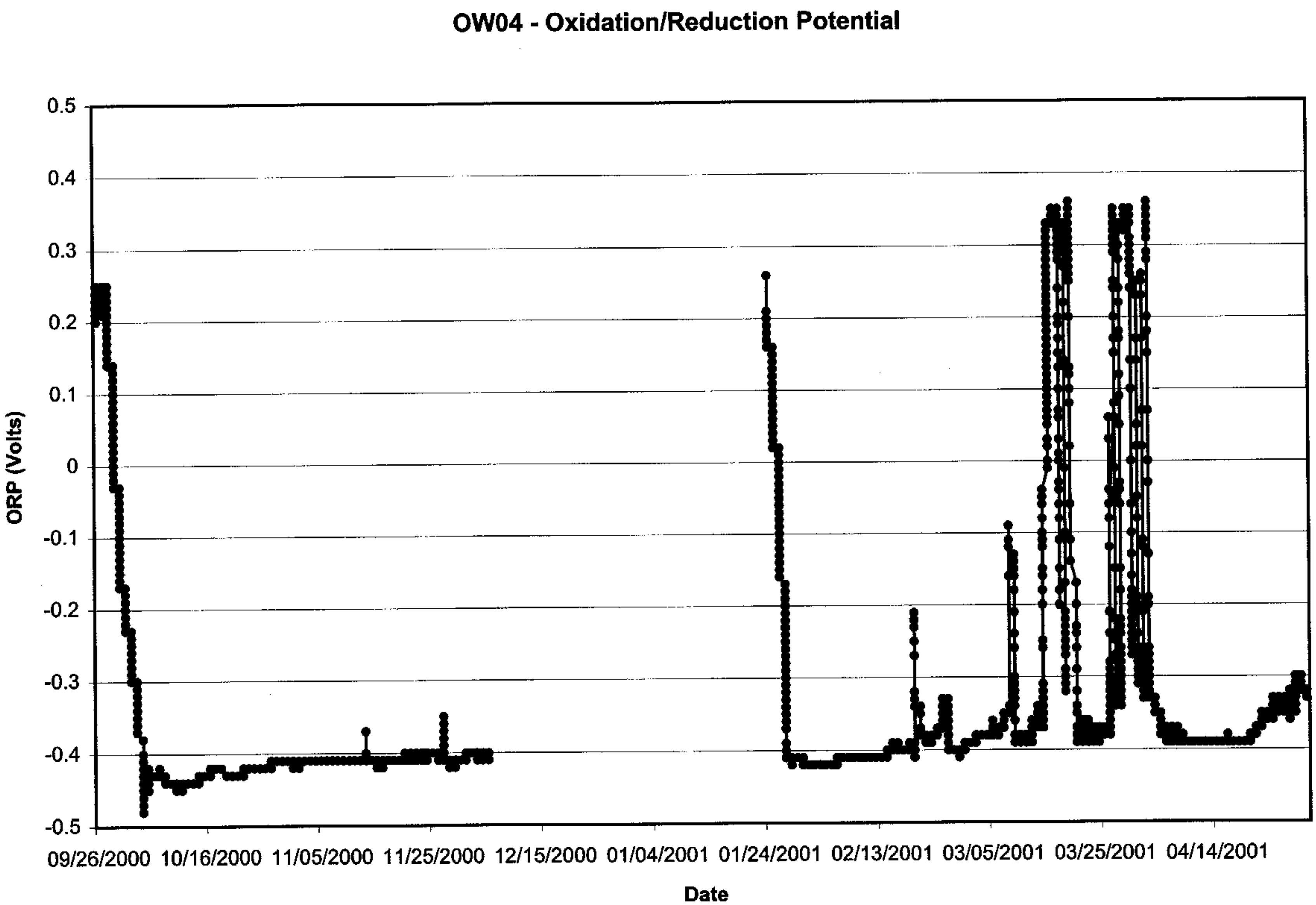
minimum maximum average

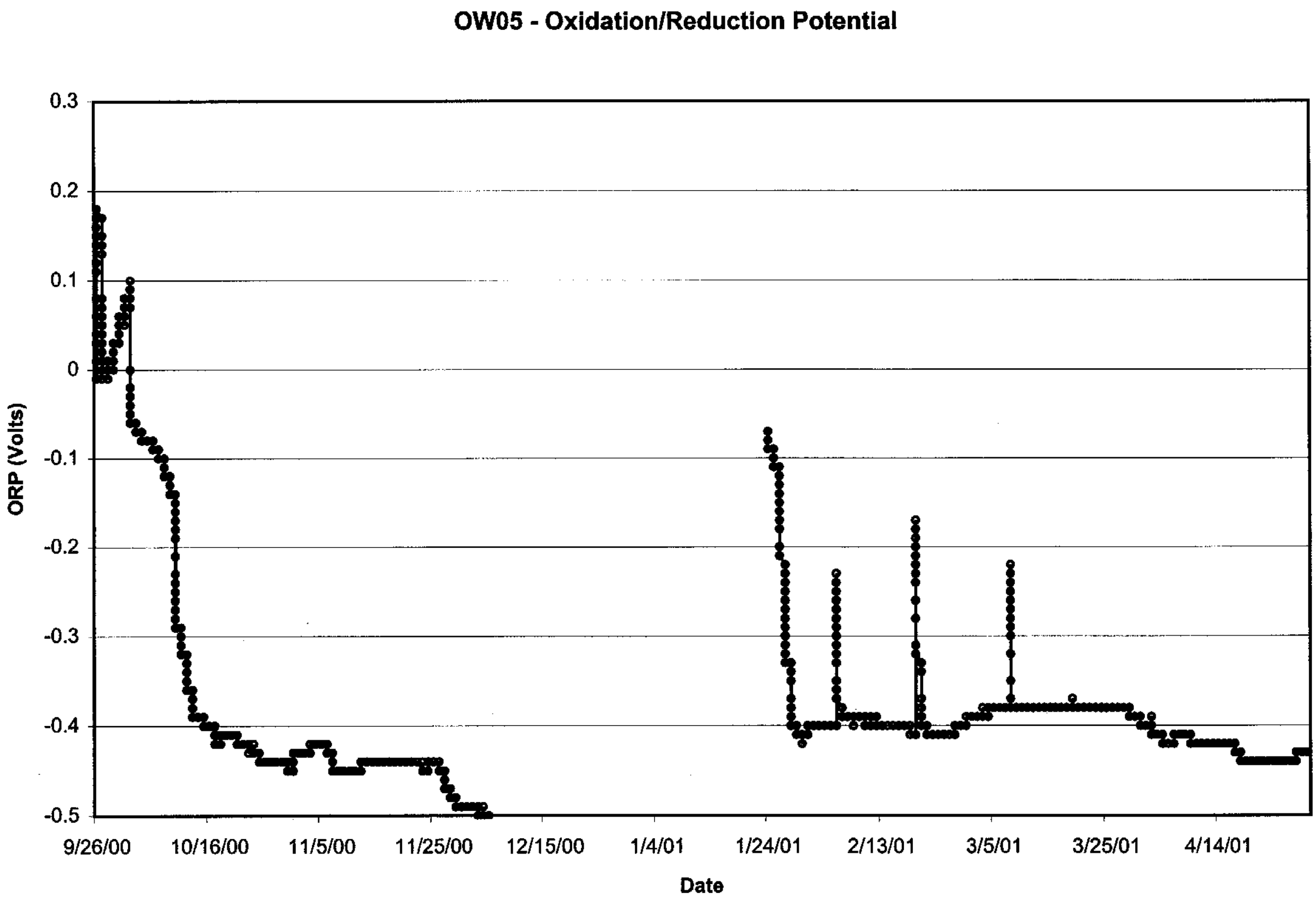
APPENDIX C
Dissolved Oxygen and Oxidation-Reduction Potential Graphs


OW01 - Oxidation/Reduction Potential
ORP (millivolts)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
9/27/00
10/17/00
11/6/00
11/26/00
12/16/00
1/5/01
1/25/01
2/14/01
3/6/01
3/26/01
4/15/01
Date


OW02 - Oxidation/Reduction Potential
ORP (volts)
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
9/27/00
10/17/00
11/6/00
11/26/00
12/16/00
1/5/01
1/25/01
2/14/01
3/6/01
3/26/01
4/15/01
Date

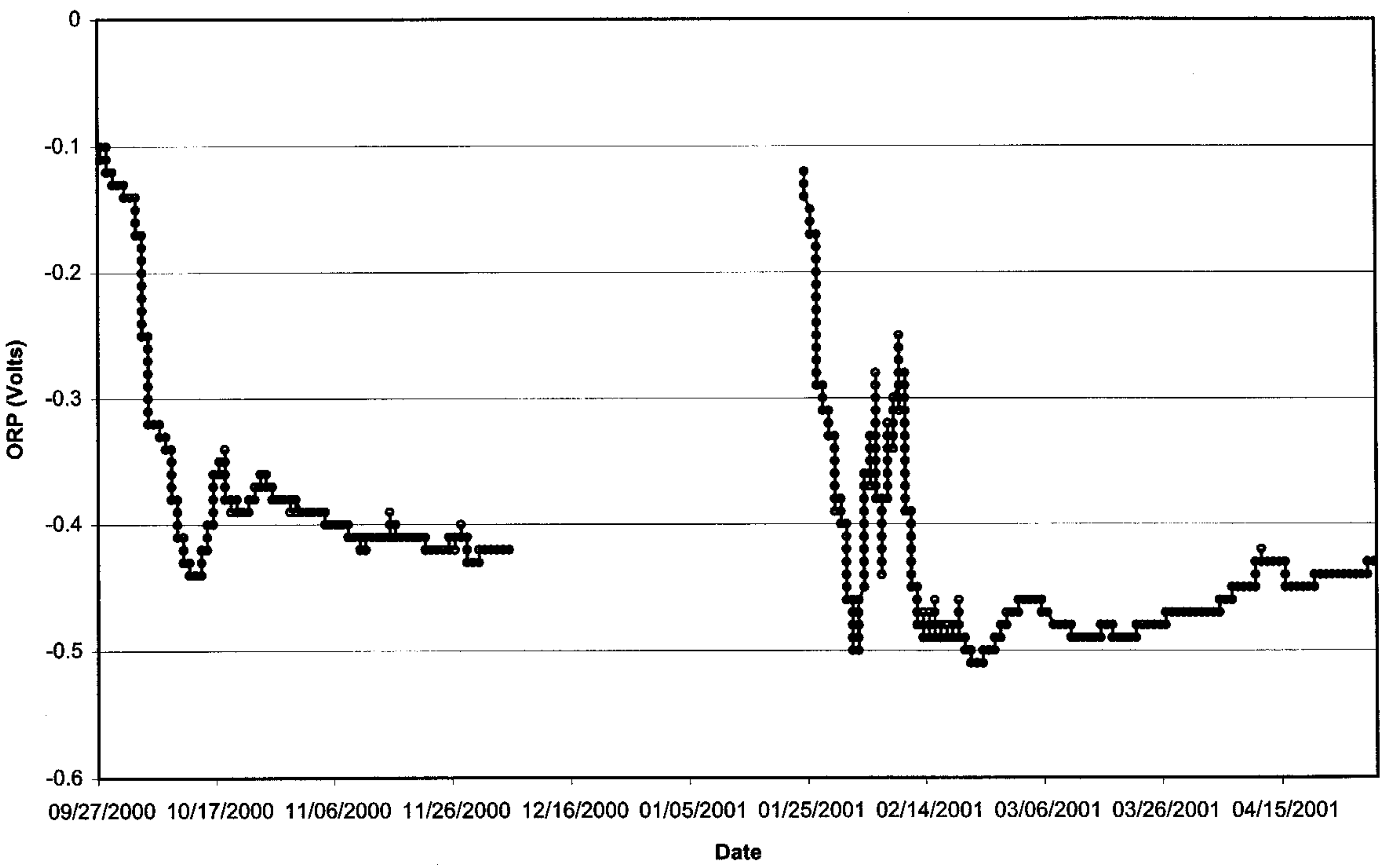

OW03 - Oxidation/Reduction Potential
ORP (Volts)
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
9/27/00
10/17/00
11/6/00
11/26/00
12/16/00
1/5/01
1/25/01
2/14/01
3/6/01
3/26/01
4/15/01
Date

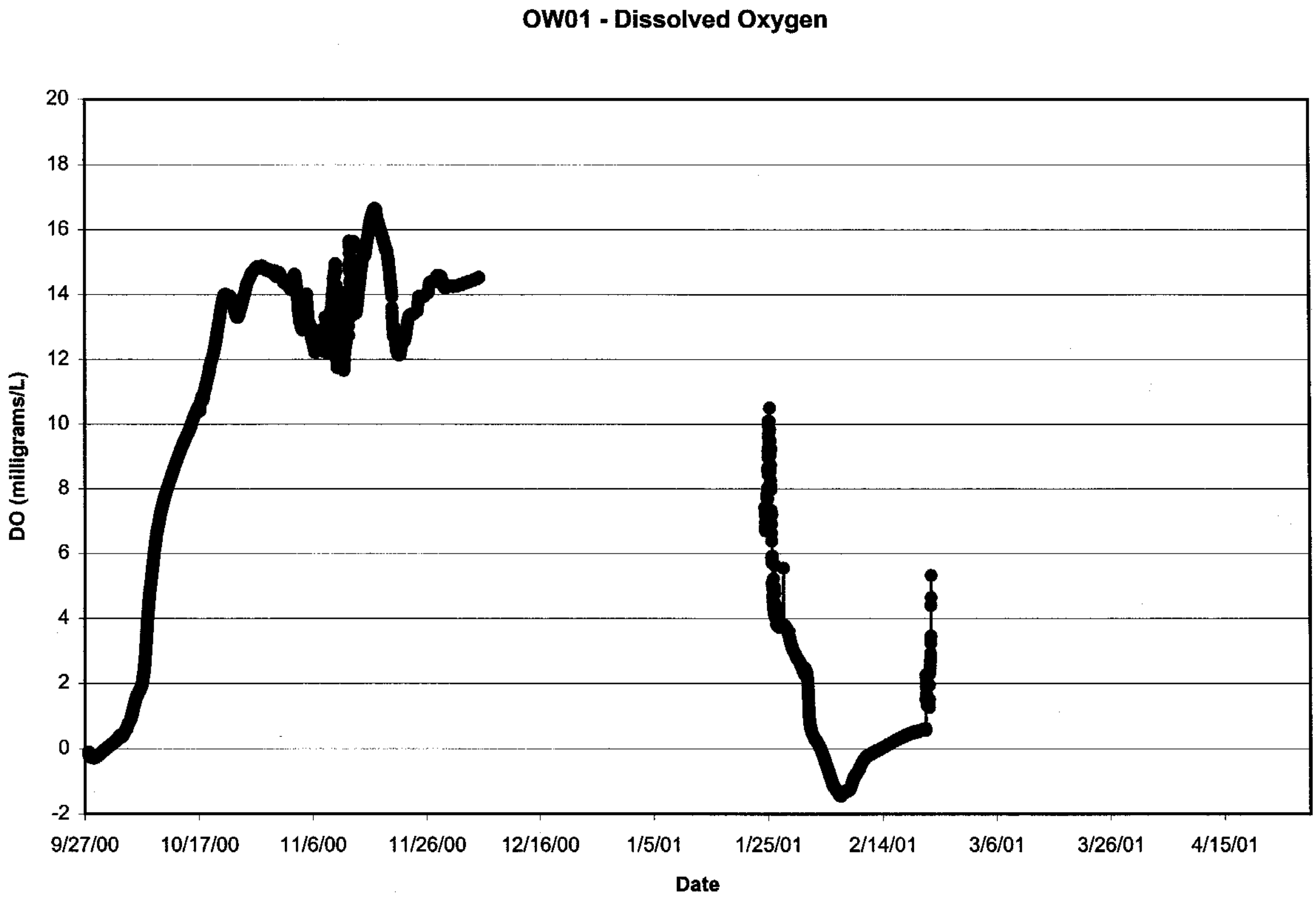

OW04 - Oxidation/Reduction Potential
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
ORP (Volts)
09/26/2000
10/16/2000
11/05/2000
11/25/2000
12/15/2000
01/04/2001
01/24/2001
02/13/2001
03/05/2001
03/25/2001
04/14/2001
Date

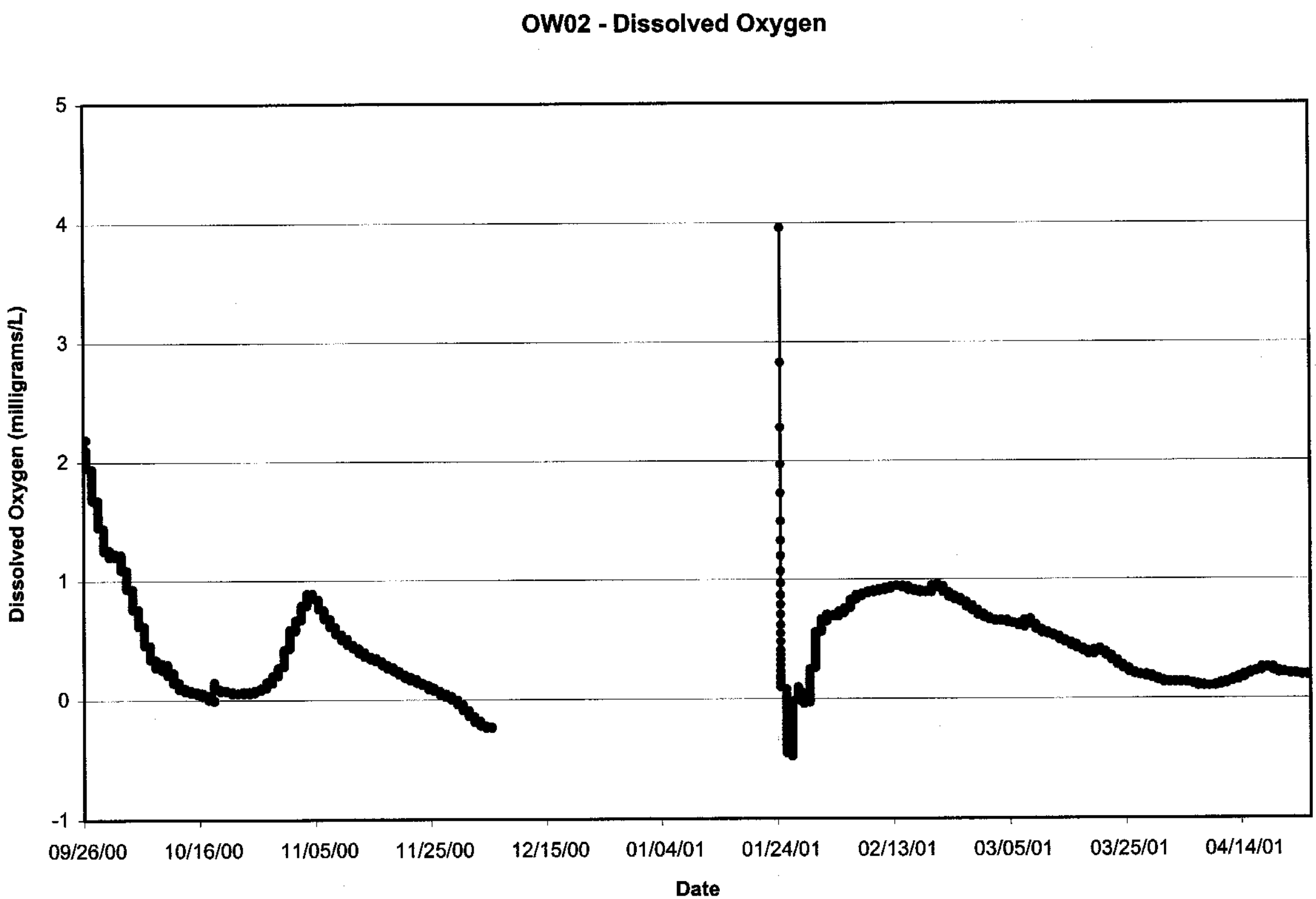


OW05 - Oxidation/Reduction Potential
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
ORP (Volts)
9/26/00
10/16/00
11/5/00
11/25/00
12/15/00
1/4/01
1/24/01
2/13/01
3/5/01
3/25/01
4/14/01
Date

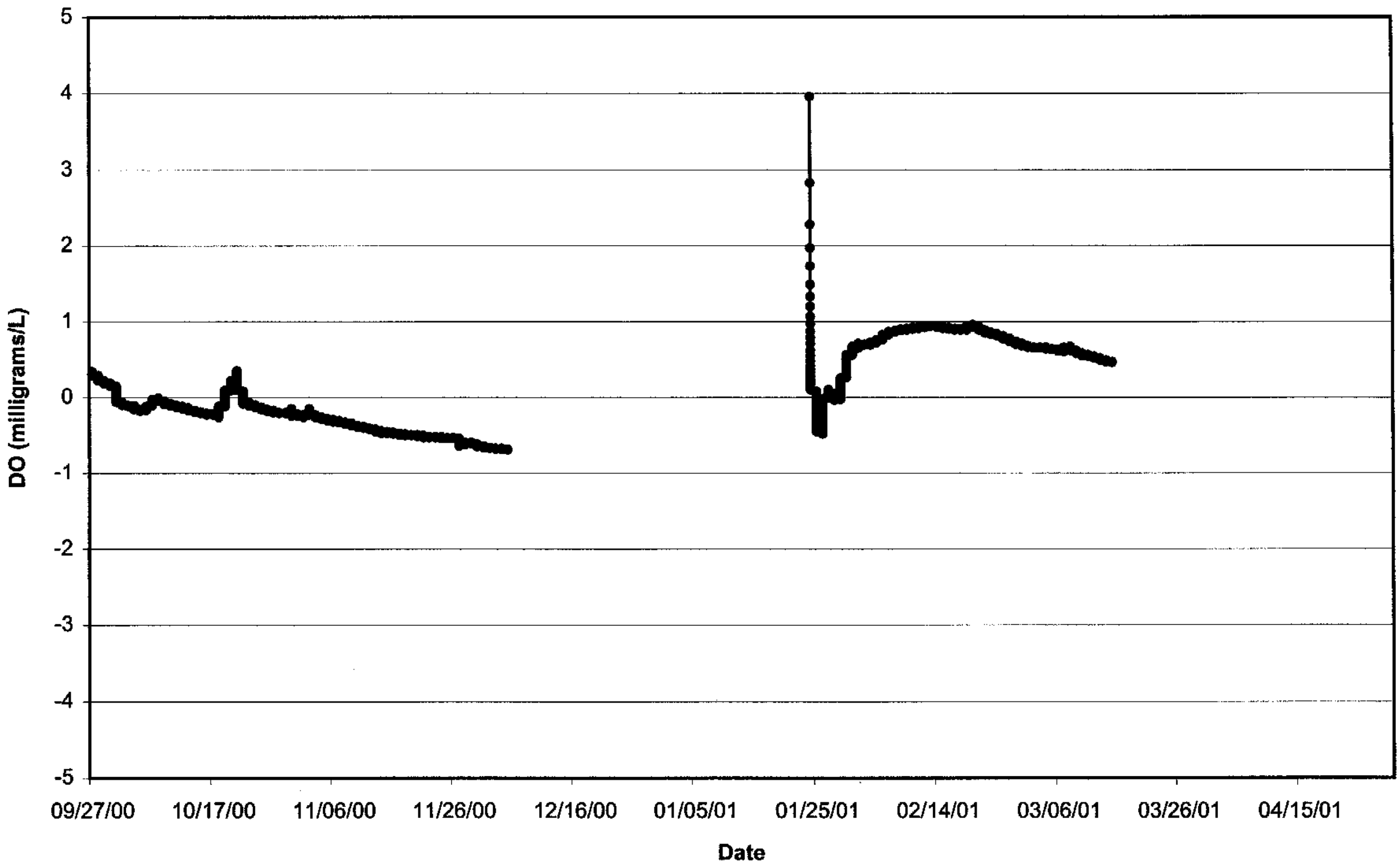
OW06 - Oxidation/Reduction Potential

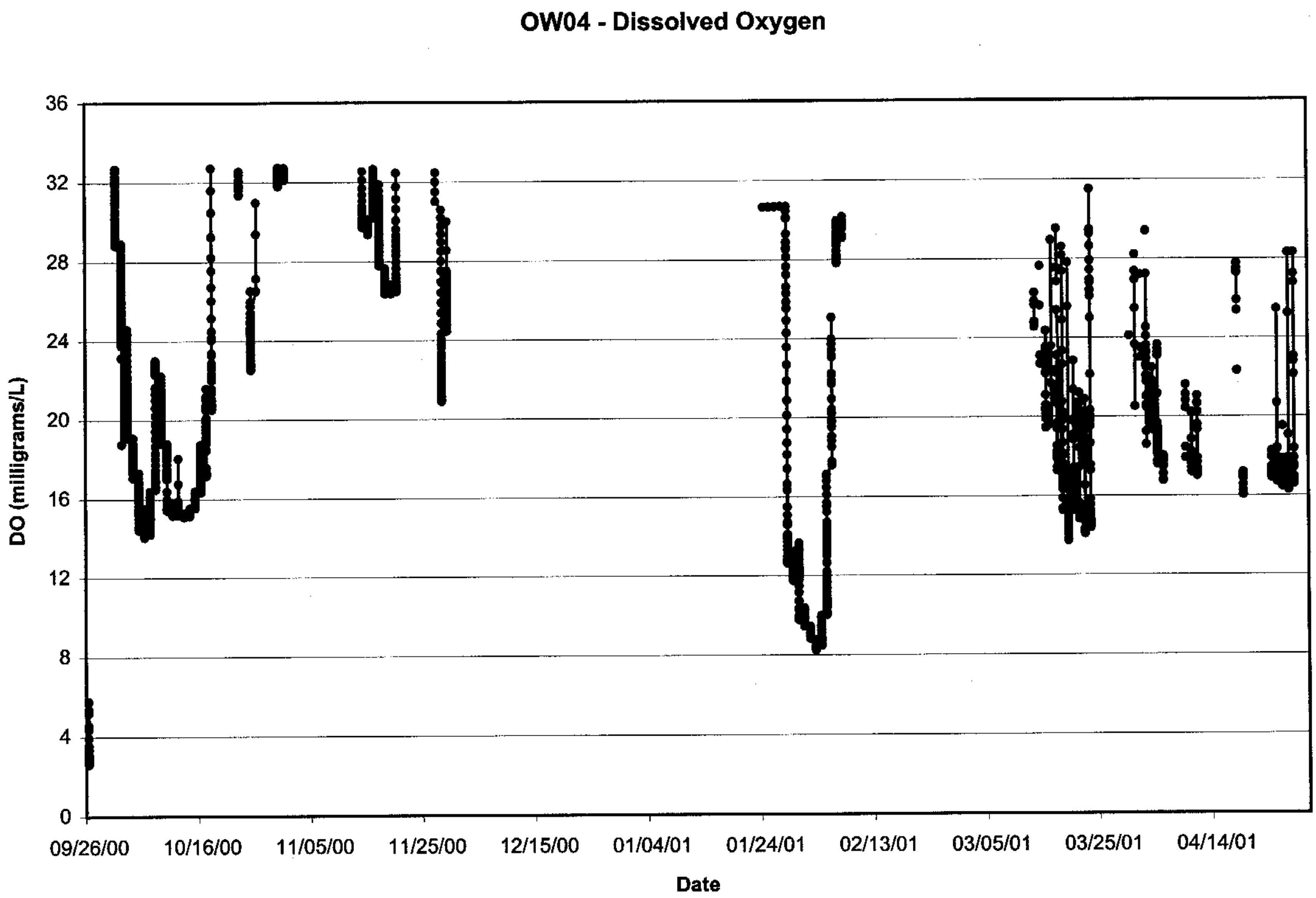


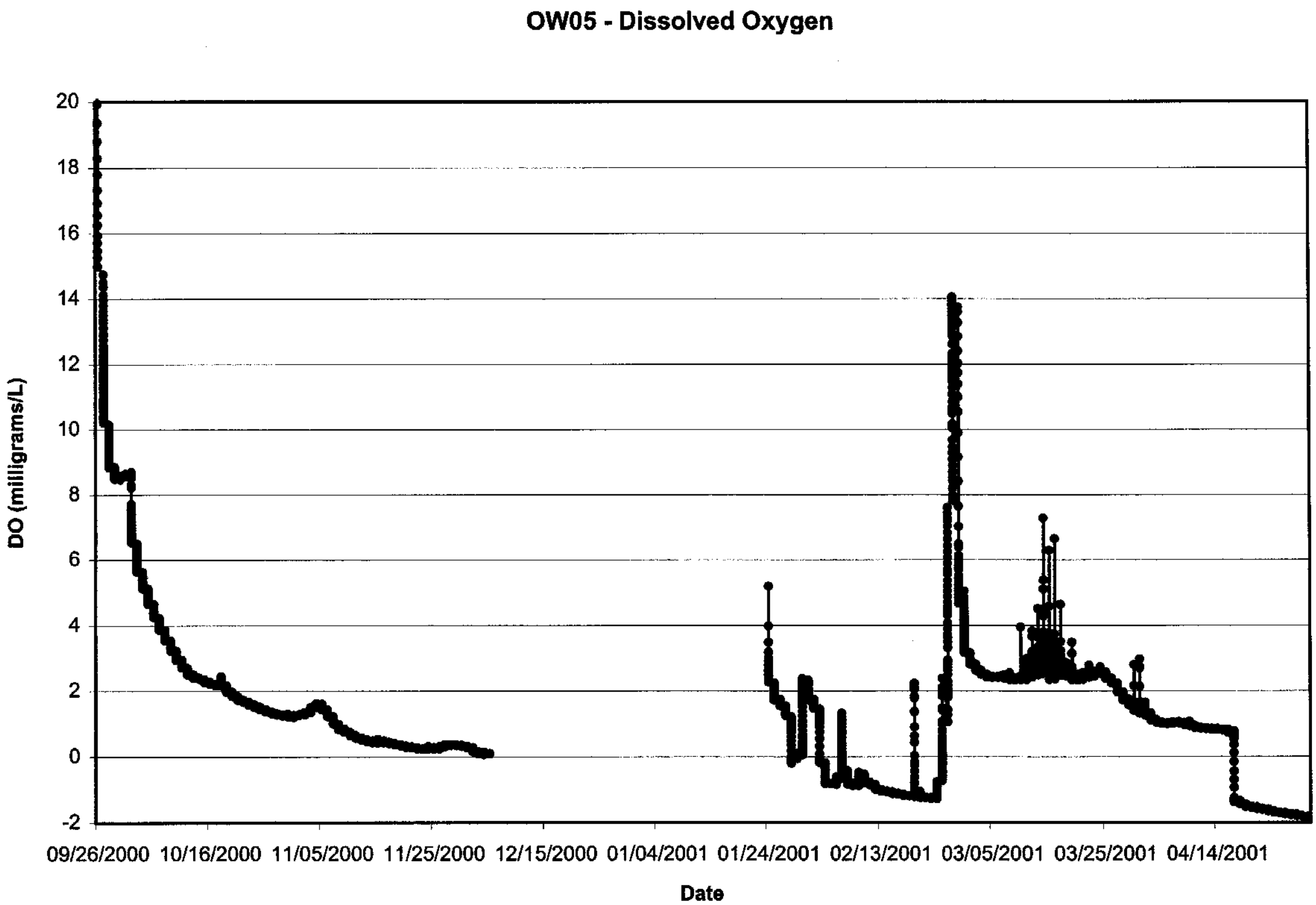

OW01 - Dissolved Oxygen
DO (milligrams/L)
20
18
16
14
12
10
8
6
4
2
0
-2
9/27/00
10/17/00
11/6/00
11/26/00
12/16/00
1/5/01
1/25/01
2/14/01
3/6/01
3/26/01
4/15/01
Date


OW02 - Dissolved Oxygen
Dissolved Oxygen (milligrams/L)
5
4
3
2
1
0
-1
09/26/00
10/16/00
11/05/00
11/25/00
12/15/00
01/04/01
01/24/01
02/13/01
03/05/01
03/25/01
04/14/01
Date

OW03 - Dissolved Oxygen

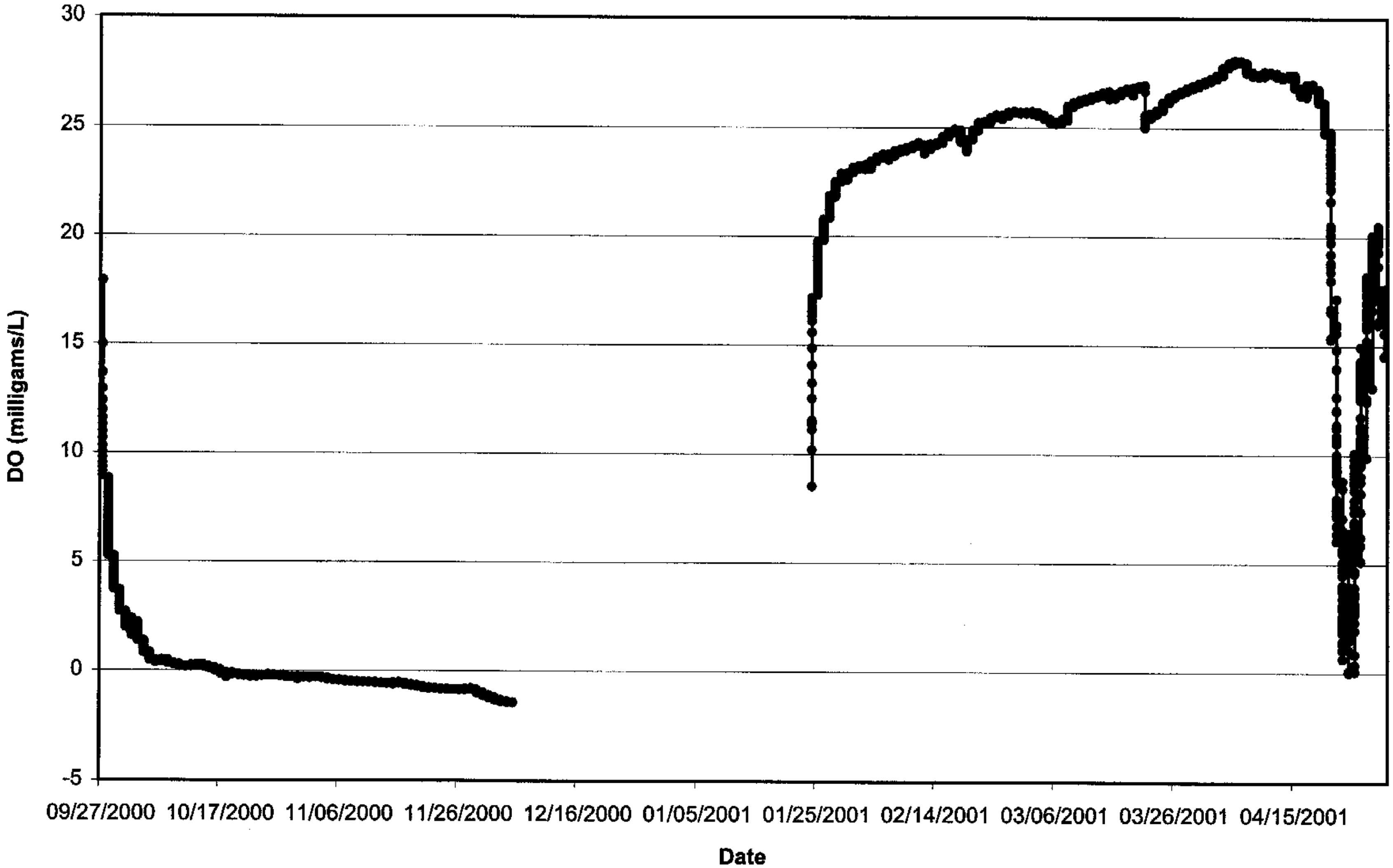



OW04 - Dissolved Oxygen
DO (milligrams/L)
36
32
28
24
20
16
12
8
4
0
09/26/00
10/16/00
11/05/00
11/25/00
12/15/00
01/04/01
01/24/01
02/13/01
03/05/01
03/25/01
04/14/01
Date



OW05 - Dissolved Oxygen
DO (milligrams/L)
20
18
16
14
12
10
8
6
4
2
0
-2
09/26/2000
10/16/2000
11/05/2000
11/25/2000
12/15/2000
01/04/2001
01/24/2001
02/13/2001
03/05/2001
03/25/2001
04/14/2001
Date

OW06 - Dissolved Oxygen



EL# 90419

MK-Ferguson Company
Weldon Spring Site Remedial Action Project

TRANSMITTAL OF CONTRACT DELIVERABLE

Date: August 10, 2001 Transmittal No.: **CD-0269-00**

Title of Document: ***Quarry Interceptor Trench Field Study-First Year Summary***

Doc. Num.: 897 Rev. No.: 0 Date of Document: August, 2001

Purpose of Transmittal: Request for Department of Energy acceptance of contract deliverable.

In compliance with the Project Management Contract, MK-Ferguson Company hereby delivers the attached document to the U.S. Department of Energy, Weldon Spring Site Office. The document has been reviewed and approved by Project Management Contractor management.

The document will be considered accepted unless we receive written notification to the contrary within 30 days of the date of this transmittal.

Number of copies transmitted: 10

Douglas E. Steffen
Project Director