1RP-277

GW Monitor Report

DATE:
Jan 2009

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TRIDENT ENVIRONMENTAL

RECEIVED

2009 JAN 26 PM 4 12

January 23, 2009

Mr. Glenn Von Gonten
New Mexico Energy, Minerals and Natural Resources Department
Oil Conservation Division – Environmental Bureau
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

SUBJECT: 2008 ANNUAL GROUNDWATER MONITORING REPORT
FORMER UNOCAL SOUTH VACUUM UNIT
NMOCD CASE NO. 1R-277
SECTION 35, TOWNSHIP 18 SOUTH, RANGE 35 EAST
LEA COUNTY, NEW MEXICO

Dear Mr. Von Gonten:

Enclosed is the 2008 Annual Groundwater Monitoring Report for the Former Unocal South Vacuum Unit site located in Lea County, New Mexico (hard copy and compact disk). Chevron Environmental Management Company has been managing the groundwater monitoring activities for the site since their acquisition of Unocal Corporation in 2005.

Please contact me at 432-638-8740, Mr. John MacLeod (Chevron EMC) at 925-842 2477, or Allen Just (Arcadis) at 714-730-9052 Ext. 38 if you have any questions or comments.

Sincerely,

Gilbert J. Van Deventer, REM, PG
Trident Environmental – Midland, TX

Attachments

xc: Mr. John MacLeod, Chevron EMC, San Ramon, CA
Mr. Allen Just, Arcadis, Irvine, CA

2008 Annual Groundwater Monitoring Report
Former Unocal South Vacuum Unit
NMOCD Case No. 1R-277
Section 35, Township 18 South, Range 35 East
Lea County, New Mexico

JANUARY 23, 2009

Prepared For:

Chevron Environmental Management Company
6111 Bollinger Canyon Rd.
San Ramon, CA 94583

Prepared By:

TRIDENT ENVIRONMENTAL

P. O. Box 7624
Midland, Texas 79708

2008 Annual Groundwater Monitoring Report

Former Unocal South Vacuum Unit

NMOCD Case NO. 1R-277

Section 35, Township 18 South, Range 35 East

Lea County, New Mexico

Prepared for:

Chevron Environmental Management Company

6111 Bollinger Canyon Road

San Ramon, CA 94583

Prepared by:

Trident Environmental
P. O. Box 7624
Midland, Texas 79708
(432) 638-8740
FAX (413) 403-9968

SUBMITTED BY:

DATE:

Gilbert J. Van Deventer, PG, REM
Project Manager

January 23, 2009

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1.0 Executive Summary

Trident Environmental (Trident) was retained by ARCADIS, on behalf of Chevron Environmental Management Company (Chevron EMC), to perform the 2008 annual groundwater sampling and monitoring operations at the Former Unocal South Vacuum Unit (site), which is located at township 18 south, range 35 east, section 35 in Lea County, New Mexico. Chevron EMC has assumed Unocal's environmental liability at the Site. This report documents the 2008 annual sampling event performed by Trident at the site on August 26, 2008. This report contains the historical groundwater elevation and analytical data from monitoring wells MW-1 through MW-6. The sampling event was conducted in accordance with the November 2, 2000 Groundwater Remediation Plan submitted by Unocal and the requirements specified in the New Mexico Oil and Conservation Division (OCD) letter dated February 8, 2001.

Based on the sampling and monitoring data to date, the following conclusions relevant to groundwater conditions at the Former Unocal South Vacuum Unit are evident:

- Chloride and total dissolved solids (TDS) concentrations in MW-1, near the source area, have generally decreased since 1996 with the exception of slight fluctuations since the 2003 sampling event. Similarly, chloride and TDS levels have decreased in the closest downgradient well, MW-4, since 1999 when that well was installed. Chloride and TDS concentrations in the remaining wells (MW-2, MW-3, MW-5, and MW-6) have remained relatively consistent with previous levels.

- The fate and transport modeling results continue to support the conclusion that the chloride and TDS plume is not likely to impact existing sources of water supply, the closest of which, a livestock (windmill) well (permit number L 05339) lies approximately 3,200 feet south of the source. Operation of the windmill well has been discontinued due to declining water levels in the area and the shallow depth of the well.

- According to conservative model simulations, the chloride plume will travel a maximum of 3,200 feet southeast of the source in approximately 149 years before concentrations return to levels below the New Mexico Water Quality Control Commission (WQCC) standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,300 feet in approximately 85 years before concentrations return to levels below the WQCC standard of 1,000 mg/L.

- Based on the modeling results and predicted natural attenuation processes (advection and dispersion), there will be no adverse impact to human health and the environment nor will the livestock well exceed WQCC standards for chlorides or TDS due to the plume originating and traveling southeast, versus south, from the former emergency overflow pit.

- Groundwater elevations have steadily decreased at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995; with the exception of the 2005 sampling event due to higher than normal rainfall during 2004 and 2005. The decreasing groundwater elevation trend has resumed since 2005.

Exemplary remedial actions were performed to the source area by Unocal, including plugging of the SWD well in 1971 and encapsulating the former surface impoundment area with solidification material in 1995, thus eliminating the threat of any continued release from the source. Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions for site closure:

- Continue the natural attenuation annual monitoring program with groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.

- Update flow and transport model to confirm the plume is naturally attenuating as described.

- Submit the 2009 annual groundwater monitoring report to OCD in January 2010 to document natural attenuation conditions.

2.0 Groundwater Sampling Procedures

On August 26, 2008, each of the six monitoring wells, MW-1 through MW-6, was gauged for depth to groundwater using a Solinst Model 101 electronic water indicator immediately prior to purging operations. A total of 39 gallons of groundwater was purged from each site monitoring well (3 to 10 gallons per well) using a decontaminated 2-inch diameter PVC bailer. After purging, groundwater samples were collected and parameters were measured using a Hanna Model 98130 pH-Conductivity-Temperature meter. Water samples for each monitoring well were transferred into 500 milliliter (ml) plastic containers for laboratory analysis of TDS using Environmental Protection Agency (EPA) Method 160.1 and chloride using EPA Method 325.3. For each set of samples, chain of custody forms documenting sample identification numbers, collection times, and delivery times to the laboratory were completed. All water samples were placed in an ice-filled cooler immediately after collection and transported to Lancaster Laboratories (Lancaster, PA) for analysis.

3.0 Groundwater Elevations, Hydraulic Gradient and Flow Direction

Depth to groundwater varies from approximately 50.80 to 71.61 feet below top of well casing at the site. Groundwater elevations are summarized in Table 1. A groundwater gradient map indicating the direction of groundwater flow is illustrated in Figure 1. A historical groundwater elevation graph is shown in Figure 2. The groundwater gradient direction is to the southeast with a hydraulic gradient of approximately 0.004 ft/ft. According to published reports (*Ground-Water Conditions in Northern Lea County, New Mexico*, Ash, 1963 and *Geology and Ground-Water Conditions in Southern Lea County, New Mexico*, Nicholson and Clebsch, 1961) the groundwater encountered at the site is that of the Tertiary Ogallala Formation. The Ogallala Formation unconformably overlies the impermeable red-beds of the Triassic Chinle Formation at an elevation of approximately 3700 feet above mean sea level (AMSL). Based on the current groundwater elevations measured on site and published data referenced, the saturated thickness of the Ogallala Formation at the site ranges from approximately 87 to 96 feet.

TRIDENT ENVIRONMENTAL

FIGURE 1

Former Unocal South Vacuum Unit

Groundwater Gradient Map

Figure 2
Historical Groundwater Elevations

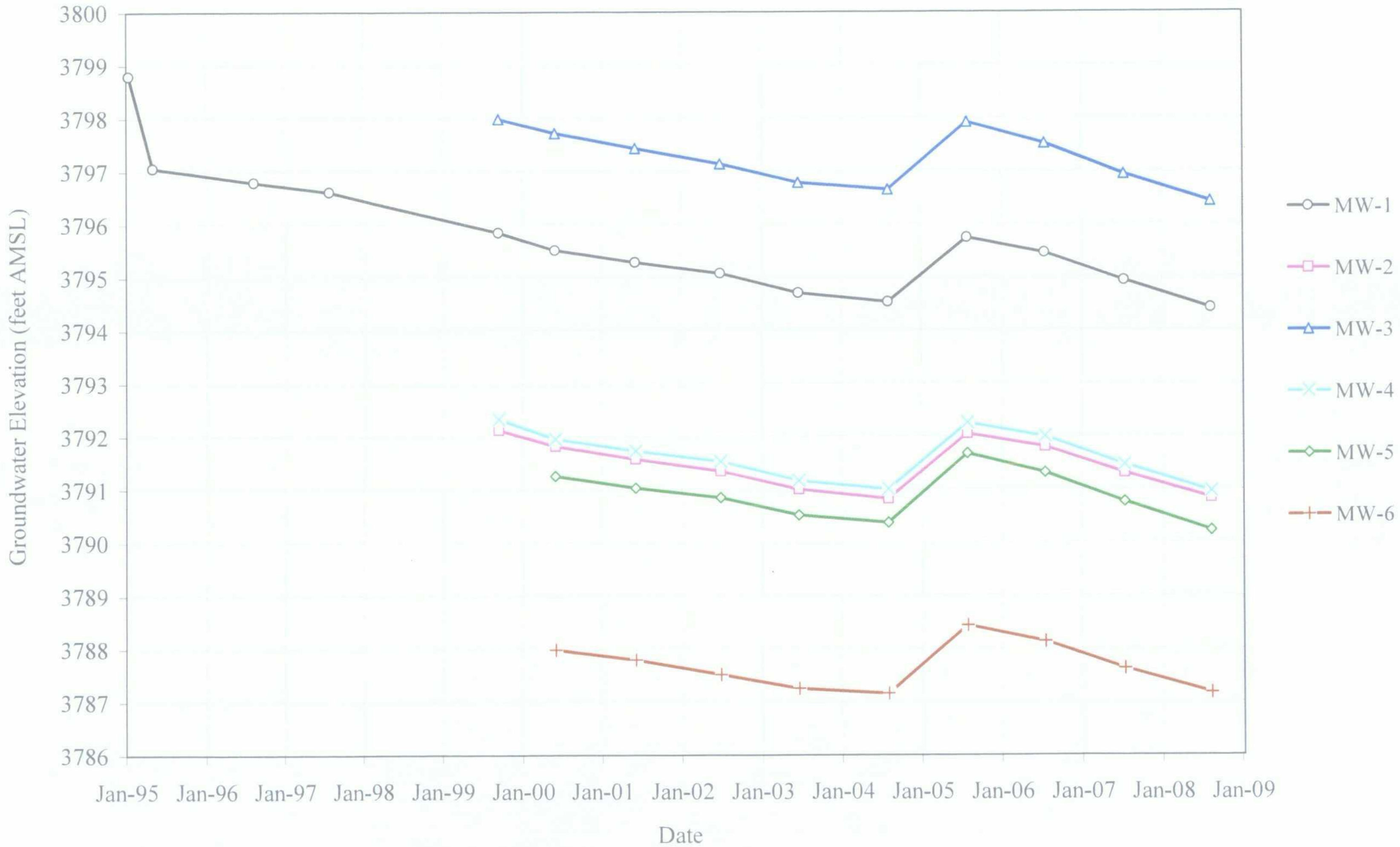

Table 1

Summary of Groundwater Sampling Results

Monitoring Well	Sampling Date	Chloride (mg/L)	TDS (mg/L)	Depth to Groundwater (feet BTOC)	Top of Casing Elevation (feet AMSL)	Groundwater Elevation (feet AMSL)
MW-1	01/27/95	**1174**	**2250**	59.57	3858.37	3798.80
	05/18/95	**983**	**2251**	61.30	3858.37	3797.07
	08/28/96	**1420**	**2730**	61.57	3858.37	3796.80
	08/13/97	**1400**	**2800**	61.75	3858.37	3796.62
	09/30/99	**1094**	**2318**	62.51	3858.37	3795.86
	06/14/00	**927**	**2040**	62.85	3858.37	3795.52
	06/18/01	**813**	**1790**	63.07	3858.37	3795.30
	07/11/02	**784**	**1680**	63.28	3858.37	3795.09
	07/02/03	**715**	**2090**	63.66	3858.37	3794.71
	08/12/04	**628**	**2050**	63.83	3858.37	3794.54
	08/10/05	**774**	**1830**	62.62	3858.37	3795.75
	07/31/06	**860**	**2010**	62.90	3858.37	3795.47
	07/27/07	**732**	**1790**	63.43	3858.37	3794.94
	08/26/08	**895**	**1960**	63.95	3858.37	3794.42
MW-2	09/30/99	**298**	922	49.51	3841.64	3792.13
	06/14/00	**317**	852	49.81	3841.64	3791.83
	06/18/01	**288**	878	50.06	3841.64	3791.58
	07/11/02	**284**	808	50.29	3841.64	3791.35
	07/02/03	**268**	859	50.63	3841.64	3791.01
	08/12/04	**451**	931	50.81	3841.64	3790.83
	08/10/05	**355**	844	49.58	3841.64	3792.06
	07/31/06	**401**	922	49.83	3841.64	3791.81
	07/27/07	**430**	984	50.33	3841.64	3791.31
	08/26/08	**354**	980	50.80	3841.64	3790.84
MW-3	09/30/99	73.6	427	66.74	3864.73	3797.99
	06/14/00	75.5	433	67.01	3864.73	3797.72
	06/18/01	86.4	495	67.29	3864.73	3797.44
	07/11/02	103	509	67.59	3864.73	3797.14
	07/02/03	98.3	588	67.94	3864.73	3796.79
	08/12/04	111	605	68.07	3864.73	3796.66
	08/10/05	122	533	66.81	3864.73	3797.92
	07/31/06	141	619	67.21	3864.73	3797.52
	07/27/07	164	705	67.79	3864.73	3796.94
	08/26/08	185	592	68.30	3864.73	3796.43
MW-4	09/30/99	**1576**	**2981**	60.18	3852.51	3792.33
	06/14/00	**1500**	**2910**	60.55	3852.51	3791.96
	06/18/01	**1530**	**3180**	60.78	3852.51	3791.73
	07/11/02	**1290**	**2660**	60.98	3852.51	3791.53
	07/02/03	**1250**	**2610**	61.34	3852.51	3791.17
	08/12/04	**1130**	**2480**	61.50	3852.51	3791.01
	08/10/05	**1050**	**2230**	60.25	3852.51	3792.26
	07/31/06	**926**	**2030**	60.51	3852.51	3792.00
	07/27/07	**758**	**1940**	61.04	3852.51	3791.47
	08/26/08	**720**	**1790**	61.55	3852.51	3790.96
MW-5	06/14/00	13.7	274	68.57	3859.84	3791.27
	06/18/01	13.6	322	68.80	3859.84	3791.04
	07/11/02	15.5	308	68.98	3859.84	3790.86
	07/02/03	12.5	359	69.32	3859.84	3790.52
	08/12/04	15.3	375	69.46	3859.84	3790.38
	08/10/05	14.9	309	68.15	3859.84	3791.69
	07/31/06	13.3	290	68.52	3859.84	3791.32
	07/27/07	14.9	296	69.07	3859.84	3790.77
	08/26/08	13.6	296	69.61	3859.84	3790.23
MW-6	06/14/00	48	382	70.79	3858.78	3787.99
	06/18/01	50.8	431	70.98	3858.78	3787.80
	07/11/02	50	422	71.26	3858.78	3787.52
	07/02/03	46.5	471	71.52	3858.78	3787.26
	08/12/04	55.1	410	71.62	3858.78	3787.16
	08/10/05	55	391	70.33	3858.78	3788.45
	07/31/06	52.4	412	70.64	3858.78	3788.14
	07/27/07	75.3	516	71.15	3858.78	3787.63
	08/26/08	88.5	548	71.61	3858.78	3787.17
WQCC Standards		250	1000			

Total Dissolved Soilds (TDS) and chloride concentrations listed in milligrams per liter (mg/L
Analyses performed by Trace Analysis Inc., Lubbock, TX (1995-1998) and SPL, Inc., Houston, TX (1999-200(
Values in boldface type indicate concentrations exceed New Mexico Water Quality Commission (WQCC) standard:
AMSL - Above Mean Sea Level; BTOC - Below Top of Casin
Groundwater flow direction is to the southeast with a gradient of approx. 0.004 ft/ft
Elevations and state plane coordinates surveyed by Basin Surveys, Hobbs, NM

4.0 Groundwater Quality Conditions

Groundwater sample analytical results are presented in Table 1. The WQCC standards are presented for comparison. Those constituents that recorded concentrations above the WQCC standards are highlighted in boldface type. The WQCC standard of 250 mg/L for chloride was exceeded in MW-1 (895 mg/L), MW-2 (354 mg/L), and MW-4 (720 mg/L). The WQCC standard of 1,000 mg/L for TDS was exceeded only in MW-1 (1,960 mg/L) and MW-4 (1,790 mg/L). The groundwater samples obtained from upgradient monitoring well MW-3 and downgradient wells MW-5 and MW-6 had chloride and TDS concentrations below WQCC standards.

The chloride and TDS concentrations are depicted graphically in Figure 3 and 4, respectively. The concentration isocons were drawn utilizing the Surfer® (version 6.0) contour modeling program (Kriging method). Since this contouring program does not take into account the known groundwater gradient, some of the isocons were manually converged into a more southeasterly orientation. Graphs depicting historical TDS and chloride concentrations in monitoring wells MW-1 through MW-6 are shown in Figures 5 and 6.

Chloride and TDS concentrations in MW-1, near the source area, have consistently decreased since 1996, with the exception of slight fluctuations since the 2003 sampling event. Similarly, chloride and TDS levels have steadily decreased in the closest downgradient well, MW-4, since 1999 when that well was installed. Chloride and TDS concentrations in monitoring well MW-3 have slightly increased since 2000, which suggests a possible offsite source of chlorides and TDS located upgradient (northwest) from the site. Chloride and TDS levels in MW-2, MW-5, and MW-6 have remained relatively consistent with previous years.

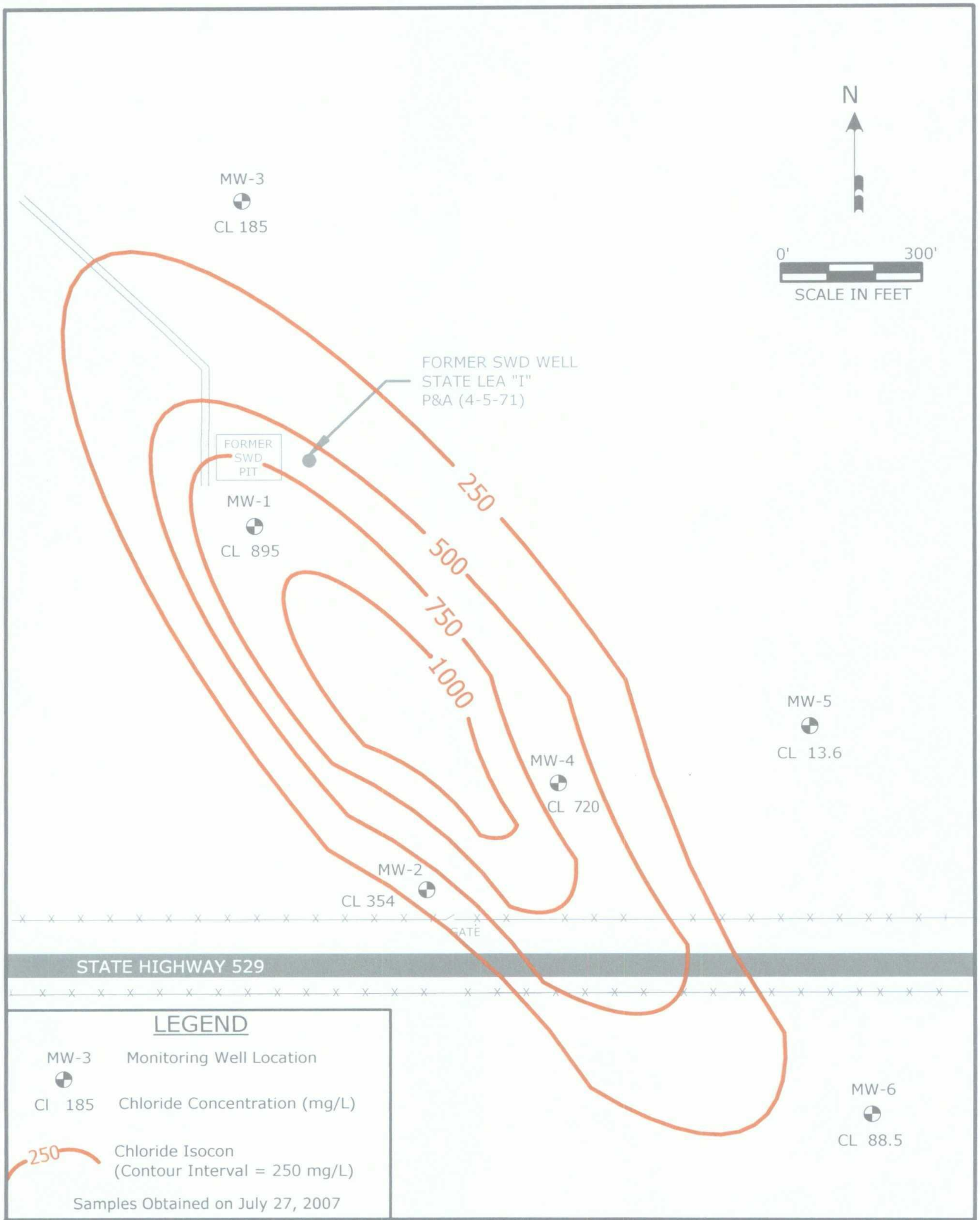

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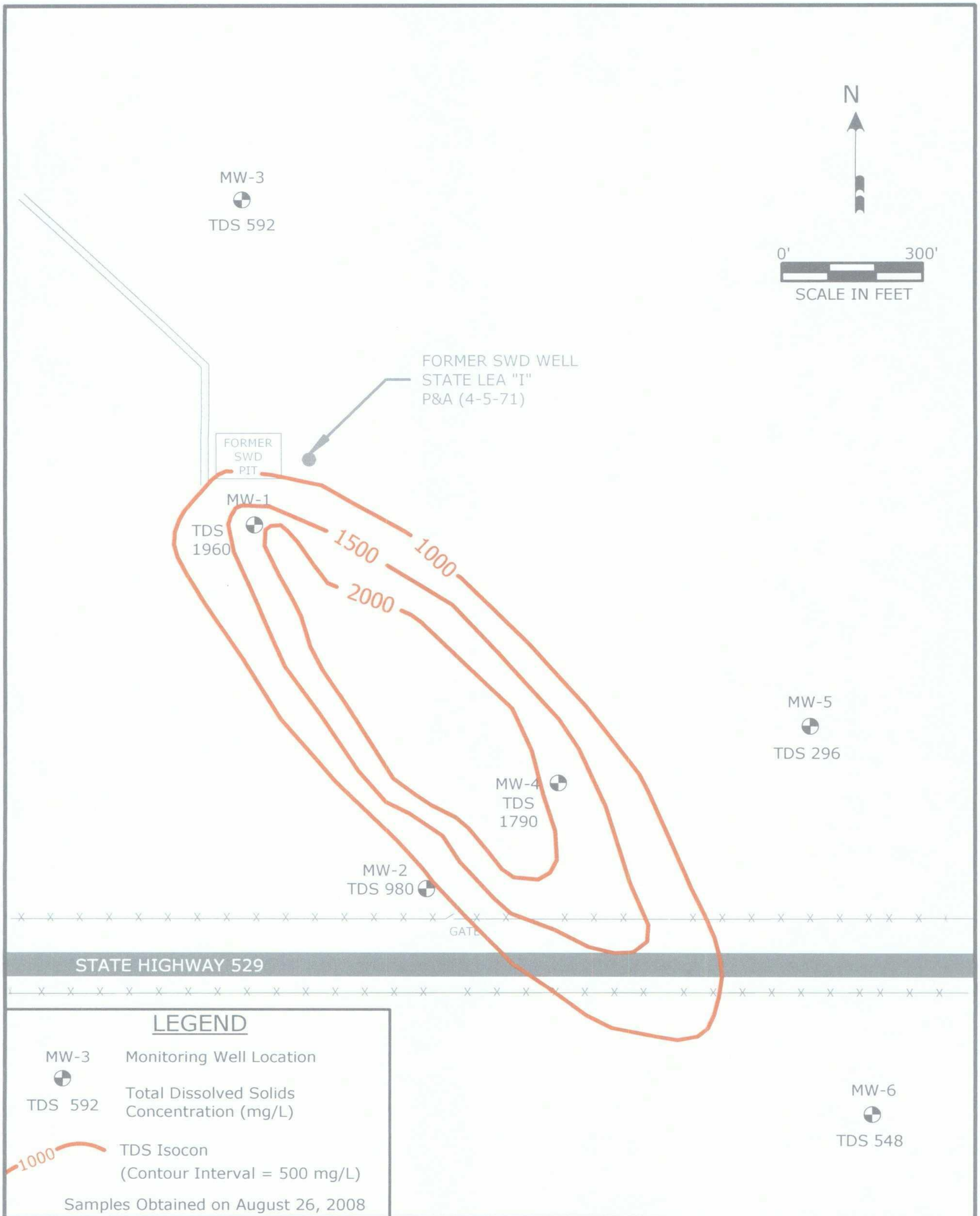
FIGURE 3

Former Unocal South Vacuum Unit
Chloride Concentration Map
Current Conditions (2008)



TRIDENT ENVIRONMENTAL

FIGURE 4

Former Unocal South Vacuum Unit
TDS Concentration Map
Current Conditions (2008)

Figure 5
Chloride Concentrations Versus Time Graph

Figure 6
Total Dissolved Solids Concentrations Versus Time Graph

5.0 Fate and Transport Modeling Results

Fate and transport modeling was performed by Trident to simulate the movement of the chloride and TDS groundwater plume over time. Simulations were conducted using the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. A more detailed discussion of the flow and transport parameters used, assumptions, model calibrations, and simulation results are described in Appendix D.

Figures displaying modeled simulations of the chloride and TDS plumes over various time increments are included in Appendix C. Advective flow moves the center of plume mass downgradient as depicted in the simulations. The simulations also demonstrate how hydrodynamic dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume.

Continued attenuation by dilution and dispersion of the plume, after the maximum chloride and TDS concentrations decrease to levels below WQCC standards, are shown in the final simulation for each constituent of concern (year 2157 for chloride and year 2093 for TDS, respectively). The center of the chloride plume is approximately 3,200 ft away from the pit and well source in the year 2157. The center of the TDS plume is approximately 2,300 ft away from the pit and well source in the year 2093.

The portions of the chloride and TDS plumes that are above WQCC standards do not reach any of the identified potential receptors at any time during their attenuation. The results of the updated fate and transport model are consistent with those determined in previous annual reports.

6.0 Conclusions

Conclusions relevant to groundwater conditions and the remediation performance at the Former Unocal South Vacuum Unit are presented below.

- Chloride and TDS concentrations in MW-1, near the source area, have generally decreased since 1996. Similarly, chloride and TDS levels have significantly decreased in the closest downgradient well, MW-4, since 1999 when that well was installed. Chloride and TDS concentrations in the remaining wells (MW-2, MW-3, MW-5, and MW-6) have remained relatively consistent with previous levels.
- The fate and transport modeling results continue to support the contention that the chloride and TDS plume is not likely to impact existing sources of water supply, the closest of which, a livestock (windmill) well (permit number L 05339) lies approximately 3,200 feet south of the source. Operation of the windmill well has been discontinued due to declining water levels in the area and the shallow depth of the well.
- According to conservative model simulations, the chloride plume will travel a maximum of 3,200 feet southeast of the source in approximately 149 years before concentrations return to levels below the WQCC standard of 250 mg/L. The same analysis indicates that the TDS plume will travel only 2,300 feet in approximately 85 years before concentrations return to levels below the WQCC standard of 1,000 mg/L.
- Based on the modeling results and predicted natural attenuation processes (dispersion and dilution), there will be no adverse impact to human health and the environment nor will the livestock well exceed WQCC standards for chlorides or TDS due to the plume originating and traveling southeast, versus south, from the former emergency overflow pit.
- Groundwater elevations had steadily decreased at a rate of approximately 0.3 feet per year since the initial sampling event of monitoring well MW-1 in January 1995; however during 2005 the groundwater table increased to an elevation similar to the 1999 level. The recent rise may be attributed to higher than normal rainfall during 2004 and 2005. The decreasing groundwater elevation trend has resumed since 2005.

7.0 Recommendations

Chevron EMC has performed exemplary remedial actions to the source area, including plugging of the SWD well in 1971 and encapsulating the former surface impoundment area with solidification material in 1995, thus eliminating the threat of any continued release from the source. Based on the identified potential receptor and fate and transport modeling results, the chloride/TDS plume at the site presents low risk to human health and the environment; therefore Trident recommends the following actions for site closure:

- Continue the natural attenuation annual monitoring program with groundwater sampling and analysis of chloride and TDS concentrations for each of the six monitoring wells.

- Update flow and transport model to confirm the plume is naturally attenuating as described.

- Submit the 2009 annual groundwater monitoring report to OCD in January 2010 to document natural attenuation conditions.

APPENDIX A

Laboratory Analytical Reports

And

Chain-of-Custody Documentation

ANALYTICAL RESULTS

Prepared for:

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

925-842-2477

Prepared by:

Lancaster Laboratories
2425 New Holland Pike
Lancaster, PA 17605-2425

SAMPLE GROUP

The sample group for this submittal is 1107500. Samples arrived at the laboratory on Thursday, August 28, 2008. The PO# for this group is 0015023629 and the release number is MACLEOD.

Client Description	Lancaster Labs Number
MW-1 Grab Water Sample	5452996
MW-2 Grab Water Sample	5452997
MW-3 Grab Water Sample	5452998
MW-4 Grab Water Sample	5452999
MW-5 Grab Water Sample	5453000
MW-6 Grab Water Sample	5453001

ELECTRONIC COPY TO	ARCADIS	Attn: Mark M. Miller
1 COPY TO	ARCADIS	Attn: Allen Just
ELECTRONIC COPY TO	Trident Environmental	Attn: Gilbert Van Deventer
ELECTRONIC COPY TO	ARCADIS	Attn: Dana Koschel
ELECTRONIC COPY TO	ARCADIS	Attn: Sarah Huff
ELECTRONIC COPY TO	ARCADIS	Attn: Robin Simon

Lancaster Laboratories

Analysis Report

2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax 717-656-2681 • www.lancasterlabs.com

Questions? Contact your Client Services Representative
Katherine A Klinefelter at (717) 656-2300

Respectfully Submitted,

Robert Heisey

Robert Heisey
Senior Specialist

Lancaster Laboratories
2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax: 717-656-2681 • www.lancasterlabs.com

Analysis Report

Lancaster Laboratories Sample No. 5452996 WW Group No. 1107500

MW-1 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected:08/26/2008 13:02 by GVD

Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:25
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	1,960	77.6	240	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	895	20.0	100	mg/l	50

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	50

*=This limit was used in the evaluation of the final result

Lancaster Laboratories

Analysis Report

2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax:717-656-2681 • www.lancasterlabs.com

Lancaster Laboratories Sample No. 5452997 WW   Group No. 1107500

MW-2 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected:08/26/2008 11:50   by GVD   Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:26
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	980	38.8	120	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	354	8.0	40.0	mg/l	20

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	20

*=This limit was used in the evaluation of the final result

Lancaster Laboratories
2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax: 717-656-2681 • www.lancasterlabs.com

Analysis Report

Lancaster Laboratories Sample No. 5452998 WW Group No. 1107500

MW-3 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected:08/26/2008 12:25 by GVD

Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:26
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	592	19.4	60.0	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	185	4.0	20.0	mg/l	10

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	10

*=This limit was used in the evaluation of the final result

Lancaster Laboratories

Analysis Report

2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax: 717-656-2681 • www.lancasterlabs.com

Lancaster Laboratories Sample No. 5452999 WW   Group No. 1107500

MW-4 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected: 08/26/2008 10:50   by GVD   Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:26
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	1,790	77.6	240	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	720	20.0	100	mg/l	50

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	50

*=This limit was used in the evaluation of the final result

Lancaster Laboratories
2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax:717-656-2681 • www.lancasterlabs.com

Analysis Report

Lancaster Laboratories Sample No. 5453000 WW Group No. 1107500

MW-5 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected:08/26/2008 10:10 by GVD

Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:26
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	296	9.7	30.0	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	13.6	1.6	8.0	mg/l	4

The reporting limit for the analyte above was raised due to matrix interference.

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	4

*=This limit was used in the evaluation of the final result

Lancaster Laboratories
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Analysis Report

Lancaster Laboratories Sample No. 5453001 WW Group No. 1107500

MW-6 Grab Water Sample
Former Unocal South Vacuum Unit
Lea County, NM

Collected:08/26/2008 13:50 by GVD

Account Number: 11969

Submitted: 08/28/2008 09:00
Reported: 09/08/2008 at 17:26
Discard: 10/09/2008

Chevron Env Mgmt Co
PO Box 6012
San Ramon CA 94583

CAT No.	Analysis Name	CAS Number	As Received Result	As Received Method Detection Limit*	As Received Limit of Quantitation	Units	Dilution Factor
00212	Total Dissolved Solids	n.a.	548	9.7	30.0	mg/l	1
01124	Chloride (titrimetric)	16887-00-6	88.5	4.0	20.0	mg/l	10

All QC is compliant unless otherwise noted. Please refer to the Quality Control Summary for overall QC performance data and associated samples.

Laboratory Chronicle

CAT No.	Analysis Name	Method	Trial#	Analysis Date and Time	Analyst	Dilution Factor
00212	Total Dissolved Solids	SM20 2540 C	1	08/29/2008 09:37	Susan E Hibner	1
01124	Chloride (titrimetric)	SM20 4500 Cl C	1	09/05/2008 14:40	Susan A Engle	10

*=This limit was used in the evaluation of the final result

Lancaster Laboratories

Analysis Report

2425 New Holland Pike, PO Box 12425, Lancaster, PA 17605-2425 • 717-656-2300 Fax: 717-656-2681 • www.lancasterlabs.com

Quality Control Summary

Client Name: Chevron Env Mgmt Co — Group Number: 1107500
Reported: 09/08/08 at 05:26 PM

Matrix QC may not be reported if site-specific QC samples were not submitted. In these situations, to demonstrate precision and accuracy at a batch level, a LCS/LCSD was performed, unless otherwise specified in the method.

Laboratory Compliance Quality Control

Analysis Name	Blank Result	Blank MDL**	Blank LOQ	Report Units	LCS %REC	LCSD %REC	LCS/LCSD Limits	RPD	RPD Max
Batch number: 08242021201A	Sample number(s): 5452996-5453001								
Total Dissolved Solids	ND	9.7	30.0	mg/l	104		80-120		
Batch number: 08249112402A	Sample number(s): 5452996-5453001								
Chloride (titrimetric)					98		96-102		

Sample Matrix Quality Control

Unspiked (UNSPK) = the sample used in conjunction with the matrix spike
Background (BKG) = the sample used in conjunction with the duplicate

Analysis Name	MS %REC	MSD %REC	MS/MSD Limits	RPD	RPD MAX	BKG Conc	DUP Conc	DUP RPD	Dup RPD Max
Batch number: 08242021201A	Sample number(s): 5452996-5453001 UNSPK: P453100 BKG: P453100								
Total Dissolved Solids	95	96	54-143	1	12	1,180	1,160	2	9
Batch number: 08249112402A	Sample number(s): 5452996-5453001 UNSPK: P453100 BKG: P453100								
Chloride (titrimetric)	99	98	91-105	1	2	352	356	1	5

*- Outside of specification
**-This limit was used in the evaluation of the final result for the blank
(1) The result for one or both determinations was less than five times the LOQ.
(2) The unspiked result was more than four times the spike added.

Analysis Request/Environmental Services Chain of Custody

Lancaster Laboratories

For Lancaster Laboratories use only

Acct. # 11969 Group# 1107500 Sample # 5452996-3001 **COC # 189902**

Please print. Instructions on reverse side correspond with circled numbers. Cooler temp 1.0°C

(1) Client: Chevron Environmental Mgmt. Co Acct. #: 11969

Project Name/#: Former Unocal S. Vacuum Unit PWSID #:

Project Manager: Allen Just P.O.#:

Sampler: Gil Van Deventer Quote #:

Name of state where samples were collected: NM

For Lab Use Only
FSC:
SCR#: 64003

(5) Analyses Requested

(2) Sample Identification	Date Collected	Time Collected	(3) Grab	Composite	Soil	Water (Potable / NPDES)	Other	(4) Total # of Containers	Chloride (325.3)	TDS (160.1)								Remarks
Preservation Codes									Ice	Ice								
MW-1	8-26-08	1302	X			X		1										
MW-2	8-26-08	1150	X			X		1										
MW-3	8-26-08	1225	X			X		1										
MW-4	8-26-08	1050	X			X		1										
MW-5	8-26-08	1010	X			X		1										
MW-6	8-26-08	1350	X			X		1										
																		FedEx Airbill # 8657 5242 0980

Preservation Codes
H=HCl T=Thiosulfate
N=HNO_3 B=NaOH
S=H_2SO_4 O=Other

(6) Temperature of samples upon receipt (if requested)

(7) **Turnaround Time Requested** (TAT) (please circle): (Normal) Rush
(Rush TAT is subject to Lancaster Laboratories approval and surcharge.)
Date results are needed:
Rush results requested by (please circle): Phone Fax E-mail
Phone #: 432-638-8740 ~~Fax~~ e-mail #: Allen.Just@arcadis-us.com
E-mail address: gil@trident-environmental.com

(8) **Data Package Options** (please circle if required)
Type I (validation/NJ Reg) TX TRRP-13
Type II (Tier II) MA MCP CT RCP
Type III (Reduced NJ)
Type IV (CLP SOW)
Type VI (Raw Data Only)

SDG Complete? Yes No

Site-specific QC (MS/MSD/Dup)? Yes (No)
(If yes, indicate QC sample and submit triplicate volume.)
Internal COC Required? Yes / No

(9)

Relinquished by:	Date	Time	Received by:	Date	Time
[signature]	8/26/08	16:00	[signature]	8/25/08	12:00p
[signature]	8/27/08	6:00p			
			[signature]	8-28-08	0900

Lancaster Laboratories, Inc., 2425 New Holland Pike, Lancaster, PA 17601 (717) 656-2300 Fax: (717) 656-6766
Copies: White and yellow should accompany samples to Lancaster Laboratories. The pink copy should be retained by the client.

2102.03

Lancaster Laboratories
Explanation of Symbols and Abbreviations

The following defines common symbols and abbreviations used in reporting technical data:

N.D.	none detected	**BMQL**	Below Minimum Quantitation Level
TNTC	Too Numerous To Count	**MPN**	Most Probable Number
IU	International Units	**CP Units**	cobalt-chloroplatinate units
umhos/cm	micromhos/cm	**NTU**	nephelometric turbidity units
C	degrees Celsius	**F**	degrees Fahrenheit
Cal	(diet) calories	**lb.**	pound(s)
meq	milliequivalents	**kg**	kilogram(s)
g	gram(s)	**mg**	milligram(s)
ug	microgram(s)	**l**	liter(s)
ml	milliliter(s)	**ul**	microliter(s)
m3	cubic meter(s)	**fib >5 um/ml**	fibers greater than 5 microns in length per ml

< less than – The number following the sign is the limit of quantitation, the smallest amount of analyte which can be reliably determined using this specific test.

> greater than

ppm parts per million – One ppm is equivalent to one milligram per kilogram (mg/kg), or one gram per million grams. For aqueous liquids, ppm is usually taken to be equivalent to milligrams per liter (mg/l), because one liter of water has a weight very close to a kilogram. For gases or vapors, one ppm is equivalent to one microliter of gas per liter of gas.

ppb parts per billion

Dry weight basis Results printed under this heading have been adjusted for moisture content. This increases the analyte weight concentration to approximate the value present in a similar sample without moisture.

U.S. EPA data qualifiers:

Organic Qualifiers

A	TIC is a possible aldol-condensation product
B	Analyte was also detected in the blank
C	Pesticide result confirmed by GC/MS
D	Compound quatitated on a diluted sample
E	Concentration exceeds the calibration range of the instrument
J	Estimated value
N	Presumptive evidence of a compound (TICs only)
P	Concentration difference between primary and confirmation columns >25%
U	Compound was not detected
X,Y,Z	Defined in case narrative

Inorganic Qualifiers

B	Value is <CRDL, but ≥IDL
E	Estimated due to interference
M	Duplicate injection precision not met
N	Spike amount not within control limits
S	Method of standard additions (MSA) used for calculation
U	Compound was not detected
W	Post digestion spike out of control limits
*****	Duplicate analysis not within control limits
+	Correlation coefficient for MSA <0.995

Analytical test results for methods listed on the laboratories' accreditation scope meet all requirements of NELAC unless otherwise noted under the individual analysis.

Tests results relate only to the sample tested. Clients should be aware that a critical step in a chemical or microbiological analysis is the collection of the sample. Unless the sample analyzed is truly representative of the bulk of material involved, the test results will be meaningless. If you have questions regarding the proper techniques of collecting samples, please contact us. We cannot be held responsible for sample integrity, however, unless sampling has been performed by a member of our staff. This report shall not be reproduced except in full, without the written approval of the laboratory.

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APPENDIX B

Monitoring Well Sampling Data Forms

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-1

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐mp If Pump, Type:

SAMPLING METHOD: ☑ Disposable Bailer ☐ect from Discharge Hose Other: ☐

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑lconox D☑illed Water Rinse Other: ☐

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge D☐ms Disp☑al Facility

TOTAL DEPTH OF WELL: 70.00 Feet
DEPTH TO WATER: 63.95 Feet
HEIGHT OF WATER COLUMN: 6.05 Feet 3.0 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
12:48	0						Staring hand bailing
12:54	1.3	20.5	3.03	7.52			
12:59	2.7	20.2	3.12	7.45			
13:02	4.0	19.9	3.05	7.62			Collected sample
0:14	:Total Time (hr:min)		4	:Total Vol (gal)		0.29	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-2

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐mp If Pump, Type: ____

SAMPLING METHOD: ☑ Disposable Bailer ☐ct from Discharge Hose Other: ☐

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑lconox D☑illed Water Rinse Other: ☐

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge D☐ms Disp☑al Facility

TOTAL DEPTH OF WELL: 71.00 Feet
DEPTH TO WATER: 50.80 Feet
HEIGHT OF WATER COLUMN: 20.20 Feet 9.9 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
11:13	0						Staring hand bailing
11:25	3	20.2	1.60	8.71			
11:38	7	20.5	1.67	9.16			
11:50	10	20.1	1.70	9.16			Collected sample
0:37	:Total Time (hr:min)		10	:Total Vol (gal)		0.27	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-3

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type:

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose Other: ☐

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse Other: ☐

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 77.00 Feet

DEPTH TO WATER: 68.30 Feet

HEIGHT OF WATER COLUMN: 8.70 Feet 4.3 Minimum Gallons to purge 3 well volumes

WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
12:06	0						Staring hand bailing
12:12	2	20.2	0.90	7.72			
12:18	4	19.8	0.90	7.95			
12:25	6	20.3	0.89	7.88			Collected sample
0:19	:Total Time (hr:min)		6	:Total Vol (gal)		0.32	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-4

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type:

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose Other: ☐

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse Other: ☐

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 71.00 Feet
DEPTH TO WATER: 61.55 Feet
HEIGHT OF WATER COLUMN: 9.45 Feet 4.6 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
10:27	0						Staring hand bailing
10:33	2	20.2	2.99	8.44			
10:40	4	20.1	2.97	8.41			
10:50	6	20.4	3.04	8.40			Sample collected
0:23	:Total Time (hr:min)		6	:Total Vol (gal)		0.26	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-5

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type: ______

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose Other: ☐ ______

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse Other: ☐ ______

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 79.00 Feet
DEPTH TO WATER: 69.61 Feet
HEIGHT OF WATER COLUMN: 9.39 Feet 4.6 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
9:27	0						Staring hand bailing
9:38	3	19.9	0.41	7.95			
9:57	7	20.4	0.42	7.62			
10:10	10	20.2	0.41	7.77			Collected sample
0:43	:Total Time (hr:min)		10	:Total Vol (gal)		0.23	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

C:/FORMS/SAMPLING DATA FORM

WELL SAMPLING DATA FORM

CLIENT: Chevron Environmental Management Co. WELL ID: MW-6

SITE NAME: Former Unocal S. Vacuum Unit DATE: 08/26/08

PROJECT NO. V-107 SAMPLER: Van Deventer

PURGING METHOD: ☑ Hand Bailed ☐ Pump If Pump, Type:

SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose Other: ☐

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rinse Other: ☐

DISPOSAL METHOD OF PURGE WATER: ☐ Surface Discharge ☐ Drums ☑ Disposal Facility

TOTAL DEPTH OF WELL: 77.20 Feet
DEPTH TO WATER: 71.61 Feet
HEIGHT OF WATER COLUMN: 5.59 Feet 2.7 Minimum Gallons to purge 3 well volumes
WELL DIAMETER: 2.0 Inch

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L	Turb	PHYSICAL APPEARANCE AND REMARKS
16:45	0						Staring hand bailing
16:49	1	20.4	0.76	8.05			
16:52	2	19.8	0.78	8.09			
16:56	3	19.8	0.79	8.08			Sample collected
0:11	:Total Time (hr:min)		3	:Total Vol (gal)		0.27	:Average Flow Rate (gal/min)

COMMENTS: Parameters obtained using a calibrated Hanna Model 98130 pH-Temperature-Conductivity meter.

Sample placed into 500 ml plastic container, and put on ice in cooler.

Delivered sample to Lancaster Laboratories (Lancaster PA) for Chloride and TDS analyses.

APPENDIX C

Chloride and TDS Plume Simulations

==

WinTran
Analytical Model of 2D Ground-Water Flow and
Finite-Element Contaminant Transport Model

Developed by

James O. Rumbaugh, III

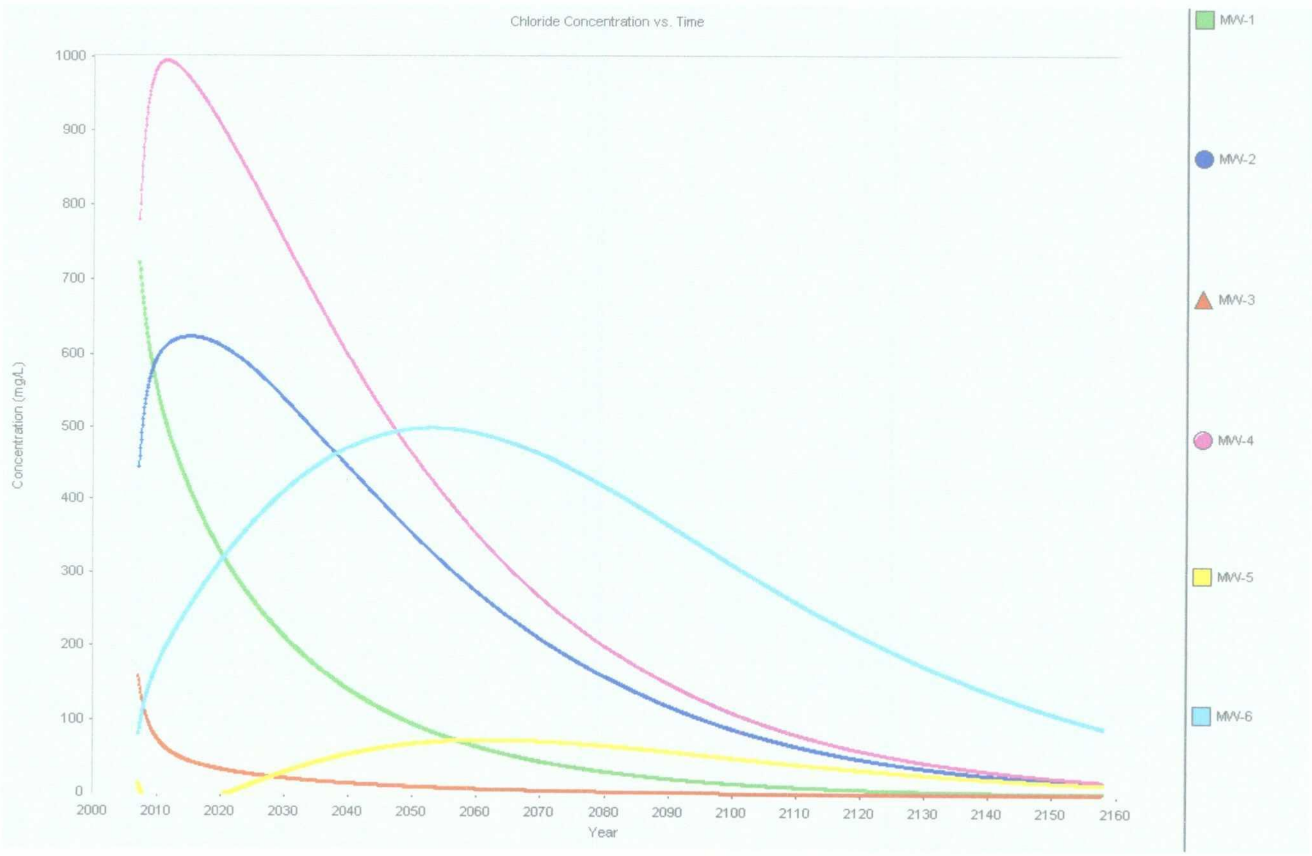
Douglas B. Rumbaugh

==

Chloride Fate & Transport Simulation run by:
Gilbert Van Deventer (Trident Environmental)

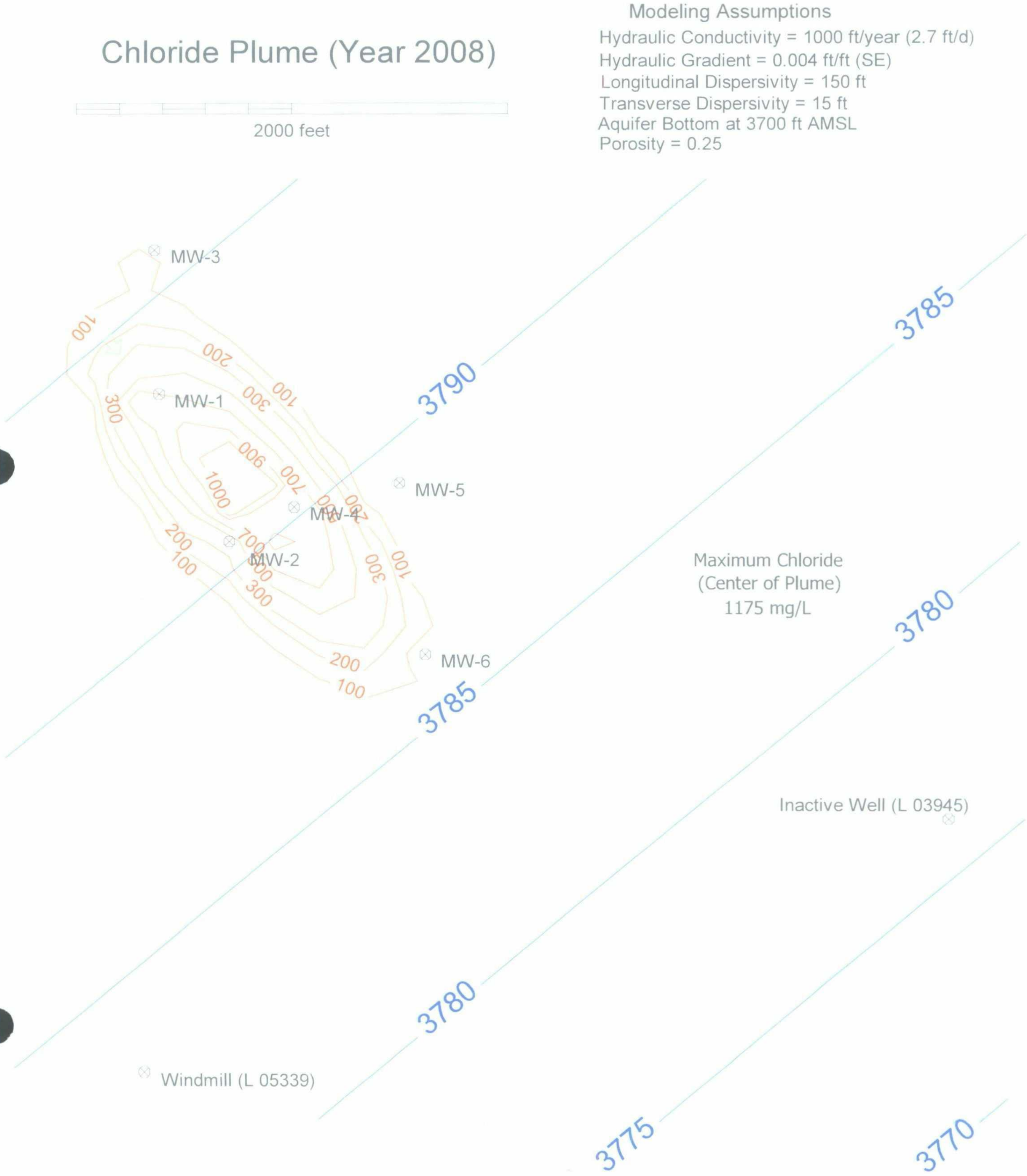
Date: 01/08/2009
Time: 12:20:00

Input File: 2008 CL
Map File :



WinTran Fate & Transport Modeling Results

Former Unocal South Vacuum Unit Site



WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2009)

2000 feet

Modeling Assumptions

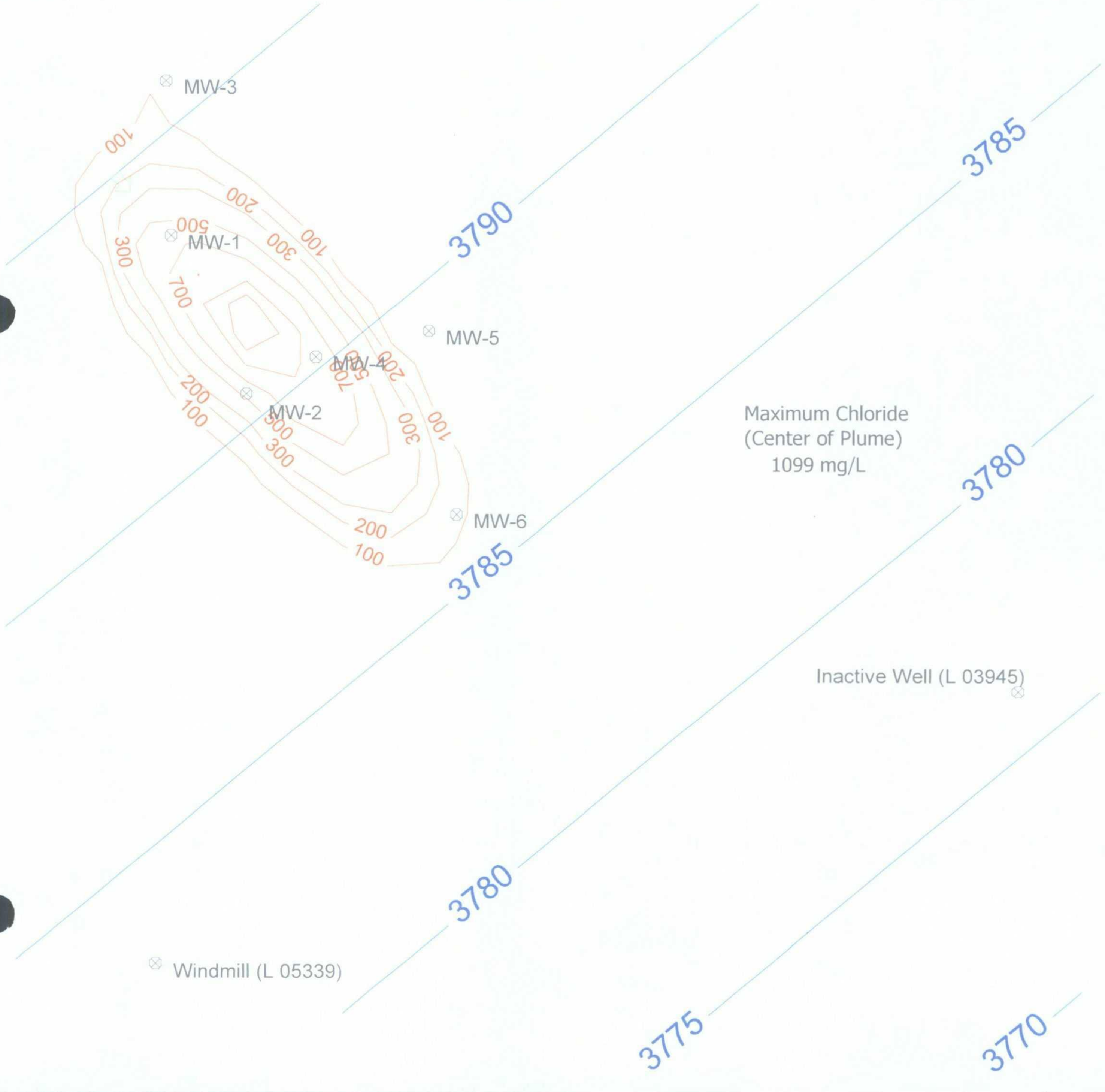
Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2010)

2000 feet

Modeling Assumptions
Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



WinTran Fate & Transport Modeling Results

Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2015)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results

Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2020)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results

Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2030)

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2040)

2000 feet

Modeling Assumptions
Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results

Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2060)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

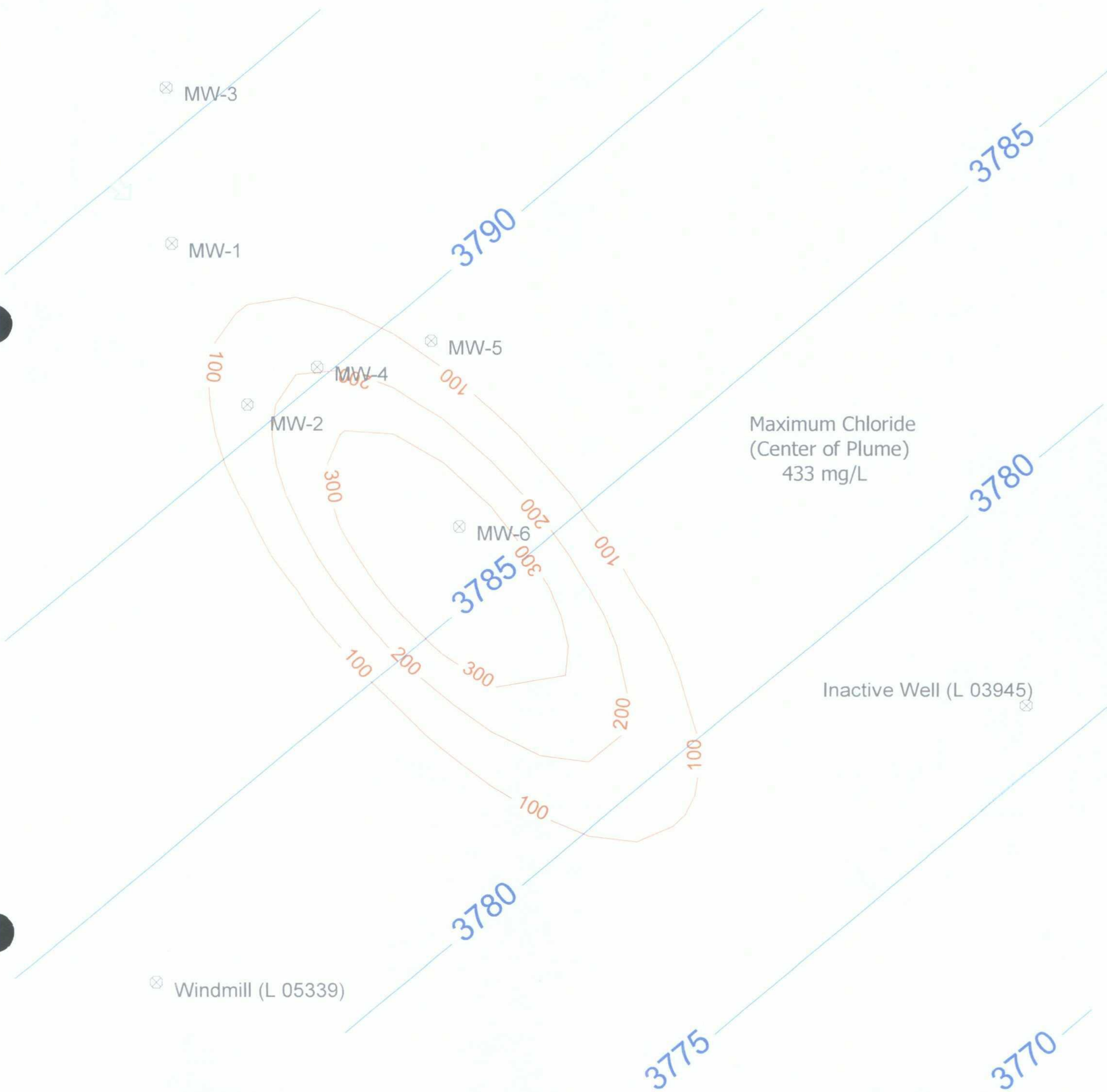
WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2080)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2100)

2000 feet

Modeling Assumptions

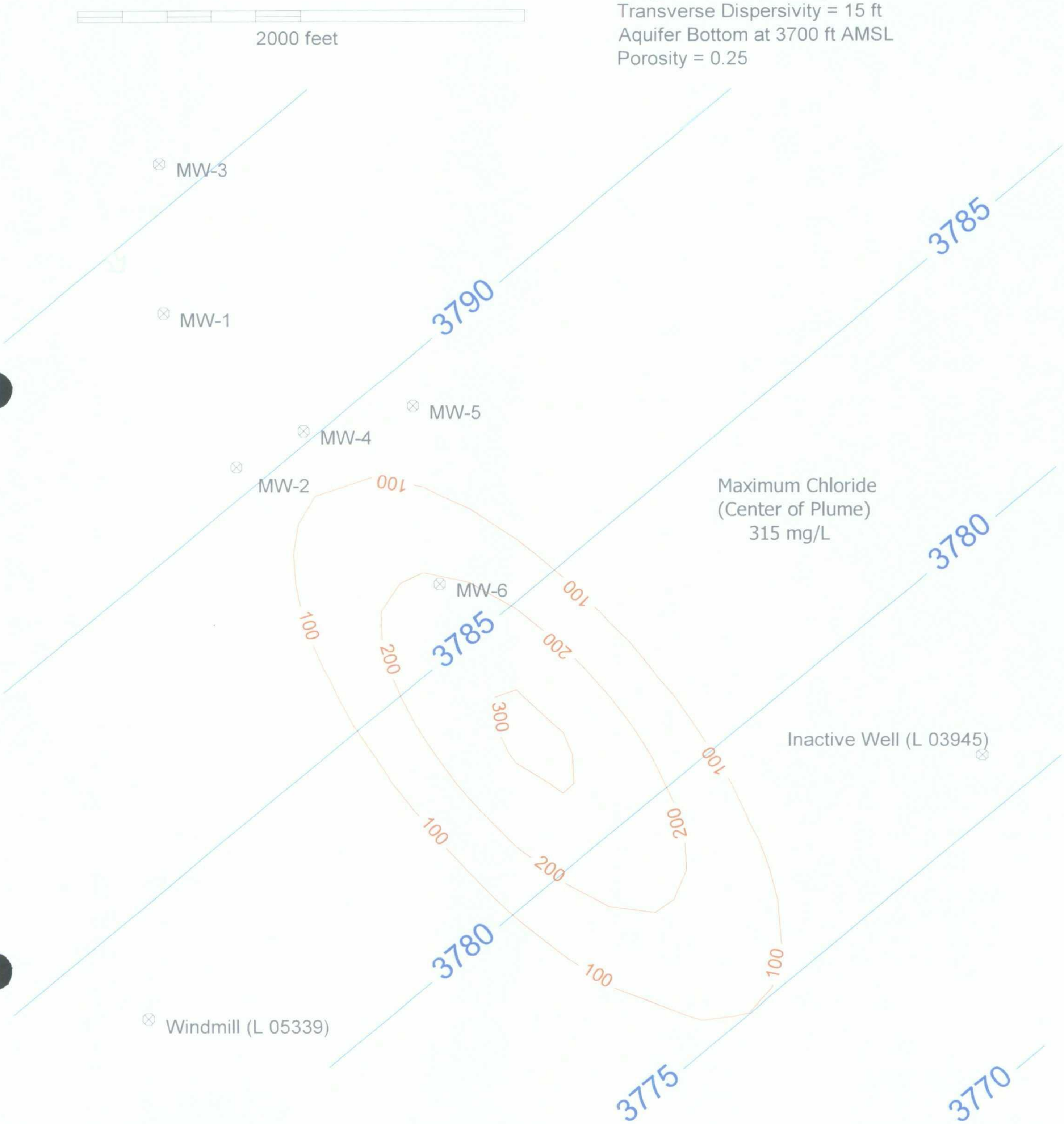
Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2120)

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2140)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit Site

Chloride Plume (Year 2157)

2000 feet

Modeling Assumptions

Hydraulic Conductivity = 1000 ft/year (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

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WinTran
Analytical Model of 2D Ground-Water Flow and
Finite-Element Contaminant Transport Model

Developed by

James O. Rumbaugh, III

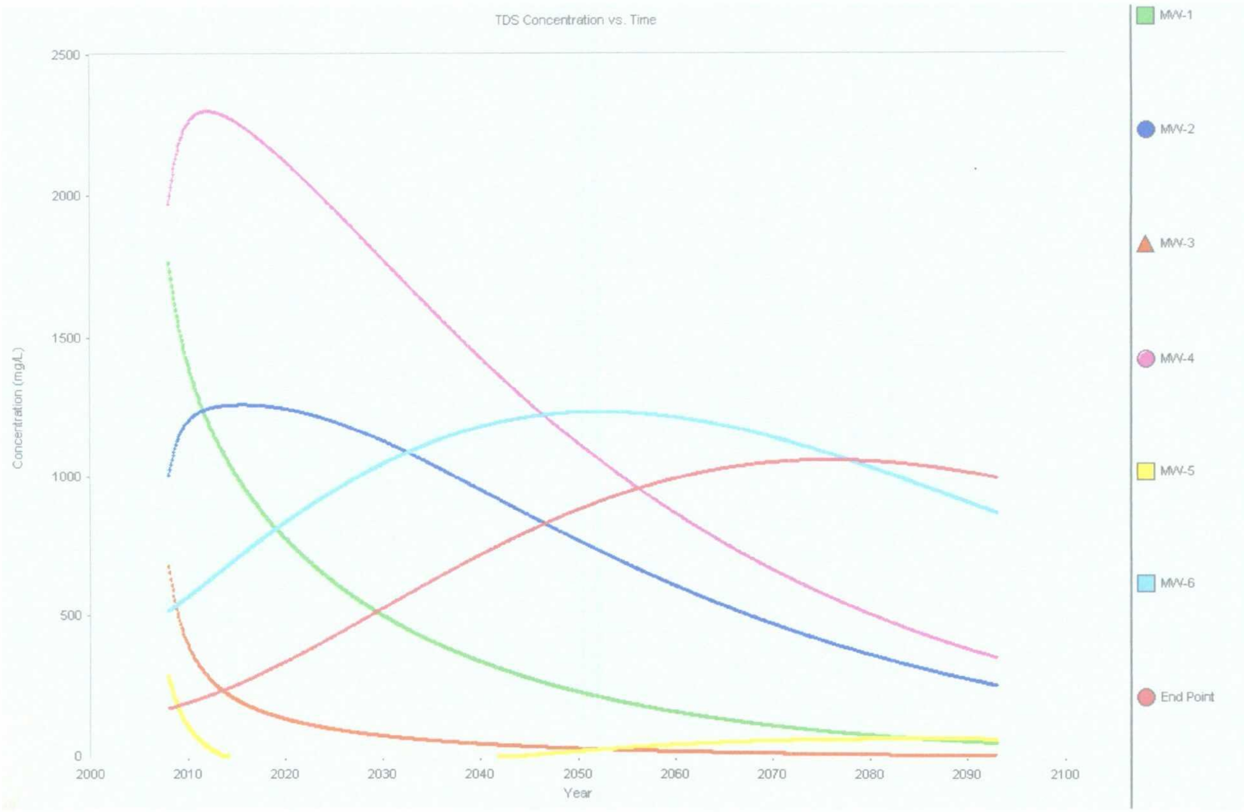
Douglas B. Rumbaugh

==

Total Dissolved Solids Fate & Transport Simulation run by:
Gilbert Van Deventer (Trident Environmental)

Date: 01/08/2009
Time: 13:28:00

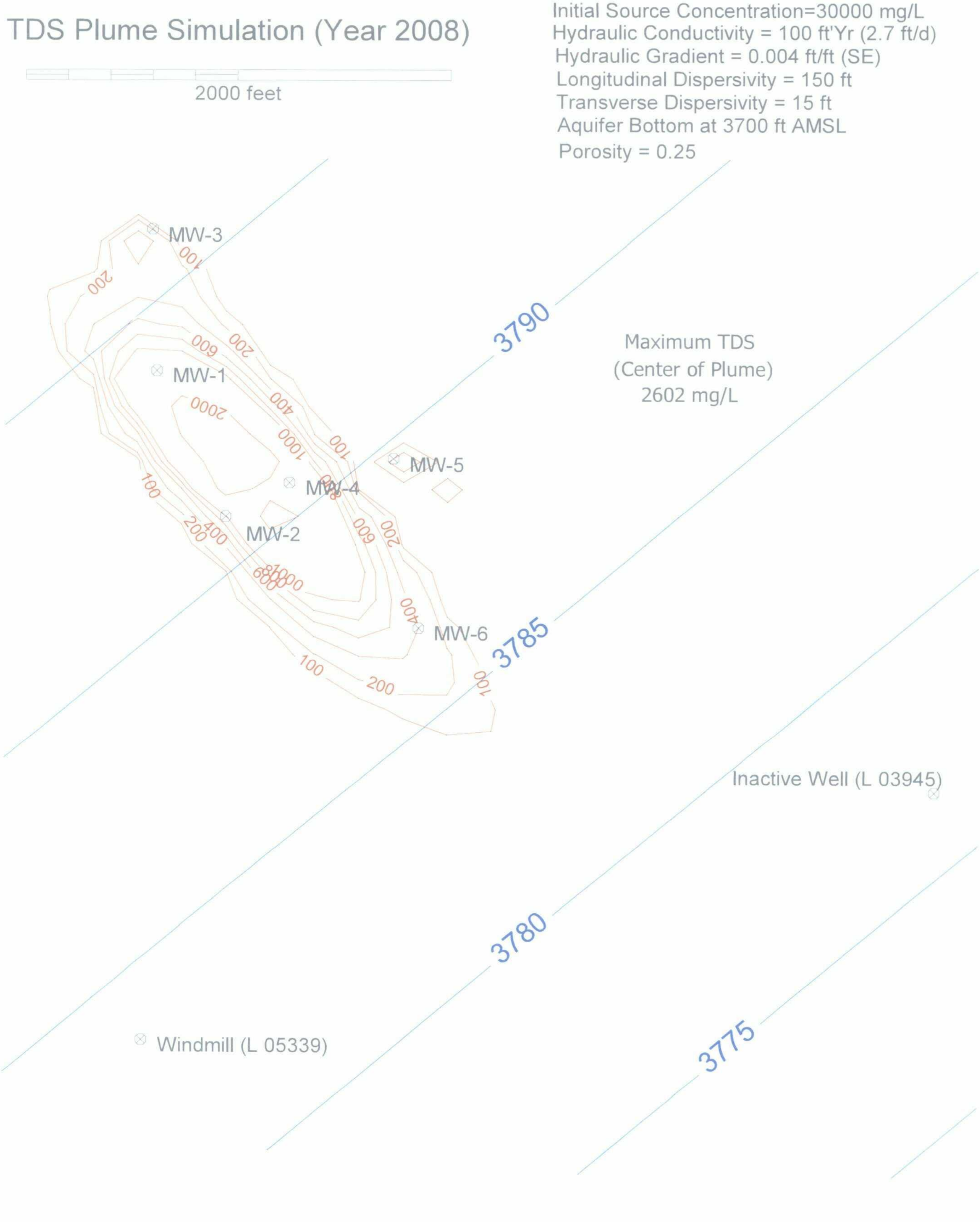
Input File: TDS 2008
Map File :



WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

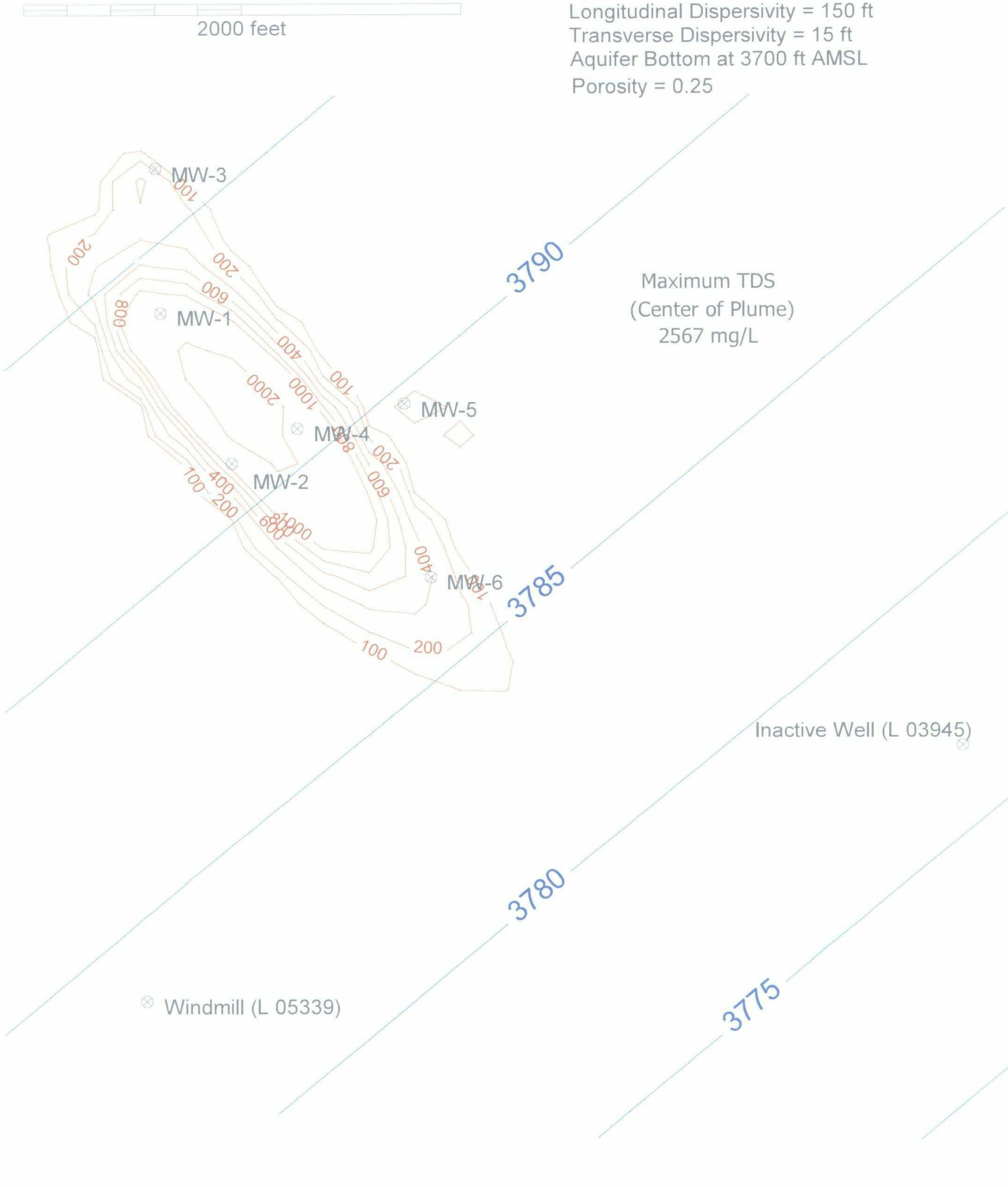


WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

TDS Plume Simulation (Year 2009)

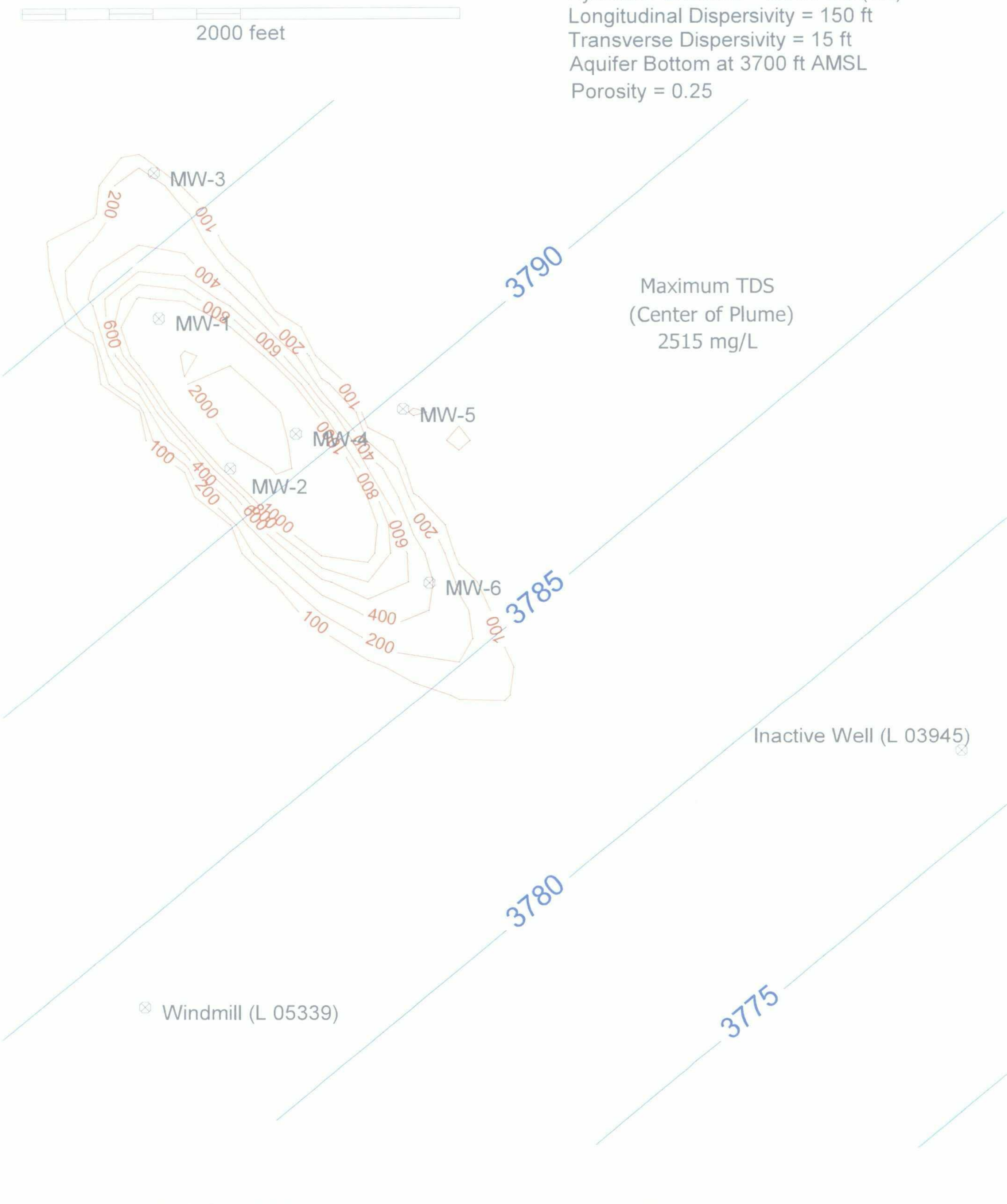


WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2010)

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



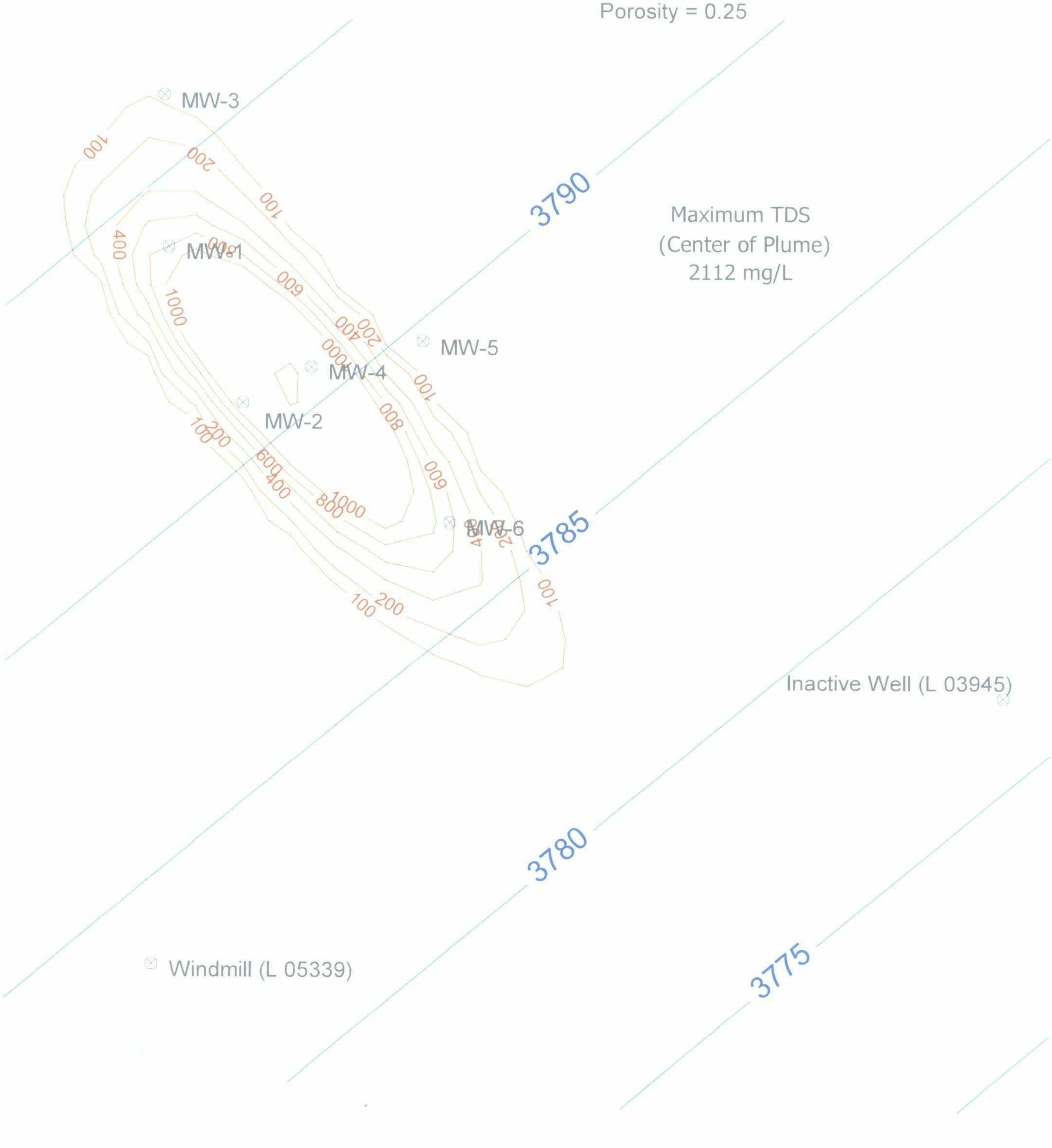
WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2020)

2000 feet

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



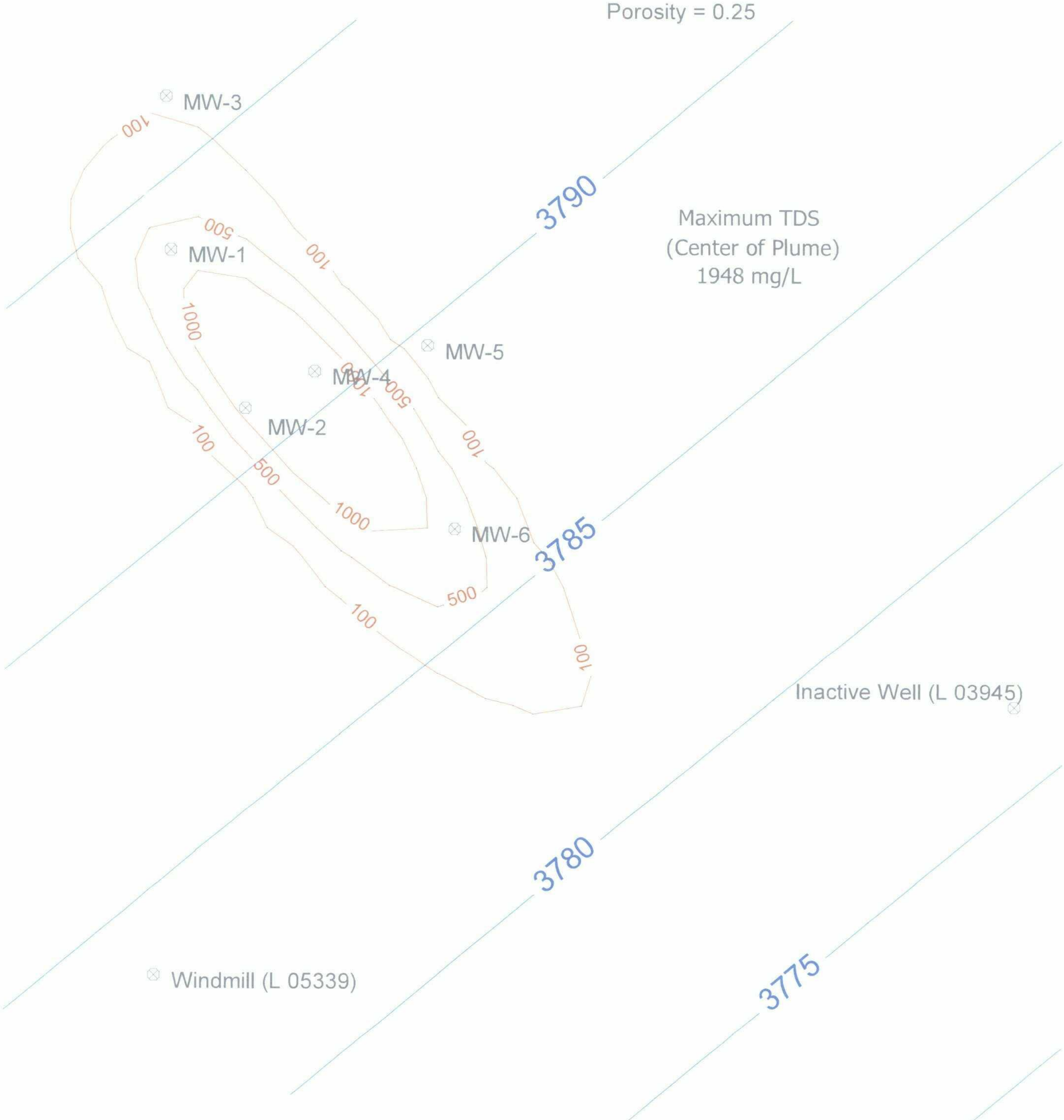
WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2025)

2000 feet

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

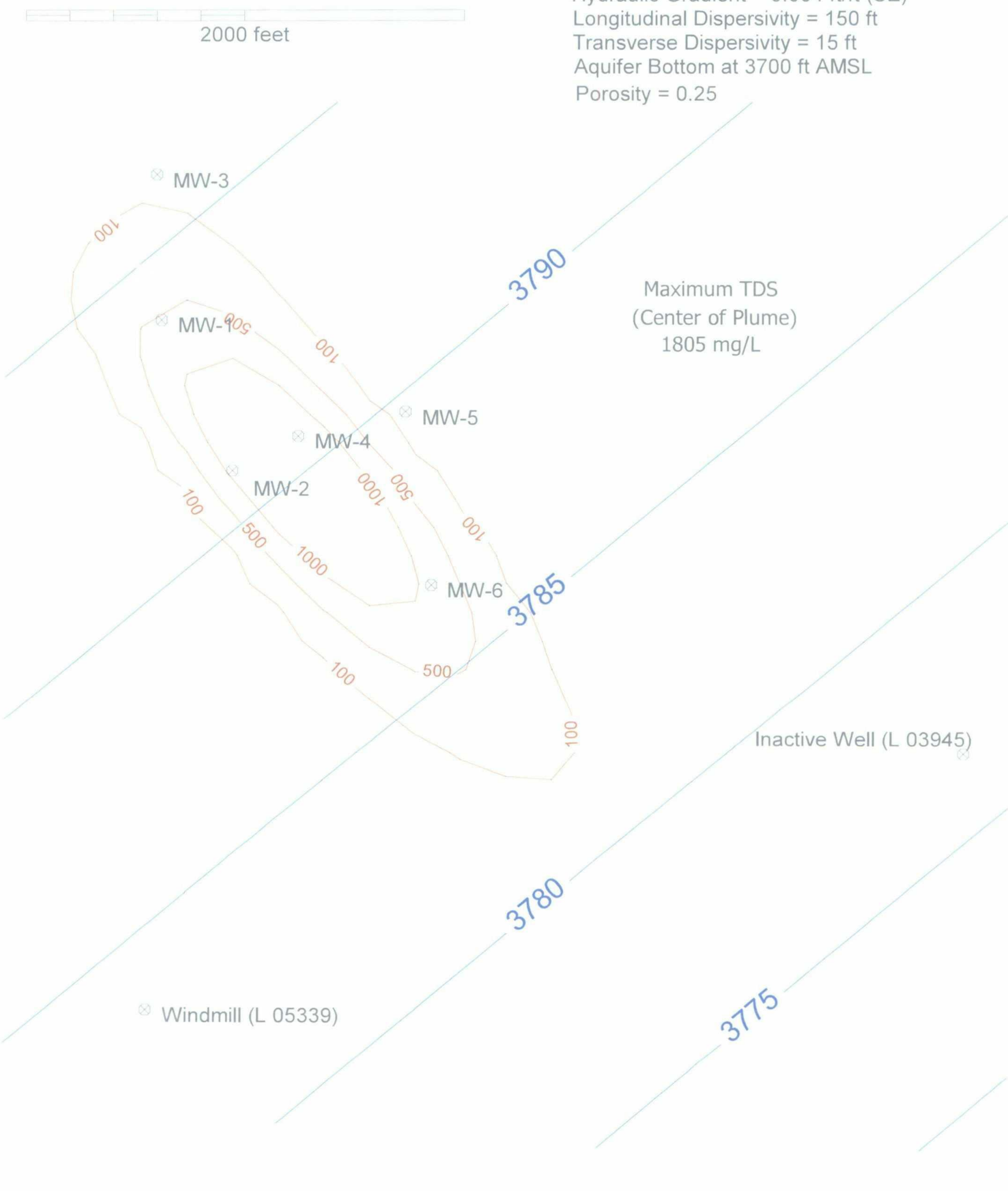


WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2030)

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



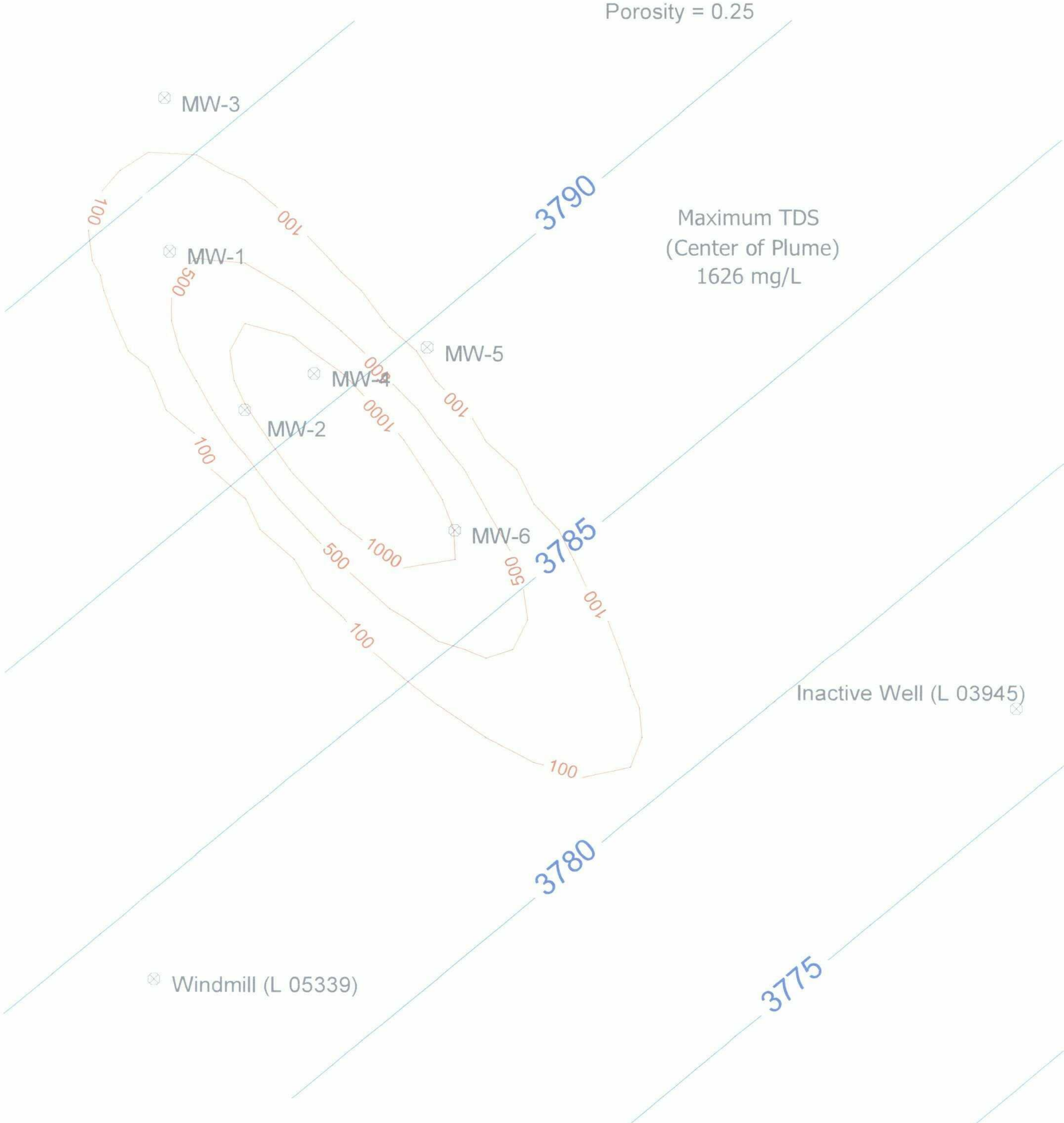
WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2040)

2000 feet

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



WinTran Fate & Transport Modeling Results

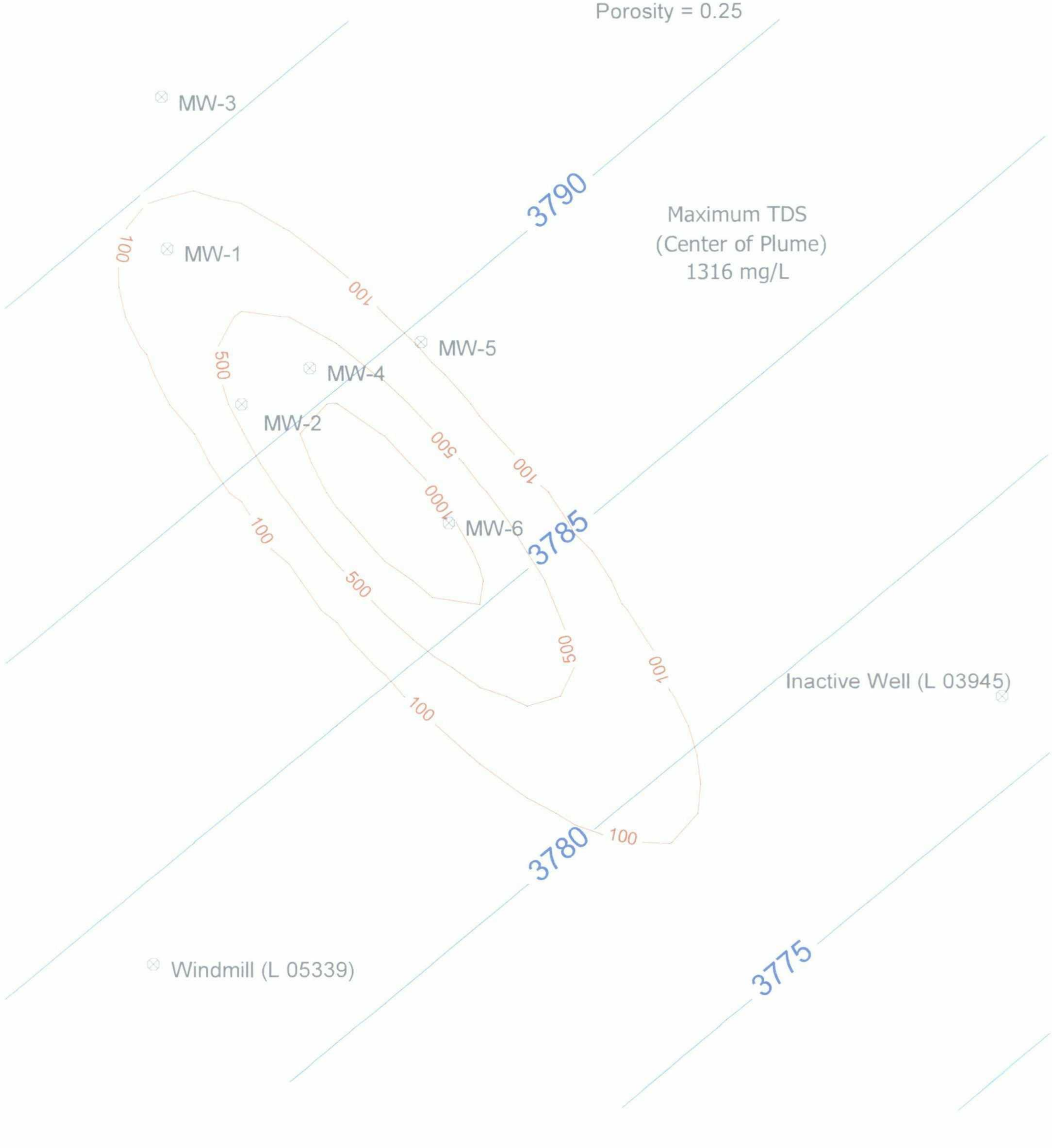
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2060)

2000 feet

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25

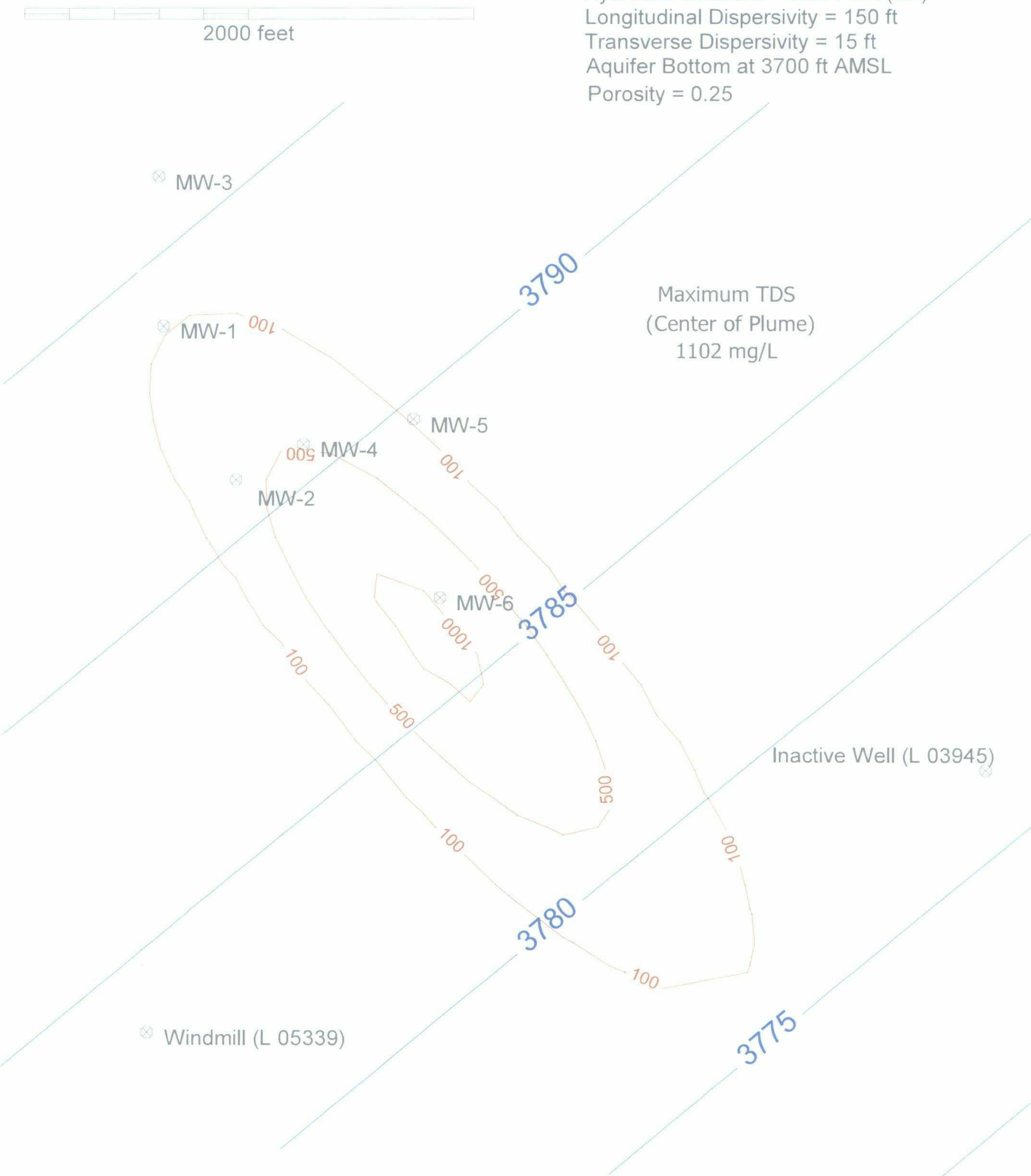


WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2080)

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



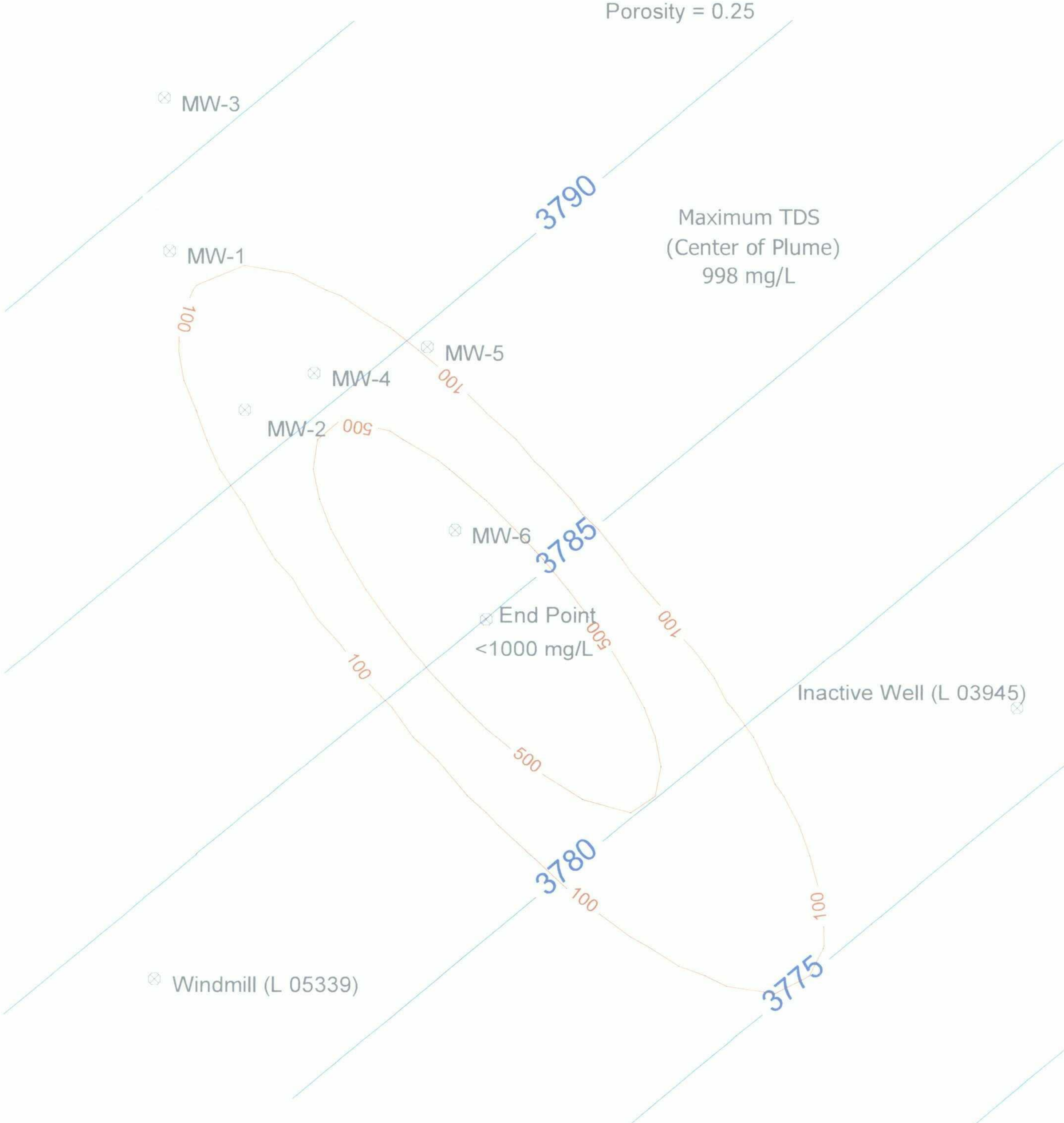
WinTran Fate & Transport Modeling Results
Former Unocal South Vacuum Unit

TDS Plume Simulation (Year 2093)

2000 feet

Modeling Assumptions

Initial Source Concentration=30000 mg/L
Hydraulic Conductivity = 100 ft'Yr (2.7 ft/d)
Hydraulic Gradient = 0.004 ft/ft (SE)
Longitudinal Dispersivity = 150 ft
Transverse Dispersivity = 15 ft
Aquifer Bottom at 3700 ft AMSL
Porosity = 0.25



APPENDIX D

Description of Fate and Transport Modeling And Output Files

Description of Fate and Transport Modeling

Conceptual Model

Produced water containing high concentrations of chloride, and resultant high levels of total dissolved solids (TDS), was reportedly discharged into a surface pit and adjoining injection well for a period of about 10 years, until the well was plugged and abandoned in1971. The chloride and TDS plume continued to migrate southeastwards for the next approximately 30 years after the source input was stopped, producing the configuration and constituent concentration distribution observed currently. Extrapolating from current conditions for decades into the future, taking account of both advective flow and attenuation by hydrodynamic dispersion, enables prediction of the probable distance that the residual plume will travel as well as the gradually declining concentrations in the plume.

Basic Site Data

Information about site conditions was obtained from data in a TRW Inc. "Report of Additional Groundwater Investigation, Former Unocal South Vacuum Unit, Lea County, New Mexico" (July 18, 2000). This included lithologic records from well installations, water level data, and water quality analytical results.

Simulation Model

Simulations were conducted with the two-dimensional groundwater flow and contaminant transport model WinTran, version 1.03 (1995) designed and distributed by Environmental Simulations, Inc. (ESI) of Herndon, Virginia. WinTran is built around a steady-state analytical element flow model, linked to a finite element contaminant transport model. The Windows interface allows for rapid data input, processing, parameter manipulation and optimization, and output in multiple formats. The fundamental mathematics of the model solutions, model verification (benchmarked against MODFLOW), and use of WinTran is documented in the "Guide to Using WinTran" published by ESI.

Base Map

A simplified site base map was created using the New Mexico State Plane Coordinates for each monitoring well which were determined by a registered surveyor after installation.

Flow Parameters

Input requirements for the steady-state groundwater flow simulation include: hydraulic gradient and direction of flow, hydraulic conductivity, aquifer top and bottom elevations, and reference head. The values used were based on the following sources:

- Hydraulic gradient – measured gradient of 0.004 feet/foot from August 26, 2008 site measurements reported by Trident.

- Direction of flow – measured direction of approximately S 40° E from August 26, 2008 site measurements reported by Trident.

- Hydraulic conductivity – no site measurements were available; therefore, a literature value based on the saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. Fetter (1988, Table 4.5, p. 80) cites an average range of 10^{-5} to 10^{-3} cm/sec for hydraulic conductivity of silty sands and fine sands. A conservative upper limit was selected, and converted from S.I. unit to 2.7 ft/day, or approximately 1000 ft/yr.

- Aquifer top and bottom elevations – bottom elevation of Ogallala Formation at 3700 feet reported by Trident. The top elevation for an unconfined aquifer must be greater than the reference head. An elevation of 4000 feet was assumed.

- Reference head – measured unconfined head of 3795 feet adjacent to the former pit and upgradient well MW-1 from August 26, 2008 measurements reported by Trident.

Transport Parameters

Input requirements for the contaminant transport numerical simulation include: longitudinal and transverse dispersivity, porosity, diffusion coefficient, contaminant half-life, and retardation coefficient. The values used were based on the following sources:

- Longitudinal and transverse dispersivity – no site measurements were available; therefore, a literature value based on the plume length was selected. Fetter (1993, Section 2.11, pp. 71-77) notes the apparent scale-dependency of longitudinal dispersivity, which typically may be about 0.1 times the flow length. For the current site scale and plume length of approximately 1500 feet, a value of 150 feet was selected for longitudinal dispersivity. Based on professional judgment, hydrologists commonly assume the longitudinal dispersivity is 5 to 10 times higher than transverse dispersivity; therefore, a value of 30 feet (i.e., one-fifth of the longitudinal value) was selected for transverse dispersivity.

- Porosity – no site measurements were available; therefore a literature value based on saturated zone lithology was selected. Typical lithology is described as silty sand and very fine sand. A range of 0.25 to 0.50 is typically given for unconsolidated "sand" (e.g., Freeze & Cherry, 1979, Table 2.4, p. 37); however, the Ogallala Formation is predominantly very fine grained, compacted and partly cemented, and may also fit within the range of 0.05 to 0.30 for sandstone. Fetter (1988, Table 4.3 and Figure 4.10, pp. 74-75) cites an average value of 0.20 for the specific yield of very fine sands. Specific retention of silty fine sand is approximately 0.05, for a total porosity of 0.25, which is the value selected for the transport modeling. WinTran uses the porosity term to estimate groundwater velocity, and actually requires an effective porosity value. Fetter (1988, Section 4.4, pp. 84-85) notes that pores of most sediments down to clay size are interconnected and that the effective porosity is virtually equal to the total porosity.

- Diffusion coefficient – this parameter is normally only relevant for very slow fluid movement, and is commonly assumed to be zero for advective-dominated transport, as in the present case.

- Contaminant half-life – this parameter accounts for chemical decay (e.g., radioisotopes, biological transformation of organic molecules); however, the species of interest in the present case are inorganic ions and are not expected to decay to any appreciable extent. A conservative value of 1000 years was used, which produces a negligible decay coefficient of less than 0.001 yr^{-1}.

- Retardation coefficient – this parameter accounts for sorption processes that slow the movement of contaminants relative to the groundwater velocity. Inorganic ions such as chloride are commonly taken as conservative tracers in groundwater and are not considered to be retarded; therefore, a value of 1.0 was selected for the retardation coefficient.

Flow Model Calibration

The vicinity of the site where water level measurements were recorded in August 26, 2008 is simulated closely by the flow model. It is known that groundwater levels in the Ogallala Formation are decreasing slowly (approximately 0.3 ft/yr), but this effect cannot be reproduced in the steady-state flow model. Water levels were probably somewhat higher than the present day during the period of brine disposal and initial transport. Even if the declining trend continues into the future, it does not affect the transport model solution for long extrapolation times, since sufficient saturated thickness remains (i.e., above the assumed aquifer base elevation of 3700 feet) for a valid flow and transport solution.

The average groundwater velocity may be estimated using the Darcy expression: $v = (k \,.\, i) / n$ where k is the hydraulic conductivity (1,000 ft/yr), i is the hydraulic gradient (0.004 ft/foot), and n is the effective porosity (0.25). The resultant average velocity is 16 ft/yr.

Transport Model Calibration

The objective of the transport modeling was to first obtain a plume configuration with concentration values that closely match current observed values. This was done by simulating an initial contaminant release to groundwater for a period of 11 years (c. 1960 to 1971) with a constant source concentration located at the pit and injection well, then simulating a 28-year transport period (c. 1971 to 1999) with no further contaminant input but restarting the model from the end of Year 11 by retaining the mass of contaminant from the initial plume. An iterative approach was needed to optimize the initial source concentration so that the plume at Year 39 resembled the actual plume conditions in 1999. An initial value of 14,000 mg/L for chloride and 30,000 mg/L for TDS were found to produce the best match. The initial chloride value was also chosen because it is typical of chloride concentrations within the producing formation (Devonian) in the South Vacuum Oil Field according to chemists at Martin Water Laboratories (verbal communication, 12-05-01). Actual disposal concentrations during the 1960s are unknown, and may have been higher than these values, but it is presumed that some attenuation and dilution may have occurred in the vadose zone, which is currently 48 to 68 feet thick. WinTran does not account for vadose zone transport, and the source input is treated as an injection well with instantaneous transfer of contaminant mass to groundwater.

After calibrating the model such it corresponded to actual 1999 conditions, the model was again run for 9 years (1999 to 2008) at one-year increments after entering in the known concentrations at each monitoring well.

Simulation of Fate and Transport

Estimation of chloride and TDS fate and transport was achieved by restarting the transport model in 2008. Figures displaying modeled simulations of the chloride and TDS plumes over various time increments are included in Appendix C. Advective flow moves the center of plume mass downgradient as depicted in the simulations. The simulations also demonstrate how hydrodynamic dispersion serves to broaden the dimensions of the plume while reducing the concentrations in the middle of the plume.

Running the model for 149 years in the future (Year 2157) produces a chloride plume center concentration of 248 mg/L (below the WQCC standard of 250 mg/L). The center of the chloride plume is approximately 3,200 ft away from the former pit and well source at that time.

Running the model for 85 years in the future (Year 2093) produces a TDS plume center concentration of 998 mg/L (below the WQCC standard of 1,000 mg/L). The center of the TDS plume is approximately 2,300 ft away from the pit and well source at that time.

These results support the contention that the chloride and TDS plume is not likely to impact any existing sources of water supply, the closest of which is a windmill (NM File No. L05339) located approximately 3,000 feet south of the source. Operation of the windmill has been discontinued due to declining water levels in the area and the shallow depth of he well.

The trend of decreasing concentration is not linear (exponential e^{-kt} function). Interestingly, the center of the plume moves at a greater rate (22 feet/year) over successive time intervals than would be assumed from the groundwater velocity alone (16 feet/year), due to the added effect of dispersion.

What is WinTran?

WinTran is designed to be an easy-to-use model for simulating the fate and transport of dissolved contaminants in fully saturated groundwater systems. The WinTran model couples the steady-state groundwater flow model from WinFlow, another product from Environmental Simulations, Inc., with a contaminant transport model. The transport model feels like an analytic model but is actually an embedded finite-element simulator. The software automatically constructs the finite-element transport so that you may quickly get answers to your groundwater problems.

The steady-state flow model in WinTran uses analytic functions developed by Strack (1989) to simulate the effects of wells, uniform recharge, circular recharge/discharge areas (called ponds), and line sources or sinks. Any number of these elements may be added to the model. The model depicts the flow field using streamlines, particle-traces, and contours of hydraulic head (water levels). Both confined and unconfined aquifers may be simulated with the WinTran flow model.

The contaminant transport model uses a finite-element formulation whereby the finite-element mesh is identical to the head contour matrix. The contour matrix is a rectangular array of points where head is computed by the flow model. WinTran computes groundwater velocity at each "node" in the contour matrix for use in the finite-element transport model. Diagnostic information is displayed on the status bar at the bottom of the window as the transport model runs. These data alert you to potential problems in the numerical transport model. These diagnostic data include the mass balance error, Peclet number, and Courant number. If these error criteria indicate problems, you may stop the simulation, choose new simulation options, and start the simulation again.

Contaminant mass may be injected or extracted using any of the analytic elements from the groundwater flow model, including wells, ponds, and linesinks. In addition, constant concentration elements may be placed in the model to keep the source contaminant concentration at a specified value. WinTran displays both head and concentration contours. Concentration versus time data may be exported to a plot file for selected monitoring locations. The transport model includes the effects of dispersion, linear sorption (retardation), and first-order decay. The latter may be used to simulate the biologic decay of organic compounds, such as benzene or the radioactive decay of elements such as uranium.

WinTran can import a Drawing Interchange Format (DXF) file (from AutoCAD, for example) to use as a digitized base map. The digitized map gives you a frame of reference for designing the flow and transport models.

WinTran produces report-quality graphics using any Windows device driver. Output may also be exported to a wide variety of file types, including SURFER, Geosoft, Spyglass, Windows Metafiles, and AutoCAD-compatible DXF files.

WinTran Features

Features unique to the transport model include the following:

Simulates transient transport in confined & unconfined aquifers;

Simulates effects of wells, linesinks, ponds, and constant concentration sources;

32-bit software uses all memory available to Windows;

Supports Windows V3.1 (with Win32s), Windows NT, and Windows 95;

Displays Peclet and Courant criteria during transport simulation;

Displays mass balance error during simulation;

Contours concentration at user-specified time steps during simulation; and

Velocities computed either analytically or using finite-element flow model.

Many of the features in WinTran are the same as WinFlow. These include the following:

Simulates both steady-state flow (transient flow not included);

Simulates both unconfined and confined aquifers;

Simulates effects of wells, linesinks, ponds, and recharge;

Imports map files in DXF format, QuickFlow format, or ModelCad format;

Visualizes model results with water-level contour maps;

Illustrates groundwater flowpaths using streamlines and particle traces;

Simple data input.

Calibration targets and calculation of calibration statistics;

Each analytic element may have a title with full font selection;

Edit elements in a scrolling list;

Double-click an element to edit;

Click and drag to reposition elements, streamlines, or particles;

Click and drag to resize linesinks and ponds;

Incorporates a multiple document interface (MDI) in which multiple models may be open at the same time;

Cut, copy, and paste elements to/from the clipboard;

Maps may be printed using any Windows device driver;

Coordinates and head are displayed as the cursor is moved;

Full context-sensitive help system (the entire manual is on-line);

DXF file import from within WinTran;

Common commands are available on the Toolbar; and

Drag-and-drop input files into the WinTran window.

Introduction

Closed form analytical solutions to the governing equations of ground-water flow have wide application in subsurface remediation projects. Complex flow problems can be solved using these analytical techniques. The analytic element method developed by Strack (1989), as discussed in the previous section, is especially useful in modeling complex two-dimensional ground-water flow systems. The analytic elements include wells, line-sinks, and recharge areas, among others, that can be used to simulate a variety of subsurface remedial alternatives. While these analytic techniques cannot treat the range of complexity provided by numerical techniques, the analytical models have advantages over numerical models in ease of use and speed of application.

Analytical solutions to the solute transport equations, on the other hand, are not as directly applicable to remediation projects. One of the primary problems with transport analytical solutions is the inability to treat changes in the flow field caused by wells, drains, and recharge. Transport solutions are normally limited to a uniform groundwater flow field. In order to obtain useful solutions to transport problems, therefore, the modeler must resort to more powerful numerical techniques, which require more time and effort to simulate.

A hybrid technique has been developed for use in WinTran that combines an analytical flow model with a numerical transport model. This technique combines the ease of use of an analytical model with the flexibility of a numerical model. The flow model utilizes the analytical element techniques of Strack (1989). The transport model is based upon the finite-element method using rectangular elements and linear basis functions. The two models are both contained within WinTran.

The hybrid model first solves for the flow field using the analytic element method. Boundary conditions for the finite-element model are then automatically taken from the analytical flow model. The finite-element mesh is coincident with the head matrix used to contour results obtained from the flow simulation. Thus, you do not need to explicitly design a numerical grid or mesh system of nodes. You simply specify the location of the mesh and the number of rows and columns in the mesh. Because you are somewhat insulated from the mesh design, significant error-checking facilities are provided to warn of large mass balance errors and other potential problems such as violating specified Peclet and Courant criteria.

The Hybrid Approach

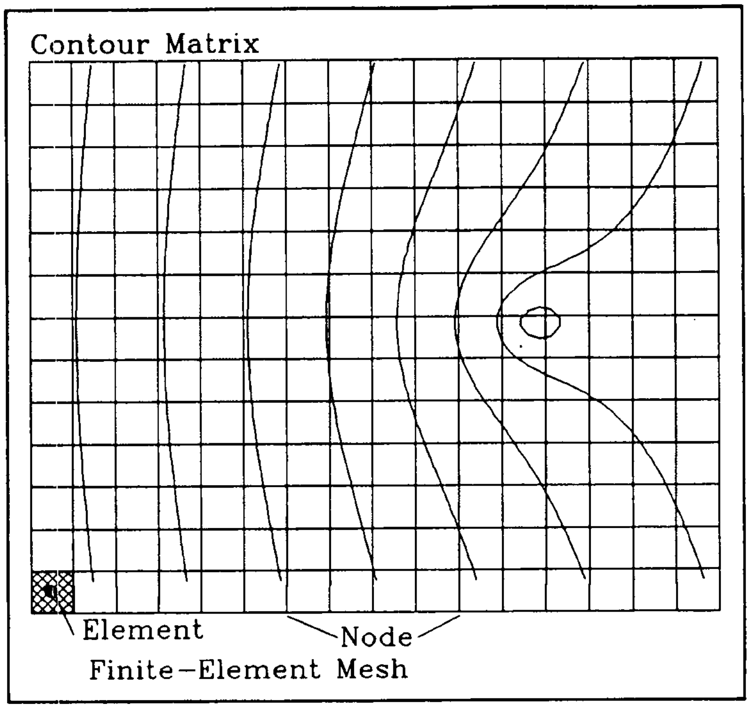
The hybrid analytical flow/numerical transport model combines the analytic element method developed by Strack (1989) with a finite-element transport technique developed by Huyakorn and others (1983). The model is constructed in six stages, most of which are transparent to the user. The six stages indude the following:

(1) The modeler designs the analytical flow model by specifying uniform aquifer properties, a regional hydraulic gradient, and analytic elements (e.g. wells, line sinks, circular recharge areas, and uniform recharge). The flow model was derived from the WinFlow model (ESI, 1995).

(2) The analytical flow model is infinite in extent; however, the user must specify a rectangular region of interest where head is computed and contoured.

(3) Head is computed at discrete points over the rectangular area of interest and a contour map is produced. These points are arranged in a regular mesh of n rows by m columns called the contour matrix. The spacings between rows and between columns are constant.

(4) Ground-water velocities are computed analytically at the centroid of each rectangular cell in the contour matrix (See the Figure below). These velocities are provided directly to the transport model and the contour matrix defines the finite-element mesh.



(5) Specify initial concentrations over the contour matrix and the nature and extent of contaminant sources.

(6) The finite-element transport model is solved for the specified simulation time(s) and results are contoured.

These six stages require relatively little user-intervention. For example, the finite-element mesh data are generated automatically. In addition, ground-water velocities are recomputed each time a change is made to the flow model. The element velocities are passed automatically to the transport model.

WinTran Assumptions

It is important to understand the many simplifying assumptions inherent in any model before the model can be applied to a real-world problem. This chapter presents potential applications of WinTran to the solution of contaminant fate and transport problems. First, however, some important assumptions are discussed as they apply to practical application of WinTran. For easy identification, the primary assumptions are underlined.

WinTran is designed to solve two-dimensional ground-water flow and transport problems in a horizontal plane. It is not designed for two-dimensional cross-sections (2D vertical plane). The two primary assumptions are that ground-water flow is horizontal and contaminant concentrations are the same throughout the entire aquifer thickness. WinTran should not be applied to aquifers exhibiting strong vertical gradients unless the scale of the problem is such that horizontal flow can still be considered dominant. WinTran can be used even in cases where there are significant vertical gradients if the horizontal scale of the model is much larger than the vertical scale, such as in regional studies.

Another assumption is that the aquifer hydraulic conductivity is assumed to be isotropic and homogeneous. The base of the aquifer is horizontal and fixed at a given elevation. The top of the aquifer is also horizontal and fixed at a given elevation. Unconfined conditions are simulated when the hydraulic head is below the top of the aquifer.

The reference head in the flow model is constant throughout all calculations. The reference head is analogous to a constant head boundary condition in a numerical model. It is therefore very important to keep the reference head far from the area of interest so that model predictions are not impacted.

All pumping rates, linesink fluxes, pond recharge, and elliptical recharge rates are constant through time. The transport model simulates transient movement of the contaminant in this steady-state velocity field.

All wells are assumed to fully penetrate the aquifer. Wells are assumed to be perfectly efficient and linesinks are in perfect hydraulic communication with the aquifer. Both assumptions are rarely encountered in practice. There is often head loss around the well screen or stream bottom caused by clogging of the pore-space by fine-grained material (clay). There are two important consequences of imperfect hydraulic communication.

(1) Pumping rates predicted by WinTran to achieve a desired response may not be attainable because more drawdown will be encountered in the actual well. The increased drawdown encountered in the field is caused by inefficiency around the well screen. The same effect will happen using linesinks to simulate trenches or drains.

(2) The amount of water produced or injected by a linesink to maintain a specified head in the linesink will be overestimated if the actual drain has less than 100 percent efficiency.

Particle traces and streamlines are two-dimensional. In cases where the aquifer receives recharge, the capture zone of a pumping well will be large enough to capture the amount of recharge equaling the pumping rate of the well (Larson et al. 1987). In two-dimensional analyses, such as in WinTran, the capture zone extends upgradient until encountering a ground-water divide or infinity. This is an important consideration in designing a containment system.

Chemical reactions are reduced to two types, (1) linear, fully-reversible sorption using a retardation coefficient, and (2) first-order decay. WinTran can be used to simulate biological decay of organic compounds only if the biological reactions can be reduced to a first-order decay reaction. That is, a contaminant half-life is estimated for the compound.