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NIROP FRIDLEY
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HYDROGEOLOGIC ANALYSIS FOR REPLACEMENT OF EXTRACTION WELL AT 3A NIROP FRIDLEY MN

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HYDROGEOLOGIC ANALYSIS FOR REPLACEMENT OF EXTRACTION WELL AT-3A

NAVAL INDUSTRIAL RESERVE ORDNANCE PLANT

FRIDLEY, MINNESOTA

NOVEMBER 2010

This Hydrogeologic Analysis for replacement of extraction well AT-3A has been prepared under Contract Task Order (CTO) F27C, as part of the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract Number N62470-08-D-1001, which is part of the Navy's Installation Restoration Program (IRP). This analysis details the methodology used to develop a recommended approach to replacing extraction well AT-3A at NIROP Fridley, Minnesota.

1.0 BACKGROUND

The current extraction system at NIROP Fridley is composed of seven extraction wells, and is in operation in order to contain the chlorinated volatile organic compound (CVOC) plume present in the shallow unconfined and semi-confined unconsolidated aquifers. The plume extents (vertical and horizontal) have been well defined through long-term monitoring over each of the zones. This analysis is intended to (1) quantify the flux of groundwater within the contaminant plume extents in the intermediate zone that is not being captured by the current extraction system components, and (2) to identify means to contain the plume in the intermediate zone.

AT-3A is an extraction well screened in the intermediate zone. The other extraction well screened in the intermediate zone is AT-10, which typically pumps at a rate of between 20 and 25 gallons per minute. AT-3A was one of the original extraction wells, and was installed in 1992 and screened from 69-130 feet below ground surface (bgs). AT-3A was later modified in October 2000 and the screened interval was changed to 69-105 feet bgs by installing a packer. The screened interval for AT-3A was shortened so that groundwater capture from the deep aquifer zone could be minimized, and capture in the intermediate zone could be maximized. AT-3A's target pumping rate is between the minimum and ideal pumping rates determined by Partnering Team consensus in July 2008, which were 115 gpm and 135 gpm, respectively. AT-3A has typically been pumping below the minimum pumping rate established by Partnering Team consensus since approximately December 2008, due to various operational issues, including iron fouling of the well screen, piping, and potentially the aquifer sediments in the immediate vicinity of the well. AT-3A has been offline for a significant portion of the time since May 2010. Rehabilitation of the well has been attempted multiple times but did not have significant or lasting results.

Of the seven extraction wells currently in the system, AT-3A has historically pumped at one of the highest pumping rates and is located in the intermediate zone, where the highest concentrations of contaminants have been detected. Therefore, AT-3A is viewed by the Partnering Team as a critical extraction well for containing the most elevated portions of the NIROP plume.

2.0 DATA EVALUATION INPUTS

2.1 Potentiometric Contours

Potentiometric contours in cross section (using all available data from the shallow, intermediate, and deep zones) (Figure 2) and map view (for the intermediate zone only) (Figure 3) of groundwater elevation data collected by BayWest on October 4, 2010 were produced using the triangulation method. The potentiometric surface for the intermediate zone near the southwest corner of the NIROP building is similar to previous non-pumping scenario data collection events, including the data presented in the USGS Report (Davis, 2007), and the 2002 AMR (Tetra Tech, 2003) (figures are presented in Attachment 1). All extraction wells except for AT-3A were pumping at the time of the synoptic water level collection event on October 4, 2010.

2.2 TCE Contours

The intermediate zone TCE contours from the 2009 Annual Monitoring Report (AMR) were overlain on Figure 3, and TCE contours were developed for the cross sections using the data from October 2009. TCE contours are used to assess plume extents because TCE is the primary COC for NIROP. Other contaminants are present (i.e., degradation products of TCE), but the areal extent of these are primarily contained within the extents of the TCE plume.

2.3 Capture Zone

Capture zones for AT-10 were produced using both the flownet method and capture zone extent calculations. The capture zone extent calculation for the operating extraction well in the intermediate zone, AT-10, including equations used and variables, is shown in Table 1. An explanation of inputs for the groundwater flux/capture zone calculations is provided below. The transmissivity that has been used in the AMRs for AT-10 was used for this calculation and was calculated from field investigations. The flow rate for AT-10 for the day the synoptic round of water levels were collected was compared to graphs of the daily flow rate data for 2010 (Figure 4) to determine if the October 4, 2010 extraction well flow rate was typical of AT-10 operation for the year. The flow rate for AT-10 on October 4, 2010 was 18.6 gpm, which was comparable to the range of flow rates shown in Figure 4. Gradients were calculated for the intermediate zone using the October 4, 2010 groundwater level data set. The gradient lines and calculations are presented on Figure 3.

The calculated capture zone for AT-10 is slightly smaller than the capture zone delineated using the flow net method. Therefore, to be more conservative in this analysis, the calculated capture zone for AT-10 was used to determine the width of the capture zone needed to contain the portion of the intermediate zone plume not captured by AT-10. The calculated and flow net capture zones are shown on Figure 3, and Figure 2 shows the calculated capture zone for AT-10 (shown in orange).

2.4 Groundwater Volume Flux

Based on the potentiometric contours and TCE contour presented in Figure 2, it is clear that a portion of the plume is not being captured. The area not currently being captured is between monitoring wells 12-IS and 11-S on Figure 3. The target capture area for new extraction wells is shaded blue on Figure 2 in cross section A-A'. Next, the groundwater flux through the target capture area was calculated using the following equation:

$$\text{Flux in shaded area} = K \times i \times A$$

$$= 150 \text{ ft/day} \times .009 \text{ ft/ft} \times 50{,}500 \text{ ft}^2$$

$$= 68{,}175 \text{ ft}^3\text{/day} = 354 \text{ gpm}$$

The gradient (i) was determined using the gradient calculation shown on Figure 3. The hydraulic conductivity (K) was calculated using a transmissivity value (12000 ft^2/day) determined from pump testing at AT-3A, divided by an average saturated aquifer thickness of approximately 80 ft. The area (A) of 50,500 ft^2 was determined from the shaded area shown on cross section A-A' on Figure 2, which is oriented perpendicular to flow direction.

Based on the calculation above, the volume of flow in the shaded area on Figure 2 is approximately 354 gpm. The shaded area in cross section A-A' on Figure 2 contains the intermediate zone and a portion of the deep zone.

An extraction well (or wells) within the target zone pumping at the calculated flux of 354 gpm through the target zone in the intermediate/deep aquifer would achieve the targeted capture width, but not in the immediate area of the extractions wells, per capture zone theory. The capture zone of a well at the location of a pumping well is ½ the maximum capture zone width, due to the locally higher flow gradients induced by pumping and the flow vectors created by the pumping. The maximum capture zone width is achieved some distance upgradient of the pumping well. To achieve complete capture of the target zone in the immediate vicinity of the proposed extraction wells requires a pumping rate that is approximately double the calculated flux (708 gpm).

2.5 Target Area Capture Analysis

The approximate configuration of the capture zone was calculated using the same data inputs as were used above to determine the groundwater flux through the target zone in the intermediate aquifer and standard capture zone equations (Javendel and Tsang, 1986). The approximate capture zone width needed at the line of extraction wells is 600 feet, and was measured between 12-IS and 24-S. Since the calculated and flownet capture zones for AT-10 matched well, it is reasonable to assume that the same equations used to calculate capture zone extents for AT-10 can be used to calculate the pumping rate (Q) needed for the target capture area. The transmissivity determined for AT-3A from pump tests was used in the calculation below, and the gradient was calculated from the October 4, 2010 potentiometric surface as shown on Figure 3.

Capture zone width at well	=	$Q/2Ti$
600 ft	=	$Q/(2 \times 12000\ ft^2/day \times 0.009)$
Q	=	$129{,}600\ ft^3/day = 672\ gpm$

3.0 DISCUSSION

3.1 Proposed Pumping Rate

The pumping rate of 672 gpm from the target capture zone analysis is similar to the pumping rate determined above from the groundwater volume flux (708 gpm). It should be noted that the actual capture zone upgradient of the extraction system will likely expand somewhat beyond what is calculated from standard capture zone calculations, as the groundwater flow gradient decreases substantially in the upgradient area and the presence of the confining units in the intermediate zone along River Road act to funnel groundwater flow through the target zone. Therefore, it is reasonable to assume that the Q derived from the standard capture zone calculations will be sufficient for capture in the area of interest. The capture zone geometry of the new wells using a Q of 672 gpm was calculated in Table 1 and the capture zone extent of the proposed pumping rate is shown on Figures 2 and 3. It is recommended that three extraction wells be used to achieve the desired pumping rate, with two wells screened within the intermediate zone and a deep extraction well paired with one of the two new intermediate wells. The three extraction wells proposed below will pump a combined total of 672 gpm.

3.2 Proposed Replacement Extraction Well Location

The proposed new extraction wells AT-11, AT-12, and AT-13, are shown on Figure 2 in cross section and on Figure 3 in map view. Extraction wells AT-11 and AT-13 are designed to capture groundwater in the upper semi-confined (i.e., intermediate) zone near the corner of the NIROP building, in combination with AT-10. Extraction well AT-12 is designed to capture groundwater in the lower semi-confined (i.e., deep zone) in combination with AT-5B, and was collocated with proposed extraction well AT-11 because of elevated TCE concentrations in the deep zone, evidenced by the TCE concentration in MS-35D from 2009 (Figure 2).

Alternatively, the extraction well(s) could be shifted to a location downgradient from the target zone (i.e. in ACP) to take advantage of capture zone expansion upgradient from the pumping well and allow for a lower overall pumping rate to achieve the desired capture width along River Road, but this places the well(s) further away from the source area/treatment system, across River Road, and would act to pull the plume into ACP on a long term basis.

3.3 Proposed Replacement Extraction Well Construction

The proposed construction for each well is provided in Table 2. It is recommended that well screens for the intermediate zone wells be placed at a depth of 70 to 100 feet below ground surface. It is not recommended that they be placed at a more shallow depth because the magnitude of drawdown observed at AT-3A might allow groundwater levels to fall below the top of the well screens, promoting iron fouling. The pumping rates shown in Table 2 are recommended beginning pumping rates that may need to be adjusted based on observations following well installation and startup.

4.0 CONCLUSIONS AND RECOMMENDATIONS

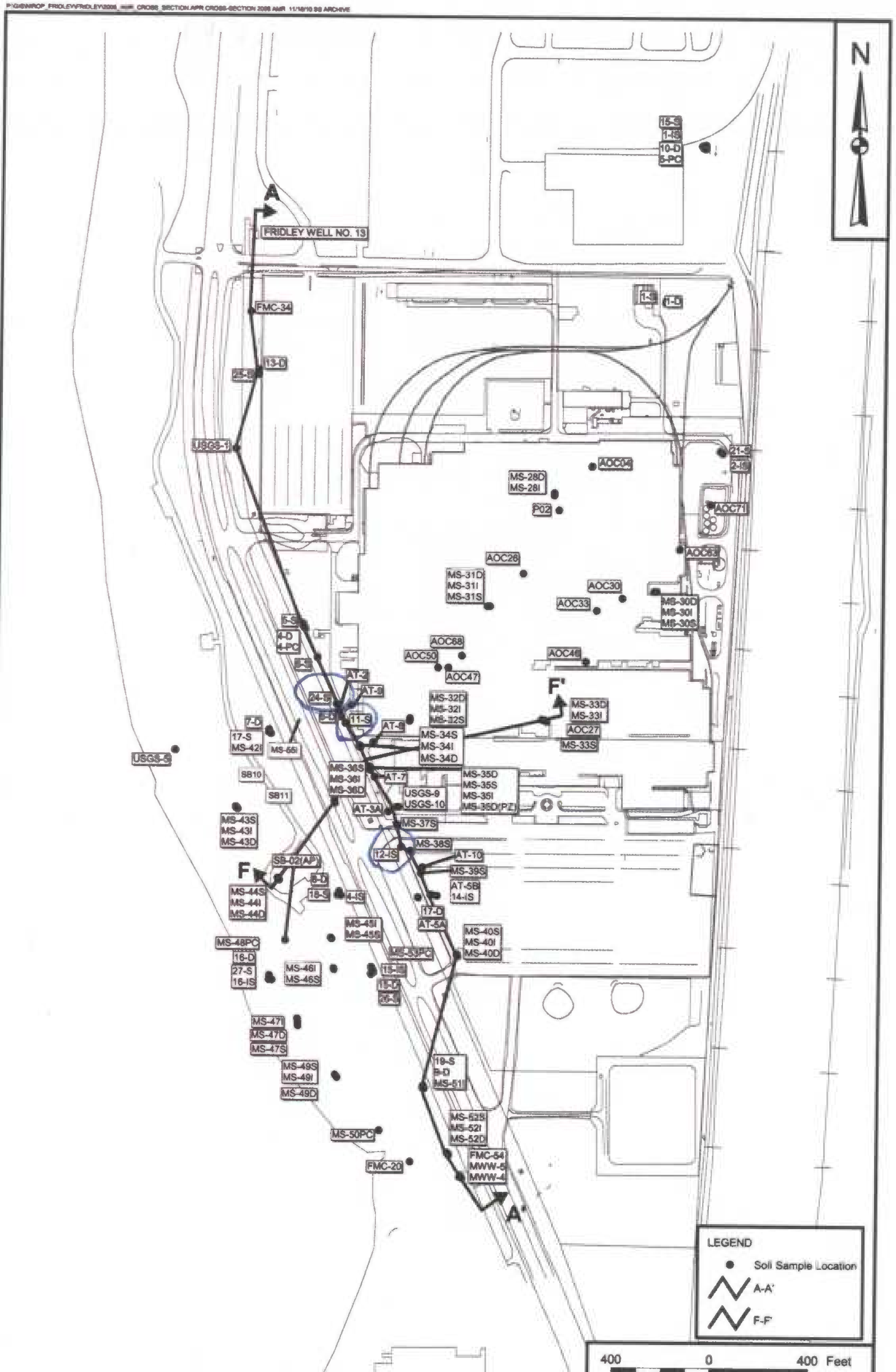
4.1 Conclusions

- The total recommended pumping rate goal for replacement of AT-3A and plume bypass for the area shown in blue on Figure 2 is 672 gpm.
- New extraction wells should be placed east of East River Road, rather than west of East River Road, to avoid drawing the plume into the ACP.
- Three new extraction wells should be installed - one deep well and two intermediate wells constructed as shown in Table 2.

4.2 Recommendations

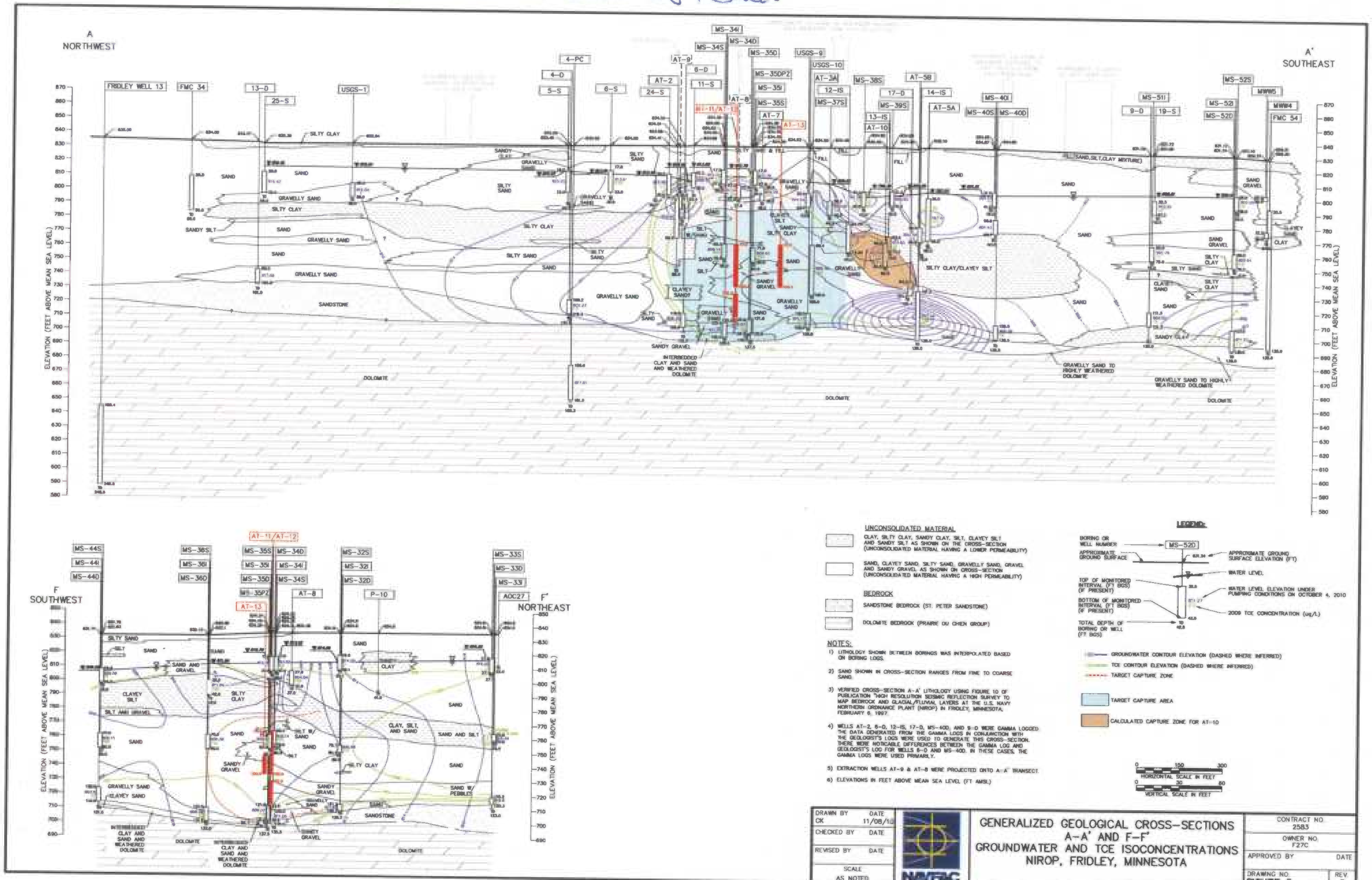
- Operation of extraction wells AT-5A, AT-5B, AT-7, AT-8, AT-9, and AT-10 should continue.
- Quarterly sampling should be conducted for key monitoring wells to determine the effectiveness new extraction wells have on plume containment for a period of up to one year following new extraction well startup.
- Once the new extraction wells are installed and their influence on the plume and interaction with the rest of the pumping system can be evaluated, the Partnering Team should consider decreasing the pumping rate of AT-5B significantly or removing AT-5B from the extraction system. TCE concentrations in the deep zone are very low, with the exception of AT-5B. Based on the TCE contours and potentiometric surface contours in Figure 2, it appears that AT-5B may be drawing TCE down from the intermediate zone.

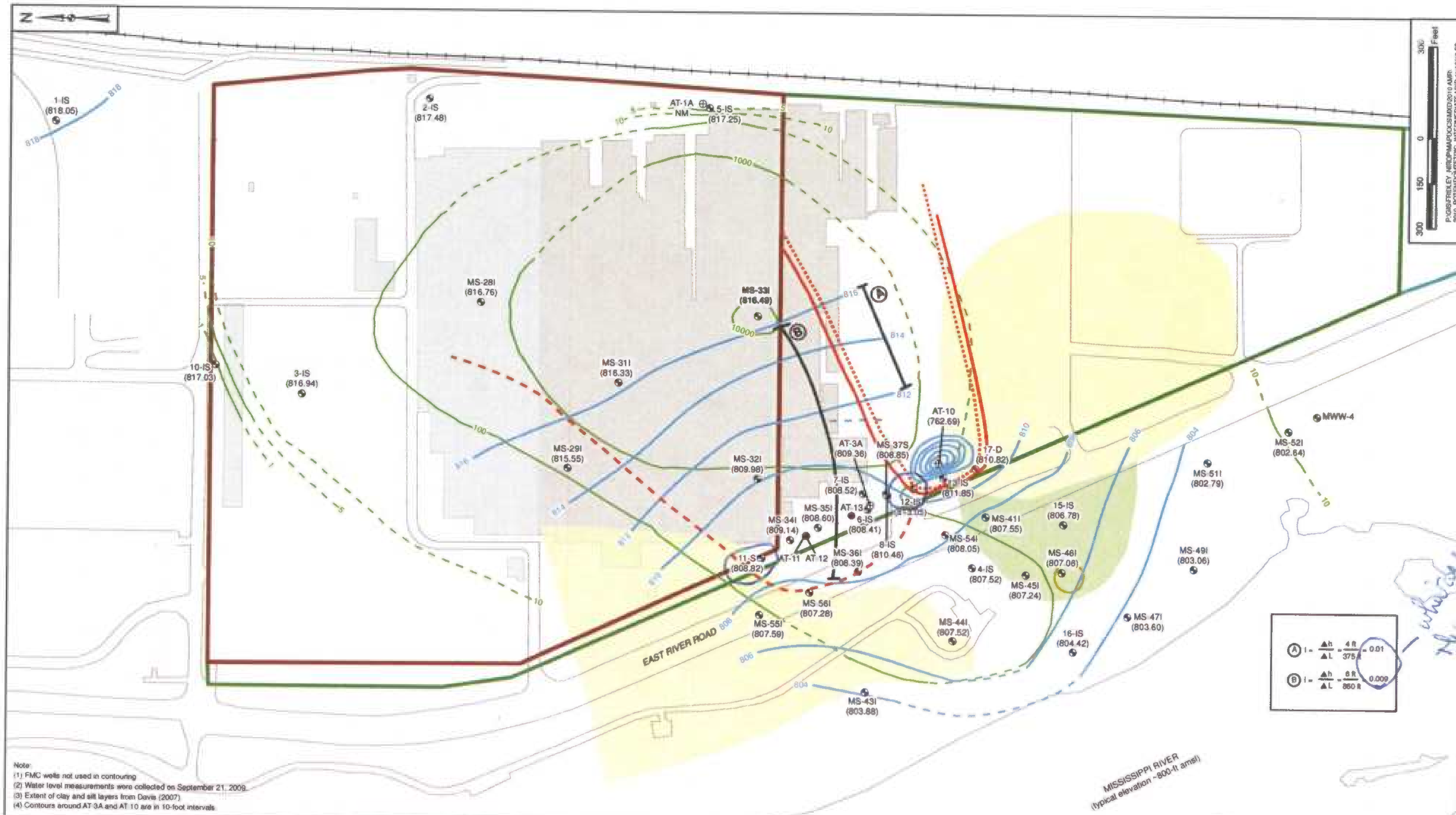
What is this saying?



DRAWN BY: K. PEILA — DATE: 08/13/03	NAVFAC	GEOLOGICAL CROSS-SECTION MAP	CONTRACT NUMBER: F27C
CHECKED BY: S. WARINO — DATE: 11/18/10		NIROP FRIDLEY, MINNESOTA	APPROVED BY: M. SLADIC — DATE: 04/23/10
COST/TIME/SCHEDULE AREA			APPROVED BY: — DATE: —
SCALE: AS NOTED			FIGURE NO.: 1 — REV: 0

Scale to small to see or read





Note:
(1) FMC wells not used in contouring
(2) Water level measurements were collected on September 21, 2009.
(3) Extent of clay and silt layers from Davis (2007)
(4) Contours around AT 3A and AT 10 are in 10-foot intervals

LEGEND

- Intermediate Monitoring Well
- Proposed Monitoring Well
- Extraction Well
- Road
- Railroad
- Water
- Building
- NIROP Fridley
- BAE
- Burlington Northern RR
- Vegetable Oil Pilot Study Area
- Intermediate Clay
- Intermediate Silt
- 25-S 815.46 Groundwater Elevation (Feet Above Mean Sea Level)
- NM = Not measured
- Gradient Calculation Line
- Flow Net Capture Zone
- Calculated Capture Zone
- Target Capture Zone
- Intermediate Potentiometric Surface Contour (Feet Above Mean Sea Level) (Dashed where Inferred)
- TCE Isocontour (Dashed where inferred)

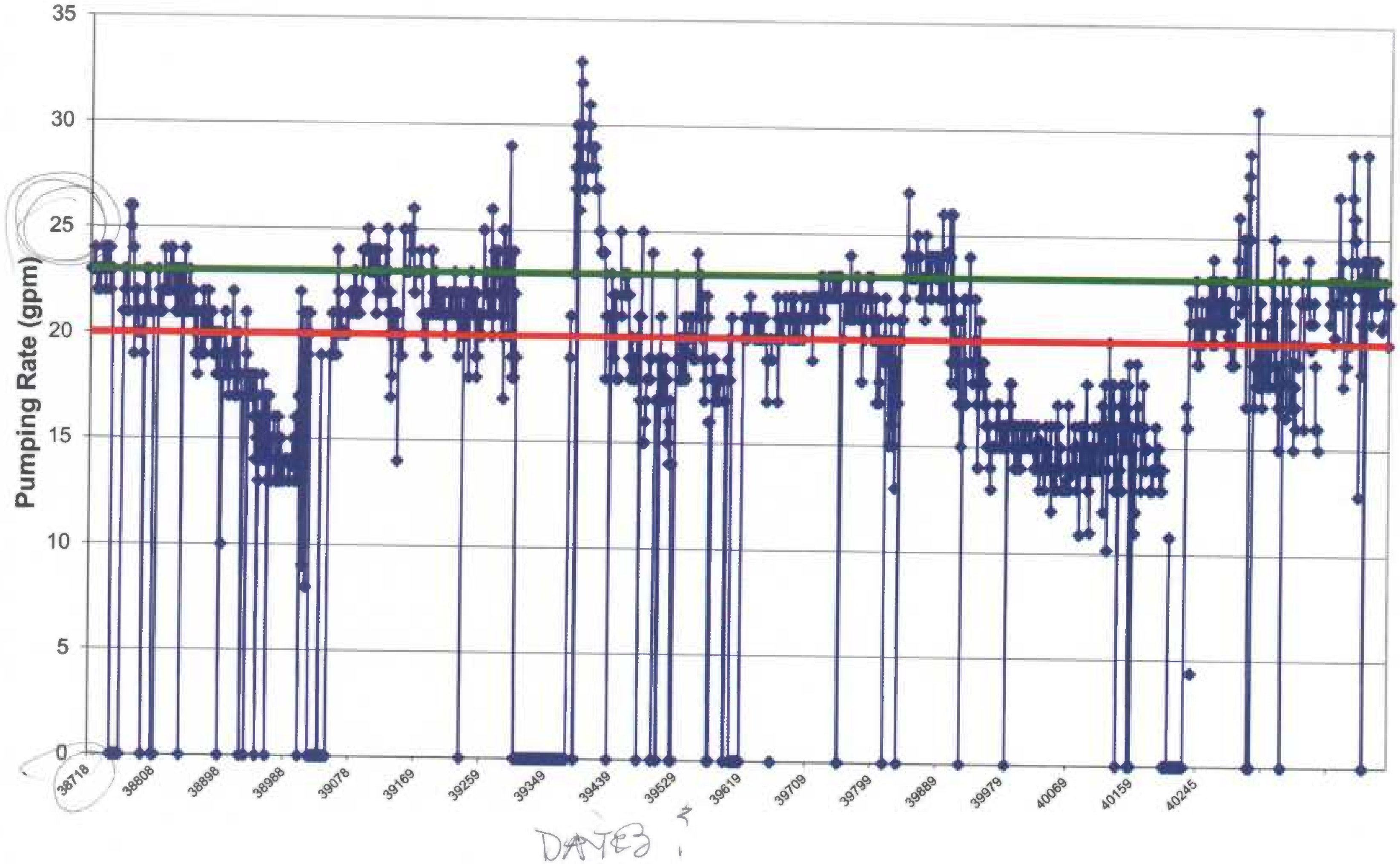
DRAWN BY J. ENGLISH	DATE 01/14/10
CHECKED BY S. WARINO	DATE 11/18/10
COST/SCHEDULE-AREA	
SCALE AS NOTED	

NAVFAC

INTERMEDIATE DRIFT GROUNDWATER ELEVATIONS UNDER PUMPING CONDITIONS ON OCTOBER 4, 2010 WITH FALL 2009 TCE ISOCONCENTRATIONS NIROP FRIDLEY, MINNESOTA

CONTRACT NO F27C	OWNER NO 02583
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO 3	REV. 0

FIGURE 4
AT-10 DAILY PUMPING RATES
JANUARY 1, 2006 TO NOVEMBER 2010
NIROP FRIDLEY, MINNESOTA



Data from Bay West 2006- 2009 monthly treatment system reports.

TABLE 1

EXTRACTION WELL CAPTURE ZONE CALCULATIONS
HYDROGEOLOGIC ANALYSIS - AT-3A REPLACEMENT
NIROP FRIDLEY, MINNESOTA

Well	Aquifer Zone	T (ft^2/day)	Q (gpm)	Q (ft^3/day)	Gradient [(1)]	Capture Zone Width (ft)		Downgradient Capture Zone Limit (ft)
						Maximum	At Well	
AT-10	Intermediate	721	18.6	3581	0.01	497	248	79
AT-11, AT-12, AT-13 (combined zone)	Intermediate/Deep	12000	672	129367	0.009	1198	599	191

1 Gradient was calculated from October 2010 potentiometric surface maps as shown on Figure 4.

Capture Zone Equations:
Maximum capture zone width = Q/Ti
Capture zone width at well = Q/2Ti
Downgradient capture zone limit = Q/2πTi

T = transmissivity
Q = discharge

TABLE 2

SUMMARY OF PROPOSED EXTRACTION WELL CONSTRUCTION DETAIL
NIROP FRIDLEY, MINNESOTA

Extraction Well	Aquifer Zone	Aquifer Classification	Screened Interval (ft bgs)	Diameter (inches)	Design Pumping Rate (gpm)
AT-11	Intermediate	Lower Unconfined	70-100	10	240
AT-12	Deep	Lower Semiconfined	105-125	10	200
AT-13	Intermediate	Lower Unconfined	70-100	10	240

Ft bgs = feet below ground surface
Gpm = Gallons per minute

CHANGED TO 70-150

ATTACHMENT 1

POTENTIOMETRIC SURFACE MAPS OF INTERMEDIATE-ZONE NON-PUMPING CONDITIONS

USGS REPORT (DAVIS, 2007) AND 2002 ANNUAL MONITORING REPORT (TETRA TECH, 2003)

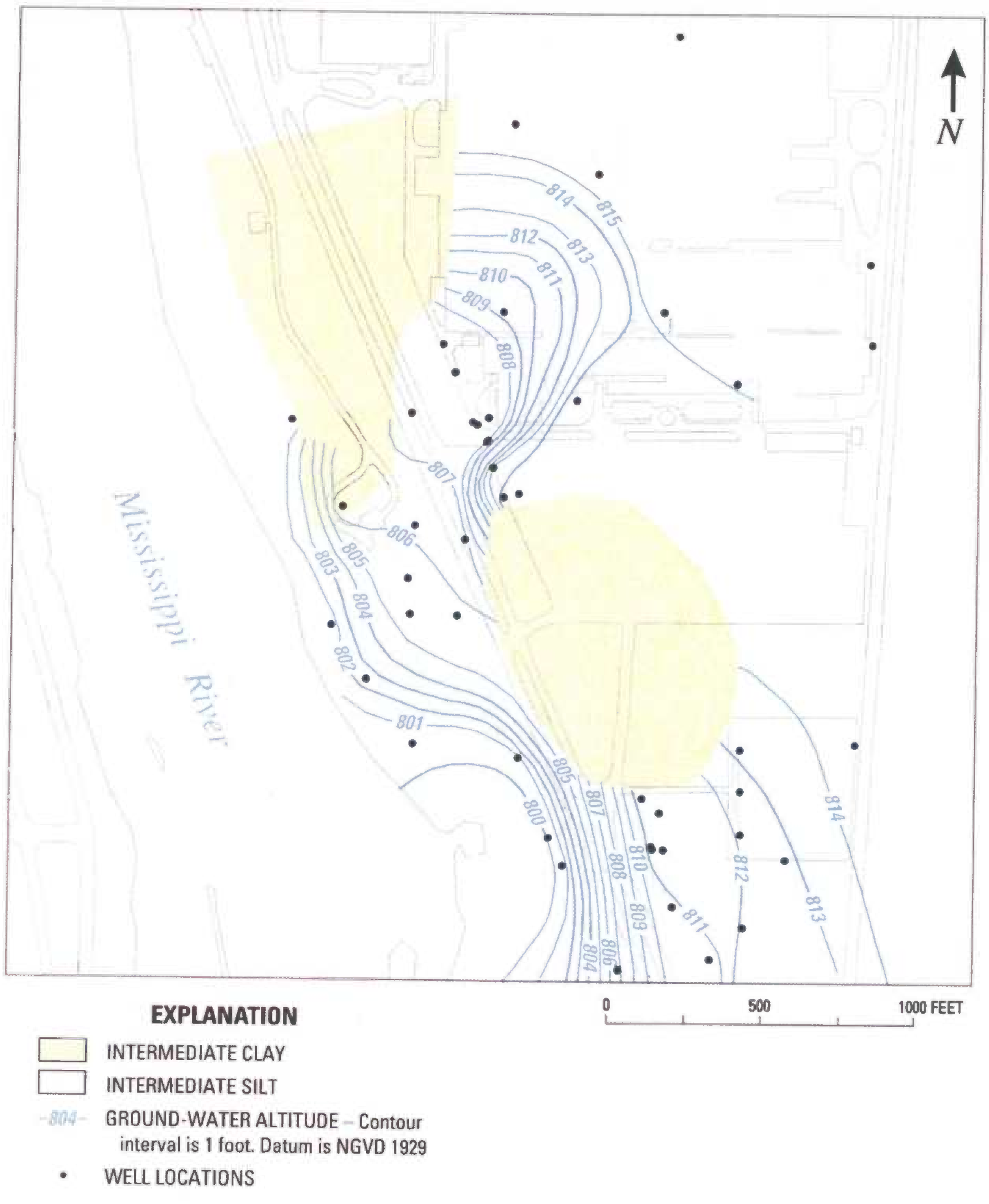
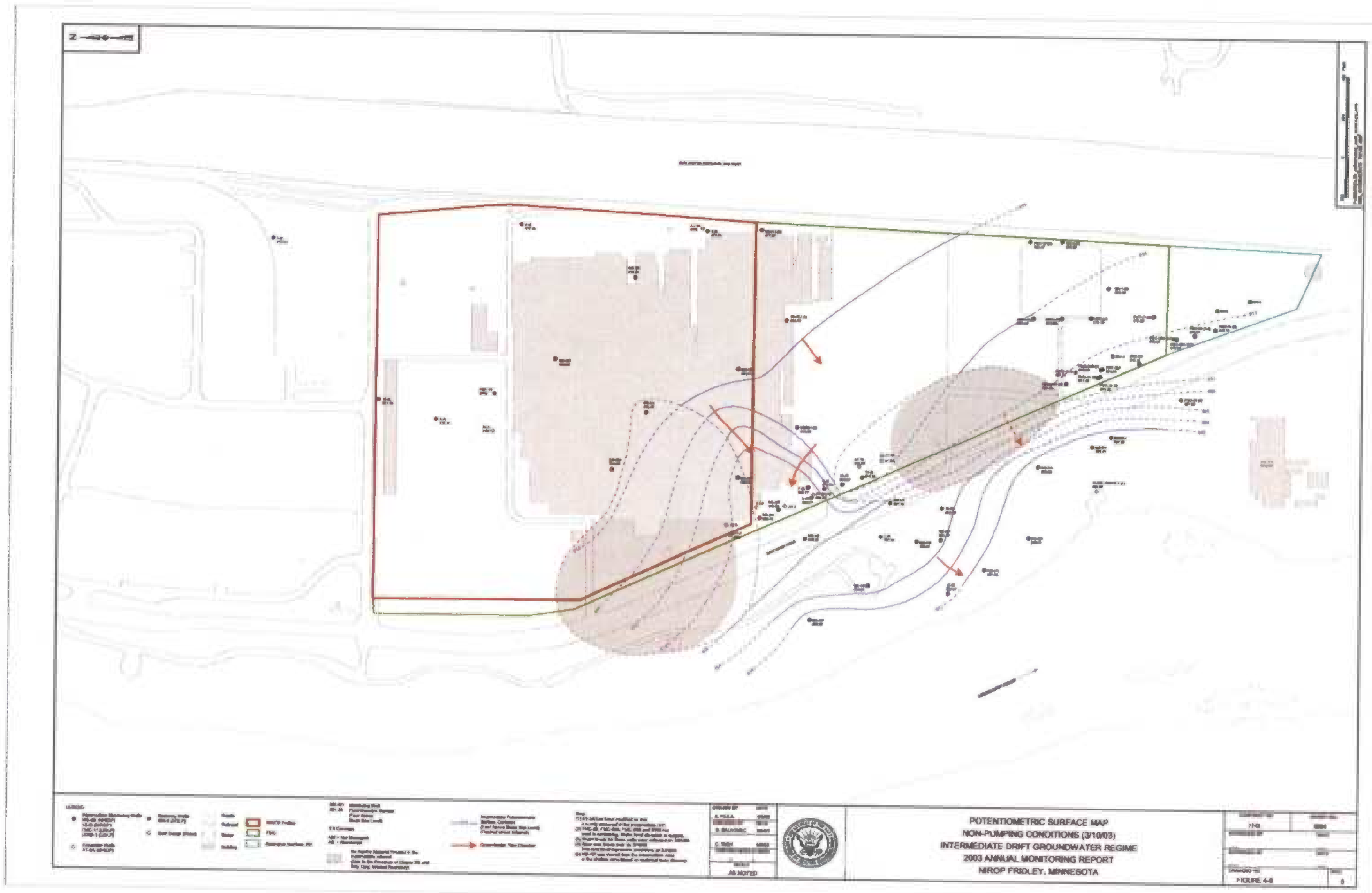


Figure 19. Potentiometric surface of the intermediate flow zone during non-pumping conditions on September 26, 2001.


POTENTIOMETRIC SURFACE MAP
NON-PUMPING CONDITIONS (3/10/03)
INTERMEDIATE DRIFT GROUNDWATER REGIME
2003 ANNUAL MONITORING REPORT
NIROP FRIDLEY, MINNESOTA
FIGURE 4-8
AS NOTED