1R - 432

REPORTS

DATE:

2004

1R0432

Executive Summary

B.C. Dickerson Site

Location

The site is situated in Lea County, New Mexico south of US 182 on fee land. The topography is unremarkable. The primary land use of the surrounding property is grazing of cattle however extensive oil and gas operations are present within the area. The area is semi-arid with a net precipitation / pan evaporation amount of -73” per year.

Site History

At this writing, we’ve little history of the location however from the surface features it appears that the site was used as a bulk storage and processing point for crude oil and natural gas. A production pit appears to have been in use as a repository for tank bottoms and the storage of contaminated soils.

Investigation

The site has been extensively cored and a series of eight monitor wells installed to determine the vertical and lateral extent of hydrocarbon and brine contamination. Water analysis of the site reveals the water to be of “non-beneficial” use with TDS concentrations exceeding 1,000 ppm. BTEX concentrations at all monitor wells appear to be within NMOCD guidelines.

The site is characterized by the presence of two plumes of hydrocarbon contamination. The first appears to be centered within the production pit having TPH concentrations of 1,798 ppm extending to a depth of 60’ below ground surface. The contaminant plumes appear to consist mainly of aliphatic fractions with a minor BTEX component. One significant chloride reading (874 ppm) was discovered at the southeast corner of the pit at a depth of 40’ below ground surface. There is no data regarding the chloride concentrations within a monitor well situated approximately 10’ down-gradient of the anomaly.

The soil morphology is initially sandy to a depth of approximately 5-7’ followed by a 12-15’ band of soft caliche underlain by yet another 20’ sand lens atop a denser caliche layer. The bulk of the plume is situated between the caliche bands.

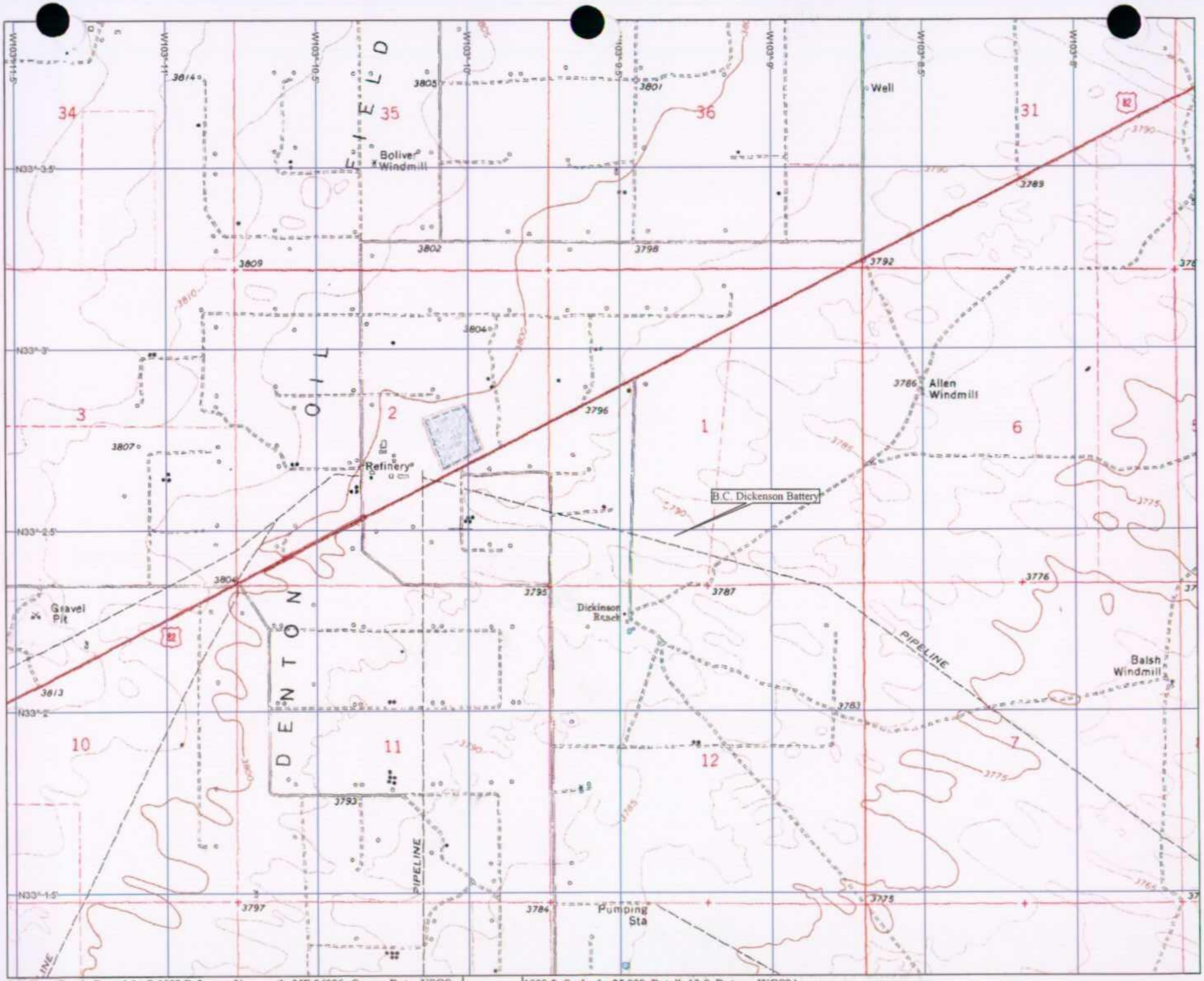
Modeling

Based on the previous site borings, a comprehensive contaminant migration model was prepared by Dr. Jan M.H. Hendrickx of New Mexico State University. The model data indicates that the contaminant migration from the two main plumes may be effectively retarded by excavating the extensive surface contamination and placing a one foot layer of compacted clay atop the remaining minor concentrations. Our protocol doubles the thickness of the clay cap to twenty-four inches. A copy of the migration model is included within the Exhibits section of this report.

Conclusions and Recommendations

The enclosed protocol proposes to use Hydrus-1D to support a remediation plan consisting of the excavation of the bulk of the plume followed by backfilling with clean soils and the establishment of a clay cap to retard vertical migration. The excavated materials may be treated on the surface by a combination of simple aeration and dilution using native topsoils and bio-augmentation. An existing monitor well will be used to check the continuing ground water quality. The well will be sampled on an annual basis for the presence and concentrations of BTEX and chlorides for a period of five years.

B.C. Dickenson
Exhibit Index



3-D TopoQuads Copyright © 1999 DeLorme Yarmouth, ME 04096 Source Data: USGS 1000 ft Scale: 1 : 25,000 Detail: 13-0 Datum: WGS84

Detail of Earlier Excavation
View to Northeast

10.02.2004 10:35

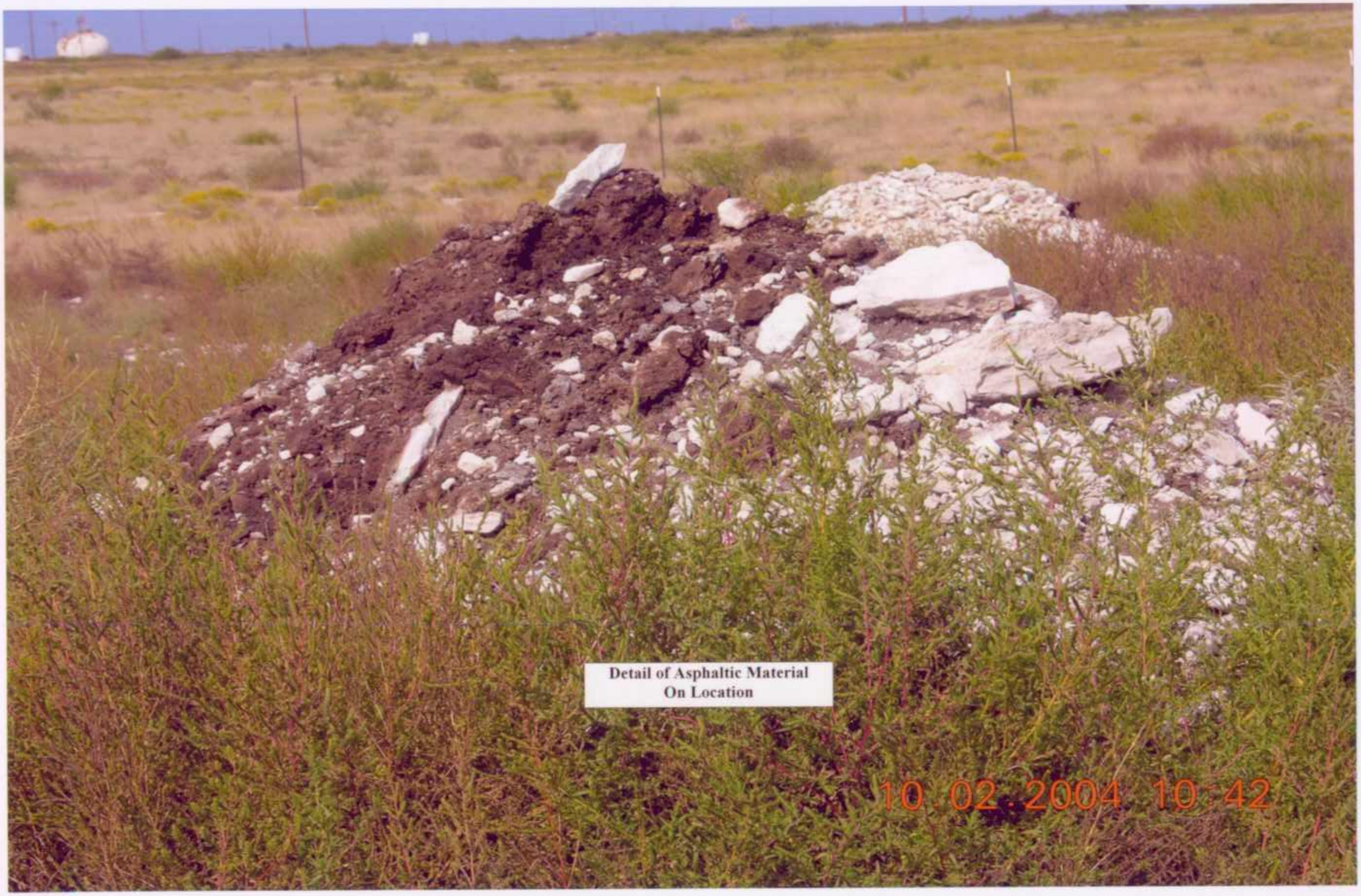
South Side of Site
View to East

10.02.2004 10:35


South Side of Site
View to Northeast

Detail of Partial Excavation
View to Northwest

10.02.2004 10:35



Detail of Asphaltic Material
On Location

10.02.2004 10:42

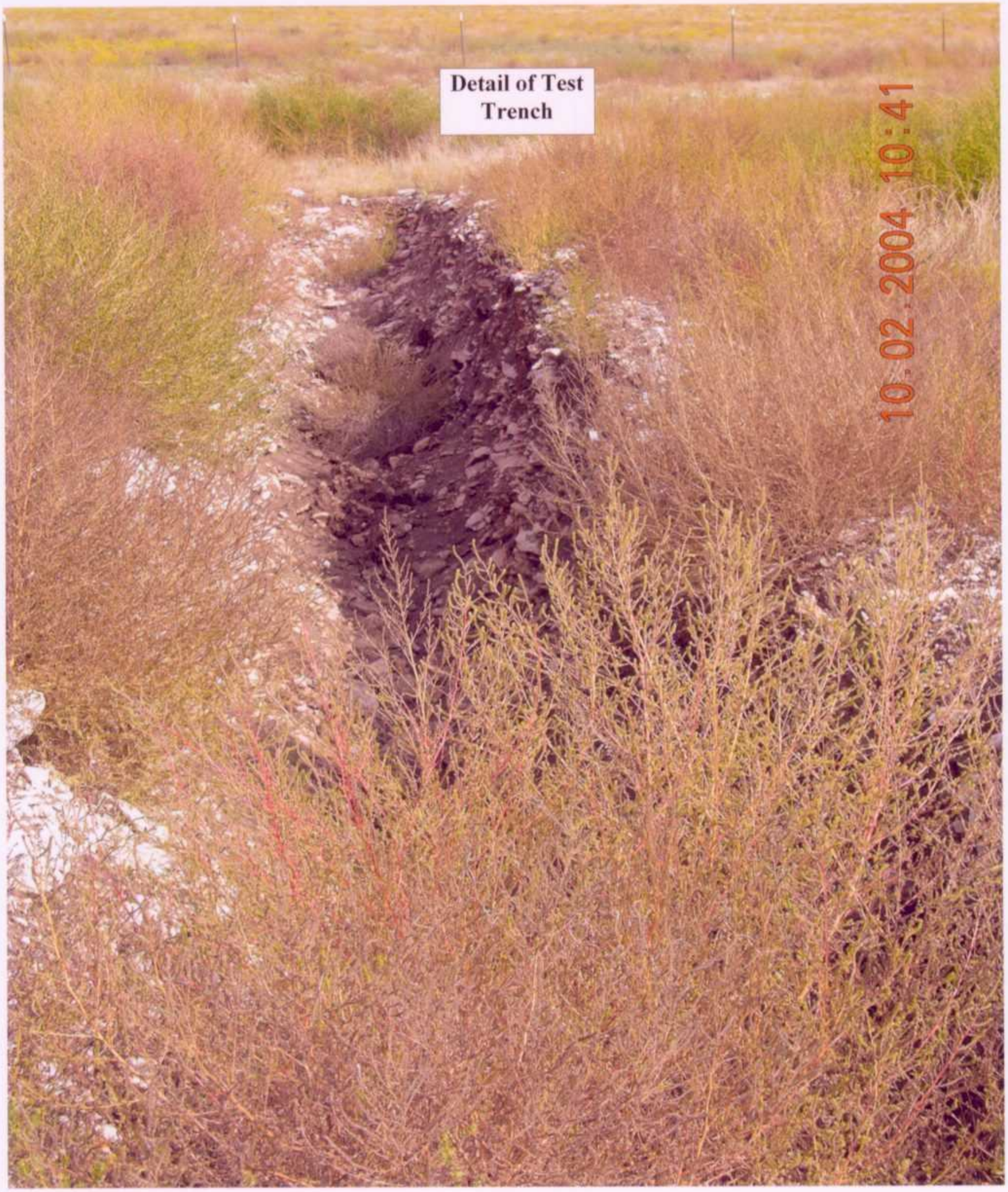

Detail of Test Trench
10 02 2004 10:41

TABLE 1

SOIL CHEMISTRY

DEVON ENERGY
DEVON B.C. DICKINSON A - 1
LEA COUNTY, NEW MEXICO
ETGI PROJECT # DV 2100

SAMPLE LOCATION	SAMPLE DATE	Methods: BTEX-EPA SW 846 8021B, 5030B				Methods: EPA SW-846 8015M			Method: 9263
		BENZENE (mg/Kg)	TOLUENE (mg/Kg)	ETHYL-BENZENE (mg/Kg)	TOTAL XYLENES (mg/Kg)	GRO (mg/Kg)	DRO (mg/Kg)	TOTAL TPH (mg/Kg)	CHLORIDES (mg/Kg)
SB - 1-35'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	
SB - 1- 60'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	
SB - 2-10'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	
SB - 2- 60'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	
SB - 3-45'	05/02/02	0.027	0.136	0.067	0.122	593	552	1,145	
SB - 3-60'	05/02/02	<0.025	0.076	<0.025	<0.025	<10.0	22.5	22.5	
SB - 4-5'	05/02/02	0.059	0.196	0.811	1.235	1,580	1,640	3,220	
SB - 4-10'	05/02/02	0.495	1.320	3.400	6.480	2,320	2,100	4,420	
SB - 4-15'	05/02/02	<0.025	0.041	0.117	0.447	659	801	1,460	
SB - 4-45'	05/02/02	<0.025	<0.025	<0.025	0.053	286	327	613	
SB - 4-55'	05/02/02	<0.025	<0.025	<0.025	<0.025	80.4	162	242	
SB - 5-5'	05/02/02	<0.025	0.104	0.790	4.342	1,810	1,510	3,320	
SB - 5-15'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	19.0	19.0	
SB - 5-45'	05/02/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	
SB - 6-10'	05/02/02	0.482	1.270	3.500	19.180	9,240	11,700	20,940	
SB - 6-30'	05/02/02	0.151	1.520	4.420	22.030	6,060	4,890	10,950	
SB - 6-55'	05/02/02	<0.025	0.041	0.196	0.872	855	912	1,767	
SB - 6-60'	05/02/02	<0.025	0.287	0.162	0.679	894	904	1,798	
MW - 4 35'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	12.4	12.4	19.7
MW - 4 60'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	23.4	23.4	14.8
MW - 5 40'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	<10.0
MW - 5 60'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	12.9	12.9	14.8
MW - 6 25'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	277
MW - 6 60'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	122
MW - 7 35'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	19.7
MW - 7 60'	05/20/02	<0.025	<0.025	<0.025	<0.025	<10.0	<10.0	<10.0	32.2
SB - 7 40'	05/20/02					1,510	1,290	2,800	874
SB - 8 50'	05/20/02					1,310	1,400	2,710	13.6
SB- 9 55'	05/20/02					250	348	598	671

TABLE 2

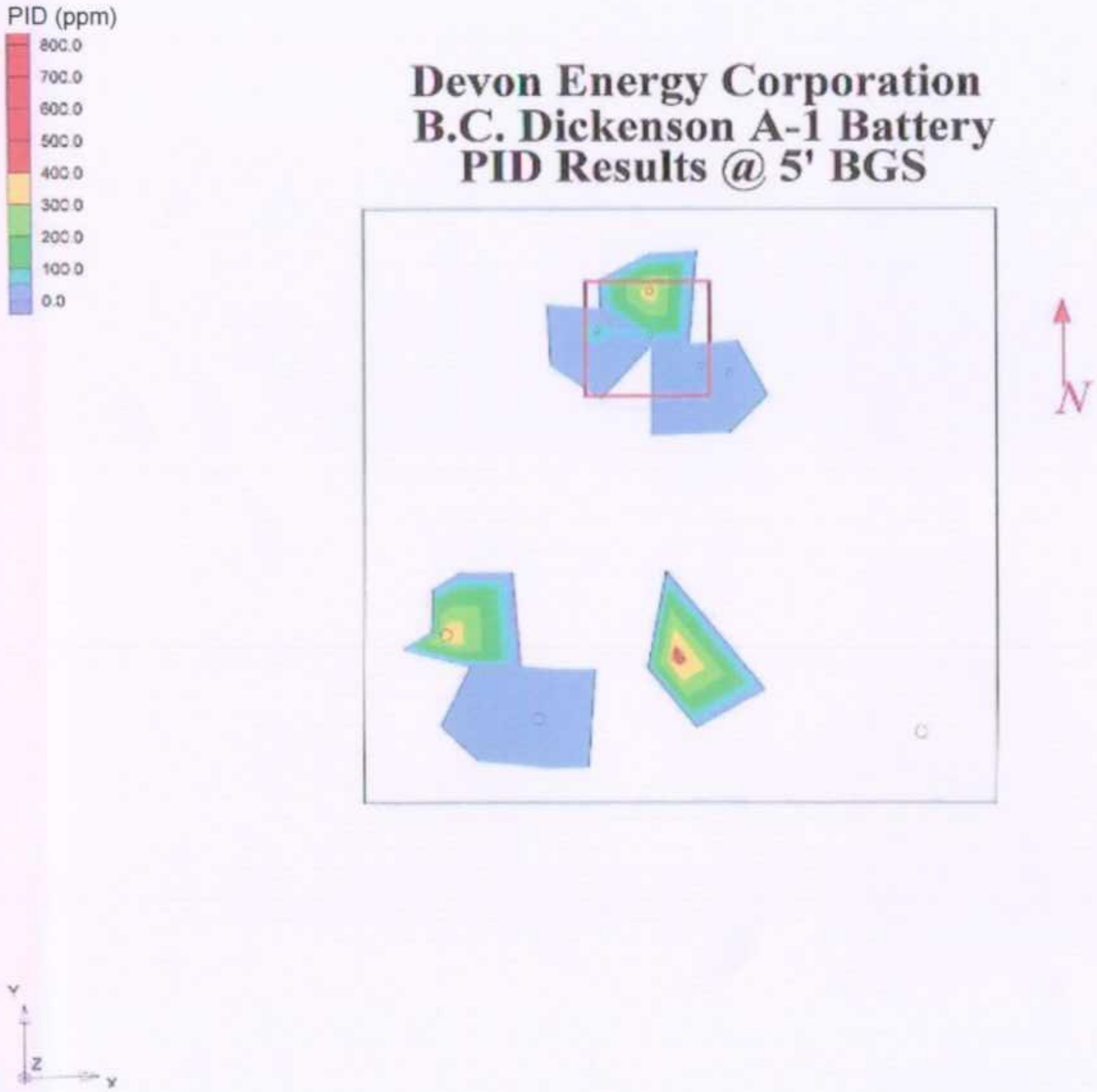
GROUNDWATER CHEMISTRY

DEVON ENERGY
DEVON B.C. DICKINSON A - 1
LEA COUNTY, NEW MEXICO
ETGI PROJECT # DV 2100

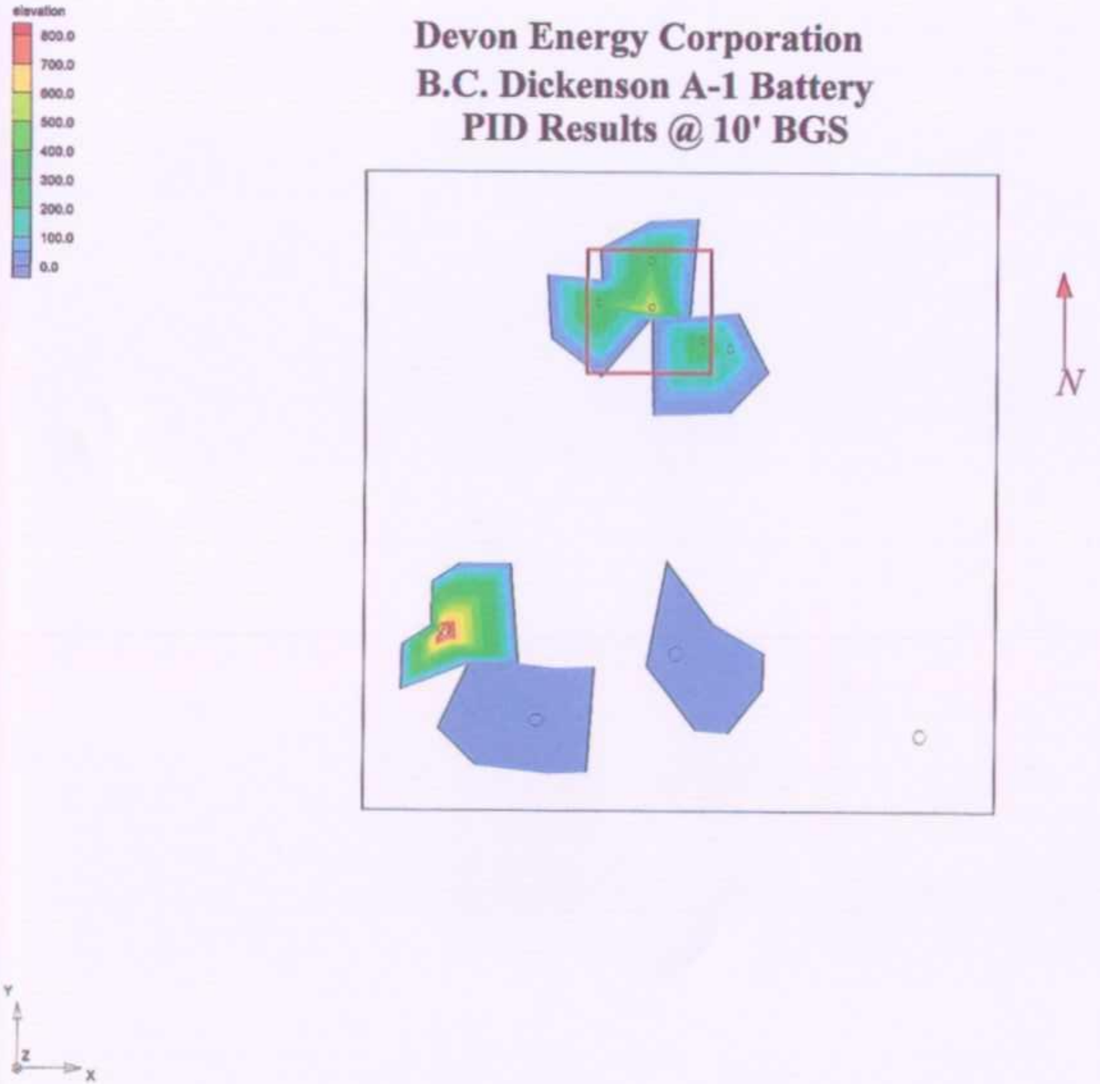
All concentrations are in mg/L

SAMPLE LOCATION	SAMPLE DATE	*METHODS: SW 846-8021B, 5030*				*Method: 9253*	*Method: 160.1*
		BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	CHLORIDES	TDS
TW - 1	05/03/02	<0.001	<0.001	<0.001	<0.001	363	1,020
TW - 2	05/03/02	<0.001	<0.001	<0.001	<0.001	1,360	4,370
TW - 3	05/03/02	0.109	<0.001	0.001	0.064	603	2,050
	05/31/02	0.004	<0.001	0.003	0.007	549	
TW - 4	05/03/02	0.006	0.002	0.012	0.046	346	1,490
MW - 4	05/22/02	<0.001	<0.001	<0.001	<0.001	62.0	600
MW - 5	05/22/02	<0.001	<0.001	<0.001	<0.001	51.0	479
MW - 6	05/22/02	<0.001	<0.001	<0.001	<0.001	523	1,500
MW - 7	05/22/02	<0.001	<0.001	<0.001	<0.001	120	632

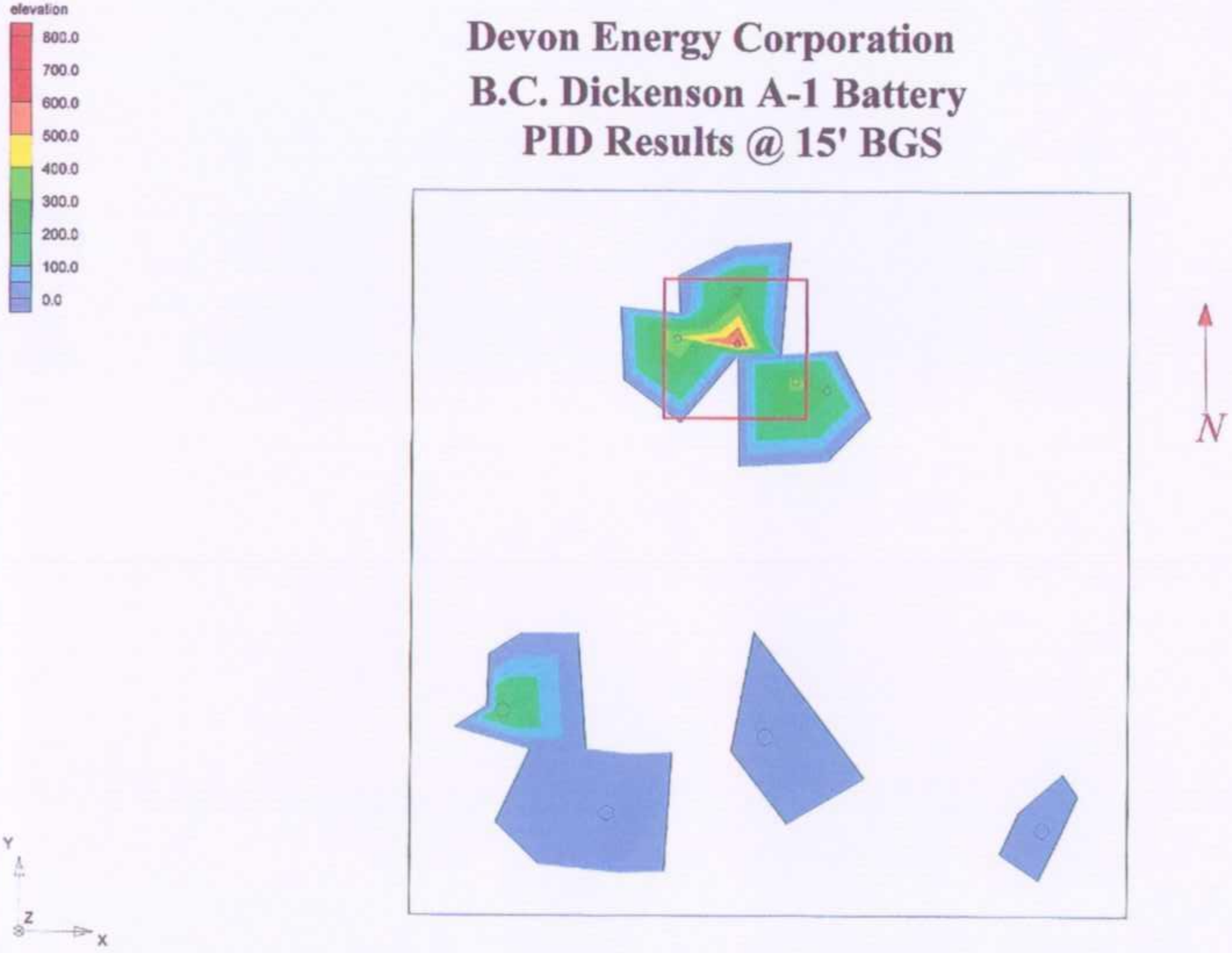
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 5' BGS



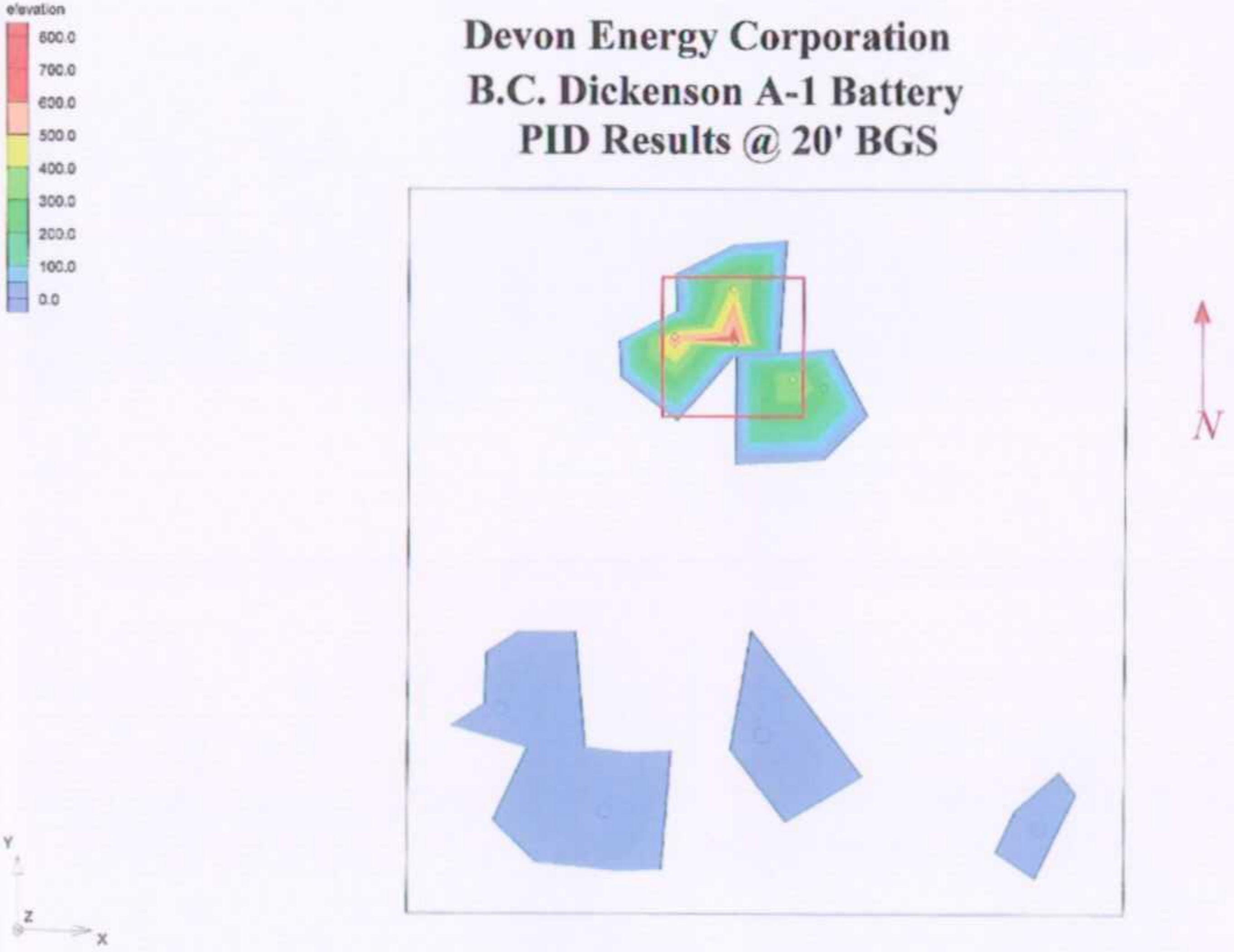
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 10' BGS



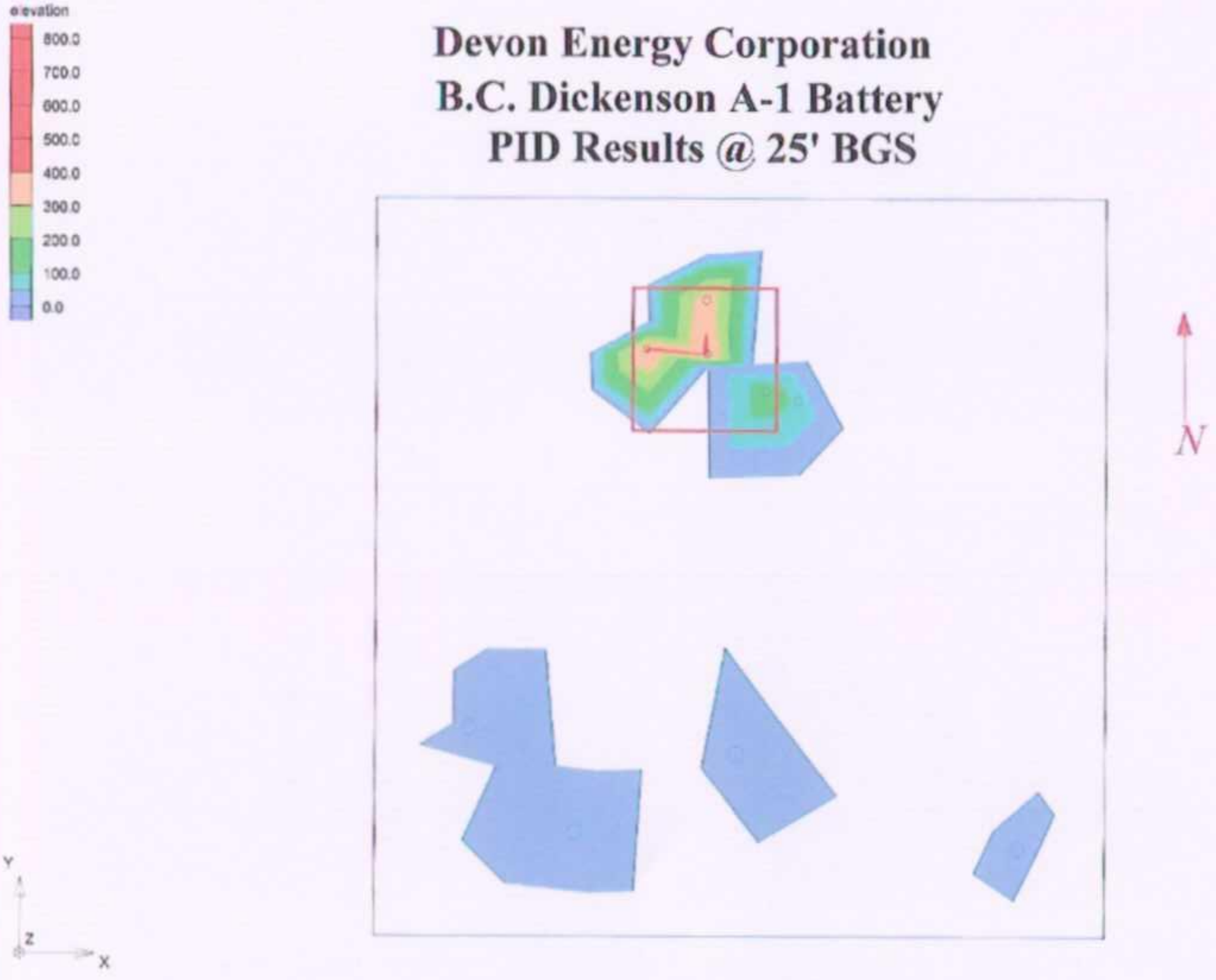
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 15' BGS



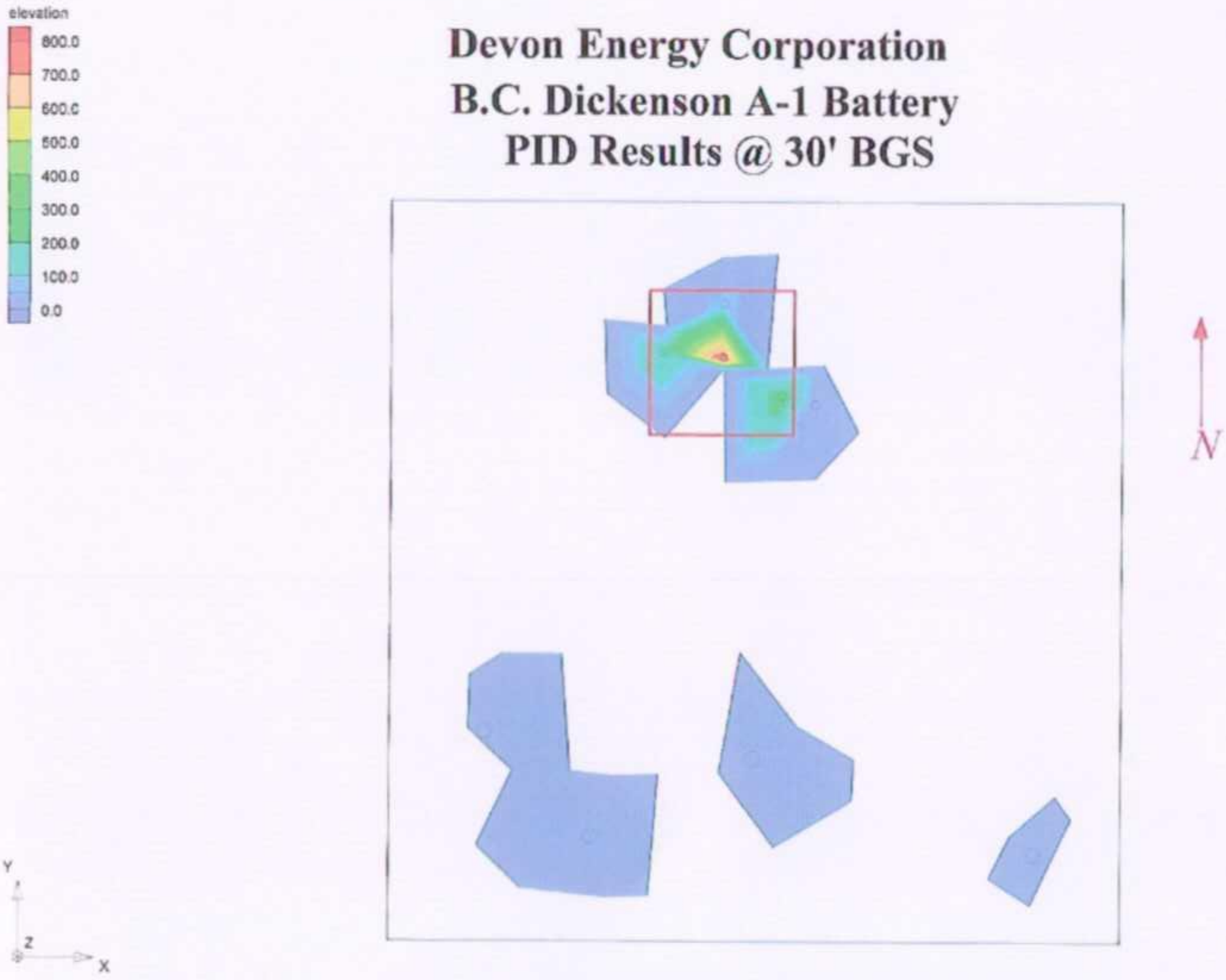
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 20' BGS



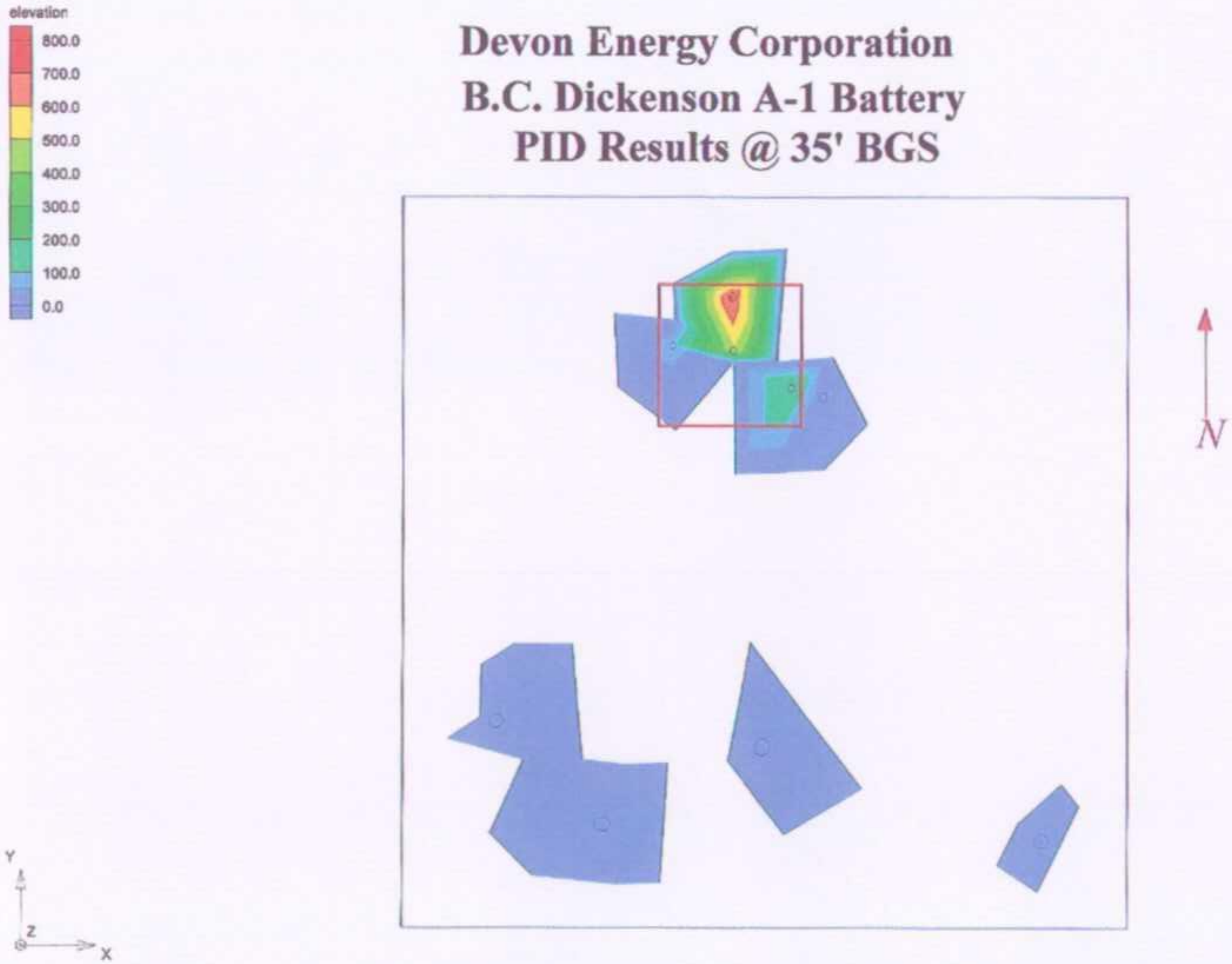
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 25' BGS



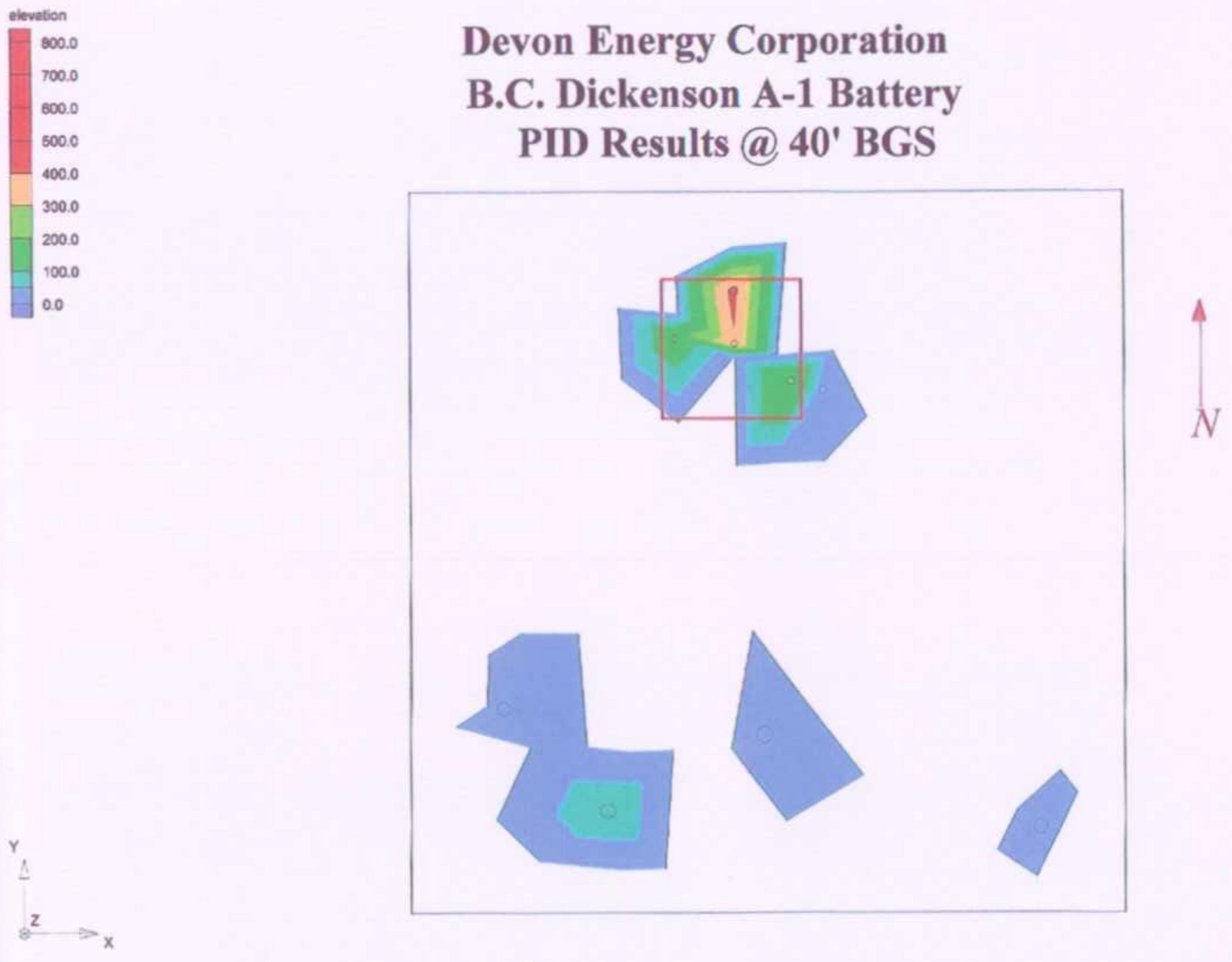
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 30' BGS



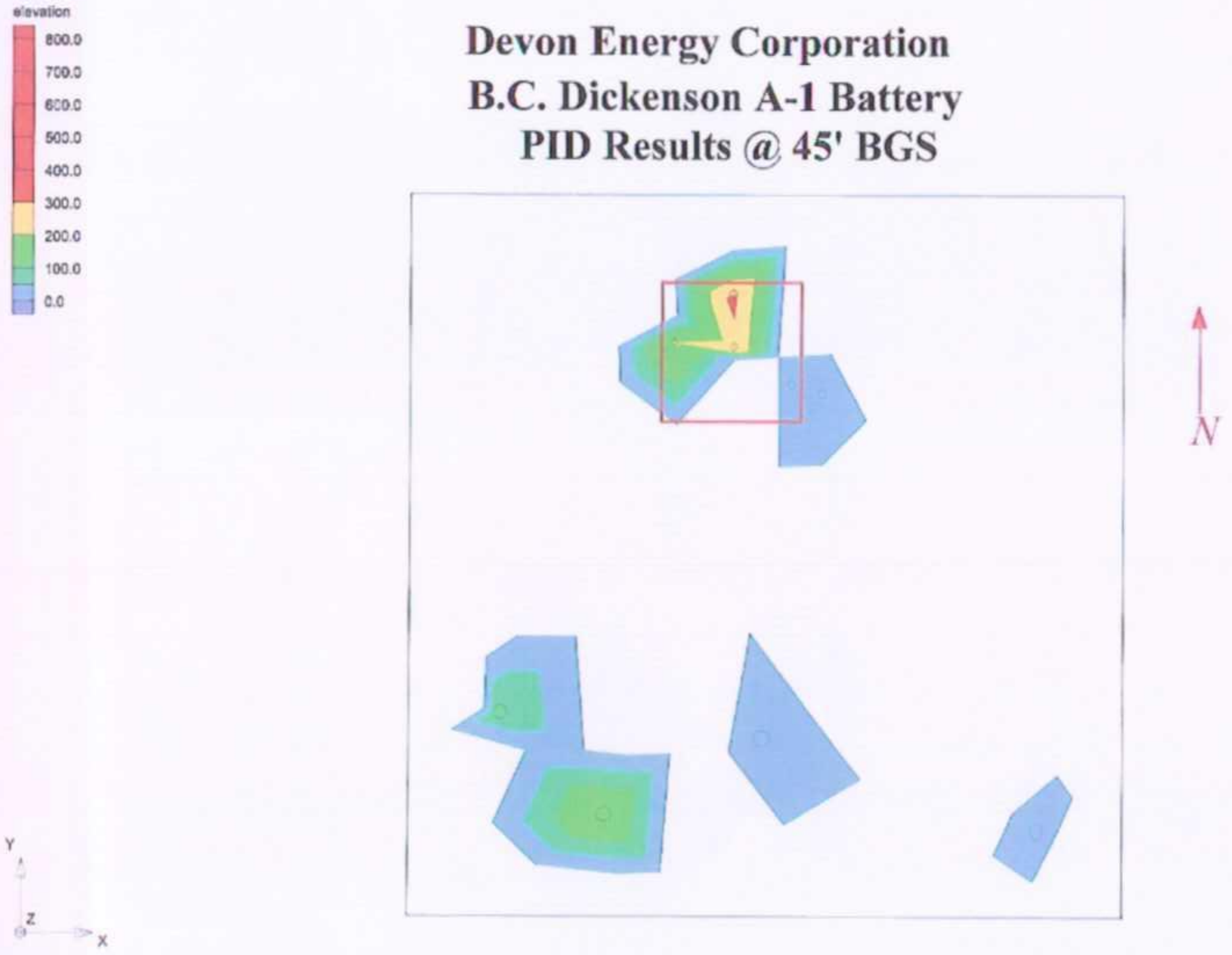
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 35' BGS



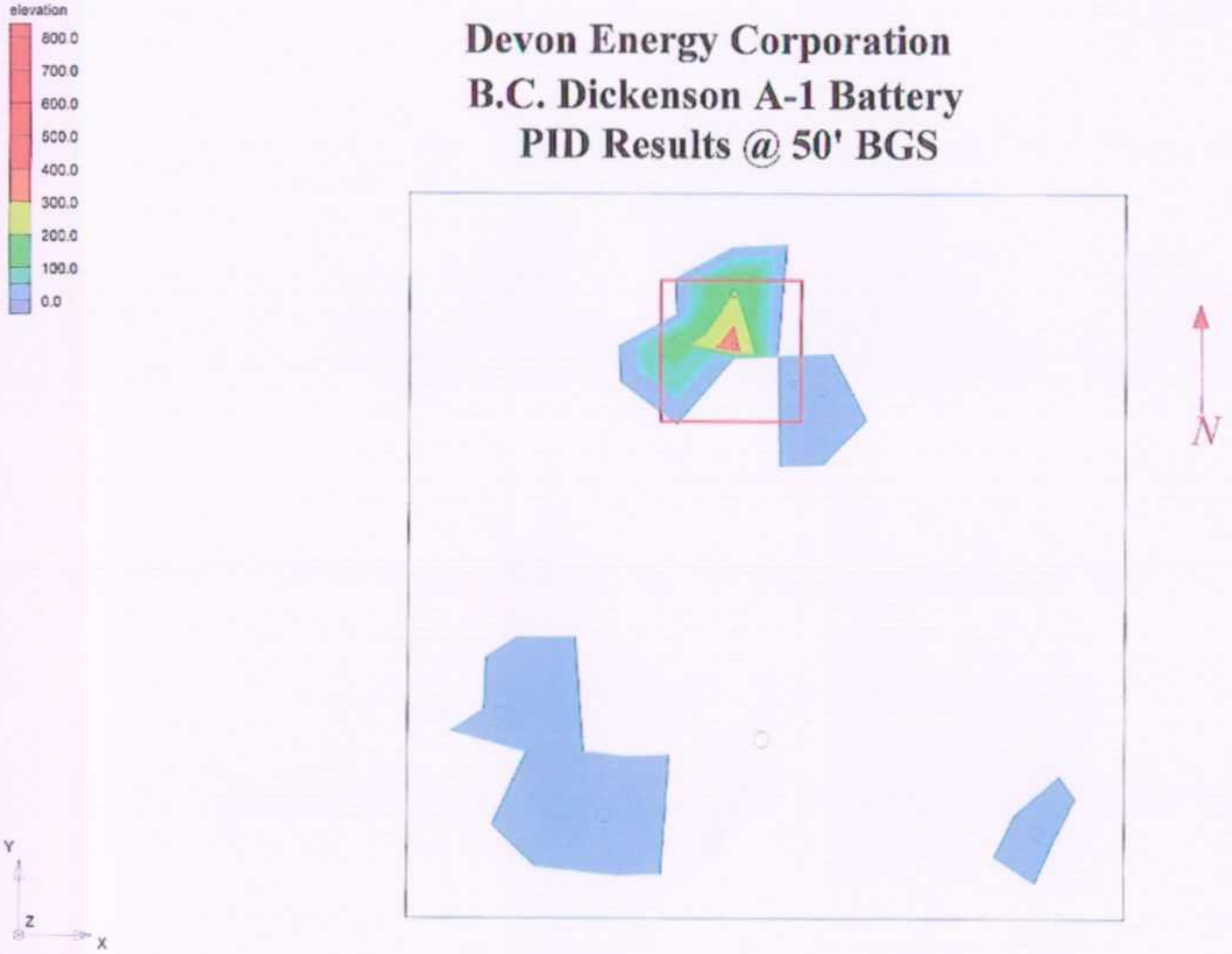
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 40' BGS



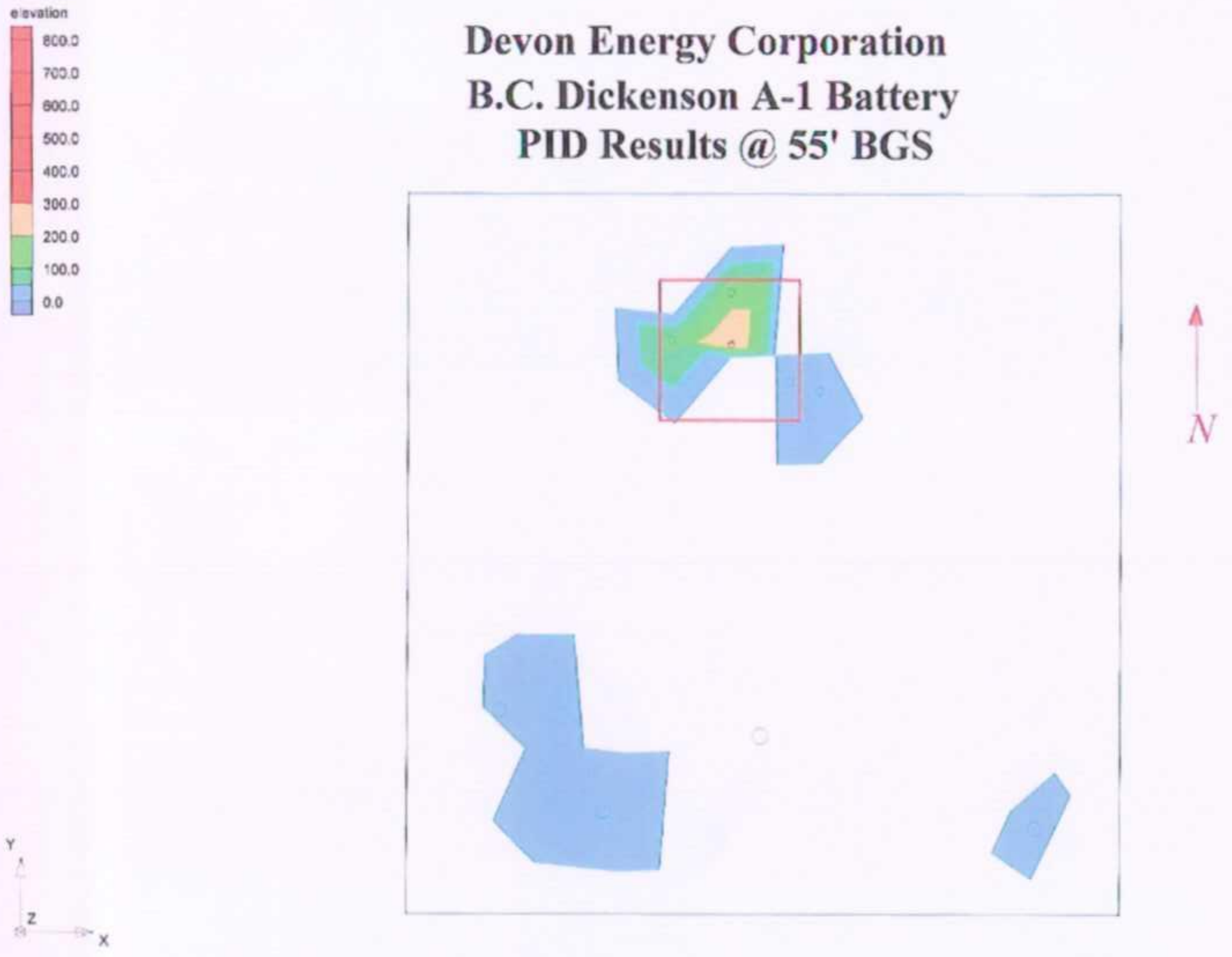
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 45' BGS



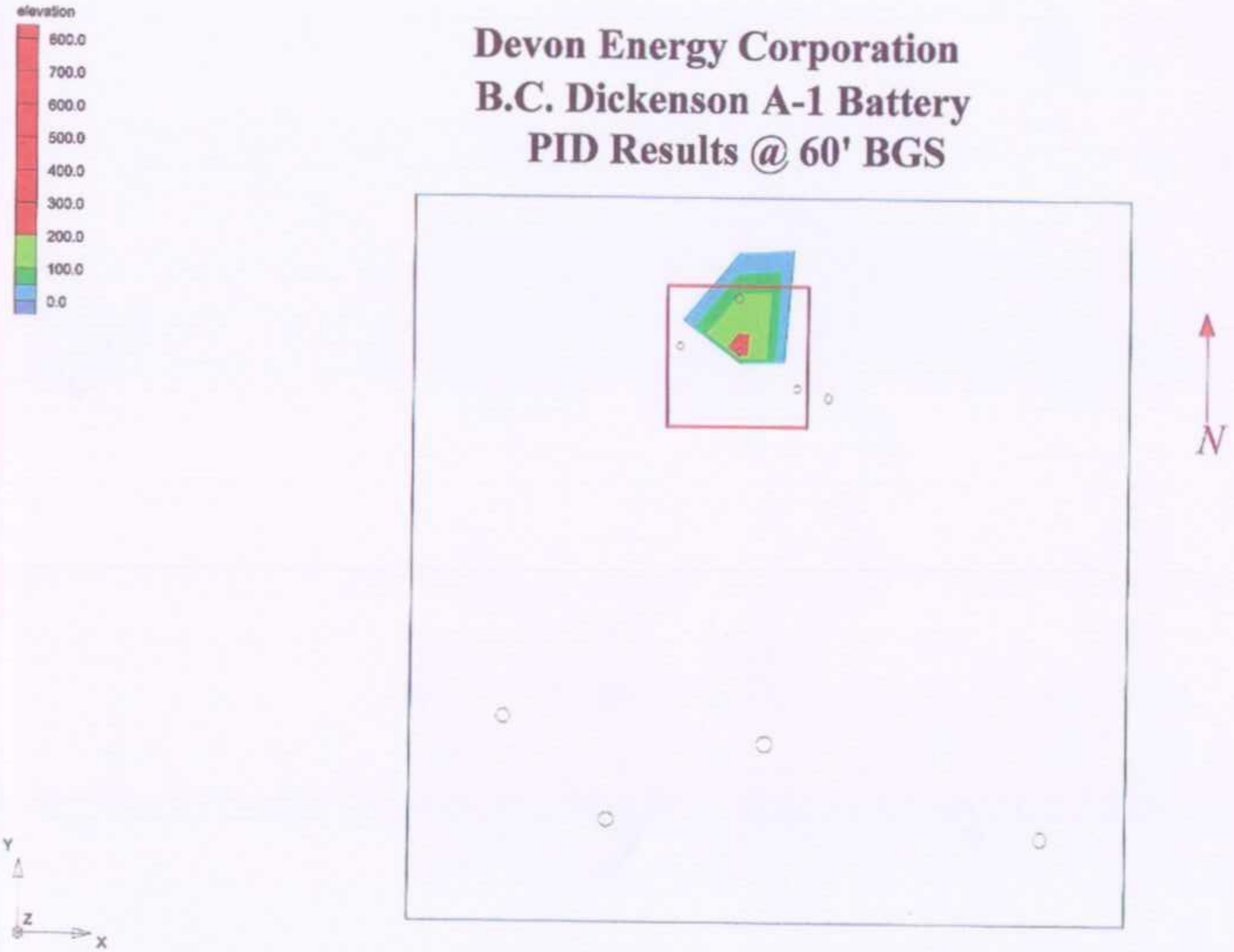
Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 50' BGS



Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 55' BGS



Devon Energy Corporation
B.C. Dickenson A-1 Battery
PID Results @ 60' BGS



DRAFT FOR REVIEW BY WHOLE EARTH ENVIRONMENTAL
January 23, 2005

SIMULATION OF REMEDIATION STRATEGIES FOR THE B.C. DICKENSON SITE, DEVON ENERGY CORPORATION

A Report Prepared for
Whole Earth Environmental, Inc.
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By

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January 2005

EXECUTIVE SUMMARY

Whole Earth Environmental, Inc. (WEE) is preparing a remediation plan for the B.C. Dickenson Battery of the Devon Energy Corporation. The purpose of this study is to conduct computer simulations for evaluation of different remediation scenarios so that WEE can optimize its final remediation plan.

No free phase hydrocarbons have been observed at the site; all benzene, toluene, ethylbenzene, and xylene fractions are dissolved in water so that remediation strategies can be evaluated with the model HYDRUS1D. Two remediation strategies are considered in this simulation study for the B.C. Dickenson site: (1) no action or natural remediation and (2) capping the site with a one foot thick clay layer.

Due to a lack of chloride measurements in the soil and ground water samples a model validation has not been possible for this site. The simulation has been conducted using hydraulic properties that have been used previously at sites with similar geological properties where model validation was possible for chloride movement.

The computer simulations demonstrate that no action is not an option even when biodegradation is taken into account since the concentrations of benzene and xylenes might exceed the legal limits in the monitoring well located 20 m down-gradient from the site. However, a one foot clay cap will be an effective remediation strategy that is not sensitive to the diameter of the spill nor the thickness of the aquifer. This remediation option is also known to be relatively insensitive for the geological composition of the vadose zone. An additional safety margin is biodegradation that has not been taken into account in the clay cap simulations. Therefore, a one foot clay cap is an attractive remediation strategy for the B.C. Dickenson site that will protect the ground water without need for an expensive excavation at the site.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SIMULATION OF REMEDIATION STRATEGIES
FOR THE B.C. DICKENSON BATTERY, DEVON ENERGY CORPORATION

Purpose

Whole Earth Environmental, Inc. (WEE) is preparing a remediation plan for the B.C. Dickenson Battery of the Devon Energy Corporation. The purpose of this study is to conduct computer simulations for evaluation of different remediation scenarios so that WEE can optimize its final remediation plan.

Site Description

The B.C. Dickenson Battery is located in Lea County, New Mexico, South of US 182 on fee land. WEE has provided us with (1) a map of the site and the locations of boreholes for soil sampling and the installation of monitoring wells, (2) laboratory analyses of soil and water samples, (3) logs of soil borings, and (4) a copy of a preliminary site investigation report and remediation work plan dated December 2002. Ground water table depth measurements in May 2002 are all around 60 feet. The direction of flow is from the NW to the SE following the topography. The aquifer is unconfined and, thus, exposed to recharge and solutes leaving the vadose zone at the phreatic level.

All laboratory analyses of soil and ground water samples that are used in this study, have been summarized in Table 1. The data indicate that up-gradient of the site no contamination has occurred by BTEX or chloride; no BTEX was detected and the chloride concentrations in wells MW4 and MW5 have not changed between May 2002 and October 2004. This observation is in agreement with the southeastern direction of ground water flow mentioned by Environmental Technology Group (2002). The ambient chloride concentration at the site is estimated as the average chloride concentrations in MW4 and MW5 which is 56 ppm. The low chloride background concentration of 56 ppm, the relatively low chloride concentrations found in wells MW1, MW2, MW3, MW6, and MW7 as well as the decrease in chloride concentration between

Table 1. Summary of laboratory analyses of soil and ground water samples that are used for this study.

Soils							Ground Water											
May 2002							May 2002							October 2004				
Loc	Depth	Ben	Tol	Et-ben	Xyl	Cl	Loc	Depth[4]	Ben	Tol	Et-ben	Xyl	Cl	Ben	Tol	Et-ben	Xyl	Cl
	feet			mg/Kg				feet						mg/L				
SB1	35	nd[1]	Nd	nd	nd													
SB1	60	nd	Nd	nd	nd		MW1	60	nd	nd	nd	nd	363	nd	nd	nd	nd	496
SB2	10	nd	Nd	nd	nd													
SB2	60	nd	Nd	nd	nd		MW2	61	nd	nd	nd	nd	1360	nd	nd	nd	nd	691
SB3	45	0.027	0.136	0.067	0.122													
SB3	60	nd	0.076	nd	nd		MW3	60	0.109	nd	0.001	0.064	603	0.0361	nd	nd	0.0131	470
							MW3[3]	60	0.004	nd	0.003	0.007	549					
SB4	5	0.059	0.196	0.811	1.235													
SB4	10	0.459	1.320	3.400	6.480													
SB4	15	nd	0.041	0.117	0.477													
SB4	45	nd	Nd	nd	0.053													
SB4	55	nd	Nd	nd	nd													
SB5	5	nd	0.104	0.790	4.342													
SB5	15	nd	Nd	nd	nd													
SB5	45	nd	Nd	nd	nd													
SB6	10	0.482	1.270	3.500	19.180													
SB6	30	0.151	1.520	4.420	22.030													
SB6	55	nd	0.041	0.196	0.872													
SB6	60	nd	0.287	0.162	0.679		TW4	60	0.006	0.002	0.012	0.046	346					
SB7	40					874												
SB8	50					14												
SB9	55					671												
MW4	35	nd	Nd	nd	nd	20												
MW4	60	nd	Nd	nd	nd	15	MW4	60	nd	nd	nd	nd	62	nd	nd	nd	nd	64
MW5	40	nd	Nd	nd	nd	<10												
MW5	60	nd	Nd	nd	nd	15	MW5	59	nd	nd	nd	nd	51	nd	nd	nd	nd	50
MW6	25	nd	Nd	nd	nd	277												
MW6	60	nd	Nd	nd	nd	122	MW6	59	nd	nd	nd	nd	523	nd	nd	nd	nd	160
MW7	35	nd	Nd	nd	nd	20												
MW7	60	nd	Nd	nd	nd	32	MW7	59	nd	nd	nd	nd	120	nd	nd	nd	nd	115

1) nd in soils indicates that concentration is below the reporting limit of 0.025 mg/Kg; 2) nd in water indicates that concentration is below the reporting limit of 0.001 ppm; 3) Sampling in MW3 was repeated on May 31, 2002, to check the high reading for benzene measured on May 3, 2002; 4) Ground water levels not reported for October 2004.

May 2002 and October 2004 in all wells except for well MW1 indicate that the impact of chloride on the ground water at this site will be limited. BTEX concentrations in all monitoring wells appear to be within NMOCD guidelines. However, the elevated BTEX concentrations observed in May 2002 in soil borings SB4, SB5, and SB6 as well as in the temporary well TW4 point to a potential adverse impact on ground water quality in the future.

The description of the geological layers is qualitative. The soil close to the surface is sandy to a depth of approximately 5-7' followed by a 12-15' band of soft caliche underlain by another 20' sand layer sometimes atop a denser caliche layer. The soil borings demonstrate that the soil profile is quite variable at the site.

An initial evaluation of the potential for ground water impairment is conducted in Table 2 by evaluating the ratio between the maximum estimated concentration of benzene, toluene, ethylbenzene, xylenes, and chloride in the soil water against the legal ground water limits for these components. The ratios between the maximum estimated soil water concentration and the legal limit varies from 500 and 355 for, respectively, benzene and xylenes to 20 and 36 for, respectively, toluene and chloride. It is evident that the major concern at the site is the prevention of ground water impairment by benzene and xylenes. Therefore, the computer simulations discussed in this report will focus on strategies to prevent ground water impairment by BTEX.

The water solubility of each component is also presented in Table 2. With the exception of xylene the maximum concentration of each component is much less than its solubility in water. The solubility of xylenes is of the same order of magnitude as the maximum concentration estimated in Table 2. Thus, it is expected that the BTEX components dissolve completely in the water phase. As a matter of fact no evidence of phase-separated hydrocarbon (PSH) was detected during drilling or ground water sampling activities (Environmental Technology Group, 2002). Therefore, the model HYDRUS1D can be used for the evaluation of BTEX movement through the vadose zone at the B.C. Dickenson site and for the development of restoration strategies.

Table 2. Characteristics of the BTEX and chloride concentrations measured at the site.

Component	Legal Limit	Maximum Soil Conc.	Maximum Conc. Soil Water[1]	Ratio Maximum to Legal Limit	Solubility in Water
	ppm	mg/Kg	ppm	-	ppm
Benzene	.01	.48	5	500	1780
Toluene	.75	1.5	15	20	500
Ethylbenzene	.75	4.4	45	60	152
Xylenes	.62	22.0	220	355	175
Chlorides	250	874	9000	36	220,000

1) A rule of thumb to convert the concentration of a substance in a moist soil (mg/Kg) to the concentration in soil water (ppm or mg/L) is multiplication by a factor of 10.

Approach

In this report we evaluate two remediation strategies that are considered suitable for the management of the BTEX contaminants found at the B.C. Dickerson site: (1) passive or natural remediation and (2) a one foot deep clay cover without excavation. Passive remediation relies on natural processes such as dispersion and biodegradation to dilute, and mitigate the effects of BTEX in the vadose zone. Mechanical remediation involves the permanent removal of contaminated soil and its replacement with clean soil. This technique is the most expensive remediation alternative due to the use of the large machinery necessary to remove and replace contaminated soils. For the B.C. Dickenson site excavation will be very expensive since the bulk of the BTEX is found between depths of 10 and 30 feet (see Table 1 at location SB6). Therefore, we also consider capping the site with a barrier of one foot compacted clay that will reduce infiltration rates and, thus, reduce BTEX and chloride fluxes into the shallow aquifer.

In addition, the effect of BTEX biodegradation will be evaluated. Natural biodegradation of BTEX in ground water aquifers and vadose zones has been reported by a number of sources and it is now considered a viable approach for site remediation (e.g. Fetter, 1999). Biodegradation is the result of chemical and microbiological processes. Although these reactions depend in a complex manner on temperature, pH, microbial population density, carbon content, and other factors, a practical approach is to describe the effect of all these factors with a simple first order decay reaction (e.g. Hamaker, 1972). To quantify this reaction we need to know the "half life" of the biodegradation process. The "half life" is the time required for one half of a substance to biodegrade.

To compare the effectiveness of the two remediation strategies we simulate the effect of each strategy on the concentrations of BTEX in a monitoring well 20 m (65 feet) downstream of the release that occurred at SB6. The modeling will be conducted by coupling two models: (1) the model HYDRUS1D for simulating vertical water movement and BTEX transport through the vadose zone (Simunek et al., 1998) and (2) a simple spreadsheet model to simulate horizontal movement of BTEX in the aquifer and to predict the BTEX concentration in a down gradient monitoring well. Both models are described in the report "Modeling of Chloride Fate after Brine releases" by R. T. Hicks Consulting, Ltd., that is in print by the American Petroleum Institute. Dr. Hendrickx is one of the senior authors of this report.

Input Parameters for Models

The models need a number of input parameters: BTEX concentrations of released produced waters, amount of produced water infiltrated, i.e the height of the spill, site lithology, hydraulic properties of each soil and geological layer, depth of ground water table, thickness of underlying aquifer, porosity of underlying aquifer, chloride content in aquifer, ground water flux in aquifer, daily precipitation rates, daily potential evapotranspiration rates, and initial soil moisture and BTEX distributions in the vadose zone. For most releases many of these input parameters are not available. Therefore, it is necessary to use a combination of forward modeling, pseudo inverse modeling, and expert judgments for evaluation of different remediation strategies.

Known Input Parameters: At the B.C. Dickenson site information is available for several parameters. Climate data for 47 recent years were obtained for Lea County, NM from the National Climatic Data Center (NCDC, www.ncdc.noaa.gov). The data consisted of historical daily temperature and **precipitation** measurements collected at specific weather stations identified by a NCDC Coop identification number. Data for Lea County were collected at the Pearl, NM weather station (Coop # 296659). **Potential evapotranspiration** (PET) was calculated from daily temperature observations using the method of Samani and Pessarakli (1986). When a HYDRUS-1D simulation was performed for a longer time period than the period of record for the weather station, the climate data was repeated for as many years as was necessary. The thickness of the vadose zone or **ground water table depth** is 60 ft (18 m).

Input Parameters with Approximately Known Values. It would take much effort to measure the characteristics of the Ogalla aquifer underlying the B.C. Dickenson site and to exactly determine the size of the release. However, often it is possible to determine reasonable values for these parameters based on literature reports and/or field observations. In this study typical Ogalalla aquifer values will be used. The **groundwater flux** represents the rate of groundwater movement and effects the ability of an aquifer to dilute BTEX of a produced water release. A large groundwater flux produces greater dilution. Using information by Native and Smith (1987) we estimate a typical average ground water flux of 0.07 ft/day (2.1 cm/day). The **porosity** of the aquifer is estimated as 25 volume percent. The **ambient chloride concentration** in the Ogalalla aquifer is typically 100 ppm or less (Nicholson and Clebsch, 1961) with a characteristic minimum value of 10 ppm. The measurements presented in Table 1 yield a ambient chloride concentration of 56 ppm at the site. The thicker the aquifer, the more opportunity for mixing (dilution), and the lower the predicted chloride concentration will be in the aquifer. In this study two **aquifer thicknesses** are selected 30 ft (10 m) and 100 ft (30 m). In many places the Ogalalla Aquifer and other unconfined, alluvial aquifers are thicker than 100 ft.

The **diameter of the release area** and the **location of the monitoring well** also influence the BTEX concentration measured in the monitoring well. Based on the data presented by Environmental Technology Group (2002) the diameter of the area affected by BTEX is estimated between 45 ft (15 m) and 100 ft (30 m). A suitable location for the monitoring well would be opposite test hole SB7 close to the caliche road. This would locate the monitoring well about 70 ft (20 m) away from the edge of the release.

The **dispersion length** of the chloride inside the vadose zone has also an impact on the chloride concentration at the bottom of the vadose zone where the chloride flux enters the aquifer. The higher the dispersion length the more dilute the chloride concentration will become at the bottom of the vadose zone. The dispersion length depends on a large number of factors; a rule of thumb is to take the dispersion length equal to one-tenth of the scale of the simulation. For the 60 ft (18 m) vadose zone at the site we have selected a dispersion length of 180 cm.

Unknown Input Parameters. Generally no quantitative information is available on (i) the **amount of produced water** that has infiltrated into the vadose zone, (ii) the **concentration of BTEX** in the produced water, and (iii) the **hydraulic properties** of the different geological layers in the vadose zone. Without these parameters it is not possible to even approximately validate models for the evaluation of remediation strategies. Fortunately, at many sites test holes have been drilled and monitoring wells have been installed that provide at least some qualitative information on the composition of the vadose zone and the quality of the ground water. Especially, when chloride and BTEX concentrations have been measured in the vadose zone as well as in the ground water, it is often possible to validate release scenarios and the impact of the vadose zone on the fate and transport of BTEX and chloride.

Unfortunately, at the B.C. Dickenson site no simultaneous measurements have been made of chloride and BTEX concentrations in the vadose zone and in the ground water. For example, in May 2002 BTEX concentrations have been measured in the soil profiles SB1, SB2, SB3, SB4, SB5, and SB6 but no chloride concentrations have been measured in the samples that were taken. In soil profiles SB7, SB8, and SB9 chloride concentrations have been measured at one depth in each profile but no BTEX concentrations were measured at these depths. If chloride concentrations had been measured in soil profile SB6, a model validation would have been possible using a pseudo-inverse method but with the current data set it is not. The only approach feasible is to take the BTEX distribution in SB6 as the initial condition for the model and to simulate the likely future BTEX concentrations in the monitoring well.

The soil hydraulic properties are derived from the soil boring log at SB6 using our expertise with similar profiles in the area. In this hole it has been observed that the first nine feet of the vadose zone consists of very fine to fine gravelly sand; below this is a layer of 14 ft of moderately firm caliche. Below this we have layers of consolidated very fine to fine sand, moderately sorted. The bottom layer consists of well sorted sand. Based on these visual observations and field observations at other sites we composed a conceptual model for the hydraulic properties of vadose zone at the B.C. Dickenson site that is presented in Table 3.

Table 3. Van Genuchten parameters that describe the hydraulic properties of the vadose zone at test hole SB6.

Material	Depth	Van Genuchten Hydraulic Parameters[¶]				
	cm	Θ_r	Θ_s	α	n	K_{sat}
		cm^3/cm^3	cm^3/cm^3	cm^{-1}	-	cm/day
Fine Sand	0-270	0.06	0.37	0.019	2.000	195
Caliche	270-690	0.0114	0.082	0.124	2.280	70
Consolidated Sand	690-810	0.078	0.43	0.036	1.560	25
Well Sorted Sand	810-925	0.065	0.41	0.075	1.890	106
Consolidated Sand	925-990	0.078	0.43	0.036	1.560	25
Well Sorted Sand	990-1800	0.065	0.41	0.075	1.890	106

[¶] θ_r residual water content, θ_s saturated water content, α and n are shape parameters, K_s saturated hydraulic conductivity.

Implementation of Conceptual Model

Hydraulic properties have been assigned to the vadose zone on basis of visual observations during the drilling of the test holes and our experience with previous simulations of brine releases (see Table 3). Soil water dynamics in the vadose zone have been simulated for approximately 100 years to obtain an estimate of the current soil moisture conditions, i.e. the initial conditions.

For lack of sufficient chloride and BTEX data in the vadose zone and aquifers a model validation is not possible at the B.C. Dickenson site. However, HYDRUS1D has been used for many simulations of fate and transport of chloride in brine waters with good success, inclusive several validation exercises. See, for example, the report "Modeling of Chloride Fate after Brine releases" by R. T. Hicks Consulting, Ltd., that is in print by the American Petroleum Institute, and the report "Simulation of remediation strategies for the January 2004 brine release at Eidson Station" prepared for Whole Earth Environmental in June 2004 by Dr. Hendrickx.

Our simulation approach is based on the worst case scenario encountered in profile SB6. In this profile the concentrations of benzene, toluene, ethylbenzene and xylenes are the highest of all profiles sampled at the site (Table 1). We simulate the future concentrations in a monitoring well located at 20 m from the edge of the spill assuming that the four components are inert conservative solutes, i.e. they don't absorb to the soil nor exhibit biodegradation. Two scenarios are modeled using the severe assumption of no absorption nor biodegradation: (1) Natural remediation or no action is simulated for all four BTEX components; (2) Covering the site with a one foot clay cap is simulated for benzene and xylenes. The simulations are conducted for four different "release diameter – aquifer thickness" combinations that cover the expected conditions at the site. Since biodegradation is a common phenomenon for BTEX a third less restrictive scenario is simulated for benzene and xylenes: natural remediation taking into consideration biodegradation with a half-life coefficient of one year.

Evaluation of Remediation Strategies

All modeled BTEX concentrations in a 20 m down-gradient monitoring well are presented in Table 4. The "no action – no decay" scenario is acceptable for toluene and ethylbenzene: none of the four "release diameter/aquifer thickness" combinations results in a concentration that exceeds the legal limits. However, the "no action – no decay" scenario is not acceptable for benzene and xylenes. Therefore, the effect of biodegradation was quantified using a half-life of one year in the "no action – decay" scenario. This scenario decreases the concentrations in the monitoring well somewhat but it turns out not to be an effective remediation option at the B.C. Dickenson site. On the other hand the one foot "clay cap – no decay" scenario appears a very effective remediation strategy since it brings the benzene and xylenes concentrations in the monitoring well below the legal limits, even for the extreme case of a 100 ft release diameter and 30 ft thin aquifer. The clay cap reduces the ground water recharge rate and, therefore, the flux of benzene and xylenes to the ground water.

Figures 3 and 4 show that it takes for benzene and xylenes, respectively, about 250 and 200 years to reach the maximum concentration in the monitoring well. This long time period will provide ample option for some biodegradation to occur and adds additional safety to the "clay cap" option. Therefore, a "one foot compacted clay cap" is an attractive and cost-effective remediation scenario at the B.C. Dickenson site.

Table 4. Maximum concentrations (ppm) of benzene, toluene, ethylbenzene, and xylenes simulated in a monitoring well 20 m down gradient of the former pit are after implementation of three remediation strategies: no action assuming no chemical reactions, no action taking biodegradation into account with half life of one year, clay cap of one feet without taking biodegradation into account. [Aquifer characteristics are typical for Ogallala Aquifer: ground water flux 2.1 cm/day and porosity 0.25.]

		Maximum Concentration under Different Remediation Strategies							
		Benzene			Xylenes			Toluene	Ethylbenzene
Release Diameter	Aquifer Thickness	No Action No Decay	No Action Decay	Clay Cap No Decay	No Action No Decay	No Action Decay	Clay Cap No Decay	No Action No Decay	No Action No Decay
Ft	ft					ppm			
33	33	0.013	0.008	0.003	0.955	0.900	0.213	0.083	0.242
100	33	0.034	0.020	0.007	2.455	2.316	0.598	0.212	0.612
33	100	0.004	0.003	0.001	0.322	0.304	0.071	0.028	0.082
100	100	0.012	0.007	0.002	0.832	0.785	0.200	0.072	0.209
Legal Limit			0.01			0.62		0.75	0.75
Over Legal Limit									

Figure 1. Interpolated initial conditions of the benzene and toluene concentrations in the soil profile. (Symbols are measurements; lines are interpolated values used as initial condition).

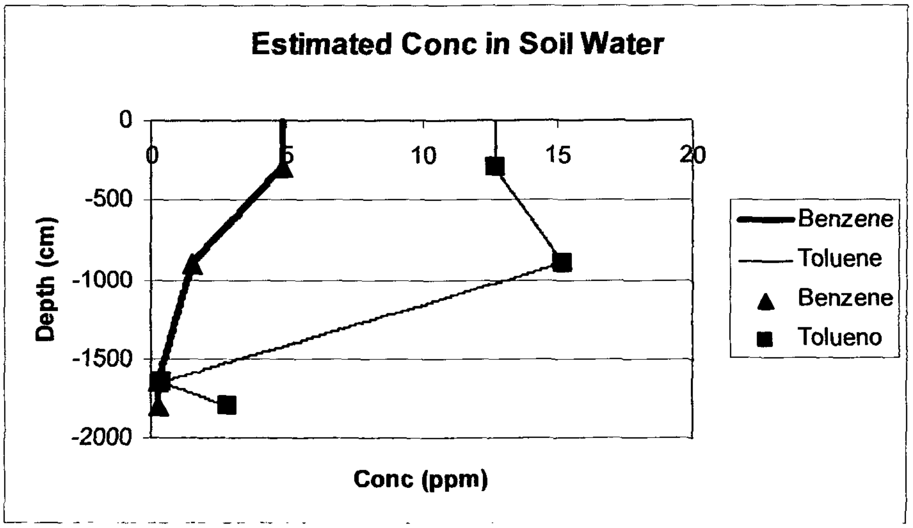


Figure 2. Interpolated initial conditions of the ethylbenzene and xylenes concentrations in the soil profile. (Symbols are measurements; lines are interpolated values used as initial condition).

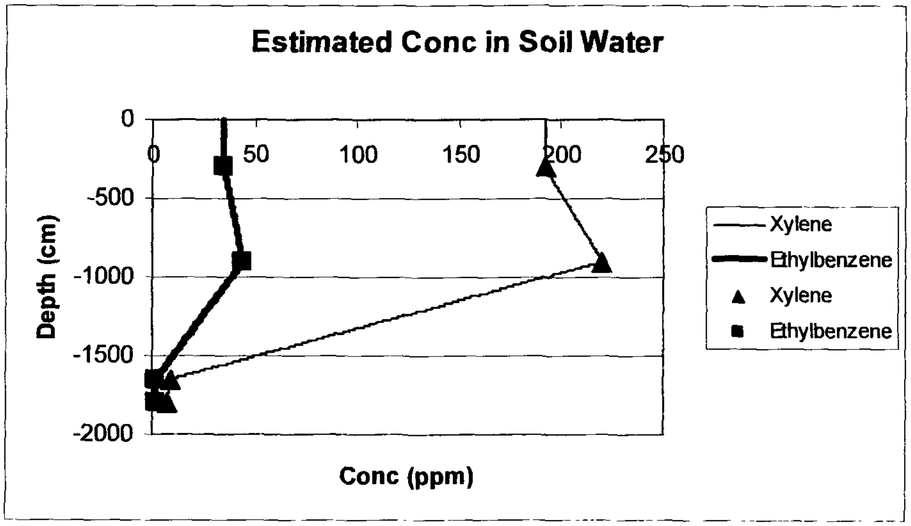


Figure 3. Concentrations (ppm) of benzene simulated in a monitoring well 20 m down gradient of the former pit are after implementation of two remediation strategies: no action assuming no chemical reactions and covering area with one foot clay cap without taking biodegradation into account. [Aquifer characteristics are typical for Ogallala Aquifer: ground water flux 2.1 cm/day and porosity 0.25.]

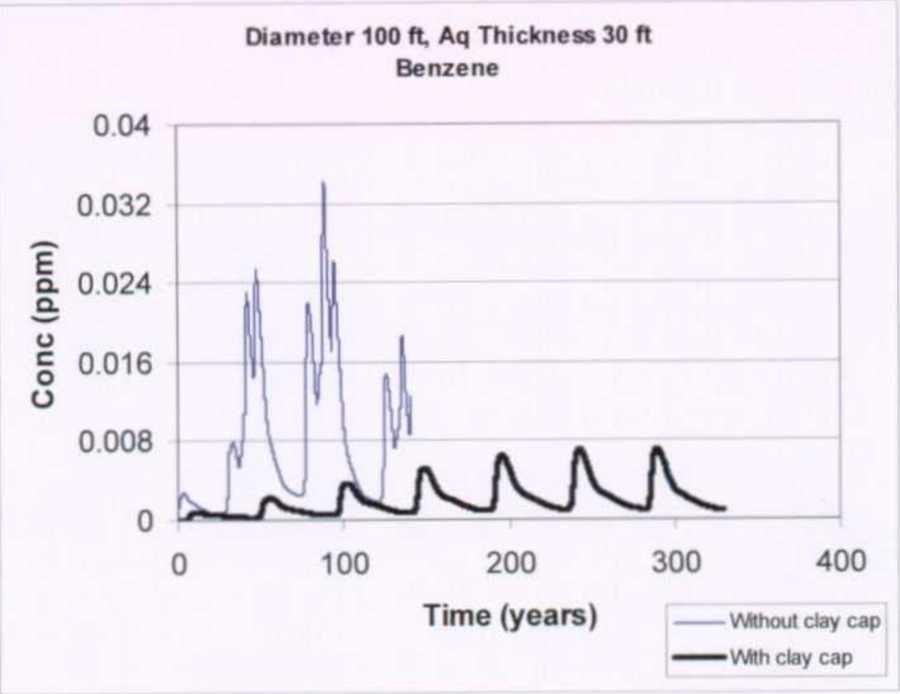
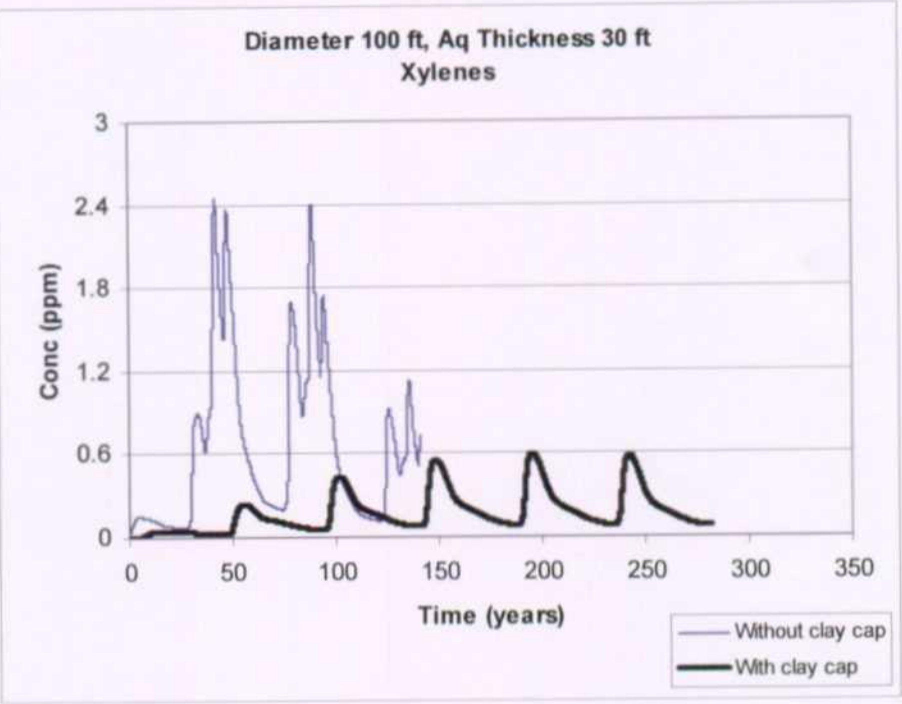


Figure 4. Concentrations (ppm) of xylenes simulated in a monitoring well 20 m down gradient of the former pit are after implementation of two remediation strategies: no action assuming no chemical reactions and covering area with one foot clay cap without taking biodegradation into account. [Aquifer characteristics are typical for Ogallala Aquifer: ground water flux 2.1 cm/day and porosity 0.25.]



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Protocol

This section contains a copy of PR-57A, the detailed remediation protocol approved for the B.C. Dickenson closure project.

PR-57A

Remediation Protocol
Devon Energy Corporation
B.C. Dickenson Battery

1.0 Purpose

This protocol is to provide a detailed outline of the steps to be employed in the remediation and closure of the B.C. Dickenson Battery located east of Lovington, New Mexico.

2.0 Scope

This protocol is site specific for the Devon Energy B.C. Dickenson remediation project.

3.0 Preliminary

Prior to any field operations, Whole Earth Environmental shall conduct the following activities:

3.1 Client Review

3.1.1 Whole Earth shall meet with cognizant personnel within Devon, the NMOCD and the landowner to review and approve this protocol.

3.1.2 Changes to this protocol will be documented and submitted for final review by all parties prior to the initiation of actual field work.

4.0 Safety

4.1 Prior to work on the site, Whole Earth shall obtain the location and phone numbers of the nearest emergency medical treatment facility. We will review all safety related issues with the appropriate Client personnel, sub-contractors and exchange phone numbers.

4.2 A tailgate safety meeting shall be held and documented each day. All sub-contractors must attend and sign the daily log-in sheet.

4.3 Anyone allowed on to location must be wearing sleeved shirts, steel toed boots, and long pants. Each vehicle must be equipped with two way communication capabilities.

4.4 Prior to any excavation, New Mexico One Call will be notified. The One Call notification number will be included within the closure report. If lines are discovered within the area to be excavated they shall be marked with pin flags on either side of the line at maximum five-foot intervals.

4.5 Prior to any field operations, Whole Earth will prepare and submit to Devon Energy a detailed site Health and Safety Plan.

5.0 Preliminary Activities

5.1 All barrels, trash and piping will be scanned for the presence and concentration of naturally occurring radioactive materials (NORM). Any component containing radiation reading exceeding 10 μrems above background will be segregated for further inspection by a third party certified to work in New Mexico on radioactive materials.

5.2 All clean trash will be collected and sent to a commercial disposal facility. A manifest will be generated and signed by the disposal company. All such manifests shall be collected and included within the final closure report.

5.3 All cement shall be collected and deep buried on-site. The top of the cement shall be a minimum distance of 5' below ground level.

5.4 Three of the four existing monitor wells will be grouted to surface and closed prior to any excavation.

6.0 Remediation

6.1 All berms and assorted piles of contaminated soils will be spread to a maximum depth of 6 inches on the surface of the site. The areas designated on the plat map as "A" and "B" shall be excavated to a minimum depth of 15' below ground surface. The contaminated soils shall be set aside of the excavation but within the existing fence perimeter.

6.2 The side walls and bottom of each excavated area shall be field screened for the presence and concentration of TPH by means of EPA method 418.1 (modified). Excavation of each site shall continue until the TPH concentrations are <5,000 ppm. Prior to backfill, laboratory confirmation samples shall be taken from each side-wall and bottom. The Hobbs office of the NMOCD will be given a minimum of forty-eight hours notification of the intended sampling event.

6.3 Each excavation will be backfilled with soils containing a TPH concentration of <500 ppm to a maximum depth of 5' below ground surface. Composite confirmation samples will be collected each 3' lift and submitted to an independent laboratory for analysis under EPA SW-846 Method 8015M. Records of each test will be incorporated within the closure report.

6.4 Upon approval by the NMOCD, Whole Earth will install a clay liner in the bottom of the excavation. The minimum depth on the bottom of the excavation shall be 18-24". All clay layers will be watered and compacted to 100% density.

6.5 All remaining contaminated soils will be land spread over the existing impoundment to a maximum depth of 12" and a maximum TPH concentration of 2,000 ppm. Surface treatment methods may include bio-augmentation, fertilization, inoculation, and phyto-remediation.

7.0 Monitoring

The remaining monitor well will be tested on an annual basis for the presence and concentration of BTEX, and chlorides for a minimum period of five years. If the well shows criteria contaminant concentrations within NMWQCC standards for a minimum of the last three of five years, Devon will request final site closure to include plugging the remaining well.

8.0 Closure Report

8.1 At the conclusion of the project, Whole Earth shall prepare a closure report that contains the following minimum information:

- Photographs of the location prior to remediation
- Photographs of the site at the point of maximum excavation
- Detail photographs of the liner installation
- Photographs of the location at time of final closure
- Lab analysis and related chain of custody for THP, BTEX and chloride testing of each side-wall and excavation bottom
- Lab analysis and related chain of custody for chloride testing of each 3'lift composite
- Procter analysis of the clay
- Clay compaction test report
- Copies of this protocol and all testing procedures

- Shipping manifests for all materials taken to disposal
- Laboratory analysis of water samples obtained from the monitoring well

Procedures

This section contains copies of the field testing and sample collection procedures employed on this project.

QP-06 Rev. C

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Procedure for Conducting Field TPH Analysis

Completed By: Approved By: Effective Date: 02/15/97

1.0 Purpose

To define the procedure to be used in conducting total percentage hydrocarbon testing in accordance with EPA Method 418.1 (modified) using the "MEGA" TPH Analyzer.

2.0 Scope

This procedure is to be used for field testing and on site remediation information.

3.0 Procedure

3.1 The G.A.C. "MEGA" TPH analyzer is an instrument that measures concentrations of aliphatic hydrocarbons by means of infra-red spectrometry. It is manufactured to our specifications and can accurately measure concentrations from two parts per million through 100,000 parts per million. The unit is factory calibrated however minor calibration adjustments may be made in the field. Quality Procedure 25 defines the field calibration methods to be employed.

3.2 Prior to taking the machine into the field, insert a 500 ppm and 5,000 ppm calibration standard into the sample port of the machine. Zero out the Range dial until the instrument records the exact standard reading.

3.3 Once in the field, insert a large and small cuvette filled with clean Freon 113 into the sample port of the machine. Use the range dial to zero in the reading. If the machine does not zero, do not attempt to adjust the span dial. Immediately implement Quality Procedure 25 .

3.4 Place a 100 g. weight standard on the field scale to insure accuracy. Zero out the scale as necessary.

3.5 Tare a clean 100 ml. sample vial with the Teflon cap removed. Add 10 g. (+/- .01 g), of sample soil into the vial taking care to remove rocks or vegetable matter from the sample to be tested. If the sample is wet, add up to 5 g. silica gel or anhydrous sodium sulfate to the sample after weighing.

3.6 Dispense 10 ml. Freon 113 into the sample vial.

3.7 Cap the vial and shake for five minutes.

3.8 Carefully decant the liquid contents of the vial into a filter/desiccant cartridge and affix the cartridge cap. Recap the sample vial and set aside.

3.9 Insert the metal tip of the pressure syringe into the cap opening and slowly pressurize. **WARNING: APPLY ONLY ENOUGH PRESSURE ON THE SYRINGE TO EFFECT FLOW THROUGH THE FILTERS. TOO MUCH PRESSURE MAY CAUSE THE CAP TO SEPARATE FROM THE BODY OF THE CARTRIDGE.** Once flow is established through the cartridge direct the flow into the 5 cm. cuvette until the cuvette is full. Reverse the pressure on the syringe and remove the syringe tip from the cartridge cap. Set the cartridge aside in vertical position.

3.10 The cuvette has two clear and two frosted sides. Hold the cuvette by the frosted sides and carefully insert into the sample port of the machine. Read the right hand digital read-out of the instrument. If the reading is less than 1,000 ppm. the results shall be recorded in the field Soil Analysis Report. If the result is higher than 1,000 ppm, continue with the dilution procedure.

4.0 Dilution Procedure

4.1 When initial readings are greater than 1,000 ppm using the 5 cm. cuvette, pour the contents of the 5 cm. cuvette into a 1 cm. cuvette. Insert the 1. cm cuvette into the metal holder and insert into the test port of the instrument.

4.1 Read the left hand digital read-out of the machine. If the results are less than 10,000 ppm, record the results into the field Soil Analysis Report. If greater than 10,000 ppm, continue the dilution process. **Concentrations >10,000 ppm are to be used for field screen purposes only.**

4.2 Pour the contents of the small cuvette into a graduated glass pipette. Add 10 ml. pure Freon 113 into the pipette. Shake the contents and pour into the 1cm. cuvette. Repeat step 4.2. adding two zeros to the end of the displayed number. If the reported result is greater than 100,000 ppm. the accuracy of further readings through additional dilutions is extremely questionable. **Do not use for reporting purposes.**

4.4 **Pour all sample Freon into the recycling container.**

5.0 Split Samples

5.1 Each tenth test sample shall be a split sample. Decant approximately one half of the extraction solvent through a filter cartridge and insert into the instrument to obtain a concentration reading. Clean and rinse the cuvette and decant the remainder of the fluid to obtain a second concentration reading from the same sample. If the second reading varies by more than 1% from the original, it will be necessary to completely recalibrate the instrument.

QP-25

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Procedure for Instrument Calibration and Quality Assurance Analysis for General Analysis "MEGA" TPH Analyzer

Completed By: Approved By: Effective Date: / /

1.0 Purpose

This procedure outlines the methods to be employed in calibrating the GAC MEGA TPH analyzer and for determining and reporting of accuracy curves.

2.0 Scope

This procedure shall be followed each day that the instrument is used.

3.0 Procedure

3.1 Turn the instrument on and allow to warm up with no cuvette in the receptacle. The instrument will take between five and ten minutes to come to equilibrium as can be determined by the concentration display readings moving a maximum of 5 ppm on the low scale. If the instrument continues to display erratic readings greater than 5 ppm, remove the cover and check both the mirrors and chopper to insure cleanliness.

3.2 All TPH standards shall be purchased form Environmental Resources Corporation and as a condition of their manufacture subject to independent certification by third party laboratories. Each standard is received with a calibration certificate.

3.3 Insert the low range (100 ppm) calibration standard into the receiving port and note the result on the right hand digital display. If the displayed reading is less than 98 ppm or greater than 102 ppm, remove the circuit board cover panel and zero out the instrument in accordance with QP-26.

3.4 Repeat the process with the mid range (500 ppm) calibration standard. If the displayed reading is less than 490 ppm or greater than 510 ppm zero out the span as described in QP-26.

3.5 Repeat the process again with the 1,000 and 5,000 ppm calibration standards.

3.6 Pour clean Freon 113 into a filter cartridge and extract into 10 ml cuvette. Insert the cuvette into the receiving port and zero out the instrument reading using the far right adjustment knob on the instrument. Repeat using the 1 ml cuvette and the left hand zero dial.

4.0 Determining & Reporting Instrument Accuracy

4.1 After making the fine adjustment with the zero dials reinsert each calibration standard into the instrument and note the concentration values. ***If <u>any</u> concentration value exceeds 2% of the standard set point, repeat all steps in section 3.0 of this Procedure.*** Note the actual concentration values displayed by the instrument after each calibration standard.

4.2 The four calibration standards shall be used in reporting span deviation as follows:

Standards Range			
100 ppm	**500 ppm**	**1,000 ppm**	**5,000 ppm**
0-250 ppm	251-750 ppm	751-2,500 ppm	2,501-10,000 ppm

4.3 Divide the actual instrument reading value of each calibration sample by the concentration shown on the standard (e.g.. 501 ppm instrument reading / 500 ppm standard = 1.002%). These readings shall be reported for each test performed.

5.0 Re-calibration

5.1 If any sample exceeds the concentration of 1,000 ppm on the 10 ml cuvette or 10,000 ppm on the 1 ml cuvette, the cuvette must be thoroughly rinsed with clean Freon and the instrument re-zeroed in accordance with 3.6 of this procedure.

QP-28

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Procedure for Developing Cased Water Monitoring Wells

Completed By: Approved By: Effective Date: / /

1.0 Purpose

This procedure outlines the methods to be employed to develop cased monitoring wells.

2.0 Scope

This procedure shall be used for developed, cased water monitoring wells. It is not to be used for standing water samples such as ponds or streams.

3.0 Preliminary

3.1 Prior to development, the static water level and height of the water column within the well casing will be measured with the use of an electric D.C. probe or a steel engineer's tape and water sensitive paste.

3.2 All measurements will be recorded within a field log notebook and subsequently reported within the driller's boring log report.

3.3 All equipment used to measure the static water level will be decontaminated after each use by means of Alconox, a phosphate free laboratory detergent, and water to reduce the possibility of cross-contamination. The volume of water in each well casing will be calculated.

4.0 Purging

4.1 Wells will be purged by removing a minimum of three well casing volumes by using a 2" decontaminated submersible pump or dedicated one liter Teflon bailer.

4.2 If a submersible is used the pump will be decontaminated prior to use by scrubbing the outside surface of tubing and wiring with an Alconox-water mixture, pumping an Alconox-water mixture through the pump, and a final flush with fresh water.

5.0 Water Disposal

5.1 All purge and decontamination water will be temporarily stored within a 60 gallon portable tank and then pumped into a permanent storage tank to be later disposed of in an appropriate manner.

6.0 Records

6.1 Whole Earth will record the amount of water removed from the well during development procedures. The purge volume will be reported to the appropriate regulatory authority when filing the closure report.

QP-76 (Rev. A)

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Procedure for Obtaining Water Samples (Cased Wells) Using One Liter Bailer

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Completed By: Approved By: Effective Date: / /

1.0 Purpose

This procedure outlines the methods to be employed in obtaining water samples from cased monitoring wells.

2.0 Scope

This procedure shall be used for developed, cased water monitoring wells. It is not to be used for standing water samples such as ponds or streams.

3.0 Preliminary

3.1 Obtain sterile sampling containers from the testing laboratory designated to conduct analyses of the water. The shipment should include a Certificate of Compliance from the manufacturer of the collection bottle or vial and a Serial Number for the lot of containers. Retain this Certificate for future documentation purposes.

3.2 The following table shall be used to select the appropriate sampling container, preservative method and holding times for the various elements and compounds to be analyzed.

Compound to be Analyzed	Sample Container Size	Sample Container Description	Cap Requirements	Preservative	Maximum Hold Time
BTEX	40 ml.	VOA Container	Teflon Lined	HCl	7 days
TPH	1 liter	clear glass	Teflon Lined	HCl	28 days
PAH	1 liter	clear glass	Teflon Lined	Ice	7 days
Cation / Anion	1 liter	clear glass	Teflon Lined	None	48 Hrs.
Metals	1 liter	HD polyethylene	Any Plastic	Ice / HNO_3	28 Days
TDS	300 ml.	clear glass	Any Plastic	Ice	7 Days

4.0 Chain of Custody

4.1 Prepare a Sample Plan. The plan will list the well identification and the individual tests to be performed at that location. The sampler will check the list against the available inventory of appropriate sample collection bottles to insure against shortage.

4.2 Transfer the data to the Laboratory Chain of Custody Form. Complete all sections of the form except those that relate to the time of delivery of the samples to the laboratory.

4.3 Pre-label the sample collection jars. Include all requested information except time of collection. (Use a fine point Sharpie to insure that the ink remains on the label). Affix the labels to the jars.

5.0 Bailing Procedure

5.1 Identify the well from the site schematics. Place pre-labeled jar(s) next to the well. Remove the bolts from the well cover and place the cover with the bolts nearby. Remove the plastic cap from the well bore by first lifting the metal lever and then unscrewing the entire assembly.

5.2 The well may be equipped with an individual 1 liter bailing tube. If so, use the tube to bail a volume of water from the well bore equal to 10 liters for each 5' of well bore in the water table. (This assumes a 2" dia. well bore).

5.3 Take care to insure that the bailing device and string do not become cross-contaminated. A clean pair of rubber gloves should be used when handling either the retrieval string or bailer. The retrieval string should not be allowed to come into contact with the ground.

6.0 Sampling Procedure

6.1 Once the well has been bailed in accordance with 5.2 of this procedure, a sample may be decanted into the appropriate sample collection jar directly from the bailer. The collection jar should be filled to the brim. Once the jar is sealed, turn the jar over to detect any bubbles that may be present. Add additional water to remove all bubbles from the sample container.

6.2 Note the time of collection on the sample collection jar with a fine Sharpie.

6.3 Place the sample directly on ice for transport to the laboratory. The preceding table shows the maximum hold times between collection and testing for the various analyses.

6.4 Complete the Chain of Custody form to include the collection times for each sample. Deliver all samples to the laboratory.

7.0 Documentation

7.1 The testing laboratory shall provide the following minimum information:

A. Client, Project and sample name.
B. Signed copy of the original Chain of Custody Form including data on the time the sample was received by the lab.
C. Results of the requested analyses
D. Test Methods employed
E. Quality Control methods and results

QP-77

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Procedure for Obtaining Soil Samples for Transportation to a Laboratory

Completed By: Approved By: Effective Date: / /

1.0 Purpose

This procedure outlines the methods to be employed when obtaining soil samples to be taken to a laboratory for analysis.

2.0 Scope

This procedure is to be used when collecting soil samples intended for ultimate transfer to a testing laboratory.

3.0 Preliminary

3.1 Obtain sterile sampling containers from the testing laboratory designated to conduct analyses of the soil. The shipment should include a Certificate of Compliance from the manufacturer of the collection bottle or vial and a Serial Number for the lot of containers. Retain this Certificate for future documentation purposes.

3.2 If collecting TPH, BTEX, RCRA 8 metals, cation / anions or O&G, the sample jar may be a clear 4 oz. container with Teflon lid. If collecting PAH's, use an amber 4 oz. container with Teflon lid.

4.0 Chain of Custody

4.1 Prepare a Sample Plan. The plan will list the number, location and designation of each planned sample and the individual tests to be performed on the sample. The sampler will check the list against the available inventory of appropriate sample collection bottles to insure against shortage.

4.2 Transfer the data to the Laboratory Chain of Custody Form. Complete all sections of the form except those that relate to the time of delivery of the samples to the laboratory.

4.3 Pre-label the sample collection jars. Include all requested information except time of collection. (Use a fine point Sharpie to insure that the ink remains on the label). Affix the labels to the jars.

5.0 Sampling Procedure

5.1 Go to the sampling point with the sample container. If not analyzing for ions or metals, use a trowel to obtain the soil. Do not touch the soil with your bare hands. Use new latex gloves with each sample to help minimize any cross-contamination.

5.2 Pack the soil tightly into the container leaving the top slightly domed. Screw the lid down tightly. Enter the time of collection onto the sample collection jar label.

5.3 Place the sample directly on ice for transport to the laboratory.

5.4 Complete the Chain of Custody form to include the collection times for each sample. Deliver all samples to the laboratory.

6.0 Documentation

6.1 The testing laboratory shall provide the following minimum information:

A. Client, Project and sample name.
B. Signed copy of the original Chain of Custody Form including data on the time the sample was received by the lab.
C. Results of the requested analyses
D. Test Methods employed
E. Quality Control methods and results

QP-96

WHOLE EARTH ENVIRONMENTAL
QUALITY PROCEDURE

Sampling and Testing Protocol
Chloride Titration Using .1 Normal
Silver Nitrate Solution

Completed By:	Approved By:	Effective Date: / /

1.0 Purpose

This procedure is to be used to determine the concentrations of chlorides in soils.

2.0 Scope

This procedure is to be used as the standard field measurement for soil chloride concentrations.

3.0 Sample Collection and Preparation

3.1 Collect at least 80 g. of soil from the sample collection point. Take care to insure that the sample is representative of the general background to include visible concentrations of hydrocarbons and soil types. If necessary, prepare a composite sample of soils obtained at several points in the sample area. Take care to insure that no loose vegetation, rocks or liquids are included in the sample(s).

3.2 The soil sample(s) shall be immediately inserted into a one quart or larger polyethylene freezer bag. Care should be taken to insure that no cross-contamination occur between the soil sample and the collection tools or sample processing equipment.

3.3 The sealed sample bag should be massaged to break up any clods.

4.0 Sample Preparation

4.1 Tare a plastic cup having a minimum six-ounce capacity. Add between 80-120 grams of the soil sample and record the weight.

4.2 Add the same weight of distilled water to the soil sample and stir thoroughly using a glass or plastic stir stick.

4.3 Allow the sample to set for a period of thirty minutes. The sample should be stirred at least three times before fluid extraction.

4.4 Carefully pour off the free liquid from the sample through a paper filter into a clean plastic cup.

5.0 Titration Procedure

5.1 Using a graduated pipette, remove 10 ml extract and dispense into a clean plastic cup.

5.2 Add 2-3 drops potassium chromate (K_2CrO_4) to mixture.

5.3 If the sample contains any sulfides (hydrogen or iron sulfides are common to oilfield soil samples) add 2-3 drops of hydrogen peroxide (H_2O_2) to mixture. Allow the mixture to set for a minimum of five minutes.

5.4 Using a 1 ml pipette, carefully add .1 normal silver nitrate solution to sample until solution turns salmon red when viewed with yellow goggles. Be consistent with endpoint recognition.

6.0 Calculation

Multiply the amount of silver nitrate used in step 5.4 by 354.5 to obtain the chloride concentration in mg / L.