AP - 076

STAGE 2
WORKPLANS

12/02/2008

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December 2, 2008

Mr. Glenn von Gonten
New Mexico Energy, Minerals, & Natural Resources
Oil Conservation Division, Environmental Bureau
1220 S. St. Francis Drive
Santa Fe, New Mexico 87504

RE: Stage 2 Abatement Plan (AP-76)
South Four Lakes #13 Site
T12S-R34E-Section 1, Unit Letter L
Lea County, New Mexico

Dear Mr. von Gonten

On behalf of Pride Energy Company, enclosed are one hard copy and one electronic copy of the Stage 2 Abatement Plan for the above-referenced site. A copy has also been sent to the District 1 office in Hobbs.

I look forward to working with you on this project. If you have any questions please call me at 432-638-8740 or Matt Pride at 918-524-9200.

Sincerely,

Gilbert Van Deventer, REM, PG
Trident Environmental

cc: Matt Pride (Pride Energy Co., Tulsa, OK)
Larry Hill- (NMOCD -District 1, Hobbs, NM)

STAGE 2 ABATEMENT PLAN (AP-76)
SOUTH FOUR LAKES #13 SITE
TOWNSHIP 12 SOUTH, RANGE 34 EAST, SECTION 1, UNIT L
LEA COUNTY, NEW MEXICO

NOVEMBER 26, 2008

Prepared For:

Pride Energy Company
P. O. Box 701950
Tulsa, OK 74170

05/07/2008

Prepared By:

TRIDENT ENVIRONMENTAL

P. O. Box 7624
Midland, Texas 79708

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1.0 EXECUTIVE SUMMARY

On May 30, 2008, and June 4-5, 2008, Trident Environmental performed a soil boring program at the South Four Lakes #13 well site to delineate the vertical and horizontal extent of groundwater impairment caused by the former drilling pit in accordance with the Stage 1 Abatement Plan (AP-76). Groundwater samples were collected from the hollow-stem drilled borings for chloride analysis and specific conductivity measurements. Groundwater samples were also collected from monitoring well MW-1 on January 23, May 13, and June 19, 2008, for laboratory analysis. Due to the minimal impact at this site, fate and transport modeling was performed to simulate the naturally attenuating characteristics of the chloride plume which is the only constituent of concern.

The conclusions and recommendations of the soil boring program, groundwater monitoring activities, and fate and transport modeling are summarized below.

- Based on the soil boring data obtained by Elke Environmental in January 2008 and Trident Environmental in May-June 2008 the chloride impact to the vadose zone is limited to the area within the perimeter of the former drilling pit.

- It is likely that brine from the pit has migrated through the vadose zone to ground water via saturated flow during operation of the drilling pit or sometime during the drying process. The uniform decline of chloride concentrations observed within the pit from about 20 feet below grade to the water table can be attributed to dilution of the migrating brine by less saline ground water residing within the capillary fringe. Low porosity in the indurated sands at these depths may also contribute to lower chloride measurements because a smaller mass of brine is retained relative to the more unconsolidated soils above which exhibit a higher porosity.

- Chloride and TDS concentrations from groundwater samples collected at monitoring well MW-1, MW-2, and soil boring B-1 exceeded WQCC standards. The higher chloride and TDS levels are at MW-1 which is expected due to its location immediately downgradient from the former drilling pit. A maximum chloride concentration of 1,330 mg/L in MW-1 was observed during the initial sampling event in January 2008, however chloride levels have decreased in this well to only 736 mg/L during the most recent sampling event. TDS concentrations in MW-1 exceed the WQCC standard by only 560 mg/L.

- Horizontal dispersion of the chloride and TDS in groundwater does not extend beyond approximately 75 to 100 feet downgradient (southeast) of the southeast corner of the pit as evidenced by the results of monitoring well MW-2 where background chloride and TDS levels are observed in groundwater.

- Fate and transport model simulations indicate that the center of chloride mass in the plume will attenuate to below the WQCC standard of 250 mg/L after migrating 434 ft to 925 ft southeast from the pit in 16 to 48 years. The average simulated distance and time of travel was about 660 ft in 28 yrs. Future monitoring will be necessary to verify and/or refine these estimates.

- There will be no adverse impact to human health and the environment nor will any portion of the chloride plume that is above the WQCC standard of 250 mg/L reach any potential receptors at any time during its natural attenuation to background levels.
- Regulated hydrocarbons are not present in groundwater or the vadose zone.
- The proposed drilling pit excavation closure is construction of an infiltration barrier to eliminate the migration of residual brines from the vadose zone to groundwater
- Continued groundwater monitoring and updating of the fate and transport model is proposed to support the efficacy of natural attenuation as the best abatement option.

2.0 SITE DESCRIPTION

2.1 *LOCATION*

The South Four Lakes #13 well site is located on State land in Township 12 South, Range 34 East, Section 1, and Unit Letter L (N 33° 18' 19.9", W 103° 28' 11.9"). To access the site:

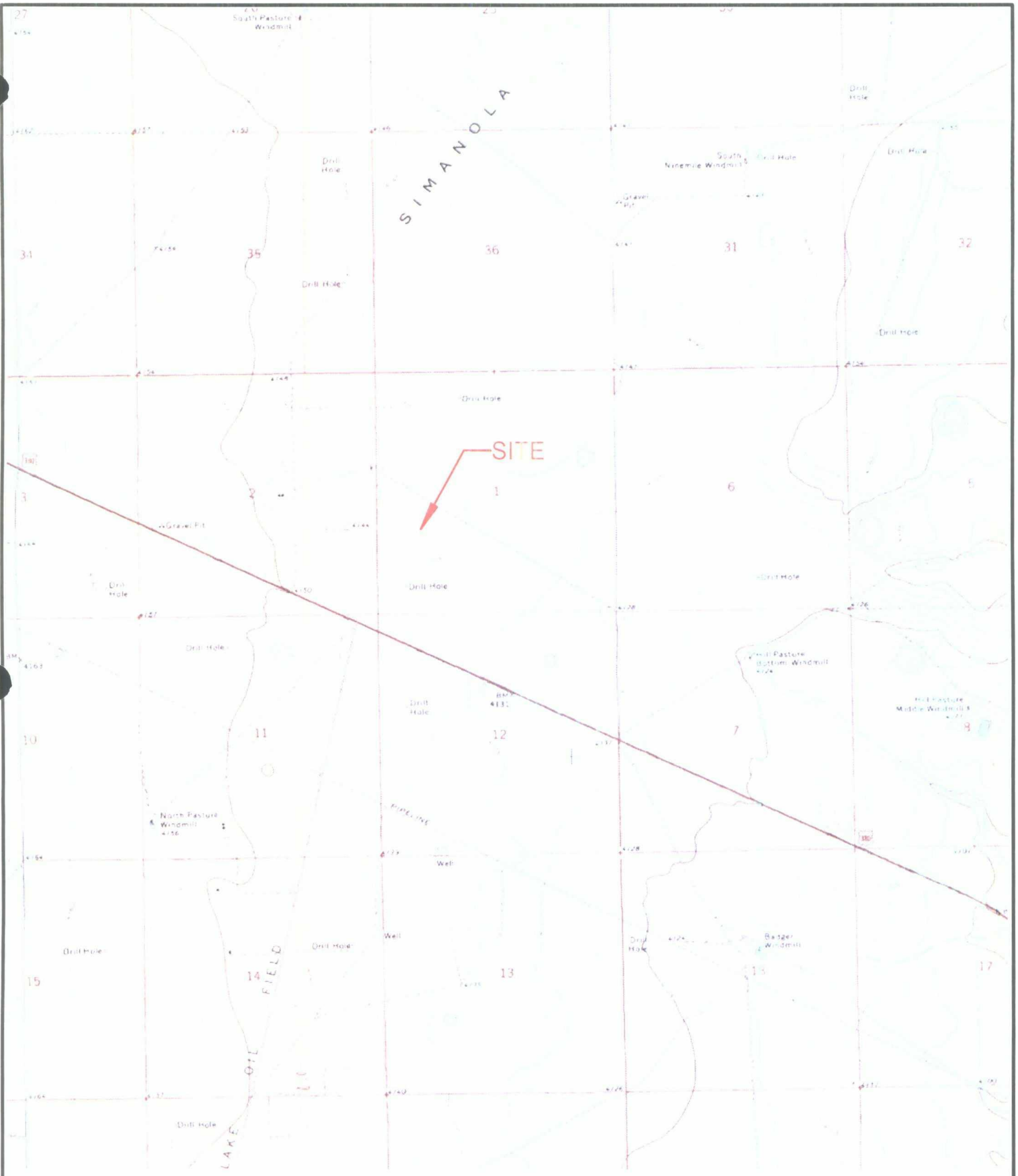
1. Drive west on Highway 380 nine miles from the intersection of Highway 380 and Highway 206 in Tatum, New Mexico.
2. Turn right, proceed through cattleguard, and continue north about 0.4 miles on the dirt lease road to the site.

Figure 1 is a topographic map and Figure 2 is an aerial photograph (2005) showing the general area and access to the site. A photograph showing the former drilling pit facing southeast is included on the front cover of this report.

As shown in Figure 3, the current environs at the site include:

- an active gas well (API # 30-025-36528) and tank battery
- an open drilling pit excavation varying from 3-ft to 5-ft deep below ground surface (bgs)
- a closed deep trench burial pit containing the former contents of the drilling pit
- five soil borings (TP-1 through TP-5) that were sampled within the pit and then plugged on January 22-23, 2008
- two soil borings (B-1 and B-2) that were sampled and then plugged on June 4-5, 2008
- one monitoring well (MW-1) located near the southeast edge of the former drilling pit.
- a second monitoring well (MW-2) located 75 feet downgradient (southeast) of MW-1

There are no surface water bodies or water wells within 1,000 feet of the site. The nearest surface water body is a livestock watering pond fed by a windmill well (NMOSE Permit # L-0656) located approximately 0.3 miles northwest (upgradient).



USGS Simanola Valley, NM 7.5" Quadrangle (1970)

TRIDENT ENVIRONMENTAL	Pride Energy Company South Four Lakes #13 T12S - R34E - Section 1 Unit L Lea County, New Mexico	FIGURE 1 SITE LOCATION MAP

TRIDENT ENVIRONMENTAL

Pride Energy Company
South Four Lakes #13
T12S - R34E - Section 1 Unit L
Lea County, New Mexico

FIGURE 2

SITE AERIAL PHOTO MAP (2005)

2.2 *SITE HISTORY*

Table 1: Site History

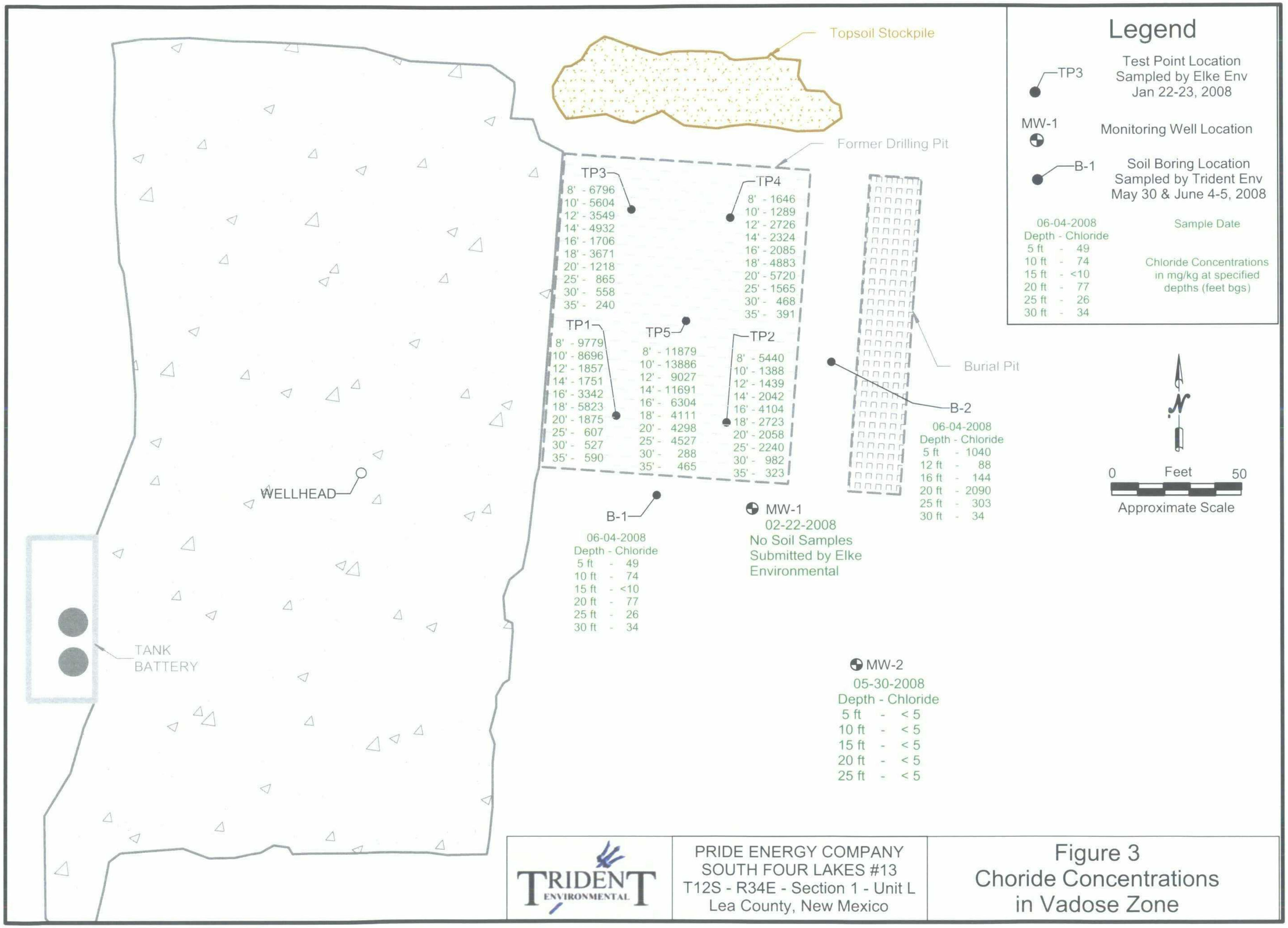
Date	Description
February 29, 2004	Well spudded.
May 26, 2004	Well completed and put into production
August 29, 2007	C-144 pit closure form approved by NMOCD
December 10, 2007	Revised C-144 submitted by Elke Environmental approved by NMOCD
January 22-23, 2008	Initial soil and groundwater sampling activities performed by Elke Env.
January 30, 2008	C-141 release notification form submitted by Elke Environmental
February 12, 2008	NMOCD requires submission of Abatement Plan and assigns AP #76
March 27, 2008	Initial site visit conducted by Trident Environmental
April 14, 2008	Stage 1 Abatement Plan submitted to NMOCD
May 13, 2008	Groundwater sampling and monitoring event performed at site (MW-1)
May 30, 2008 June 4-5, 2008	Soil boring program initiated to define vertical and horizontal extent of any impairment to groundwater.
June 19, 2008	Groundwater sampling and monitoring event performed at site (MW-1 and MW-2)
September 9, 2008	Groundwater sampling and monitoring event performed at site (MW-1 and MW-2)

3.0 PROCEDURES – SOIL BORING AND GROUNDWATER INVESTIGATION

On May 30, 2008, Trident Environmental mobilized to the site to perform soil boring activities. The drilling contractor, Atkins Engineering (Roswell NM) utilized a Mobile 58 drilling rig and a 7 ¼- inch O.D. hollow stem augers to start the first boring however, due to auger refusal conditions at approximately 23 feet bgs, air rotary tools had to be utilized on June 4, 2008, to complete the downgradient monitoring well (MW-2) and two soil borings (B-1 and B-2) at the site as depicted in Figure 3. The following procedures were performed at each boring location:

1. Llithologic descriptions of the soils encountered in each boring were recorded in a field log book.
2. When borehole conditions within the saturated zone allowed, ground water samples were collected by injecting air into the borehole and collecting sediment-laden groundwater at the surface directly into the sample container. This method worked successfully at two depth intervals in borings MW-1 and B-1 but attempts to collect groundwater samples at B-2 were unsuccessful (no returns). The specific conductance (SC) of these samples was measured using a Hanna Combo pH & EC meter (Model No. HI 98130). SC measurements were used to a.) determine the vertical and horizontal extent of any ground water impairment and b.) determine the location of additional boreholes.
3. Groundwater samples collected from the borings were also submitted to XENCO Laboratories (Odessa TX) for analysis for chloride and total dissolved solids (TDS) analysis.
4. On June 19 and September 9, 2008, groundwater sampling at monitoring wells MW-1 and MW-2 was conducted by Rozanne Johnson (Arc Environmental).

Since regulated hydrocarbons were not detected in any groundwater samples from MW-1 or from the deep soil samples from within the former drilling pit, we did not submit samples from the auger borings or monitoring wells for analysis of regulated hydrocarbons. In addition, there were no observations (visual or odor) of hydrocarbons during the soil boring activities.



PRIDE ENERGY COMPANY
SOUTH FOUR LAKES #13
T12S - R34E - Section 1 - Unit L
Lea County, New Mexico

Figure 3
Choride Concentrations
in Vadose Zone

4.0 RESULTS

4.1 *SOIL BORING DELINEATION PROGRAM*

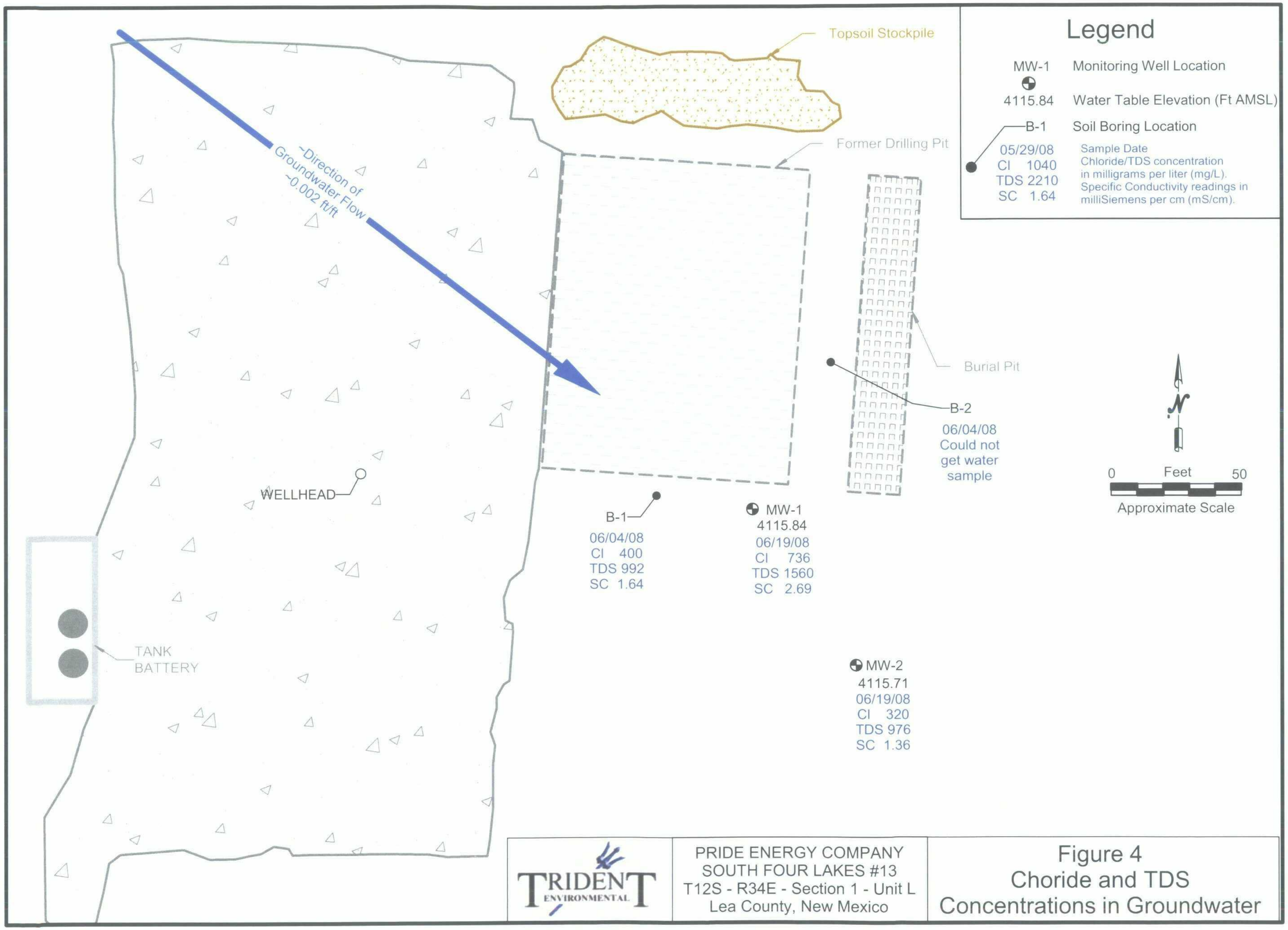
On May 30, 2008, a hollow-stem auger rig was utilized for the first boring (MW-1) located approximately 75 feet downgradient of existing monitoring well MW-1, which is located near the southeast corner of the former drilling pit. Auger refusal at about 23 feet bgs occurred due to the hard quartzite and sandstone layer at that depth, therefore drilling with air rotary tools was scheduled for June 4, 2008, whence the completion of MW-2 was performed. A second (B-1) and third (B-2) soil boring were then installed approximately 25 feet south and 25 feet east, respectively, of the former drilling pit to horizontally delineate conditions closer to the targeted source. The location of each soil boring is shown on Figure 3.

Generally, the upper foot of topsoil consisted of silty sandy loam. Below the topsoil alternating layers of very fine-grained sand and caliche were encountered until a depth of approximately 21 to 25 feet was reached where a very hard quartzite and sandstone layer was encountered. Below this depth fine- to medium-grained sand continued to a depth of approximately 54 feet where a very hard sandstone/quartzite layer was encountered. Groundwater was encountered at approximately 25 feet bgs. A more detailed description of each soil boring is provided on the lithologic logs in Appendix A.

Laboratory analysis of chloride concentrations in each soil boring is summarized in Table 2 below, depicted on Figure 3, and shown on the individual lithologic logs in Appendix A. Field and laboratory analysis of groundwater samples from the soil boring program are summarized in Table 3 below and depicted on Figure 4.

Table 2
Soil Sample Chloride Analyses from Borings

Boring ID	Depth (ft bgs)	Chloride Concentration (mg/kg)
MW-2	5’	<5.0
	10’	<5.0
	15’	<5.0
	20’	<5.0
	25’	<5.0
B-1	5’	49
	10’	74
	15’	<10
	20’	77
	25’	26
	30’	34
B-2	5’	1040
	10’	88
	15’	144
	20’	2090
	25’	303
	30’	34



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Lea County, New Mexico

Figure 4
Choride and TDS
Concentrations in Groundwater

Table 3

Groundwater Analyses from Soil Borings

Boring ID	Field Measured Values		Lab Analyzed Values	
	Depth (ft bgs)	SC (mS/cm)	Chloride (mg/L)	TDS (mg/L)
MW-2	31	1.54	319	654
	40	---	840	1430
B-1	48	1.13	160	566
	59	1.64	400	992

--- Indicates insufficient sample volume for field analysis
Attempts to collect groundwater samples at B-2 were unsuccessful (no returns).

The laboratory analytical reports and chain of custody documentation for the soil and groundwater sampling are in Appendix B.

4.2 *GROUNDWATER MONITORING WELL SAMPLING*

On June 20, 2008, Rozanne Johnson (Arc Environmental) performed the sampling at monitoring wells MW-1 and MW-2. The recent and historic groundwater chemistry and groundwater elevation measurements at MW-1 and MW-2 are summarized in Table 4. The laboratory analytical reports and chain of custody documentation for the last two sampling events are in Appendix B. The well sampling data forms are included in Appendix B.

Table 4

Summary of Groundwater Monitoring Results

Sample Location	Sample Date	Depth to Groundwater (feet btoc)	SC (mS/cm)	Chloride (mg/L)	TDS (mg/L)	Benzene (mg/L)	Toluene (mg/L)	Ethyl-benzene (mg/L)	Xylene (mg/L)
MW-1	01/23/08	27.5	---	**1,330**	---	---	---	---	---
	03/13/08	27.63	2.20	**665**	**1,461**	<0.001	<0.002	<0.001	<0.003
	06/19/08	27.88	2.69	**736**	**1,560**	---	---	---	---
	09/09/08	28.05	2.75	**760**	**1,790**	<0.001	<0.001	<0.001	<0.003
MW-2	06/19/08	27.54	1.36	**320**	976	---	---	---	---
	09/09/08	27.71	1.02	172	848	<0.001	<0.001	<0.001	<0.003
WQCC Standards				250	1,000	0.01	0.75	0.75	0.62

--- Indicates sample not analyzed for this constituent.
Values in boldface type indicate concentrations exceed New Mexico Water Quality Commission (WQCC) standards.

4.3 *FATE & TRANSPORT MODELING RESULTS*

Preliminary fate and transport modeling was performed to simulate the movement of the chloride in groundwater over time. Simulations were conducted using *WinTran* which is a two-dimensional groundwater flow and contaminant transport modeling software program (version 3.28) 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 following table lists the various parameters input into the fate and transport model simulations.

Table 5

Summary of Modeling Parameters

Parameter	Value	Source of Data
Hydraulic Conductivity (K_x, K_y, K_z)	6 and 10 ft/d	Aquifer tests (Appendix C)
Hydraulic Gradient	0.002 ft/ft	Observed and measured at nearby site
Gradient Direction	315° (southeast)	Observed and measured at nearby site
Longitudinal Dispersivity	18 ft, 23 ft, & 28 ft	10% of estimated plume length (2008)
Transverse Dispersivity	1.8 to 5.6 ft	One-fifth & one-half of longitudinal
Porosity	0.25	Professional judgement
Base elevation of aquifer	50 ft bgs	Top of quartzite/sandstone layer
Depth to groundwater	25 ft bgs	Observed and measured
Saturated thickness	25 ft	Observed and measured
Model X Extent (100 nodes)	1000 ft (10 ft/node)	Professional judgement
Model Y Extent (100 nodes)	1000 ft (10 ft/node)	Professional judgement

Aquifer testing (constant rate and recovery) using the monitoring well network located at the nearby South Four Lakes Tank Battery Site (NMOCD Case No. 1R-204) was conducted on September 16-17, 2008, to determine site-specific hydraulic parameters. Results and analyses of the aquifer test data are included in Appendix C. A more detailed discussion of the flow and transport parameters used, assumptions, model calibrations, and simulation results are described in Appendix D. The features, equations, and benchmarking documentation for the *WinTran* software are included in Appendix E.

The transport model was calibrated to closely match the current observed chloride plume in year 2008. This was accomplished by simulating source terms to the model (5 injection wells within the pit) and inputting a source chloride concentration of 100,000 mg/L (typical of brine used in oil well drilling) at a flow rate of approximately 5 gal/d, which resulted in a total chloride mass of 3,473 kg. The flow rate of each simulated injection well was apportioned in correlation to the chloride load at each of the five test points sampled in January 2008. The total chloride mass was estimated based on a conservative mass balance calculation based on the full dimensions of the current observed plume and observed chloride concentrations in groundwater as detailed in Appendix D. The length of the simulation was chosen to approximate the length of time that the source of chlorides has been affecting the groundwater system (5 years).

Subsequent model simulations were performed under the assumption that the chloride source was eliminated with the implementation of the vadose zone remedy as proposed in section 6.1. Ten scenarios of the model were simulated by inputting a range of hydraulic conductivity (6ft/d and 10 ft/d), longitudinal dispersivity (18 ft, 23 t, and 28 ft), and transverse dispersivity (1.8 ft to 5.6 ft) values. With each scenario the model simulations were continued through time until the center of chloride mass attenuated to a level below WQCC standard of 250 mg/L.

The ten fate and transport model simulations resulted in the center of chloride mass in the plume attenuating after migrating 434 ft to 925 ft southeast from the pit in 16 to 48 years. The average simulated distance and time of travel was about 660 ft in 28 yrs. A summary of each simulation is listed below.

Table 6

Summary of Fate & Transport Modeling Simulations

Simulation Number	Time (yrs)	K (ft/d)	Dispersivity (ft^2/d)		Distance (ft)	Velocity (ft/yr)	Max. Chloride in 2008 (mg/L)
			Longitudinal	Transverse			
1	16	10	28	2.8	375	23.4	1,523
2	19	10	18	3.6	434	22.8	1,731
3	20	10	23	2.3	470	23.5	1,665
4	22	6	28	5.6	302	13.7	2,195
5	26	10	18	1.8	589	22.7	1,846
6	28	6	23	4.6	375	13.4	2,427
7	31	6	28	2.8	425	13.7	2,371
8	36	6	18	3.6	471	13.1	2,730
9	40	6	23	2.3	520	13.0	2,611
10	48	6	18	1.8	925	18.3	2,917

Figures displaying each modeled simulation of the chloride plumes over various time increments and all other output are included in Appendix E.

5.0 CONCLUSIONS

Based on the soil boring data obtained by Elke Environmental in January 2008 (TP-1 through TP-5) and Trident Environmental in May 2008 (MW-2, B-1, and B-2) the chloride impact to the vadose zone is limited to within the perimeter of the former drilling pit. Highest chloride levels were observed at the TP-5 at the center of the pit.

It is likely that brine from the pit has migrated through the vadose zone to ground water via saturated flow during operation of the drilling pit or sometime during the drying process. The uniform decline of chloride concentrations observed within the pit from about 20 feet below grade to the water table can be attributed to dilution of the migrating brine by less saline ground water residing within the capillary fringe. Low porosity in the indurated sands at these depths may also contribute to lower chloride measurements because a smaller mass of brine is retained relative to the more unconsolidated soils above which exhibit a higher porosity.

Chloride and TDS concentrations from groundwater samples collected at monitoring well MW-1, MW-2, and soil boring B-1 exceeded WQCC standards. The higher chloride and TDS levels are at MW-1 which is expected due to its location immediately downgradient from the former drilling pit. A maximum chloride concentration of 1,330 mg/L in MW-1 was observed during the initial sampling event in January 2008, however chloride levels have decreased in this well to only 736 mg/L during the most recent sampling event. TDS concentrations in MW-1 exceed the WQCC standard by only 560 mg/L.

Horizontal dispersion of the chloride and TDS in groundwater does not extend beyond approximately 75 to 100 feet downgradient (southeast) of the southeast corner of the pit as evidenced by the results of monitoring well MW-2 where background chloride and TDS levels are observed in groundwater.

Fate and transport model simulations indicate that the center of chloride mass in the plume will attenuate to below the WQCC standard of 250 mg/L after migrating 434 ft to 925 ft southeast from the pit in 16 to 48 years. The average simulated distance and time of travel was about 660 ft in 28 yrs. Future monitoring and sampling events will provide the necessary time-variant and spatial data to verify and refine these estimates.

There will be no adverse impact to human health and the environment nor will any portion of the chloride plume that is above the WQCC standard of 250 mg/L reach any potential receptors at any time during its natural attenuation to background levels.

6.0 STAGE 2 ABATEMENT PLAN

Data collected to date indicates chloride/TDS-impaired groundwater exists beneath the site and chloride concentrations above 1,000 mg/kg exist in the vadose zone below the former drilling pit. The suspected source of the chloride in the vadose zone and groundwater at the site is the former drilling pit.

6.1 *VADOSE ZONE REMEDY AND SCHEDULE OF ACTIVITIES*

1. Expand the existing pit excavation as necessary to create a 3-foot wide area where subsurface impact of pit leakage does not exist (Figure 5, step 1).
2. Use the material from the pit expansion or deepen the excavation as necessary to create a sloping surface on the bottom of the excavation as shown in Figure 5, step 2.
3. Over the sloping surface, place "shingles" of recycled or new 20-mil, reinforced liner material with a permeability of less than 10^{-9} cm/sec. The shingles are laid to shed any infiltrated water from the pit area to native soil and to prevent any upward migration of chloride into the root zone.
4. Backfill the excavation with clean material, beginning with caliche and/or sand and finishing the top of the backfill with about 6-inches of soil that is capable of supporting native vegetation.
5. The new grade is a 3-5% slope that drains to a "ponding area". The final grade of the surface over the former pit should blend with the surroundings as much as possible. Figure 5, step 3, which shows a 5% slope that resembles a large "pitchers mound", is one example of a final surface that allows for drainage of stormwater away from the former drilling pit.
6. Seed the reclaimed pit with a mixture acceptable to the State Land Office.

Upon OCD approval of the vadose zone abatement plan, Pride will commence the proposed work elements.

6.2 *GROUNDWATER REMEDY AND SCHEDULE OF ACTIVITIES*

Pride Energy proposes the following to address corrective actions to the groundwater:

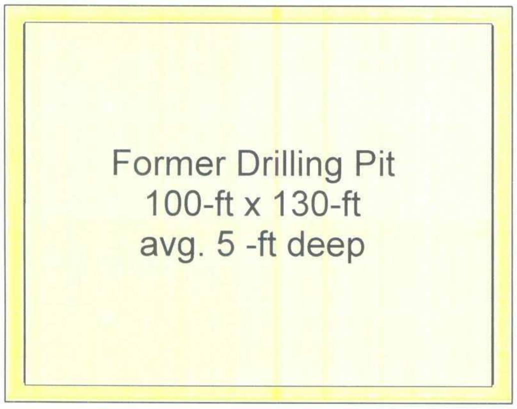
1. Install one additional downgradient well (MW-3) approximately 100 feet east-southeast of MW-1 to complete horizontal delineation and determine site-specific gradient magnitude and direction.
2. Continue the quarterly groundwater monitoring program through the end of 2008.

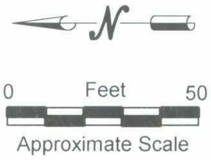
3. Refine our characterization of the natural attenuation conditions in progress by inputting the site-specific hydraulic parameters determined from the aquifer test(s) into a fate and transport model (*AquiferWin32*).
4. Provide the 2008 Annual Groundwater Monitoring Report to NMOCD by April 1, 2009, which will include all groundwater monitoring data and the fate and transport modeling results.
5. Continue the quarterly groundwater monitoring program through the end of 2009 to complete eight consecutive quarters of monitoring data.
6. Provide the 2009 Annual Groundwater Monitoring Report to NMOCD by April 1, 2010, which will include all groundwater monitoring data and the fate and transport modeling results.

If the results of the fate and transport modeling continue to support a natural attenuation remedy, such that chloride concentrations are less than 250 mg/L after a 30 year period (year 2039), or less than 500 mg/L after a 20 year period (year 2029), or sooner, a request for closure and plugging of monitoring wells will be made to NMOCD with the 2009 Annual Groundwater Monitoring Report.

If the results of the fate and transport modeling do not support a natural attenuation remedy then an alternate remedy will be proposed such as a longer-term monitoring program and/or installation of a recovery well for beneficial use of the extracted groundwater.

Upon OCD approval of the groundwater abatement plan, Pride will commence the proposed work elements.

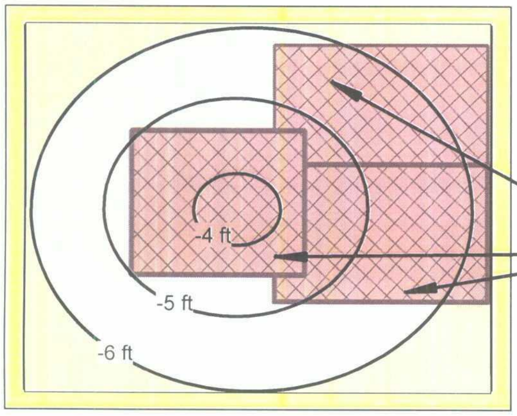




STEP 1

Excavate as required to create 3-foot clean zone around chloride impact

Reserve all topsoil and clean caliche



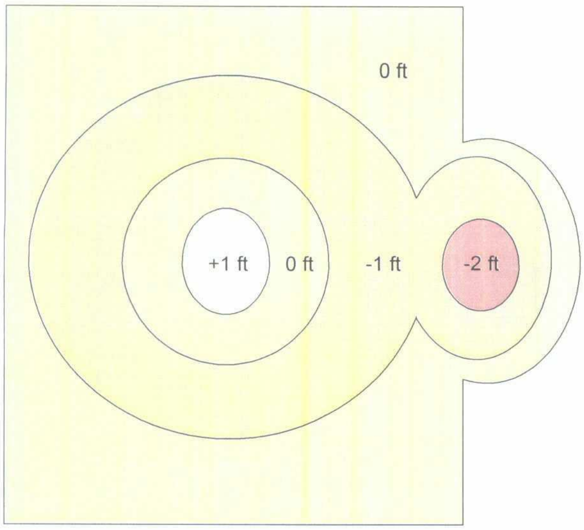
STEP 2

Create sloping surface at bottom of excavation

Center of sloping surface should be 3 to 4 feet below grade

Place 20-mil liner "shingles" over prepared surface

Shingles drain to un-impacted caliche



STEP 3

Excavate ponding area(s)

Backfill excavation with clean caliche and sand over liner - retain slope

Place about 6-inches of topsoil over clean caliche/sand - retain slope

Grade to allow excess runoff to ponding area

Re-seed with native species or a mix approved by the State Land Office

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Pride Energy Company
South Four Lakes #13 (AP-76)
T12S - R34E - Section 1 - Unit L
Lea County, New Mexico

Figure 5

Drilling Pit Excavation
and Closure Diagrams

APPENDIX A

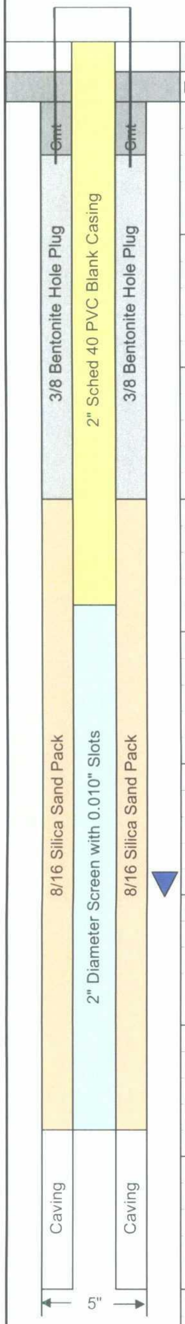
Lithologic Logs

Monitoring Well (MW-2) Construction Diagram

LITHOLOGIC LOG AND MONITORING WELL CONSTRUCTION DIAGRAM

TRIDENT ENVIRONMENTAL

MONITORING WELL NO.: MW-2
TOTAL DEPTH: 45
SITE NAME: South Four Lakes No. 13
CLIENT: Pride Energy Company
CONTRACTOR: Atkins Engineering
COUNTY: Lea
DRILLING METHOD: Hollow Stem / Air Rotary
STATE: New Mexico
START DATE: May 30, 2008
LOCATION: T12S - R34E - Section 1 - Unit Letter L
COMPLETION DATE: June 4, 2008
FIELD REP.: Gil Van Deventer / Dale Littlejohn
COMMENTS: Located 75 ft southeast of monitoring well MW-1

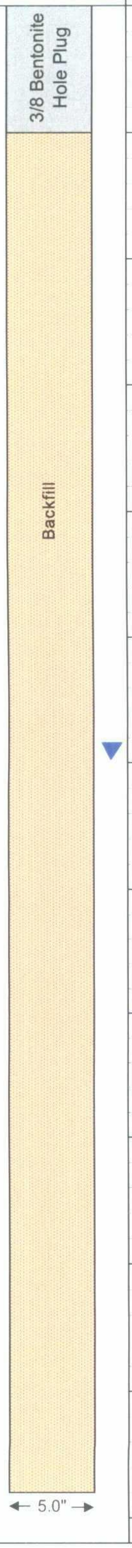


Depth	Sample Time	Sample Type	Chloride (mg/kg)	PID (ppm)	USCS	LITHOLOGIC DESCRIPTION: LITHOLOGY, COLOR, GRAIN SIZE, SORTING, ROUNDING, CONSOLIDATION, DISTINGUISHING FEATURES
	1030	Surface				
5	1037	Cuttings				Very fine- to fine-grained sand with caliche, very pale orange (10yr 8/2). Sand grains ae poorly sorted, subangular/subrounded, unconsolidated, dry.
10	1041	Cuttings				Grayish orange (10yr 7/4) fine to medium grain, moderately sorted, subrounded sand with <5% CaCO3 content
15	1045	Cuttings				Grayish orange (10yr 7/4) fine to medium grain, moderately sorted, subrounded sand with interbedded hard sandstone layers.
20	1046	Cuttings				Very pale orange (10yr 8/2) fine to medium grain sand, medium sorted, subangular to subrounded with caliche
	0840	Cuttings				Sandstone, Light brown, cemented with some quartzite fragments.
25					Lost Returns	
	0848	Cuttings			SW	Sand, brown, medium grain, medium sorting, moist.
30	0910	Cuttings				Sandstone (poorly consolidated) dark brown grains in light matrix, poorly sorted, with some small quartz gravel
35	0910	Cuttings				Sandstone (poorly consolidated) dark brown grains in light matrix, poorly sorted, with some small quartz gravel
40	0920	Cuttings				Sand, brown, very fine grain, with interbedded sandstone (as above)
45						Bottom of boring at 45 ft below ground surface, caved back to 39 ft.
50						

LITHOLOGIC LOG AND MONITORING WELL CONSTRUCTION DIAGRAM

TRIDENT ENVIRONMENTAL

MONITORING WELL NO.: B-1
TOTAL DEPTH: 59 Feet bgs
SITE NAME: South Four Lakes #13
CLIENT: Pride Energy Company
CONTRACTOR: Atkins Engineering
COUNTY: Lea
DRILLING METHOD: Air Rotary
STATE: New Mexico
START DATE: June 4, 2008
LOCATION: T12S - R34E - Section 1 - Unit Letter L
COMPLETION DATE: June 4, 2008
FIELD REP.: Dale Littlejohn
COMMENTS: Located ~25-ft south of drilling pit.



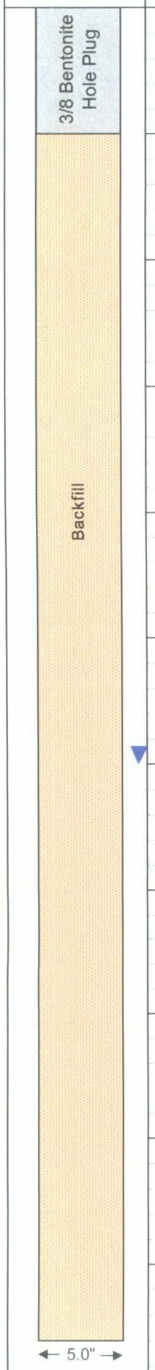
Sample Depth	Time	Type	Chloride (mg/kg)	SC (mS/cm)	USCS	LITHOLOGIC DESCRIPTION: LITHOLOGY, COLOR, GRAIN SIZE, SORTING, ROUNDING, CONSOLIDATION
					SM	Silty Sand (top soil) dark brown, very fine grain with some caliche
					CAL	Caliche grayish white, massive, hard
5	1126	Cuttings				
					SM	Silty sand light pinkins brown, very fine grain
					CAL	Caliche light grayish brown with some silt (<5%)
10	1145	Cuttings				
					SM	Silty sand light brown, very fine grain
15	1150	Cuttings				
20	1228	Cuttings			SW	Sandstone light brown cemented with some quartzite fragments, interbedded with light brown very fine grain sand, very hard drilling
25	1235	Cuttings				
30	1240	No Returns (soil or water)			No Cutting Returns	
35						
40						
45						
	1415	Water		1.13		
50						
55					SW	Sandstone brown with purple tint, medium grain, poorly sorted, very hard (did not fully penetrate)
	1455	Water		1.64		
60						

LITHOLOGIC LOG AND MONITORING WELL CONSTRUCTION DIAGRAM

TRIDENT ENVIRONMENTAL

MONITORING WELL NO.: B-2
SITE NAME: South Four Lakes #13
CONTRACTOR: Atkins Engineering
DRILLING METHOD: Air Rotary
START DATE: June 4, 2008
COMPLETION DATE: June 5, 2008
COMMENTS: Located ~25-ft east of drilling pit.

TOTAL DEPTH: 53 Feet bgs
CLIENT: Pride Energy Company
COUNTY: Lea
STATE: New Mexico
LOCATION: T12S - R34E - Section 1 - Unit Letter L
FIELD REP.: Dale Littlejohn



Sample Depth	Time	Type	Chloride (mg/kg)	SC (mS/cm)	USCS	LITHOLOGIC DESCRIPTION: LITHOLOGY, COLOR, GRAIN SIZE, SORTING, ROUNDING, CONSOLIDATION
					SM	Silty Sand (top soil) dark brown, very fine grain with some caliche
5	1550	Cuttings			CAL/SM	Caliche light brown to gray with silt
10	1620	Cuttings			CAL	Caliche grayish white, very hard
15	0958	Cuttings			SW/CAL	Sand light brown, very fine grain with interbedded (thin) caliche. Compressor broke down, will continue drilling tomorrow
					CAL	Caliche white soft with very little sand
20	1003	Cuttings			SW	Sand, light brown, very fine grain, poorly sorted, sub angular.
					QTZ	Quartzite, brown, fine crystilline, very hard, with some gray medium grain, poorly sorted, sub angular sandstone
25	1013	Cuttings			SW	Sand, light grayish brown, very fine grain, well sorted, sith some (thin) sandstone layers
		No Returns (soil or water)				
30 35 40 45					No Cutting Returns	
50					No Cutting Returns	Possible sandstone (based on B-1)
55 60						

APPENDIX B

Laboratory Analytical Reports
Chain-of-Custody Documentation
Monitoring Well Sampling Data Forms

Analytical Report 305296

for

Pride Energy Company

Project Manager: Matt Pride

Pride Energy Company

South Four Lakes #13

10-JUN-08

ENVIRONMENTAL
LAB OF

12600 West I-20 East Odessa, Texas 79765

Texas certification numbers:
Houston, TX T104704215

Florida certification numbers:
Houston, TX E871002 - Miami, FL E86678 - Tampa, FL E86675
Norcross(Atlanta), GA E87429

South Carolina certification numbers:
Norcross(Atlanta), GA 98015

North Carolina certification numbers:
Norcross(Atlanta), GA 483

Houston - Dallas - San Antonio - Austin - Tampa - Miami - Latin America
Midland - Corpus Christi - Atlanta

ENVIRONMENTAL
LAB OF

10-JUN-08

Project Manager: **Matt Pride**
Pride Energy Company
P.O. Box 701950

Tulsa, OK 74170

Reference: XENCO Report No: **305296**
Pride Energy Company
Project Address: T12S-R34E, Section 1, Unit Letter L

Matt Pride:

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number 305296. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. Estimation of data uncertainty for this report is found in the quality control section of this report unless otherwise noted. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 305296 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Brent Barron, II
Odessa Laboratory Manager

Sample Cross Reference 305296

Pride Energy Company, Tulsa, OK

Pride Energy Company

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
MW-2 (27 ft)	S	Jun-04-08 08:48		305296-001
SB-1 (5 ft)	S	Jun-04-08 11:26		305296-002
SB-1 (10 ft)	S	Jun-04-08 11:45		305296-003
SB-1 (15 ft)	S	Jun-04-08 11:50		305296-004
SB-1 (20 ft)	S	Jun-04-08 12:28		305296-005
SB-1 (25 ft)	S	Jun-04-08 12:35		305296-006
SB-1 (30 ft)	S	Jun-04-08 12:40		305296-007
SB-2 (5 ft)	S	Jun-04-08 15:50		305296-008
SB-2 (12 ft)	S	Jun-04-08 16:20		305296-009
SB-2 (16 ft)	S	Jun-05-08 09:58		305296-010
SB-2 (20 ft)	S	Jun-05-08 10:03		305296-011
SB-2 (25 ft)	S	Jun-05-08 10:13		305296-012

Certificate of Analysis Summary 305296

Pride Energy Company, Tulsa, OK

Project Name: Pride Energy Company

Project Id: South Four Lakes #13
Contact: Matt Pride
Project Location: T12S-R34E, Section 1, Unit Letter L

Date Received in Lab: Thu Jun-05-08 04:00 pm
Report Date: 10-JUN-08
Project Manager: Brent Barron, II

Analysis Requested	*Lab Id:*	305296-001		305296-002		305296-003		305296-004		305296-005		305296-006	
	Field Id:	MW-2 (27 ft)		SB-1 (5 ft)		SB-1 (10 ft)		SB-1 (15 ft)		SB-1 (20 ft)		SB-1 (25 ft)	
	Depth:												
	Matrix:	SOIL		SOIL		SOIL		SOIL		SOIL		SOIL	
	Sampled:	Jun-04-08 08:48		Jun-04-08 11:26		Jun-04-08 11:45		Jun-04-08 11:50		Jun-04-08 12:28		Jun-04-08 12:35	
Inorganic Anions by EPA 300	*Extracted:*												
	Analyzed:	Jun-09-08 17:53		Jun-09-08 17:53		Jun-09-08 17:53		Jun-09-08 17:53		Jun-09-08 17:53		Jun-09-08 17:53	
	Units/RL:	mg/kg	RL	mg/kg	RL	mg/kg	RL	mg/kg	RL	mg/kg	RL	mg/kg	RL
Chloride		17.6	5.00	49.1	5.00	73.9	5.00	ND	10.0	76.5	5.00	25.5	5.00

Brent Barron
Odessa Laboratory Director

Certificate of Analy[illegible]Summary 305296

Pride Energy Company, Tulsa, OK

Project Name: Pride Energy Company

Project Id: South Four Lakes #13
Contact: Matt Pride
Project Location: T12S-R34E, Section 1, Unit Letter L

Date Received in Lab: Thu Jun-05-08 04:00 pm
Report Date: 10-JUN-08
Project Manager: Brent Barron, II

Analysis Requested							
	Lab Id:	305296-007	305296-008	305296-009	305296-010	305296-011	305296-012
	Field Id:	SB-1 (30 ft)	SB-2 (5 ft)	SB-2 (12 ft)	SB-2 (16 ft)	SB-2 (20 ft)	SB-2 (25 ft)
	Depth:						
	Matrix:	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
	Sampled:	Jun-04-08 12:40	Jun-04-08 15:50	Jun-04-08 16:20	Jun-05-08 09:58	Jun-05-08 10:03	Jun-05-08 10:13
Inorganic Anions by EPA 300	*Extracted:*						
	Analyzed:	Jun-09-08 17:53	Jun-09-08 17:53	Jun-09-08 17:53	Jun-09-08 17:53	Jun-09-08 17:53	Jun-09-08 17:53
	Units/RL:	mg/kg RL	mg/kg RL	mg/kg RL	mg/kg RL	mg/kg RL	mg/kg RL
Chloride		33.8 5.00	1040 10.0	88.3 10.0	144 10.0	2090 25.0	303 5.00

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Brent Barron
Odessa Laboratory Director

XENCO Laboratories

Flagging Criteria

X In our quality control review of the data a QC deficiency was observed and flagged as noted. MS/MSD recoveries were found to be outside of the laboratory control limits due to possible matrix /chemical interference, or a concentration of target analyte high enough to effect the recovery of the spike concentration. This condition could also effect the relative percent difference in the MS/MSD.

B A target analyte or common laboratory contaminant was identified in the method blank. Its presence indicates possible field or laboratory contamination.

D The sample(s) were diluted due to targets detected over the highest point of the calibration curve, or due to matrix interference. Dilution factors are included in the final results. The result is from a diluted sample.

E The data exceeds the upper calibration limit; therefore, the concentration is reported as estimated.

F RPD exceeded lab control limits.

J The target analyte was positively identified below the MQL(PQL) and above the SQL(MDL).

U Analyte was not detected.

L The LCS data for this analytical batch was reported below the laboratory control limits for this analyte. The department supervisor and QA Director reviewed data. The samples were either reanalyzed or flagged as estimated concentrations.

H The LCS data for this analytical batch was reported above the laboratory control limits. Supporting QC Data were reviewed by the Department Supervisor and QA Director. Data were determined to be valid for reporting.

K Sample analyzed outside of recommended hold time.

* Outside XENCO'S scope of NELAC Accreditation

Recipient of the Prestigious Small Business Administration Award of Excellence in 1994.
Certified and approved by numerous States and Agencies.
A Small Business and Minority Status Company that delivers SERVICE and QUALITY

Houston - Dallas - San Antonio - Austin - Tampa - Miami - Atlanta - Corpus Christi - Latin America

	Phone	Fax
11381 Meadowglen Lane Suite L Houston, Tx 77082-2647	(281) 589-0692	(281) 589-0695
9701 Harry Hines Blvd , Dallas, TX 75220	(214) 902 0300	(214) 351-9139
5332 Blackberry Drive, Suite 104, San Antonio, TX 78238	(210) 509-3334	(210) 509-3335
2505 N. Falkenburg Rd., Tampa, FL 33619	(813) 620-2000	(813) 620-2033
5757 NW 158th St, Miami Lakes, FL 33014	(305) 823-8500	(305) 823-8555
6017 Financial Dr., Norcross, GA 30071	(770) 449-8800	(770) 449-5477

Blank Spike Recovery

Project Name: Pride Energy Company

Work Order #: 305296 **Project ID:** South Four Lakes #13

Lab Batch #: 724913 **Sample:** 724913-1-BKS **Matrix:** Solid

Date Analyzed: 06/09/2008 **Date Prepared:** 06/09/2008 **Analyst:** LATCOR

Reporting Units: mg/kg **Batch #:** 1

BLANK /BLANK SPIKE RECOVERY STUDY

Inorganic Anions by EPA 300 Analytes	Blank Result [A]	Spike Added [B]	Blank Spike Result [C]	Blank Spike %R [D]	Control Limits %R	Flags
Chloride	ND	10.0	11.4	114	75-125	

Blank Spike Recovery [D] = 100*[C]/[B]
All results are based on MDL and validated for QC purposes.

XENCO Laboratories

Form 3 - MS Recoveries

Project Name: Pride Energy Company

Work Order #:	305296				
Lab Batch #:	724913			**Project ID:**	South Four Lakes #13
Date Analyzed:	06/09/2008	**Date Prepared:**	06/09/2008	**Analyst:**	LATCOR
QC- Sample ID:	305296-001 S	**Batch #:**	1	**Matrix:**	Soil
Reporting Units:	mg/kg				

MATRIX / MATRIX SPIKE RECOVERY STUDY

Inorganic Anions by EPA 300 Analytes	Parent Sample Result [A]	Spike Added [B]	Spiked Sample Result [C]	%R [D]	Control Limits %R	Flag
Chloride	17.6	100	144	126	75-125	X

Matrix Spike Percent Recovery [D] = 100*(C-A)/B
Relative Percent Difference [E] = 200*(C-A)/(C+B)
All Results are based on MDL and Validated for QC Purposes

Sample Duplicate Recovery

Project Name: Pride Energy Company

Work Order #: 305296

Lab Batch #: 724913
Project ID: South Four Lakes #13
Date Analyzed: 06/09/2008
Date Prepared: 06/09/2008
Analyst: LATCOR
QC- Sample ID: 305296-001 D
Batch #: 1
Matrix: Soil
Reporting Units: mg/kg

Inorganic Anions by EPA 300	SAMPLE / SAMPLE DUPLICATE RECOVERY				
Analyte	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Chloride	17.6	17.6	0	20	

Spike Relative Difference RPD 200 * | (B-A)/(B+A) |
All Results are based on MDL and validated for QC purposes.

XENCO Laboratories / Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Company Name: Pride Energy Company
Direct Invoice To: Matt Pride
Billing Address: P. O. Box 710950
City, State, Zip Code: Tulsa, OK 74170-1950
Telephone No: 918-524-9200
Fax No: 918-524-9292
Email Report to: mattp@pride-energy.com
Sampler: Dale Littlejohn (Printed)

Company Name: Trident Environmental
Project Manager: Gil Van Deventer
Address: P. O. Box 7624
City, State, Zip Code: Midland TX 79708-7624
Telephone No: 432-638-8740
Fax No: 413-403-9968
Email Report to: gil@trident-environmental.com
Dal T Littlejohn (Signature)

Project Name: Pride Energy Company
Project #: South Four Lakes #13
Project Location: T12S-R34E, Section 1, Unit Letter L
COC #: V126-060408-2

1 of 2

					Preservative							Matrix				Analyze For (TCLP / TOTAL)															
305296 LAB # (lab use only)	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice 4°C	HNO3	HCl	NaOH	H2SO4	None	Other (Specify)	Water	Sludge	Soil	Other (Specify)	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B	RCI	N.O.R.M.	Total Dissolved Solids (160.1)	SPLP 1312	Chloride	Total Fe and Mn	RUSH TAT (Pre-Schedule)	Standard TAT
1	MW-2 (27 ft)	6-4-08	0848	1	X									X														X			X
2	SB-1 (5 ft)	"	1126	1	X									X														X			X
3	SB-1 (10 ft)	"	1145	1	X									X														X			X
4	SB-1 (15 ft)	"	1150	1	X									X														X			X
5	SB-1 (20 ft)	"	1228	1	X									X														X			X
6	SB-1 (25 ft)	"	1235	1	X									X														X			X
7	SB-1 (30 ft)	"	1240	1	X									X														X			X
8	SB-2 (5 ft)	"	1550	1	X									X														X			X
9	SB-2 (12 ft)	"	1620	1	X									X														X			X
10	SB-2 (16 ft)	6-5-08	0958	1	X									X														X			X

Special Instructions:
Email results to: gil@trident-environmental.com and mattp@pride-energy.com

Relinquished by	Date	Time	Received by:	Date	Time
Dal T Littlejohn	6/5/08	1600			

Relinquished by:	Date	Time	Received by ELOT:	Date	Time
			Bill	6/5/08	16:00

Sample Containers Intact? [✓ Y] N
Temperature Upon Receipt: [illegible] °
Laboratory Comments:

XENCO Laboratories / Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Company Name: Pride Energy Company
Direct Invoice To: Matt Pride
Billing Address: P. O. Box 710950
City, State, Zip Code: Tulsa, OK 74170-1950
Telephone No: 918-524-9200
Fax No: 918-524-9292
Email Report to: mattp@pride-energy.com
Sampler: Dale Littlejohn (Printed) Dal 7 Littlejoh (Signature)

Company Name: Trident Environmental
Project Manager: Gil Van Deventer
Address: P. O. Box 7624
City, State, Zip Code: Midland TX 79708-7624
Telephone No. 432-638-8740
Fax No: 413-403-9968
Email Report to: gil@trident-environmental.com

Project Name: Pride Energy Company
Project #: South Four Lakes #13
Project Location: T12S-R34E, Section 1, Unit Letter L
COC #: V126-060408-3

2 of 2

LAB # (lab use only) 305296	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Preservative: Ice	HNO3	HCl BTEX only	NaOH	H2SO4	None	Other (Specify)	Matrix: Water	Sludge	Soil	Other (specify)	Analyze For: TPH 418.1 8015M 1005 1006	Cations (Ca Mg Na K)	Anions (Cl SO4 CO3 HCO3)	SAR / ESP / CEC	Metals As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B	RCI	N.O.R.M.	Total Dissolved Solids (160.1)	SPLP 1312	Chlorides	Total Fe and Mn	RUSH TAT (Pre-Schedule)	Standard TAT
11	SB-2 (20 ft)	6/5/08	1003	1	X									X														X			X
12	SB-2 (25 ft)	6/5/08	1013																												

Special Instructions:
Email results to: gil@trident-environmental.com and mattp@pride-energy.com

Sample Containers Intact? [✓ Y] N
Temperature Upon Receipt: 1.0°
Laboratory Comments:

Relinquished by:	Date	Time	Received by:	Date	Time
Dal 7. Littlejoh	6/5/08	1600			
Relinquished by:	Date	Time	Received by ELOT:	Date	Time
				6/5/08	16:00

Environmental Lab of Texas

Variance/ Corrective Action Report- Sample Log-In

Client: Pride
Date/ Time: 6/5/08 16:00
Lab ID # : 305296
Initials: ck

Sample Receipt Checklist

				Client Initials
#1 Temperature of container/ cooler?	Yes	No	1.0 °C	
#2 Shipping container in good condition?	[✓ Yes]	No		
#3 Custody Seals intact on shipping container/ cooler?	Yes	No	[✓ Not Present]	
#4 Custody Seals intact on sample bottles/ container?	Yes	No	[✓ Not Present]	
#5 Chain of Custody present?	[✓ Yes]	No		
#6 Sample instructions complete of Chain of Custody?	[✓ Yes]	No		
#7 Chain of Custody signed when relinquished/ received?	[✓ Yes]	No		
#8 Chain of Custody agrees with sample label(s)?	Yes	No	[✓ ID written on Cont./ Lid]	
#9 Container label(s) legible and intact?	[✓ Yes]	No	Not Applicable	
#10 Sample matrix/ properties agree with Chain of Custody?	[✓ Yes]	No		
#11 Containers supplied by ELOT?	[✓ Yes]	No		
#12 Samples in proper container/ bottle?	[✓ Yes]	No	See Below	
#13 Samples properly preserved?	[✓ Yes]	No	See Below	
#14 Sample bottles intact?	[✓ Yes]	No		
#15 Preservations documented on Chain of Custody?	[✓ Yes]	No		
#16 Containers documented on Chain of Custody?	[✓ Yes]	No		
#17 Sufficient sample amount for indicated test(s)?	[✓ Yes]	No	See Below	
#18 All samples received within sufficient hold time?	[✓ Yes]	No	See Below	
#19 Subcontract of sample(s)?	Yes	No	[✓ Not Applicable]	
#20 VOC samples have zero headspace?	Yes	No	[✓ Not Applicable]	

Variance Documentation

Contact: ______ Contacted by: ______ Date/ Time: ______

Regarding: ______

Corrective Action Taken:

Check all that Apply:
☐ See attached e-mail/ fax
☐ Client understands and would like to proceed with analysis
☐ Cooling process had begun shortly after sampling event

Analytical Report 305298

for

Pride Energy Company

Project Manager: Matt Pride

Pride Energy Company

South Four Lakes #13

12-JUN-08

ENVIRONMENTAL
LAB OF

12600 West I-20 East Odessa, Texas 79765

Texas certification numbers:
Houston, TX T104704215

Florida certification numbers:
Houston, TX E871002 - Miami, FL E86678 - Tampa, FL E86675
Norcross(Atlanta), GA E87429

South Carolina certification numbers:
Norcross(Atlanta), GA 98015

North Carolina certification numbers:
Norcross(Atlanta), GA 483

Houston - Dallas - San Antonio - Austin - Tampa - Miami - Latin America
Midland - Corpus Christi - Atlanta

12-JUN-08

Project Manager: **Matt Pride**
Pride Energy Company
P.O. Box 701950

Tulsa, OK 74170

Reference: XENCO Report No: **305298**
Pride Energy Company
Project Address: T12S-R34E, Section 1, Unit Letter L

Matt Pride:

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number 305298. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. Estimation of data uncertainty for this report is found in the quality control section of this report unless otherwise noted. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 305298 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Brent Barron, II
Odessa Laboratory Manager

Sample Cross Reference 305298

Pride Energy Company, Tulsa, OK

Pride Energy Company

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
MW-2 (31 ft)	W	Jun-04-08 09:10		305298-001
MW-2 (40 ft)	W	Jun-04-08 09:20		305298-002
SB-1 (48 ft)	W	Jun-04-08 14:15		305298-003
SB-1 (59 ft)	W	Jun-04-08 14:55		305298-004

Certificate of Analy Summary 305298

Pride Energy Company, Tulsa, OK

Project Name: Pride Energy Company

Project Id: South Four Lakes #13
Contact: Matt Pride
Project Location: T12S-R34E, Section 1, Unit Letter L

Date Received in Lab: Thu Jun-05-08 04:00 pm
Report Date: 12-JUN-08
Project Manager: Brent Barron, II

Analysis Requested	*Lab Id:*	305298-001	305298-002	305298-003	305298-004		
	Field Id:	MW-2 (31 ft)	MW-2 (40 ft)	SB-1 (48 ft)	SB-1 (59 ft)		
	Depth:						
	Matrix:	WATER	WATER	WATER	WATER		
	Sampled:	Jun-04-08 09:10	Jun-04-08 09:20	Jun-04-08 14:15	Jun-04-08 14:55		
Inorganic Anions by EPA 300	*Extracted:*						
	Analyzed:	Jun-10-08 17:28	Jun-10-08 17:28	Jun-10-08 17:28	Jun-10-08 17:28		
	Units/RL:	mg/L RL	mg/L RL	mg/L RL	mg/L RL		
Chloride		319 5.00	654 10.0	160 5.00	400 5.00		
TDS by SM2540C	*Extracted:*						
	Analyzed:	Jun-09-08 16:15	Jun-09-08 16:15	Jun-09-08 16:15	Jun-09-08 16:15		
	Units/RL:	mg/L RL	mg/L RL	mg/L RL	mg/L RL		
Total dissolved solids		840 5.00	1430 5.00	566 5.00	992 5.00		

Brent Barron
Odessa Laboratory Director

XENCO Laboratories

Flagging Criteria

X In our quality control review of the data a QC deficiency was observed and flagged as noted. MS/MSD recoveries were found to be outside of the laboratory control limits due to possible matrix /chemical interference, or a concentration of target analyte high enough to effect the recovery of the spike concentration. This condition could also effect the relative percent difference in the MS/MSD.

B A target analyte or common laboratory contaminant was identified in the method blank. Its presence indicates possible field or laboratory contamination.

D The sample(s) were diluted due to targets detected over the highest point of the calibration curve, or due to matrix interference. Dilution factors are included in the final results. The result is from a diluted sample.

E The data exceeds the upper calibration limit; therefore, the concentration is reported as estimated.

F RPD exceeded lab control limits.

J The target analyte was positively identified below the MQL(PQL) and above the SQL(MDL).

U Analyte was not detected.

L The LCS data for this analytical batch was reported below the laboratory control limits for this analyte. The department supervisor and QA Director reviewed data. The samples were either reanalyzed or flagged as estimated concentrations.

H The LCS data for this analytical batch was reported above the laboratory control limits. Supporting QC Data were reviewed by the Department Supervisor and QA Director. Data were determined to be valid for reporting.

K Sample analyzed outside of recommended hold time.

* Outside XENCO'S scope of NELAC Accreditation

Blank Spike Recovery

Project Name: Pride Energy Company

Work Order #: 305298 **Project ID:** South Four Lakes #13

Lab Batch #: 725062 **Sample:** 725062-1-BKS **Matrix:** Water

Date Analyzed: 06/10/2008 **Date Prepared:** 06/10/2008 **Analyst:** LATCOR

Reporting Units: mg/L **Batch #:** 1

BLANK /BLANK SPIKE RECOVERY STUDY

Inorganic Anions by EPA 300 Analytes	Blank Result [A]	Spike Added [B]	Blank Spike Result [C]	Blank Spike %R [D]	Control Limits %R	Flags
Chloride	ND	10.0	11.9	119	85-115	H

Blank Spike Recovery [D] = 100*[C]/[B]
All results are based on MDL and validated for QC purposes.

XENCO Laboratories

Form 3 - MS Recoveries

Project Name: Pride Energy Company

Work Order #: 305298

Lab Batch #: 725062

Project ID: South Four Lakes #13

Date Analyzed: 06/10/2008

Date Prepared: 06/10/2008

Analyst: LATCOR

QC- Sample ID: 305298-001 S

Batch #: 1

Matrix: Water

Reporting Units: mg/L

Inorganic Anions by EPA 300 Analytes	MATRIX / MATRIX SPIKE RECOVERY STUDY					
	Parent Sample Result [A]	Spike Added [B]	Spiked Sample Result [C]	%R [D]	Control Limits %R	Flag
Chloride	319	100	458	139	85-115	X

Matrix Spike Percent Recovery [D] = 100*(C-A)/B
Relative Percent Difference [E] = 200*(C-A)/(C+B)
All Results are based on MDL and Validated for QC Purposes

Sample Duplicate Recovery

Project Name: Pride Energy Company

Work Order #: 305298

Lab Batch #: 725062 **Project ID:** South Four Lakes #13
Date Analyzed: 06/10/2008 **Date Prepared:** 06/10/2008 **Analyst:** LATCOR
QC- Sample ID: 305298-001 D **Batch #:** 1 **Matrix:** Water
Reporting Units: mg/L

Inorganic Anions by EPA 300 Analyte	SAMPLE / SAMPLE DUPLICATE RECOVERY				
	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Chloride	319	333	4	20	

Lab Batch #: 725008
Date Analyzed: 06/09/2008 **Date Prepared:** 06/09/2008 **Analyst:** WRU
QC- Sample ID: 305308-001 D **Batch #:** 1 **Matrix:** Water
Reporting Units: mg/L

TDS by SM2540C Analyte	SAMPLE / SAMPLE DUPLICATE RECOVERY				
	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Total dissolved solids	38400	38000	1	30	

Spike Relative Difference RPD 200 * | (B-A)/(B+A) |
All Results are based on MDL and validated for QC purposes.

XENCO Laboratories / Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Company Name: Pride Energy Company
Direct Invoice To: Matt Pride
Billing Address: P. O. Box 710950
City, State, Zip Code: Tulsa, OK 74170-1950
Telephone No. 918-524-9200
Fax No: 918-524-9292
Email Report to: mattp@pride-energy.com
Sampler: Dale Littlejohn (Printed) Dal T Littlejohn (Signature)

Company Name: Trident Environmental
Project Manager: Gil Van Deventer
Address: P. O. Box 7624
City, State, Zip Code: Midland TX 79708-7624
Telephone No: 432-638-8740
Fax No: 413-403-9968
Email Report to: gil@trident-environmental.com

Project Name: Pride Energy Company
Project #: South Four Lakes #13
Project Location: T12S-R34E, Section 1, Unit Letter L
COC #: V125-060408-1

					Preservative							Matrix				Analyze For															
LAB # (lab use only) 352298	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice 500 poly	HNO_3	HCl (BTEX only)	NaOH	H_2SO_4	None	Other (Specify)	Water	Sludge	Soil	Other (specify)	TPH 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K, F)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEX 8021B	RCI	N.O.R.M.	[illegible]	SPLP 1312	Chloride	Total Fe and Mn	RUSH TAT (Pre-Schedule)	Standard TAT
1	MW-2 (31 ft)	6/4/08	0910	1	X							X														X		X			X
2	MW-2 (40 ft)	"	0920	1	X							X														X		X			X
3	SB-1 (48 ft)	"	1415	1	X							X														X		X			X
4	SB-1 (59 ft)	"	1455	1	X							X														X		X			X

Special Instructions:
Email results to: gil@trident-environmental.com and mattp@pride-energy.com

Sample Containers Intact? [✓ Y] N
Temperature Upon Receipt: 1.0°
Laboratory Comments:

Relinquished by:	Date	Time	Received by:	Date	Time
Dal T Littlejohn	6/5/08	1600			
Relinquished by:	Date	Time	Received by ELOT:	Date	Time
				6/5/08	16.30

Environmental Lab of Texas

Variance/ Corrective Action Report- Sample Log-In

Client: Pride
Date/ Time: 6/5/08 16:00
Lab ID # : 305298
Initials: VK

Sample Receipt Checklist

				Client Initials
#1 Temperature of container/ cooler?	Yes	No	1.0 °C	
#2 Shipping container in good condition?	[✓ Yes]	No		
#3 Custody Seals intact on shipping container/ cooler?	Yes	No	[✓ Not Present]	
#4 Custody Seals intact on sample bottles/ container?	Yes	No	[✓ Not Present]	
#5 Chain of Custody present?	[✓ Yes]	No		
#6 Sample instructions complete of Chain of Custody?	[✓ Yes]	No		
#7 Chain of Custody signed when relinquished/ received?	[✓ Yes]	No		
#8 Chain of Custody agrees with sample label(s)?	Yes	No	[✓ ID written on Cont./ Lid]	
#9 Container label(s) legible and intact?	[✓ Yes]	No	Not Applicable	
#10 Sample matrix/ properties agree with Chain of Custody?	[✓ Yes]	No		
#11 Containers supplied by ELOT?	[✓ Yes]	No		
#12 Samples in proper container/ bottle?	[✓ Yes]	No	See Below	
#13 Samples properly preserved?	[✓ Yes]	No	See Below	
#14 Sample bottles intact?	[✓ Yes]	No		
#15 Preservations documented on Chain of Custody?	[✓ Yes]	No		
#16 Containers documented on Chain of Custody?	[✓ Yes]	No		
#17 Sufficient sample amount for indicated test(s)?	[✓ Yes]	No	See Below	
#18 All samples received within sufficient hold time?	[✓ Yes]	No	See Below	
#19 Subcontract of sample(s)?	Yes	No	[✓ Not Applicable]	
#20 VOC samples have zero headspace?	Yes	No	[✓ Not Applicable]	

Variance Documentation

Contact: ______ Contacted by: ______ Date/ Time: ______

Regarding: ______

Corrective Action Taken: ______

Check all that Apply:
☐ See attached e-mail/ fax
☐ Client understands and would like to proceed with analysis
☐ Cooling process had begun shortly after sampling event

Analytical Report 306333

for

Pride Energy Company

Project Manager: Matt Pride

Pride Energy Company
South Four Lakes # 13

27-JUN-08

ENVIRONMENTAL
LAB OF

12600 West I-20 East Odessa, Texas 79765

Texas certification numbers:
Houston, TX T104704215

Florida certification numbers:
Houston, TX E871002 - Miami, FL E86678 - Tampa, FL E86675
Norcross(Atlanta), GA E87429

South Carolina certification numbers:
Norcross(Atlanta), GA 98015

North Carolina certification numbers:
Norcross(Atlanta), GA 483

Houston - Dallas - San Antonio - Austin - Tampa - Miami - Latin America
Midland - Corpus Christi - Atlanta

XENCO Laboratories

27-JUN-08

Project Manager: **Matt Pride**
Pride Energy Company
P.O. Box 701950

Tulsa, OK 74170

Reference: XENCO Report No: **306333**
Pride Energy Company
Project Address: T12S-R34E, Section 1, Unit Letter L

Matt Pride:

We are reporting to you the results of the analyses performed on the samples received under the project name referenced above and identified with the XENCO Report Number 306333. All results being reported under this Report Number apply to the samples analyzed and properly identified with a Laboratory ID number. Subcontracted analyses are identified in this report with either the NELAC certification number of the subcontract lab in the analyst ID field, or the complete subcontracted report attached to this report.

Unless otherwise noted in a Case Narrative, all data reported in this Analytical Report are in compliance with NELAC standards. Estimation of data uncertainty for this report is found in the quality control section of this report unless otherwise noted. Should insufficient sample be provided to the laboratory to meet the method and NELAC Matrix Duplicate and Matrix Spike requirements, then the data will be analyzed, evaluated and reported using all other available quality control measures.

The validity and integrity of this report will remain intact as long as it is accompanied by this letter and reproduced in full, unless written approval is granted by XENCO Laboratories. This report will be filed for at least 5 years in our archives after which time it will be destroyed without further notice, unless otherwise arranged with you. The samples received, and described as recorded in Report No. 306333 will be filed for 60 days, and after that time they will be properly disposed without further notice, unless otherwise arranged with you. We reserve the right to return to you any unused samples, extracts or solutions related to them if we consider so necessary (e.g., samples identified as hazardous waste, sample sizes exceeding analytical standard practices, controlled substances under regulated protocols, etc).

We thank you for selecting XENCO Laboratories to serve your analytical needs. If you have any questions concerning this report, please feel free to contact us at any time.

Respectfully,

Brent Barron, II
Odessa Laboratory Manager

Recipient of the Prestigious Small Business Administration Award of Excellence in 1994.
Certified and approved by numerous States and Agencies.
A Small Business and Minority Status Company that delivers SERVICE and QUALITY
Houston - Dallas - San Antonio - Austin - Tampa - Miami - Atlanta - Corpus Christi - Latin America

Sample Cross Reference 306333

Pride Energy Company, Tulsa, OK

Pride Energy Company

Sample Id	Matrix	Date Collected	Sample Depth	Lab Sample Id
MW-1	W	Jun-19-08 14:15		306333-001
MW-2	W	Jun-19-08 13:20		306333-002

ENVIRONMENTAL LAB OF

Certificate of Analysis Summary 306333

Pride Energy Company, Tulsa, OK

Project Name: Pride Energy Company

Project Id: South Four Lakes # 13
Contact: Matt Pride
Project Location: T12S-R34E, Section 1, Unit Letter L

Date Received in Lab: Jun-20-08 05:00 pm
Report Date: 27-JUN-08
Project Manager: Brent Barron, II

Analysis Requested	*Lab Id:*	306333-001		306333-002			
	Field Id:	MW-1		MW-2			
	Depth:						
	Matrix:	WATER		WATER			
	Sampled:	Jun-19-08 14:15		Jun-19-08 13:20			
Alkalinity by SM2320B	*Extracted:*						
	Analyzed:	Jun-26-08 10:45		Jun-26-08 10:45			
	Units/RL:	mg/L	RL	mg/L	RL		
Alkalinity, Total (as CaCO3)		196	4.00	164	4.00		
Alkalinity, Bicarbonate (as CaCO3)		196	4.00	164	4.00		
Alkalinity, Carbonate (as CaCO3)		ND	4.00	ND	4.00		
Inorganic Anions by EPA 300	*Extracted:*						
	Analyzed:	Jun-23-08 08:50		Jun-23-08 08:50			
	Units/RL:	mg/L	RL	mg/L	RL		
Chloride		736	12.5	320	5.00		
Sulfate		166	12.5	168	5.00		
Metals per ICP by SW846 6010B	*Extracted:*						
	Analyzed:	Jun-23-08 11:59		Jun-23-08 11:59			
	Units/RL:	mg/L	RL	mg/L	RL		
Calcium		106	0.100	136	0.100		
Magnesium		24.5	0.010	23.3	0.010		
Potassium		2.44	0.500	2.33	0.500		
[illegible]dium		345	0.500	90.3	0.500		
TDS by SM2540C	*Extracted:*						
	Analyzed:	Jun-23-08 16:30		Jun-23-08 16:30			
	Units/RL:	mg/L	RL	mg/L	RL		
Total dissolved solids		1560	5.00	976	5.00		

Brent Barron
Odessa Laboratory Director

Flagging Criteria

X In our quality control review of the data a QC deficiency was observed and flagged as noted. MS/MSD recoveries were found to be outside of the laboratory control limits due to possible matrix /chemical interference, or a concentration of target analyte high enough to effect the recovery of the spike concentration. This condition could also effect the relative percent difference in the MS/MSD.

B A target analyte or common laboratory contaminant was identified in the method blank. Its presence indicates possible field or laboratory contamination.

D The sample(s) were diluted due to targets detected over the highest point of the calibration curve, or due to matrix interference. Dilution factors are included in the final results. The result is from a diluted sample.

E The data exceeds the upper calibration limit; therefore, the concentration is reported as estimated.

F RPD exceeded lab control limits.

J The target analyte was positively identified below the MQL(PQL) and above the SQL(MDL).

U Analyte was not detected.

L The LCS data for this analytical batch was reported below the laboratory control limits for this analyte. The department supervisor and QA Director reviewed data. The samples were either reanalyzed or flagged as estimated concentrations.

H The LCS data for this analytical batch was reported above the laboratory control limits. Supporting QC Data were reviewed by the Department Supervisor and QA Director. Data were determined to be valid for reporting.

K Sample analyzed outside of recommended hold time.

* Outside XENCO'S scope of NELAC Accreditation

XENCO Laboratories

Blank Spike Recovery

Project Name: Pride Energy Company

Work Order #: 306333 **Project ID:** South Four Lakes # 13

Lab Batch #: 726566 **Sample:** 726566-1-BKS **Matrix:** Water
Date Analyzed: 06/26/2008 **Date Prepared:** 06/26/2008 **Analyst:** WRU
Reporting Units: mg/L **Batch #:** 1

		BLANK /BLANK SPIKE RECOVERY STUDY				
Alkalinity by SM2320B **Analytes**	**Blank Result [A]**	**Spike Added [B]**	**Blank Spike Result [C]**	**Blank Spike %R [D]**	**Control Limits %R**	**Flags**
Alkalinity, Bicarbonate (as CaCO3)	ND	200	176	88	80-120	

Lab Batch #: 726337 **Sample:** 726337-1-BKS **Matrix:** Water
Date Analyzed: 06/23/2008 **Date Prepared:** 06/23/2008 **Analyst:** LATCOR
Reporting Units: mg/L **Batch #:** 1

		BLANK /BLANK SPIKE RECOVERY STUDY				
Inorganic Anions by EPA 300 **Analytes**	**Blank Result [A]**	**Spike Added [B]**	**Blank Spike Result [C]**	**Blank Spike %R [D]**	**Control Limits %R**	**Flags**
Chloride	ND	10.0	11.6	116	80-120	
Sulfate	ND	10.0	12.0	120	80-120	

Blank Spike Recovery [D] = 100*[C]/[B]
All results are based on MDL and validated for QC purposes.

Form 3 - MS Recoveries

Project Name: Pride Energy Company

Work Order #: 306333
Lab Batch #: 726337
Date Analyzed: 06/23/2008
QC- Sample ID: 306329-001 S
Reporting Units: mg/L

Date Prepared: 06/23/2008
Batch #: 1

Project ID: South Four Lakes # 13
Analyst: LATCOR
Matrix: Water

Inorganic Anions by EPA 300	MATRIX / MATRIX SPIKE RECOVERY STUDY					
Analytes	Parent Sample Result [A]	Spike Added [B]	Spiked Sample Result [C]	%R [D]	Control Limits %R	Flag
Chloride	2600	500	3270	134	80-120	X
Sulfate	477	500	1080	121	80-120	X

Matrix Spike Percent Recovery [D] = 100*(C-A)/B
Relative Percent Difference [E] = 200*(C-A)/(C+B)
All Results are based on MDL and Validated for QC Purposes

Sample Duplicate Recovery

Project Name: Pride Energy Company

Work Order #: 306333

Lab Batch #: 726566
Project ID: South Four Lakes # 13
Date Analyzed: 06/26/2008
Date Prepared: 06/26/2008
Analyst: WRU
QC- Sample ID: 306329-001 D
Batch #: 1
Matrix: Water
Reporting Units: mg/L

Alkalinity by SM2320B	SAMPLE / SAMPLE DUPLICATE RECOVERY				
Analyte	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Alkalinity, Bicarbonate (as CaCO3)	190	180	20	20	
Alkalinity, Carbonate (as CaCO3)	ND	ND	20	20	
Alkalinity, Total (as CaCO3)	190	180	20	20	

Lab Batch #: 726337
Date Analyzed: 06/23/2008
Date Prepared: 06/23/2008
Analyst: LATCOR
QC- Sample ID: 306329-001 D
Batch #: 1
Matrix: Water
Reporting Units: mg/L

Inorganic Anions by EPA 300	SAMPLE / SAMPLE DUPLICATE RECOVERY				
Analyte	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Chloride	2600	2590	20	20	
Sulfate	477	463	20	20	

Lab Batch #: 726094
Date Analyzed: 06/23/2008
Date Prepared: 06/23/2008
Analyst: LATCOR
QC- Sample ID: 306329-001 D
Batch #: 1
Matrix: Water
Reporting Units: mg/L

Metals per ICP by SW846 6010B	SAMPLE / SAMPLE DUPLICATE RECOVERY				
Analyte	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Calcium	ND	603	NC	25	
Magnesium	120	116	3	25	
Potassium	4.41	4.85	10	25	
Sodium	564	575	2	25	
Fluoride	ND	ND	NC	20	

Lab Batch #: 726342
Date Analyzed: 06/23/2008
Date Prepared: 06/23/2008
Analyst: WRU
QC- Sample ID: 306329-001 D
Batch #: 1
Matrix: Water
Reporting Units: mg/L

TDS by SM2540C	SAMPLE / SAMPLE DUPLICATE RECOVERY				
Analyte	Parent Sample Result [A]	Sample Duplicate Result [B]	RPD	Control Limits %RPD	Flag
Total dissolved solids	5700	5580	2	30	

Spike Relative Difference RPD 200 * | (B-A)/(B+A) |
All Results are based on MDL and validated for QC purposes.

XENCO Laboratories / Environmental Lab of Texas

12600 West I-20 East
Odessa, Texas 79765

Phone: 432-563-1800
Fax: 432-563-1713

CHAIN OF CUSTODY RECORD AND ANALYSIS REQUEST

Company Name: Pride Energy Company
Direct Invoice To: Matt Pride
Billing Address: P. O. Box 710950
City, State, Zip Code: Tulsa, OK 74170-1950
Telephone No: 918-524-9200
Fax No: 918-524-9292
Email Report to: mattp@pride-energy.com

Company Name: Trident Environmental
Project Manager: Gil Van Deventer
Address: P. O. Box 7624
City, State, Zip Code: Midland TX 79708-7624
Telephone No: 432-638-8740
Fax No: 413-403-9968
Email Report to: gil@trident-environmental.com

Project Name: Pride Energy Company
Project #: South Four Lakes # 13
Project Location: T12S-R34E, Section 1, Unit Letter L
COC #:

Sampler: Rozanne Johnson (575) 631-9310 rozanne@valornet.com
Printed
Signature

Analyze For: TCLP: TOTAL:

					Preservative							Matrix				Analyze For																
306333 LAB # (lab use only)	FIELD CODE	Date Sampled	Time Sampled	No. of Containers	Ice	HNO_3	HCl BTEX only)	NaOH	H_2SO_4	None	Other (Specify)	Water	Sludge	Soil	Other (specify):	TPH: 418.1 8015M 1005 1006	Cations (Ca, Mg, Na, K, F)	Anions (Cl, SO4, CO3, HCO3)	SAR / ESP / CEC	Metals: As Ag Ba Cd Cr Pb Hg Se	Volatiles	Semivolatiles	BTEXN 8021B/5030 or BTEXN 8260	RCI	N.O.R.M.	Total Dissolved Solids (160.1)	SPLP 1312	Chloride	Total Fe and Mn	RUSH TAT (Pre-Schedule)	Standard TAT	
-01	MW-1	06/19/08	14:15	1	X							X					X	X								X		X				
-02	MW-2	06/19/08	13:20	1	X							X					X	X								X		X				

Special Instructions:

Email results to: gil@trident-environmental.com, mattp@pride-energy.com, rozanne@valornet.com

Relinquished by: Rozanne Johnson	Date 6/20/08	Time 17:00	Received by:	Date	Time
Relinquished by:	Date	Time	Received by ELOT: Andrea Lam	Date 6.20.08	Time 17:00

Sample Containers Intact? [✓ Y] N
Temperature Upon Receipt:
Laboratory Comments:
1 L poly
5.0 w/labels & seals

Environmental Lab of Texas

Variance/ Corrective Action Report- Sample Log-In

Client: Pride Energy

Date/ Time: 6.20.08 17:00

Lab ID # : 306333

Initials: aL

Sample Receipt Checklist

				Client Initials
#1 Temperature of container/ cooler?	[✓ Yes]	No	5.0 °C	
#2 Shipping container in good condition?	[✓ Yes]	No		
#3 Custody Seals intact on shipping container/ cooler?	Yes	No	[✓ Not Present]	
#4 Custody Seals intact on sample bottles/ container?	[✓ Yes]	No	Not Present	
#5 Chain of Custody present?	[✓ Yes]	No		
#6 Sample instructions complete of Chain of Custody?	[✓ Yes]	No		
#7 Chain of Custody signed when relinquished/ received?	[✓ Yes]	No		
#8 Chain of Custody agrees with sample label(s)?	[✓ Yes]	No	ID written on Cont./ Lid	
#9 Container label(s) legible and intact?	[✓ Yes]	No	Not Applicable	
#10 Sample matrix/ properties agree with Chain of Custody?	[✓ Yes]	No		
#11 Containers supplied by ELOT?	[✓ Yes]	No		
#12 Samples in proper container/ bottle?	[✓ Yes]	No	See Below	
#13 Samples properly preserved?	[✓ Yes]	No	See Below	
#14 Sample bottles intact?	[✓ Yes]	No		
#15 Preservations documented on Chain of Custody?	[✓ Yes]	No		
#16 Containers documented on Chain of Custody?	[✓ Yes]	No		
#17 Sufficient sample amount for indicated test(s)?	[✓ Yes]	No	See Below	
#18 All samples received within sufficient hold time?	[✓ Yes]	No	See Below	
#19 Subcontract of sample(s)?	Yes	No	[✓ Not Applicable]	
#20 VOC samples have zero headspace?	Yes	No	[✓ Not Applicable]	

Variance Documentation

Contact: ______ Contacted by: ______ Date/ Time: ______

Regarding: ______

Corrective Action Taken:

Check all that Apply:
- ☐ See attached e-mail/ fax
- ☐ Client understands and would like to proceed with analysis
- ☐ Cooling process had begun shortly after sampling event

CARDINAL LABORATORIES

PHONE (575) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

ANALYTICAL RESULTS FOR
TRIDENT ENVIRONMENTAL
ATTN: GIL VAN DEVENTER
P.O. BOX 7624
MIDLAND, TEXAS 79708-7624
FAX TO: (413) 403-9968

Receiving Date: 09/11/08
Reporting Date: 09/15/08
Project Number: SOUTH FOUR LAKES #13
Project Name: PRIDE ENERGY COMPANY
Project Location: T12S-R34E-SEC1 UNIT LETTER L
LEA CO., NM

Sampling Date: 09/09/08
Sample Type: WATER
Sample Condition: COOL & INTACT
Sample Received By: ML
Analyzed By: HM/TR

LAB NUMBE SAMPLE ID	Na (mg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Conductivity (uS/cm)	T-Alkalinity ($mgCaCO_3/L$)
ANALYSIS DATE:	09/15/08	09/15/08	09/15/08	09/15/08	09/12/08	09/12/08
H15911-1 MW-1	445	128	31.6	22.4	2,750	180
H15911-2 MW-2	93	106	21.4	2.6	1,020	172
Quality Control	NR	48.1	46.2	3.06	1,406	NR
True Value QC	NR	50.0	50.0	3.00	1,413	NR
% Recovery	NR	96.2	92.4	102.0	99.5	NR
Relative Percent Difference	NR	<0.1	9.9	0.3	0.6	NR
METHODS:		SM3500-Ca-D	3500-Mg E	8049	120.1	310.1

	Cl (mg/L)	SO_4 (mg/L)	CO_3 (mg/L)	HCO_3 (mg/L)	pH (s.u.)	TDS (mg/L)
ANALYSIS DATE:	09/12/08	09/12/08	09/12/08	09/12/08	09/12/08	09/15/08
H15911-1 MW-1	760	187	0	220	7.42	1,790
H15911-2 MW-2	172	138	0	210	7.47	848
Quality Control	490	43.3	NR	976	7.00	NR
True Value QC	500	40.0	NR	1000	7.00	NR
% Recovery	98.0	108	NR	97.6	100	NR
Relative Percent Difference	< 0.1	1.6	NR	1.2	<0.1	NR
METHODS:	SM4500-Cl-B	375.4	310.1	310.1	150.1	160.1

Chemist

09-16-08
Date

H15911 TRIDENT

CARDINAL LABORATORIES

PHONE (575) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

ANALYTICAL RESULTS FOR
TRIDENT ENVIRONMENTAL
ATTN: GIL VAN DEVENTER
P.O.BOX 7624
MIDLAND, TX 79708-7624
FAX TO: (413) 403-9968

Receiving Date: 09/11/08
Reporting Date: 09/15/08
Project Number: SOUTH FOUR LAKES #13
Project Name: PRIDE ENERGY COMPANY
Project Location: T12S-R34E-SEC1 UNIT LETTER L
LEA CO., NM

Sampling Date: 09/09/08
Sample Type: WATER
Sample Condition: COOL & INTACT
Sample Received By: ML
Analyzed By: ZL

LAB NUMBER	SAMPLE ID	BENZENE (mg/L)	TOLUENE (mg/L)	ETHYL BENZENE (mg/L)	TOTAL XYLENES (mg/L)
ANALYSIS DATE		09/12/08	09/12/08	09/12/08	09/12/08
H15911-1	MW-1	<0.001	<0.001	<0.001	<0.003
H15911-2	MW-2	<0.001	<0.001	<0.001	<0.003
Quality Control		0.053	0.045	0.047	0.151
True Value QC		0.050	0.050	0.050	0.150
% Recovery		106	90.0	94.0	101
Relative Percent Difference		1.0	4.3	4.0	2.6

METHOD: EPA SW-846 8021B

TEXAS NELAP CERTIFICATION T104704398-08-TX FOR BENZENE, TOLUENE, ETHYL BENZENE, AND TOTAL XYLENES.

Chemist

09/15/08
Date

H15911WB.TRIDENT

Page 1 of 1

101 East Marland - Hobbs, New Mexico 88240
Tel (575) 393-2326
Fax (575) 393-2478

Cardinal Laboratories, Inc.

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

LAB Order ID # ____________

Company Name: Trident Environmental

Project Manager: Gil Van Deventer / Trident Environmental

Address: (Street, City, Zip) P. O. Box 7624 ~ Midland, Texas 79708-7624

Phone #: (432) 638-8740

Fax #: (413) 403-9968

Project #: South Four Lakes #13

Project Location: T12S-R34E-Sec1 Unit Letter L ~ Lea County - New Mexico

BILL TO Company: Pride Energy Company / Matt Pride

PO#

Address: (Street, City, Zip) P. O. Box 710950 ~ Tulsa, OK 74170-1950

Phone#: (918) 524-9200

Fax#: (918) 524-9292

Project Name: Pride Energy Company

Sampler Signature: Rozanne Johnson (575)631-9310 rozanne@valornet.com

ANALYSIS REQUEST
(Circle or Specify Method No.)

				MATRIX					PRESERVATIVE METHOD						SAMPLING																						
LAB # (LAB USE ONLY)	FIELD CODE	(G)rab or (C)omp	# CONTAINERS	WATER	SOIL	AIR	SLUDGE		HCL (2 40ml VOA)	HNO_3	$NaHSO_4$	H_2SO_4	ICE (1-1Liter HDPE)	NONE	DATE (2008)	TIME	MTBE 8021B/602	BTEX 8021 B	TPH 418.1/TX1005 / TX1005 Extended (C35)	PAH 8270C	Total Metals Ag As Ba Cd Cr Pb Se Hg 6010B/200.7	TCLP Metals Ag As Ba Cd Cr Pb Se Hg	TCLP Volatiles	TCLP Semi Volatiles	TCLP Pesticides	RCI	GC/MS Vol. 8260B/624	GC/MS Semi. Vol. 8270C/625	PCB's 8082/608	Pesticides 8081A/608	BOD, TSS, pH	Moisture Content		Cations (Ca, Mg, Na, K)	Anions (Cl, SO4, CO3, HCO3)	Total Dissolved Solids (160.1 / SM2540C)	Chlorides (325.3 / SM4500 B)	Turn Around Time ~ 24 Hours
H15911-1	MW-1	G	3	X					2				1		9-9	14:20		X																X	X	X	X	
-2	MW-2	G	3	X					2				1		9-9	14:00		X																X	X	X	X	

Relinquished by: Rozanne Johnson Date: 9-11-2008 Time: 3:40

Received by: Date: 9/11/08 Time: 3:40

Relinquished by: Date: Time:

Received By: (Laboratory Staff) Date: Time:

Delivered By: (Circle One)
[✓ Sampler] - UPS - Bus - Other:

Sample Condition
Cool: Yes ☑ No ☐
Intact: Yes ☑ No ☐

CHECKED BY: (Initials)

Phone Results ☐ Yes ☐ No

Fax Results ☐ Yes ☐ No Additional Fax Number:

REMARKS:

Email Results to:
gil@trident-environmental.com
mattp@pride-energy.com
rozanne@valornet.com

WELL SAMPLING DATA FORM

CLIENT: Pride Energy Company
WELL ID: Monitor Well #1
SYSTEM: South Four Lakes #13
DATE: June 19, 2008
SITE LOCATION: T12S R34E Sec1 Unit L
SAMPLER: Rozanne Johnson

PURGING METHOD: ☐ Hand Bailed ☑ Pump, Type: Variable Controlled Purge Pump
SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other:

DISPOSAL METHOD OF PURGE WATER: ☐ On-site Drum ☐ Drums ☑ SWD Disposal Facility

TOTAL DEPTH OF WELL: 43.28 Feet
DEPTH TO WATER: 27.88 Feet
HEIGHT OF WATER COLUMN: 15.40 Feet
2 In. Well Diameter
WELL VOLUME: 2.5 Gal.
8 Gallons purged prior to sampling

TIME	TEMP. °C	COND. mS/cm	pH	PHYSICAL APPEARANCE AND REMARKS
14:00	21.7	2.12	7.42	Silt and Sand
14:04	20.8	2.60	7.41	Clear
14:07	20.6	2.69	7.39	
14:15				Samples Collected with Disposable Bailer
				Major Ions/TDS (1-1000ml Plastic)

COMMENTS: Equipment decontamination consists of gloves, Alconox, and Distilled Water Rinse.
Myron Model 6P instrument used to obtain pH, conductivity, and temperature measurements.
Delivered samples to Xenco Laboratories for Major Ions and TDS analysis.

WELL SAMPLING DATA FORM

CLIENT: Pride Energy Company
WELL ID: Monitor Well #2
SYSTEM: South Four Lakes #13
DATE: June 19, 2008
SITE LOCATION: T12S R34E Sec1 Unit L
SAMPLER: Rozanne Johnson

PURGING METHOD: ☐ Hand Bailed ☑ Pump, Type: Variable Controlled Purge Pump
SAMPLING METHOD: ☑ Disposable Bailer ☐ Direct from Discharge Hose ☐ Other:

DISPOSAL METHOD OF PURGE WATER: ☐ On-site Drum ☐ Drums ☑ SWD Disposal Facility

TOTAL DEPTH OF WELL: 42.10 Feet
DEPTH TO WATER: 27.54 Feet
HEIGHT OF WATER COLUMN: 14.56 Feet
2 In. Well Diameter
WELL VOLUME: 2.3 Gal.
8 Gallons purged prior to sampling

TIME	TEMP. °C	COND. mS/cm	pH	PHYSICAL APPEARANCE AND REMARKS
13:10	21.3	1.23	7.57	Silt and Sand
13:12	20.4	1.26	7.39	Clear
13:14	20.4	1.36	7.38	
13:20				Samples Collected with Disposable Bailer
				Major Ions/TDS (1-1000ml Plastic)

COMMENTS: Equipment decontamination consists of gloves, Alconox, and Distilled Water Rinse.

Myron Model 6P instrument used to obtain pH, conductivity, and temperature measurements.

Delivered samples to Xenco Laboratories for Major Ions and TDS analysis.

WELL SAMPLING DATA FORM

CLIENT: Pride Energy Company
WELL ID: MW- 1
SITE NAME: South Four Lakes #13
DATE: September 9, 2008
SITE LOCATION: T12S-R34E-Sec 1 Unit L
SAMPLER: Rozanne Johnson
LAT/LONG: N 33° 18' 19.9", W 103° 28' 11.9"

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

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 ☑ SWD Disposal Facility

TOTAL DEPTH OF WELL: 43.28 Feet
DEPTH TO WATER: 28.05 Feet
HEIGHT OF WATER COLUMN: 15.23 Feet
WELL DIAMETER: 2.0 Inch
7.5 Minimum gallons to purge 3 well volumes
8 Actual Gallons purged

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L		PHYSICAL APPEARANCE AND REMARKS
13:50	0						Begin purging
13:58	4	18.8	2.94	7.50			Silt and Sand
14:02	6	18.6	2.93	7.48			Clear
14:06	8	18.6	2.93	7.47			Clear
14:20							Samples Collected
							Major Ions (1-1000ml Plastic)
							BTEX 8021B (2-40 ml glass VOA)
0:16	:Total Time (hr:min)		8	:Total Vol (gal)		0.50	:Average Flow Rate (gal/min)

COMMENTS:

Myron Model 6P instrument used to obtain pH, conductivity and temperature measurements.

Delivered samples to Cardinal Laboratories Hobbs, New Mexico for analyses.

WELL SAMPLING DATA FORM

CLIENT: Pride Energy Company
WELL ID: MW- 2
SITE NAME: South Four Lakes #13
DATE: September 9, 2008
SITE LOCATION: T12S-R34E-Sec 1 Unit L
SAMPLER: Rozanne Johnson
LAT/LONG: N 33° 18' 19.9", W 103° 28' 11.9"

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

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

DESCRIBE EQUIPMENT DECONTAMINATION METHOD BEFORE SAMPLING THE WELL:

☑ Gloves ☑ Alconox ☑ Distilled Water Rins☐ Other:

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

TOTAL DEPTH OF WELL: 42.10 Feet
DEPTH TO WATER: 27.71 Feet
HEIGHT OF WATER COLUMN: 14.39 Feet
WELL DIAMETER: 2.0 Inch

7.0 Minimum gallons to purge 3 well volumes
8 Actual Gallons purged

TIME	VOLUME PURGED	TEMP. °C	COND. mS/cm	pH	DO mg/L		PHYSICAL APPEARANCE AND REMARKS
13:20	0						Begin purging
13:28	4	19.3	1.11	7.58			Silt and Sand
13:32	6	18.9	1.13	7.55			Clear
13:36	8	18.9	1.14	7.56			Clear
14:00							Samples Collected
							Major Ions (1-1000ml Plastic)
							BTEX 8021B (2-40 ml glass VOA)
0:16 :Total Time (hr:min)		8 :Total Vol (gal)			0.50 :Average Flow Rate (gal/min)		

COMMENTS:

Myron Model 6P instrument used to obtain pH, conductivity and temperature measurements.

Delivered samples to Cardinal Laboratories Hobbs, New Mexico for analyses.

APPENDIX C

Aquifer Test Analysis

AQUIFER TEST ANALYSIS

Hydraulic conductivity (K) is one of the most critical parameters used for any fate and transport modeling effort, and the various published values researched for Lea County, New Mexico, range widely over two orders of magnitude, from less than 2 ft/day to 200 ft/day. Therefore, an aquifer test at the nearby South Four Lakes Tank Battery site was performed on September 16-17, 2008, to determine a site-specific value for hydraulic conductivity.

Drawdown data was collected during pumping (time-drawdown) and after pumping (recovery) in recovery well RW-02d. In addition, drawdown and recovery data were collected in nearby monitoring wells (RW-1d, MW-7, MW-9, and MW-10). Pressure transducers (WinSitu Level TROLL® 700) with data logging capability and compensation for barometric pressure were used in RW-02d (pumping well), RW-1d (60 ft distant from pumping well), and MW-9 (72 ft distant from pumping well) to record the pumping and recovery drawdown data. In addition, periodic measurements were collected for the more distant observation wells, MW-10 (85 ft) and MW-7 (113 ft) to be used for the distance-drawdown evaluation method (Thiem).

The test began with adjusting the pump rate until a sustainable rate of 3.11 gallons per minute was chosen and continued for approximately 18 hours resulting in an average constant-rate of 3.01 gpm. After the cessation of pumping, recovery data was recorded for approximately 5 hours after which the depth to water approached pre-pumping levels.

Aquifer testing and analysis was performed by Trident Environmental with peer/technical review provided by R. T Hicks Consultants, Ltd. (Albuquerque, NM) and Balleau Groundwater (Albuquerque, NM). Various analytical methods were used to estimate values for hydraulic conductivity as shown in Table 1 below.

Table 1
Transmissivity and Hydraulic Conductivity Values Based on Aquifer Test Analysis

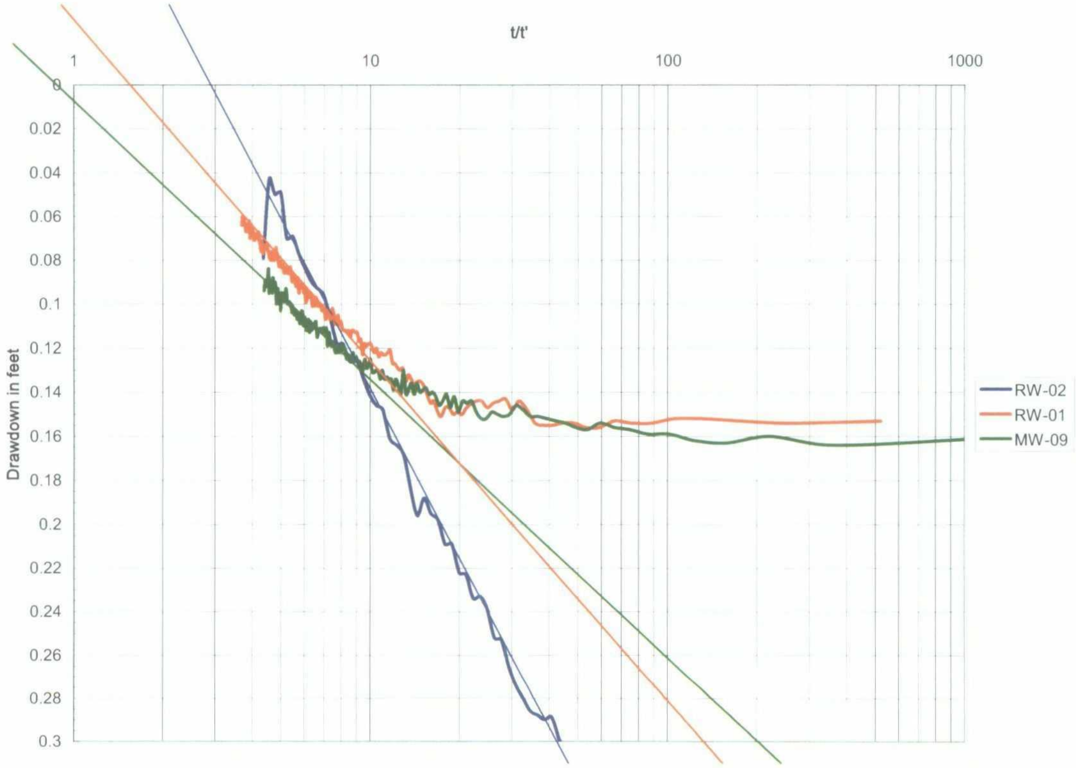
T (ft^2/d)	K (ft/d)	Analysis Method	Observation Well(s)	Program / Consultant
366	5.3	Theis Recovery	RW-02d	Excel/ Balleau Groundwater
664	9.5	Theis Recovery	RW-01d	Excel/ Balleau Groundwater
836	12.0	Theis Recovery	MW-09	Excel/ Balleau Groundwater
400	5.7	Jacob Recovery	RW-02d	USGS OFR 02-197 / Trident
450	6.4	Theis Pumping	RW-02d	Excel/ Balleau Groundwater
800	11.4	Theis Pumping	RW-01d	Excel/ Balleau Groundwater
800	11.4	Theis Pumping	MW-09	Excel/ Balleau Groundwater
801	11.4	Theis Pumping	RW-01d	AquiferWin32 / Trident
736	10.5	Theis Pumping	MW-09	AquiferWin32 / Trident
707	10.1	Neuman Pumping	RW-01d	AquiferWin32 / Trident
596	8.5	Neuman Pumping	MW-09	AquiferWin32 / Trident
728	10.4	Thiem Pumping	RW-01d, MW-9, MW-10, & MW-7	AquiferWin32 / Trident
700	10.0	Thiem Pumping	MW-9, MW-10, & MW-7	USGS OFR 02-197 / Trident

Graphical output of the results obtained from the methods listed above and a description of the technique utilized follow in the discussion below. Actual time and depth measurements for each measured well are attached as tab-delimited files.

Theis Recovery Analysis

Use of the pressure transducers made it possible to obtain many data points early on in the test (first few minutes) which was essential for subsequent analysis and interpretation of the recovery results. Data was recorded immediately after the water well pump was turned off to provide recovery drawdown data. Collection of data was terminated after the water table equilibrated to near static conditions; consequently the tests were of relatively short duration (about 5 hours).

In this Theis (1935) recovery analysis, as described in *Groundwater and Wells* (Fletcher Driscoll, Second Edition, pgs. 256-257), residual drawdown (s') was plotted versus the ratio of t/t' for the pumping well (RW-2d) and each observation well (RW-1d and MW-9). A line was then fitted through the late time data (close to the origin) as depicted below.



The resulting slope within one logarithmic cycle was used to compute transmissivity (T) based on the following equation:

$$T = \frac{264\ Q}{\Delta s' \text{ per log cycle } t/t'}$$

Hydraulic conductivity (K) values were then computed based on the transmissivity values and an estimated aquifer thickness (b) of 70 ft of a nearby fully-penetrating well (NMOSE Permit # L-3005) using the following equation:

$$K = T/b$$

The results of this Theis recovery analysis are summarized as follows:

Parameter (units)	Well ID		
	RW-2d	RW-1d	MW-09
s_min (ft)	0.005	0.123	0.135
s_max (ft)	0.295	0.283	0.262
Δs' (ft)	0.290	0.160	0.127
T (ft^2/day)	366	664	836
b (ft)	70	70	70
K (ft/day)	5.2	9.5	11.9

Jacob Straight-Line Method using Time-Drawdown Data from Pumping Well (RW-02d)

The Cooper-Jacob method (Cooper and Jacob, 1946), commonly referred to as the straight-line method, is a simplification of the Theis (1935) solution. The method may be used to analyze data from a single pumping well. The Jacob (1947) equation for predicting drawdown at the well is:

$$s = \frac{Q}{4\pi T} \ln \frac{2.25\,T\,t}{r_w^2\,S}$$

where,

T is aquifer transmissivity (L^2/T),
Q is the constant discharge rate (L^3/T),
S is the storage coefficient (L/L),
s is drawdown (L),
t is time (T), and
$\mathbf{r_w}$ is the well radius (L).

The same assumptions apply to the Cooper-Jacob analytical solution as the Theis solution, but the well function **W(u)** is calculated for **u** < 0.01 in order to neglect all but the first two terms of the infinite series of the well function in the Theis equation. A straight-line approximation of **W(u)** is adequate for most applications even where **u** is as great as 0.1. For the Cooper-Jacob straight-line method, drawdown is plotted with an arithmetic scale on the y-axis versus time plotted with a logarithmic scale on the x-axis. Transmissivity (**T**) is estimated from the pumping rate (**Q**) and the change in drawdown per log-cycle (Δ**s**) from the following equation:

$$T = \frac{2.3Q}{4\pi} \frac{1}{\Delta s}$$

where,

Δ**s** is change in drawdown per log-cycle (L).

Well losses and partial-penetration have a minimal effect on transmissivity values that are estimated using the Cooper-Jacob method. Well losses and partial penetration affect drawdowns by a fixed amount that changes very little after a well has been discharging for a while (minutes to hours after production begins). Additional drawdown at later times is due to declining heads in the aquifer and the rate of decline is controlled mostly by the transmissivity of the aquifer. Analyzing the change in drawdown at later times negates the effect of a fixed offset due to well losses and partial-penetration on the determination of transmissivity.

An Excel spreadsheet program (USGS Open-File 02-197, Keith Halford, 2002) was used to determine hydraulic conductivity values using the Cooper-Jacob analysis of the recovery data as described above. Results of the aquifer test analysis are shown on the following table and graph.

WELL ID: RW-02d (Recovery) Jacob Straight-Line Method

Site Name: South Four Lakes Tank Battery
Begin Time: 9/17/08 9:16 AM
End Time: 9/17/08 2:09 PM
Recovery Duration: 4:53 Hrs:Min

INPUT

Construction:	
Casing dia. (d_c)	4 Inch
Annulus dia. (d_w)	12 Inch
Screen Length (L)	5 Feet
Depths to:	
water level (DTW)	24.45 Feet
Top of Aquifer	24.45 Feet
Base of Well	94 Feet
Annular Fill:	
across screen --	Medium Sand
above screen --	Bentonite
Aquifer Material --	Fine Sand
FLOW RATE	3.01 GPM

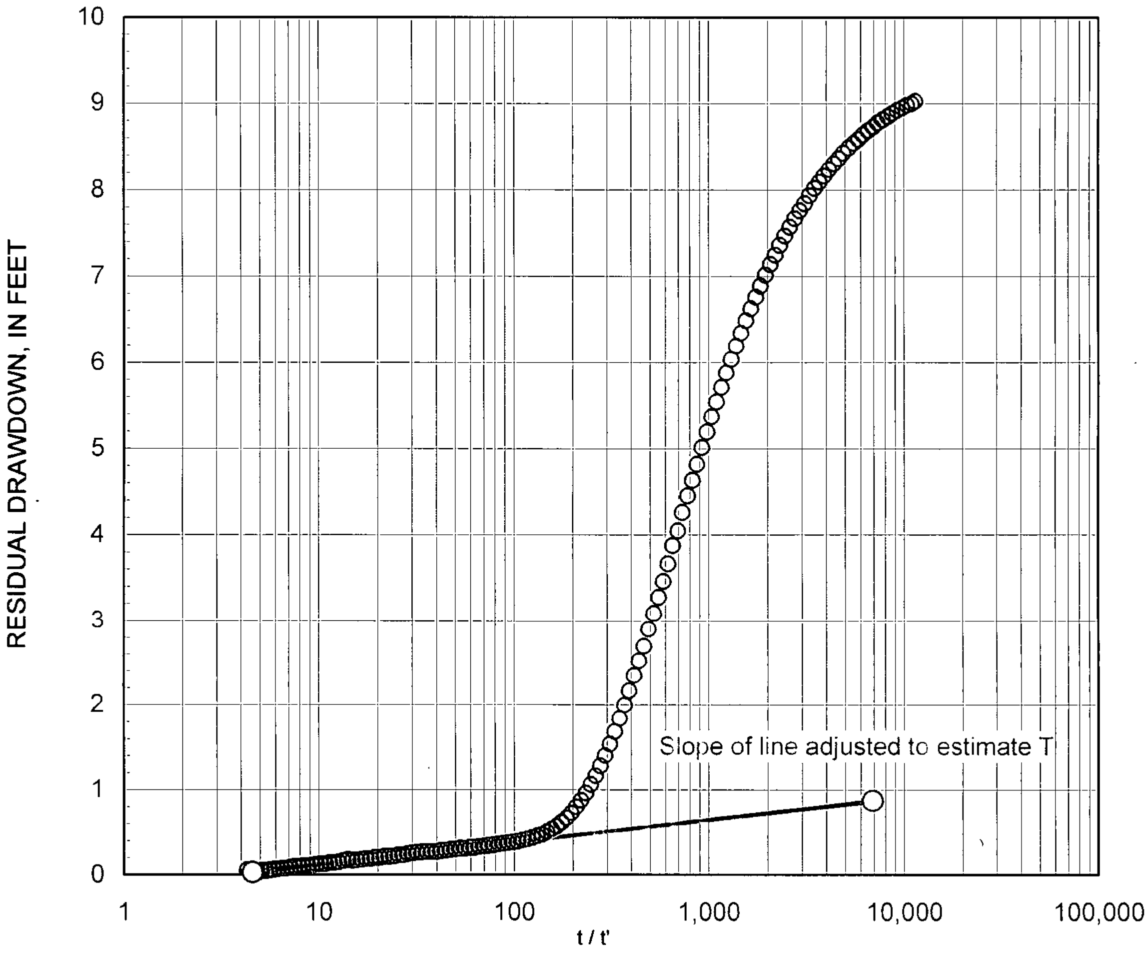
COMPUTED

Aquifer thickness = 70 Feet

Slope = 0.264234 Feet/log10

Input is consistent.

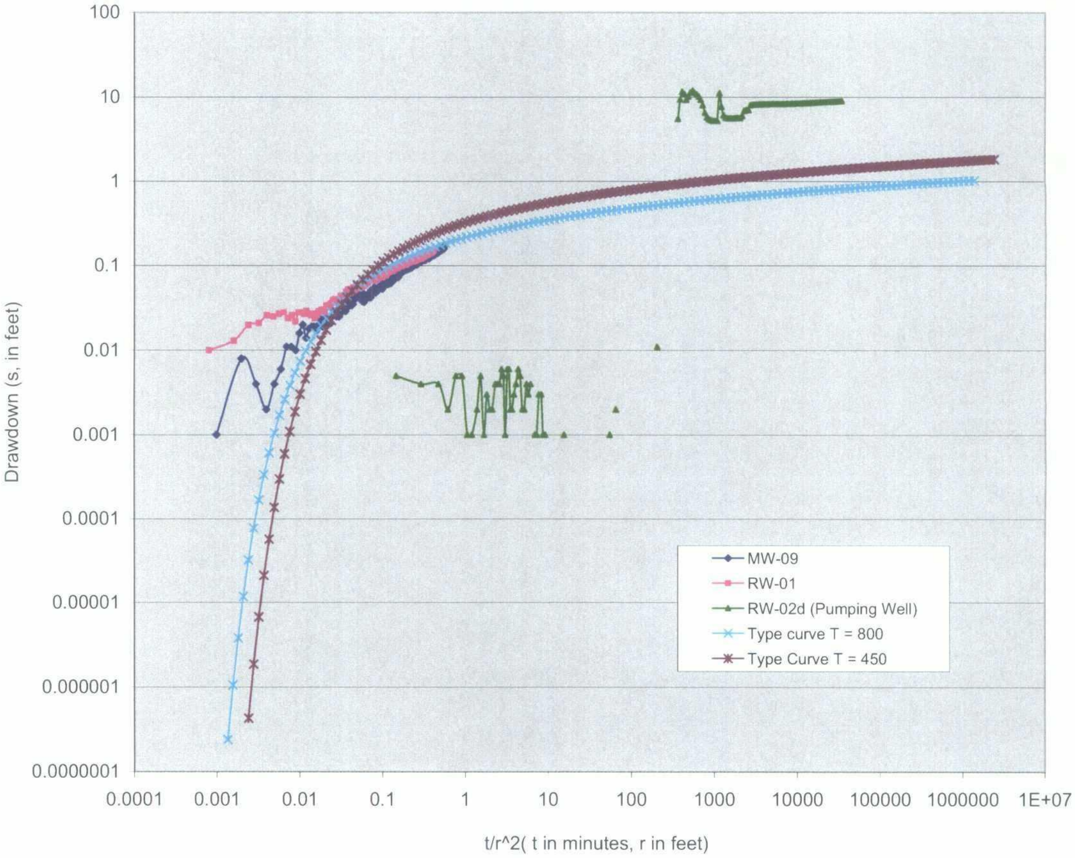
K = 5.8 Feet/Day
T = 400 Feet²/Day



The slope near the later time drawdown data provided the best estimation. Note that the time axis is plotted as t/t' so time increases from right to left. This is the preferred method to analyze recovery data from a pumping well. The Jacob straight-line method resulted in a transmissivity of 400 ft^2/d and a hydraulic conductivity of 5.8 ft/d.

Theis Pumping Analysis

The Theis solution was also used for the pumping portion of the aquifer test. R. T Hicks Consultants, Ltd with peer/technical support from Balleau Groundwater performed this analysis using in-house spreadsheets that were developed based on type-curve matching techniques. Below is graphical output of this analysis.

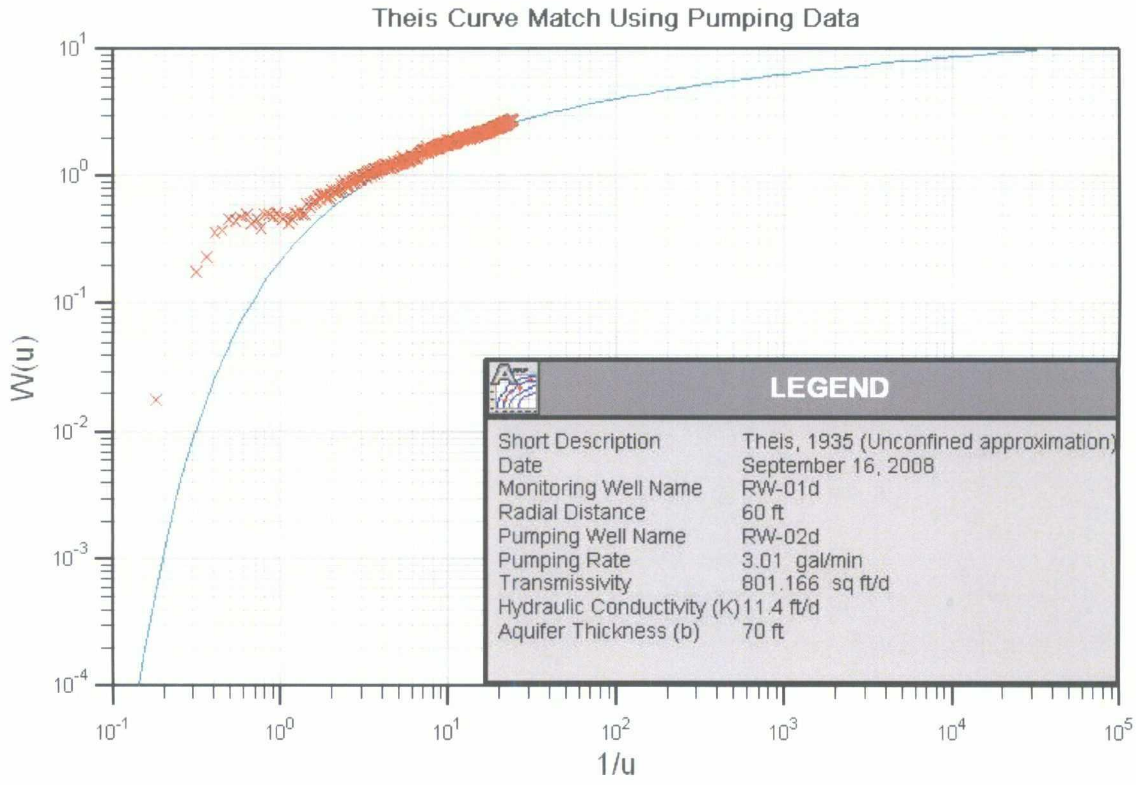


Two Theis type curves are plotted because transmissivity is quite different from the pumping well, RW-02d (about 450 ft^2/day) compared to the observation wells, MW-01d and MW-09 (800 ft^2/day). Basically, storativity (S), transmissivity (T), and the pump rate (Q) are altered to fit the pump test data to the type curves. Since Q is fixed (3.01 gpm) from the data and T is known from the recovery test, S is the estimated parameter. The results of this analysis are summarized as follows:

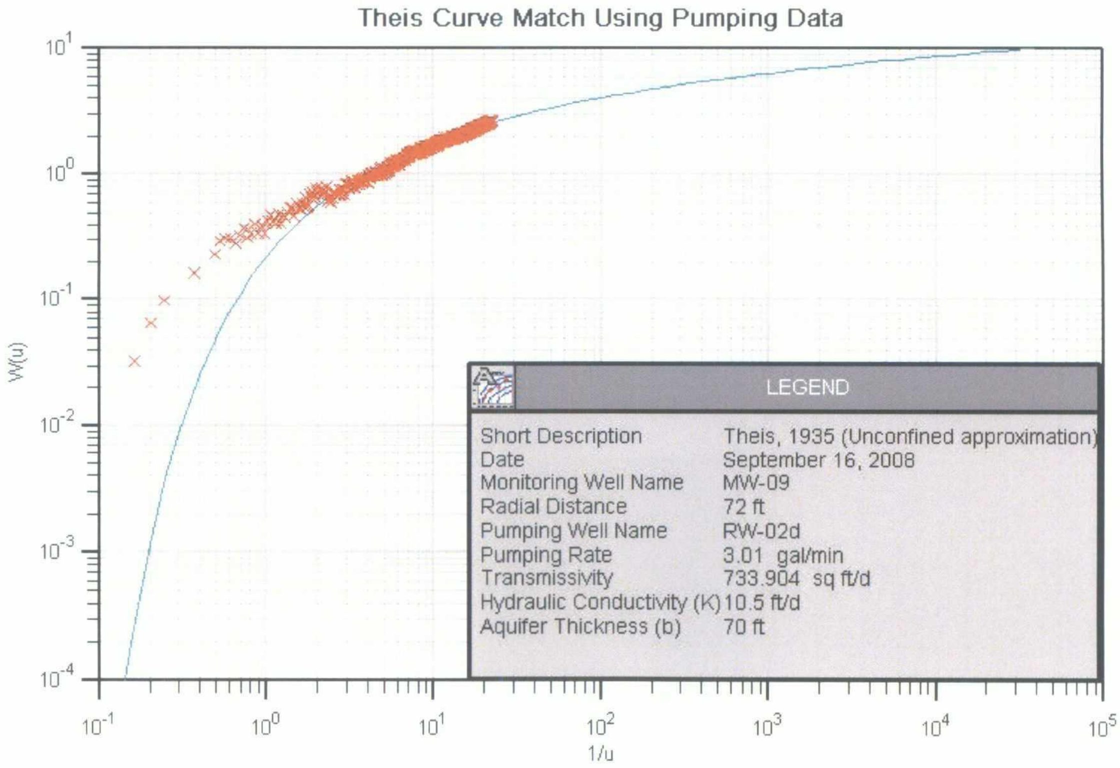
Parameter (units)	Well ID		
	RW-1d	MW-09	RW-02d
T (ft^2/day)	800	800	450
b (ft)	70	70	70
K (ft/d)	11.4	11.4	6.4
S	0.003	0.003	0.003

The observation wells give a pretty convincing value of 0.03 and therefore, there exists little reason to not use this for the pumping well, too. Wth a longer test, this value would likely grow to 0.1 to 0.15 reflecting pore water drainage. That the pumping well has more drawdown than the type curve is a measure of the inefficiency of the well.

The preceeding analysis was also performed for the observation wells (RW-01d and MW-09) by Trident Environmental using the AquiferWin32 aquifer analysis program as a benchmark to the Balleau method and resulted in comparable values. Graphical output is shown below.


Theis Curve Match Using Pumping Data

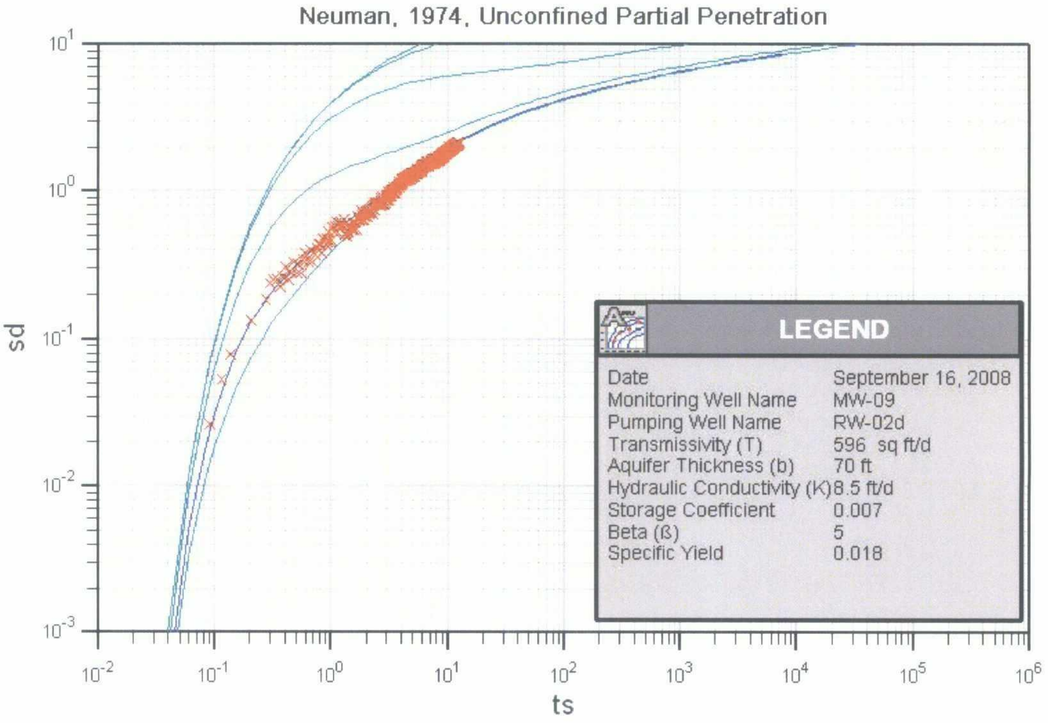
Short Description	Theis, 1935 (Unconfined approximation)
Date	September 16, 2008
Monitoring Well Name	RW-01d
Radial Distance	60 ft
Pumping Well Name	RW-02d
Pumping Rate	3.01 gal/min
Transmissivity	801.166 sq ft/d
Hydraulic Conductivity (K)	11.4 ft/d
Aquifer Thickness (b)	70 ft


Theis Curve Match Using Pumping Data

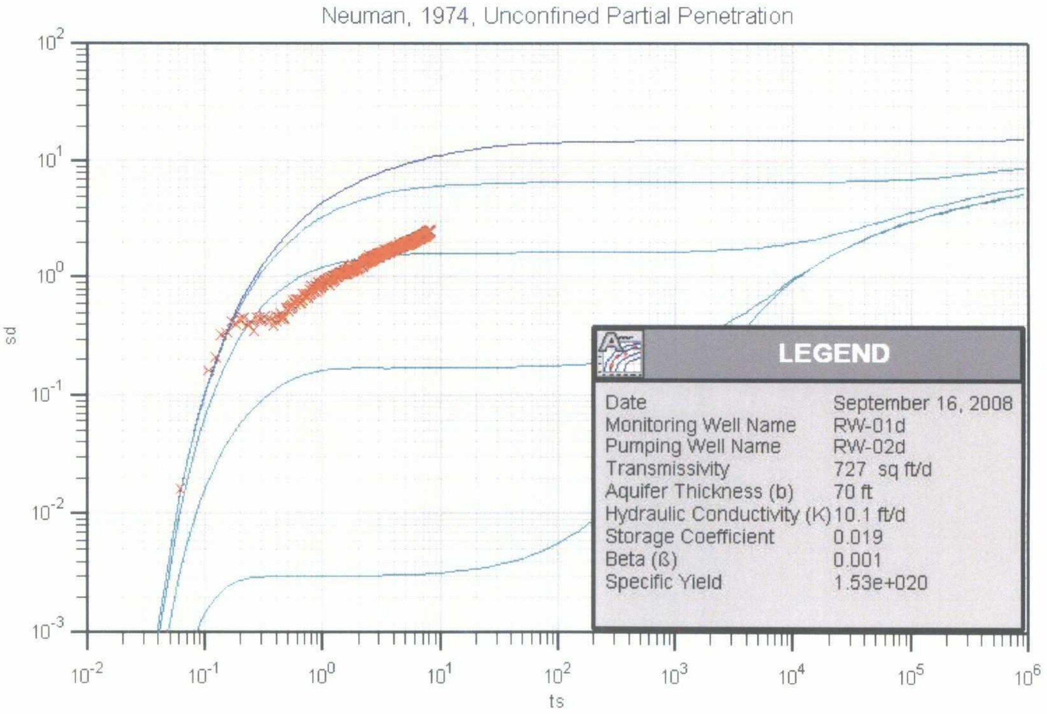
Short Description	Theis, 1935 (Unconfined approximation)
Date	September 16, 2008
Monitoring Well Name	MW-09
Radial Distance	72 ft
Pumping Well Name	RW-02d
Pumping Rate	3.01 gal/min
Transmissivity	733.904 sq ft/d
Hydraulic Conductivity (K)	10.5 ft/d
Aquifer Thickness (b)	70 ft

Neuman, 1974, Unconfined Partial Penetration Analysis

The AquiferWin32 aquifer analysis program was also used for the mathematical solution by Neuman (1974) for determining the transmissivity, hydraulic conductivity ,storage coefficient, and specific yield. The analysis involves matching the water-level displacement data during the pumping phase of the test with several type curves. The Neuman solution accounts for delayed gravity response and partial penetration of the well screen.


Neuman, 1974, Unconfined Partial Penetration

Date	September 16, 2008
Monitoring Well Name	MW-09
Pumping Well Name	RW-02d
Transmissivity (T)	596 sq ft/d
Aquifer Thickness (b)	70 ft
Hydraulic Conductivity (K)	8.5 ft/d
Storage Coefficient	0.007
Beta (ß)	5
Specific Yield	0.018


Neuman, 1974, Unconfined Partial Penetration

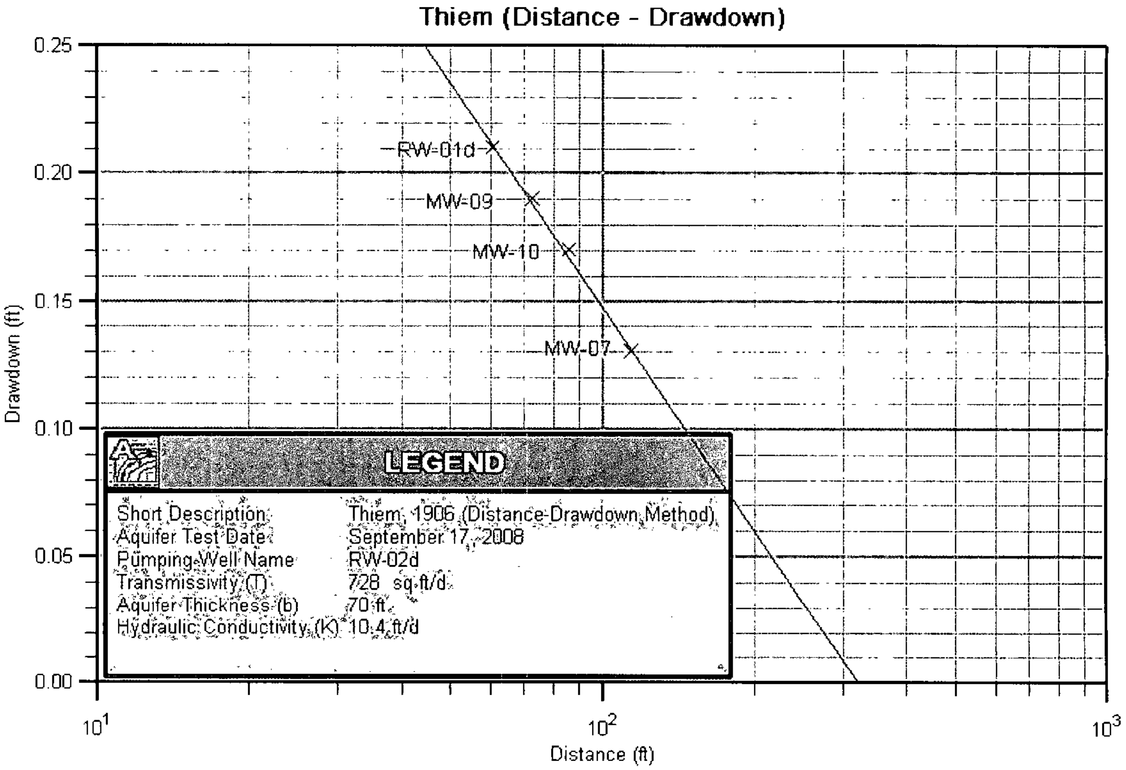
Date	September 16, 2008
Monitoring Well Name	RW-01d
Pumping Well Name	RW-02d
Transmissivity	727 sq ft/d
Aquifer Thickness (b)	70 ft
Hydraulic Conductivity (K)	10.1 ft/d
Storage Coefficient	0.019
Beta (ß)	0.001
Specific Yield	1.53e+020

Thiem Distant-Drawdown Analysis

The distance-drawdown method can be used for multi-well aquifer-test data once the drawdown has reached quasi-steady-state. A quasi-steady-state is reached after u is less than 0.01 at the well furthest from the pumping well. Most of the water released from storage originates beyond the wells that are being analyzed once quasi-steady-state conditions are established. Distance-drawdown is a simple graphical method (Weissman and others, 1977).

Transmissivity or hydraulic conductivity are estimated by fitting a straight line to water-level data at several log-radial distances from the production well. The hydraulic conductivity of unconfined aquifers is estimated by plotting saturated thickness squared versus log-radial distance.

Both the AquiferWin32 software program and spreadsheet program from USGS OFR 02-197 were used for this analysis with results as follows:



Short Description: Thiem, 1906 (Distance-Drawdown Method)
Aquifer Test Date: September 17, 2008
Pumping Well Name: RW-02d
Transmissivity (T): 728 sq ft/d
Aquifer Thickness (b): 70 ft
Hydraulic Conductivity (K): 10.4 ft/d

WELL	DISTANCE, Feet	DRAWDOWN IN, FEET
RW-2d	0.33	9.03
RW-1d	60.00	0.19
MW-9	72.00	0.19
MW-10	85.00	0.17
MW-7	113.00	0.13

PUMPING WELL ID: RW-2d

Local ID: South Four Lakes Tank Battery

Date: 09/16/08
Time: 16:00

INPUT

Construction:
Casing dia. (d_c) 4 Inch
Annulus dia. (d_w) 8 Inch
Screen Length (L) 5 Feet

Depths to:
Initial Depth to Water 24.45 Feet
Top of Aquifer 24.45 Feet
Base of Aquifer 94 Feet

Annular Fill:
across screen -- Medium Sand
above screen -- Bentonite
Aquifer Material -- Fine Sand

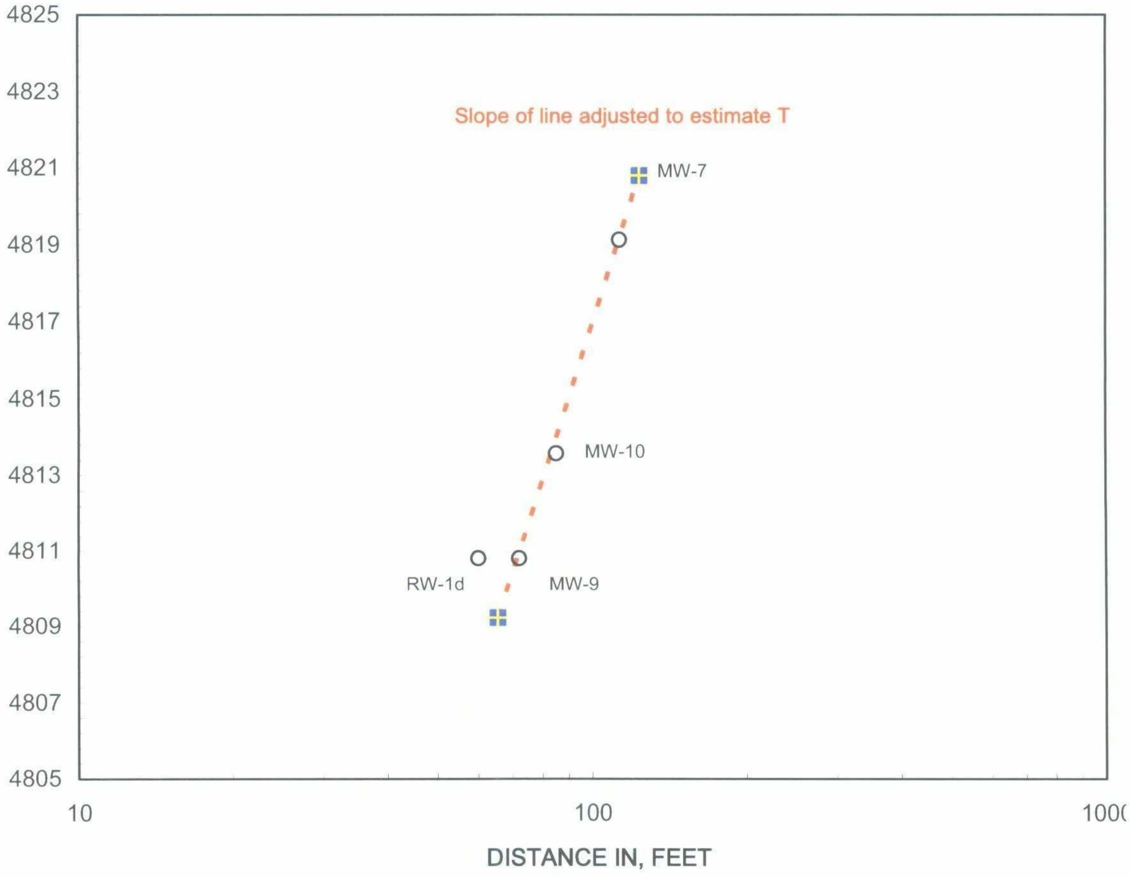
FLOW RATE 3.01 GPM

COMPUTED

Aquifer thickness = 70.0 Feet
Aquifer is: **UNCONFINED**
Slope = 41.92029 Feet²/log10

Input is consistent.

K = 10.0 Feet/Day
T = 700 Feet²/Day



REMARKS: Distance-Drawdown analysis of multi-well aquifer test

MW- 09, MW-10, and MW-07 give the most consistent linear fit for the sloped line.

References for methods used:

Cooper, H.H. and Jacob, C.E., 1946, A generalized graphical method for evaluating formation constants and summarizing well field history, American Geophysical Union Transactions, v. 27, 526–534.

D5920-96 Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method, ASTM, 8 p. (AquiferWin32).

D 4105 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method, ASTM, 5 p. (AquiferWin32).

Hantush, M.S. and Jacob, C.E., 1955, Non-steady flow in an infinite leaky aquifer: Transactions of the American Geophysical Union, vl. 36, 95–100.

Kruseman, G.P. and N.A. de Ridder, 1990, Analysis and Evaluation of Pumping Test Data, Second Edition, ILRI publication 47, International Institute for Land Reclamation and Improvement, The Netherlands, 377 p.

Neuman, S.P., 1974, Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response, Water Resources Research, vol. 10, pp 303-312.

APPENDIX D

Description of Fate and Transport Modeling

DESCRIPTION OF FATE AND TRANSPORT MODELING

Basic Site Data

The saturated thickness of the Ogallala Formation the site is estimated at approximately 90 ft based on driller logs for water wells permitted by the New Mexico Office of the State Engineer (OSE). The upper 25 feet of the aquifer was modeled in the fate and transport simulations based on a hard, near-impermeable quartzite/sandstone layer encountered at 50 ft bgs at the site. Assuming the center of chloride mass has traveled approximately 75 to 125 ft downgradient from the former drilling pit between February 29, 2004 (well spudding date) and the date of highest chloride concentrations observed in MW-1 (June 19, 2008) that would correspond to a linear velocity of ranging from 17 to 29 ft/yr. Inputting these estimates for linear velocity, porosity, and hydraulic gradient into Darcy's Law results in hydraulic conductivity values ranging from 6 to 10 ft/day which is consistent with the range of values (5.3 ft/d and 12.0 ft/d) determined from the aquifer testing (Appendix C).

Estimation of the Chloride Mass in Groundwater

First, a 27,400 ft^2 area of the chloride plume from this release was conservatively estimated based on the 100 mg/L isopleth surrounding the area of impact. The affected aquifer thickness was estimated to be 25 ft (depth to water table at 25 feet subtracted from depth to the quartzite/sandstone layer encountered at 50 ft bgs. The total area multiplied by the thickness of the aquifer and its porosity (0.25) results in a total saturated pore space volume of 4.849E+06 liters. Next, the average chloride concentration (716 mg/L) observed within the plume multiplied by the saturated pore space volume results in a chloride mass of 3,473 kg. Future monitoring results might dictate re-calculation by this method. These calculations are shown in the following table in the same order as described above.

Parameter Type	Value	Parameter Validation and Rationale
Area of Chloride Impact	27,400 ft^2	Area of Chloride Plume within 250 mg/L isopleth
Aquifer Thickness	25 ft	Depth to lower quartzite/sandstone layer (50 ft bgs) minus the depth to groundwater (25 ft bgs).
Porosity	0.25	Professional and conservative estimate for water saturated pore volume.
Volume of impacted ground water in cubic feet	171,250 ft^3	Simple multiplication of each parameter listed above
Volume of Impacted Groundwater in Liters	4.849E+06 L	Unit conversion of previous value to liters.
Chloride concentration	716 mg/L	Average chloride concentration observed within area of plume
Total chloride mass	**3,473 kg**	Simple multiplication of two parameters listed above and converted to units of kilograms.

Simulation Model

Simulations were conducted with the two-dimensional groundwater flow and contaminant transport model WinTran, version 3.28 (2008) 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.

Model Input Parameters

The following table lists the various parameters input into the fate and transport model simulations, followed by the rationale for their use in the model.

Parameter	Value	Source of Data
Hydraulic Conductivity (K)	6 and 10 ft/d	Aquifer tests (Appendix C)
Hydraulic Gradient (*dh/dl*)	0.002 ft/ft	Observed and measured at nearby site
Gradient Direction	315° (southeast)	Observed and measured at nearby site
Longitudinal Dispersivity ($\acute{\alpha}_l$)	18 ft, 23 ft, & 28 ft	10% of estimated plume length (2008)
Transverse Dispersivity ($\acute{\alpha}_t$)	1.8 to 5.6 ft	One-tenth and one-fifth of longitudinal
Porosity (θ)	0.25	Professional judgment
Base elevation of aquifer	4091 ft AMSL	Top of quartzite/sandstone at 50 ft bgs
Depth to groundwater	4116 ft AMSL	Observed and measured at 25 ft bgs
Saturated thickness	25 ft	Difference of the two parameters above
Model X Extent (100 nodes)	1000 ft (10 ft/node)	Professional judgment
Model Y Extent (100 nodes)	1000 ft (10 ft/node)	Professional judgment

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 0.002 feet/foot from site measurements at several sites in the South Four Lakes Unit during 2008.

- Direction of flow – Southeast (315°) based on site measurements at several sites in the South Four Lakes Unit during 2008.

- Hydraulic conductivity – Assuming the center of chloride mass has traveled approximately 75 to 125 ft downgradient from the former drilling pit between February 29, 2004 (well spudding date) and the date of highest chloride concentrations observed in MW-1 (June 19, 2008) that would correspond to a linear velocity of ranging from 17 to 29 ft/yr. Inputting these estimates for linear velocity, porosity, and hydraulic gradient into Darcy's Law results in hydraulic conductivity values ranging from 6 to 10 ft/day which is consistent with the range of values (5.3 ft/d and 12.0 ft/d) determined from the results of aquifer testing done at a nearby site (South Four Lakes Tank Battery) as described in Appendix C.

- Aquifer top and bottom elevations – bottom elevation of aquifer is estimated at 4,091 feet based on depth to quartzite/sandstone layer. The top elevation for an unconfined aquifer must be greater than the reference head. An elevation of 4142 feet (ground surface) was assumed.

- Reference head – measured unconfined head of 4116 feet adjacent to the former pit and upgradient well MW-1 from September 9, 2008 measurements.

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:

- Dispersivity - is a scale-dependent parameter which is generally larger as the scale of the contaminant plume increases. There are two values of dispersivity used in the WinTran transport model, longitudinal and transverse. Longitudinal dispersivity represents the spreading of the contaminant plume in the direction of groundwater flow. The transverse component represents spreading perpendicular to the flow direction. A typical rule of thumb is that the dispersivity is 10 percent of the length of the contaminant plume (National Research Council, 1990, and Fetter, *Applied Hydrogeology*, 2nd Edition, Section 10.6.5, p. 394). The length of the chloride plume is estimated at approximately 230 feet as measured from the northwest corner of the pit to monitoring well MW-2. Therefore, values of 18 ft, 23 ft, and 28 ft were selected for longitudinal dispersivity to allow for a variation in scenarios. According to the WinTran user's guide and professional judgment, longitudinal dispersivity is usually 5 to 10 times higher than transverse dispersivity; therefore, a value of one-tenth and one-fifth of the longitudinal values were selected for transverse dispersivity to allow for additional scenarios.

- 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, *Groundwater*, 1st Edition, 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 (*Applied Hydrogeology*, 2nd Edition, 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 (*Applied Hydrogeology*, 2nd Edition, 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. A conservative value of 9.3 E-04 ft^2/d was used; however this parameter has neglible effect to the other site parameters.

- 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 1.0 E-08 years was used, to produce a negligible decay coefficient of less than 0.0001 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 June 19, 2008, is simulated closely by the flow model. The average groundwater velocity may be estimated using the darcy expression: $v = (k . i) / n$ where *k* is the hydraulic conductivity (6 to 10 ft/day), *i* is the hydraulic gradient (0.002 ft/foot), and *n* is the effective porosity (0.25). The resultant average velocity is 17 to 29 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. WinTran does not account for vadose zone transport, so the source input was treated as an injection well with instantaneous transfer of contaminant mass to groundwater. This was accomplished by simulating source terms to the model (5 injection wells within the pit) and inputting a source chloride concentration of 100,000 mg/L (typical of brine used in oil well drilling) at a flow rate of approximately 5 gal/d, to match the total chloride mass of 3,473 kg estimated in the section above. The flow rate of each simulated injection well was apportioned in correlation to the chloride load at each of the five test points sampled in January 2008.

Simulation of Fate and Transport

The length of the simulation was chosen to approximate the length of time that the source of chlorides has been affecting the groundwater system (5 years) which resulted in a close match to the observed chloride plume in year 2008. Subsequent model simulations were performed under the assumption that the chloride source was eliminated with the implementation of the vadose zone remedy as proposed in section 6.1.

Inputting the aquifer test results into ten fate and transport model simulations resulted in the center of chloride mass in the plume attenuating to less than the WQCC standard of 250 mg/L after migrating between 434 ft to 925 ft southeast from the pit in 16 to 48 years. A summary of each simulation is listed below.

Summary of Fate & Transport Modeling Simulations

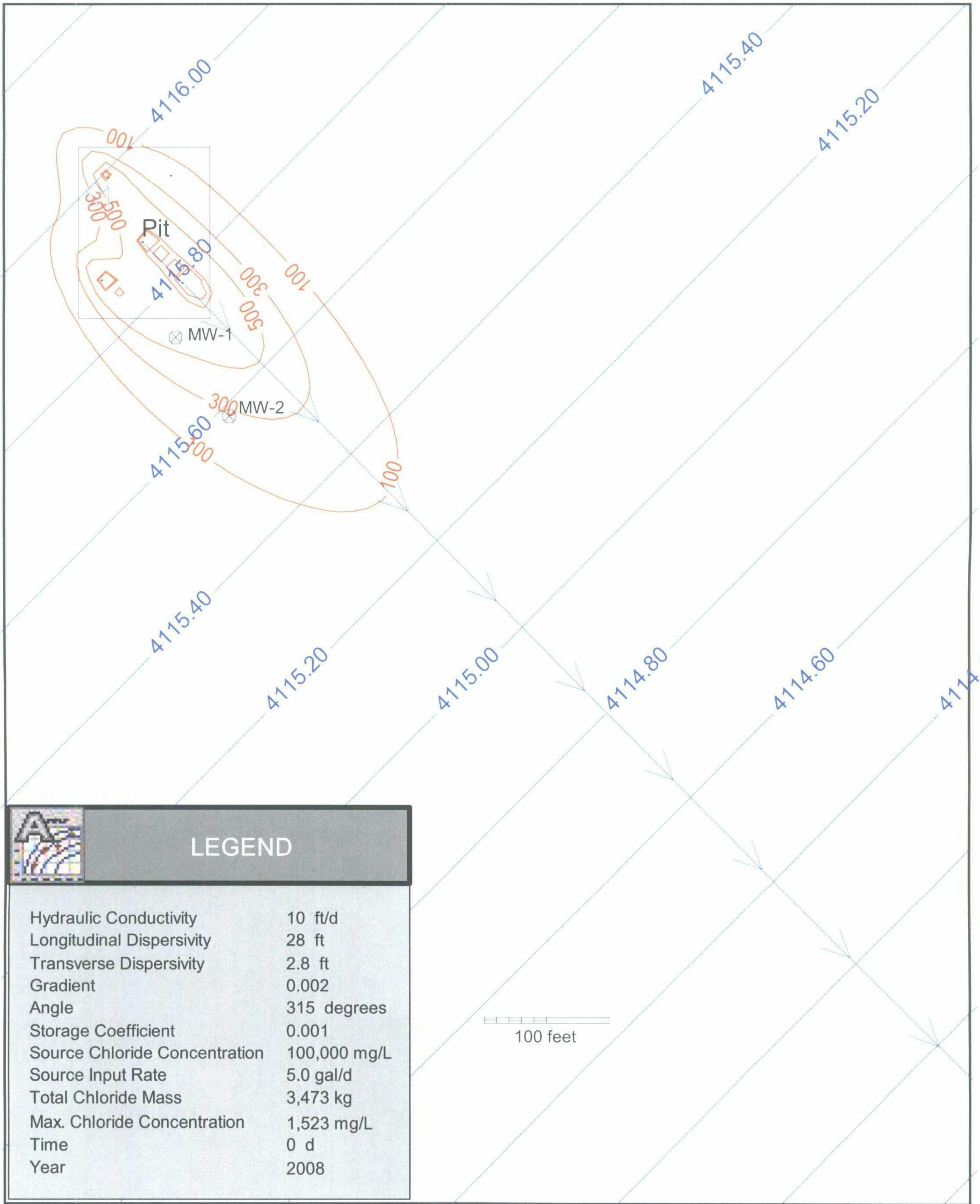
Simulation Number	Time (yrs)	K (ft/d)	Dispersivity (ft^2/d)		Distance (ft)	Velocity (ft/yr)	Max. Chloride in 2008 (mg/L)
			Longitudinal	Transverse			
1	16	10	28	2.8	535	33.5	1,523
2	19	10	18	3.6	621	32.7	1,731
3	20	10	23	2.3	663	33.1	1,665
4	22	6	28	5.6	434	19.7	2,195
5	26	10	18	1.8	837	32.2	1,846
6	28	6	23	4.6	535	19.1	2,427
7	31	6	28	2.8	600	19.3	2,371
8	36	6	18	3.6	700	17.7	2,730
9	38	6	23	2.3	742	19.5	2,610
10	48	6	18	1.8	925	18.3	2,917

Explanation:
Time (yrs): Time that it took for chloride concentrations to attenuate below 250 mg/L.
Distance (ft): Distance plume traveled until chloride concentrations attenuated below 250 mg/L.

Figures displaying modeled simulations of the chloride plumes as listed above and are included at the end of this Appendix D. 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. The trend of decreasing concentration is not linear (exponential e^{-kt} function). Thus, the fate and transport model simulations depict the center of the plume moving at a slightly greater rate (18.3 to 33.5 feet/year) over successive time intervals than would be assumed from the linear groundwater velocity based on Darcy's Law (17 to 29 feet/year), due to the added effect of dispersion.

Future monitoring will provide the necessary time-variant and spatial data to refine these estimates.

Chloride Plume Simulations

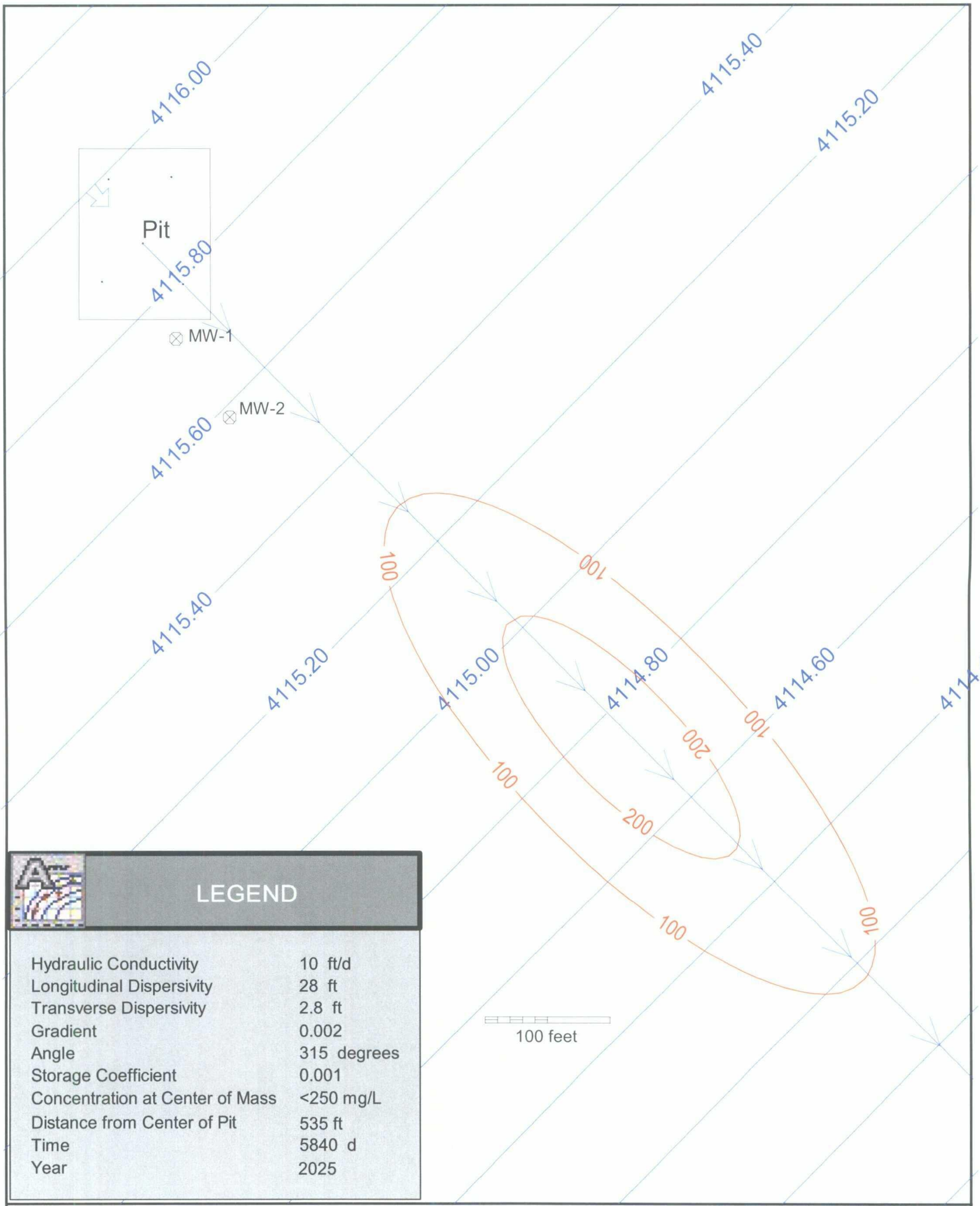


LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	2.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	1,523 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT
ENVIRONMENTAL

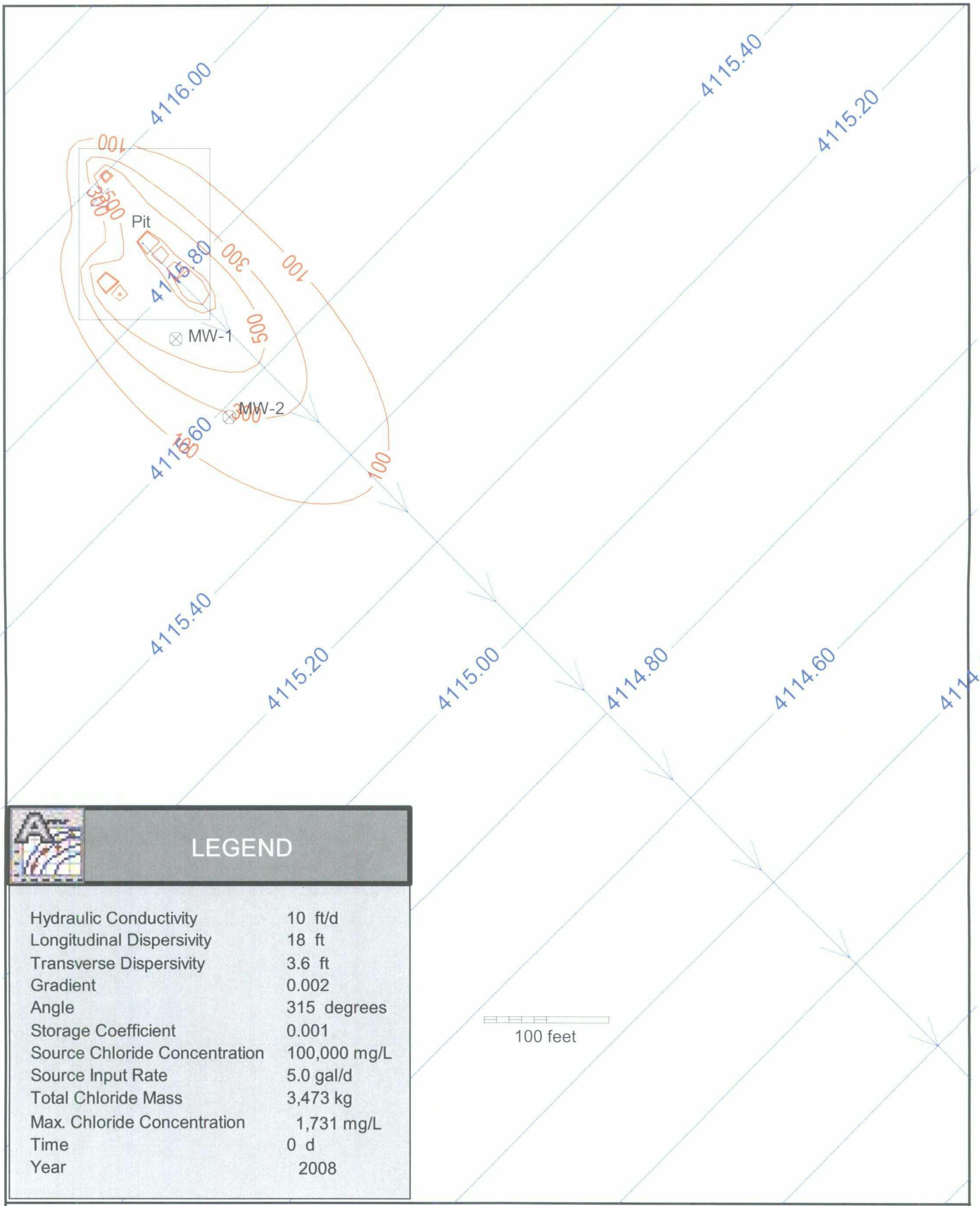


LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	2.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	535 ft
Time	5840 d
Year	2025

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT
ENVIRONMENTAL

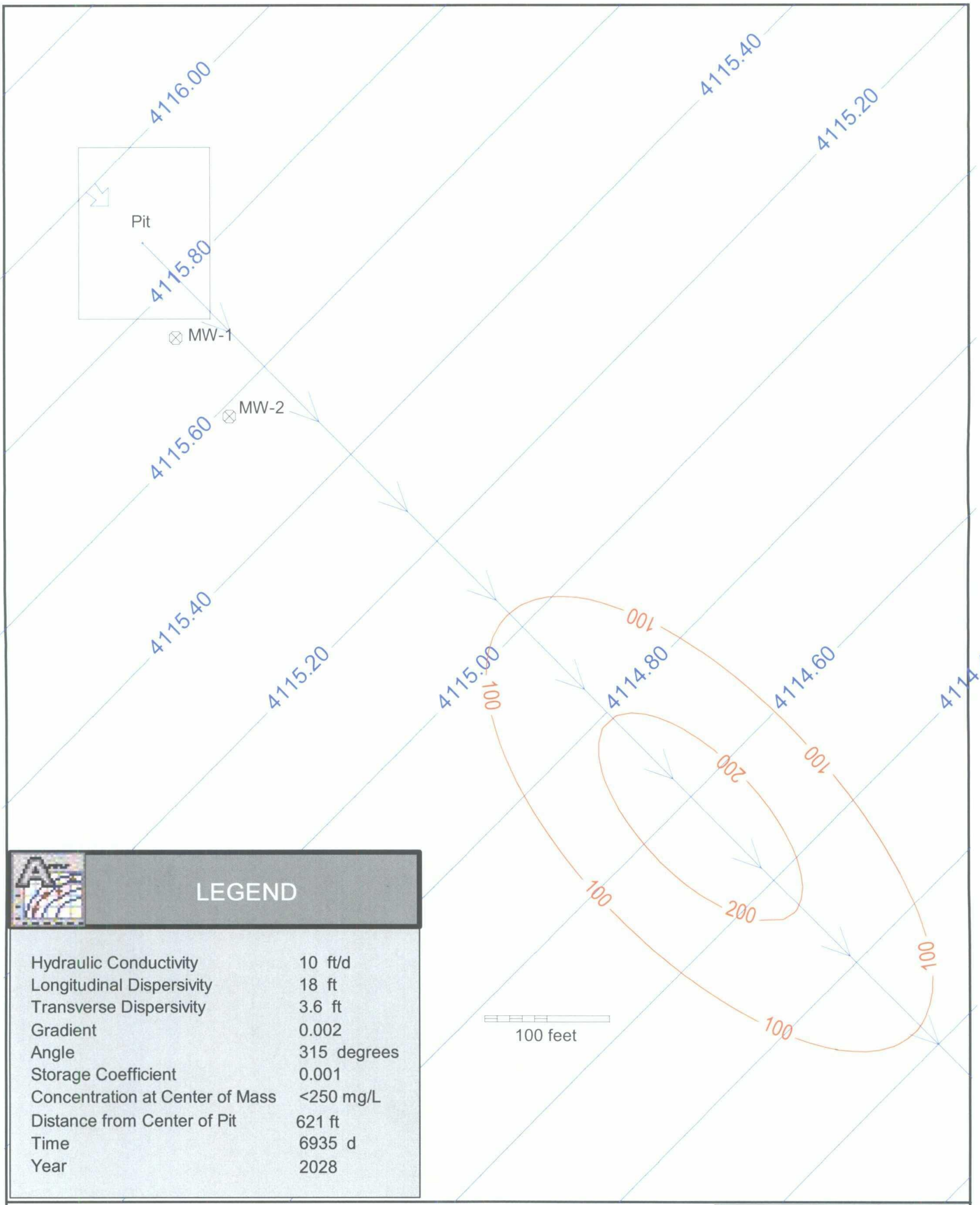


LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	3.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	1,731 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT
ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	3.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	621 ft
Time	6935 d
Year	2028

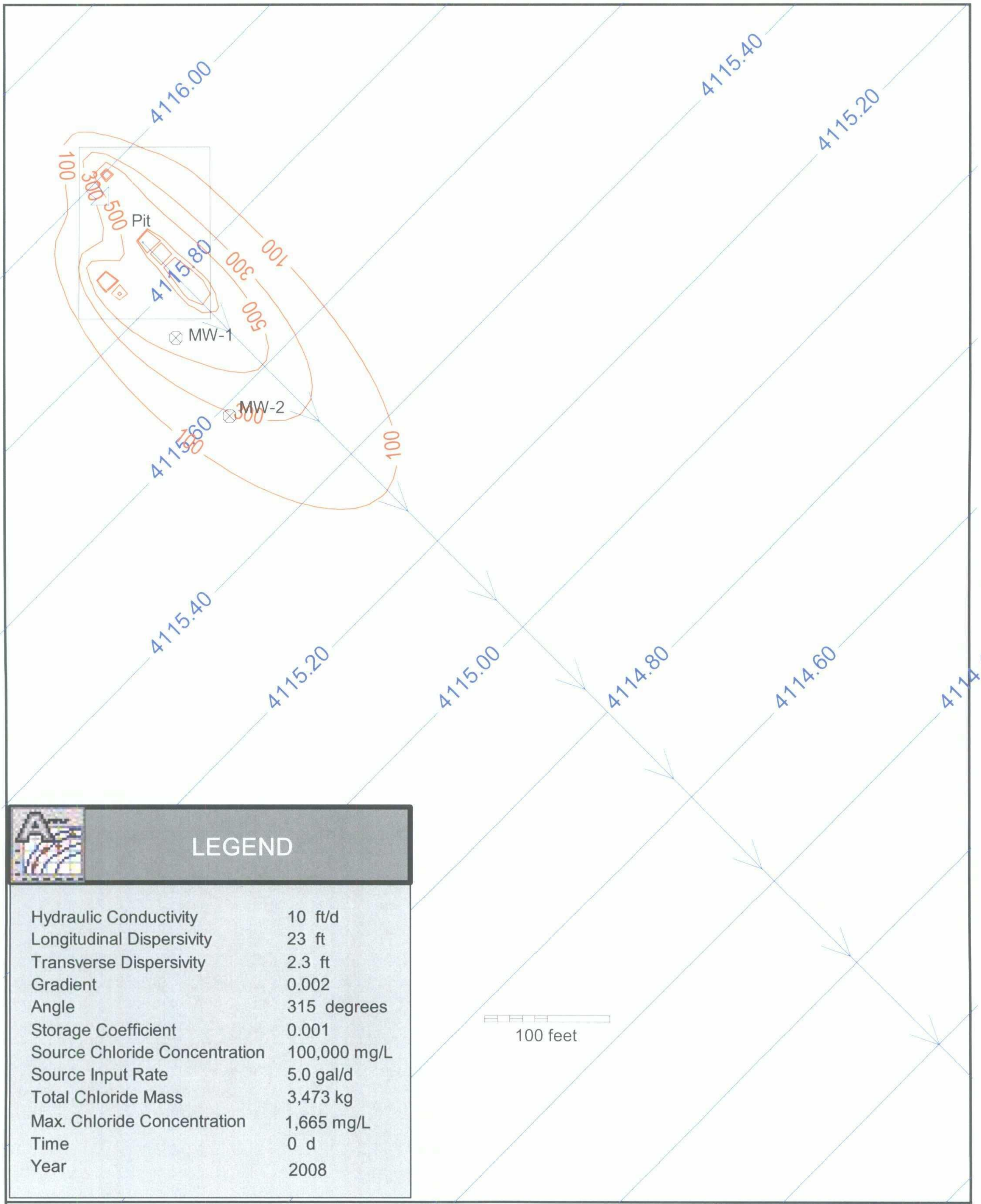
SOUTH FOUR LAKES #13 SITE

Fate & Transport Model Simulations

WinTran (Version 3.28)

Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	2.3 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	1,665 mg/L
Time	0 d
Year	2008

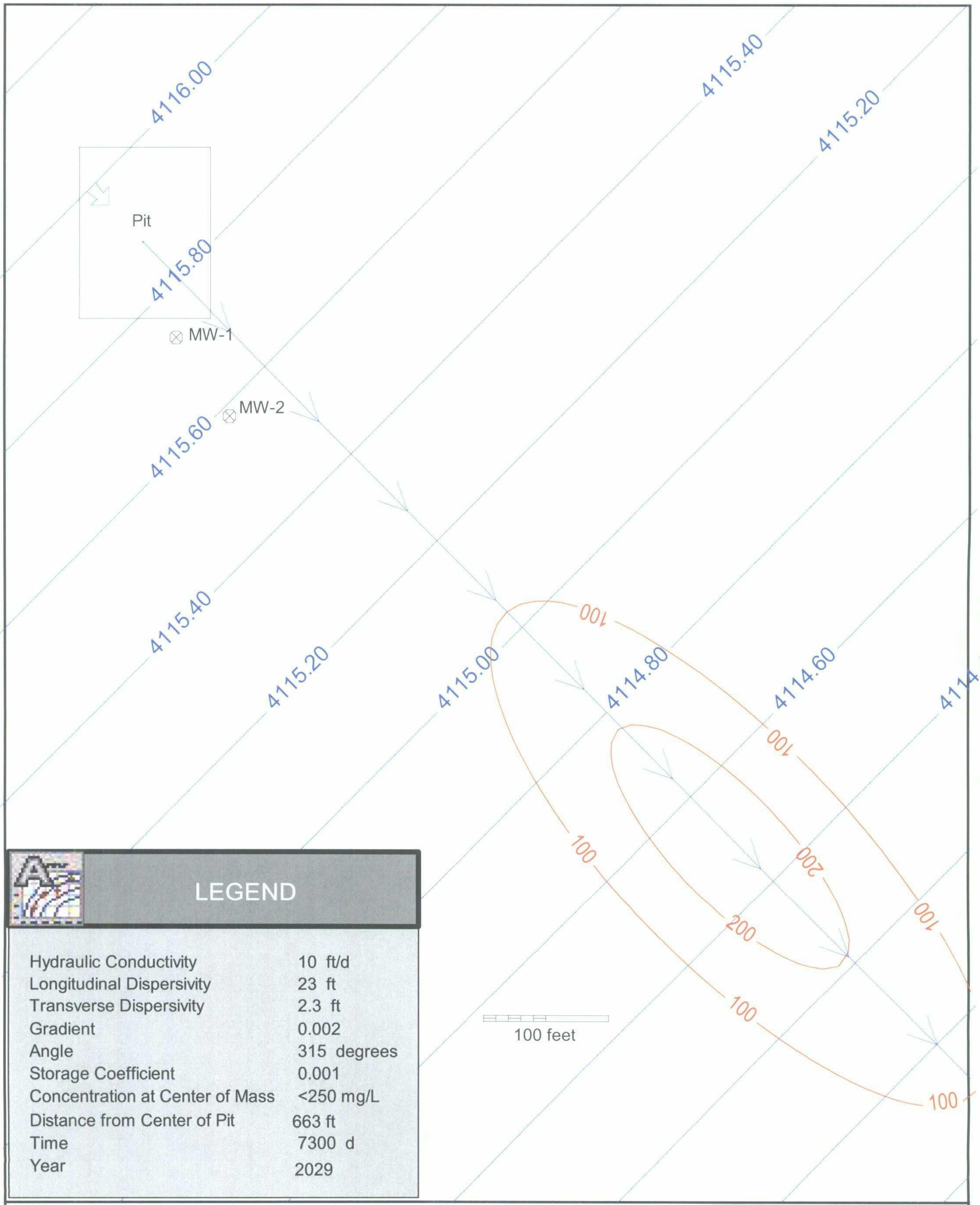
SOUTH FOUR LAKES #13 SITE

Fate & Transport Model Simulations

WinTran (Version 3.28)

Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

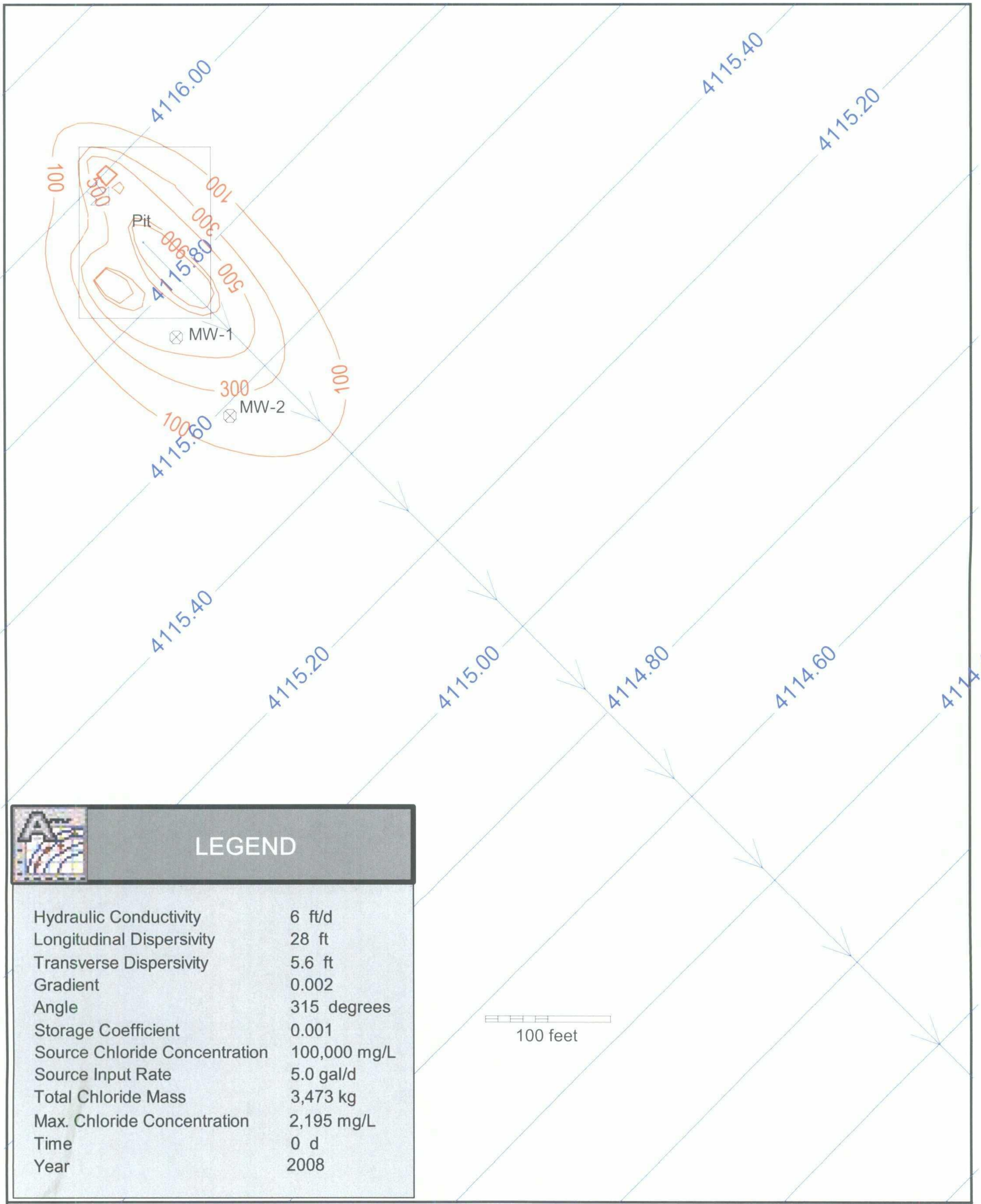


LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	2.3 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	663 ft
Time	7300 d
Year	2029

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT
ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	5.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,195 mg/L
Time	0 d
Year	2008

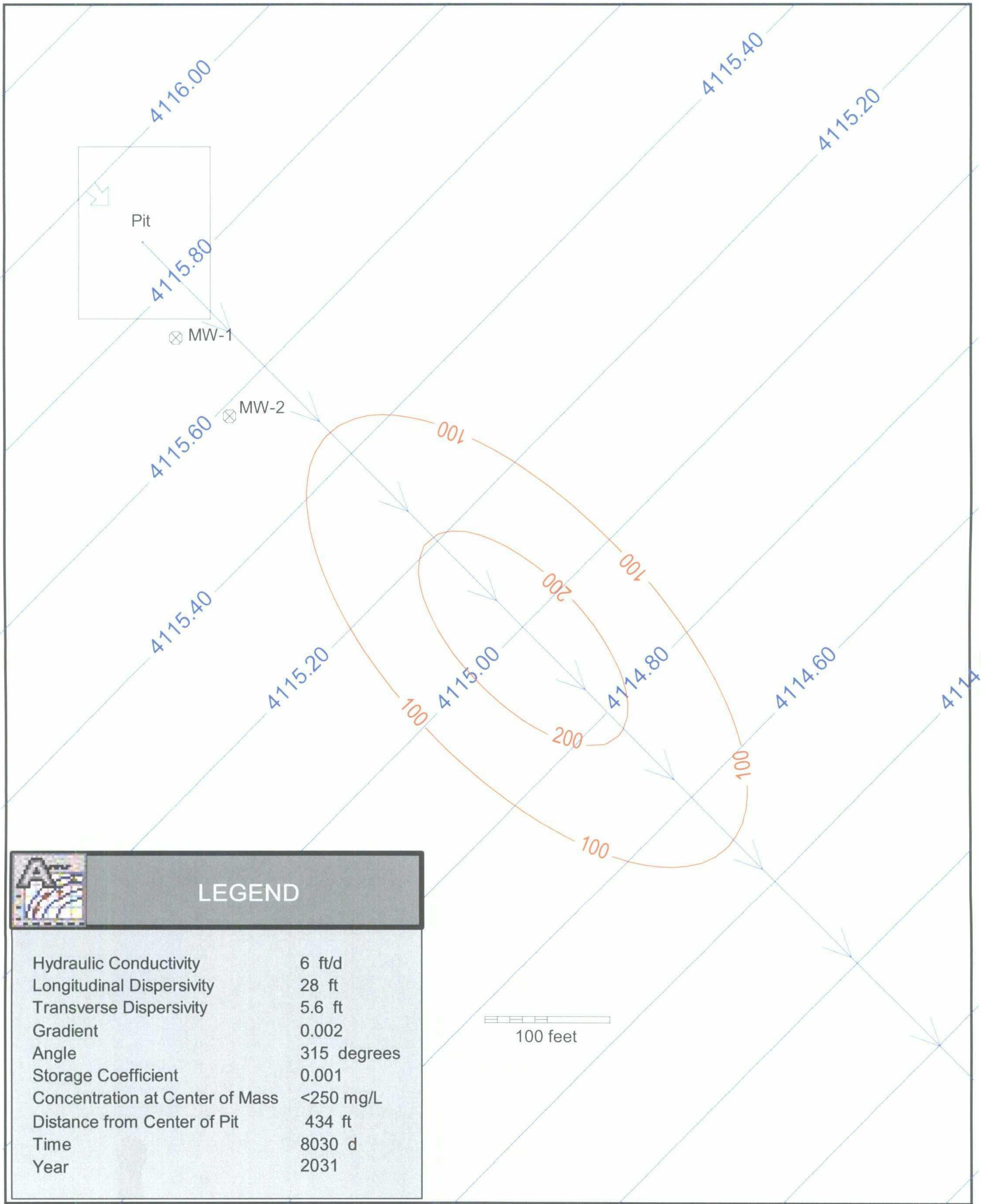
SOUTH FOUR LAKES #13 SITE

Fate & Transport Model Simulations

WinTran (Version 3.28)

Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	5.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	434 ft
Time	8030 d
Year	2031

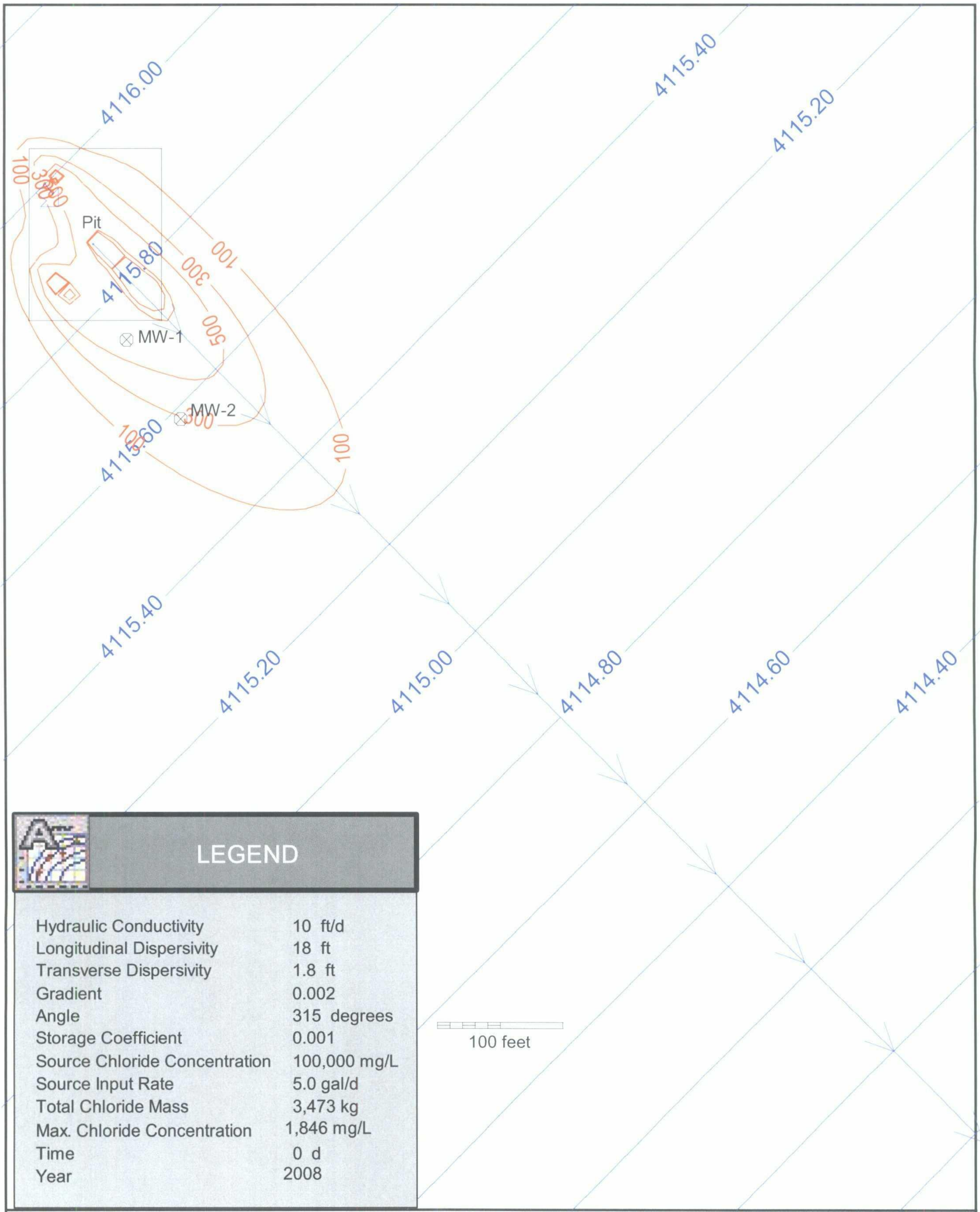
SOUTH FOUR LAKES #13 SITE

Fate & Transport Model Simulations

WinTran (Version 3.28)

Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

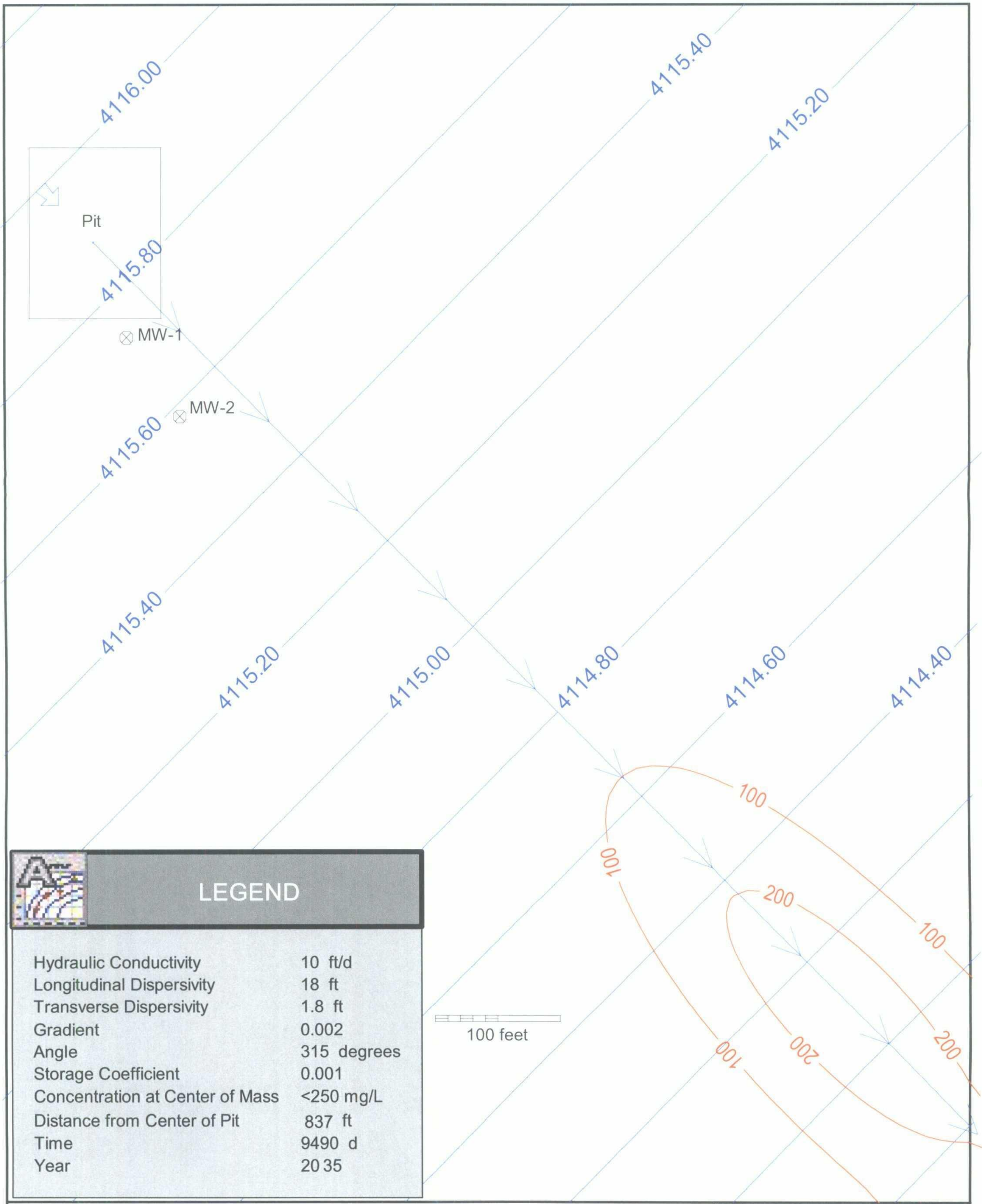


LEGEND

Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	1.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	1,846 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

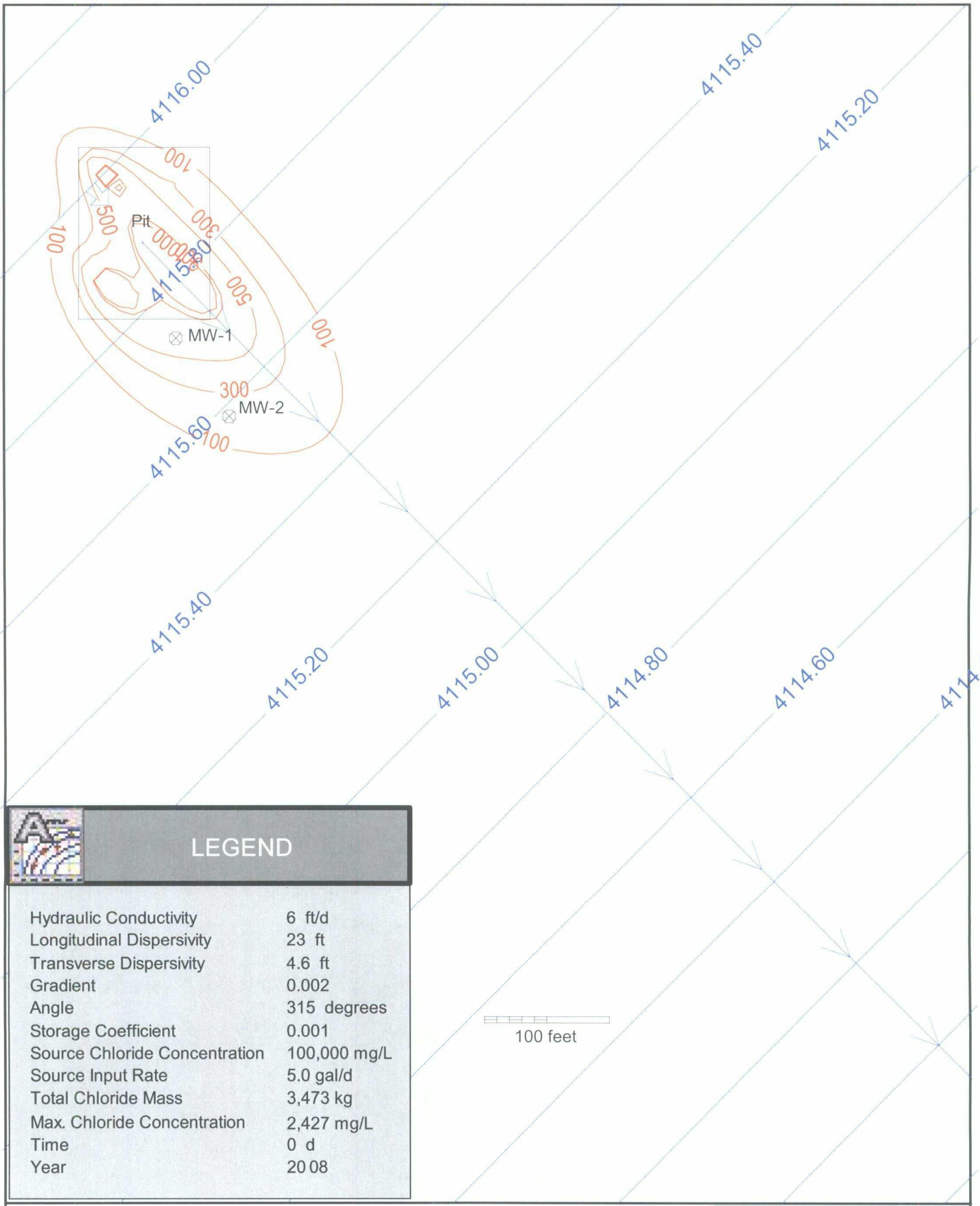
TRIDENT ENVIRONMENTAL



Hydraulic Conductivity	10 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	1.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	837 ft
Time	9490 d
Year	20 35

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT
ENVIRONMENTAL

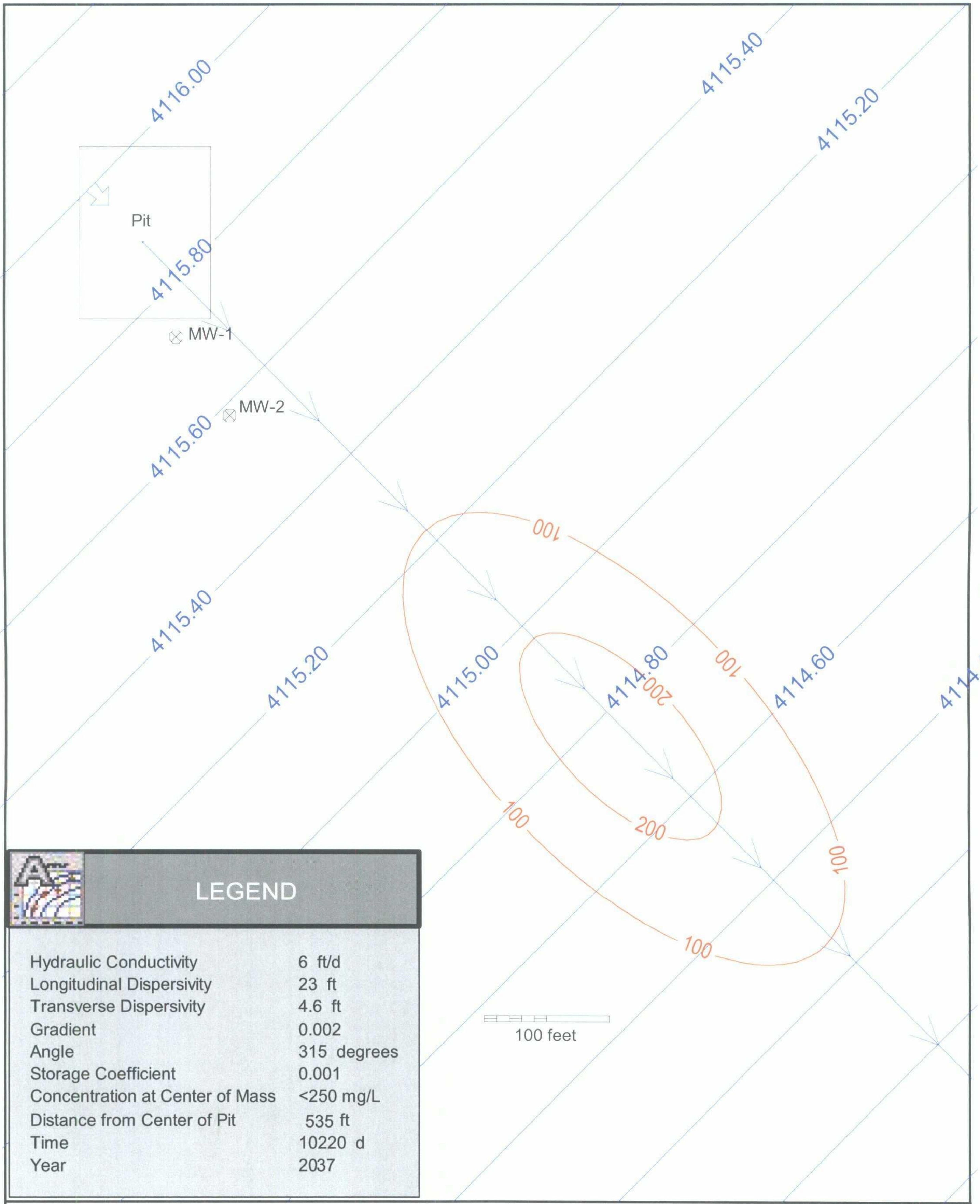


LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	4.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,427 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

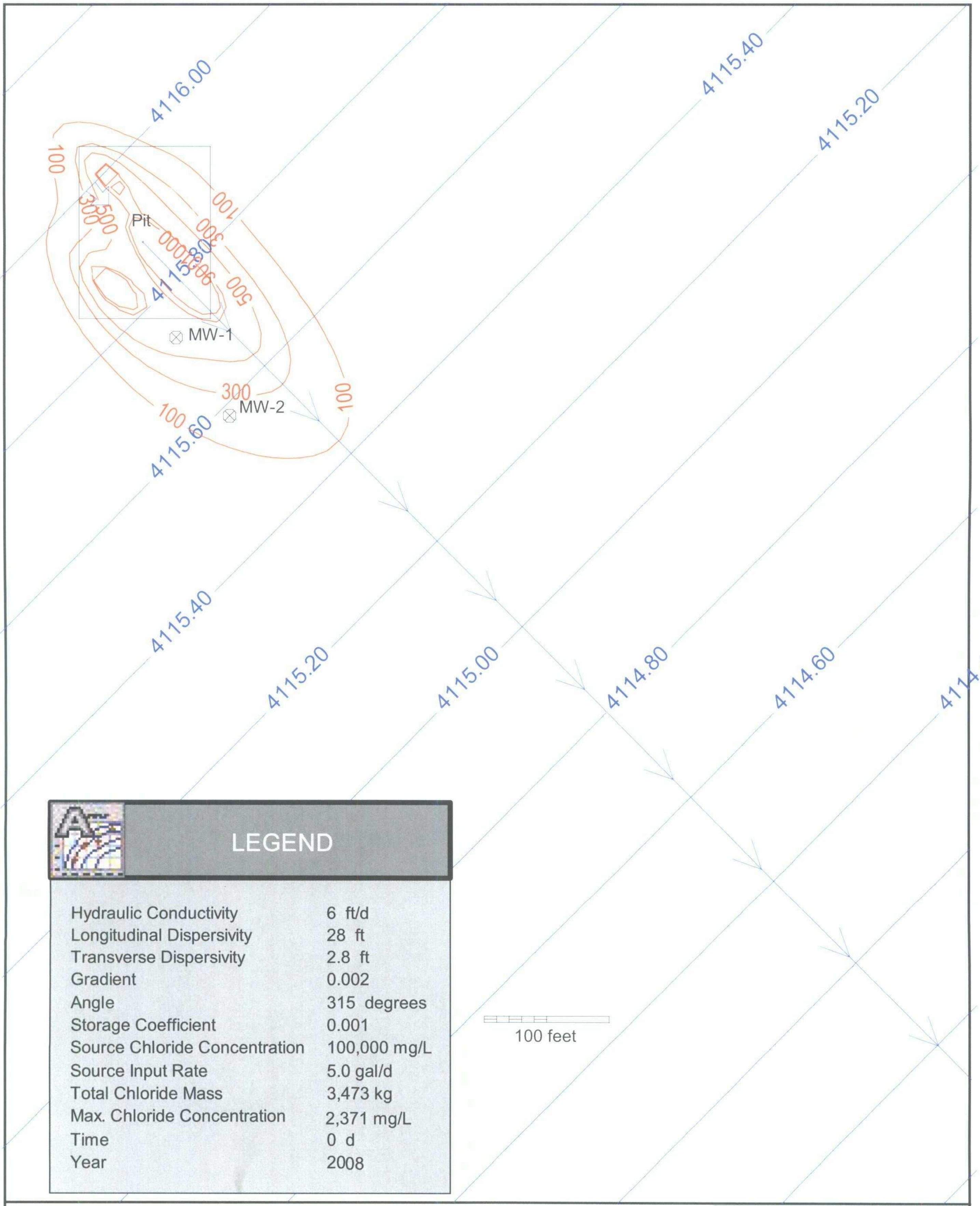


LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	4.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	535 ft
Time	10220 d
Year	2037

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	2.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,371 mg/L
Time	0 d
Year	2008

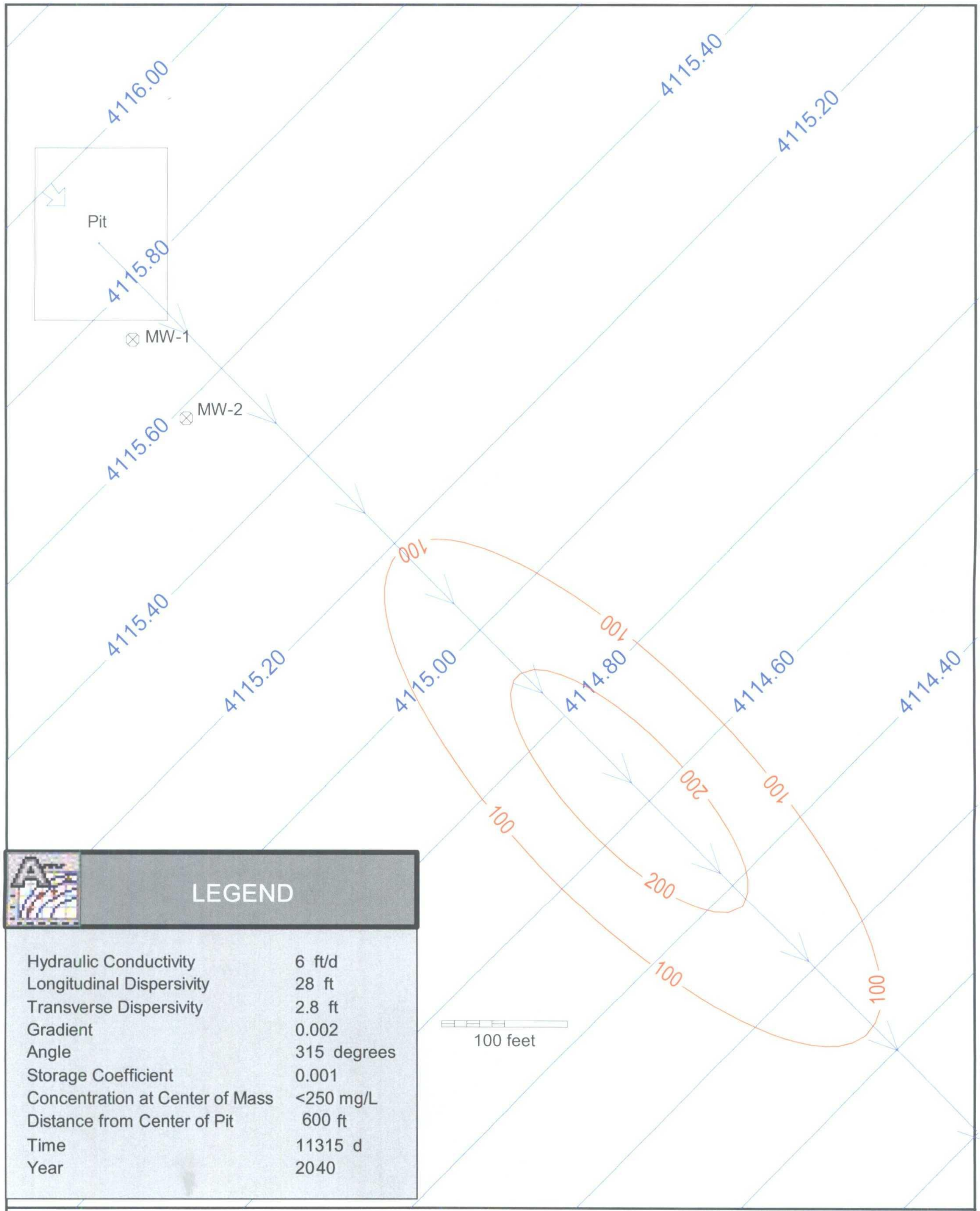
SOUTH FOUR LAKES #13 SITE

Fate & Transport Model Simulations

WinTran (Version 3.28)

Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

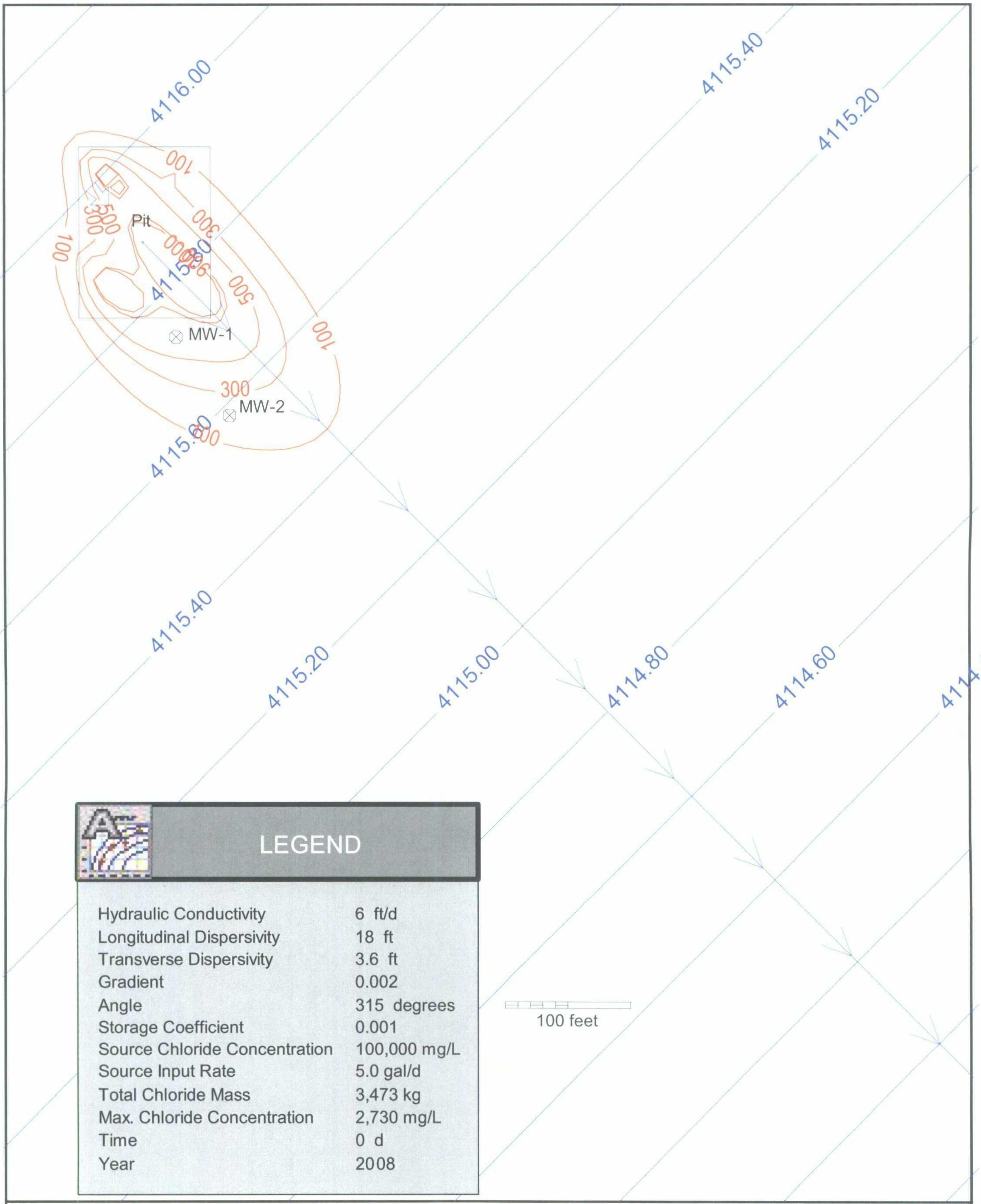


LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	28 ft
Transverse Dispersivity	2.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	600 ft
Time	11315 d
Year	2040

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

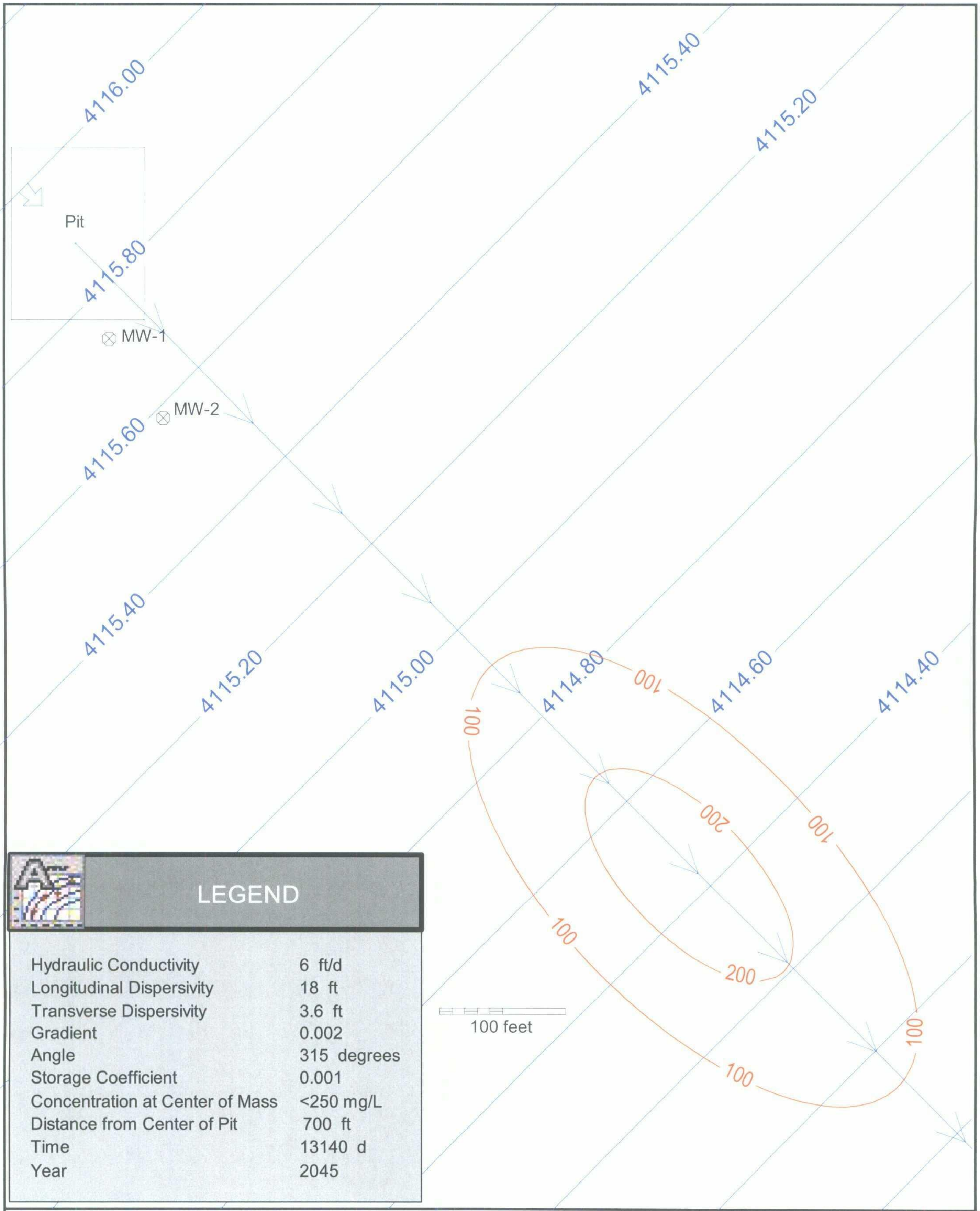


LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	3.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,730 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL

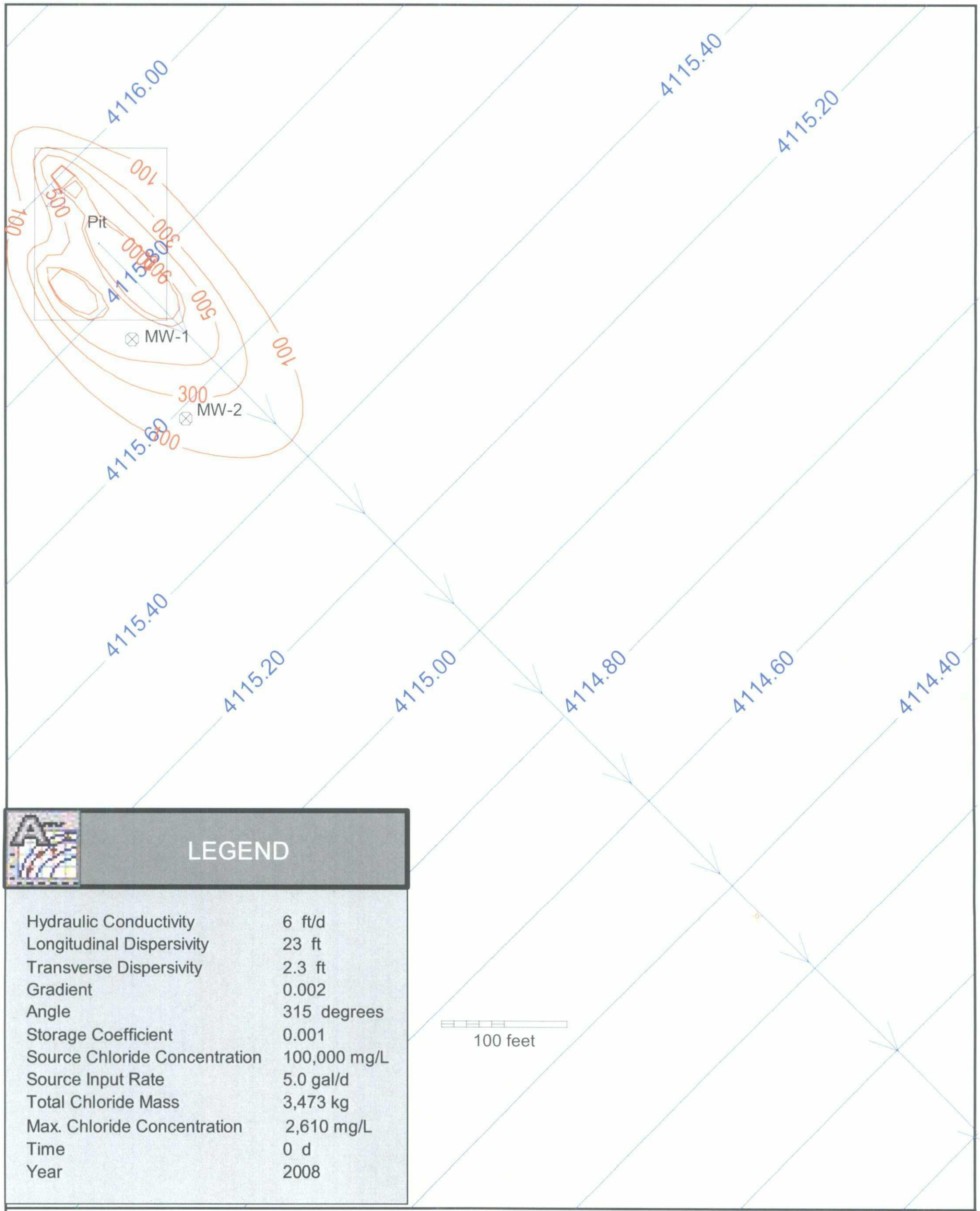


LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	3.6 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	700 ft
Time	13140 d
Year	2045

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
Analysis By: Gil Van Deventer

TRIDENT ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	2.3 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,610 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
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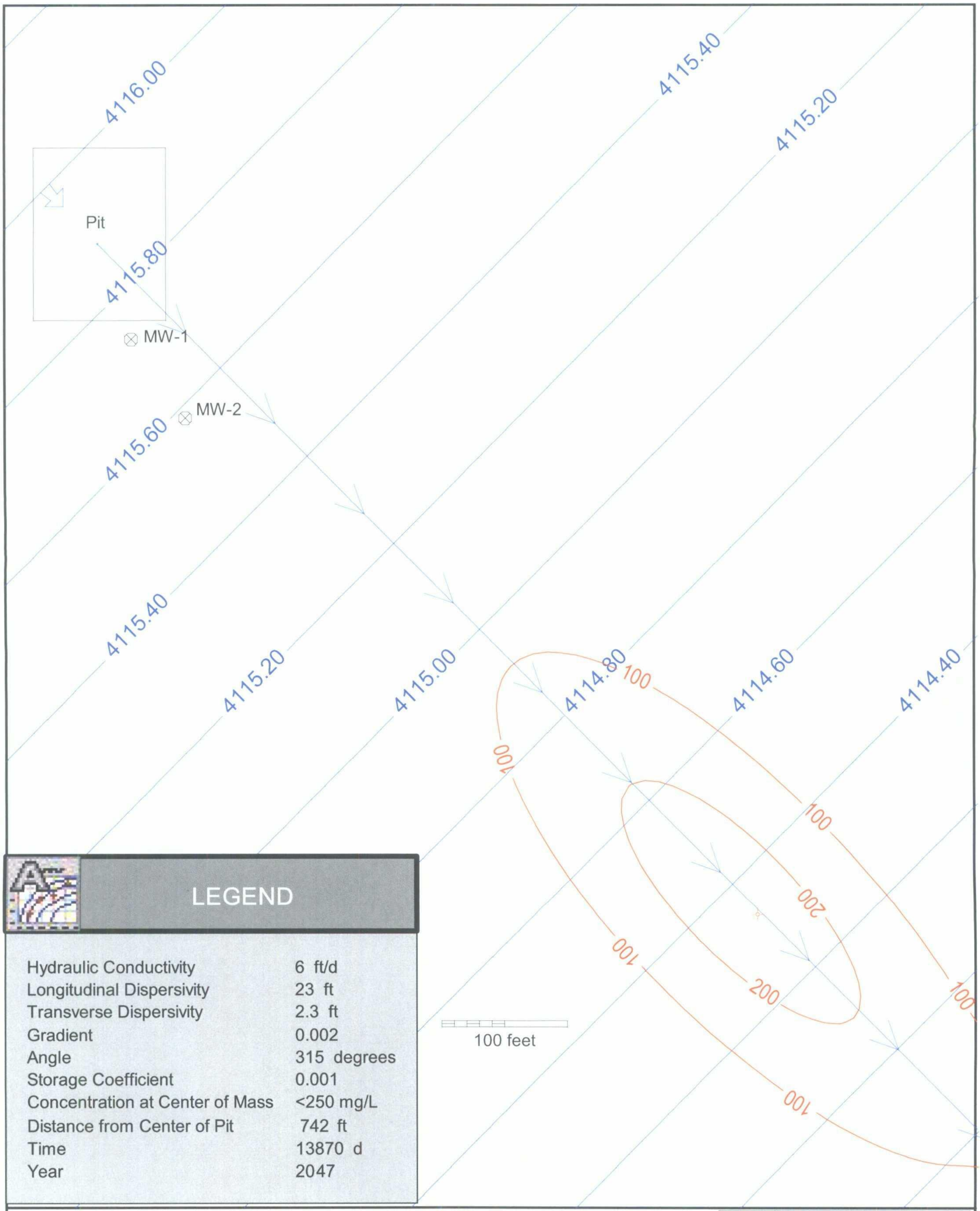

LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	23 ft
Transverse Dispersivity	2.3 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	742 ft
Time	13870 d
Year	2047

SOUTH FOUR LAKES #13 SITE
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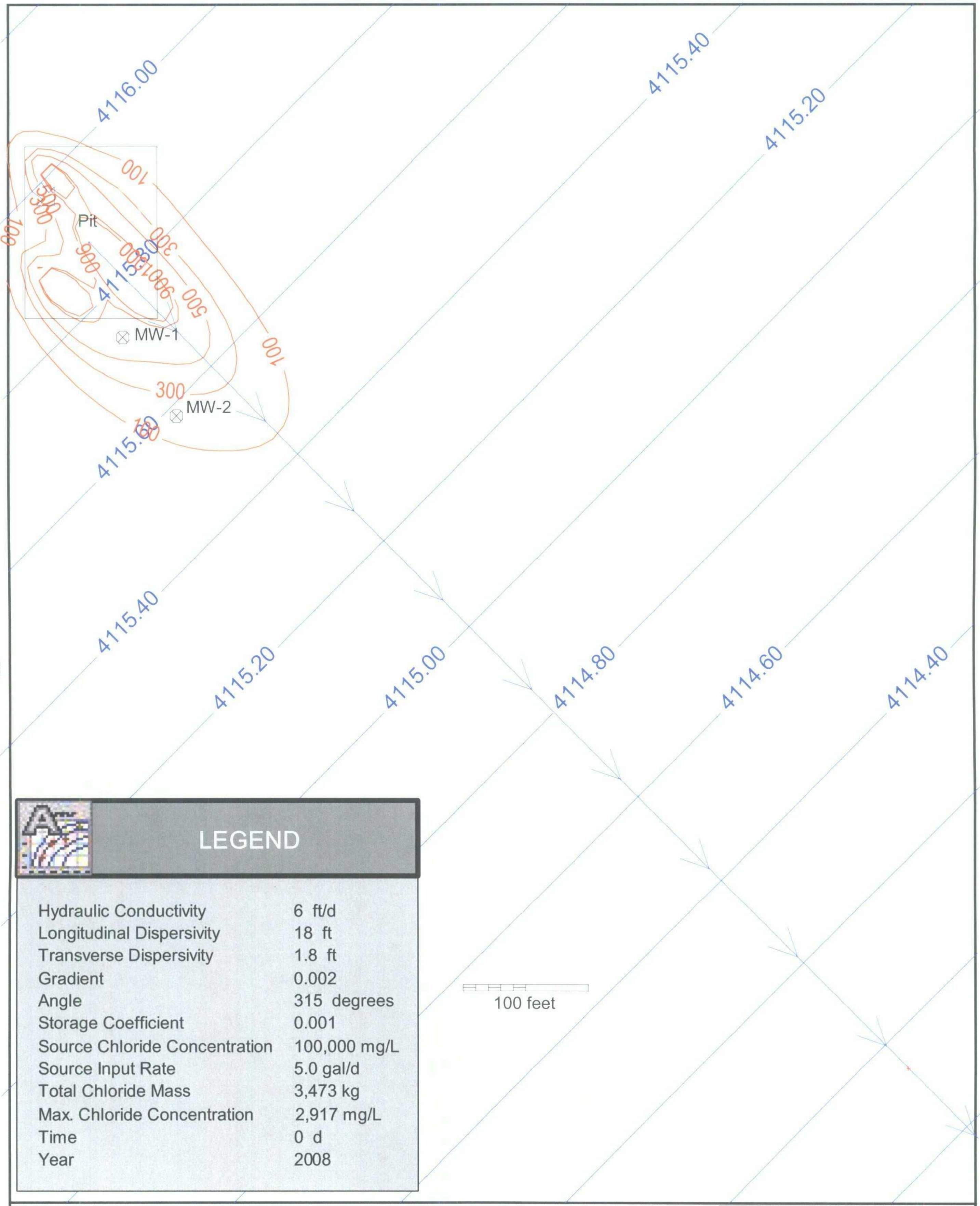
TRIDENT
ENVIRONMENTAL



LEGEND

Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	1.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Source Chloride Concentration	100,000 mg/L
Source Input Rate	5.0 gal/d
Total Chloride Mass	3,473 kg
Max. Chloride Concentration	2,917 mg/L
Time	0 d
Year	2008

SOUTH FOUR LAKES #13 SITE
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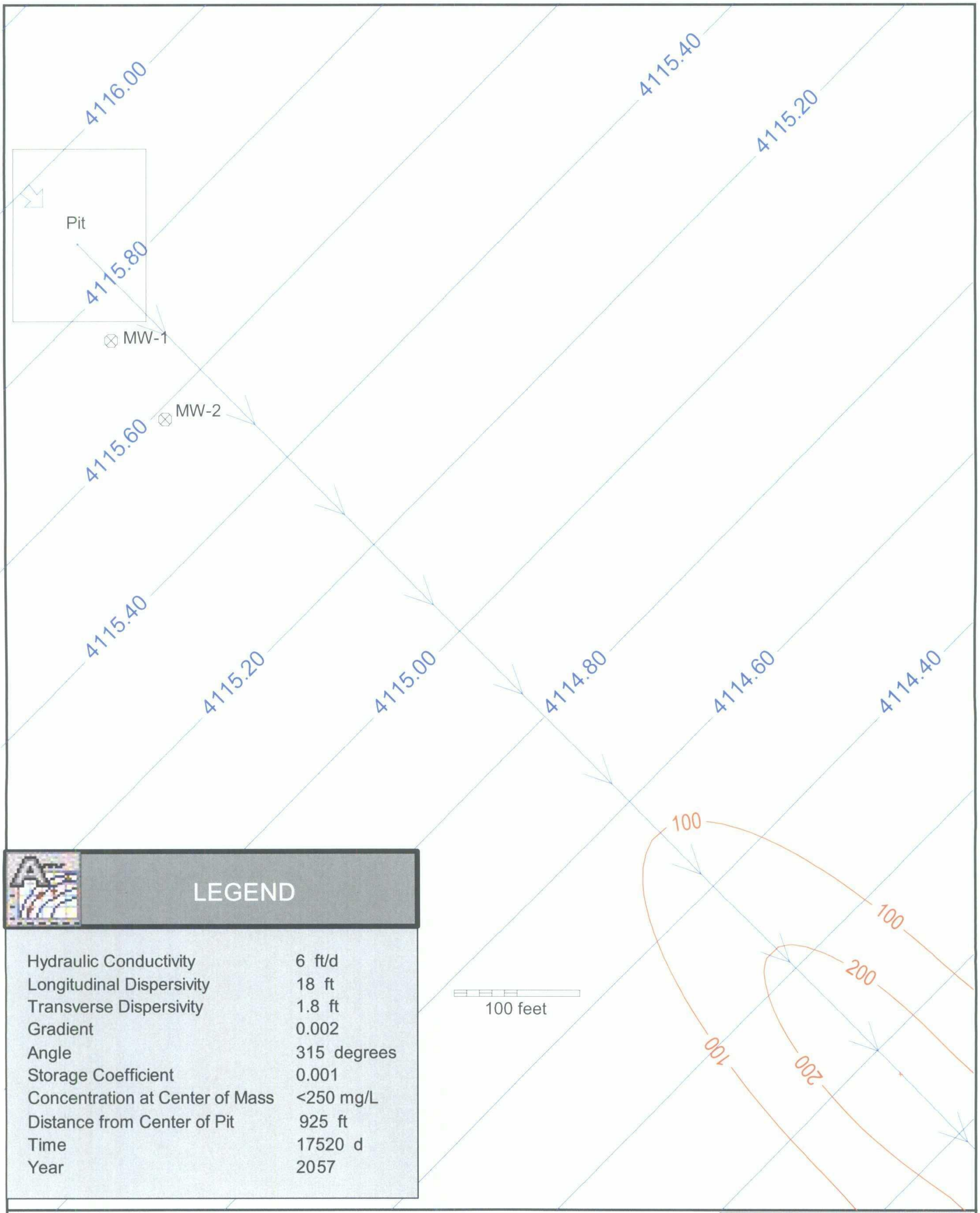
TRIDENT ENVIRONMENTAL



Hydraulic Conductivity	6 ft/d
Longitudinal Dispersivity	18 ft
Transverse Dispersivity	1.8 ft
Gradient	0.002
Angle	315 degrees
Storage Coefficient	0.001
Concentration at Center of Mass	<250 mg/L
Distance from Center of Pit	925 ft
Time	17520 d
Year	2057

SOUTH FOUR LAKES #13 SITE
Fate & Transport Model Simulations
WinTran (Version 3.28)
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TRIDENT
ENVIRONMENTAL

APPENDIX E

Description of *WinTran* Fate and Transport Model

And

Water Level Data from Aquifer Test
(Raw Data)

Introduction

Combined Manual

Aquifer^{Win32}, WinFlow and WinTran are now basically the same product so we have merged the manual into one. With the exception of the program name, the default icon, and the types of document files you can create everything is the same.

An Aquifer^{Win32} Flow Model document file is identical to a WinFlow document file and the user-interfaces are identical as well. The only reason we sell two products is for those who want the modeling capabilities but not the pumping test analysis capabilities. In that case, WinFlow is the solution. For everyone else, one of the levels of Aquifer^{Win32} is the solution.

We have eliminated WinTran as a separate product and included it in both WinFlow and the Modeling Version of Aquifer^{Win32}.

The Modeling version of Aquifer^{Win32} contains the capabilities of all three products!

What is Aquifer^{Win32}?

Aquifer^{Win32} is the most sophisticated and most Windows™ compliant application for the analysis and presentation of aquifer tests including pump tests, slug tests, step tests and analytic element flow and contaminant transport models. The analysis of these data incorporates a wide variety of solution types with comprehensive plotting features.

Aquifer^{Win32} comes in four different versions, *Modeling*, *Professional*, *Standard*, and *Slug Test.* Aquifer^{Win32} is an OLE Full Server allowing the results to be linked to or embedded in OLE client applications. The *Slug Test* version is limited to the analysis of slug test data using any one of the 6 slug test solutions; these solutions range from the simple Hvorslev to the complex Kansas Geological Survey (KGS) Model supporting confined or unconfined conditions, partial penetration, well skin effects and the response of a monitoring well. The *Standard* version adds over a dozen pump test analyses including solutions for confined, leaky confined, unconfined and fracture rock aquifers with support for variable pumping rates, partial penetration, delayed yield and well bore storage. The *Professional* version adds derivative analysis, Step tests and a Pump Test Simulator. The *Modeling* version extends many of the pump test solutions into a modeling environment supporting any number of pumping wells with variable pumping rates. Output includes contour maps of hydraulic head or drawdown, color floods, particle traces and graphs of drawdown versus time at any number of monitoring wells. Auto-calibration to any number of transient targets is also supported.

The following are some of the most important features of Aquifer^{Win32}:

About data entry...

- As simple as entering or importing data into a spreadsheet, characterize pumping and monitoring well, select solution type and match data
- Alternatively, designed as a repository for raw aquifer test data with programmatic data conversions
  - Define a site plan including a site map, well locations and well construction information
  - Define an aquifer test including pumping schedule, wells monitored and raw drawdown versus time data
  - Define an analysis by grouping wells, transforming and clipping well response data, optionally adjust for radial distance on a well by well basis

About data analysis...

- Primary support for traditional manual curve matching techniques
- User selectable and unlimited type curves on curve match graph
- Multiple parameters available as type curves for many analyses
- Graphically visualize the impact of specific parameters with custom type curve suites
- Extensive curve match optimization capability
  - Control which parameters are optimized
  - Set minimum and maximum bounds on parameters
  - Optimize any parameters across multiple data sets
- Manual and optimized curve match of the first-order derivative of the data to first-order derivative type curves
- Support for variable pumping rates
- Pump test simulations with contour maps and time/drawdown graphs
- Steamline and particle trace analysis
- Analytic element modeling with recharge, ponds, linesinks etc.
- Auto-calibration of flow modeling parameters

About units...

- Full control of parameter and data units on a parameter by parameter and well by well basis
- On-the-fly unit conversions
- Peer review process assisted by instantaneous global unit conversions without affecting match results
- Parameter-based unit conversion calculator

About graphics…

- Full control of graphs including size, titles, axes, colors, fonts, dash patterns and line thickness
- Type curve graph, predicted drawdown curve through data points, observed drawdown data
- Contours of predicted drawdown at a given time and predicted drawdown versus time data at any number of monitoring wells
- Annotate maps and graphs with text, parameters, symbols, lines, frames and legends
- Frames support display of bitmaps and metafiles
- Exports to DXF, Windows Metafile and ArcView™ Shapefile formats
- Site map and well location plan displayed in map view
- Color flood maps in addition to or as an alternative to contour maps
- Three dimensional perspective display using the Visualization Toolkit (vtk), written and copyrighted by Ken Martin, Will Schroeder and Bill Lorensen.

About printing…

- WYSIWYG printing with Print Preview of all views
- Customizable margins and scaling
- Customizable headers and/or footers supporting bitmaps and metafiles
- Supports any Windows™ printer driver

About Windows™ features…

- Multiple Document Interface
- OLE Full-server supporting linked and embedded items
- Copy views to clipboard as metafiles and OLE objects
- Tab views including spreadsheet, type curves, predicted curves, map and simulator
- Data spreadsheet in split window
- Context-sensitive help
- Context menus
- Property Sheets (Tab Dialogs) to maximize ease of use
- Tip of the Day
- Dockable toolbars with tool tips

Slug Test Analyses

Hvorslev, 1951	Time Lag and Soil Permeability in Ground-Water Observations

Bouwer & Rice, 1976	Slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells
Black, 1978	The use of the slug test in groundwater investigations (Modified Bouwer & Rice unconfined aquifer slug test analysis using an exponential type curve)
Cooper, Bredehoeft & Papadopulos, 1967	Response of a Finite-Diameter Well to an Instantaneous Charge of Water
Hyder, Butler, McElwee & Liu, 1994	Slug tests in partially penetrating wells (KGS Model including well skin and monitoring well response)
Kipp, 1985	Type Curve Analysis of Inertial Effects in the Response of a Well to a Slug Test

Pumping Test Analyses

Cooper and Jacob, 1946	A generalized graphical method for evaluating formation constants and summarizing well field history. (Cooper Jacob Straight Line Method)
Theis, 1935	Constant discharge from a fully penetrating well in a nonleaky aquifer*
Theis, 1935 (Unconfined)	Constant discharge from a fully penetrating well in a nonleaky aquifer*
Theis, 1946 (Recovery)	Recovery test after constant discharge from a fully penetrating well in a nonleaky aquifer
Hantush, 1961	Constant discharge from a partially penetrating well in a nonleaky aquifer*
Papadopulos and Cooper, 1967	Constant discharge from a fully penetrating well of finite diameter in a nonleaky aquifer*
Hantush, 1960	Constant discharge from a well in a leaky aquifer with storage of water in the confining beds*
Hantush and Jacob, 1955	Constant discharge from a fully penetrating well in a leaky aquifer*
Hantush, 1964	Constant discharge from a partially penetrating well in a leaky aquifer*
Neuman, 1972	Theory of flow in unconfined aquifers considering delayed response of the water table*
Neuman, 1974	Effects of partial penetration on flow in unconfined aquifers considering delayed aquifer response*
Moench, 1984	Double-Porosity Models for a Fissured Groundwater Reservoir with Fracture Skin*
Moench, 1985	Transient Flow to a Large-Diameter Well in an Aquifer With Storative Semiconfining Layers*
Moench, 1997	Flow to a well of finite diameter in a homogeneous, anisotropic water table aquifer

*** Analysis available for use in pump test simulator**

Step/Variable Rate Test Analyses

Eden and Hazel, 1973	Step-drawdown test analysis for fully penetrating well in a confined aquifer. Determines well losses and aquifer transmissivity.
Birsoy and Summers, 1980	Variable or intermittent discharge rate analysis for well in a confined aquifer. Determination of aquifer transmissivity and storage.

Model Solutions

Theis, 1935	Constant discharge from a fully penetrating well in a nonleaky aquifer
Hantush, 1960	Constant discharge from a well in a leaky aquifer with storage of water in the confining beds
Hantush and Jacob, 1955	Constant discharge from a fully penetrating well in a leaky aquifer
Neuman, 1972	Theory of flow in unconfined aquifers considering delayed response of the water table
WinFlow	Analytic element flow model developed by ESI
WinTran	Analytic element flow and Finite element contaminant transport model developed by ESI

What is WinFlow?

WinFlow is a powerful yet easy-to-use groundwater flow model. The user-interface represents the most sophisticated and Windows^{TM} compliant available today. WinFlow provides an extensible common user-interface for analytical analyses and models capable of hosting other calculation engines in the future.

WinFlow is an interactive, analytical modeling tool that simulates two-dimensional steady-state and transient ground-water flow. The steady-state module simulates ground-water flow in a horizontal plane using analytical functions developed by Strack (1989). The transient module uses equations developed by Theis (1935) for confined aquifers, Hantush and Jacob (1955) and Hantush (1960) for leaky aquifers, and Neuman (1972) for unconfined aquifers. Each module uses the principle of superposition to evaluate the effects from multiple analytical functions (wells, etc.) in a uniform regional flow field.

The steady-state module simulates the effects of the following analytic elements in two-dimensional flow: wells, uniform recharge, circular recharge/discharge areas, and line sources or sinks. Any number of these elements may be added to the model, including a uniform regional hydraulic gradient. The model depicts the flow field using streamlines, particle traces, and contours of hydraulic head. The streamlines are computed semi-analytically to illustrate ground-water flow directions. Particle-tracking techniques are implemented numerically to compute travel times and flow directions. Both confined and unconfined aquifers are simulated with the steady-state module.

The transient module simulates the effects of wells, circular ponds, linear sources/sinks, and a uniform regional gradient for confined and leaky aquifers. Numerical particle-tracking is also available in the transient module. The transient module computes hydraulic heads using the Theis (1935) equation for confined aquifers and the Hantush and Jacob (1955) or Hantush (1960) equation for leaky aquifers. Neuman's method (1972) can also be used for unconfined aquifers with delayed yield from storage.

In addition to the WinFlow calculation engine described above, WinFlow extends other analytical solutions from the popular Aquifer^{Win32} pumping test analysis application into its modeling environment. These additional solutions support any number of pumping wells with variable pumping rates. Auto-calibration to any number of transient targets is also supported for these additional solutions.

WinFlow is simple to use and highly interactive, allowing you to create an analytical model in minutes. The software features standard Windows pulldown menus and tab dialogs to facilitate the model design. The model is recomputed and recontoured either by selecting a menu item or by pressing a toolbar button. Streamlines and particle-traces are added interactively and recomputed each time new wells or other elements are added.

WinFlow can import a Drawing Interchange Format (DXF) file (from AutoCAD for example) to use as a digitized base map. QuickFlow and ModelCad-format map files may also be imported into WinFlow. The digitized map gives the modeler a frame of reference for designing the analytical model.

WinFlow 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.

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, 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 model 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, contours of hydraulic head (water levels) and color floods of hydraulic heads. 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 calculated and graphically displayed 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.

Installation

Aquifer$^{\text{Win32}}$ and WinFlow are distributed on CD-ROM and use a sophisticated installation wizard that is similar to other Windows™ products. You simply run “Setup” from the CD-ROM and follow the directions as the installation proceeds. Start by placing the CD-ROM in the drive. Now, select **Run** from the **Start** menu and enter the following:

```
d:\setup.exe
```

You must first agree to the "ENVIRONMENTAL SIMULATIONS SOFTWARE LICENSE AGREEMENT" in order to continue installing the software. The next page prompts for the directory where the files will be stored. The default is "c:\aquifer3" or “c:\winflow3”. If you would like to place the files in a different directory, click the **Browse** button and locate a new directory. Click the **Next** button when you are done. Select **Cancel** at any time to terminate the installation process. The next step is to decide which optional components to install. By default, example files are installed and documentation files, in .pdf format, are not. Click the **Next** button after checking the optional components you want to install.

The next page of the wizard allows you to specify the name of the submenu to add to the **Start->Programs** menu; the default name is AquiferWin32 Version 3 or WinFLow Version 3. To change this, you may select from an existing submenu listed or type a new name. Select **Next** to accept your choice. Finally, select the **Next** button again to begin the installation. After all the files have been installed, another wizard will be started to install the security block device driver; you must have administrator rights to install this driver. After the device driver installation is complete, click the **Finish** button on this wizard and on the main installation wizard.

Optionally Obtaining a Security Code

Aquifer$^{\text{Win32}}$ and WinFlow are protected by a security block (dongle) or an optional security code that is tied to the computer you install it on. By default, Aquifer$^{\text{Win32}}$ and WinFlow both ship with a security block. If you opt for a security code instead, you are licensed to run Aquifer$^{\text{Win32}}$ or WinFlow on only one computer and you must obtain a security code in order to complete the installation. If you obtain a security block, you are licensed to install Aquifer$^{\text{Win32}}$ or WinFlow on any number of computers; however, Aquifer$^{\text{Win32}}$ and WinFlow will require the security block to be installed on a given computer before its full functionality is activated.

WinFlow/WinTran Mathematical Models

Steady-state Model

The equations used in the steady-state portion of WinFlow are derived by Otto D. L. Strack's Groundwater Mechanics (Strack, 1989). If you intend to use WinFlow routinely, you should get a copy of Groundwater Mechanics. It is well written and will give you valuable insight into the underlying assumptions of the analytical equations. You will also be introducted to more advanced techniques not included in WinFlow. The book contains sample FORTRAN source code for the analytical functions in WinFlow.

Dr. Strack is well known for his SLAEM software (Single Layer Analytic Element Model), which is much more advanced than WinFlow. He has also developed a three-dimensional version of SLAEM. If you like analytical modeling with WinFlow but need more power and flexibility, you may be interested in SLAEM. Dr. Strack can be reached in the Civil and Mineral Engineering Department of the University of Minnesota.

The analytic functions developed by Strack (1989) use the principle of superposition to compute the head at a point in the aquifer system. The total effect resulting from several analytic functions, such as a pumping wells, is equal to the sum of the individual effect caused by each analytic function acting separately. For example, if you wanted to compute the total drawdown at a point resulting from three pumping wells, you would compute the drawdown caused by each well at that point and then sum the drawdowns.

WinFlow allows you to select from a number of analytic functions to simulate two-dimensional horizontal ground-water flow, including

Uniform regional flow,

Wells,

Recharge (elliptical area),

Circular recharge areas (Ponds), and

Line sinks and sources.

The head at any point in the system may be computed by summing the effects of any number of the above functions. The equations used to compute the head are described below.

The analytic equations are expressed in terms of discharge potential to keep the equations linear for both confined and unconfined flow. The discharge vector points in the direction of ground-water flow and the magnitude of the discharge potential equals the volume of water flowing through a cross-section of unit width. In computing head at a point, the discharge potential is computed first and then converted to head using the following equations:

for confined flow:

$$\phi = \frac{\Phi + \frac{1}{2} K H^2}{KH}$$

and for unconfined flow:

$$\phi = \sqrt{\frac{2\Phi}{K}}$$

where:

Φ = discharge potential (L^3/T)

K = hydraulic conductivity (L/T)

H = aquifer thickness (L)

ϕ = head (L)

Using these formulae, WinFlow automatically accounts for the transition from confined to unconfined flow. The following equations are used to compute the discharge potential at any point (x,y) in the system. The equations above are then used to convert the discharge potential to head.

Uniform Flow

$$\Phi(x,y) = -Q_o(x\cos\alpha_u + y\sin\alpha_u) + C$$

Wells

$$\sum_{j=1}^{n} \frac{Q_j}{4\pi} \ln[r_j^2(x,y)] +$$

Recharge

$$-\tfrac{1}{2}\frac{N}{a^2+b^2}[(a^2\sin^2\alpha_r+b^2\cos^2\alpha_r)(x-x_r)^2-$$

$$2(a^2-b^2)(x-x_r)(y-y_r)\sin\alpha_r\cos\alpha_r$$

$$+(a^2\cos^2\alpha_r+b^2\sin^2\alpha_r)(y-y_r)^2-a^2b^2]$$

Ponds

Inside Pond:

$$-\textstyle\sum_{j=1}^{n}\tfrac{1}{4}[(x-x_{p_j})^2+(y-y_{p_j})^2-R^2{}_{p_j}]\,N_{p_j}$$

Outside Pond:

$$-\textstyle\sum_{j=1}^{n}\tfrac{1}{4}[R^2{}_{p_j}\ln[\frac{(x-x_{p_j})^2+(y-y_{p_j})^2}{R^2{}_{p_j}}]]\,N_{p_j}$$

Linesinks of Known Flux

$$+\sum_{j=1}^{n}\frac{\sigma_j L_j}{4\pi}\Re\{(Z_j+1)\ln(Z_j+1)-(Z_j-1)\ln(Z_j-1)+2\ln[\frac{1}{2}(\frac{2}{z_j}-\frac{1}{z_j}]-2\}$$

where:

x = x coordinate of calculation point

y = y coordinate of calculation point

Q_o = uniform flow [L^2/T]

α_u = angle between uniform flow and x-axis

Q_j = discharge of well j [L^3/T]

r_j = distance from well j to calculation point [L]

N = recharge rate [L/T]

a = length of a-axis of recharge ellipse [L]

b = length of b-axis of recharge ellipse [L]

x_r = x coordinate of center of recharge ellipse [L]

y_r = y coordinate of center of recharge ellipse [L]

α_r = angle between a-axis and x-axis

x_{pj} = x coordinate of center of pond j [L]

y_{pj} = y coordinate of center of pond j [L]

R_{pj} = radius of pond j [L]

N_{pj} = infiltration rate of pond j

σ_j = flow per unit length for linesink j [L^2/T]

L_j = length of linesink j [L]

z^1 = starting coordinates of linesink j

z^2 = ending coordinates of linesink j

C = constant

z = x + iy

$$Z_j = Z_j(z, \frac{1}{z_j}, \frac{2}{z_j}) = \frac{z - \frac{1}{2}(\frac{1}{z_j} + \frac{2}{z_j})}{\frac{1}{2}(\frac{2}{z_j} - \frac{1}{z_j})}$$

The uniform flow component above does not contain a gradient term explicitly, even though you enter the gradient in WinFlow to define uniform regional flow. The Q_o term represents the flow per unit width of aquifer and is computed as Q_o = KBi, where: i = the gradient, K = hydraulic conductivity, and B = saturated thickness. WinFlow computes the Q_o term at the reference point; therefore, you do not need to enter Q_o.

There are two equations for ponds depending upon whether the point (x,y) is located inside the pond or outside of the pond. Thus, either pond equation is used, but not both.

The term that computes the contribution to the discharge potential for line sinks is expressed in terms of complex numbers. The expression $\Re\{\}$ signifies that the real portion of the complex number computed by the complex expression {} is used in the equation.

The expression for the discharge potential contains one unknown constant C. The constant C is evaluated by requiring that the potential be known at some point (x_o,y_o) in the system. Once this potential is known, the equation is solved for the constant C. An important ramification of this approach is that the head always equals the reference head at the reference point. This approach is equivalent to setting a constant head cell in a numerical model. It is very important to keep this reference head as far as possible from the area of interest.

WinFlow allows you to specify linesinks of unknown flux by defining a head at the center of the linesink. For *n* linesinks of specified head, there are *n+1* unknowns (the flux for each linesink and the constant C). In this case, the equations are solved numerically to compute the constant C and the flux for each linesink of specified head.

Transient Model

Basic Models

The transient model in WinFlow uses the analytical solutions of Theis (1935) and Hantush and Jacob (1955) to compute drawdown from a pumping well. Drawdowns from multiple individual wells are then added using the principle of superposition (Reilly et al., 1987) to compute the effective drawdown at a point. Finally, the cumulative drawdown is subtracted from a planar potentiometric surface. The surface may be horizontal or inclined at some angle, given by the uniform gradient vector.

The procedure for calculating the head at any point and time (x,y,t) is given below:

$$\phi(x,y,t) = C - G(x\cos\alpha + y\sin\alpha) - \sum_{j=1}^{n} s_j$$

where:

ϕ = head

G = regional gradient [L/L]

α = angle between regional gradient and x-axis

(x,y) = coordinates of calculation point

t = time to compute drawdown

s_j = drawdown computed for well j

C = constant

The constant C is computed using the reference head, as in the steady-state model. The main difference between the steady-state model and the transient model is that the reference head is maintained at a constant value in the steady-state model. However, the reference head is simply a starting point for calculations in the transient model. That is, drawdowns computed at the reference location are subtracted from the reference head. The constant C is evaluated as follows:

$$C = \phi_r + G(x_o\cos\alpha + y_o\sin\alpha)$$

where:

ϕ_r = reference head

x_o = x coordinate of reference head

y_o = y coordinate of reference head

There is an option, however, to keep the reference head at a constant value. This option was added so that the results would be consistent with the steady-state model. If you elect to keep the reference head constant in the transient model, drawdown is computed at the reference head location and then added to all heads in the contour matrix. The result is that the potentiometric surface is raised by a constant value.

Although the absolute values of head will be different between the two approaches, the flow directions and travel times (using particle-tracking) will be identical. The reference head should not be held constant if a drawdown model is being calculated because there would be zero drawdown at the reference head location.

The drawdown (s_j) is computed from one of two equations. If the leakage factor (L) is zero, the Theis equation is used. If leakage is nonzero, the Hantush and Jacob leaky aquifer solution is computed.

The Theis (1935) equation for unsteady flow to a well in a confined aquifer makes the following simplifying assumptions:

aquifer has infinite areal extent;

aquifer is homogeneous, isotropic, and of uniform thickness;

aquifer potentiometric surface is initially horizontal;

pumping rate is constant;

well fully penetrates the aquifer;

horizontal ground-water flow;

aquifer is confined;

flow is unsteady;

water is released instantaneously from storage with decline of hydraulic head;

diameter of pumping well is very small so that storage in the well can be neglected;

Drawdown is calculated as described below.

$$s = \frac{Q}{4\pi T} w(u)$$

where:

w(u) = Theis well function = $\int_u^\infty \frac{e^{-y}}{y} dy$

$u = r^2 S / (4 T t)$

r = distance from well to point (x,y)

T = aquifer transmissivity [L^2/T]

S = storage coefficient [dimensionless]

t = time

Q = pumping rate [L^3/T]

The Theis well function, also known as the exponential integral, is computed in WinFlow using a numerical approximation given by Abramowitz and Stegun (1965). This approach is verified in the next chapter.

The Hantush and Jacob (1955) equation for unsteady flow to a well in a semi-confined aquifer with no storage in aquitards makes the following simplifying assumptions:

aquifer has infinite areal extent;

aquifer is homogeneous, isotropic, and of uniform thickness;

aquifer potentiometric surface is initially horizontal;

pumping rate is constant;

well fully penetrates the aquifer;

horizontal ground-water flow;

aquifer is semi-confined;

flow is unsteady;

water is released instantaneously from storage with decline of hydraulic head;

diameter of pumping well is very small so that storage in the well can be neglected;

confining bed(s) has infinite areal extent, uniform vertical hydraulic conductivity, and uniform thickness;

confining bed(s) is overlain or underlain by an infinite constant-head plane source; and

flow in the aquitard is vertical.

Drawdown is calculated as described below.

$$s = \frac{Q}{4\pi T} w(u, \frac{r}{B})$$

where:

w(u,r/B) = Hantush well function = $\int_u^\infty \frac{1}{y} e^{[-y-\frac{r^2}{4B^2y}]} dy$

u = $r^2 S / (4 T t)$

B = $\sqrt{\frac{Tb'}{K'}}$

b' = thickness of aquitard [L]

K' = vertical hydraulic conductivity of aquitard [L/T]

T = aquifer transmissivity [L^2/T]

The Hantush and Jacob well function is evaluated numerically using a method described by Case et al. (1979). The next chapter verifies that the Hantush and Jacob (1955) well function calculations are accurate.

Implementing Ponds and Linesinks

Ponds and linesinks are available for the transient model as well as the steady-state model. The pond element is implemented using the Hantush (1967) analytical solution for computing the water-table rise beneath a circular recharging area. Linesinks (flux only) are implemented approximately using a series of wells evenly spaced along the linesink. You may determine the number of wells used to approximate each linesink. It will be more accurate as the number of wells increases. Both pond and linesink transient elements are described below.

Ponds are computed in the transient model using the Hantush (1967) method for circular recharge areas. WinFlow uses the approximate version of the Hantush mound equation, given as follows:

for $r < R$:

$$h^2 - h_i^2 = \frac{V}{2\pi K}[W(u_0) - (\frac{r}{R})^2 e^{-u_0} + \frac{1}{u_0}(1 - e^{-u_0})]$$

and for $r > R$:

$$h^2 - h_i^2 = \frac{V}{2\pi K}[W(u) + 0.5\, u_0 e^{-u}]$$

where:

h = the water-table elevation (above the datum plane)

h_i = the initial water-table elevation without the pond

K = hydraulic conductivity (L/T) of the aquifer

$W(u)$ = Theis well function

u_0 = $R^2/4vt$

u = $r^2/4vt$

t = time after start of infiltration

v = Kb/S

V = $w\pi R^2$

w = constant percolation rate (L/T)

S = storativity

b = $0.5[h_i + h]$

R = radius of the pond (L)

r = radius of calculation point from center of pond (L)

The Hantush (1967) mound solution was developed with the following simplifying assumptions:

- the water-table rise is less than 2 percent of the saturated thickness
- $t \geq 0.5\ r^2/v\ (u \leq 0.5)$ for $r < R$
- $t \geq 0.5\ R^2/v$ for $r > R$
- otherwise, it uses the same assumptions as the Theis solution.

Linesinks are simulated in the transient model using an approximate method. The linesink is discretized into *n* evenly spaced wells with one well located at either end of the linesink. Each well in the interior of the linesink pumps at a rate of Q/(n-1) and the wells at the endpoints of the linesink pump at a rate of 0.5 Q/(n-1). This approximation becomes more accurate as the number of wells increases. You control the number of wells used to approximate linesinks in WinFlow.

Solute Transport Model

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

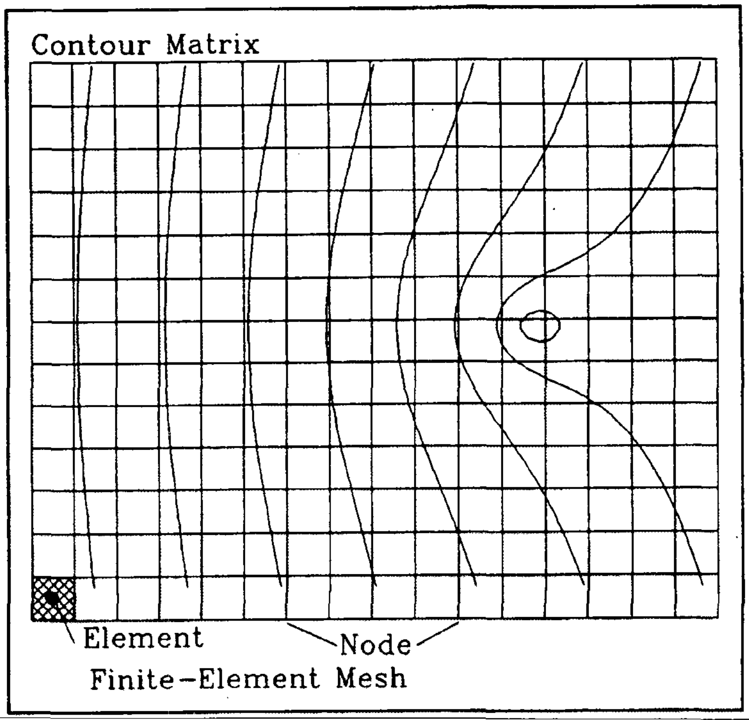
The hybrid analytical flow/numerical transport model combines the analytic element method developed by Strack (1989) with a finite- element transport technique developed by Huyakorn and others (1983). The model is constructed in six stages, most of which are transparent to the user. The six stages indude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

The Finite Element Transport Model

The solute transport model solves the partial differential equation describing the advection and dispersion of the dissolved species, as shown below:

$$\frac{\partial}{\partial x}(D_{xx}\frac{\partial c}{\partial x})+\frac{\partial}{\partial y}(D_{yy}\frac{\partial c}{\partial y})+\frac{\partial}{\partial x}(D_{xy}\frac{\partial c}{\partial y})+\frac{\partial}{\partial y}(D_{yx}\frac{\partial c}{\partial x})$$

$$-V_x\frac{\partial c}{\partial x}-V_y\frac{\partial c}{\partial y}=\phi R\frac{\partial c}{\partial t}+\lambda\phi Rc+q(c-c^*)$$

where c is the solute concentration (M/L^3); c' is the solute concentration in the injected water (M/L^3); D_{xx}, D_{yy}, D_{xy}, and D_{yx} are the components of the hydrodynamic dispersion tensor (L^2/T); ϕ is porosity (dimensionless); R is the retardation factor (dimensionless); q is the injection rate per volume of aquifer material ($L^3/T/L^3$); and λ is the first- order decay coefficient (T^{-1}). The Darcy velocity components are computed by the analytical flow model at the element centroids, as described above.

The dispersion coefficients are computed as described below:

$$D_{xx}=\frac{(\alpha_L-\alpha_T)V_x^2}{|V|}+\alpha_T|V|+D_{xx}^*$$

$$D_{yy}=\frac{(\alpha_L-\alpha_T)V_y^2}{|V|}+\alpha_T|V|+D_{yy}^*$$

$$D_{xy}=D_{yx}=\frac{(\alpha_L-\alpha_T)V_yV_x}{|V|}$$

where α_L is the longitudinal dispersivity, α_T is the transverse dispersivity, D* is the molecular diffusion coefficient (L^2/T), and |V| is the magnitude of the Darcy velocity (L/T).

The retardation factor is computed from the aquifer bulk density (ρ_s in M/L^3) and the distribution coefficient (k_d in L^3/M) as described below:

$$R=\frac{\rho_s k_d}{\phi}+1$$

Boundary conditions for the transport model include prescribed concentration and mixed- type boundaries. The latter are used around the edges of the finite- element mesh, where solute is removed if flow is exiting the model domain.

The solute transport equation is solved at each node in the finite element mesh using the Galerkin finite element method. A simplification has been adopted for rectangular elements with linear basis functions. The technique is called the influence coefficient method and is described by Huyakorn and others (1983). The finite element formulation results in a system of linear algebraic equations with an asymmetric banded coefficient matrix. The matrix is solved using a direct solver based on the LU decomposition of a banded matrix. The finite element equations are not presented but can be found in Huyakorn and others (1983) or in Huyakorn and Pinder (1983).

WinFlow/WinTran Verification

Introduction

Verification is the process of demonstrating that the computer program performs as documented. In the case of a model, such as WinFlow, verification tests for proper implementation of the applicable equations. These equations are documented in Chapter 5 and are tested in this chapter.

The steady-state and transient models are tested separately, as described below. In each case, the model is first tested using a simple example that can be solved with a calculator. Next, WinFlow computations are compared against either another code solving the same problem or against published answers. The steady-state model is further tested by comparing WinFlow results against those of a popular numerical model, MODFLOW (McDonald and Harbaugh, 1988).

Steady-state Model

Three sets of verification problems are presented for the steady-state analytical functions used in WinFlow. In the first problem, a simple uniform flow field with a single pumping well is solved using WinFlow and a calculator. This is one of the more common uses for WinFlow and illustrates that the basic code functions are programmed accurately. In the second case, a series of problems are benchmarked against the program SLWL (Strack, 1989). Finally, a simple test case of a single well in a uniform unconfined flow field is a benchmark against the numerical model, MODFLOW.

Case 1: Uniform Flow with a Single Well

The steady-state analytic function for a single well in a uniform flow field is given by Strack (1989) as follows:

$$\Phi = -Q_o(x\cos\alpha + y\sin\alpha) + \frac{Q}{4\pi}\ln[r^2(x,y)] + C$$

where

Φ = discharge potential $[L^3/T]$,

Q_o = uniform ground-water flow $[L^2/T]$,

x,y = coordinates of the calculation point,

α = angle between uniform flow and x-axis,

r(x,y) = distance from the well to the calculation point (x,y),

Q = well discharge $[L^3/T]$,

C = constant.

In a confined aquifer system, the discharge potential, Φ, is converted to head (ϕ) by the following equation.

$$\phi = \frac{\Phi + \frac{1}{2} KH^2}{KH}$$

where

ϕ = head [L],

K = hydraulic conductivity [L/T],

H = aquifer thickness [L].

The constant, C, is evaluated by specifying a reference head at a certain location within the flow system. The reference head remains constant during all subsequent calculations. The constant, C, is computed as follows:

$$C = \Phi_o + Q_o(x_o \cos\alpha + y_o \sin\alpha) - \frac{Q}{4\pi} \ln[r^2(x_o, y_o)]$$

where

Φ_o = reference discharge potential,

(x_o,y_o) = coordinates of reference head.

In the first verification problem, the aquifer is confined with a uniform regional gradient parallel to the x-axis. The problem assumptions and parameters are listed below.

K = 100 ft/d

H = 100 ft

Gradient (i) = 0.01 ft/ft

Q_o = KiH = 100 ft^2/d

reference head, ϕ_o = 200 ft at (x_o=0,y_o=0)

$\Phi_o = KH\phi_o - \frac{1}{2}KH^2 = 1500000$ ft^3/d

Q = 100,000 ft^3/d at (x=1000,y=1000)

Using these parameters and equation (3), the constant C equals 1,384,541. Table 1 lists the results of hand calculations and WinFlow results (using the Point Calculation option) for a series of coordinates. The two results are identical to five significant figures; the calculator results were rounded to five figures. Thus, WinFlow computes the correct answer for this test case.

Table 1 Comparison between WinFlow and calculator results for test case 1.

X	Y	Φ	ϕ	ϕ (WinFlow)
0	1000	1,494,480	199.45	199.448
250	1000	1,464,902	196.49	196.491
500	1000	1,433,449	193.34	193.345
750	1000	1,397,417	189.74	189.742
1000	1000	1,284,441	178.44	178.444
1250	1000	1,347,417	184.74	184.742
1500	1000	1,333,449	183.34	183.345
1750	1000	1,314,902	181.49	181.491
2000	1000	1,294,481	179.45	179.448

Case 2: Benchmark with SLWL

The SLWL program is provided with the book, Groundwater Mechanics, (Strack, 1989). SLWL performs the same calculations as WinFlow. The primary difference between the two codes is that SLWL is written in FORTRAN, while WinFlow is written in the C programming language. SLWL has additional capabilities to those of WinFlow but is not as user-friendly nor does SLWL have good output capabilities.

A series of twelve test cases are developed to test each of the major components in WinFlow, including wells, ponds, linesinks, and recharge. Each feature added to the simulation is designed to produce a significant impact on the flow field, so that significant errors would be easily detected. Both confined and unconfined conditions are tested. These verification data sets are included on the WinFlow disk. The data file names are VER1.WFL, VER2.WFL, ..., and VER12.WFL.

SLWL was modified to export a SURFER contour matrix (grid file) in the same manner as WinFlow. The SURFER grid files were then subtracted from one another to create a matrix of differences. A simple program was created to compute the mean and maximum difference. The results are summarized in Table 2. The features tested in each simulation are summarized in Table 2, along with the mean and maximum differences between the two codes. The specific details of each test may be examined by retrieving the verification data files from within WinFlow.

The maximum difference for each simulation was a uniform value of 0.000198 feet. The maximum error was constant, probably due to a consistent difference in the computational algorithms used in the C and FORTRAN compilers used for the two codes (Microsoft FORTRAN and Microsoft Visual C++). The mean error for each run varied from a low of 0.00000186 (VER6.WFL) to a high of 0.0000139

(VER7.WFL). In all cases, the differences between the two codes are on the order of 1.0×10^{-6} percent.

Table 2 Mean and maximum differences between WinFlow and SLWL in 12 test cases.

Data File	Uniform	Wells	Ponds	Line-sinks (head)	Line-sinks (flux)	Recharge	Aquifer Type (C/U)	Max. Error	Mean Error
ver1.wfl	✓	✓					C	0.000198	0.0000037
ver2.wfl	✓	✓					U	0.000198	0.0000019
ver3.wfl	✓	✓	✓				C	0.000198	0.0000038
ver4.wfl	✓	✓	✓				U	0.000198	0.0000020
ver5.wfl	✓	✓		✓			C	0.000198	0.0000051
ver6.wfl	✓	✓		✓			U	0.000198	0.0000019
ver7.wfl	✓	✓			✓		C	0.000198	0.0000014
ver8.wfl	✓	✓			✓		U	0.000198	0.0000066
ver9.wfl	✓	✓	✓	✓	✓		C	0.000198	0.0000048
ver10.wfl	✓	✓	✓	✓	✓		U	0.000198	0.0000030
ver11.wfl	✓	✓	✓	✓	✓	✓	C	0.000198	0.0000048
ver12.wfl	✓	✓	✓	✓	✓	✓	U	0.000198	0.0000030

Case 3: Benchmark with Numerical Model

A final test of the steady-state analytic functions in WinFlow is a comparison with a numerical model. The model chosen for comparison is MODFLOW (McDonald and Harbaugh, 1988), which is a three-dimensional, finite-difference ground-water flow model developed by the United States Geological Survey. MODFLOW is one of the most widely used numerical ground-water flow models.

A simple problem involving a single pumping well in a uniform flow field is chosen as the test case. The aquifer is unconfined with homogeneous properties. The model parameters are summarized below for the WinFlow data set.

K = 100 ft/d;

Aquifer bottom elevation = 0.0 ft;

Gradient (i) = 0.001 ft/ft at an angle of 0° to the x-axis;

$Q_o = KiH = 10\ ft^2/d$;

$\phi_o = 100$ ft at (x_o=0, y_o=0).

A single well located at coordinates (x=5000, y=5000) pumps 100,000 ft^3/d. The WinFlow input data file for this problem is provided on the distribution disk. The file name is "modfl.wfl".

Additional information is required to simulate the same system with a numerical model, such as MODFLOW. A finite-difference grid was constructed measuring 10,000 feet in both the x- and y-directions. There are 125 rows and 125 columns in the grid, with a cell spacing of 80 ft. A constant head of 100 ft was placed along the first column and a constant head of 89.532 was placed along the last column. The odd number was used to maintain a constant regional flow of 10 $ft^3/d/ft$ across the finite-difference grid under nonpumping conditions. The MODFLOW data set for this problem are contained on the WinFlow disk. Several files are required for input to the MODFLOW code. The files have a common root file name of "wflow" and a three-letter extension designating the MODFLOW package name. The MODFLOW files for this problem are as follows:

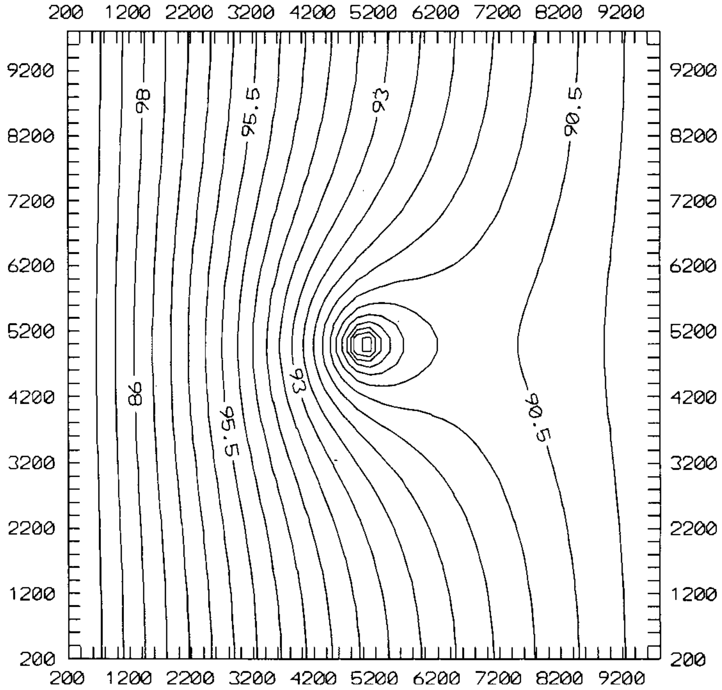
WFLOW.BAS	Basic Package Input
WFLOW.BCF	Block-Centered-Flow Package Input
WFLOW.SIP	Strongly Implicit Package Input
WFLOW.WEL	Well Package Input
WFLOW.OC	Output Control Input

The WinFlow and MODFLOW calculations were compared by producing a SURFER grid file with 50 rows and 50 columns. The grid corners are located at (x=200, y=200) and (x=9800, y=9800). The two grid files were subtracted from each other to obtain a head difference file. A simple program was written to compute the maximum and mean differences. Contour maps produced for the WinFlow and MODFLOW results are also shown in Figure 1.

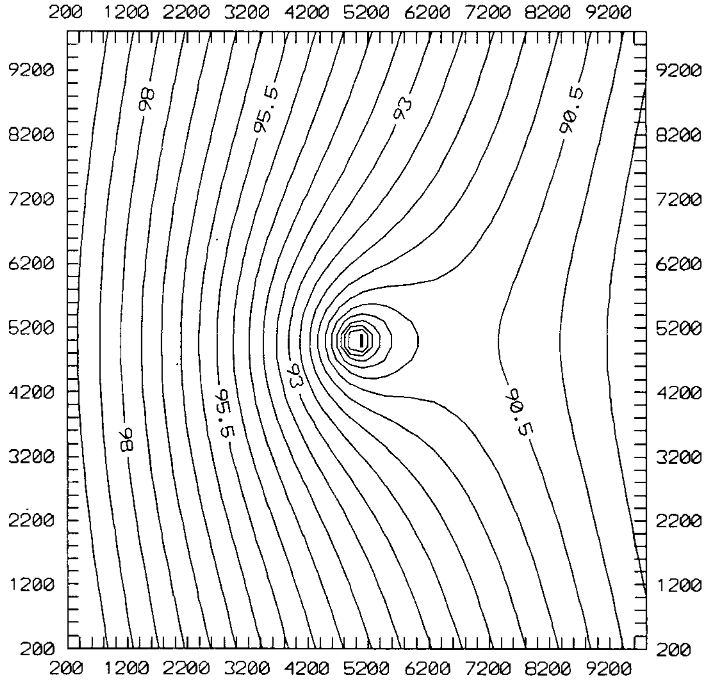
In the initial test case, MODFLOW and WinFlow compare favorably, with a maximum error of 0.84 feet and a mean error of 0.25 feet. The change in head across the model is 10.468 feet. Thus, there is a maximum difference of about 8 percent between the two codes. The contour maps shown in Figure 1 for the two codes are very similar. The primary difference is the behavior of the contours at the upper and lower (north and south) edge of the model. Contours from the MODFLOW run are perpendicular to the boundary, while WinFlow generated contours hit the boundary at an angle. This happens because MODFLOW treats the edge of the model as a no-flow or impermeable boundary forcing the contours to hit the boundary at right angles. WinFlow, on the other hand, assumes that the aquifer is infinite without any no-flow or impermeable boundaries.

A second test case was simulated by both WinFlow and MODFLOW in which no-flow boundaries were simulated with WinFlow. The northern and southern no-flow boundaries were reproduced in WinFlow using image wells. Two image wells were placed at coordinates (x=5000, y=15000) and (x=5000, y=-5000). Each image well pumped 100,000 ft^3/d. Contour maps for the second test case are shown in Figure 2. Now the WinFlow contours also strike the boundary at close to right angles. The maximum difference between WinFlow and MODFLOW for the second case is 0.39 feet, with a mean difference of 0.11 feet. This represents a significant improvement over the first test case. The maximum difference is 3.7 percent in this case.

The two test cases presented for the benchmark between WinFlow and MODFLOW show that both codes calculate similar head fields for the same problem. Even though the method of solution is different (analytical vs. numerical), each software package gives similar results. These comparisons provide the user with confidence that WinFlow is solving the ground-water flow equations properly.



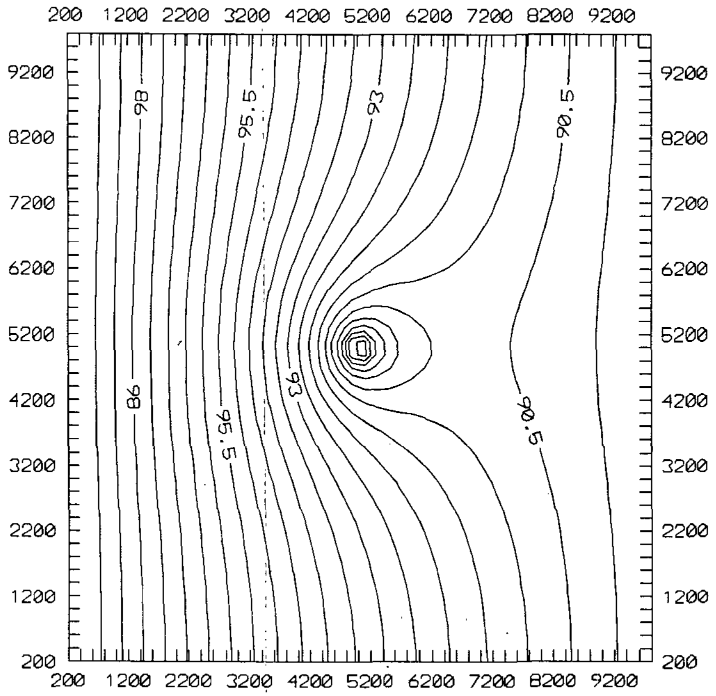
MODFLOW



WinFlow

Figure 1. Comparison between WinFlow and MODFLOW for Test Case 1.

MODFLOW



WinFlow with Image Wells

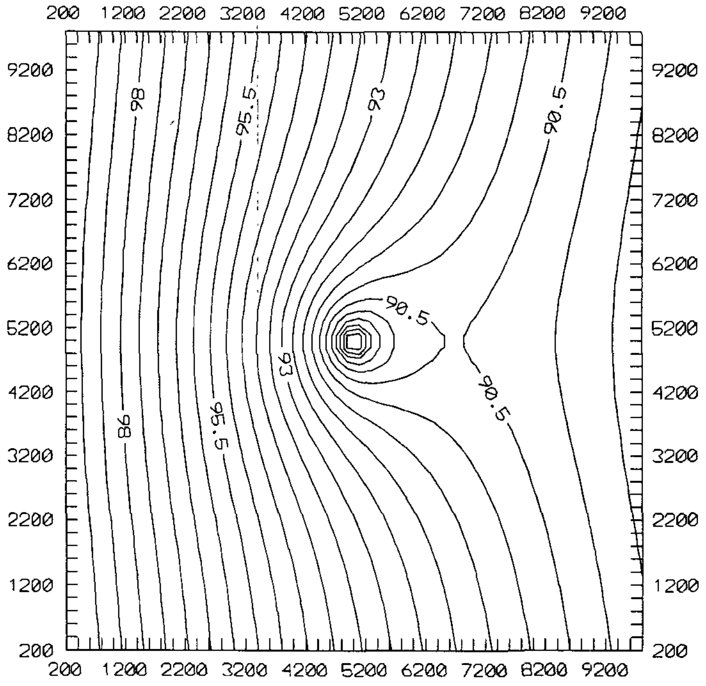


Figure 2. Comparison between WinFlow and MODFLOW for Test Case 2.

Transient Model

Three sets of verification problems are presented for the transient analytical functions used in WinFlow. In the first problem, drawdown is computed for a single well. In the second case, a uniform regional gradient is added to the problem. In each of the first two test cases, WinFlow calculations are compared to those performed with a calculator. The final test presents tables of the Theis (1935) and Hantush and Jacob (1955) well functions for comparison with published tables.

Case 1: Drawdown from a Single Well

The drawdown due to a single pumping well may be computed for any point in an aquifer using the following equation (Theis 1935):

$$s = \frac{Q}{4\pi T} W(u)$$

where

s = drawdown [L],

Q = well pumping rate [L^3/T],

T = transmissivity [L^2/T],

u = (r^2 S)/(4 T t),

r = distance between well and calculation point,

S = storage coefficient [dimensionless],

t = time after start of pumping [T],

W(u) = Theis well function.

In this example problem, we will choose the values of the parameters so that calculation is straightforward on a hand calculator and published tables of the Theis well function. The following parameters are used for Case 1:

T = 2500 ft^2/d

S = 0.01

t = 1.0 d

Q = 10,000 ft^3/d

WinFlow computed the same values of drawdown (s) as those computed using a calculator to four significant figures. The results of Case 1 are presented in Table 3.

Table 3 Comparison between WinFlow and calculator results for transient case 1.

Radius (ft)	u	W(u)	s (ft)	s (WinFlow)
1.0	10^{-6}	13.24	4.214	4.214
10.0	10^{-4}	8.633	2.748	2.748
20.0	4×10^{-4}	7.247	2.307	2.307
30.0	9×10^{-4}	6.437	2.049	2.049
40.0	1.6×10^{-3}	5.862	1.866	1.866
50.0	2.5×10^{-3}	5.417	1.724	1.724
60.0	3.6×10^{-3}	5.053	1.608	1.608
70.0	4.9×10^{-3}	4.746	1.511	1.511
80.0	6.4×10^{-3}	4.481	1.426	1.426
90.0	8.1×10^{-3}	4.247	1.352	1.352
100.0	0.01	4.038	1.285	1.285

Case 2: Drawdown from a Single Well in a Uniform Flow Field

The same parameters used in Case 1 above will be used in Case 2 and a uniform regional gradient will be added. Assume that the gradient is 0.001 ft/ft, with a reference head of 100 ft at the well. Because the transient model does not assume that the reference head is constant, the reference head may be specified anywhere (even at the well). We will also assume that the origin of the coordinate system (x=0, y=0) is at the well center.

The equation for a single well in a uniform flow field under transient conditions was given in the last chapter as

$$\phi(x,y,t) = C - G(x\cos\alpha + y\sin\alpha) - s$$

where

ϕ = head [L],

G = regional gradient [L/L],

α = angle between regional gradient and x-axis,

(x,y) = coordinates of calculation point,

t = time since start of pumping,

s = drawdown from well,

C = constant.

The constant, C, is equal to the reference head in this case.

The heads computed by WinFlow and using a hand calculator are presented in Table 4. Again, WinFlow results and the calculator results are identical to six significant figures.

Table 4 Comparison between WinFlow and hand calculations for transient case 2.

X	Y	ϕ	ϕ (WinFlow)

1.0	0.0	95.786	95.786
10.0	0.0	97.152	97.152
20.0	0.0	97.493	97.493
30.0	0.0	97.651	97.651
40.0	0.0	97.734	97.734
50.0	0.0	97.776	97.776
60.0	0.0	97.792	97.792
70.0	0.0	97.789	97.789
80.0	0.0	97.774	97.774
90.0	0.0	97.748	97.748
100.0	0.0	97.715	97.715

Case 3: Calculation of Well Function Tables

The first two transient test cases tested the ability of WinFlow to compute drawdown with and without a regional gradient. These tests illustrated that WinFlow internal drawdown calculations are properly implemented. A further test of the software is calculation of well function tables, which tests WinFlow's ability to accurately compute drawdown over a wide range of conditions.

WinFlow uses two transient analytical functions: (1) the Theis (1935) equation for confined aquifers, and (2) the Hantush and Jacob (1955) equation for semi-confined (or leaky) aquifers. Values of the Theis well function, W(u), were computed using the numerical routines in WinFlow for a wide range of values of u. These calculations are shown in Table 5. These values can be compared to any published values, although the format of the table is identical to that published by Kruseman and deRidder (1990) in Annex 3.1, page 294. Table 5 and Annex 3.1 (Kruseman and deRidder 1990) are identical, illustrating that WinFlow can calculate the Theis well function accurately over a wide range in u.

Similarly, the Hantush and Jacob (1955) well function, W(u,r/L), was computed using the routines in WinFlow for a range of u and r/L values. These are shown in Tables 6, 7, and 8. Kruseman and deRidder (1990) have published similar tables in Annex 4.2 (pages 298 and 299). The Kruseman and deRidder (1990) tables and Tables 6, 7, and 8 are identical, confirming that WinFlow accurately computes values for the Hantush and Jacob leaky well function.

Table 5 Theis well function, W(u), computed using routines in WinFlow.

u	W(u)	W(u 10^{-1})	W(u 10^{-2})	W(u 10^{-3})	W(u 10^{-4})	W(u 10^{-5})	W(u 10^{-6})	W(u 10^{-7})	W(u 10^{-8})	W(u 10^{-9})	W(u 10^{-10})
1.0	2.194e- 01	1.823e+00	4.038e+00	6.332e+00	8.633e+00	1.094e+01	1.324e+01	1.554e+01	1.784e+01	2.015e+01	2.245e+01
1.2	1.584e- 01	1.660e+00	3.858e+00	6.149e+00	8.451e+00	1.075e+01	1.306e+01	1.536e+01	1.766e+01	1.996e+01	2.227e+01
1.5	1.000e- 01	1.464e+00	3.637e+00	5.927e+00	8.228e+00	1.053e+01	1.283e+01	1.514e+01	1.744e+01	1.974e+01	2.204e+01
2.0	4.890e- 02	1.223e+00	3.355e+00	5.639e+00	7.940e+00	1.024e+01	1.255e+01	1.485e+01	1.715e+01	1.945e+01	2.176e+01
2.5	2.491e- 02	1.044e+00	3.137e+00	5.417e+00	7.717e+00	1.002e+01	1.232e+01	1.462e+01	1.693e+01	1.923e+01	2.153e+01
3.0	1.305e- 02	9.057e- 01	2.959e+00	5.235e+00	7.535e+00	9.837e+00	1.214e+01	1.444e+01	1.674e+01	1.905e+01	2.135e+01
3.5	6.970e- 03	7.942e- 01	2.810e+00	5.081e+00	7.381e+00	9.683e+00	1.199e+01	1.429e+01	1.659e+01	1.889e+01	2.120e+01
4.0	3.779e- 03	7.024e- 01	2.681e+00	4.948e+00	7.247e+00	9.549e+00	1.185e+01	1.415e+01	1.646e+01	1.876e+01	2.106e+01
4.5	2.073e- 03	6.253e- 01	2.568e+00	4.831e+00	7.129e+00	9.432e+00	1.173e+01	1.404e+01	1.634e+01	1.864e+01	2.094e+01
5.0	1.148e- 03	5.598e- 01	2.468e+00	4.726e+00	7.024e+00	9.326e+00	1.163e+01	1.393e+01	1.623e+01	1.854e+01	2.084e+01
6.0	3.601e- 04	4.544e- 01	2.295e+00	4.545e+00	6.842e+00	9.144e+00	1.145e+01	1.375e+01	1.605e+01	1.835e+01	2.066e+01
7.0	1.155e- 04	3.738e- 01	2.151e+00	4.392e+00	6.688e+00	8.990e+00	1.129e+01	1.359e+01	1.590e+01	1.820e+01	2.050e+01
8.0	3.767e- 05	3.106e- 01	2.027e+00	4.259e+00	6.554e+00	8.856e+00	1.116e+01	1.346e+01	1.576e+01	1.807e+01	2.037e+01
9.0	1.245e- 05	2.602e- 01	1.919e+00	4.142e+00	6.437e+00	8.739e+00	1.104e+01	1.334e+01	1.565e+01	1.795e+01	2.025e+01

Table 6 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	0.005	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
1.0e- 06	1.32e+01	1.08e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e- 06	1.25e+01	1.08e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
4.0e- 06	1.19e+01	1.07e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
6.0e- 06	1.14e+01	1.06e+01	9.44e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
8.0e- 06	1.12e+01	1.05e+01	9.43e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
1.0e- 05	1.09e+01	1.04e+01	9.42e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e- 05	1.02e+01	9.95e+00	9.30e+00	8.06e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
4.0e- 05	9.55e+00	9.40e+00	9.01e+00	8.03e+00	7.25e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
6.0e- 05	9.14e+00	9.04e+00	8.77e+00	7.98e+00	7.24e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
8.0e- 05	8.86e+00	8.78e+00	8.57e+00	7.91e+00	7.23e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
1.0e- 04	8.63e+00	8.57e+00	8.40e+00	7.84e+00	7.21e+00	6.67e+00	6.23e+00	5.87e+00	5.56e+00	5.29e+00	5.06e+00
2.0e- 04	7.94e+00	7.91e+00	7.82e+00	7.50e+00	7.07e+00	6.62e+00	6.22e+00	5.86e+00	5.56e+00	5.29e+00	5.06e+00
4.0e- 04	7.25e+00	7.23e+00	7.19e+00	7.01e+00	6.76e+00	6.45e+00	6.14e+00	5.83e+00	5.55e+00	5.29e+00	5.06e+00
6.0e- 04	6.84e+00	6.83e+00	6.80e+00	6.68e+00	6.50e+00	6.27e+00	6.02e+00	5.77e+00	5.51e+00	5.27e+00	5.05e+00
8.0e- 04	6.55e+00	6.55e+00	6.52e+00	6.43e+00	6.29e+00	6.11e+00	5.91e+00	5.69e+00	5.46e+00	5.25e+00	5.04e+00
1.0e- 03	6.33e+00	6.33e+00	6.31e+00	6.23e+00	6.12e+00	5.97e+00	5.80e+00	5.61e+00	5.41e+00	5.21e+00	5.01e+00
2.0e- 03	5.64e+00	5.64e+00	5.63e+00	5.59e+00	5.53e+00	5.45e+00	5.35e+00	5.24e+00	5.12e+00	4.98e+00	4.85e+00
4.0e- 03	4.95e+00	4.95e+00	4.94e+00	4.92e+00	4.89e+00	4.85e+00	4.80e+00	4.74e+00	4.67e+00	4.59e+00	4.51e+00
6.0e- 03	4.54e+00	4.54e+00	4.54e+00	4.53e+00	4.51e+00	4.48e+00	4.45e+00	4.41e+00	4.36e+00	4.30e+00	4.24e+00
8.0e- 03	4.26e+00	4.26e+00	4.26e+00	4.25e+00	4.23e+00	4.21e+00	4.19e+00	4.15e+00	4.12e+00	4.08e+00	4.03e+00
1.0e- 02	4.04e+00	4.04e+00	4.04e+00	4.03e+00	4.02e+00	4.00e+00	3.98e+00	3.95e+00	3.93e+00	3.89e+00	3.86e+00
2.0e- 02	3.35e+00	3.35e+00	3.35e+00	3.35e+00	3.34e+00	3.34e+00	3.33e+00	3.31e+00	3.30e+00	3.28e+00	3.26e+00
4.0e- 02	2.68e+00	2.68e+00	2.68e+00	2.68e+00	2.68e+00	2.67e+00	2.67e+00	2.66e+00	2.66e+00	2.65e+00	2.64e+00
6.0e- 02	2.30e+00	2.30e+00	2.29e+00	2.29e+00	2.29e+00	2.29e+00	2.29e+00	2.28e+00	2.28e+00	2.27e+00	2.27e+00
8.0e- 02	2.03e+00	2.03e+00	2.03e+00	2.03e+00	2.02e+00	2.02e+00	2.02e+00	2.02e+00	2.02e+00	2.01e+00	2.01e+00
1.0e- 01	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.82e+00	1.81e+00	1.81e+00	1.81e+00
2.0e- 01	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00	1.22e+00
4.0e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.02e- 01	7.01e- 01	7.01e- 01	7.00e- 01
6.0e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.54e- 01	4.53e- 01
8.0e- 01	3.11e- 01	3.11e- 01	3.11e- 01	3.11e- 01	3.11e- 01	3.10e- 01	3.10e- 01	3.10e- 01	3.10e- 01	3.10e- 01	3.10e- 01

Table 7 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	0.1	0.2	0.3	0.4	0.6	0.8
1.0e- 04	8.63e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
2.0e- 04	7.94e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
4.0e- 04	7.25e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
6.0e- 04	6.84e+00	4.85e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
8.0e- 04	6.55e+00	4.84e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
1.0e- 03	6.33e+00	4.83e+00	3.51e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
2.0e- 03	5.64e+00	4.71e+00	3.50e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
4.0e- 03	4.95e+00	4.42e+00	3.48e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
6.0e- 03	4.54e+00	4.18e+00	3.43e+00	2.74e+00	2.23e+00	1.56e+00	1.13e+00
8.0e- 03	4.26e+00	3.98e+00	3.36e+00	2.73e+00	2.23e+00	1.56e+00	1.13e+00
1.0e- 02	4.04e+00	3.82e+00	3.29e+00	2.71e+00	2.23e+00	1.56e+00	1.13e+00
2.0e- 02	3.35e+00	3.24e+00	2.95e+00	2.57e+00	2.18e+00	1.55e+00	1.13e+00
4.0e- 02	2.68e+00	2.63e+00	2.48e+00	2.27e+00	2.02e+00	1.52e+00	1.13e+00
6.0e- 02	2.30e+00	2.26e+00	2.17e+00	2.02e+00	1.85e+00	1.46e+00	1.11e+00
8.0e- 02	2.03e+00	2.00e+00	1.94e+00	1.83e+00	1.69e+00	1.39e+00	1.08e+00
1.0e- 01	1.82e+00	1.80e+00	1.75e+00	1.67e+00	1.56e+00	1.31e+00	1.05e+00
2.0e- 01	1.22e+00	1.22e+00	1.19e+00	1.16e+00	1.11e+00	9.96e- 01	8.58e- 01
4.0e- 01	7.02e- 01	7.00e- 01	6.93e- 01	6.81e- 01	6.65e- 01	6.21e- 01	5.65e- 01
6.0e- 01	4.54e- 01	4.53e- 01	4.50e- 01	4.44e- 01	4.36e- 01	4.15e- 01	3.87e- 01
8.0e- 01	3.11e- 01	3.10e- 01	3.08e- 01	3.05e- 01	3.01e- 01	2.89e- 01	2.73e- 01
1.0e+00	2.19e- 01	2.19e- 01	2.18e- 01	2.16e- 01	2.14e- 01	2.06e- 01	1.97e- 01
2.0e+00	4.89e- 02	4.89e- 02	4.87e- 02	4.85e- 02	4.82e- 02	4.72e- 02	4.60e- 02

Table 8 Hantush well function, W(u,r/L), computed using routines in WinFlow.

u	r/L = 0	1.0	2.0	3.0	4.0	5.0	6.0
1.0e- 02	4.04e+00	8.42e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
2.0e- 02	3.35e+00	8.42e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
4.0e- 02	2.68e+00	8.42e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
6.0e- 02	2.30e+00	8.39e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
8.0e- 02	2.03e+00	8.32e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
1.0e- 01	1.82e+00	8.19e- 01	2.28e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
2.0e- 01	1.22e+00	7.15e- 01	2.27e- 01	6.95e- 02	2.23e- 02	7.38e- 03	2.49e- 03
4.0e- 01	7.02e- 01	5.02e- 01	2.10e- 01	6.91e- 02	2.23e- 02	7.38e- 03	2.49e- 03
6.0e- 01	4.54e- 01	3.54e- 01	1.77e- 01	6.64e- 02	2.22e- 02	7.38e- 03	2.49e- 03
8.0e- 01	3.11e- 01	2.54e- 01	1.44e- 01	6.07e- 02	2.17e- 02	7.36e- 03	2.49e- 03
1.0e+00	2.19e- 01	1.85e- 01	1.14e- 01	5.34e- 02	2.07e- 02	7.27e- 03	2.49e- 03
2.0e+00	4.89e- 02	4.44e- 02	3.34e- 02	2.10e- 02	1.12e- 02	5.13e- 03	2.10e- 03
4.0e+00	3.78e- 03	3.58e- 03	3.06e- 03	2.35e- 03	1.63e- 03	1.03e- 03	5.86e- 04

Transport Model

Introduction

The finite-element transport model in WinTran is verified through comparison with an analytical solution from Wexler (1992) and with another finite-element transport model called SEFTRAN (Huyakorn et al., 1984). The Wexler analytical solution models transport of a dissolved contaminant from a point source in a two-dimensional uniform flow field. Six test cases were investigated with SEFTRAN for the three different source configurations (injection well, pond, and linesink) in both uniform flow and in non-uniform flow fields.

Comparison to an Analytical Solution

Wexler (1992) presents a series of analytical solutions to the partial differential equations of dissolved contaminant transport in porous media. WinTran was compared to the solution for a continuous point source in an aquifer of infinite extent (see page 26 of Wexler, 1992). The analytical solution was implemented by Wexler in a FORTRAN program called POINT2.

The data for the test problem are presented in Table 1. Concentration is plotted versus time at two locations downgradient of the source for both WinTran and SEFTRAN (see Figure 1). These curves show that WinTran results are virtually identical to those of the analytical solution. Contours for both WinTran results and POINT2 results are shown in Figure 2. Again, these contours are almost identical for the two solutions. The largest difference is at the source, where WinTran slightly underpredicts the source concentration. This is probably caused by dilution of the source concentration in the finite-element cell. The majority of the plume, however, matches quite well between WinTran and POINT2.

Comparison of WinTran to an analytical solution confirms that the basic transport model has been coded properly. The analytical solution, however, assumes that the flow field is uniform and the source is a single point and continuous over time. The next section presents a series of tests that illustrate that WinTran performs properly for more complex scenarios.

Table 1. Model Parameters for the Analytical Solution Comparison

Parameter	Value
Hydraulic conductivity	100 ft/d
Top Elevation	-75 ft
Bottom Elevation	-100 ft
Porosity	0.2
Hydraulic Gradient	0.01 to the East
Groundwater Velocity	5 ft/d
Longitudinal Dispersivity	30 ft
Transverse Dispersivity	3 ft
Retardation Coefficient	1
X coordinate of source	212.32 ft
Y coordinate of source	230.87 ft
Source fluid flow rate	-1 ft^3/d
Source concentration	100
Number of X nodes	70
Number of Y nodes	70
Minimum X coordinate	50.0 ft
Minimum Y coordinate	50.0 ft
Nodal Spacing in X	8.116 ft
Nodal Spacing in Y	5.652 ft
Number of time steps	50
Minimum time step size	0.5 day
Maximum time step size	10 days
Time step multiplier	1.1
Final time value	280.569 days

Figure 1. Time-series comparison between WinTran and an analytical solution at two downgradient nodes

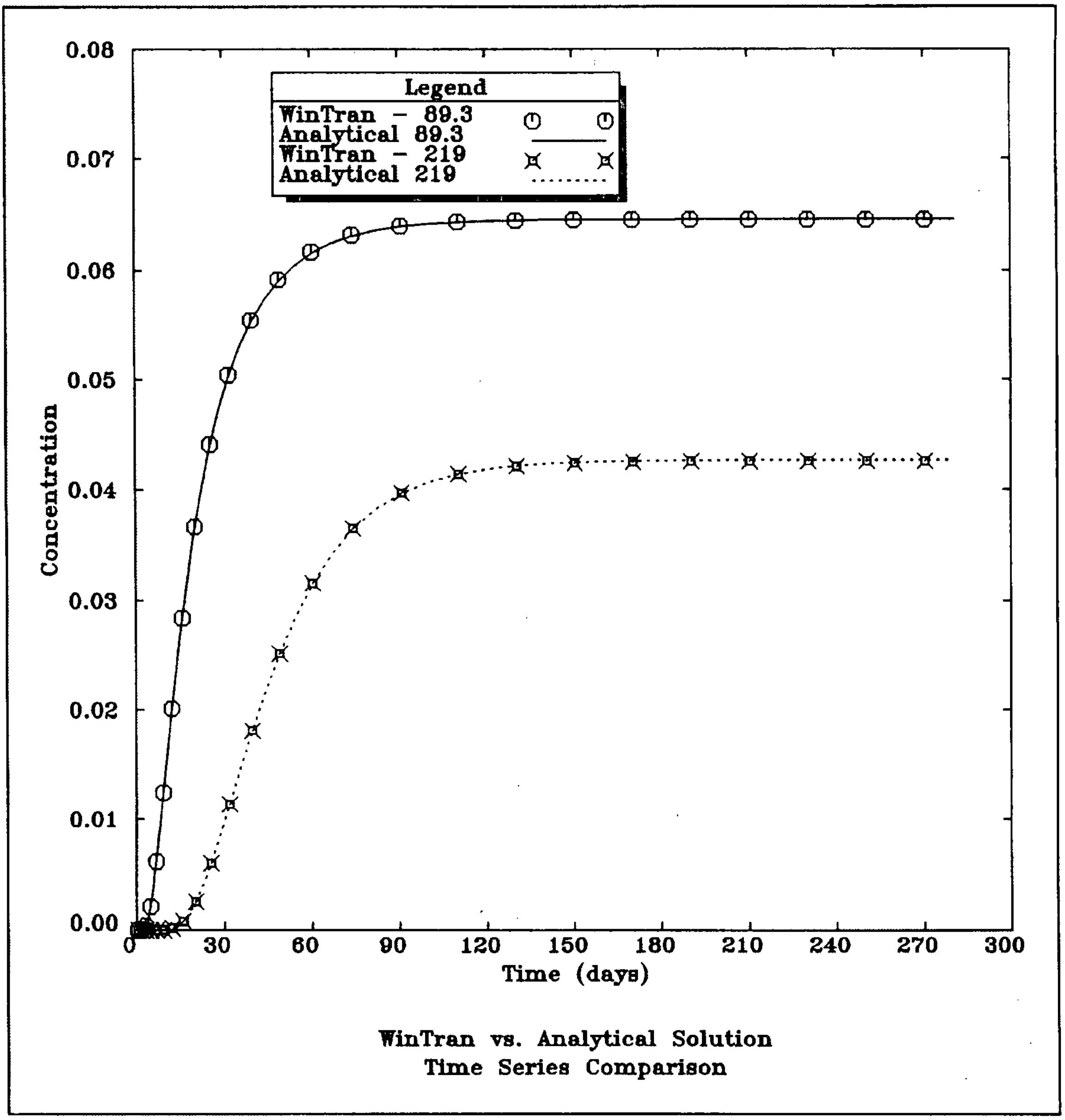
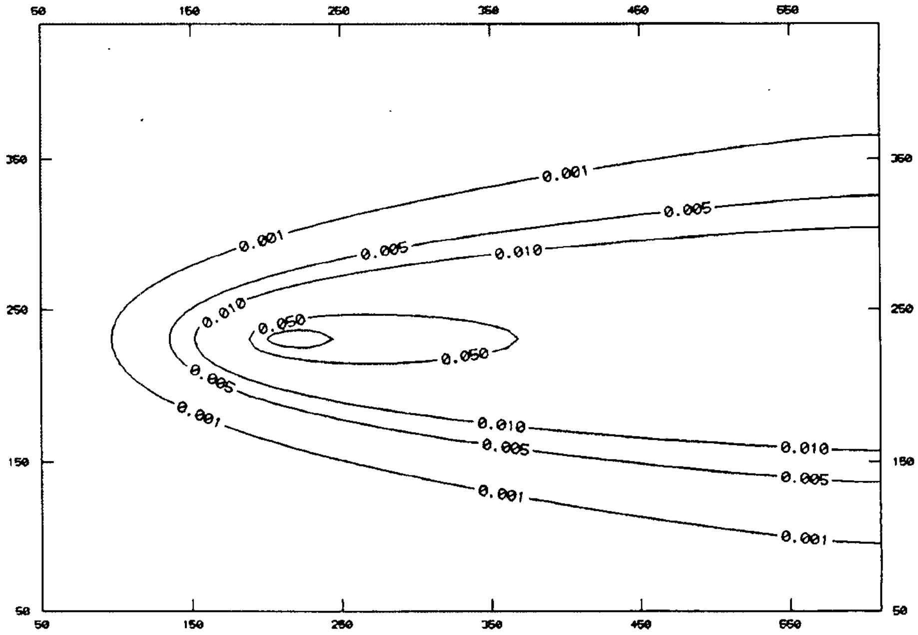
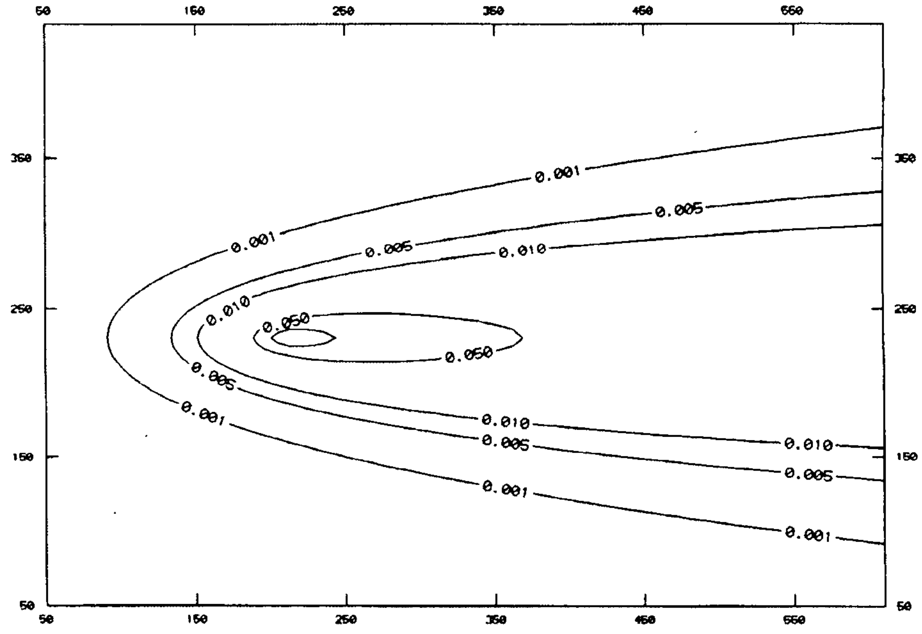


Figure 2. Concentration contours for WinTran and the analytical solution at time=260.569 days.

WinTran



Analytical Model



Benchmarking with SEFTRAN

SEFTRAN (Huyakorn et al., 1984) was chosen for the majority of testing because it uses the same finite-element techniques that are employed by WinTran. SEFTRAN also makes a good choice for benchmark testing because it has undergone a significant amount of testing at the International Ground Water Modeling Center (Huyakorn et al., 1984).

To facilitate this testing, a special option has been added to the WinTran Export menu allowing WinTran to create SEFTRAN data input files. Three files are created, (1) a SEFTRAN flow data set (always called FLOW.IN), (2) a SEFTRAN transport data set (you specify the name in the dialog), and (3) a velocity file with analytically-computed velocities (always called FLOW.VEL).

A series of six simulations were performed to test the three different source configurations (point source using an injection well, pond infiltration, and linesink injection). Each of the three source terms was tested in both a uniform flow field and a non-uniform flow field. The non-uniform flow field was produced by adding a pumping well downgradient from the source. The results for the six simulations are summarized in Table 2 and Table 2b. Data for the simulations are shown in Table 3.

The benchmark simulations are evaluated by presenting the following in Table 2: (1) maximum source concentration computed by WinTran and SEFTRAN, (2) the mean and maximum differences (errors) when SEFTRAN uses WinTran-computed velocities, (3) the mean and maximum differences when SEFTRAN uses SEFTRAN-computed velocities, and (4) mass balance errors for the two models. The source concentrations were scaled to a value of 1.0 in WinTran. The mass balance errors are in percent.

The mean and maximum differences between the two codes are very low for the case when each code uses velocities computed by WinTran. This tests the WinTran transport model because both codes are using the same velocity field. The tests illustrate that the transport model in WinTran is functioning properly for all cases. The mass balance error for each code is comparable for all cases and the source concentrations are accurate to the fourth decimal place.

The second set of errors (differences) presented in Table 2 are for SEFTRAN results computed using velocities computed by the SEFTRAN flow model. In the first set of differences described in the previous paragraph, the SEFTRAN transport model read velocity data computed by WinTran. The second set of comparisons, therefore, are used to evaluate the hybrid modeling approach. The results show that for uniform flow conditions, WinTran and SEFTRAN velocities produce virtually the same results. In a non-uniform flow field, however, the differences are larger. This indicates that the analytically-computed velocities are slightly in error.

Table 2b presents the differences between SEFTRAN and WinTran when velocities in WinTran are computed using finite elements (rather than the analytical model). In this case, the differences are very minor. Thus, for complex flow fields, you may want to consider using the finite-element flow model to compute velocities. You may select this option using the **Model->Flow Model Type** menu.

Figures 3 through 8 present concentration contour maps created by WinTran and SEFTRAN. These figures further substantiate that the two models are producing the same results.

Table 2. Comparison Between WinTran and SEFTRAN for Six Simulations.

Description	Maximum Conc.	Maximum Conc.	WinTran Velocities		Seftran Velocities		Mass Balance Error	Mass Balance Error
	WinTran	Seftran	Mean Error	Maximum Error	Mean Error	Maximum Error	WinTran	Seftran
Test 1 Point Source Uniform Flow	1.0	1.000052	-1.1e-05	7.5e-05	3.8e-05	7.0e-05	0.0129	0.00082
Test 2 Pond Source Uniform Flow	1.0	1.00024	-4.2e-05	2.4e-04	4.9e-05	1.99e-04	0.00758	0.0069
Test 3 Line Source Uniform Flow	1.0	0.99992	1.66e-05	2.04e-04	1.47e-04	2.4e-03	0.00438	0.018
Test 4 Point Source Nonuniform Flow	1.0	1.00005	-9.8e-06	7.3e-05	7.5e-06	5.8e-03	0.2057	0.195
Test 5 Pond Source Nonuniform Flow	1.0	0.99996	7.5e-06	7.23e-05	2.0e-05	0.045	0.147	0.136
Test 6 Line Source Nonuniform Flow	1.0	0.99991	1.06e-05	1.4e-04	4.2e-05	0.025	0.056	0.046

Table 2b. Comparison Between WinTran (Using the Finite Element Flow Model) and SEFTRAN for the Nonuniform Flow Test Cases.

Description	Mean Error	Maximum Error	WinTran Mass Balance Error
Test 4	-6.33e-06	6.78e-05	0.145
Test 5	1.3e-06	1.4e-04	0.161
Test 6	2.6e-05	2.7e-04	0.20

Table 3. Model Parameters for the SEFTRAN Benckmarking

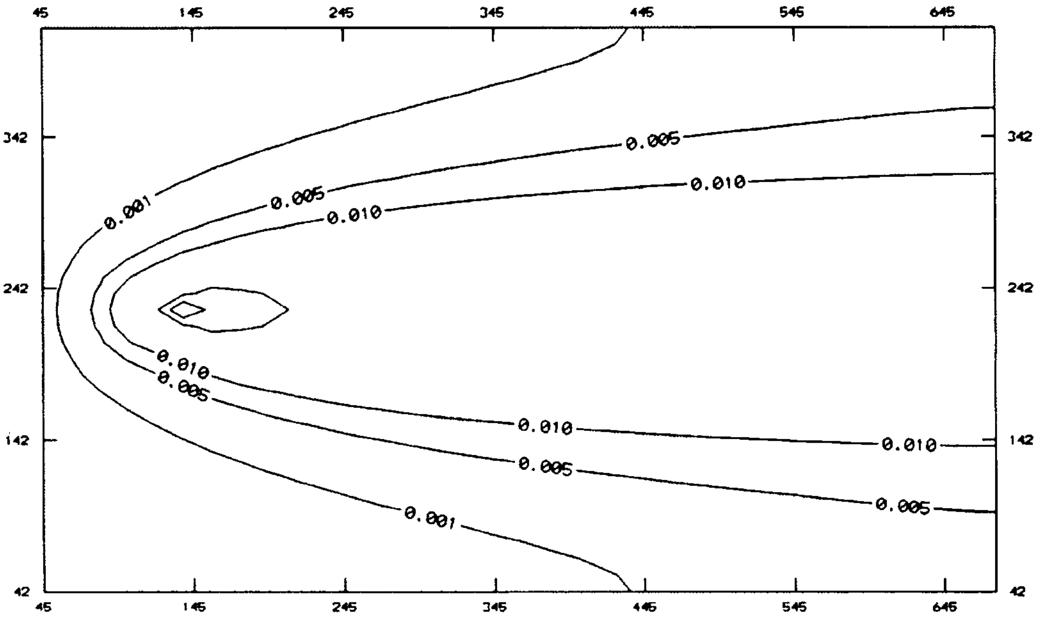
Parameter	Value
Hydraulic conductivity	100 ft/d
Top Elevation	100 ft
Bottom Elevation	0 ft
Reference Head	25 ft at (75,65)
Porosity	0.2
Hydraulic Gradient	0.01 to the East
Longitudinal Dispersivity	30 ft
Transverse Dispersivity	6 ft
Retardation Coefficient	1
Number of X nodes	35
Number of Y nodes	35
Minimum X coordinate	45.03 ft
Minimum Y coordinate	42.29 ft
Maximum X coordinate	678.81 ft
Maximum Y coordinate	413.66 ft
Number of time steps	30
Minimum time step size	1 day
Maximum time step size	100 days
Time step multiplier	1.2
Point Source Information (Simulation 1 and 4)	
Fluid Injection Râte	-1.0 ft^3/d
Concentration in fluid	100
Coordinates of Well (x,y)	(138.23,227.98)
Pumping Well Information (Simulations 4 through 6)	
Pumping Rate	10,000 ft^3/d
Coordinates of Well (x,y)	(604.25,315.36)

Table 3 (continued). Model Parameters for the SEFTRAN Benckmarking

Linesink Source Information (Simulations 3 and 6)	
Linesink Injection Rate	-1 ft^2/d
Concentration in fluid	100
Beginning Coordinates of line (x,y)	(145.27,275.11)
Ending Coordinates of line (x,y)	(143.65,167.59)
Pond Source Information (Simulations 2 and 5)	
Pond Infiltration Rate	0.0015 ft/d
Concentration in fluid	100
Pond Radius	24.68 ft
Coordinates of pond center (x,y)	(137.99,227.41)

Figure 3. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 1.

WinTran Results



SEFTRAN Results

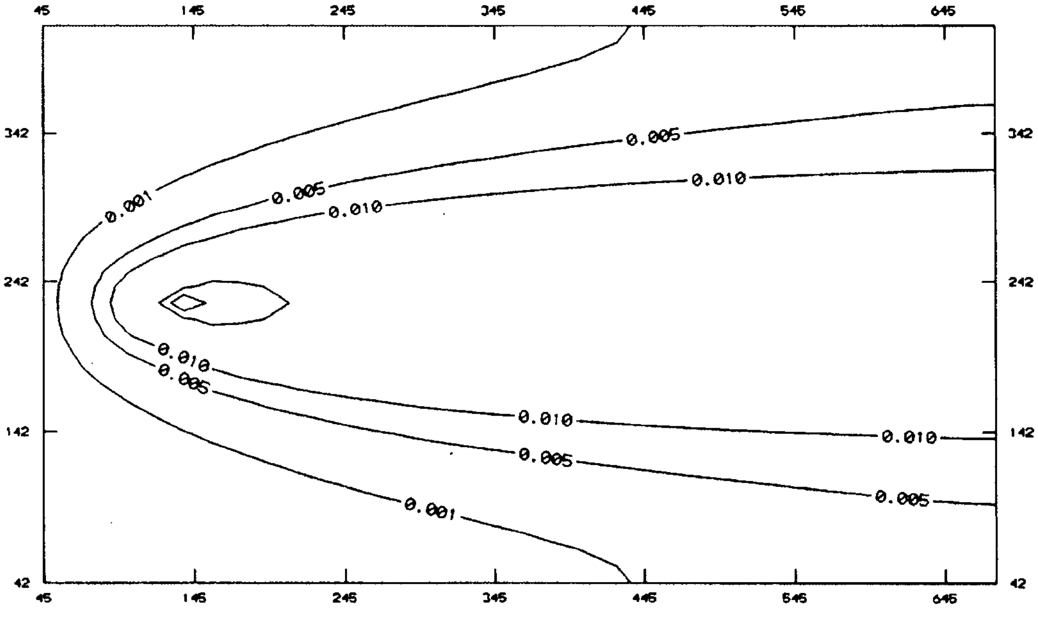
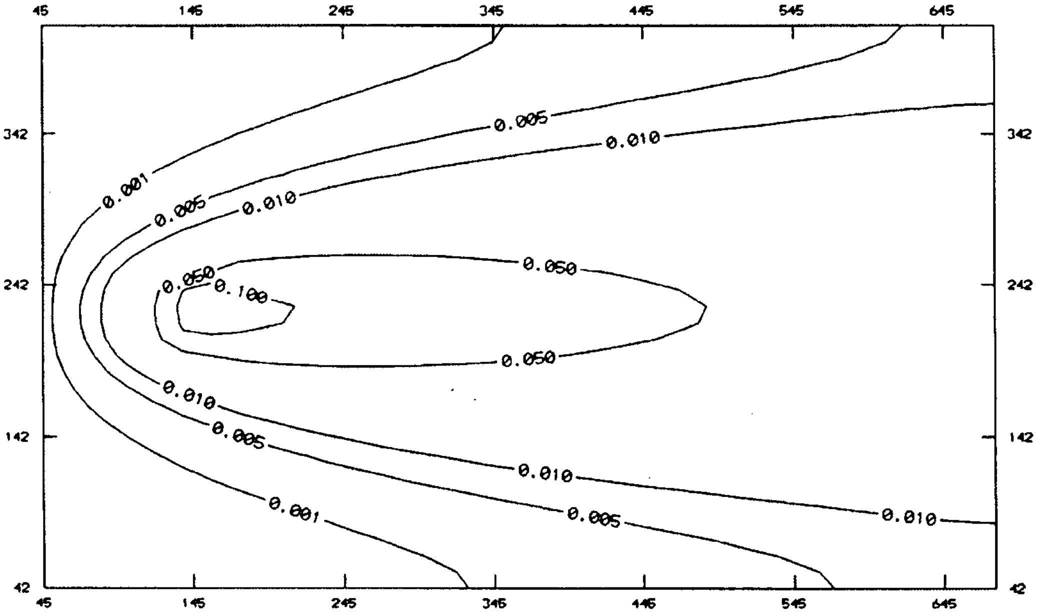


Figure 4. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 2.

WinTran Results



SEFTRAN Results

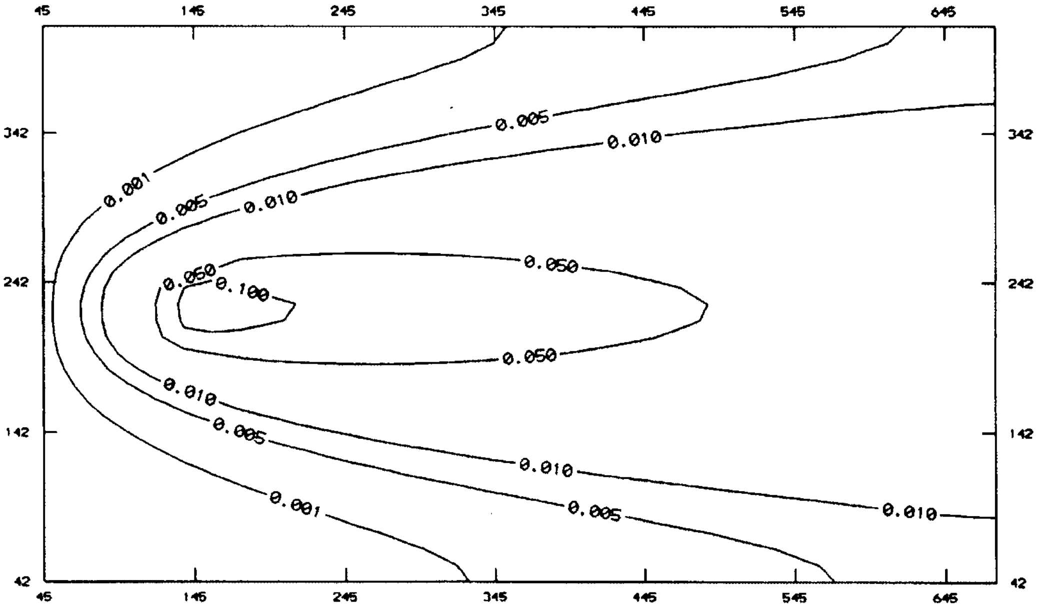
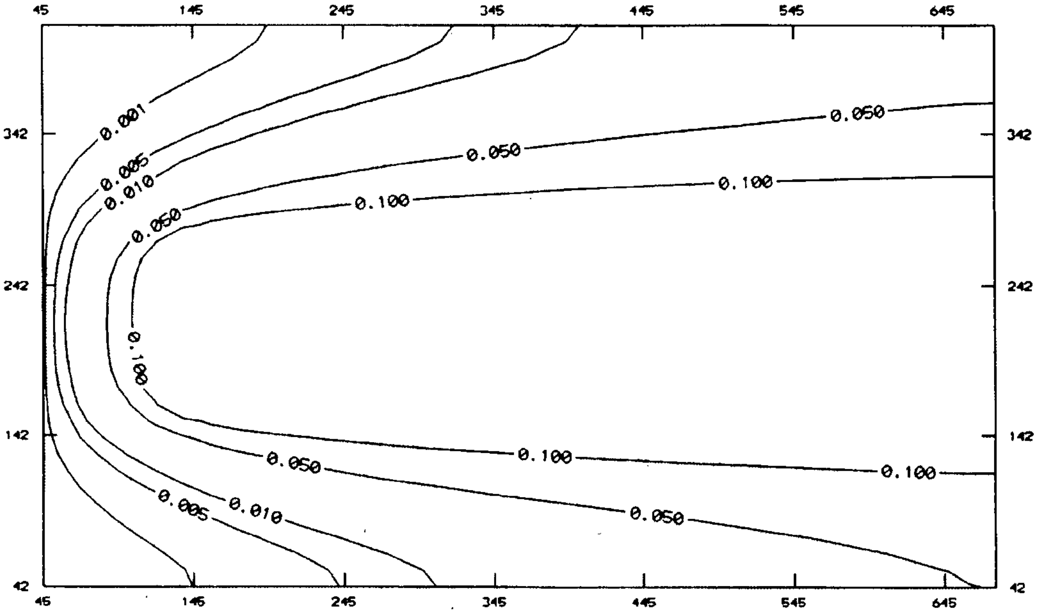


Figure 5. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 3.

WinTran Results



SEFTRAN Results

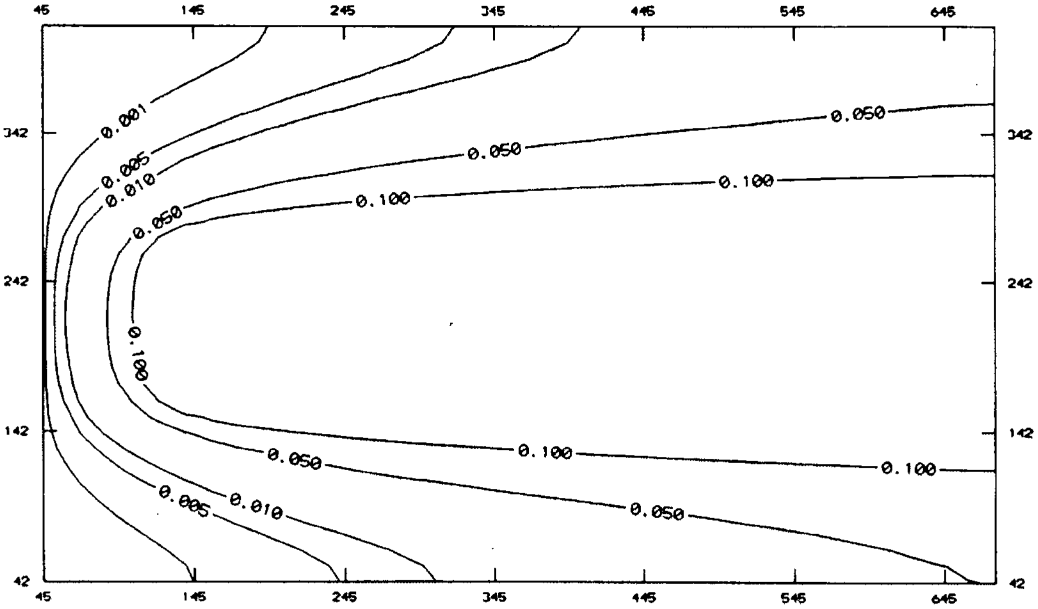
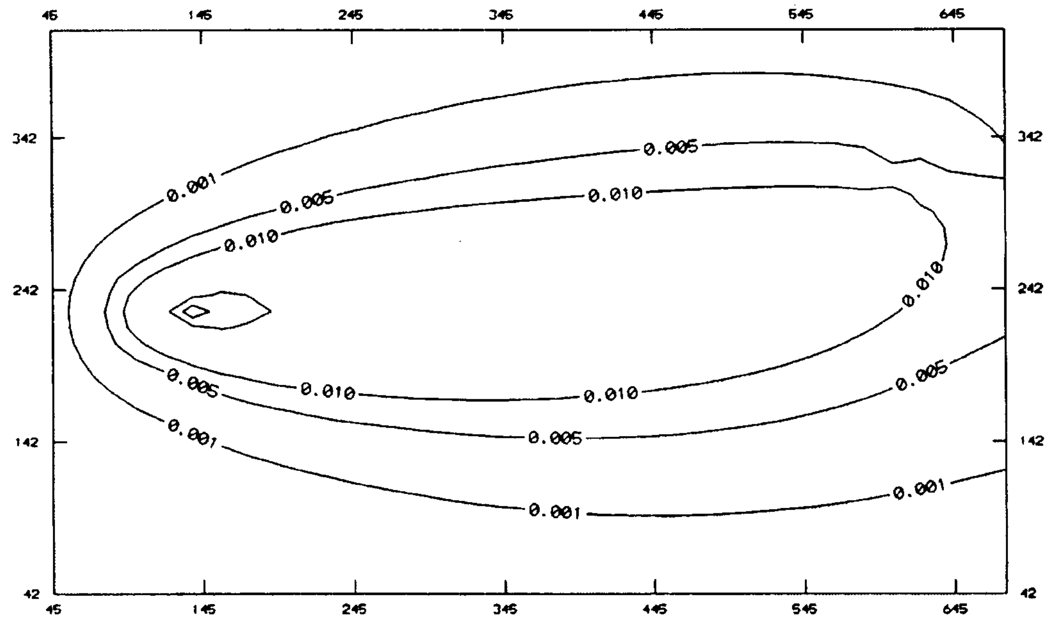


Figure 6. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 4.

WinTran Results



SEFTRAN Results

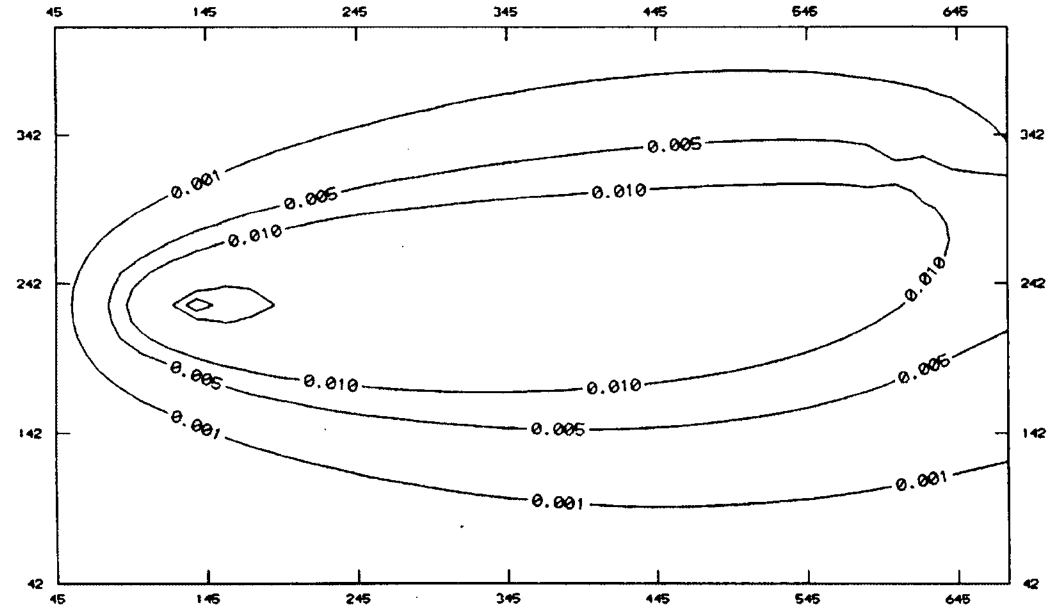
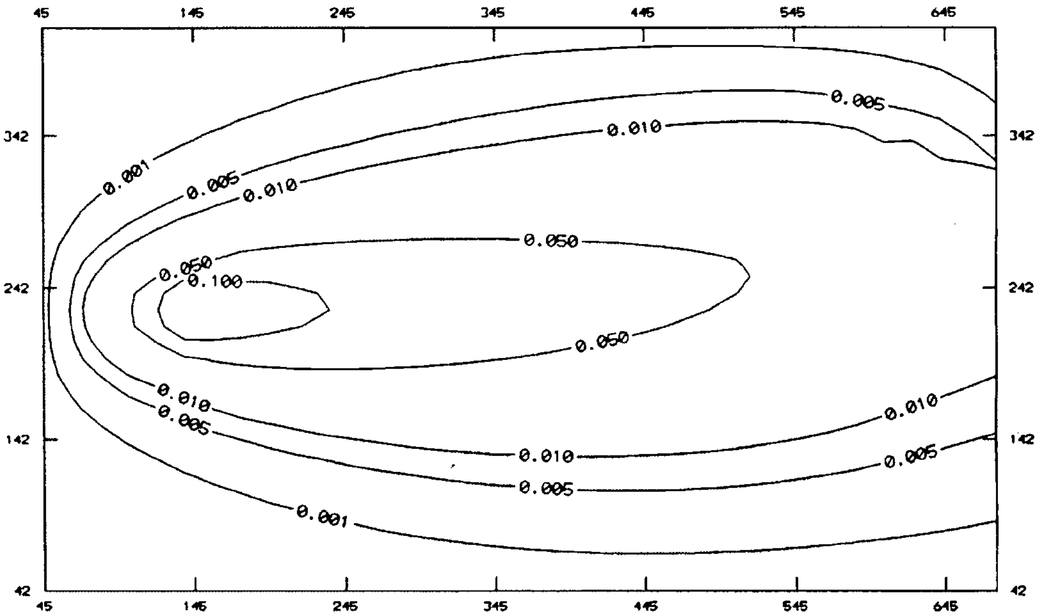
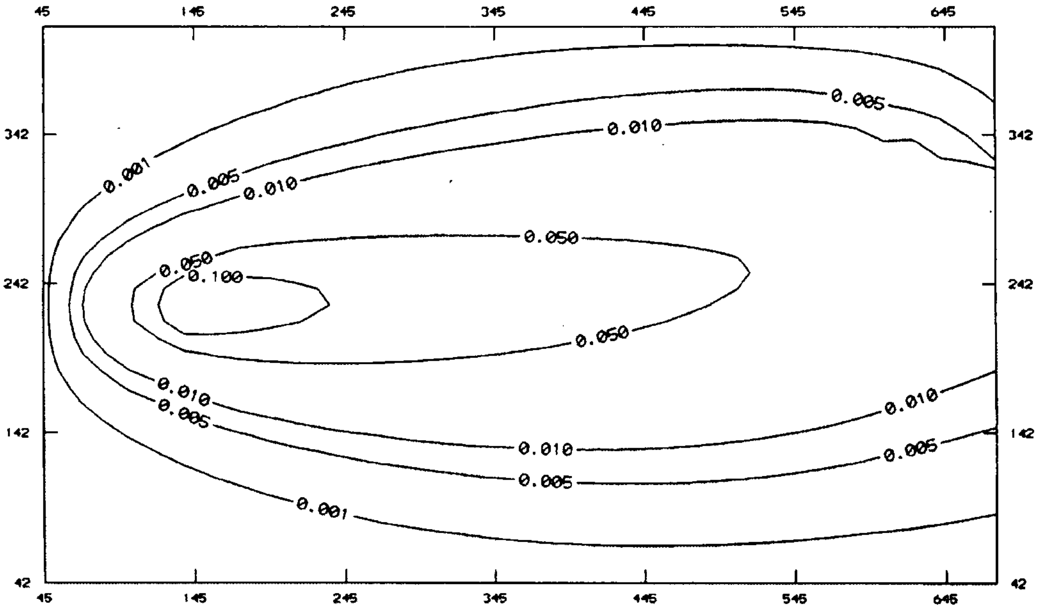


Figure 7. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 5.



WinTran Results



SEFTRAN Results

Figure 8. Concentration contours for WinTran and SEFTRAN at the final time step for Test Case 6.

WinFlow Application Guide

WinFlow Assumptions

It is important to understand the many simplifying assumptions inherent in an analytical model before the model can be applied to a real-world problem. Chapter 5 described the equations that are solved in WinFlow. Chapter 6 verified that these equations are properly implemented in the WinFlow software. This chapter presents potential applications of WinFlow to the solution of ground-water problems. First, however, some important assumptions are discussed as they apply to the practical application of WinFlow. For easy identification, the primary assumptions are underlined.

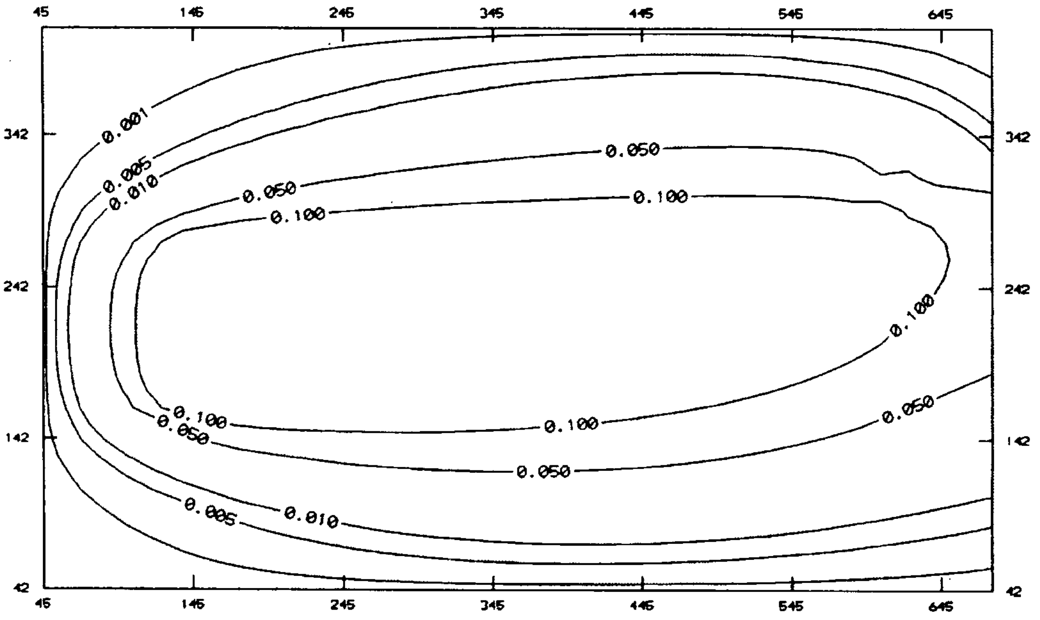
WinFlow is designed to solve two-dimensional ground-water flow problems in a horizontal plane. It is not designed for two-dimensional cross-sections (2D vertical plane). The two primary assumptions are that ground-water flow is horizontal and occurs in an infinite aquifer. WinFlow should not be applied to aquifers exhibiting strong vertical gradients unless the scale of the problem is such that horizontal flow can still be considered dominant. WinFlow 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. In the steady-state and transient models, the top of the aquifer is also horizontal and fixed at a given elevation. In the steady-state model, however, unconfined conditions are simulated when the hydraulic head is below the top of the aquifer. In the transient model, the aquifer is always confined, even when the head falls below the top of the aquifer.

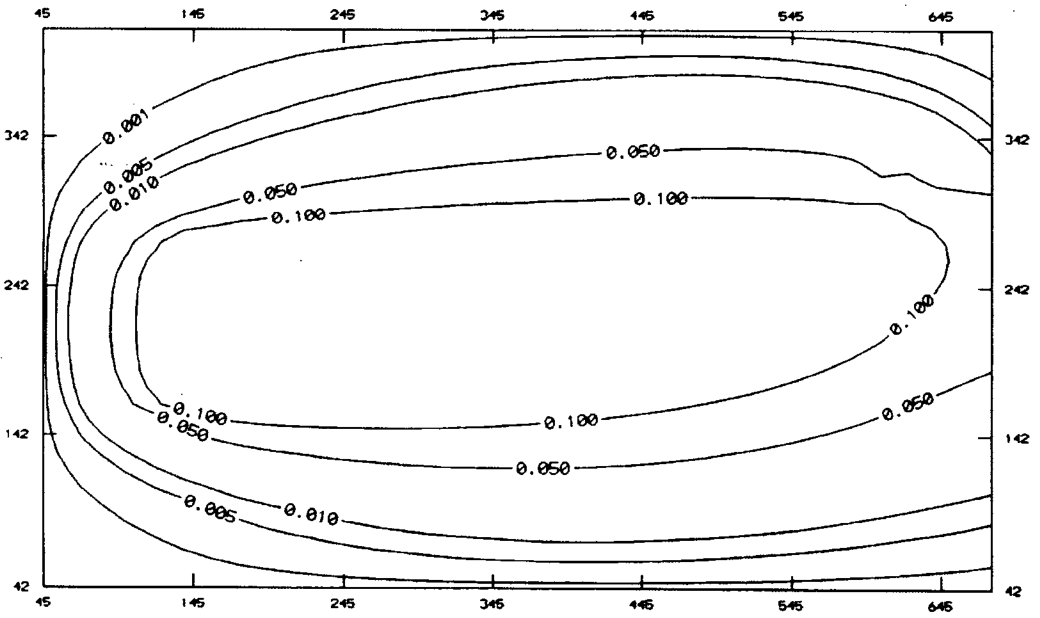
The reference head in the steady-state model is constant throughout all calculations. The reference head is analogous to a constant head boundary condition in a numerical model. It is therefore very important to keep the reference head far from the area of interest so that model predictions are not impacted.

The reference head in the transient model is only used in combination with the uniform gradient to compute an initial planar potentiometric surface. Drawdowns computed by either the Theis (1935) or the Hantush and Jacob (1955) methods are then subtracted from the planar potentiometric surface to obtain the resulting flow field. Drawdowns are also subtracted from the reference head in the transient model; however, there is an option that allows the user to keep the reference head constant in the transient model. This option should only be used when trying to compare the transient model to the steady-state model.

WinTran Results



SEFTRAN Results



All pumping rates, linesink fluxes, pond recharge, and elliptical recharge rates are constant through time. In the transient model, all wells start pumping or injecting water at time zero.

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 WinFlow 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 WinFlow, the capture zone extends upgradient until encountering a ground-water divide or infinity. This is an important consideration in designing a containment system.

Analysis of Remedial Actions

WinFlow can provide valuable guidance in designing a ground-water remediation system. The most obvious remedial action that WinFlow can simulate is "pump & treat" where the goal is to contain a volume of contaminated aquifer. WinFlow can simulate the effects of both pumping and injection wells. To illustrate the capture zone of a well, use reverse particle-tracking and start the particles in a circle around the well.

WinFlow can simulate trenches and drains using linesinks. There are two options in simulating drains: (1) specify a head to be maintained in the drain and WinFlow will compute the discharge rate necessary to achieve the given head; or (2) specify the discharge rate and compute the resulting head in the drain. To illustrate the capture zone of the drain, use reverse particle-tracking and start the particles along two lines on either side of the linesink.

WinFlow can simulate a lagoon closure by using ponds. To do this, set up the initial analytical model with ponds that simulate the lagoon. Adjust the pond recharge rate to match field-measured heads. Finally, remove the pond (or set the pond recharge equal to zero) to simulate the effects of closure.

The effects of capping can be simulated with a combination of elliptical recharge and circular ponds. Set up the initial analytical model using recharge to match field-measured heads. A circular cap can then be simulated with a pond that has a recharge rate equivalent to the regional recharge rate but opposite in sign (e.g. negative).

Pumping Test Analysis and Design

WinFlow's transient model can simulate the effects of a pumping test to facilitate interpreting test results or designing a future test. Pumping test results can be interpreted by contouring drawdown at a specified time after the start of the test. To contour drawdown, set the reference head equal to zero and the gradient equal to zero. Make sure that the top of the aquifer is less than zero if the steady-state model is used.

Drawdowns computed by WinFlow can be compared to drawdown contours from the pumping test. Hydraulic conductivity and storage can be adjusted until a reasonable match between observed and computed drawdown is achieved. Image wells can be added to the model to simulate boundary effects. Use calibration targets to provide a quantitative match between the results of your aquifer test and the model calculations.

When designing an aquifer test, WinFlow estimates the drawdown likely to occur at selected times and at various distances from the pumping well. Time and drawdown estimates can help select appropriate wells to monitor and determine the length of the test.

Regional Modeling

Strack (1989) advocates the use of "analytic element models" (his term for the superposition of analytical functions) in regional flow system modeling. At a regional scale, most aquifers are very thin compared to the distance across the aquifer in the horizontal plane. Thus, the z-axis (vertical dimension) becomes quite small and vertical gradients are negligible compared to horizontal gradients. In this case, the problem becomes two-dimensional and can be easily simulated with analytical functions.

The regional model is constructed using linesinks to simulate rivers and streams. Recharge from precipitation is applied in a large ellipse covering the area of interest. Circular recharge areas (ponds) simulate lakes. Obviously, wells represent areas of ground-water extraction, such as wellfields.

Strack (1989) has developed many complex analytical functions or analytic elements to facilitate regional modeling. The Single-Layer Analytic Element Model (SLAEM) developed by Strack contains these advanced functions not available in WinFlow. SLAEM is available from Dr. Strack.

Well Head Protection

Many states are requiring water companies to model the ground-water flow system around all public supply wells to determine the "zone of contribution" for each well. Small water companies will find it difficult to pay for expensive numerical modeling studies. WinFlow is ideally suited for these small wellfields, because a simple regional model can be constructed to comply with wellhead protection regulations at little cost. WinFlow can also be useful for preliminary studies at larger wellfields prior to numerical modeling.

To determine the zone of contribution for a particular time of travel, use reverse particle-tracking. Start the particles in a circle around each well and set the maximum travel time to the desired value.

WinTran Application Guide

Introduction

This chapter presents the major assumptions inherent in WinTran and guidelines for the use of the transport model. These guidelines include estimating memory requirements, dealing with model instabilities, and suggestions for simulating various transport scenarios.

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). <u>The two primary assumptions are that ground-water flow is horizontal and contaminant concentrations are the same throughout the entire aquifer thickness</u>. 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 <u>aquifer hydraulic conductivity is assumed to be isotropic and homogeneous.</u> 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.

<u>The reference head in the flow model is constant throughout all calculations</u>. 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.

<u>All pumping rates, linesink fluxes, pond recharge, and elliptical recharge rates are constant through time</u>. 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.

Memory Requirements

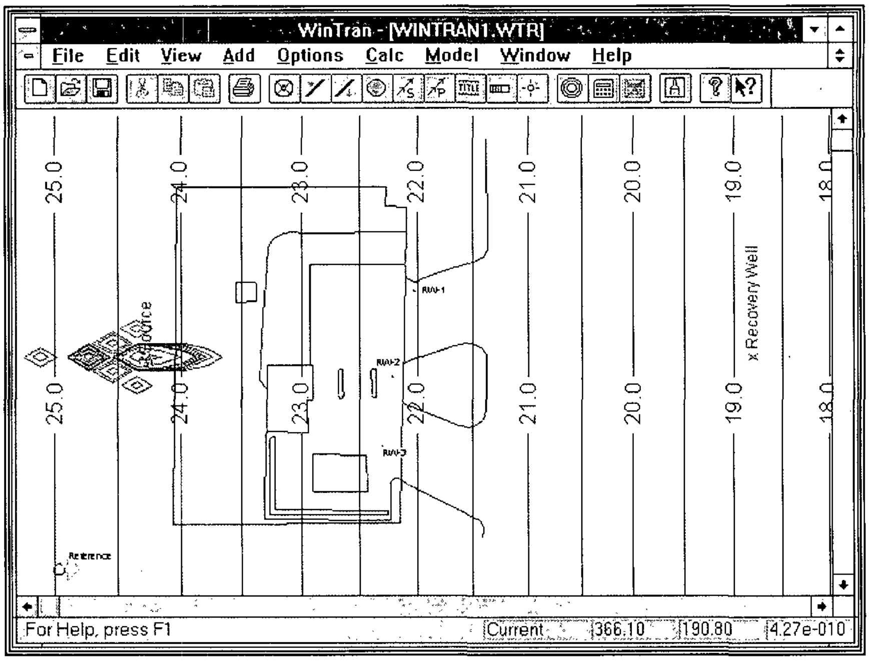
WinTran uses a substantial amount of computer memory to solve the finite-element transport model. The amount of memory required for each model is determined by the size of the contour matrix. The default size of the contour matrix is 35 x 35 (35 nodes in both the X- and Y-directions). In this case, the model requires about 1 megabyte of memory. The maximum matrix size allowed in WinTran is 100 x 100, requiring about 18 megabytes of memory. Other matrix sizes and memory requirements are shown below:

Matrix Size	Memory Required
35 x 35	1 megabyte
50 x 50	2.6 megabytes
75 x 75	8 megabytes
100 x 100	18 megabytes

Problems with Model Stability

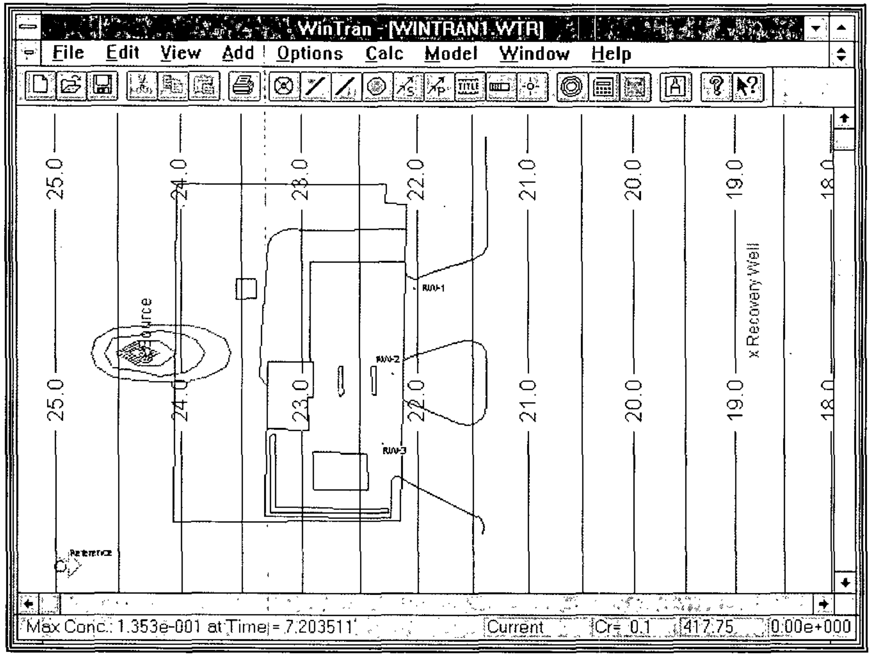
Numerical transport models require the user to carefully evaluate each simulation for potential errors. WinTran assists you in evaluating model error by displaying the mass balance error on the status bar when the transport model is running. The mass balance error is expressed as a percentage and should be less than 10 percent for a valid simulation. Usually, the mass balance error is less than 1 percent.

Even if the mass balance error is below 10 percent, there can be oscillations in the transport solution. Oscillations are indicated by negative concentrations computed by WinTran. In extreme cases, alternating nodes will have positive and negative concentrations producing diamond-shaped contours. The following screen shows a contour pattern that is typical of numerical oscillations:



Note the diamond shaped contours upgradient of the source. These contours are produced because alternating nodes are positive and negative. The contouring routine draws "bulls-eyes" around these high and low points producing the diamond-shaped contours. This is very typical of oscillating solutions and is probably the most common problem you will run into with WinTran.

The pattern above was produced in the tutorial model by lowering the time-step size to 0.1 days, using centered-in-time, and reducing the longitudinal dispersivity to 3 ft. This produces a Peclet number of 6.2, which is above the recommended limit of 2. In the screen shown below, the dispersivity value was increased to 30 ft, dropping the Peclet number to 0.62. This was enough to remove the oscillations.



Max Conc.: 1.353e-001 at Time = 7.203511 Cr= 0.1 417.75 0.00e+000

When the transport solution oscillates, check the following:

(1) The Peclet number is displayed on the status bar as "Pe=" and is computed by dividing the nodal spacing (the distance between nodes in the contour matrix) by the longitudinal dispersivity. The Peclet number should generally be less than 2 for a stable solution. If you are experiencing mass balance problems or oscillations, increase dispersivity until the Peclet number is less than 2, as described above.

(2) The Courant number is another criterion used to judge the stability of a transport simulation. The Courant number is computed as the velocity times time-step size divided by nodal spacing. This criterion is displayed as "Cr=" on the status bar and should generally be less than 1. Again, if you are experiencing mass balance or oscillation problems, try decreasing the initial and maximum time-step sizes.

There are also times when the Courant number is too low. In cases where the Courant number is less than 0.1, there can be round-off errors in the matrix solver. In this case, you should increase the initial and maximum time-step sizes until the Courant number is close to 1.

There are two other WinTran options that can aid in model stability. These include the time discretization method (backward and centered in time) and upstream weighting. The time discretization methods are selected using the **Edit->Time Stepping** menu. Backward in time is unconditionally stable but is only first-order accurate, while centered in time is second-order accurate but may be subject to instability (Javandel et al., 1984). It is usually best to start with backward in time.

Upstream weighting factors in the X- and Y-directions are edited from the **Edit->Transport Parameters** menu. Upstream weighting factors of 1.0 indicate full upstream weighting, while a weighting factor of 0.0 turns off upstream weighting. Upstream weighting adds stability to the solution (helps eliminate oscillations) at the expense of added numerical dispersion. Numerical dispersion is artificial dispersion that produces similar results to an increase in the dispersivity coefficient.

Analysis of Remedial Actions

Setting Up the Flow Model

WinTran can provide valuable guidance in designing a ground-water remediation system. The most obvious remedial action that WinTran can simulate is "pump & treat" where the goal is to contain a volume of contaminated aquifer. WinTran can simulate the effects of both pumping and injection wells.

WinTran can simulate trenches and drains using linesinks. There are two options in simulating drains: (1) specify a head to be maintained in the drain and WinTran will compute the discharge rate necessary to achieve the given head; or (2) specify the discharge rate and compute the resulting head in the drain. To illustrate the capture zone of the drain, use reverse particle-tracking and start the particles along two lines on either side of the linesink.

WinTran can simulate a lagoon closure by using ponds. To do this, set up the initial analytical model with ponds that simulate the lagoon. Adjust the pond recharge rate to match field-measured heads. Finally, remove the pond (or set the pond recharge equal to zero) to simulate the effects of closure.

The effects of capping can be simulated with a combination of elliptical recharge and circular ponds. Set up the initial analytical model using recharge to match field-measured heads. A circular cap can then be simulated with a pond that has a recharge rate equivalent to the regional recharge rate but opposite in sign (e.g. negative).

Setting Up the Transport Model

Remedial alternatives are usually simulated in several stages, as described below:

(1) Calibrate the transport model to the observed contaminant plume. This is accomplished by adding source terms to the model (injection wells, infiltrating ponds, or injecting linesinks) and adjusting the source concentration until the desired plume is simulated. The length of the simulation should be chosen to approximate the length of time that the source of contamination has been effecting the groundwater system.

An alternative approach to calibrating the plume configuration is to import a SURFER grid file (e.g. test.grd) containing the contaminant distribution data (use **File->Import** from the main menu). The contoured concentrations are then used as initial conditions for the remedial simulation.

(2) Save the calibrated concentrations as initial conditions using the **Calc->Restart** option on the main menu. Skip this step if you have imported a SURFER grid file for initial conditions.

(3) Add the remediation system (pumping wells or linesinks, etc.) and rerun the transport model. To simulate source removal, delete the source terms added in State 1 above. This is accomplished by moving the cursor over the source element (well, pond, or linesink) until the four-arrow cursor (✥) is displayed. Click the left mouse button to select the element and then press the delete key or select **Edit->Delete** from the main menu. Now, rerun the transport model to simulate source removal.

At any time during the simulations, you may save concentrations for later restart using the **File->Export** menu. Exporting concentration as a restart file (*.rst) will allow you to **Import** these concentrations in later simulations.

Simulating Biodegradation

Simulating the biodegradation of organic compounds is a popular modeling scenario, especially for dissolved hydrocarbons. WinTran does not simulate these complex degradation processes; however, the decay term in WinTran can be used to approximate biodecay. The biodegradation process is reduced to specifying a half-life for the compound. The half-life is the time required to remove half of the original mass. While the half-life is most often used for radioactive elements, such as uranium, it can also be used to express the decay of organic compounds through biodecay. The *Handbook of Environmental Degradation Rates* (Howard et al., 1991) is a good reference for contaminant half-life data.

Performing Risk Assessments

WinTran is not a risk assessment model but can be useful in risk assessments by providing concentration data over time at receptor locations. To obtain the concentration over time at these receptor locations, you must add a well at the receptor. Specify the flow rate as zero (0.0) and check the "Observation well" option on the well dialog. These concentration-time data may then be saved to a file for use in other programs. To save these data, select **File->Export** and choose the file time **Conc-Time** (*.cvt). The file is a DOS text file delimited by commas. The first line contains the well names and subsequent lines list the time and concentration for each well.

References

ASTM Standards

D 4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to instantaneous Change in Head (Slug Tests), ASTM, 4 p.

D 4105 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method, ASTM, 5 p.

D 4106 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method, ASTM, 5 p.

D5920-96. Test Method (Analytical Procedure) for Tests of Anisotropic Unconfined Aquifers by Neuman Method, ASTM, 8 p.

Books

Bear, J. And A. Verruijt, 1987, *Modeling Groundwater Flow and Pollution*, D. Reidel Publishing Company, Boston, 414 p.

Butler, J. J., Jr., 1998, *The Design, Performance, and Analysis of Slug Tests,* Lewis Publishers, CRC Press, Boca Raton, Florida, 252 p.

Horne, R. N., 1995, *Modern Well Test Analysis*, Petroway, Inc., Palo Alto, California, 257 p.

Howard, P., R. Boethling, W. Jarvis, W. Meylan, and E. Michalenko, 1991, *Handbook of Environmental Degradation Rates*, Lewis Publishers, Inc., Chelsea, MI.

Huyakorn, P.S., A.G. Kretschek, R.W. Broome, B.H. Lester, J.W. Mercer, 1984, Testing and Validation of Models for Simulating Solute Transport in Groundwater: Development, Evaluation, and Comparison of Benchmark Techniques, International Groundwater Modeling Center Report GWMI 84-13, Golden, Colorado.

Javandel, I., C. Doughty, and C.F. Tsang, 1984, *Groundwater Transport: Handbook of Mathematical Models*, American Geophysical Union, Water Resources Monograph 10, Washington, D.C.

Kruseman, G.P. and N.A. de Ridder, 1990, *Analysis and Evaluation of Pumping Test Data*, Second Edition, ILRI publication 47, International Institute for Land Reclamation and Improvement, The Netherlands, 377 p.

Lohman, S.W., 1979, *Ground-Water Hydraulics*, U.S.G.S. Professional Paper 708, 70 p.

Reed, J.E., 1980, *Type Curves for Selected Problems of Flow to Wells in Confined Aquifers*, USGS TWRI Book 3, Chapter B3.

Strack, O.D.L., 1989, Groundwater Mechanics, Prentice Hall, Englewood Cliffs, New Jersey, 732 p.

Wexler, E.J., 1992, *Analytical Solutions for One-, Two-, and Three-Dimensional Solute Transport in Ground-Water Systems with Uniform Flow*, USGS Techniques of Water Resource Investigations (TWRI), Book 3, Chapter B7.

Journal Papers

Abramowitz, M., and I.A. Stegun, 1965, Handbook of Mathematical Functions, Dover Publications, New York.

Case, C.M., D.L. Ghiglieri, and K. Fallon, 1979, Tables of the Leaky Aquifer Well Function, Desert Research Institute Publication No. 45016, Water Resources Center, Desert Research Institute, Reno, Nevada, 31 p.

Birsoy Y.K. and Summers W.K., 1980, *Determination of aquifer parameters from step tests and intermittent pumping data.* Ground Water, 18, 137-146.

Black, J H, 1978, *The use of the slug test in groundwater investigations*, Water Services, March, p. 174-178.

Bouwer, H. and R.C. Rice, 1976, *A slug test for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells*, Water Resources Research, v. 12, p. 423-428.

Case, C.M., D.L. Ghiglieri, and K. Fallon, 1979, Tables of the Leaky Aquifer Well Function, Desert Research Institute Publication No. 45016, Water Resources Center, Desert Research Institute, Reno, Nevada, 31 p.

Cooper, H.H., J.D. Bredehoeft, and I.S. Papadopulos, 1967, *Response of a finite-diameter well to an instantaneous charge of water*, Water Resources Research, v.3, no. 1, p. 263-269.

Eden, R.N. and Hazel C.P., 1973, *Computer and graphical analysis of variable discharge pumping tests of wells.* Inst. Engrs. Australia, Civil Eng. Trans., 5-10

Hantush, M.S., 1956, *Analysis of data from pumping tests in leaky aquifers*, Am. Geophys. Union Trans., v. 37, no. 6, p. 702-714.

Hantush, M.S., 1960, *Modification of the theory of leaky aquifers*, Journal of Geophysical Research, v. 65, no. 11, p. 3713-3725.

Hantush, M.S., 1964, *Hydraulics of Wells*, In *Advances in hydroscience* (V.T. Chow, editor), Vol. 1, pp. 281-432, Academic Press, New York.

Hantush, M.S., 1967, Growth and decay of groundwater-mounds in response to uniform percolation, Water Resources Research, Vol. 3, No. 1, pp. 227-234.

Hantush, M.S. and C.E. Jacob, 1955, *Non-steady radial flow in an infinite leaky aquifer,* Am. Geophys. Union Trans., v. 36, no. 1, p. 95-100.

Hvorslev, M.J., 1951, *Time lag and soil permeability in ground water observations*, U.S. Army Corps of Engineers Waterway Experimentation Station, Bulletin 36.

Hyder, Z., Butler, J. J., Jr., McElwee, C. D., and Liu, W. Z., *Slug tests in partially penetrating wells*, Water Resour. Res., 30(11), 2945, 1994.

Jacob, C.E., 1944, *Notes on determining permeability by pumping tests under watertable conditions*, USGS Open File Report, In: USGS Water Supply Paper 1536-I, 1963, pp. 245-271.

Jacob, C.E., 1963, *Determining the permeability of water-table aquifers, in Bentall, Ray, compiler, Methods of determining permeability, transmissibility, and drawdown*, U.S. Geol. Survey Water-Supply Paper 1536-1, p. 245-271.

Kipp, K. L., Jr., 1985, *Type curve analysis of inertial effects in the response of a well to a slug test*, Water Resources Research, v.21, no. 9, p. 1397-1408.

Larson, S.P., C.B. Andrews, M.D. Howland, and D.T. Feinstein, 1987, Three-dimensional modeling analysis of ground water pumping schemes for containment of shallow ground water contamination, Proceedings of the Solving Ground-Water Problems with Models Conference, National Ground Water Association, Denver, pp. 517-531.

McDonald, M.G. and A.W. Harbaugh, 1988, A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model, USGS Techniques of Water Resource Investigations, Book 6, Chapter A1, 528 p.

Moench, Allen F., 1997, *Flow to a well of finite diameter in a homogeneous, anisotropic water table aquifer.*, Water Resources Research, vol. 33, no. 6, pp 1397-1407.

Moench, A.F., 1996, *Flow to a well in a water-table aquifer: An improved Laplace Transform solution*, Ground Water, vol. 34, no. 4, pp. 593-596.

Moench, A.F., 1985,*Transient Flow to a Large-Diameter Well in an Aquifer With Storative Semiconfining Layers*, Water Resources Research, vol. 21, no. 8, pp. 1121-1131.

Moench, A.F., 1984, *Double-porosity models for a fissured groundwater reservoir with fracture skin*, Water Resources Research, vol. 20, no. 7, pp. 831-846.

Neuman, S.P., 1972, *Theory of flow in unconfined aquifers considering delayed response of the watertable*, Water Resources Research, vol. 8, pp 1031-1045.

Neuman, S.P., 1974, *Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response*, Water Resources Research, vol. 10, pp 303-312.

Papadopulos, IS. and H.H. Cooper, 1967, *Drawdown in a well of large diameter*, Water Resources Research, vol. 3, no. 1, pp. 157-168.

Reilly, T.E., O.L. Franke, G.D. Bennett, 1987, The Principle of Superposition and Its Application in Ground-Water Hydraulics, USGS Techniques of Water Resource Investigations, Book 3, Chapter B6, 28 p.

Rumbaugh, J.O., 1991, QuickFlow - Analytical 2D Ground-Water Flow Model, Version 1.0, Geraghty & Miller, Inc., Reston, Virginia.

Shafer, J., 1987, GWPATH: Interactive Ground-Water Flow Path Analysis, Bulletin 69, Illinois State Water Survey, Champaign, Illinois.

Spane, F.A. and S.K. Wurstner, *DERIV: A Computer Program for Calculating Pressure Derivatives for Use in Hydraulic Test Analysis*, Ground Water, vol. 31, no. 5, pp. 814-822.

Theis, C.V., 1935, *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage*, Trans. Amer. Geophys. Union, Vol. 16, pp. 519-524.

Software

Huyakorn, P.S., R.W. Broome, B.H. Lester, J.W. Mercer, 1984, SEFTRAN: Simple Efficient Flow and Transport Model, GeoTrans, Sterling, Virginia.

Rumbaugh, J.O., 1991, *QuickFlow - Analytical 2D Ground-Water Flow Model*, Version 1.0, Geraghty & Miller, Inc., Reston, Virginia.

Water Levels from Aquifer Test
(Raw Data)

```
Report Date:                    09/18/08 7:29
Report User NameAndrewP
Report Computer NameSOURCE3-7B7FDF2


Log File Properties
File Name        RW-02D 2008-09-16 18-37-17.wsl
Create Date                     09/17/08 9:08

Device Properties
Device           Level TROLL® 700
Site             Tank Battery
Device Name      Geotecch Rental # 1698
Serial Number                          102592
Firmware Version                         2.07

Log Configuration
                 Log Name                  RW-02D
                 Created By                AndrewP
                 Computer Name             SOURCE3-7B7FDF2
                 Application               WinSitu.exe
                 Application Version       5.6.4.6
                 Create Date                 09/16/08 14:36
                 Notes Size(bytes)                   4096
                 Type                      True Logarithmic
                 Overwrite when full       Disabled
                 Scheduled Start Time        09/16/08 14:45
                 Scheduled Stop Time       No Stop Time
                 Max Interval              Days: 1 hrs: 00 mins: 00 secs: 00


Level Reference Settings At Log Creation
                    Level Measurement Mode Level Depth To Water
                          Specific Gravity          0.999
                     Level Reference Mode: Set new reference
                    Level Reference Value: 24.45 (ft)
           Level Reference Head Pressure   5.59793 (PSI)
                           Head Pressure   5.60079 (PSI)
                             Temperature   18.9597 (C)
                          Depth of Probe   12.9321 (ft)


Log Notes:
Date and Time    Note
  09/16/08 18:37 User Note: "Downloading log - Used Batt: 20% Memory: 1% User: AndrewP"
   09/17/08 8:45 User Note: "Downloading log - Used Batt: 20% Memory: 1% User: AndrewP"
   09/17/08 9:08 Manual Stop Command


Log Data:
Record Count                             186

                                           Sensor: Pres 69ft   Sensor: Pres 69ftSensor: Pres 69ft
```

Date and Time	Elapsed Time Minutes	SN#: 102592 Pressure (PSI)	SN#: 102592 Temperature (C)	SN#: 102592 Level Depth To Water (ft)
09/16/08 14:45	0	5.607	18.781	24.43
09/16/08 14:45	0.004	5.605	18.795	24.435
09/16/08 14:45	0.008	5.605	18.806	24.434
09/16/08 14:45	0.013	5.605	18.813	24.434
09/16/08 14:45	0.017	5.606	18.823	24.432
09/16/08 14:45	0.021	5.605	18.828	24.435
09/16/08 14:45	0.025	5.605	18.833	24.435
09/16/08 14:45	0.029	5.606	18.836	24.431
09/16/08 14:45	0.033	5.606	18.841	24.431
09/16/08 14:45	0.038	5.606	18.841	24.432
09/16/08 14:45	0.042	5.604	18.846	24.435
09/16/08 14:45	0.046	5.606	18.845	24.431
09/16/08 14:45	0.05	5.605	18.849	24.433
09/16/08 14:45	0.054	5.606	18.849	24.432
09/16/08 14:45	0.058	5.606	18.857	24.432
09/16/08 14:45	0.063	5.605	18.855	24.434
09/16/08 14:45	0.067	5.605	18.855	24.434
09/16/08 14:45	0.071	5.605	18.86	24.434
09/16/08 14:45	0.075	5.604	18.863	24.436
09/16/08 14:45	0.079	5.605	18.858	24.435
09/16/08 14:45	0.083	5.606	18.861	24.431
09/16/08 14:45	0.088	5.604	18.865	24.436
09/16/08 14:45	0.092	5.604	18.862	24.436
09/16/08 14:45	0.096	5.606	18.864	24.432
09/16/08 14:45	0.1	5.606	18.87	24.432
09/16/08 14:45	0.106	5.605	18.859	24.433
09/16/08 14:45	0.112	5.605	18.854	24.434
09/16/08 14:45	0.119	5.604	18.88	24.436
09/16/08 14:45	0.126	5.604	18.858	24.435
09/16/08 14:45	0.133	5.606	18.854	24.432
09/16/08 14:45	0.141	5.606	18.842	24.432
09/16/08 14:45	0.15	5.605	18.835	24.434
09/16/08 14:45	0.158	5.605	18.834	24.433
09/16/08 14:45	0.168	5.605	18.831	24.434
09/16/08 14:45	0.178	5.606	18.827	24.43
09/16/08 14:45	0.188	5.606	18.824	24.431
09/16/08 14:45	0.199	5.606	18.824	24.431
09/16/08 14:45	0.211	5.605	18.819	24.433
09/16/08 14:45	0.226	5.605	18.826	24.433
09/16/08 14:45	0.237	5.606	18.818	24.431
09/16/08 14:45	0.251	5.606	18.816	24.431
09/16/08 14:45	0.266	5.608	18.815	24.426
09/16/08 14:45	0.282	5.607	18.808	24.428
09/16/08 14:45	0.298	5.606	18.808	24.43
09/16/08 14:45	0.316	5.609	18.804	24.425
09/16/08 14:45	0.335	5.608	18.801	24.428
09/16/08 14:45	0.355	5.609	18.801	24.425
09/16/08 14:45	0.376	5.607	18.809	24.428
09/16/08 14:45	0.398	5.609	18.798	24.424
09/16/08 14:45	0.422	5.606	18.797	24.431
09/16/08 14:45	0.447	5.609	18.8	24.424
09/16/08 14:45	0.473	5.608	18.808	24.428

09/16/08 14:45	0.501	5.608	18.799	24.428
09/16/08 14:45	0.531	5.608	18.799	24.427
09/16/08 14:45	0.562	5.609	18.794	24.424
09/16/08 14:45	0.596	5.608	18.797	24.428
09/16/08 14:45	0.631	5.607	18.788	24.428
09/16/08 14:45	0.668	5.608	18.79	24.427
09/16/08 14:45	0.71	5.608	18.799	24.427
09/16/08 14:45	0.75	5.609	18.793	24.425
09/16/08 14:45	0.794	5.609	18.784	24.425
09/16/08 14:45	0.841	5.608	18.792	24.426
09/16/08 14:45	0.891	5.609	18.786	24.425
09/16/08 14:45	0.944	5.608	18.781	24.428
09/16/08 14:46	1	5.609	18.78	24.424
09/16/08 14:46	1.06	5.609	18.778	24.425
09/16/08 14:46	1.12	5.607	18.779	24.429
09/16/08 14:46	1.19	5.607	18.805	24.429
09/16/08 14:46	1.26	5.612	18.775	24.417
09/16/08 14:46	1.33	5.607	18.78	24.429
09/16/08 14:46	1.41	5.609	18.769	24.424
09/16/08 14:46	1.5	5.606	18.776	24.431
09/16/08 14:46	1.58	5.608	18.776	24.426
09/16/08 14:46	1.682	5.607	18.798	24.429
09/16/08 14:46	1.78	5.606	18.77	24.432
09/16/08 14:46	1.88	5.608	18.765	24.426
09/16/08 14:46	1.99	5.609	18.763	24.424
09/16/08 14:47	2.11	5.607	18.766	24.429
09/16/08 14:47	2.24	5.607	18.758	24.429
09/16/08 14:47	2.37	5.607	18.758	24.43
09/16/08 14:47	2.51	5.608	18.759	24.427
09/16/08 14:47	2.66	5.61	18.758	24.423
09/16/08 14:47	2.82	5.609	18.758	24.423
09/16/08 14:47	2.98	5.61	18.757	24.423
09/16/08 14:48	3.16	5.609	18.745	24.424
09/16/08 14:48	3.35	5.608	18.759	24.427
09/16/08 14:48	3.55	5.61	18.746	24.422
09/16/08 14:48	3.76	5.611	18.742	24.42
09/16/08 14:48	3.98	5.609	18.741	24.424
09/16/08 14:49	4.22	5.609	18.747	24.425
09/16/08 14:49	4.47	5.608	18.74	24.426
09/16/08 14:49	4.73	5.609	18.736	24.425
09/16/08 14:50	5.01	5.61	18.731	24.423
09/16/08 14:50	5.31	5.609	18.729	24.425
09/16/08 14:50	5.62	5.602	18.723	24.441
09/16/08 14:50	5.96	5.608	18.714	24.427
09/16/08 14:51	6.31	5.61	18.714	24.423
09/16/08 14:51	6.68	5.608	18.705	24.427
09/16/08 14:52	7.08	5.61	18.699	24.422
09/16/08 14:52	7.5	5.611	18.696	24.42
09/16/08 14:52	7.94	5.606	18.686	24.43
09/16/08 14:53	8.41	5.608	18.687	24.428
09/16/08 14:53	8.91	5.607	18.685	24.428
09/16/08 14:54	9.44	5.607	18.69	24.428
09/16/08 14:55	10	3.219	18.674	29.942
09/16/08 14:55	10.6	1.567	18.699	33.758

09/16/08 14:56	11.2	0.618	18.75	35.949
09/16/08 14:56	11.9	0.907	18.769	35.282
09/16/08 14:57	12.6	1.611	18.71	33.657
09/16/08 14:58	13.3	1.222	18.649	34.555
09/16/08 14:59	14.1	0.724	18.604	35.703
09/16/08 15:00	15	0.454	18.572	36.328
09/16/08 15:00	15.8	0.76	18.543	35.62
09/16/08 15:01	16.8	0.977	18.512	35.121
09/16/08 15:02	17.8	1.23	18.489	34.535
09/16/08 15:03	18.8	1.615	18.463	33.646
09/16/08 15:04	19.9	2.156	18.45	32.397
09/16/08 15:06	21.1	2.793	18.438	30.927
09/16/08 15:07	22.4	3.126	18.443	30.158
09/16/08 15:08	23.7	3.257	18.436	29.854
09/16/08 15:10	25.101	3.312	18.441	29.728
09/16/08 15:11	26.6	3.344	18.434	29.654
09/16/08 15:13	28.2	3.347	18.434	29.647
09/16/08 15:14	29.8	3.345	18.436	29.652
09/16/08 15:16	31.6	0.828	18.457	35.465
09/16/08 15:18	33.5	2.31	18.452	32.042
09/16/08 15:20	35.5	2.976	18.443	30.505
09/16/08 15:22	37.6	3.147	18.43	30.108
09/16/08 15:24	39.8	3.184	18.432	30.023
09/16/08 15:27	42.2	3.18	18.439	30.033
09/16/08 15:29	44.7	3.187	18.428	30.016
09/16/08 15:32	47.3	3.182	18.419	30.028
09/16/08 15:35	50.1	3.163	18.434	30.072
09/16/08 15:38	53.1	3.168	18.438	30.06
09/16/08 15:41	56.2	3.169	18.447	30.059
09/16/08 15:44	59.6	3.022	18.442	30.398
09/16/08 15:48	63.1	2.633	18.46	31.295
09/16/08 15:51	66.8	2.587	18.457	31.401
09/16/08 15:55	70.8	2.569	18.45	31.443
09/16/08 16:00	75	2.146	18.46	32.421
09/16/08 16:04	79.4	2.109	18.455	32.505
09/16/08 16:09	84.1	2.093	18.444	32.542
09/16/08 16:14	89.1	2.084	18.444	32.563
09/16/08 16:19	94.4	2.079	18.443	32.574
09/16/08 16:25	100	2.074	18.437	32.586
09/16/08 16:31	106	2.06	18.44	32.619
09/16/08 16:37	112	2.055	18.438	32.63
09/16/08 16:44	119	2.045	18.436	32.653
09/16/08 16:51	126	2.042	18.419	32.66
09/16/08 16:58	133	2.043	18.421	32.658
09/16/08 17:06	141	2.031	18.42	32.685
09/16/08 17:15	150	2.037	18.417	32.673
09/16/08 17:23	158	2.032	18.414	32.683
09/16/08 17:33	168	2.042	18.415	32.661
09/16/08 17:43	178	2.036	18.417	32.675
09/16/08 17:53	188	2.028	18.415	32.693
09/16/08 18:04	199	2.028	18.413	32.694
09/16/08 18:16	211	2.013	18.416	32.727
09/16/08 18:29	224	2.009	18.419	32.737
09/16/08 18:42	237	1.994	18.418	32.771

09/16/08 18:56	251	2.001	18.415	32.755
09/16/08 19:11	266	1.982	18.417	32.8
09/16/08 19:27	282	1.981	18.422	32.801
09/16/08 19:43	298	1.969	18.42	32.829
09/16/08 20:01	316	1.96	18.418	32.85
09/16/08 20:20	335	1.948	18.423	32.877
09/16/08 20:40	355	1.945	18.423	32.884
09/16/08 21:01	376	1.94	18.425	32.895
09/16/08 21:23	398	1.919	18.425	32.945
09/16/08 21:47	422	1.908	18.43	32.969
09/16/08 22:12	447	1.903	18.427	32.981
09/16/08 22:38	473	1.891	18.433	33.009
09/16/08 23:06	501	1.873	18.432	33.05
09/16/08 23:36	531	1.86	18.432	33.081
09/17/08 0:07	562	1.857	18.433	33.089
09/17/08 0:41	596	1.841	18.434	33.125
09/17/08 1:16	631	1.83	18.437	33.151
09/17/08 1:53	668	1.807	18.439	33.203
09/17/08 2:33	708	1.799	18.437	33.222
09/17/08 3:15	750	1.792	18.437	33.239
09/17/08 3:59	794	1.783	18.439	33.259
09/17/08 4:46	841	1.756	18.444	33.322
09/17/08 5:36	891	1.738	18.443	33.363
09/17/08 6:29	944	1.731	18.445	33.379
09/17/08 7:25	1000	1.711	18.445	33.426
09/17/08 8:25	1060	1.689	18.446	33.477

```
Report Date:                    09/18/08 7:29
Report User NameAndrewP
Report Computer NameSOURCE3-7B7FDF2


Log File Properties
File Name       RW-02 Deep Recovery 2008-09-17 14-34-38.wsl
Create Date                     09/17/08 14:34

Device Properties
Device          Level TROLL® 700
Site            Tank Battery
Device Name     Geotecch Rental # 1698
Serial Number                          102592
Firmware Version                         2.07

Log Configuration
                Log Name                  MW-02 Deep Recovery
                Created By                AndrewP
                Computer Name             SOURCE3-7B7FDF2
                Application               WinSitu.exe
                Application Version       5.6.4.6
                Create Date                09/17/08 9:10
                Notes Size(bytes)                4096
                Type                      True Logarithmic
                Overwrite when full       Disabled
                Scheduled Start Time      Manual Start
                Scheduled Stop Time       No Stop Time
                Max Interval              Days: 0 hrs: 08 mins: 00 secs: 00


Level Reference Settings At Log Creation
                   Level Measurement Mode Level Depth To Water
                      Specific Gravity           0.999
                    Level Reference Mode: Set new reference
                   Level Reference Value: 33.48 (ft)
           Level Reference Head Pressure 1.6781 (PSI)
                         Head Pressure    1.67548 (PSI)
                          Temperature     18.5023 (C)
                        Depth of Probe    3.86862 (ft)


Log Notes:
Date and Time   Note
  09/17/08 9:11 Manual Start Command
 09/17/08 14:34 Manual Stop Command
```

Log Data:
Record Count 165

Date and Time	Elapsed Time Minutes	Sensor: Pres 69ft SN#: 102592 Pressure (PSI)	Sensor: Pres 69ft SN#: 102592 Temperature (C)	Sensor: Pres 69ft SN#: 102592 Level Depth To Water (ft)
09/17/08 9:11	0	1.68	18.463	33.475
09/17/08 9:11	0.004	1.694	18.486	33.442
09/17/08 9:11	0.009	1.687	18.509	33.459
09/17/08 9:11	0.013	1.68	18.517	33.475
09/17/08 9:11	0.017	1.679	18.527	33.477
09/17/08 9:11	0.021	1.677	18.53	33.482
09/17/08 9:11	0.025	1.674	18.532	33.489
09/17/08 9:11	0.029	1.679	18.54	33.479
09/17/08 9:11	0.033	1.681	18.542	33.472
09/17/08 9:11	0.037	1.683	18.543	33.469
09/17/08 9:11	0.042	1.677	18.542	33.482
09/17/08 9:11	0.046	1.686	18.546	33.462
09/17/08 9:11	0.05	1.676	18.552	33.485
09/17/08 9:11	0.054	1.67	18.553	33.498
09/17/08 9:11	0.058	1.68	18.555	33.475
09/17/08 9:11	0.063	1.678	18.555	33.48
09/17/08 9:11	0.067	1.676	18.557	33.484
09/17/08 9:11	0.071	1.674	18.559	33.488
09/17/08 9:11	0.075	1.679	18.559	33.479
09/17/08 9:11	0.079	1.683	18.565	33.468
09/17/08 9:11	0.083	1.678	18.566	33.481
09/17/08 9:11	0.087	1.68	18.566	33.476
09/17/08 9:11	0.092	1.633	18.562	33.584
09/17/08 9:11	0.096	1.692	18.566	33.447
09/17/08 9:11	0.1	1.699	18.563	33.432
09/17/08 9:11	0.106	1.713	18.56	33.399
09/17/08 9:11	0.112	1.726	18.556	33.37
09/17/08 9:11	0.119	1.741	18.548	33.335
09/17/08 9:11	0.126	1.756	18.546	33.299
09/17/08 9:12	0.133	1.773	18.541	33.261
09/17/08 9:12	0.141	1.788	18.538	33.225
09/17/08 9:12	0.15	1.809	18.53	33.178
09/17/08 9:12	0.158	1.827	18.532	33.136
09/17/08 9:12	0.168	1.847	18.529	33.089
09/17/08 9:12	0.178	1.871	18.522	33.035
09/17/08 9:12	0.188	1.89	18.523	32.991
09/17/08 9:12	0.199	1.913	18.52	32.938
09/17/08 9:12	0.211	1.939	18.517	32.877
09/17/08 9:12	0.225	1.966	18.542	32.815
09/17/08 9:12	0.237	1.991	18.522	32.756
09/17/08 9:12	0.251	2.021	18.521	32.688
09/17/08 9:12	0.266	2.053	18.512	32.615
09/17/08 9:12	0.282	2.084	18.513	32.542

09/17/08 9:12	0.298	2.116	18.509	32.469
09/17/08 9:12	0.316	2.153	18.504	32.384
09/17/08 9:12	0.335	2.193	18.508	32.291
09/17/08 9:12	0.355	2.228	18.504	32.21
09/17/08 9:12	0.376	2.269	18.501	32.116
09/17/08 9:12	0.398	2.312	18.499	32.017
09/17/08 9:12	0.422	2.355	18.5	31.916
09/17/08 9:12	0.447	2.402	18.497	31.809
09/17/08 9:12	0.475	2.451	18.526	31.695
09/17/08 9:12	0.501	2.498	18.504	31.588
09/17/08 9:12	0.531	2.551	18.495	31.465
09/17/08 9:12	0.563	2.605	18.511	31.34
09/17/08 9:12	0.596	2.662	18.501	31.209
09/17/08 9:12	0.631	2.72	18.497	31.075
09/17/08 9:12	0.668	2.779	18.507	30.937
09/17/08 9:12	0.708	2.843	18.5	30.791
09/17/08 9:12	0.75	2.908	18.508	30.641
09/17/08 9:12	0.794	2.975	18.505	30.486
09/17/08 9:12	0.841	3.043	18.507	30.328
09/17/08 9:12	0.893	3.116	18.537	30.159
09/17/08 9:12	0.944	3.19	18.513	29.99
09/17/08 9:12	1	3.264	18.521	29.819
09/17/08 9:12	1.06	3.341	18.545	29.641
09/17/08 9:12	1.12	3.418	18.524	29.462
09/17/08 9:13	1.19	3.501	18.527	29.27
09/17/08 9:13	1.26	3.582	18.538	29.083
09/17/08 9:13	1.33	3.66	18.544	28.903
09/17/08 9:13	1.41	3.745	18.548	28.708
09/17/08 9:13	1.5	3.837	18.554	28.495
09/17/08 9:13	1.58	3.91	18.564	28.326
09/17/08 9:13	1.68	4.002	18.569	28.114
09/17/08 9:13	1.78	4.09	18.574	27.911
09/17/08 9:13	1.88	4.17	18.578	27.727
09/17/08 9:13	1.99	4.251	18.596	27.54
09/17/08 9:13	2.11	4.333	18.598	27.351
09/17/08 9:14	2.243	4.421	18.615	27.147
09/17/08 9:14	2.37	4.497	18.615	26.972
09/17/08 9:14	2.51	4.573	18.622	26.797
09/17/08 9:14	2.66	4.651	18.64	26.616
09/17/08 9:14	2.823	4.724	18.656	26.446
09/17/08 9:14	2.98	4.792	18.681	26.29
09/17/08 9:15	3.16	4.858	18.673	26.137
09/17/08 9:15	3.35	4.922	18.676	25.989
09/17/08 9:15	3.55	4.982	18.685	25.853
09/17/08 9:15	3.76	5.034	18.699	25.731
09/17/08 9:15	3.98	5.085	18.728	25.614
09/17/08 9:16	4.22	5.13	18.708	25.51
09/17/08 9:16	4.47	5.173	18.718	25.41
09/17/08 9:16	4.73	5.21	18.757	25.325

09/17/08 9:16	5.01	5.244	18.738	25.247
09/17/08 9:17	5.31	5.275	18.743	25.175
09/17/08 9:17	5.62	5.3	18.753	25.118
09/17/08 9:17	5.96	5.323	18.764	25.065
09/17/08 9:18	6.31	5.342	18.771	25.02
09/17/08 9:18	6.68	5.357	18.785	24.985
09/17/08 9:18	7.08	5.37	18.802	24.954
09/17/08 9:19	7.5	5.384	18.809	24.923
09/17/08 9:19	7.94	5.39	18.821	24.908
09/17/08 9:20	8.41	5.399	18.845	24.888
09/17/08 9:20	8.91	5.407	18.86	24.87
09/17/08 9:21	9.44	5.412	18.872	24.859
09/17/08 9:21	10	5.419	18.901	24.842
09/17/08 9:22	10.6	5.422	18.914	24.835
09/17/08 9:23	11.2	5.426	18.932	24.826
09/17/08 9:23	11.901	5.428	18.992	24.821
09/17/08 9:24	12.6	5.432	18.989	24.812
09/17/08 9:25	13.3	5.437	19.013	24.802
09/17/08 9:25	14.1	5.44	19.052	24.794
09/17/08 9:26	15	5.444	19.084	24.784
09/17/08 9:27	15.8	5.446	19.093	24.781
09/17/08 9:28	16.8	5.451	19.109	24.769
09/17/08 9:29	17.8	5.452	19.117	24.766
09/17/08 9:30	18.8	5.455	19.124	24.758
09/17/08 9:31	19.901	5.454	19.143	24.761
09/17/08 9:32	21.1	5.459	19.132	24.75
09/17/08 9:34	22.401	5.461	19.156	24.745
09/17/08 9:35	23.7	5.465	19.147	24.736
09/17/08 9:36	25.1	5.468	19.14	24.729
09/17/08 9:38	26.6	5.472	19.136	24.719
09/17/08 9:40	28.2	5.472	19.129	24.72
09/17/08 9:41	29.8	5.473	19.125	24.718
09/17/08 9:43	31.6	5.474	19.126	24.716
09/17/08 9:45	33.5	5.476	19.124	24.71
09/17/08 9:47	35.5	5.479	19.116	24.704
09/17/08 9:49	37.6	5.483	19.108	24.695
09/17/08 9:51	39.8	5.488	19.106	24.683
09/17/08 9:54	42.2	5.489	19.096	24.682
09/17/08 9:56	44.7	5.494	19.079	24.669
09/17/08 9:59	47.3	5.497	19.069	24.663
09/17/08 10:01	50.1	5.496	19.049	24.664
09/17/08 10:04	53.1	5.501	19.041	24.653
09/17/08 10:08	56.2	5.501	19.033	24.652
09/17/08 10:11	59.6	5.507	19.016	24.639
09/17/08 10:14	63.1	5.507	18.999	24.639
09/17/08 10:18	66.8	5.512	18.982	24.628
09/17/08 10:22	70.8	5.513	18.959	24.625
09/17/08 10:26	75	5.516	18.944	24.618
09/17/08 10:31	79.4	5.513	18.925	24.626

09/17/08 10:35	84.1	5.518	18.901	24.613
09/17/08 10:40	89.1	5.525	18.872	24.598
09/17/08 10:46	94.4	5.526	18.858	24.594
09/17/08 10:51	100	5.528	18.839	24.591
09/17/08 10:57	106	5.534	18.824	24.578
09/17/08 11:03	112	5.534	18.805	24.576
09/17/08 11:10	119	5.536	18.781	24.571
09/17/08 11:17	126	5.54	18.762	24.563
09/17/08 11:24	133	5.543	18.75	24.555
09/17/08 11:32	141	5.543	18.73	24.556
09/17/08 11:41	150	5.547	18.712	24.548
09/17/08 11:49	158	5.547	18.693	24.548
09/17/08 11:59	168	5.552	18.673	24.536
09/17/08 12:09	178	5.556	18.654	24.526
09/17/08 12:19	188	5.557	18.639	24.523
09/17/08 12:30	199	5.559	18.627	24.52
09/17/08 12:42	211	5.561	18.612	24.514
09/17/08 12:55	224	5.564	18.594	24.507
09/17/08 13:08	237	5.568	18.576	24.499
09/17/08 13:22	251	5.567	18.558	24.5
09/17/08 13:37	266	5.576	18.548	24.479
09/17/08 13:53	282	5.576	18.538	24.48
09/17/08 14:09	298	5.579	18.524	24.473
09/17/08 14:27	316	5.563	18.515	24.509

```
Report Date:                  09/18/08 7:29
Report User NameAndrewP
Report Computer NameSOURCE3-7B7FDF2


Log File Properties
File Name         RW-01DEEP 2008-09-16 18-40-23.wsl
Create Date                   09/17/08 14:37

Device Properties
Device            Level TROLL® 700
Site              Tank Battery
Device Name       Geotech Rental # 1710
Serial Number                       106205
Firmware Version                      2.07

Log Configuration
                  Log Name                     RW-01DEEP
                  Created By                   AndrewP
                  Computer Name                SOURCE3-7B7FDF2
                  Application                  WinSitu.exe
                  Application Version          5.6.4.6
                  Create Date                  09/16/08 14:25
                  Notes Size(bytes)                  4096
                  Type                         Linear
                  Overwrite when full          Disabled
                  Scheduled Start Time         09/16/08 14:45
                  Scheduled Stop Time          No Stop Time
                  Interval                     Days: 0 hrs: 00 mins: 02 secs: 00


Level Reference Settings At Log Creation
                     Level Measurement Mode    Level Depth To Water
                        Specific Gravity             0.999
                      Level Reference Mode:    Set new reference
                      Level Reference Value:   24.36 (ft)
                 Level Reference Head Pressure 5.76189 (PSI)
                          Head Pressure        5.76426 (PSI)
                          Temperature          42.7974 (C)
                         Depth of Probe        13.3095 (ft)


Log Notes:
Date and Time     Note
  09/16/08 18:40  User Note: "Downloading log - Used Batt: 16% Memory: 1% User: AndrewP"
  09/17/08 14:36  Manual Stop Command


Log Data:
Record Count                          716

                                               Sensor: Pres 69ftSensor: Pres 69ftSensor: Pres 69ft
                  Elapsed Time                 SN#: 106205   SN#: 106205SN#: 106205
Date and Time     Minutes                      Pressure (PSI)  Temperature (C)Level Depth To Water (ft)
  09/16/08 14:45                        0            5.74      18.528     24.409
```

09/16/08 14:47	2	5.739	18.483	24.413
09/16/08 14:49	4	5.739	18.453	24.413
09/16/08 14:51	6	5.741	18.427	24.409
09/16/08 14:53	8	5.74	18.409	24.41
09/16/08 14:55	10	5.741	18.388	24.407
09/16/08 14:57	12	5.741	18.374	24.409
09/16/08 14:59	14	5.737	18.36	24.419
09/16/08 15:01	16	5.735	18.351	24.422
09/16/08 15:03	18	5.732	18.342	24.429
09/16/08 15:05	20	5.732	18.338	24.43
09/16/08 15:07	22	5.729	18.325	24.435
09/16/08 15:09	24	5.73	18.321	24.434
09/16/08 15:11	26	5.729	18.314	24.436
09/16/08 15:13	28	5.728	18.306	24.437
09/16/08 15:15	30	5.73	18.302	24.433
09/16/08 15:17	32	5.729	18.295	24.435
09/16/08 15:19	34	5.731	18.288	24.431
09/16/08 15:21	36	5.728	18.286	24.437
09/16/08 15:23	38	5.729	18.279	24.437
09/16/08 15:25	40	5.729	18.276	24.436
09/16/08 15:27	42	5.728	18.274	24.438
09/16/08 15:29	44	5.729	18.265	24.436
09/16/08 15:31	46	5.729	18.262	24.435
09/16/08 15:33	48	5.729	18.259	24.436
09/16/08 15:35	50	5.73	18.256	24.433
09/16/08 15:37	52	5.73	18.251	24.435
09/16/08 15:39	54	5.728	18.252	24.438
09/16/08 15:41	56	5.728	18.245	24.437
09/16/08 15:43	58	5.728	18.24	24.439
09/16/08 15:45	60	5.728	18.239	24.437
09/16/08 15:47	62	5.728	18.235	24.437
09/16/08 15:49	64	5.726	18.23	24.443
09/16/08 15:51	66	5.727	18.23	24.441
09/16/08 15:53	68	5.726	18.227	24.443
09/16/08 15:55	70	5.726	18.225	24.444
09/16/08 15:57	72	5.725	18.219	24.445
09/16/08 15:59	74	5.724	18.216	24.448
09/16/08 16:01	76	5.725	18.214	24.446
09/16/08 16:03	78	5.724	18.214	24.449
09/16/08 16:05	80	5.724	18.211	24.449
09/16/08 16:07	82	5.723	18.208	24.449
09/16/08 16:09	84	5.724	18.205	24.447
09/16/08 16:11	86	5.724	18.206	24.447
09/16/08 16:13	88	5.723	18.202	24.449
09/16/08 16:15	90	5.722	18.197	24.453
09/16/08 16:17	92	5.723	18.198	24.451
09/16/08 16:19	94	5.723	18.197	24.451
09/16/08 16:21	96	5.722	18.192	24.453
09/16/08 16:23	98	5.722	18.188	24.451
09/16/08 16:25	100	5.721	18.186	24.453
09/16/08 16:27	102	5.719	18.186	24.458
09/16/08 16:29	104	5.721	18.183	24.454
09/16/08 16:31	106	5.718	18.183	24.461
09/16/08 16:33	108	5.72	18.179	24.456
09/16/08 16:35	110	5.72	18.178	24.456
09/16/08 16:37	112	5.72	18.178	24.457

09/16/08 16:39	114	5.72	18.176	24.456
09/16/08 16:41	116	5.718	18.173	24.461
09/16/08 16:43	118	5.72	18.174	24.458
09/16/08 16:45	120	5.719	18.17	24.46
09/16/08 16:47	122	5.717	18.167	24.464
09/16/08 16:49	124	5.718	18.168	24.461
09/16/08 16:51	126	5.718	18.164	24.46
09/16/08 16:53	128	5.717	18.167	24.463
09/16/08 16:55	130	5.716	18.165	24.465
09/16/08 16:57	132	5.717	18.163	24.463
09/16/08 16:59	134	5.718	18.162	24.462
09/16/08 17:01	136	5.716	18.157	24.466
09/16/08 17:03	138	5.716	18.159	24.466
09/16/08 17:05	140	5.716	18.157	24.467
09/16/08 17:07	142	5.716	18.153	24.465
09/16/08 17:09	144	5.715	18.154	24.468
09/16/08 17:11	146	5.717	18.155	24.463
09/16/08 17:13	148	5.714	18.152	24.47
09/16/08 17:15	150	5.714	18.151	24.471
09/16/08 17:17	152	5.715	18.152	24.468
09/16/08 17:19	154	5.716	18.152	24.466
09/16/08 17:21	156	5.714	18.15	24.471
09/16/08 17:23	158	5.714	18.147	24.472
09/16/08 17:25	160	5.715	18.146	24.467
09/16/08 17:27	162	5.714	18.147	24.472
09/16/08 17:29	164	5.713	18.146	24.473
09/16/08 17:31	166	5.715	18.143	24.469
09/16/08 17:33	168	5.713	18.143	24.473
09/16/08 17:35	170	5.714	18.144	24.472
09/16/08 17:37	172	5.712	18.142	24.475
09/16/08 17:39	174	5.713	18.142	24.472
09/16/08 17:41	176	5.713	18.14	24.472
09/16/08 17:43	178	5.712	18.138	24.475
09/16/08 17:45	180	5.712	18.137	24.474
09/16/08 17:47	182	5.711	18.137	24.477
09/16/08 17:49	184	5.712	18.134	24.475
09/16/08 17:51	186	5.711	18.134	24.478
09/16/08 17:53	188	5.711	18.135	24.478
09/16/08 17:55	190	5.712	18.135	24.476
09/16/08 17:57	192	5.712	18.134	24.476
09/16/08 17:59	194	5.712	18.133	24.475
09/16/08 18:01	196	5.712	18.132	24.476
09/16/08 18:03	198	5.71	18.129	24.479
09/16/08 18:05	200	5.712	18.132	24.475
09/16/08 18:07	202	5.71	18.131	24.479
09/16/08 18:09	204	5.712	18.131	24.476
09/16/08 18:11	206	5.711	18.128	24.477
09/16/08 18:13	208	5.712	18.13	24.476
09/16/08 18:15	210	5.709	18.129	24.482
09/16/08 18:17	212	5.709	18.124	24.481
09/16/08 18:19	214	5.711	18.127	24.478
09/16/08 18:21	216	5.71	18.124	24.479
09/16/08 18:23	218	5.711	18.128	24.478
09/16/08 18:25	220	5.709	18.122	24.482
09/16/08 18:27	222	5.71	18.124	24.479
09/16/08 18:29	224	5.709	18.123	24.483

09/16/08 18:31	226	5.71	18.123	24.48
09/16/08 18:33	228	5.709	18.123	24.482
09/16/08 18:35	230	5.708	18.121	24.484
09/16/08 18:37	232	5.71	18.121	24.479
09/16/08 18:39	234	5.706	18.122	24.488
09/16/08 18:41	236	5.709	18.143	24.482
09/16/08 18:43	238	5.71	18.131	24.48
09/16/08 18:45	240	5.709	18.123	24.482
09/16/08 18:47	242	5.708	18.121	24.485
09/16/08 18:49	244	5.708	18.12	24.484
09/16/08 18:51	246	5.707	18.12	24.486
09/16/08 18:53	248	5.708	18.121	24.484
09/16/08 18:55	250	5.708	18.12	24.484
09/16/08 18:57	252	5.708	18.12	24.485
09/16/08 18:59	254	5.708	18.121	24.484
09/16/08 19:01	256	5.709	18.115	24.483
09/16/08 19:03	258	5.709	18.117	24.481
09/16/08 19:05	260	5.708	18.118	24.484
09/16/08 19:07	262	5.707	18.115	24.487
09/16/08 19:09	264	5.708	18.117	24.484
09/16/08 19:11	266	5.707	18.117	24.486
09/16/08 19:13	268	5.705	18.113	24.49
09/16/08 19:15	270	5.707	18.113	24.486
09/16/08 19:17	272	5.708	18.116	24.485
09/16/08 19:19	274	5.706	18.113	24.489
09/16/08 19:21	276	5.706	18.112	24.488
09/16/08 19:23	278	5.706	18.112	24.489
09/16/08 19:25	280	5.706	18.113	24.488
09/16/08 19:27	282	5.707	18.111	24.488
09/16/08 19:29	284	5.708	18.111	24.485
09/16/08 19:31	286	5.707	18.112	24.487
09/16/08 19:33	288	5.705	18.112	24.491
09/16/08 19:35	290	5.705	18.108	24.49
09/16/08 19:37	292	5.706	18.112	24.489
09/16/08 19:39	294	5.705	18.111	24.492
09/16/08 19:41	296	5.704	18.111	24.493
09/16/08 19:43	298	5.704	18.108	24.493
09/16/08 19:45	300	5.703	18.11	24.495
09/16/08 19:47	302	5.704	18.107	24.494
09/16/08 19:49	304	5.704	18.111	24.494
09/16/08 19:51	306	5.705	18.108	24.492
09/16/08 19:53	308	5.704	18.107	24.493
09/16/08 19:55	310	5.703	18.107	24.497
09/16/08 19:57	312	5.703	18.108	24.495
09/16/08 19:59	314	5.703	18.108	24.497
09/16/08 20:01	316	5.702	18.106	24.499
09/16/08 20:03	318	5.703	18.106	24.497
09/16/08 20:05	320	5.704	18.106	24.494
09/16/08 20:07	322	5.703	18.106	24.495
09/16/08 20:09	324	5.703	18.106	24.496
09/16/08 20:11	326	5.702	18.105	24.499
09/16/08 20:13	328	5.7	18.104	24.504
09/16/08 20:15	330	5.702	18.108	24.498
09/16/08 20:17	332	5.703	18.104	24.496
09/16/08 20:19	334	5.703	18.106	24.496
09/16/08 20:21	336	5.704	18.106	24.494

09/16/08 20:23	338	5.703	18.106	24.496
09/16/08 20:25	340	5.702	18.104	24.499
09/16/08 20:27	342	5.701	18.106	24.501
09/16/08 20:29	344	5.701	18.106	24.501
09/16/08 20:31	346	5.702	18.103	24.497
09/16/08 20:33	348	5.702	18.104	24.499
09/16/08 20:35	350	5.701	18.102	24.501
09/16/08 20:37	352	5.701	18.104	24.501
09/16/08 20:39	354	5.702	18.105	24.499
09/16/08 20:41	356	5.701	18.104	24.502
09/16/08 20:43	358	5.701	18.105	24.501
09/16/08 20:45	360	5.7	18.105	24.503
09/16/08 20:47	362	5.7	18.099	24.502
09/16/08 20:49	364	5.701	18.104	24.501
09/16/08 20:51	366	5.699	18.102	24.504
09/16/08 20:53	368	5.699	18.1	24.505
09/16/08 20:55	370	5.7	18.103	24.503
09/16/08 20:57	372	5.699	18.104	24.506
09/16/08 20:59	374	5.7	18.103	24.503
09/16/08 21:01	376	5.699	18.1	24.505
09/16/08 21:03	378	5.701	18.101	24.501
09/16/08 21:05	380	5.7	18.102	24.502
09/16/08 21:07	382	5.699	18.1	24.505
09/16/08 21:09	384	5.699	18.101	24.505
09/16/08 21:11	386	5.698	18.101	24.507
09/16/08 21:13	388	5.698	18.102	24.507
09/16/08 21:15	390	5.7	18.103	24.502
09/16/08 21:17	392	5.7	18.102	24.504
09/16/08 21:19	394	5.698	18.099	24.507
09/16/08 21:21	396	5.699	18.101	24.505
09/16/08 21:23	398	5.698	18.102	24.508
09/16/08 21:25	400	5.698	18.103	24.507
09/16/08 21:27	402	5.698	18.1	24.508
09/16/08 21:29	404	5.697	18.099	24.509
09/16/08 21:31	406	5.697	18.102	24.509
09/16/08 21:33	408	5.697	18.101	24.51
09/16/08 21:35	410	5.698	18.102	24.508
09/16/08 21:37	412	5.697	18.098	24.51
09/16/08 21:39	414	5.698	18.1	24.507
09/16/08 21:41	416	5.697	18.102	24.51
09/16/08 21:43	418	5.698	18.098	24.507
09/16/08 21:45	420	5.698	18.097	24.508
09/16/08 21:47	422	5.698	18.098	24.507
09/16/08 21:49	424	5.698	18.1	24.508
09/16/08 21:51	426	5.697	18.102	24.509
09/16/08 21:53	428	5.698	18.103	24.508
09/16/08 21:55	430	5.698	18.099	24.508
09/16/08 21:57	432	5.697	18.103	24.51
09/16/08 21:59	434	5.696	18.1	24.511
09/16/08 22:01	436	5.698	18.098	24.508
09/16/08 22:03	438	5.695	18.1	24.516
09/16/08 22:05	440	5.697	18.099	24.51
09/16/08 22:07	442	5.697	18.1	24.51
09/16/08 22:09	444	5.696	18.1	24.512
09/16/08 22:11	446	5.695	18.097	24.515
09/16/08 22:13	448	5.696	18.1	24.513

09/16/08 22:15	450	5.697	18.096	24.51
09/16/08 22:17	452	5.695	18.098	24.515
09/16/08 22:19	454	5.697	18.098	24.51
09/16/08 22:21	456	5.696	18.099	24.513
09/16/08 22:23	458	5.696	18.101	24.513
09/16/08 22:25	460	5.696	18.098	24.512
09/16/08 22:27	462	5.697	18.1	24.511
09/16/08 22:29	464	5.696	18.099	24.513
09/16/08 22:31	466	5.697	18.1	24.511
09/16/08 22:33	468	5.695	18.098	24.513
09/16/08 22:35	470	5.696	18.1	24.512
09/16/08 22:37	472	5.697	18.099	24.51
09/16/08 22:39	474	5.694	18.098	24.517
09/16/08 22:41	476	5.696	18.097	24.513
09/16/08 22:43	478	5.696	18.096	24.513
09/16/08 22:45	480	5.696	18.096	24.512
09/16/08 22:47	482	5.697	18.097	24.51
09/16/08 22:49	484	5.695	18.098	24.514
09/16/08 22:51	486	5.696	18.1	24.512
09/16/08 22:53	488	5.695	18.094	24.514
09/16/08 22:55	490	5.696	18.101	24.513
09/16/08 22:57	492	5.694	18.099	24.517
09/16/08 22:59	494	5.694	18.097	24.517
09/16/08 23:01	496	5.694	18.095	24.517
09/16/08 23:03	498	5.694	18.099	24.518
09/16/08 23:05	500	5.694	18.098	24.516
09/16/08 23:07	502	5.694	18.097	24.516
09/16/08 23:09	504	5.694	18.097	24.516
09/16/08 23:11	506	5.694	18.097	24.516
09/16/08 23:13	508	5.693	18.097	24.518
09/16/08 23:15	510	5.694	18.099	24.517
09/16/08 23:17	512	5.694	18.095	24.518
09/16/08 23:19	514	5.693	18.095	24.519
09/16/08 23:21	516	5.693	18.097	24.52
09/16/08 23:23	518	5.693	18.097	24.519
09/16/08 23:25	520	5.692	18.096	24.52
09/16/08 23:27	522	5.693	18.096	24.52
09/16/08 23:29	524	5.692	18.095	24.52
09/16/08 23:31	526	5.693	18.097	24.519
09/16/08 23:33	528	5.692	18.096	24.522
09/16/08 23:35	530	5.693	18.095	24.519
09/16/08 23:37	532	5.694	18.095	24.517
09/16/08 23:39	534	5.691	18.096	24.523
09/16/08 23:41	536	5.693	18.095	24.52
09/16/08 23:43	538	5.693	18.096	24.519
09/16/08 23:45	540	5.694	18.095	24.518
09/16/08 23:47	542	5.691	18.098	24.524
09/16/08 23:49	544	5.693	18.094	24.52
09/16/08 23:51	546	5.691	18.096	24.523
09/16/08 23:53	548	5.693	18.097	24.519
09/16/08 23:55	550	5.693	18.097	24.52
09/16/08 23:57	552	5.693	18.094	24.52
09/16/08 23:59	554	5.691	18.098	24.523
09/17/08 0:01	556	5.691	18.095	24.523
09/17/08 0:03	558	5.691	18.096	24.523
09/17/08 0:05	560	5.692	18.097	24.522

09/17/08 0:07	562	5.692	18.094	24.521
09/17/08 0:09	564	5.692	18.094	24.521
09/17/08 0:11	566	5.692	18.092	24.52
09/17/08 0:13	568	5.692	18.097	24.522
09/17/08 0:15	570	5.692	18.097	24.521
09/17/08 0:17	572	5.691	18.095	24.523
09/17/08 0:19	574	5.692	18.094	24.521
09/17/08 0:21	576	5.691	18.095	24.523
09/17/08 0:23	578	5.691	18.094	24.523
09/17/08 0:25	580	5.691	18.097	24.523
09/17/08 0:27	582	5.691	18.097	24.523
09/17/08 0:29	584	5.692	18.098	24.521
09/17/08 0:31	586	5.691	18.094	24.523
09/17/08 0:33	588	5.69	18.096	24.526
09/17/08 0:35	590	5.693	18.097	24.52
09/17/08 0:37	592	5.692	18.095	24.521
09/17/08 0:39	594	5.691	18.094	24.524
09/17/08 0:41	596	5.688	18.092	24.53
09/17/08 0:43	598	5.691	18.095	24.523
09/17/08 0:45	600	5.691	18.095	24.524
09/17/08 0:47	602	5.691	18.095	24.523
09/17/08 0:49	604	5.69	18.097	24.526
09/17/08 0:51	606	5.69	18.098	24.525
09/17/08 0:53	608	5.69	18.098	24.525
09/17/08 0:55	610	5.69	18.092	24.527
09/17/08 0:57	612	5.689	18.095	24.528
09/17/08 0:59	614	5.69	18.095	24.526
09/17/08 1:01	616	5.69	18.093	24.526
09/17/08 1:03	618	5.69	18.097	24.527
09/17/08 1:05	620	5.691	18.096	24.524
09/17/08 1:07	622	5.69	18.095	24.526
09/17/08 1:09	624	5.689	18.096	24.528
09/17/08 1:11	626	5.689	18.093	24.527
09/17/08 1:13	628	5.69	18.097	24.527
09/17/08 1:15	630	5.691	18.096	24.523
09/17/08 1:17	632	5.689	18.095	24.528
09/17/08 1:19	634	5.688	18.093	24.53
09/17/08 1:21	636	5.689	18.096	24.528
09/17/08 1:23	638	5.689	18.095	24.527
09/17/08 1:25	640	5.69	18.096	24.526
09/17/08 1:27	642	5.69	18.096	24.526
09/17/08 1:29	644	5.689	18.095	24.528
09/17/08 1:31	646	5.69	18.097	24.527
09/17/08 1:33	648	5.689	18.092	24.528
09/17/08 1:35	650	5.69	18.095	24.526
09/17/08 1:37	652	5.689	18.093	24.528
09/17/08 1:39	654	5.69	18.095	24.527
09/17/08 1:41	656	5.688	18.095	24.531
09/17/08 1:43	658	5.688	18.095	24.531
09/17/08 1:45	660	5.69	18.094	24.526
09/17/08 1:47	662	5.689	18.096	24.528
09/17/08 1:49	664	5.69	18.092	24.527
09/17/08 1:51	666	5.689	18.097	24.527
09/17/08 1:53	668	5.687	18.096	24.532
09/17/08 1:55	670	5.687	18.095	24.533
09/17/08 1:57	672	5.686	18.096	24.534

09/17/08 1:59	674	5.688	18.094	24.53
09/17/08 2:01	676	5.687	18.095	24.533
09/17/08 2:03	678	5.689	18.096	24.529
09/17/08 2:05	680	5.689	18.095	24.529
09/17/08 2:07	682	5.689	18.096	24.528
09/17/08 2:09	684	5.688	18.093	24.53
09/17/08 2:11	686	5.688	18.093	24.53
09/17/08 2:13	688	5.687	18.094	24.533
09/17/08 2:15	690	5.689	18.094	24.528
09/17/08 2:17	692	5.687	18.095	24.533
09/17/08 2:19	694	5.688	18.098	24.531
09/17/08 2:21	696	5.688	18.094	24.53
09/17/08 2:23	698	5.688	18.094	24.53
09/17/08 2:25	700	5.689	18.095	24.529
09/17/08 2:27	702	5.686	18.095	24.534
09/17/08 2:29	704	5.689	18.096	24.528
09/17/08 2:31	706	5.687	18.094	24.533
09/17/08 2:33	708	5.687	18.096	24.534
09/17/08 2:35	710	5.687	18.092	24.532
09/17/08 2:37	712	5.688	18.091	24.531
09/17/08 2:39	714	5.687	18.093	24.534
09/17/08 2:41	716	5.688	18.096	24.53
09/17/08 2:43	718	5.686	18.097	24.535
09/17/08 2:45	720	5.688	18.092	24.532
09/17/08 2:47	722	5.687	18.096	24.533
09/17/08 2:49	724	5.688	18.096	24.53
09/17/08 2:51	726	5.688	18.094	24.531
09/17/08 2:53	728	5.687	18.094	24.533
09/17/08 2:55	730	5.688	18.097	24.531
09/17/08 2:57	732	5.688	18.095	24.532
09/17/08 2:59	734	5.686	18.097	24.534
09/17/08 3:01	736	5.687	18.096	24.534
09/17/08 3:03	738	5.685	18.092	24.537
09/17/08 3:05	740	5.687	18.092	24.534
09/17/08 3:07	742	5.686	18.096	24.536
09/17/08 3:09	744	5.688	18.096	24.531
09/17/08 3:11	746	5.687	18.096	24.533
09/17/08 3:13	748	5.686	18.094	24.535
09/17/08 3:15	750	5.687	18.096	24.533
09/17/08 3:17	752	5.685	18.094	24.537
09/17/08 3:19	754	5.685	18.093	24.537
09/17/08 3:21	756	5.686	18.095	24.536
09/17/08 3:23	758	5.686	18.093	24.535
09/17/08 3:25	760	5.685	18.092	24.538
09/17/08 3:27	762	5.686	18.092	24.536
09/17/08 3:29	764	5.684	18.095	24.539
09/17/08 3:31	766	5.685	18.094	24.538
09/17/08 3:33	768	5.684	18.093	24.539
09/17/08 3:35	770	5.685	18.094	24.537
09/17/08 3:37	772	5.685	18.095	24.538
09/17/08 3:39	774	5.685	18.095	24.538
09/17/08 3:41	776	5.685	18.097	24.538
09/17/08 3:43	778	5.685	18.092	24.537
09/17/08 3:45	780	5.686	18.093	24.535
09/17/08 3:47	782	5.686	18.092	24.535
09/17/08 3:49	784	5.684	18.093	24.539

09/17/08 3:51	786	5.684	18.095	24.539
09/17/08 3:53	788	5.685	18.094	24.538
09/17/08 3:55	790	5.685	18.095	24.538
09/17/08 3:57	792	5.685	18.094	24.538
09/17/08 3:59	794	5.685	18.094	24.539
09/17/08 4:01	796	5.684	18.095	24.54
09/17/08 4:03	798	5.683	18.094	24.541
09/17/08 4:05	800	5.685	18.092	24.537
09/17/08 4:07	802	5.685	18.091	24.538
09/17/08 4:09	804	5.684	18.092	24.541
09/17/08 4:11	806	5.685	18.093	24.538
09/17/08 4:13	808	5.684	18.092	24.539
09/17/08 4:15	810	5.683	18.094	24.542
09/17/08 4:17	812	5.685	18.094	24.539
09/17/08 4:19	814	5.683	18.094	24.543
09/17/08 4:21	816	5.682	18.092	24.545
09/17/08 4:23	818	5.683	18.091	24.541
09/17/08 4:25	820	5.683	18.094	24.543
09/17/08 4:27	822	5.684	18.092	24.54
09/17/08 4:29	824	5.684	18.093	24.541
09/17/08 4:31	826	5.682	18.093	24.544
09/17/08 4:33	828	5.684	18.093	24.54
09/17/08 4:35	830	5.682	18.092	24.544
09/17/08 4:37	832	5.681	18.091	24.546
09/17/08 4:39	834	5.683	18.09	24.543
09/17/08 4:41	836	5.682	18.093	24.544
09/17/08 4:43	838	5.681	18.094	24.546
09/17/08 4:45	840	5.683	18.091	24.542
09/17/08 4:47	842	5.682	18.091	24.545
09/17/08 4:49	844	5.682	18.091	24.544
09/17/08 4:51	846	5.683	18.093	24.542
09/17/08 4:53	848	5.683	18.093	24.543
09/17/08 4:55	850	5.683	18.094	24.542
09/17/08 4:57	852	5.682	18.097	24.545
09/17/08 4:59	854	5.682	18.092	24.543
09/17/08 5:01	856	5.682	18.093	24.544
09/17/08 5:03	858	5.68	18.094	24.548
09/17/08 5:05	860	5.681	18.092	24.547
09/17/08 5:07	862	5.682	18.092	24.545
09/17/08 5:09	864	5.682	18.091	24.545
09/17/08 5:11	866	5.68	18.095	24.549
09/17/08 5:13	868	5.682	18.092	24.545
09/17/08 5:15	870	5.682	18.094	24.543
09/17/08 5:17	872	5.683	18.093	24.542
09/17/08 5:19	874	5.682	18.092	24.544
09/17/08 5:21	876	5.68	18.09	24.548
09/17/08 5:23	878	5.681	18.092	24.546
09/17/08 5:25	880	5.681	18.094	24.547
09/17/08 5:27	882	5.681	18.092	24.546
09/17/08 5:29	884	5.682	18.091	24.545
09/17/08 5:31	886	5.68	18.097	24.55
09/17/08 5:33	888	5.681	18.09	24.547
09/17/08 5:35	890	5.681	18.094	24.546
09/17/08 5:37	892	5.681	18.097	24.546
09/17/08 5:39	894	5.68	18.095	24.548
09/17/08 5:41	896	5.68	18.093	24.548

09/17/08 5:43	898	5.681	18.094	24.548
09/17/08 5:45	900	5.679	18.096	24.551
09/17/08 5:47	902	5.68	18.095	24.549
09/17/08 5:49	904	5.68	18.096	24.548
09/17/08 5:51	906	5.68	18.093	24.55
09/17/08 5:53	908	5.681	18.092	24.547
09/17/08 5:55	910	5.679	18.094	24.55
09/17/08 5:57	912	5.679	18.092	24.551
09/17/08 5:59	914	5.678	18.094	24.553
09/17/08 6:01	916	5.678	18.097	24.553
09/17/08 6:03	918	5.679	18.09	24.552
09/17/08 6:05	920	5.679	18.095	24.551
09/17/08 6:07	922	5.679	18.093	24.551
09/17/08 6:09	924	5.679	18.093	24.552
09/17/08 6:11	926	5.679	18.091	24.55
09/17/08 6:13	928	5.679	18.091	24.551
09/17/08 6:15	930	5.679	18.097	24.55
09/17/08 6:17	932	5.679	18.093	24.552
09/17/08 6:19	934	5.678	18.091	24.553
09/17/08 6:21	936	5.68	18.094	24.548
09/17/08 6:23	938	5.679	18.094	24.55
09/17/08 6:25	940	5.678	18.095	24.554
09/17/08 6:27	942	5.678	18.091	24.553
09/17/08 6:29	944	5.678	18.092	24.555
09/17/08 6:31	946	5.678	18.093	24.554
09/17/08 6:33	948	5.678	18.094	24.554
09/17/08 6:35	950	5.68	18.094	24.55
09/17/08 6:37	952	5.678	18.091	24.555
09/17/08 6:39	954	5.679	18.093	24.551
09/17/08 6:41	956	5.677	18.094	24.556
09/17/08 6:43	958	5.678	18.093	24.553
09/17/08 6:45	960	5.678	18.096	24.554
09/17/08 6:47	962	5.678	18.095	24.555
09/17/08 6:49	964	5.677	18.093	24.555
09/17/08 6:51	966	5.679	18.094	24.55
09/17/08 6:53	968	5.679	18.093	24.552
09/17/08 6:55	970	5.677	18.094	24.557
09/17/08 6:57	972	5.677	18.092	24.556
09/17/08 6:59	974	5.678	18.092	24.553
09/17/08 7:01	976	5.677	18.094	24.557
09/17/08 7:03	978	5.677	18.094	24.556
09/17/08 7:05	980	5.678	18.092	24.554
09/17/08 7:07	982	5.677	18.092	24.555
09/17/08 7:09	984	5.677	18.092	24.556
09/17/08 7:11	986	5.677	18.092	24.555
09/17/08 7:13	988	5.677	18.093	24.557
09/17/08 7:15	990	5.678	18.095	24.553
09/17/08 7:17	992	5.675	18.093	24.56
09/17/08 7:19	994	5.676	18.093	24.557
09/17/08 7:21	996	5.676	18.092	24.557
09/17/08 7:23	998	5.676	18.091	24.557
09/17/08 7:25	1000	5.675	18.091	24.561
09/17/08 7:27	1002	5.676	18.09	24.559
09/17/08 7:29	1004	5.676	18.095	24.558
09/17/08 7:31	1006	5.675	18.09	24.56
09/17/08 7:33	1008	5.676	18.093	24.559

09/17/08 7:35	1010	5.675	18.091	24.56
09/17/08 7:37	1012	5.677	18.092	24.557
09/17/08 7:39	1014	5.677	18.093	24.556
09/17/08 7:41	1016	5.676	18.093	24.557
09/17/08 7:43	1018	5.676	18.091	24.558
09/17/08 7:45	1020	5.675	18.091	24.561
09/17/08 7:47	1022	5.675	18.094	24.561
09/17/08 7:49	1024	5.676	18.094	24.559
09/17/08 7:51	1026	5.675	18.091	24.56
09/17/08 7:53	1028	5.676	18.09	24.559
09/17/08 7:55	1030	5.674	18.092	24.563
09/17/08 7:57	1032	5.674	18.093	24.563
09/17/08 7:59	1034	5.674	18.09	24.563
09/17/08 8:01	1036	5.675	18.092	24.56
09/17/08 8:03	1038	5.673	18.094	24.564
09/17/08 8:05	1040	5.673	18.093	24.564
09/17/08 8:07	1042	5.673	18.091	24.565
09/17/08 8:09	1044	5.674	18.094	24.562
09/17/08 8:11	1046	5.674	18.092	24.563
09/17/08 8:13	1048	5.674	18.094	24.562
09/17/08 8:15	1050	5.675	18.091	24.561
09/17/08 8:17	1052	5.675	18.092	24.561
09/17/08 8:19	1054	5.674	18.09	24.563
09/17/08 8:21	1056	5.674	18.091	24.563
09/17/08 8:23	1058	5.674	18.091	24.562
09/17/08 8:25	1060	5.673	18.094	24.565
09/17/08 8:27	1062	5.673	18.09	24.565
09/17/08 8:29	1064	5.674	18.093	24.563
09/17/08 8:31	1066	5.674	18.094	24.563
09/17/08 8:33	1068	5.674	18.093	24.564
09/17/08 8:35	1070	5.674	18.09	24.564
09/17/08 8:37	1072	5.674	18.094	24.563
09/17/08 8:39	1074	5.676	18.094	24.557
09/17/08 8:41	1076	5.678	18.098	24.553
09/17/08 8:43	1078	5.677	18.093	24.557
09/17/08 8:45	1080	5.679	18.091	24.552
09/17/08 8:47	1082	5.678	18.094	24.553
09/17/08 8:49	1084	5.678	18.093	24.554
09/17/08 8:51	1086	5.677	18.094	24.556
09/17/08 8:53	1088	5.678	18.094	24.553
09/17/08 8:55	1090	5.679	18.094	24.553
09/17/08 8:57	1092	5.678	18.096	24.554
09/17/08 8:59	1094	5.677	18.092	24.556
09/17/08 9:01	1096	5.676	18.093	24.559
09/17/08 9:03	1098	5.676	18.093	24.558
09/17/08 9:05	1100	5.676	18.093	24.559
09/17/08 9:07	1102	5.677	18.093	24.556
09/17/08 9:09	1104	5.677	18.091	24.556
09/17/08 9:11	1106	5.675	18.092	24.56
09/17/08 9:13	1108	5.676	18.091	24.558
09/17/08 9:15	1110	5.678	18.093	24.553
09/17/08 9:17	1112	5.678	18.094	24.554
09/17/08 9:19	1114	5.68	18.095	24.55
09/17/08 9:21	1116	5.681	18.093	24.546
09/17/08 9:23	1118	5.682	18.093	24.544
09/17/08 9:25	1120	5.682	18.093	24.544

09/17/08 9:27	1122	5.682	18.092	24.546
09/17/08 9:29	1124	5.683	18.095	24.543
09/17/08 9:31	1126	5.683	18.092	24.541
09/17/08 9:33	1128	5.682	18.092	24.544
09/17/08 9:35	1130	5.685	18.091	24.538
09/17/08 9:37	1132	5.685	18.091	24.539
09/17/08 9:39	1134	5.685	18.094	24.538
09/17/08 9:41	1136	5.686	18.094	24.536
09/17/08 9:43	1138	5.686	18.096	24.536
09/17/08 9:45	1140	5.688	18.092	24.53
09/17/08 9:47	1142	5.688	18.094	24.531
09/17/08 9:49	1144	5.687	18.094	24.532
09/17/08 9:51	1146	5.687	18.093	24.532
09/17/08 9:53	1148	5.688	18.095	24.531
09/17/08 9:55	1150	5.687	18.094	24.533
09/17/08 9:57	1152	5.689	18.093	24.529
09/17/08 9:59	1154	5.688	18.094	24.531
09/17/08 10:01	1156	5.689	18.095	24.529
09/17/08 10:03	1158	5.69	18.096	24.527
09/17/08 10:05	1160	5.689	18.092	24.527
09/17/08 10:07	1162	5.689	18.094	24.528
09/17/08 10:09	1164	5.689	18.091	24.527
09/17/08 10:11	1166	5.687	18.094	24.532
09/17/08 10:13	1168	5.69	18.093	24.525
09/17/08 10:15	1170	5.69	18.093	24.526
09/17/08 10:17	1172	5.692	18.091	24.522
09/17/08 10:19	1174	5.692	18.094	24.522
09/17/08 10:21	1176	5.692	18.093	24.521
09/17/08 10:23	1178	5.692	18.091	24.521
09/17/08 10:25	1180	5.691	18.096	24.524
09/17/08 10:27	1182	5.692	18.094	24.521
09/17/08 10:29	1184	5.692	18.096	24.522
09/17/08 10:31	1186	5.692	18.094	24.521
09/17/08 10:33	1188	5.692	18.093	24.521
09/17/08 10:35	1190	5.693	18.095	24.52
09/17/08 10:37	1192	5.694	18.094	24.517
09/17/08 10:39	1194	5.693	18.093	24.518
09/17/08 10:41	1196	5.695	18.094	24.514
09/17/08 10:43	1198	5.694	18.094	24.517
09/17/08 10:45	1200	5.693	18.095	24.518
09/17/08 10:47	1202	5.696	18.093	24.513
09/17/08 10:49	1204	5.697	18.093	24.511
09/17/08 10:51	1206	5.694	18.095	24.516
09/17/08 10:53	1208	5.695	18.095	24.515
09/17/08 10:55	1210	5.696	18.095	24.513
09/17/08 10:57	1212	5.696	18.093	24.512
09/17/08 10:59	1214	5.694	18.094	24.516
09/17/08 11:01	1216	5.696	18.095	24.511
09/17/08 11:03	1218	5.696	18.093	24.511
09/17/08 11:05	1220	5.696	18.095	24.512
09/17/08 11:07	1222	5.697	18.093	24.509
09/17/08 11:09	1224	5.697	18.095	24.509
09/17/08 11:11	1226	5.697	18.094	24.51
09/17/08 11:13	1228	5.698	18.091	24.507
09/17/08 11:15	1230	5.699	18.093	24.506
09/17/08 11:17	1232	5.697	18.093	24.51

09/17/08 11:19	1234	5.698	18.095	24.508
09/17/08 11:21	1236	5.697	18.094	24.51
09/17/08 11:23	1238	5.699	18.091	24.504
09/17/08 11:25	1240	5.699	18.093	24.506
09/17/08 11:27	1242	5.7	18.092	24.504
09/17/08 11:29	1244	5.7	18.095	24.503
09/17/08 11:31	1246	5.698	18.093	24.507
09/17/08 11:33	1248	5.698	18.095	24.508
09/17/08 11:35	1250	5.7	18.095	24.502
09/17/08 11:37	1252	5.7	18.092	24.504
09/17/08 11:39	1254	5.701	18.094	24.5
09/17/08 11:41	1256	5.701	18.093	24.501
09/17/08 11:43	1258	5.701	18.094	24.501
09/17/08 11:45	1260	5.701	18.095	24.5
09/17/08 11:47	1262	5.699	18.093	24.504
09/17/08 11:49	1264	5.703	18.095	24.497
09/17/08 11:51	1266	5.701	18.094	24.5
09/17/08 11:53	1268	5.701	18.093	24.501
09/17/08 11:55	1270	5.702	18.095	24.499
09/17/08 11:57	1272	5.703	18.094	24.497
09/17/08 11:59	1274	5.703	18.093	24.496
09/17/08 12:01	1276	5.702	18.093	24.499
09/17/08 12:03	1278	5.703	18.093	24.496
09/17/08 12:05	1280	5.705	18.094	24.492
09/17/08 12:07	1282	5.703	18.093	24.495
09/17/08 12:09	1284	5.704	18.095	24.494
09/17/08 12:11	1286	5.703	18.096	24.495
09/17/08 12:13	1288	5.705	18.095	24.492
09/17/08 12:15	1290	5.704	18.093	24.493
09/17/08 12:17	1292	5.704	18.095	24.493
09/17/08 12:19	1294	5.704	18.094	24.495
09/17/08 12:21	1296	5.704	18.095	24.494
09/17/08 12:23	1298	5.705	18.091	24.491
09/17/08 12:25	1300	5.705	18.094	24.492
09/17/08 12:27	1302	5.705	18.093	24.491
09/17/08 12:29	1304	5.706	18.096	24.49
09/17/08 12:31	1306	5.705	18.094	24.492
09/17/08 12:33	1308	5.705	18.092	24.492
09/17/08 12:35	1310	5.706	18.094	24.489
09/17/08 12:37	1312	5.707	18.094	24.486
09/17/08 12:39	1314	5.707	18.093	24.486
09/17/08 12:41	1316	5.708	18.095	24.483
09/17/08 12:43	1318	5.706	18.092	24.488
09/17/08 12:45	1320	5.706	18.091	24.489
09/17/08 12:47	1322	5.706	18.096	24.489
09/17/08 12:49	1324	5.708	18.091	24.485
09/17/08 12:51	1326	5.706	18.095	24.489
09/17/08 12:53	1328	5.708	18.094	24.485
09/17/08 12:55	1330	5.706	18.095	24.489
09/17/08 12:57	1332	5.706	18.093	24.488
09/17/08 12:59	1334	5.707	18.095	24.488
09/17/08 13:01	1336	5.707	18.095	24.486
09/17/08 13:03	1338	5.708	18.093	24.485
09/17/08 13:05	1340	5.709	18.095	24.482
09/17/08 13:07	1342	5.709	18.094	24.483
09/17/08 13:09	1344	5.708	18.095	24.484

09/17/08 13:11	1346	5.709	18.093	24.482
09/17/08 13:13	1348	5.709	18.097	24.482
09/17/08 13:15	1350	5.708	18.091	24.483
09/17/08 13:17	1352	5.708	18.091	24.485
09/17/08 13:19	1354	5.707	18.095	24.486
09/17/08 13:21	1356	5.709	18.093	24.483
09/17/08 13:23	1358	5.71	18.095	24.48
09/17/08 13:25	1360	5.708	18.097	24.485
09/17/08 13:27	1362	5.709	18.093	24.482
09/17/08 13:29	1364	5.709	18.096	24.481
09/17/08 13:31	1366	5.711	18.092	24.479
09/17/08 13:33	1368	5.712	18.094	24.476
09/17/08 13:35	1370	5.711	18.093	24.477
09/17/08 13:37	1372	5.71	18.095	24.479
09/17/08 13:39	1374	5.71	18.096	24.479
09/17/08 13:41	1376	5.711	18.095	24.477
09/17/08 13:43	1378	5.711	18.093	24.478
09/17/08 13:45	1380	5.711	18.095	24.477
09/17/08 13:47	1382	5.71	18.094	24.48
09/17/08 13:49	1384	5.711	18.093	24.477
09/17/08 13:51	1386	5.712	18.095	24.476
09/17/08 13:53	1388	5.712	18.094	24.476
09/17/08 13:55	1390	5.712	18.094	24.474
09/17/08 13:57	1392	5.712	18.091	24.475
09/17/08 13:59	1394	5.712	18.094	24.476
09/17/08 14:01	1396	5.712	18.094	24.476
09/17/08 14:03	1398	5.71	18.092	24.479
09/17/08 14:05	1400	5.714	18.093	24.471
09/17/08 14:07	1402	5.713	18.095	24.473
09/17/08 14:09	1404	5.713	18.094	24.472
09/17/08 14:11	1406	5.712	18.092	24.475
09/17/08 14:13	1408	5.713	18.093	24.473
09/17/08 14:15	1410	5.711	18.094	24.476
09/17/08 14:17	1412	5.713	18.096	24.474
09/17/08 14:19	1414	5.711	18.093	24.476
09/17/08 14:21	1416	5.712	18.095	24.474
09/17/08 14:23	1418	5.714	18.093	24.472
09/17/08 14:25	1420	5.714	18.093	24.471
09/17/08 14:27	1422	5.714	18.095	24.47
09/17/08 14:29	1424	5.715	18.096	24.469
09/17/08 14:31	1426	5.715	18.095	24.469
09/17/08 14:33	1428	5.715	18.093	24.469
09/17/08 14:35	1430	5.713	18.094	24.473

```
Report Date:                         09/18/08 7:29
Report User Name:        AndrewP
Report Computer Name:    SOURCE3-7B7FDF2


Log File Properties
File Name                MW-09 2008-09-16 18-43-22.wsl
Create Date                          09/17/08 14:39

Device Properties
Device                   Level TROLL® 700
Site                     Tank Battery
Device Name              GEOTECH RENTAL # 2368
Serial Number                              125565
Firmware Version                             2.07

Log Configuration
                         Log Name                  MW-09
                         Created By                AndrewP
                         Computer Name             SOURCE3-7B7FDF2
                         Application               WinSitu.exe
                         Application Version       5.6.4.6
                         Create Date                09/16/08 14:31
                         Notes Size(bytes)                   4096
                         Type                      Linear
                         Overwrite when full       Disabled
                         Scheduled Start Time       09/16/08 14:45
                         Scheduled Stop Time       No Stop Time
                         Interval                  Days: 0 hrs: 00 mins: 02 secs: 00


Level Reference Settings At Log Creation
                            Level Measurement Mode Level Depth To Water
                               Specific Gravity             0.999
                             Level Reference Mode: Set new reference
                            Level Reference Value: 25.26 (ft)
                      Level Reference Head Pressure 1.25873 (PSI)
                                  Head Pressure    1.25887 (PSI)
                                   Temperature     40.519 (C)
                                  Depth of Probe   2.90669 (ft)


Log Notes:
Date and Time            Note
         09/16/08 18:42 User Note: "Downloading log - Used Batt: 4% Memory: 1% User: AndrewP"
         09/17/08 14:38 Manual Stop Command
```

Log Data:
Record Count 717

		Sensor: Pres 69ft	Sensor: Pres 69ft	Sensor: Pres 69ft
	Elapsed Time	SN#: 125565	SN#: 125565	SN#: 125565
Date and Time	Minutes	Pressure (PSI)	Temperature (C)	Level Depth To Water (ft)
09/16/08 14:45	0	1.248	18.672	25.284
09/16/08 14:47	2	1.248	18.509	25.285
09/16/08 14:49	4	1.245	18.405	25.292
09/16/08 14:51	6	1.247	18.334	25.288
09/16/08 14:53	8	1.247	18.291	25.286
09/16/08 14:55	10	1.247	18.25	25.288
09/16/08 14:57	12	1.246	18.219	25.29
09/16/08 14:59	14	1.244	18.198	25.295
09/16/08 15:01	16	1.244	18.177	25.295
09/16/08 15:03	18	1.244	18.16	25.294
09/16/08 15:05	20	1.241	18.151	25.3
09/16/08 15:07	22	1.24	18.136	25.304
09/16/08 15:09	24	1.242	18.124	25.298
09/16/08 15:11	26	1.241	18.112	25.302
09/16/08 15:13	28	1.24	18.105	25.303
09/16/08 15:15	30	1.24	18.098	25.303
09/16/08 15:17	32	1.241	18.092	25.301
09/16/08 15:19	34	1.24	18.084	25.304
09/16/08 15:21	36	1.238	18.078	25.307
09/16/08 15:23	38	1.24	18.07	25.303
09/16/08 15:25	40	1.239	18.065	25.305
09/16/08 15:27	42	1.238	18.058	25.309
09/16/08 15:29	44	1.239	18.056	25.305
09/16/08 15:31	46	1.238	18.05	25.308
09/16/08 15:33	48	1.239	18.047	25.305
09/16/08 15:35	50	1.237	18.043	25.31
09/16/08 15:37	52	1.236	18.036	25.313
09/16/08 15:39	54	1.237	18.035	25.31
09/16/08 15:41	56	1.237	18.032	25.309
09/16/08 15:43	58	1.235	18.027	25.314
09/16/08 15:45	60	1.238	18.024	25.309
09/16/08 15:47	62	1.236	18.025	25.313
09/16/08 15:49	64	1.236	18.019	25.312
09/16/08 15:51	66	1.235	18.017	25.315
09/16/08 15:53	68	1.234	18.018	25.317
09/16/08 15:55	70	1.234	18.014	25.317
09/16/08 15:57	72	1.236	18.011	25.313
09/16/08 15:59	74	1.233	18.011	25.32
09/16/08 16:01	76	1.233	18.008	25.319
09/16/08 16:03	78	1.234	18.005	25.317
09/16/08 16:05	80	1.233	18.004	25.32
09/16/08 16:07	82	1.234	18.003	25.318
09/16/08 16:09	84	1.231	18.002	25.324

09/16/08 16:11	86	1.234	18	25.318
09/16/08 16:13	88	1.233	18.003	25.319
09/16/08 16:15	90	1.23	17.997	25.327
09/16/08 16:17	92	1.231	17.997	25.324
09/16/08 16:19	94	1.229	17.996	25.328
09/16/08 16:21	96	1.23	17.995	25.325
09/16/08 16:23	98	1.228	17.991	25.331
09/16/08 16:25	100	1.229	17.992	25.328
09/16/08 16:27	102	1.229	17.99	25.329
09/16/08 16:29	104	1.229	17.991	25.33
09/16/08 16:31	106	1.228	17.989	25.331
09/16/08 16:33	108	1.229	17.985	25.328
09/16/08 16:35	110	1.229	17.99	25.328
09/16/08 16:37	112	1.227	17.988	25.333
09/16/08 16:39	114	1.232	17.987	25.322
09/16/08 16:41	116	1.231	17.987	25.323
09/16/08 16:43	118	1.231	17.982	25.324
09/16/08 16:45	120	1.232	17.983	25.321
09/16/08 16:47	122	1.231	17.983	25.324
09/16/08 16:49	124	1.229	17.98	25.328
09/16/08 16:51	126	1.229	17.983	25.328
09/16/08 16:53	128	1.23	17.98	25.326
09/16/08 16:55	130	1.23	17.982	25.327
09/16/08 16:57	132	1.23	17.979	25.326
09/16/08 16:59	134	1.229	17.979	25.33
09/16/08 17:01	136	1.23	17.979	25.326
09/16/08 17:03	138	1.23	17.977	25.327
09/16/08 17:05	140	1.228	17.976	25.33
09/16/08 17:07	142	1.229	17.979	25.33
09/16/08 17:09	144	1.23	17.976	25.326
09/16/08 17:11	146	1.226	17.977	25.335
09/16/08 17:13	148	1.226	17.976	25.335
09/16/08 17:15	150	1.227	17.976	25.334
09/16/08 17:17	152	1.227	17.976	25.333
09/16/08 17:19	154	1.228	17.974	25.331
09/16/08 17:21	156	1.227	17.975	25.334
09/16/08 17:23	158	1.226	17.975	25.336
09/16/08 17:25	160	1.225	17.974	25.339
09/16/08 17:27	162	1.227	17.975	25.333
09/16/08 17:29	164	1.226	17.974	25.337
09/16/08 17:31	166	1.228	17.976	25.332
09/16/08 17:33	168	1.226	17.971	25.335
09/16/08 17:35	170	1.226	17.973	25.335
09/16/08 17:37	172	1.226	17.971	25.336
09/16/08 17:39	174	1.225	17.971	25.338
09/16/08 17:41	176	1.225	17.972	25.338
09/16/08 17:43	178	1.226	17.973	25.335
09/16/08 17:45	180	1.225	17.968	25.339
09/16/08 17:47	182	1.224	17.97	25.34

09/16/08 17:49	184	1.225	17.973	25.338
09/16/08 17:51	186	1.225	17.971	25.337
09/16/08 17:53	188	1.224	17.97	25.341
09/16/08 17:55	190	1.225	17.971	25.338
09/16/08 17:57	192	1.224	17.968	25.339
09/16/08 17:59	194	1.223	17.97	25.342
09/16/08 18:01	196	1.225	17.968	25.338
09/16/08 18:03	198	1.223	17.969	25.344
09/16/08 18:05	200	1.225	17.968	25.337
09/16/08 18:07	202	1.223	17.969	25.342
09/16/08 18:09	204	1.224	17.968	25.341
09/16/08 18:11	206	1.222	17.967	25.345
09/16/08 18:13	208	1.221	17.969	25.347
09/16/08 18:15	210	1.222	17.967	25.345
09/16/08 18:17	212	1.222	17.966	25.346
09/16/08 18:19	214	1.222	17.968	25.345
09/16/08 18:21	216	1.222	17.968	25.345
09/16/08 18:23	218	1.222	17.967	25.345
09/16/08 18:25	220	1.221	17.968	25.348
09/16/08 18:27	222	1.222	17.965	25.346
09/16/08 18:29	224	1.221	17.966	25.347
09/16/08 18:31	226	1.221	17.967	25.346
09/16/08 18:33	228	1.222	17.968	25.344
09/16/08 18:35	230	1.221	17.968	25.346
09/16/08 18:37	232	1.219	17.967	25.351
09/16/08 18:39	234	1.22	17.967	25.349
09/16/08 18:41	236	1.221	17.968	25.348
09/16/08 18:43	238	1.222	17.975	25.345
09/16/08 18:45	240	1.218	17.978	25.353
09/16/08 18:47	242	1.221	17.969	25.346
09/16/08 18:49	244	1.221	17.966	25.347
09/16/08 18:51	246	1.219	17.967	25.351
09/16/08 18:53	248	1.219	17.965	25.352
09/16/08 18:55	250	1.219	17.968	25.351
09/16/08 18:57	252	1.221	17.964	25.346
09/16/08 18:59	254	1.221	17.966	25.347
09/16/08 19:01	256	1.22	17.967	25.35
09/16/08 19:03	258	1.219	17.964	25.352
09/16/08 19:05	260	1.22	17.963	25.35
09/16/08 19:07	262	1.219	17.965	25.353
09/16/08 19:09	264	1.218	17.965	25.354
09/16/08 19:11	266	1.218	17.964	25.353
09/16/08 19:13	268	1.22	17.965	25.35
09/16/08 19:15	270	1.216	17.965	25.359
09/16/08 19:17	272	1.218	17.967	25.355
09/16/08 19:19	274	1.217	17.966	25.357
09/16/08 19:21	276	1.217	17.964	25.357
09/16/08 19:23	278	1.217	17.963	25.355
09/16/08 19:25	280	1.217	17.964	25.357

09/16/08 19:27	282	1.218	17.963	25.355
09/16/08 19:29	284	1.216	17.962	25.359
09/16/08 19:31	286	1.217	17.963	25.357
09/16/08 19:33	288	1.216	17.966	25.358
09/16/08 19:35	290	1.215	17.963	25.36
09/16/08 19:37	292	1.217	17.961	25.357
09/16/08 19:39	294	1.215	17.964	25.361
09/16/08 19:41	296	1.214	17.965	25.364
09/16/08 19:43	298	1.214	17.963	25.362
09/16/08 19:45	300	1.215	17.963	25.362
09/16/08 19:47	302	1.217	17.962	25.357
09/16/08 19:49	304	1.214	17.962	25.362
09/16/08 19:51	306	1.214	17.961	25.363
09/16/08 19:53	308	1.215	17.963	25.361
09/16/08 19:55	310	1.217	17.964	25.357
09/16/08 19:57	312	1.214	17.965	25.364
09/16/08 19:59	314	1.214	17.963	25.364
09/16/08 20:01	316	1.214	17.961	25.363
09/16/08 20:03	318	1.214	17.962	25.364
09/16/08 20:05	320	1.213	17.963	25.365
09/16/08 20:07	322	1.213	17.96	25.365
09/16/08 20:09	324	1.212	17.965	25.367
09/16/08 20:11	326	1.213	17.963	25.366
09/16/08 20:13	328	1.212	17.961	25.367
09/16/08 20:15	330	1.213	17.963	25.366
09/16/08 20:17	332	1.214	17.962	25.364
09/16/08 20:19	334	1.212	17.965	25.367
09/16/08 20:21	336	1.21	17.963	25.372
09/16/08 20:23	338	1.212	17.965	25.368
09/16/08 20:25	340	1.212	17.96	25.369
09/16/08 20:27	342	1.211	17.961	25.37
09/16/08 20:29	344	1.211	17.962	25.37
09/16/08 20:31	346	1.212	17.961	25.367
09/16/08 20:33	348	1.211	17.963	25.369
09/16/08 20:35	350	1.211	17.961	25.37
09/16/08 20:37	352	1.211	17.963	25.371
09/16/08 20:39	354	1.209	17.963	25.374
09/16/08 20:41	356	1.208	17.962	25.376
09/16/08 20:43	358	1.211	17.96	25.37
09/16/08 20:45	360	1.209	17.96	25.374
09/16/08 20:47	362	1.209	17.96	25.374
09/16/08 20:49	364	1.209	17.964	25.376
09/16/08 20:51	366	1.21	17.963	25.373
09/16/08 20:53	368	1.209	17.963	25.375
09/16/08 20:55	370	1.208	17.962	25.377
09/16/08 20:57	372	1.209	17.964	25.375
09/16/08 20:59	374	1.208	17.963	25.377
09/16/08 21:01	376	1.21	17.96	25.373
09/16/08 21:03	378	1.209	17.962	25.375

09/16/08 21:05	380	1.209	17.962	25.375
09/16/08 21:07	382	1.208	17.963	25.377
09/16/08 21:09	384	1.209	17.963	25.374
09/16/08 21:11	386	1.209	17.965	25.374
09/16/08 21:13	388	1.21	17.961	25.373
09/16/08 21:15	390	1.209	17.962	25.375
09/16/08 21:17	392	1.209	17.959	25.376
09/16/08 21:19	394	1.209	17.963	25.375
09/16/08 21:21	396	1.208	17.962	25.377
09/16/08 21:23	398	1.207	17.96	25.379
09/16/08 21:25	400	1.207	17.962	25.379
09/16/08 21:27	402	1.208	17.962	25.376
09/16/08 21:29	404	1.206	17.962	25.383
09/16/08 21:31	406	1.206	17.96	25.382
09/16/08 21:33	408	1.209	17.963	25.375
09/16/08 21:35	410	1.207	17.962	25.379
09/16/08 21:37	412	1.208	17.963	25.376
09/16/08 21:39	414	1.209	17.959	25.376
09/16/08 21:41	416	1.207	17.962	25.379
09/16/08 21:43	418	1.205	17.962	25.383
09/16/08 21:45	420	1.209	17.962	25.376
09/16/08 21:47	422	1.206	17.961	25.381
09/16/08 21:49	424	1.206	17.963	25.382
09/16/08 21:51	426	1.206	17.962	25.382
09/16/08 21:53	428	1.208	17.963	25.377
09/16/08 21:55	430	1.207	17.961	25.38
09/16/08 21:57	432	1.205	17.962	25.385
09/16/08 21:59	434	1.206	17.961	25.382
09/16/08 22:01	436	1.207	17.963	25.38
09/16/08 22:03	438	1.206	17.961	25.381
09/16/08 22:05	440	1.206	17.961	25.383
09/16/08 22:07	442	1.206	17.961	25.383
09/16/08 22:09	444	1.205	17.96	25.385
09/16/08 22:11	446	1.206	17.962	25.383
09/16/08 22:13	448	1.207	17.961	25.379
09/16/08 22:15	450	1.205	17.961	25.384
09/16/08 22:17	452	1.205	17.961	25.385
09/16/08 22:19	454	1.207	17.961	25.379
09/16/08 22:21	456	1.205	17.96	25.385
09/16/08 22:23	458	1.205	17.962	25.385
09/16/08 22:25	460	1.204	17.961	25.386
09/16/08 22:27	462	1.205	17.96	25.384
09/16/08 22:29	464	1.205	17.96	25.385
09/16/08 22:31	466	1.205	17.962	25.384
09/16/08 22:33	468	1.204	17.961	25.386
09/16/08 22:35	470	1.203	17.962	25.389
09/16/08 22:37	472	1.206	17.963	25.383
09/16/08 22:39	474	1.205	17.96	25.384
09/16/08 22:41	476	1.203	17.96	25.39

09/16/08 22:43	478	1.204	17.961	25.387
09/16/08 22:45	480	1.204	17.961	25.387
09/16/08 22:47	482	1.203	17.958	25.389
09/16/08 22:49	484	1.204	17.962	25.385
09/16/08 22:51	486	1.204	17.961	25.387
09/16/08 22:53	488	1.203	17.96	25.389
09/16/08 22:55	490	1.204	17.962	25.387
09/16/08 22:57	492	1.203	17.96	25.388
09/16/08 22:59	494	1.204	17.961	25.386
09/16/08 23:01	496	1.204	17.963	25.386
09/16/08 23:03	498	1.202	17.959	25.39
09/16/08 23:05	500	1.202	17.96	25.391
09/16/08 23:07	502	1.203	17.963	25.39
09/16/08 23:09	504	1.203	17.963	25.389
09/16/08 23:11	506	1.203	17.963	25.389
09/16/08 23:13	508	1.202	17.958	25.391
09/16/08 23:15	510	1.202	17.956	25.392
09/16/08 23:17	512	1.203	17.96	25.389
09/16/08 23:19	514	1.201	17.96	25.394
09/16/08 23:21	516	1.203	17.96	25.388
09/16/08 23:23	518	1.204	17.962	25.386
09/16/08 23:25	520	1.201	17.962	25.393
09/16/08 23:27	522	1.203	17.958	25.389
09/16/08 23:29	524	1.2	17.961	25.395
09/16/08 23:31	526	1.202	17.962	25.391
09/16/08 23:33	528	1.2	17.959	25.396
09/16/08 23:35	530	1.2	17.96	25.395
09/16/08 23:37	532	1.2	17.959	25.396
09/16/08 23:39	534	1.198	17.962	25.399
09/16/08 23:41	536	1.201	17.962	25.393
09/16/08 23:43	538	1.2	17.961	25.396
09/16/08 23:45	540	1.2	17.962	25.395
09/16/08 23:47	542	1.2	17.96	25.397
09/16/08 23:49	544	1.199	17.962	25.399
09/16/08 23:51	546	1.2	17.961	25.396
09/16/08 23:53	548	1.2	17.961	25.396
09/16/08 23:55	550	1.2	17.961	25.395
09/16/08 23:57	552	1.199	17.96	25.398
09/16/08 23:59	554	1.2	17.958	25.396
09/17/08 0:01	556	1.2	17.96	25.395
09/17/08 0:03	558	1.199	17.962	25.397
09/17/08 0:05	560	1.2	17.962	25.396
09/17/08 0:07	562	1.199	17.961	25.397
09/17/08 0:09	564	1.2	17.958	25.397
09/17/08 0:11	566	1.2	17.959	25.395
09/17/08 0:13	568	1.199	17.96	25.399
09/17/08 0:15	570	1.197	17.959	25.403
09/17/08 0:17	572	1.198	17.96	25.4
09/17/08 0:19	574	1.199	17.963	25.398

09/17/08 0:21	576	1.198	17.961	25.4
09/17/08 0:23	578	1.198	17.964	25.401
09/17/08 0:25	580	1.198	17.959	25.4
09/17/08 0:27	582	1.2	17.964	25.397
09/17/08 0:29	584	1.199	17.96	25.397
09/17/08 0:31	586	1.199	17.959	25.398
09/17/08 0:33	588	1.197	17.96	25.403
09/17/08 0:35	590	1.2	17.959	25.396
09/17/08 0:37	592	1.199	17.96	25.399
09/17/08 0:39	594	1.197	17.958	25.403
09/17/08 0:41	596	1.199	17.958	25.397
09/17/08 0:43	598	1.198	17.961	25.401
09/17/08 0:45	600	1.198	17.961	25.4
09/17/08 0:47	602	1.197	17.96	25.402
09/17/08 0:49	604	1.197	17.959	25.401
09/17/08 0:51	606	1.198	17.96	25.4
09/17/08 0:53	608	1.197	17.96	25.402
09/17/08 0:55	610	1.198	17.962	25.4
09/17/08 0:57	612	1.198	17.958	25.401
09/17/08 0:59	614	1.197	17.96	25.402
09/17/08 1:01	616	1.197	17.961	25.402
09/17/08 1:03	618	1.197	17.958	25.401
09/17/08 1:05	620	1.198	17.96	25.401
09/17/08 1:07	622	1.197	17.96	25.402
09/17/08 1:09	624	1.195	17.962	25.407
09/17/08 1:11	626	1.196	17.959	25.405
09/17/08 1:13	628	1.198	17.961	25.4
09/17/08 1:15	630	1.197	17.96	25.403
09/17/08 1:17	632	1.198	17.961	25.401
09/17/08 1:19	634	1.196	17.959	25.404
09/17/08 1:21	636	1.197	17.962	25.401
09/17/08 1:23	638	1.195	17.961	25.408
09/17/08 1:25	640	1.197	17.962	25.402
09/17/08 1:27	642	1.198	17.961	25.401
09/17/08 1:29	644	1.198	17.96	25.4
09/17/08 1:31	646	1.196	17.959	25.404
09/17/08 1:33	648	1.198	17.96	25.401
09/17/08 1:35	650	1.197	17.958	25.403
09/17/08 1:37	652	1.197	17.961	25.403
09/17/08 1:39	654	1.197	17.959	25.402
09/17/08 1:41	656	1.196	17.96	25.405
09/17/08 1:43	658	1.197	17.959	25.403
09/17/08 1:45	660	1.195	17.96	25.408
09/17/08 1:47	662	1.197	17.961	25.401
09/17/08 1:49	664	1.196	17.96	25.404
09/17/08 1:51	666	1.197	17.958	25.403
09/17/08 1:53	668	1.196	17.96	25.405
09/17/08 1:55	670	1.196	17.96	25.405
09/17/08 1:57	672	1.196	17.961	25.406

09/17/08 1:59	674	1.196	17.961	25.405
09/17/08 2:01	676	1.197	17.961	25.404
09/17/08 2:03	678	1.196	17.96	25.405
09/17/08 2:05	680	1.193	17.959	25.411
09/17/08 2:07	682	1.194	17.957	25.411
09/17/08 2:09	684	1.196	17.96	25.405
09/17/08 2:11	686	1.195	17.961	25.408
09/17/08 2:13	688	1.194	17.961	25.41
09/17/08 2:15	690	1.195	17.961	25.407
09/17/08 2:17	692	1.194	17.962	25.409
09/17/08 2:19	694	1.195	17.958	25.406
09/17/08 2:21	696	1.194	17.958	25.41
09/17/08 2:23	698	1.194	17.96	25.409
09/17/08 2:25	700	1.196	17.958	25.406
09/17/08 2:27	702	1.196	17.958	25.406
09/17/08 2:29	704	1.196	17.957	25.406
09/17/08 2:31	706	1.195	17.961	25.408
09/17/08 2:33	708	1.195	17.962	25.408
09/17/08 2:35	710	1.195	17.96	25.407
09/17/08 2:37	712	1.194	17.957	25.41
09/17/08 2:39	714	1.194	17.961	25.409
09/17/08 2:41	716	1.193	17.959	25.411
09/17/08 2:43	718	1.194	17.959	25.408
09/17/08 2:45	720	1.194	17.96	25.41
09/17/08 2:47	722	1.196	17.962	25.405
09/17/08 2:49	724	1.194	17.961	25.41
09/17/08 2:51	726	1.195	17.961	25.407
09/17/08 2:53	728	1.194	17.959	25.41
09/17/08 2:55	730	1.192	17.958	25.413
09/17/08 2:57	732	1.194	17.956	25.41
09/17/08 2:59	734	1.195	17.961	25.406
09/17/08 3:01	736	1.194	17.96	25.41
09/17/08 3:03	738	1.193	17.959	25.412
09/17/08 3:05	740	1.193	17.958	25.412
09/17/08 3:07	742	1.194	17.96	25.409
09/17/08 3:09	744	1.194	17.96	25.409
09/17/08 3:11	746	1.193	17.963	25.411
09/17/08 3:13	748	1.192	17.96	25.413
09/17/08 3:15	750	1.193	17.959	25.412
09/17/08 3:17	752	1.191	17.959	25.416
09/17/08 3:19	754	1.192	17.962	25.413
09/17/08 3:21	756	1.193	17.957	25.412
09/17/08 3:23	758	1.194	17.962	25.41
09/17/08 3:25	760	1.192	17.962	25.414
09/17/08 3:27	762	1.193	17.957	25.411
09/17/08 3:29	764	1.192	17.961	25.413
09/17/08 3:31	766	1.19	17.96	25.418
09/17/08 3:33	768	1.191	17.961	25.416
09/17/08 3:35	770	1.192	17.96	25.413

09/17/08 3:37	772	1.191	17.96	25.415
09/17/08 3:39	774	1.191	17.959	25.416
09/17/08 3:41	776	1.193	17.96	25.412
09/17/08 3:43	778	1.192	17.961	25.413
09/17/08 3:45	780	1.19	17.959	25.419
09/17/08 3:47	782	1.192	17.961	25.415
09/17/08 3:49	784	1.192	17.958	25.414
09/17/08 3:51	786	1.19	17.957	25.418
09/17/08 3:53	788	1.191	17.96	25.415
09/17/08 3:55	790	1.191	17.961	25.417
09/17/08 3:57	792	1.192	17.961	25.414
09/17/08 3:59	794	1.191	17.96	25.417
09/17/08 4:01	796	1.189	17.964	25.42
09/17/08 4:03	798	1.192	17.959	25.415
09/17/08 4:05	800	1.189	17.958	25.42
09/17/08 4:07	802	1.19	17.964	25.418
09/17/08 4:09	804	1.19	17.958	25.42
09/17/08 4:11	806	1.19	17.959	25.42
09/17/08 4:13	808	1.191	17.961	25.416
09/17/08 4:15	810	1.188	17.958	25.424
09/17/08 4:17	812	1.191	17.96	25.415
09/17/08 4:19	814	1.19	17.959	25.418
09/17/08 4:21	816	1.19	17.961	25.418
09/17/08 4:23	818	1.19	17.963	25.418
09/17/08 4:25	820	1.188	17.959	25.423
09/17/08 4:27	822	1.19	17.959	25.42
09/17/08 4:29	824	1.188	17.96	25.423
09/17/08 4:31	826	1.188	17.962	25.422
09/17/08 4:33	828	1.189	17.962	25.42
09/17/08 4:35	830	1.189	17.961	25.421
09/17/08 4:37	832	1.188	17.96	25.424
09/17/08 4:39	834	1.188	17.96	25.423
09/17/08 4:41	836	1.187	17.958	25.426
09/17/08 4:43	838	1.189	17.96	25.42
09/17/08 4:45	840	1.188	17.963	25.423
09/17/08 4:47	842	1.188	17.96	25.423
09/17/08 4:49	844	1.189	17.958	25.421
09/17/08 4:51	846	1.188	17.96	25.422
09/17/08 4:53	848	1.19	17.959	25.419
09/17/08 4:55	850	1.189	17.959	25.421
09/17/08 4:57	852	1.188	17.958	25.424
09/17/08 4:59	854	1.19	17.961	25.418
09/17/08 5:01	856	1.19	17.96	25.419
09/17/08 5:03	858	1.189	17.96	25.421
09/17/08 5:05	860	1.186	17.961	25.427
09/17/08 5:07	862	1.188	17.962	25.422
09/17/08 5:09	864	1.188	17.959	25.424
09/17/08 5:11	866	1.187	17.959	25.425
09/17/08 5:13	868	1.188	17.961	25.423

09/17/08 5:15	870	1.188	17.96	25.423
09/17/08 5:17	872	1.186	17.958	25.428
09/17/08 5:19	874	1.188	17.959	25.422
09/17/08 5:21	876	1.187	17.958	25.425
09/17/08 5:23	878	1.187	17.96	25.425
09/17/08 5:25	880	1.188	17.96	25.424
09/17/08 5:27	882	1.186	17.964	25.429
09/17/08 5:29	884	1.188	17.96	25.423
09/17/08 5:31	886	1.187	17.96	25.425
09/17/08 5:33	888	1.186	17.96	25.429
09/17/08 5:35	890	1.186	17.958	25.427
09/17/08 5:37	892	1.186	17.961	25.427
09/17/08 5:39	894	1.187	17.957	25.425
09/17/08 5:41	896	1.186	17.96	25.429
09/17/08 5:43	898	1.185	17.959	25.43
09/17/08 5:45	900	1.187	17.961	25.427
09/17/08 5:47	902	1.183	17.96	25.435
09/17/08 5:49	904	1.186	17.962	25.429
09/17/08 5:51	906	1.185	17.958	25.431
09/17/08 5:53	908	1.186	17.96	25.427
09/17/08 5:55	910	1.186	17.963	25.428
09/17/08 5:57	912	1.185	17.961	25.43
09/17/08 5:59	914	1.188	17.962	25.424
09/17/08 6:01	916	1.186	17.962	25.428
09/17/08 6:03	918	1.185	17.961	25.429
09/17/08 6:05	920	1.186	17.963	25.428
09/17/08 6:07	922	1.186	17.958	25.429
09/17/08 6:09	924	1.186	17.96	25.429
09/17/08 6:11	926	1.185	17.96	25.43
09/17/08 6:13	928	1.184	17.961	25.433
09/17/08 6:15	930	1.186	17.959	25.428
09/17/08 6:17	932	1.186	17.961	25.429
09/17/08 6:19	934	1.186	17.96	25.428
09/17/08 6:21	936	1.186	17.961	25.429
09/17/08 6:23	938	1.183	17.959	25.434
09/17/08 6:25	940	1.184	17.959	25.431
09/17/08 6:27	942	1.185	17.959	25.431
09/17/08 6:29	944	1.184	17.959	25.432
09/17/08 6:31	946	1.186	17.964	25.429
09/17/08 6:33	948	1.184	17.958	25.433
09/17/08 6:35	950	1.183	17.964	25.435
09/17/08 6:37	952	1.184	17.96	25.431
09/17/08 6:39	954	1.185	17.958	25.429
09/17/08 6:41	956	1.184	17.96	25.432
09/17/08 6:43	958	1.184	17.963	25.431
09/17/08 6:45	960	1.184	17.961	25.433
09/17/08 6:47	962	1.184	17.962	25.433
09/17/08 6:49	964	1.184	17.96	25.432
09/17/08 6:51	966	1.184	17.958	25.432

09/17/08 6:53	968	1.185	17.96	25.431
09/17/08 6:55	970	1.183	17.959	25.434
09/17/08 6:57	972	1.182	17.957	25.437
09/17/08 6:59	974	1.182	17.96	25.437
09/17/08 7:01	976	1.183	17.961	25.434
09/17/08 7:03	978	1.182	17.96	25.438
09/17/08 7:05	980	1.184	17.959	25.432
09/17/08 7:07	982	1.183	17.958	25.434
09/17/08 7:09	984	1.184	17.96	25.433
09/17/08 7:11	986	1.183	17.96	25.436
09/17/08 7:13	988	1.183	17.959	25.435
09/17/08 7:15	990	1.183	17.959	25.435
09/17/08 7:17	992	1.183	17.961	25.436
09/17/08 7:19	994	1.183	17.957	25.435
09/17/08 7:21	996	1.182	17.96	25.437
09/17/08 7:23	998	1.18	17.961	25.441
09/17/08 7:25	1000	1.181	17.962	25.439
09/17/08 7:27	1002	1.183	17.961	25.435
09/17/08 7:29	1004	1.182	17.958	25.438
09/17/08 7:31	1006	1.182	17.959	25.437
09/17/08 7:33	1008	1.18	17.958	25.442
09/17/08 7:35	1010	1.181	17.959	25.439
09/17/08 7:37	1012	1.183	17.961	25.435
09/17/08 7:39	1014	1.182	17.959	25.438
09/17/08 7:41	1016	1.182	17.96	25.437
09/17/08 7:43	1018	1.181	17.959	25.44
09/17/08 7:45	1020	1.182	17.958	25.437
09/17/08 7:47	1022	1.179	17.962	25.443
09/17/08 7:49	1024	1.181	17.962	25.439
09/17/08 7:51	1026	1.181	17.957	25.44
09/17/08 7:53	1028	1.18	17.958	25.441
09/17/08 7:55	1030	1.181	17.959	25.44
09/17/08 7:57	1032	1.182	17.959	25.438
09/17/08 7:59	1034	1.181	17.96	25.439
09/17/08 8:01	1036	1.179	17.961	25.444
09/17/08 8:03	1038	1.18	17.961	25.441
09/17/08 8:05	1040	1.181	17.96	25.44
09/17/08 8:07	1042	1.181	17.962	25.438
09/17/08 8:09	1044	1.18	17.96	25.442
09/17/08 8:11	1046	1.178	17.96	25.446
09/17/08 8:13	1048	1.179	17.962	25.445
09/17/08 8:15	1050	1.181	17.959	25.439
09/17/08 8:17	1052	1.179	17.962	25.444
09/17/08 8:19	1054	1.179	17.96	25.444
09/17/08 8:21	1056	1.179	17.962	25.444
09/17/08 8:23	1058	1.178	17.96	25.448
09/17/08 8:25	1060	1.179	17.959	25.445
09/17/08 8:27	1062	1.178	17.962	25.445
09/17/08 8:29	1064	1.18	17.964	25.443

09/17/08 8:31	1066	1.178	17.961	25.447
09/17/08 8:33	1068	1.18	17.959	25.441
09/17/08 8:35	1070	1.18	17.97	25.443
09/17/08 8:37	1072	1.177	17.968	25.448
09/17/08 8:39	1074	1.179	17.963	25.443
09/17/08 8:41	1076	1.18	17.963	25.442
09/17/08 8:43	1078	1.179	17.96	25.445
09/17/08 8:45	1080	1.178	17.96	25.446
09/17/08 8:47	1082	1.179	17.961	25.445
09/17/08 8:49	1084	1.18	17.961	25.442
09/17/08 8:51	1086	1.179	17.962	25.444
09/17/08 8:53	1088	1.177	17.963	25.448
09/17/08 8:55	1090	1.178	17.96	25.446
09/17/08 8:57	1092	1.18	17.963	25.442
09/17/08 8:59	1094	1.179	17.96	25.444
09/17/08 9:01	1096	1.178	17.962	25.447
09/17/08 9:03	1098	1.179	17.96	25.444
09/17/08 9:05	1100	1.18	17.961	25.443
09/17/08 9:07	1102	1.177	17.962	25.448
09/17/08 9:09	1104	1.179	17.958	25.445
09/17/08 9:11	1106	1.179	17.961	25.445
09/17/08 9:13	1108	1.178	17.96	25.448
09/17/08 9:15	1110	1.179	17.96	25.444
09/17/08 9:17	1112	1.178	17.958	25.447
09/17/08 9:19	1114	1.178	17.96	25.446
09/17/08 9:21	1116	1.18	17.961	25.443
09/17/08 9:23	1118	1.18	17.963	25.443
09/17/08 9:25	1120	1.18	17.96	25.441
09/17/08 9:27	1122	1.181	17.959	25.44
09/17/08 9:29	1124	1.182	17.96	25.438
09/17/08 9:31	1126	1.18	17.958	25.441
09/17/08 9:33	1128	1.181	17.959	25.44
09/17/08 9:35	1130	1.182	17.958	25.438
09/17/08 9:37	1132	1.182	17.961	25.437
09/17/08 9:39	1134	1.183	17.959	25.436
09/17/08 9:41	1136	1.183	17.961	25.435
09/17/08 9:43	1138	1.183	17.96	25.435
09/17/08 9:45	1140	1.184	17.956	25.432
09/17/08 9:47	1142	1.185	17.959	25.43
09/17/08 9:49	1144	1.183	17.96	25.434
09/17/08 9:51	1146	1.183	17.961	25.435
09/17/08 9:53	1148	1.183	17.958	25.434
09/17/08 9:55	1150	1.184	17.958	25.433
09/17/08 9:57	1152	1.182	17.96	25.436
09/17/08 9:59	1154	1.183	17.958	25.436
09/17/08 10:01	1156	1.184	17.96	25.433
09/17/08 10:03	1158	1.186	17.959	25.428
09/17/08 10:05	1160	1.185	17.96	25.429
09/17/08 10:07	1162	1.186	17.959	25.428

09/17/08 10:09	1164	1.184	17.96	25.433
09/17/08 10:11	1166	1.187	17.959	25.426
09/17/08 10:13	1168	1.185	17.961	25.431
09/17/08 10:15	1170	1.187	17.958	25.425
09/17/08 10:17	1172	1.186	17.958	25.428
09/17/08 10:19	1174	1.185	17.958	25.43
09/17/08 10:21	1176	1.187	17.961	25.426
09/17/08 10:23	1178	1.188	17.958	25.424
09/17/08 10:25	1180	1.187	17.959	25.425
09/17/08 10:27	1182	1.188	17.96	25.422
09/17/08 10:29	1184	1.188	17.96	25.423
09/17/08 10:31	1186	1.188	17.956	25.424
09/17/08 10:33	1188	1.189	17.96	25.42
09/17/08 10:35	1190	1.187	17.958	25.425
09/17/08 10:37	1192	1.189	17.96	25.42
09/17/08 10:39	1194	1.188	17.96	25.423
09/17/08 10:41	1196	1.187	17.96	25.425
09/17/08 10:43	1198	1.192	17.961	25.414
09/17/08 10:45	1200	1.187	17.958	25.425
09/17/08 10:47	1202	1.189	17.959	25.421
09/17/08 10:49	1204	1.19	17.961	25.418
09/17/08 10:51	1206	1.188	17.959	25.423
09/17/08 10:53	1208	1.19	17.963	25.418
09/17/08 10:55	1210	1.19	17.959	25.418
09/17/08 10:57	1212	1.191	17.961	25.417
09/17/08 10:59	1214	1.19	17.962	25.418
09/17/08 11:01	1216	1.192	17.958	25.414
09/17/08 11:03	1218	1.19	17.962	25.418
09/17/08 11:05	1220	1.192	17.958	25.414
09/17/08 11:07	1222	1.192	17.961	25.414
09/17/08 11:09	1224	1.192	17.96	25.415
09/17/08 11:11	1226	1.192	17.959	25.415
09/17/08 11:13	1228	1.194	17.96	25.409
09/17/08 11:15	1230	1.193	17.958	25.412
09/17/08 11:17	1232	1.193	17.956	25.413
09/17/08 11:19	1234	1.194	17.959	25.409
09/17/08 11:21	1236	1.192	17.957	25.414
09/17/08 11:23	1238	1.193	17.958	25.412
09/17/08 11:25	1240	1.194	17.961	25.41
09/17/08 11:27	1242	1.194	17.959	25.41
09/17/08 11:29	1244	1.195	17.959	25.408
09/17/08 11:31	1246	1.194	17.957	25.41
09/17/08 11:33	1248	1.195	17.959	25.406
09/17/08 11:35	1250	1.194	17.959	25.41
09/17/08 11:37	1252	1.195	17.962	25.408
09/17/08 11:39	1254	1.195	17.959	25.407
09/17/08 11:41	1256	1.194	17.958	25.409
09/17/08 11:43	1258	1.196	17.958	25.405
09/17/08 11:45	1260	1.197	17.958	25.403

09/17/08 11:47	1262	1.196	17.959	25.405
09/17/08 11:49	1264	1.197	17.957	25.403
09/17/08 11:51	1266	1.196	17.958	25.406
09/17/08 11:53	1268	1.197	17.959	25.403
09/17/08 11:55	1270	1.195	17.96	25.406
09/17/08 11:57	1272	1.195	17.959	25.406
09/17/08 11:59	1274	1.197	17.961	25.403
09/17/08 12:01	1276	1.198	17.958	25.401
09/17/08 12:03	1278	1.197	17.961	25.403
09/17/08 12:05	1280	1.198	17.96	25.4
09/17/08 12:07	1282	1.199	17.958	25.397
09/17/08 12:09	1284	1.197	17.957	25.403
09/17/08 12:11	1286	1.2	17.957	25.395
09/17/08 12:13	1288	1.2	17.959	25.397
09/17/08 12:15	1290	1.2	17.962	25.395
09/17/08 12:17	1292	1.2	17.962	25.395
09/17/08 12:19	1294	1.199	17.962	25.397
09/17/08 12:21	1296	1.2	17.959	25.395
09/17/08 12:23	1298	1.2	17.958	25.396
09/17/08 12:25	1300	1.199	17.959	25.397
09/17/08 12:27	1302	1.199	17.96	25.399
09/17/08 12:29	1304	1.202	17.958	25.392
09/17/08 12:31	1306	1.201	17.958	25.393
09/17/08 12:33	1308	1.2	17.958	25.395
09/17/08 12:35	1310	1.201	17.958	25.393
09/17/08 12:37	1312	1.2	17.959	25.396
09/17/08 12:39	1314	1.201	17.959	25.392
09/17/08 12:41	1316	1.2	17.96	25.397
09/17/08 12:43	1318	1.202	17.962	25.391
09/17/08 12:45	1320	1.2	17.961	25.395
09/17/08 12:47	1322	1.2	17.962	25.396
09/17/08 12:49	1324	1.202	17.962	25.392
09/17/08 12:51	1326	1.203	17.959	25.39
09/17/08 12:53	1328	1.201	17.961	25.394
09/17/08 12:55	1330	1.203	17.96	25.389
09/17/08 12:57	1332	1.204	17.958	25.387
09/17/08 12:59	1334	1.202	17.962	25.39
09/17/08 13:01	1336	1.201	17.959	25.393
09/17/08 13:03	1338	1.203	17.96	25.388
09/17/08 13:05	1340	1.203	17.961	25.389
09/17/08 13:07	1342	1.202	17.961	25.391
09/17/08 13:09	1344	1.204	17.96	25.387
09/17/08 13:11	1346	1.204	17.963	25.387
09/17/08 13:13	1348	1.203	17.959	25.389
09/17/08 13:15	1350	1.203	17.961	25.388
09/17/08 13:17	1352	1.204	17.963	25.385
09/17/08 13:19	1354	1.204	17.962	25.388
09/17/08 13:21	1356	1.205	17.96	25.384
09/17/08 13:23	1358	1.205	17.962	25.385

09/17/08 13:25	1360	1.206	17.961	25.383
09/17/08 13:27	1362	1.205	17.96	25.383
09/17/08 13:29	1364	1.205	17.958	25.384
09/17/08 13:31	1366	1.206	17.96	25.381
09/17/08 13:33	1368	1.208	17.96	25.377
09/17/08 13:35	1370	1.207	17.958	25.379
09/17/08 13:37	1372	1.206	17.959	25.383
09/17/08 13:39	1374	1.207	17.961	25.379
09/17/08 13:41	1376	1.207	17.958	25.38
09/17/08 13:43	1378	1.207	17.961	25.379
09/17/08 13:45	1380	1.207	17.964	25.379
09/17/08 13:47	1382	1.204	17.962	25.387
09/17/08 13:49	1384	1.207	17.957	25.38
09/17/08 13:51	1386	1.205	17.961	25.384
09/17/08 13:53	1388	1.207	17.962	25.38
09/17/08 13:55	1390	1.208	17.959	25.377
09/17/08 13:57	1392	1.207	17.96	25.379
09/17/08 13:59	1394	1.205	17.958	25.384
09/17/08 14:01	1396	1.208	17.96	25.376
09/17/08 14:03	1398	1.209	17.957	25.374
09/17/08 14:05	1400	1.208	17.959	25.378
09/17/08 14:07	1402	1.208	17.959	25.376
09/17/08 14:09	1404	1.21	17.959	25.372
09/17/08 14:11	1406	1.207	17.958	25.379
09/17/08 14:13	1408	1.21	17.959	25.373
09/17/08 14:15	1410	1.208	17.96	25.376
09/17/08 14:17	1412	1.209	17.96	25.375
09/17/08 14:19	1414	1.209	17.959	25.375
09/17/08 14:21	1416	1.207	17.958	25.379
09/17/08 14:23	1418	1.212	17.958	25.368
09/17/08 14:25	1420	1.21	17.957	25.373
09/17/08 14:27	1422	1.209	17.96	25.376
09/17/08 14:29	1424	1.21	17.96	25.373
09/17/08 14:31	1426	1.209	17.961	25.376
09/17/08 14:33	1428	1.21	17.96	25.373
09/17/08 14:35	1430	1.209	17.962	25.375
09/17/08 14:37	1432	1.207	17.959	25.378