TABLE OF CONTENTS

<u>LIST OF FIGURES</u>
(Following Text)

## LIST OF FIGURES
(Following Text)



## LIST OF TABLES
(Following Text)

## E-1 SEASONAL CHANGES IN GROUNDWATER FLOW CONDITIONS

In response to the Agencies' April 3, 2003 comments on the SCR-H and July 9, 2003 comments on the RCR-03, a detailed evaluation of the influence of seasonal fluctuations on the performance of the hydraulic containment system has been completed. In both of these comments the Agencies expressed a concern that seasonal fluctuations in water levels at the Site could change groundwater flow conditions and possibly the interpretation of the hydraulic containment. The seasonal evaluation presented here is based on the 18 months of data collected that have been collected from the new piezometer network.

There are both climatic factors and anthropogenic factors that influence water levels at the site. Further, there are hydraulic boundary conditions that are important to identify and consider when assessing changing groundwater levels.

The climatic factors influencing water level changes are:

- barometric pressure;
- precipitation/ snowmelt; and
- evapotranspiration.

Anthropogenic factors that influence water levels include:

- pumping from Site purge wells;
- tourist-season versus winter-season operation of the NYPA hydroelectric power generating station; and
- non-Site-related groundwater pumping.

Hydraulic boundary conditions (points/ areas of groundwater recharge and discharge) that have an important influence on water levels are:

- The gorge of the Lower Niagara River;
- NYPA Forebay and conduits; and
- The abandoned railroad line, sewers, tunnels, and vertical shafts.

In the assessment of seasonal fluctuations it is important to recognize that daily fluctuations and intermittent influences are "noise" in the seasonal data. The noise, while potentially interesting on its own, interferes with evaluation of seasonal conditions. For the seasonal assessment, the noise has been filtered out of the data by calculating monthly-averaged water levels. As appropriate, instantaneous or daily average data are presented and discussed.

## E-2 FACTORS INFLUENCING GROUNDWATER LEVELS

### Climatic Factors

The climatic factors influencing seasonal water level changes are:

- barometric pressure;
- precipitation;
- snowmelt; and
- evapotranspiration.

Each of these factors influences water levels with different timing and magnitude.

*Precipitation, Snowmelt, and Evapotranspiration*

Natural seasonal fluctuations in water levels are determined by seasonal patterns in areal recharge to groundwater and changes in aquifer boundary conditions (elevation changes in surface water bodies). Areal recharge to groundwater comes from precipitation infiltration and is generally accepted to be a function of precipitation, snowmelt, evapotranspiration, and overland runoff. In the wintertime, precipitation accumulates as snowfall and does not recharge the aquifer. When the snow melts in the springtime, the melt water becomes potential recharge. In the summer, the rate of evaporation typically exceeds the rate of precipitation, removing precipitation before it can recharge the aquifer. The following discussion presents the interrelationships of precipitation, snowmelt, and evapotranspiration at the Site. Runoff has been ignored in the evaluation presented here. Runoff will influence the magnitude of the potential recharge, but should have little impact on the seasonal trends of potential recharge. This evaluation is focused on the seasonal patterns, not the absolute magnitude.

Precipitation and temperature data were obtained from the National Climate Data Center for the Niagara Falls International Airport for the period from January 2003 to March 2004. These data are presented on Figure E-1. The precipitation data include snowfall. Precipitation that falls when the average temperature is below freezing (January and February) accumulates as snowpack, and there is no infiltration to the groundwater. When temperatures rise in March and April, the snowpack melts, providing water for groundwater recharge.

Based on inspection of the temperature data and groundwater level data, it appears that the snow melt occurs rapidly when temperatures rise above freezing for several days.

Figure E-2 shows three brief "heat-waves" that occurred in March 2003, April 2003, and March 2004 and the groundwater levels in AFW-1M-09. The peaks in the groundwater levels in AFW-1M-09 correspond to the spring snowmelt events.

The red line on Figure E-2 shows the actual precipitation. The green line on the graph represents the conceptualized "apparent precipitation". The apparent precipitation accounts for the typical pattern of snow accumulation during January and February and snowmelt events that occur in March and April. The apparent precipitation line was developed by assuming that precipitation falling during January and February melts equally over March and April.

Potential evapotranspiration (PET) was evaluated using the Thornthwaite empirical model (Thornthwaite and Mather, 1955). The model computations are summarized in Table E-1. Figure E-3 presents the results of the Thornthwaite model. The figure shows both the monthly precipitation and PET. In the summer months, evapotranspiration is greatest and is large enough to account for all of the precipitation that falls during the summer months. In the fall evapotranspiration declines and precipitation exceeds the evapotranspiration. Figure E-3 presents the "potential recharge" the maximum amount of precipitation that could infiltrate and replenish the groundwater. Snowmelt is assumed to be the total January and February precipitation distributed equally in March and April.

Figure E-4 presents the monthly average groundwater level in piezometer G1U-01 relative to the potential recharge. The seasonal pattern in water levels is characterized as follows:

- a rapid rise in March and April due to snow melt and low evapotranspiration;
- declining water levels from May into September when evapotranspiration removes most to all of the precipitation;
- a rise in water levels in October and December when precipitation exceeds evapotranspiration; and
- a decline in water levels in January and February when precipitation is accumulating as snow.

Figure E-5 presents a conceptual seasonal groundwater fluctuation for FZ-01. This conceptual seasonal groundwater fluctuation is observed in most of the shallow piezometers (FZ-01 to FZ-04) and is considered to be the "seasonal climatic" influence.

*Barometric Pressure*

Variations in barometric pressure cause minor variations in piezometer water levels. One transducer at the site has been dedicated to continuously monitoring barometric pressure at ten-minute intervals. Figure E-6 presents raw 10-minute sampling and monthly-averaged air pressure data. The pressure data is plotted in terms of feet of water (ft $H_2O$). This conversion reflects the maximum change in a piezometer water level that could be attributed to barometric pressure. The maximum change in a monthly-averaged water level fluctuation attributable to barometric pressure was 0.13 foot. There appears to be no seasonal component of the barometric pressure and an influence of 0.13 foot is considered an insignificant influence at the Site.

Anthropogenic Factors

In addition to the climatic factors that influence water levels, there are significant fluctuations that are the result of anthropogenic factors. The most significant anthropogenic factors are:

- pumping from Site purge wells; and
- tourist-season versus winter-season operation of the NYPA hydroelectric power generating station.

*Purge Well Pumping*

The Site bedrock remedial system consists of 19 active bedrock purge wells. Figure E-7 presents the average monthly pumping rates for these purge wells.

Each bedrock purge well is operated to maintain a fixed groundwater elevation in the well. A target water level, the "set-point", is defined and maintained by either a variable speed drive, allowing continuous flow adjustment to maintain the set-point, or by cycling the pump on and off to maintain pumping levels within a set-point window. Conceptually, this set-point control operation should subdue the effects of seasonal groundwater fluctuations, and a seasonal trend in monthly average pumping rates should be observable. The influence on water levels is discussed in Section E-3.

The average monthly pumping data were reviewed to identify seasonal fluctuations in pumping rates. No seasonal trend was identified. The lack of an apparent trend may be related to the many adjustments made to the pumping system in 2003. Three wells: PW-1L, PW-2M, and PW-10U were off-line for some extended duration in 2003. PW-10U was modified to seal off FZ-06 in the well. PW-1L was out of service from

January 2003 to early July 2003. PW-2M was off-line or operating at a reduced rate until mid September 2003 while working on increasing its pumping capacity. Any trends that might have been present were likely masked by variability in the system operation.

*NYPA Influence*

Water levels in the NYPA forebay and conduits significantly affect the bedrock groundwater levels in some areas of the Site. A detailed discussion of these two features was presented in the SCR-M, Sections 2.5.2 and 2.5.3.

Figure E-8 presents the NYPA forebay water levels for the period from January 2003 to May 2004. Three lines are shown, one representing actual levels measured electronically by NYPA every 20 minutes, daily-averaged levels, and monthly-averaged levels. The levels recorded at 20-minute intervals show that there is a typical daily fluctuation of approximately 15 feet. The daily fluctuations are clearly observable in several of the Site piezometers. Figure E-8 shows the forebay levels and water levels from J6-07 for October 2003. The daily fluctuations in J6-07 match the fluctuations in the forebay water levels, although the magnitude of the fluctuation is subdued.

There are two operational "seasons" for the NYPA facility: tourist and winter season. During tourist season, less water is diverted for power (more goes over the "Falls") than in the winter season. Tourist season begins April 1, and winter season begins November 1 of each year. A review of Figure E-8 indicates that the highest monthly forebay water level was April 2003 (tourist season) and the lowest level was is March 2004 (winter season). The forebay water level is, on average, higher during tourist season operation.

As explained in the SCR-M, the NYPA forebay is intersected by flow zones FZ-06 through FZ-11, and the conduits are intersected by flow zones FZ-05 through FZ-11 in the vicinity of the Site.

<u>Hydraulic Boundaries</u>

There are numerous natural and man-made features in the Site vicinity that exert a controlling influence on bedrock water levels. These features create "hydraulic boundaries". There are two general categories of boundaries: fixed-elevation, such as gorge of the Lower Niagara River, and the network of sewer, tunnels, and shafts; and variable-elevation, such as the NYPA forebay. For fixed-elevation boundaries, the fluctuation of groundwater levels is constrained relative to the water elevation at the boundary. Each of the major hydraulic boundaries is discussed in turn.

*NYPA Forebay and Conduits*

As explained in the SCR-M, the NYPA forebay is intersected by flow zones FZ-06 through FZ-11, and the conduits are intersected by flow zones FZ-05 through FZ-11 in the vicinity of the Site. These flow zones may either be submerged or represent a seepage face depending on the operational water level in these features. When submerged, flow zones may receive water. When exposed to air, the flow zones may discharge water to the feature, provided the water level in the flow zone is higher than the elevation at the point of potential discharge.

*Lower Niagara River Gorge*

The gorge face of the Lower Niagara River represents the natural point of discharge for the groundwater system at the Site. As described in Section 2.5.1 of the SCR-M, the bedrock units of interest at the Site with respect to groundwater flow all terminate at the gorge. Figure E-9 presents a geologic profile at the Niagara River gorge near the Site. Flow zones FZ-6 to FZ-11 outcrop at the gorge. The flow zone outcrops are well above the Niagara River. Thus, these are seepage face boundaries. Piezometers located close to the gorge face should exhibit little fluctuation in water level, provided that the piezometer is located in an area with a moderately high transmissivity.

*Abandoned Railroad Line, Sewers, Tunnels, and Shafts*

The network of sewers, tunnels, and shafts, and the abandoned railroad line (described in detail in the SCR-H) represent potential drains and recharge areas for bedrock groundwater. The RCR-03 identified several locations where vertically upward hydraulic gradients are attributed to these man-made features, as the natural vertical hydraulic gradient would be downward.

## E-3 ASSESSMENT OF SEASONAL CLIMATIC AND ANTHROPOGENIC INFLUENCES ON GROUNDWATER LEVELS

Water level fluctuations, both seasonal and anthropogenic, have been evaluated for each flow zone to assess any influence the fluctuations may have on hydraulic containment.

The seasonal climatic influence described on Figure E-5 is observed primarily within flow zones FZ-01 through FZ-05. These flow zones are closest to ground surface and flow in these flow zones is primarily vertical.

Anthropogenic effects occur primarily within flow zones FZ-06 through FZ-11. Flow in these deeper, generally transmissive zones, is primarily horizontal. These deeper flow zones intersect the NYPA forebay and terminate at the gorge face.

The following sections provide an assessment of the potential influence of water level fluctuations on the demonstration of hydraulic containment for each of the flow zones monitored.

### E-3.1 FZ-01

FZ-01 Potentiometric Surface

Monthly-averaged water levels for all FZ-01 piezometers for the period from January 2003 to May 2004 were presented on Figure E-5. All of the FZ-01 piezometers exhibit water level fluctuations in response to seasonal climatic conditions. High water levels occur in April and low levels in October. The following table presents the approximate range of the magnitude of seasonal fluctuations at each FZ-01 piezometer.

| *Piezometer* | *Seasonal Fluctuation (ft)* | *Transmissivity ($ft^2$/day)* |
|---|---|---|
| G1U-01 | 6 | 66 |
| G6-01 | insufficient record | 70 |
| H2U-01 | 5 | 80 |
| H5-01 | 8-9 | 75 |
| I1-01 | 6-10 | 0.5 |

Figure E-10 presents a potentiometric surface for FZ-01; both April 2004 and October 2003 contours are shown. These months were selected as they represent the seasonal high and low water level conditions. April 2004 was selected over April 2003 because the purge well operation in April 2004 was more representative of normal operating conditions and consistent with the pumping conditions in October 2003.

The contours are very similar demonstrating that seasonal fluctuations have very little influence on groundwater flow directions.

A plot of vertical gradients over time between FZ-01 and FZ-02 piezometers is presented on Figure E-11. Vertical gradients in FZ-01 are strongly downward year-round. A seasonal pattern is present in the vertical gradients between FZ-01 and FZ-02. The maximum downward gradient occurs in the spring and the minimum occurs in the fall. The change in vertical gradient is relatively small.

### E-3.2 FZ-02

Figure E-12 presents hydrographs of the monthly-averaged water levels at FZ-02 piezometers. Similar to the water levels in FZ-01, there is a seasonal response at all FZ-02 piezometers. The following table presents the approximate range of the magnitude of seasonal fluctuations at each FZ-02 piezometer.

| *Piezometer* | *Seasonal Fluctuation (ft)* | *Transmissivity ($ft^2$/day)* |
|---|---|---|
| F2U-02 | 2 | 30 |
| F4U-02 | 2 | 14 |
| G1-02 | 5-6 | 0.7 |
| G6-02 | insufficient record | 240 |
| H2U-02 | 5 | 0.5 |
| H5-02 | 4 | 1.6 |
| I1-02 | 9-10 | 9.0 |
| J2U-02 | 10 | 44 |
| J5U-02 | 10 | 75 |
| J6-02 | 10 | 71 |

The seasonal fluctuation at F2U-02 and F4U-02 is approximately 2 feet in both cases. This reduced seasonal variation is likely indicative of hydraulic boundaries, e.g., sewers or sewer bedding, on the water levels at these two locations. Figure 2-5 in the RCR-04 shows a sewer running along Hyde Park Boulevard close to F4U-02. It is likely that there are also sewers located close to F2U-02.

The greatest magnitude of fluctuation occurs at piezometer locations I1-02, J5U-02, and J6-02, all of which exhibit a seasonal fluctuation of approximately 10 feet. The greatest fluctuations generally occur in piezometers furthest from hydraulic boundaries.

Figure E-13 presents potentiometric contours for April 2004 and October 2003. Groundwater flow conditions are not appreciably different for the two dates.

A plot of vertical gradients over time between FZ-02 and FZ-04 piezometers is presented on Figure E-14. The gradients at I1, J5, and J6 are consistently downward. The fluctuations at J5 and J6 locations show a seasonal trend similar to vertical gradients at the shown on Figure E-12 for location G1. Locations where the vertical gradient is essentially zero or upward show no apparent seasonal trends in the vertical gradients. This may be indicative of a nearby hydraulic boundary.

### E-3.3 FZ-04

Hydrographs for the monthly-averaged water levels in FZ-04 piezometers are presented on Figure E-15. Similar to FZ-01 and FZ-02, there is a seasonal fluctuation in the majority of the FZ-04 piezometers. The following table presents the approximate range of the magnitude of seasonal fluctuations at each FZ-04 piezometer.

| *Piezometer* | *Seasonal Fluctuation (ft)* | *Transmissivity ($ft^2$/day)* |
|---|---|---|
| AFW-2U-04 | 3-4 | 77 |
| D1U-04 | 3 | 49 |
| D2U-04 | 4 | 28.5 |
| E6-04 | <1 | 1.4 |
| F2U-04 | 3 | 422 |
| F4U-04 | 3 | 0.3 |
| F6-04 | <1 | 40 |
| G1U-04 | 4 | 0.009 |
| G6-04 | insufficient record | 190 |
| H5-04 | 4-5 | 0.6 |
| I1-04 | 9-11 | 3.1 |
| J2U-04 | insufficient record | 140 |
| J5U-04 | 6 | 0.01 |
| J6-04 | 5 | 4.2 |

The magnitude of the fluctuation ranges from near zero at F6-04 and E6-04 to approximately 11 feet at I1-04. In general, the magnitude of the fluctuation is smallest in areas where there is a hydraulic boundary, and greatest furthest away from hydraulic boundaries. The lack of seasonal response at F6-04 may be indicative of the influence of a nearby sewer or the sewer bedding.

Figure E-16 presents potentiometric contours for April 2004 and October 2003. Groundwater flow conditions are generally unchanged despite the range of variability in the magnitude of the seasonal fluctuations in water levels.

A plot of vertical gradients over time between FZ-04 and FZ-05 piezometers is presented on Figure E-17. The gradients at D1, D2, F4, H5, and J5 are consistently downward. The fluctuations in the gradient at these five piezometers do not show a clear trend, and do not appear to be related to seasonal water fluctuations.

### E-3.4 FZ-05

Hydrographs for the monthly-averaged water levels in FZ-05 piezometers are presented on Figure E-18. Similar to the shallower flow zones, there is a seasonal fluctuation in the majority of the FZ-05 piezometers. The following table presents the approximate range of the magnitude of seasonal fluctuations at each FZ-05 piezometer.

| *Piezometer* | *Seasonal Fluctuation (ft)* | *Transmissivity ($ft^2$/day)* |
|---|---|---|
| AFW-2U-05 | 3-5 | 13 |
| AGW-1U-05 | 8-9 | 360 |
| D1U-05 | 2-3 | 22 |
| D2U-05 | 2-3 | 30 |
| E6-05 | 2 | 0.7 |
| F2U-05 | 2-3 | 0.07 |
| F4U-05 | 3-4 | 0.030 |
| F6-05 | 2 | 0.3 |
| G6-05 | insufficient record | 8 |
| H2M-05 | 4-5 | 0.001 |
| H5-05 | 4 | 16 |
| I1-05 | 2 | 0.2 |
| J2U-05 | insufficient record | 300 |
| J5U-05 | 6 | 66 |
| J6-05 | 4-6 | 64 |
| PMW-1U-05 | 1-2 | 2.1 |

The magnitudes of seasonal fluctuations in FZ-05 range from less than 3 feet at E6-05 and F6-05 to approximately 9 feet at AGW-1U-05. Similar to FZ-04, the smallest variation occurs at E6-05 and F6-05. These piezometers are located close to hydraulic boundaries.

Water levels in I1-05 appear to be responding to the NYPA conduits. This is consistent with the piezometer's location, being the closest piezometer to the NYPA conduits that lie east of the Site. The lower water level at this location is also consistent.

Figure E-19 presents potentiometric contours for April 2004 and October 2003. Groundwater flow conditions are generally unchanged despite the range of variability in the magnitude of the seasonal fluctuations in water level, on average five higher in April than in October.

Vertical gradients were not inspected from FZ-05 and deeper. The groundwater flow in these flow zones is primarily horizontal and the evaluation of vertical gradients was considered to be unnecessary.

### E-3.5 FZ-06

FZ-06 Potentiometric Surface

The FZ-06 monthly-averaged water levels are presented on Figure E-20. None of the FZ-06 piezometers exhibit a seasonal fluctuation. This is consistent with the conceptual model developed in the SCR-H and extended in the SCR-M. FZ-06 is considered to be the first flow zone in which flow is predominantly horizontal. Conceptually, a horizontally transmissive flow zone should be largely unaffected by additional water infiltrating from above since water level fluctuations would tend to damped, or transmitted, across the flow zone.

The water level responses in FZ-06 can generally be divided into four distinct groups (A, B, C, and D) and are identified on Figure E-20. The groups are defined as follows:

- Group A: Locations that respond significantly to pumping from the bedrock remedial system (inspection of the hydrographs presented in Appendix D of this RCR-04 report is necessary to recognize the pumping response);
- Group B: Locations that respond to fluctuations in the NYPA forebay;

- Group C: Locations that are located close to the gorge face, tunnels, or shafts; and
- Group D: Locations south of the Site that appear to be influenced by long-interval wells connecting the various bedrock flow zones.

Group A piezometers, D1U-06, D2U-06, J5M-06, and PMW-1U-06, respond to the pumping of the bedrock remedial system. This group of piezometers has water levels well below the other FZ-06 piezometers, and each of these piezometers is essentially dewatered under pumping conditions. The response of these piezometers to the pumping system is evident on Figure E-20 by the small recovery that occurs in January 2003 as a result of the system shutdown test, and again in May 2003 when PW-2M was shut down for deepening.

Group B piezometers, AGW-1U-06, B2U-06, and I1-06, respond to fluctuations in the NYPA forebay. The water level in these piezometers is approximately the same as the water level in the forebay. As explained in the SCR-M, FZ-06 is the first flow zone that is intersected by the forebay.

There are four Group C piezometers in FZ-06: ABP-7-06, AFW-1U-06, AFW-2U-06, and C3-06. Only one of these piezometers, AFW-1U-06, has water, the others are all dewatered. These four piezometers are essentially dry because of their proximity to hydraulic boundaries, either the gorge face of the Lower Niagara River, or tunnels and shafts.

Group D piezometers, E6-06, F6-06, G1M-06, G6-06, and H2M-06, are all located south of the Site. As noted in the SCR-H, RCR-03, and RCR-04, there appears to be an interconnection of the FZ-01 to FZ-11 in this area. This was first identified by FZ-11 piezometers that fluctuate more like FZ-01 than FZ-09 immediately above FZ-11. The clear seasonal fluctuation in these FZ-06 piezometers supports this interconnection hypothesis, although the location/ mode of interconnection is uncertain.

Piezometer H2M-06 has a low transmissivity, and the water level in this piezometer slowly drops throughout 2003 to the water level of the other Group D piezometers.

There is no consistent seasonal or anthropogenic high or low water level for the FZ-06 piezometers. As is evident from Figure E-20 the pumping of the bedrock system lowers the water levels in the Group A piezometers. Each of the four Group A piezometers, D1U-06, D2U-06, J5M-06, and PMW-1M-06, is located within the FZ-06 containment area, and each piezometer is essentially dewatered under the operation of the bedrock remedial system. This condition is unaffected by either seasonal or anthropogenic water level fluctuations.

The potentiometric contours for October 2003 are presented on Figure E-21 for comparison to April 2004 conditions. The groundwater mound south of the Site, corresponding to Group A piezometers, is lower in October 2003 than in April 2004. However, groundwater flow conditions are very similar, and, in particular, the containment boundary is unchanged.

### E-3.6 FZ-07

#### FZ-07 Potentiometric Surface

The FZ-07 monthly-averaged water levels are presented on Figure E-22. Only one piezometer exhibits a typical seasonal response, C3-07. The water level in this piezometer rose in both March 2003 and March 2004. This piezometer is located very close to the former NYC&H railroad cut.

Similar to FZ-06, the FZ-07 piezometers have been categorized into four groups according to their water level responses. However, these groupings are not as evident in FZ-07 as FZ-06. This is primarily related to the number of Group C piezometers, piezometers located close to hydrologic boundary features, shown on the plot. The elevations of the boundary features that exert the controlling influence on water levels occur at varying elevations, and therefore, the Group C piezometers appear at different levels on Figure E-22.

There are only two Group A piezometers shown on the figure, F2M-07 and F4M-07. There are three other Group A piezometers, D1M-07, D2M-07, PMW-1M-07; however, each of these piezometers are excluded from the figure because of their very low transmissivities. These piezometers do exhibit a response to the bedrock pumping system, despite their very low transmissivities, although changes in water level occur very slowly.

In order to evaluate the effects of a low water level condition in FZ-07, November 2003 was selected for comparison to the high water level condition, April 2004. The water levels in Group B piezometers are low because the NYPA forebay level is at its lowest in November 2003. Potentiometric contours for November 2003 are shown on Figure E-23. There is little change in the contours relative to April 2004 because water levels are generally unchanged except at the Group B piezometers located to the north of the Site.

The constant nature of water levels within the containment area is consistent with the set-point operation of the bedrock remedial system implemented at the Site, and containment in FZ-07 is unaffected by fluctuations in the NYPA forebay.

### E-3.7 FZ-09

#### FZ-09 Potentiometric Surface

The FZ-09 monthly-averaged water levels are presented on Figure E-24. There is one FZ-09 piezometer that exhibits a typical seasonal response, AFW-1M-09. This piezometer is dry under pumping conditions except during the spring, when snowmelt and increased precipitation cause water levels to rise locally in the vicinity of this piezometer. This pattern is evident on the plot of piezometer water levels in both March/ April 2003 and March/ April 2004 (refer to Appendix D). This appears to be a localized phenomenon at the gorge face at this location.

Similar to FZ-06 and FZ-07, Figure E-24 shows the groupings of water level responses. Group A piezometers are all located within the FZ-09 stagnation area. The response at each piezometer in this Group is nearly identical for the entire period of record.

The water level fluctuations observed in piezometers ABP-7-09 and C3-09, both Group C piezometers, do not correspond to seasonal effects, variations in the operation of the bedrock pumping system, or the NYPA forebay. Similar to the response at C3-07, the water level fluctuations at C3-09 are likely related to the network of sewers, tunnels, and shafts located nearby.

In order to evaluate the effect of low water level conditions in the NYPA forebay, potentiometric contours for November 2003 are presented relative to April 2004 contours on Figure E-25. There is essentially no change in the contours between these two periods, except that the elevation of the stagnation area is lowered from 522 to 520 feet above mean sea level. The set-point control operation of the bedrock remedial system is effective in providing containment regardless of the operational level of the NYPA forebay.

## E-3.8 FZ-11

### FZ-11 Potentiometric Surface

The FZ-11 monthly-averaged water levels are presented on Figure E-26. The only piezometer to exhibit a seasonal fluctuation in this flow zone is AFW-1L-11, located at the gorge face. Similar to AFW-1M-09, water levels in this piezometer increase in response to the spring snowmelt. Otherwise, there is very little variation in water levels at any FZ-11 piezometer, except for piezometers located close to PW-1L. These piezometers appear to respond to the bedrock pumping system because of the connection between flow zones FZ-09 and FZ-11 that is provided through purge well PW-1L. As presented in Major Ions Report and Section 4.4.8 of the RCR-04, the groundwater in FZ-11 is isolated from the groundwater circulating in FZ-01 to FZ-09.

## E-4 REFERENCES

Thornthwaite, C.W.; Mather, J.R., 1955. The water balance. Publications in Climatology. Centerton, N.J. Drexel Institute of Technology. Vol. VIII, No. 1.


figure E-1
NFIA PRECIPITATION & TEMPERATURE DATA
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_1_nfia_precip_temp.grf) AUG 26/2004

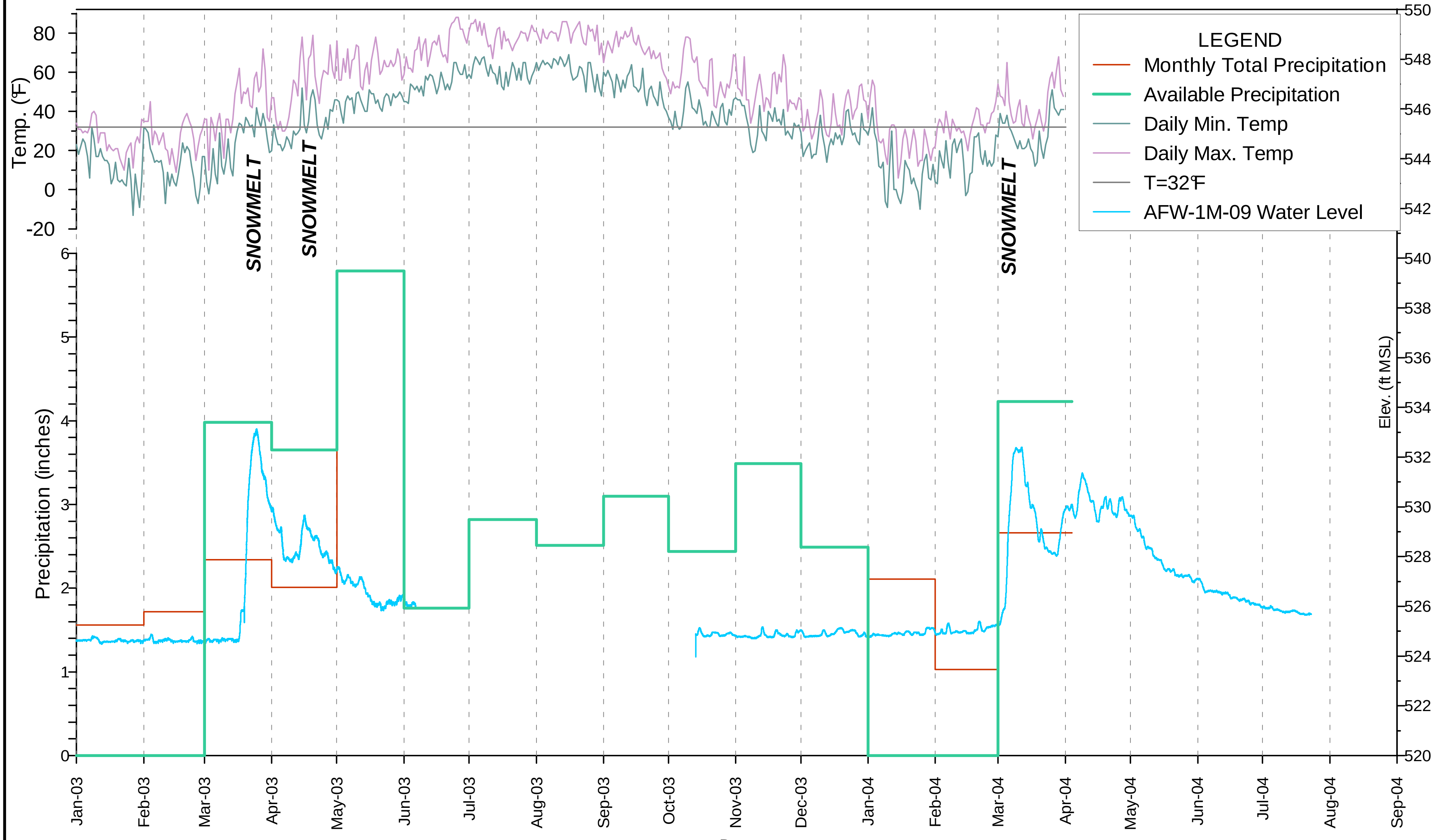



figure E-2

APPARENT PRECIPITATION VERSUS AFW-1M-09 WATER LEVELS

REMEDIAL CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(324)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_2_nfia_precip_AFW1M09.grf) AUG 26/2004

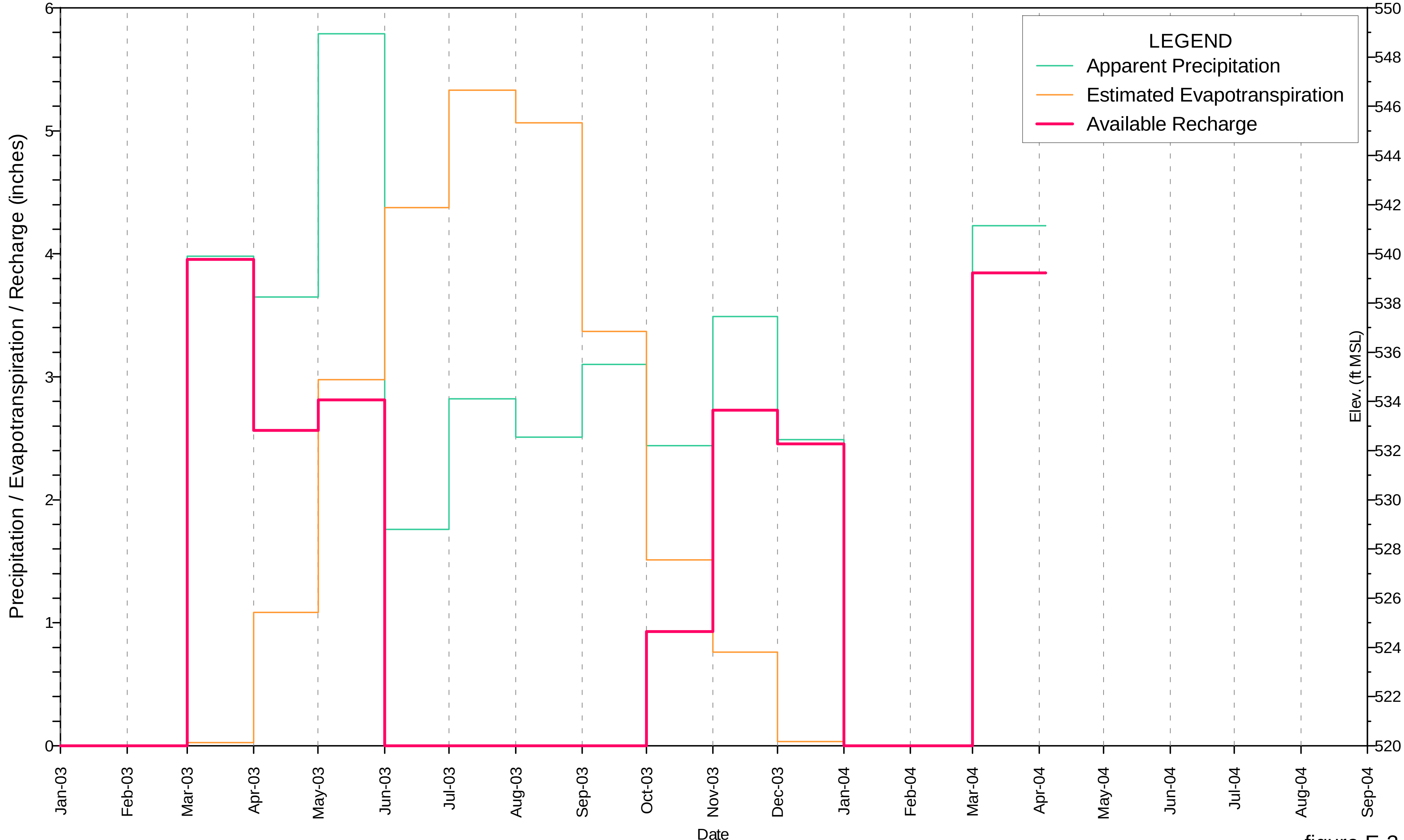



figure E-3
AVAILABLE RECHARGE
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

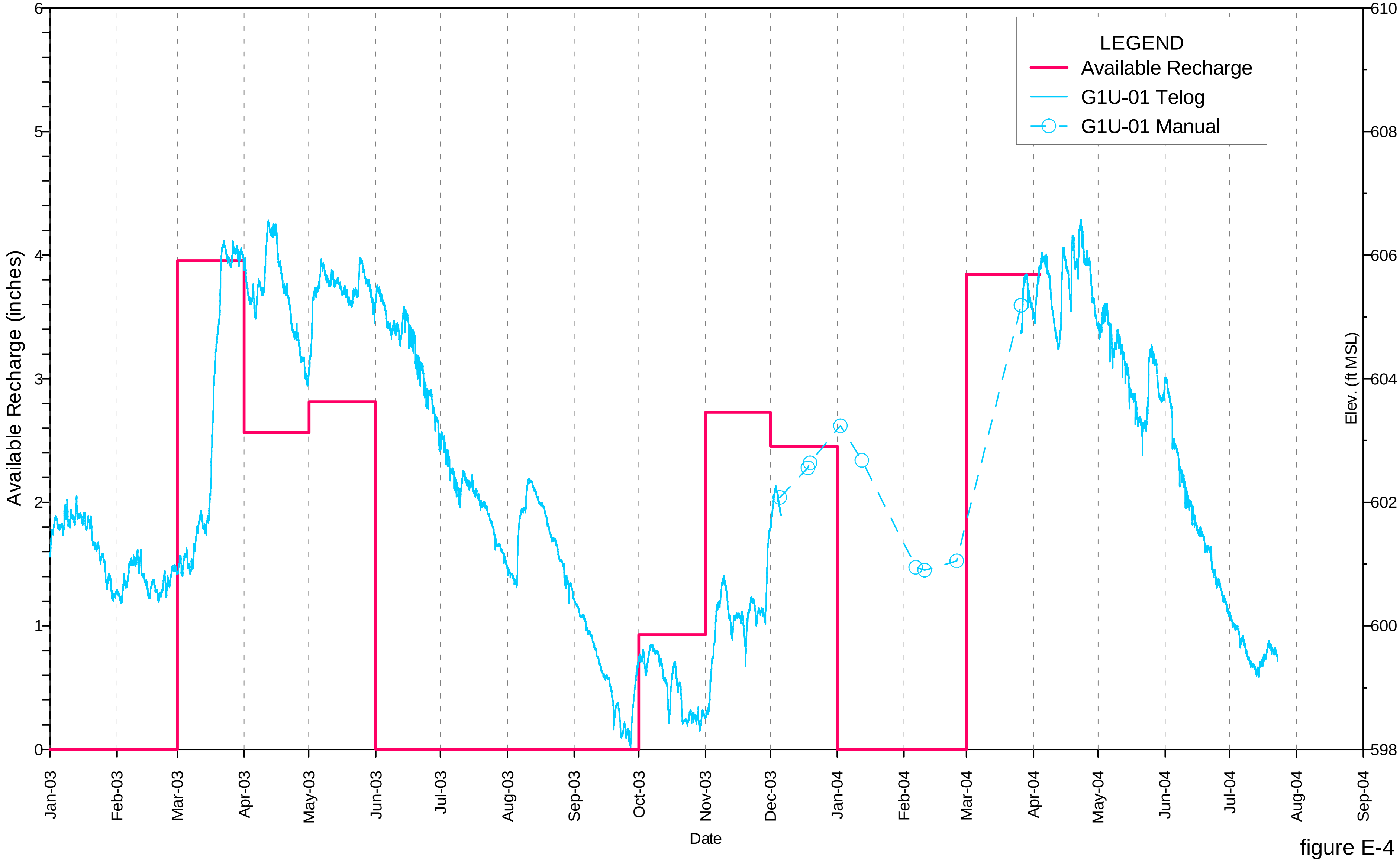



figure E-4

AVAILABLE RECHARGE VERSUS G1U-01 WATER LEVELS

REMEDIAL CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

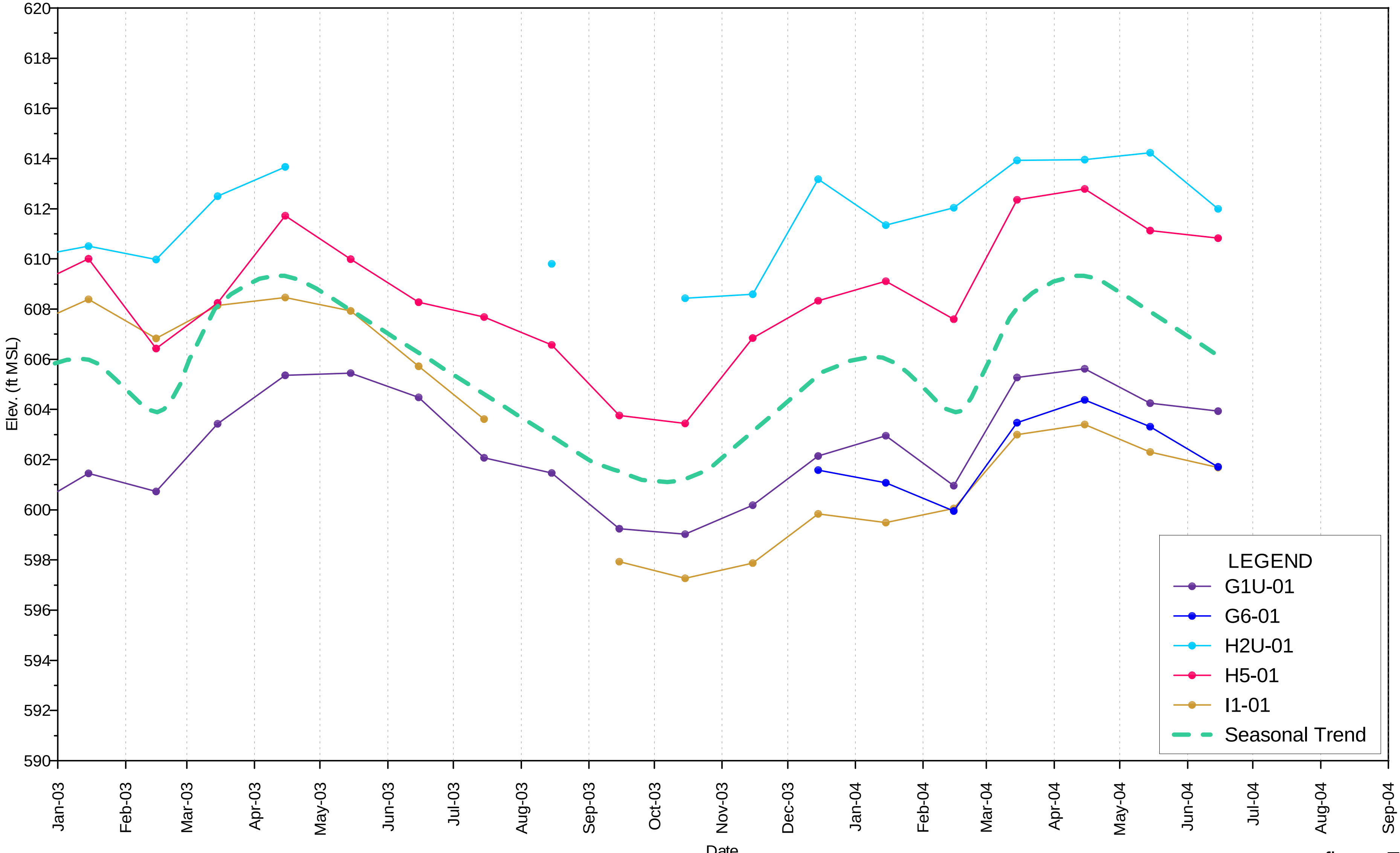



figure E-5
FZ-01 WATER LEVELS AND ESTIMATED SEASONAL FLUCTUATION
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_5_FZ01_seasonal.grf) AUG 26/2004

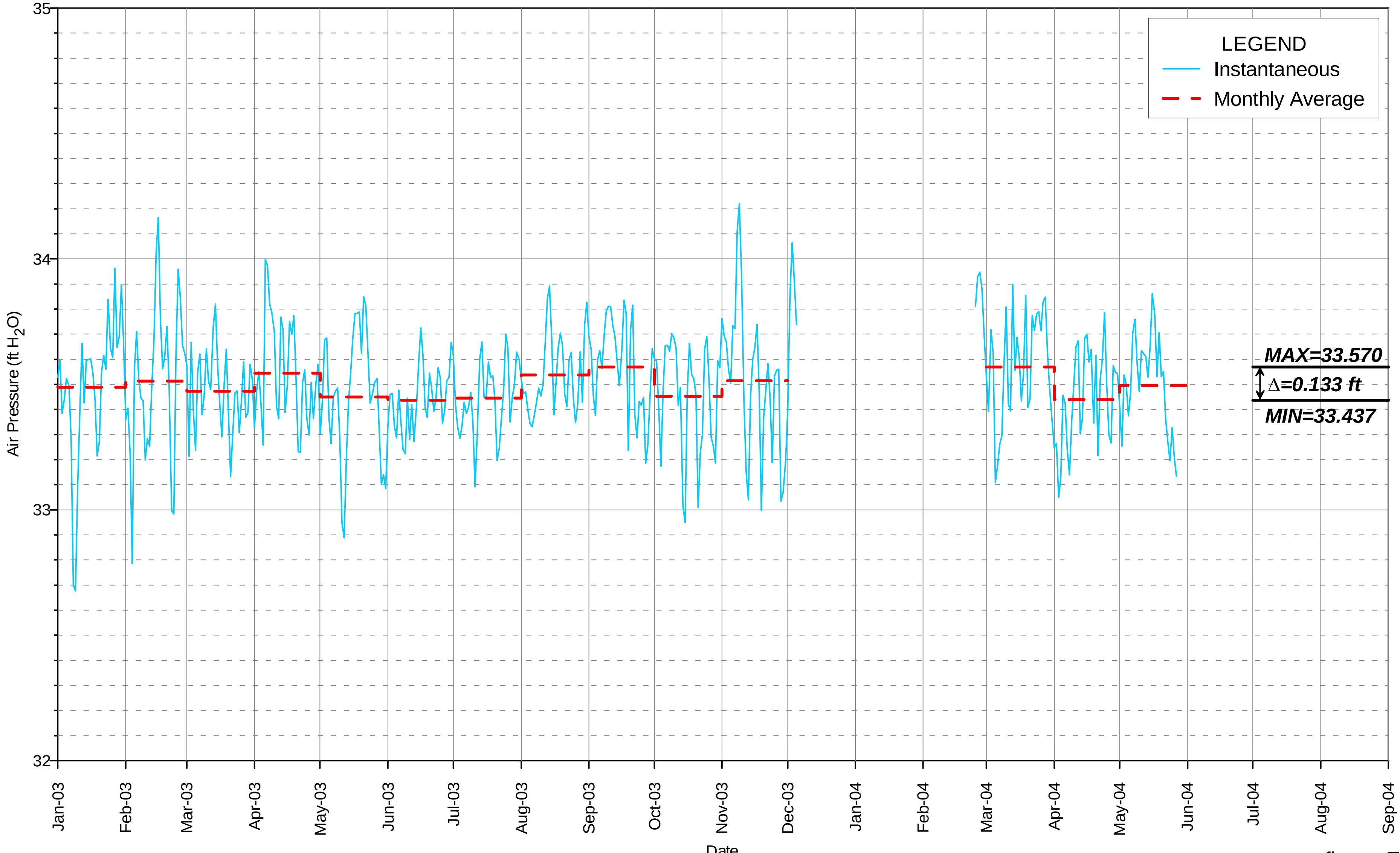



figure E-6

EFFECT OF AIR PRESSURE FLUCTUATIONS ON WATER LEVELS

REMEDIAL CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_6_air_pressure.grf) AUG 26/2004

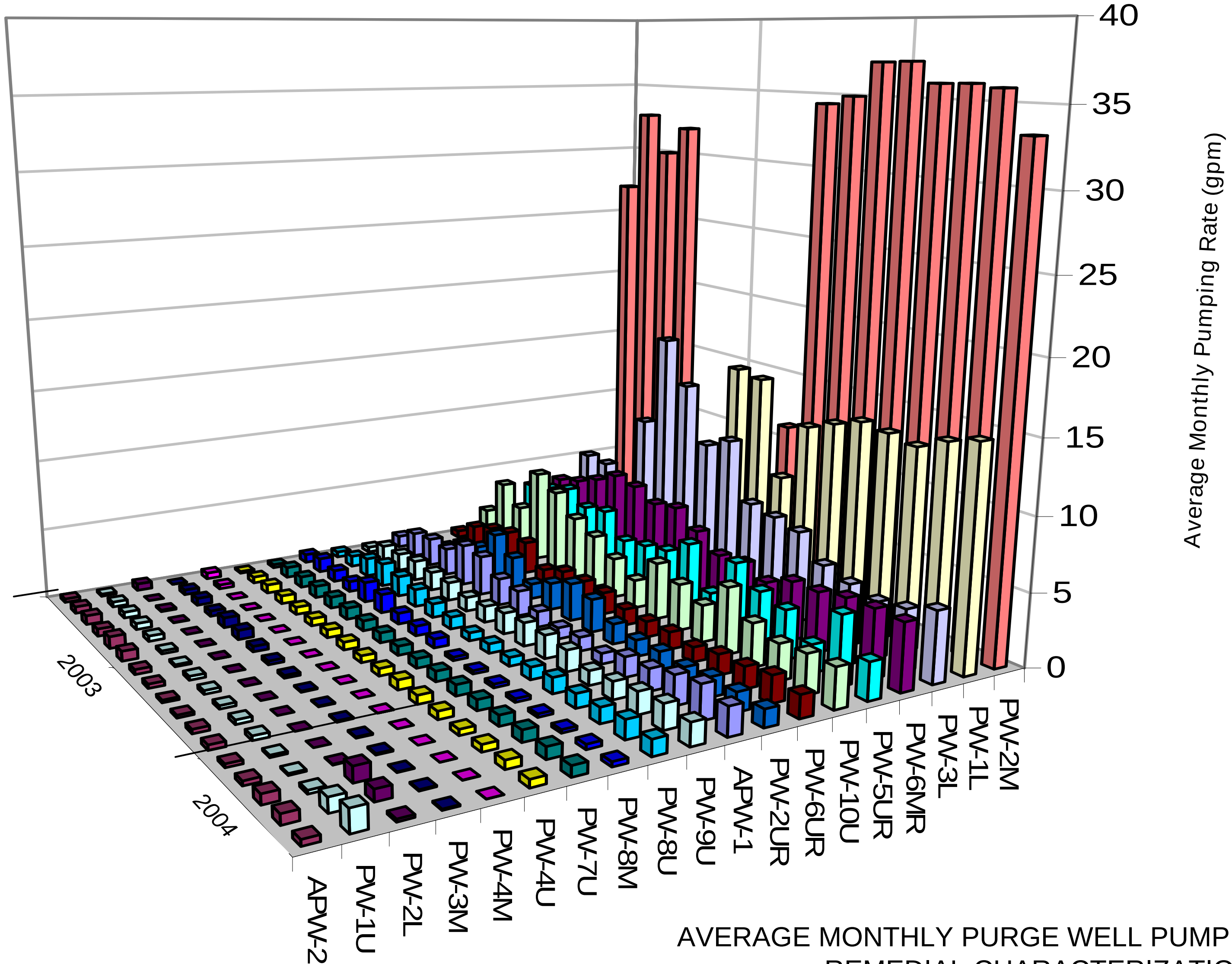



figure E-7
AVERAGE MONTHLY PURGE WELL PUMPING RATES
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

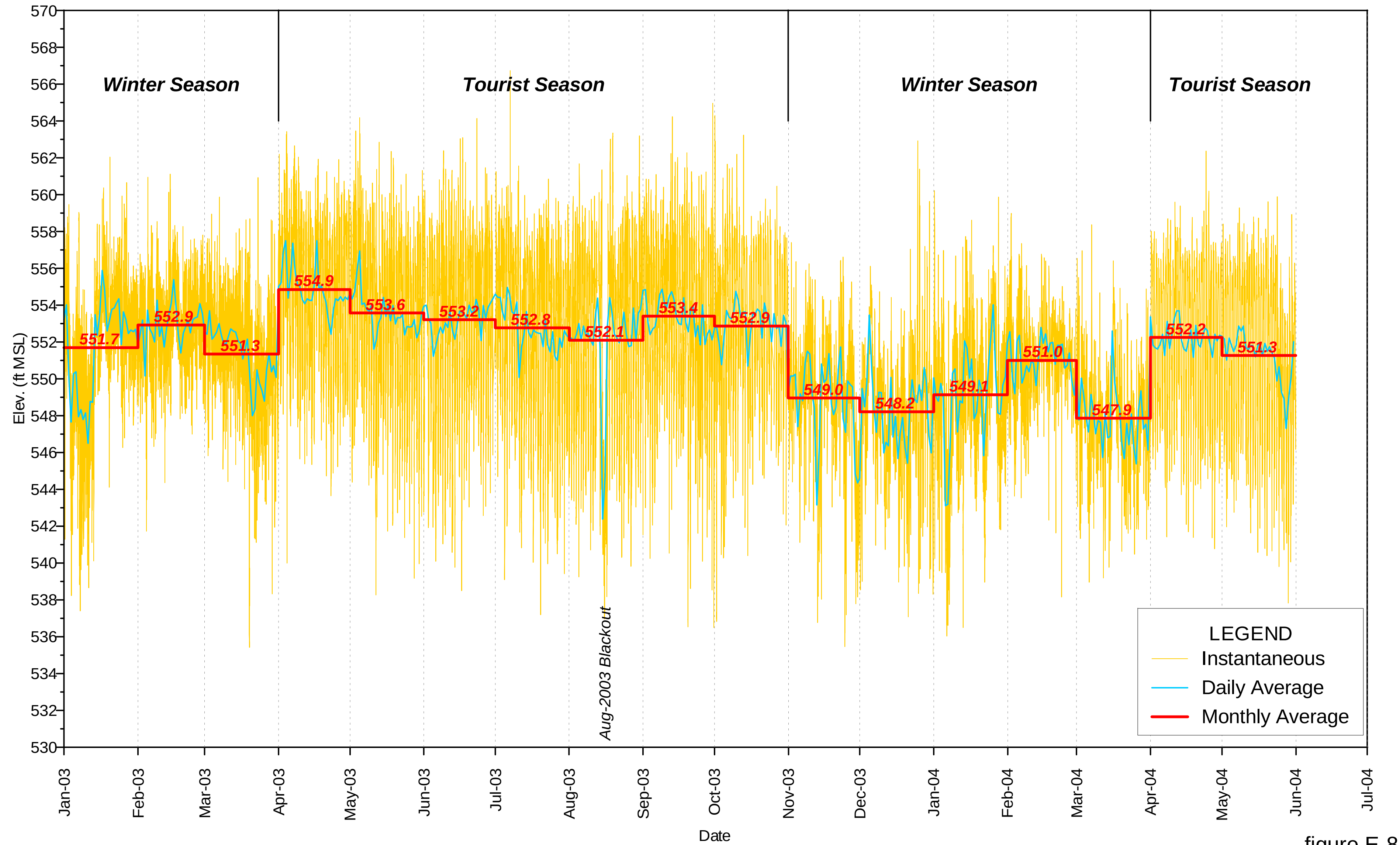
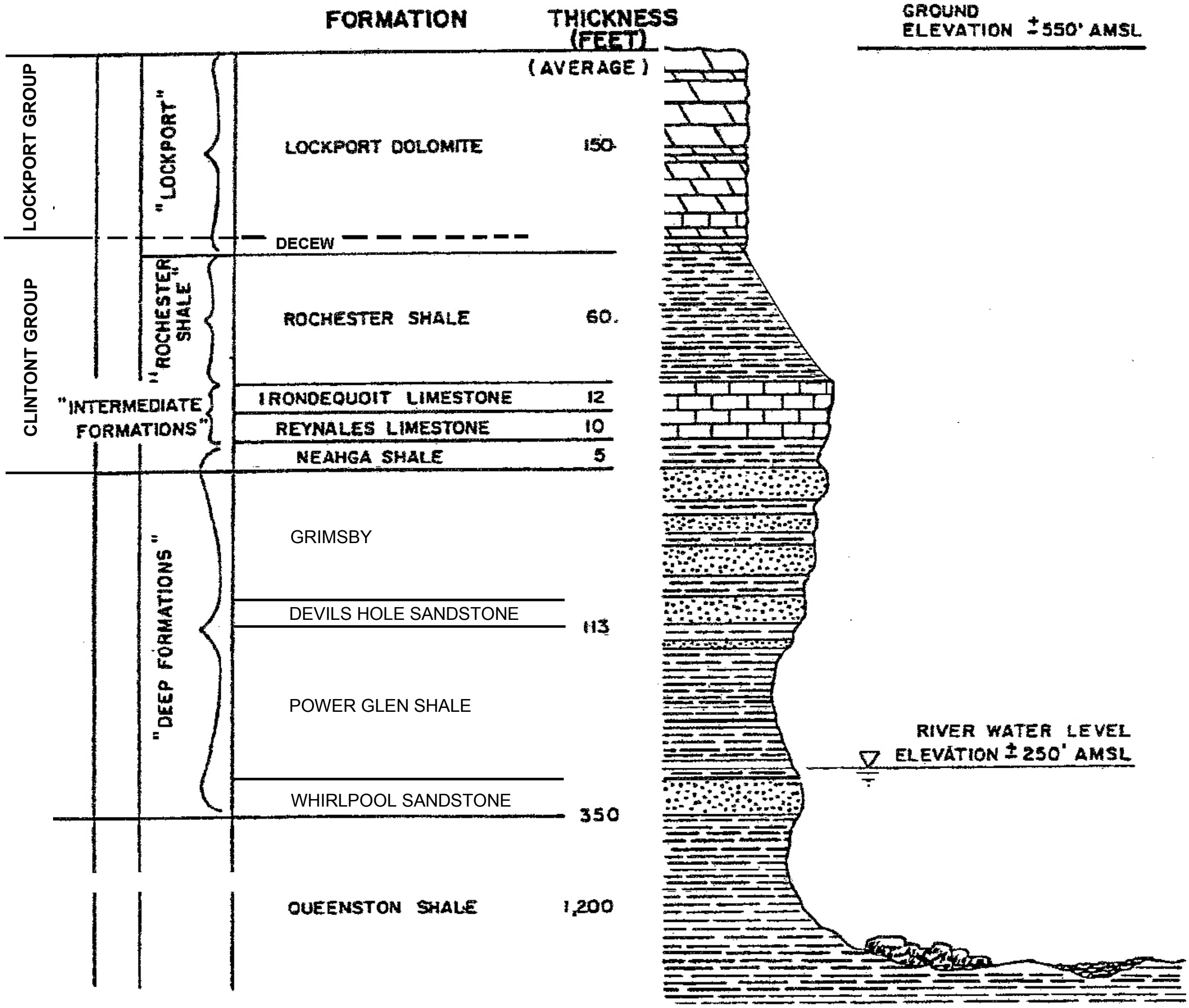



figure E-8
NYPA FOREBAY WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\piezometer_data\fA_8_forebay.grf) AUG 26/2004




Modified from: "Groundwater in the Niagara Falls Area, New York", Richard H. Johnston, USGS Bulletin, GW-53, 1964

figure E-9
GEOLOGIC PROFILE AT GORGE FACE
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

**Miller Springs Remediation Management, Inc.**

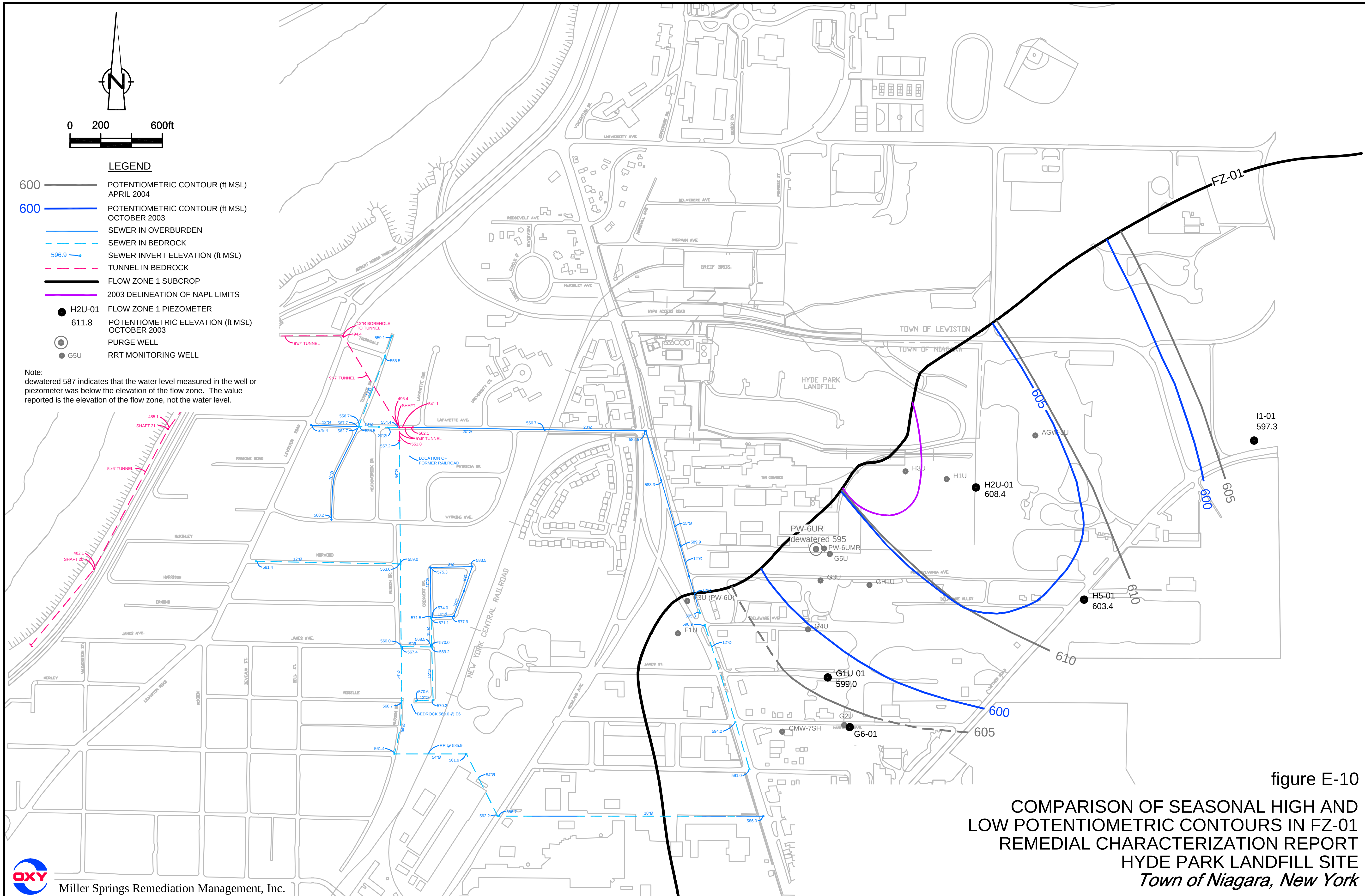



figure E-10

COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-01
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

01069-30(342)GN-WA027 AUG 26/2004

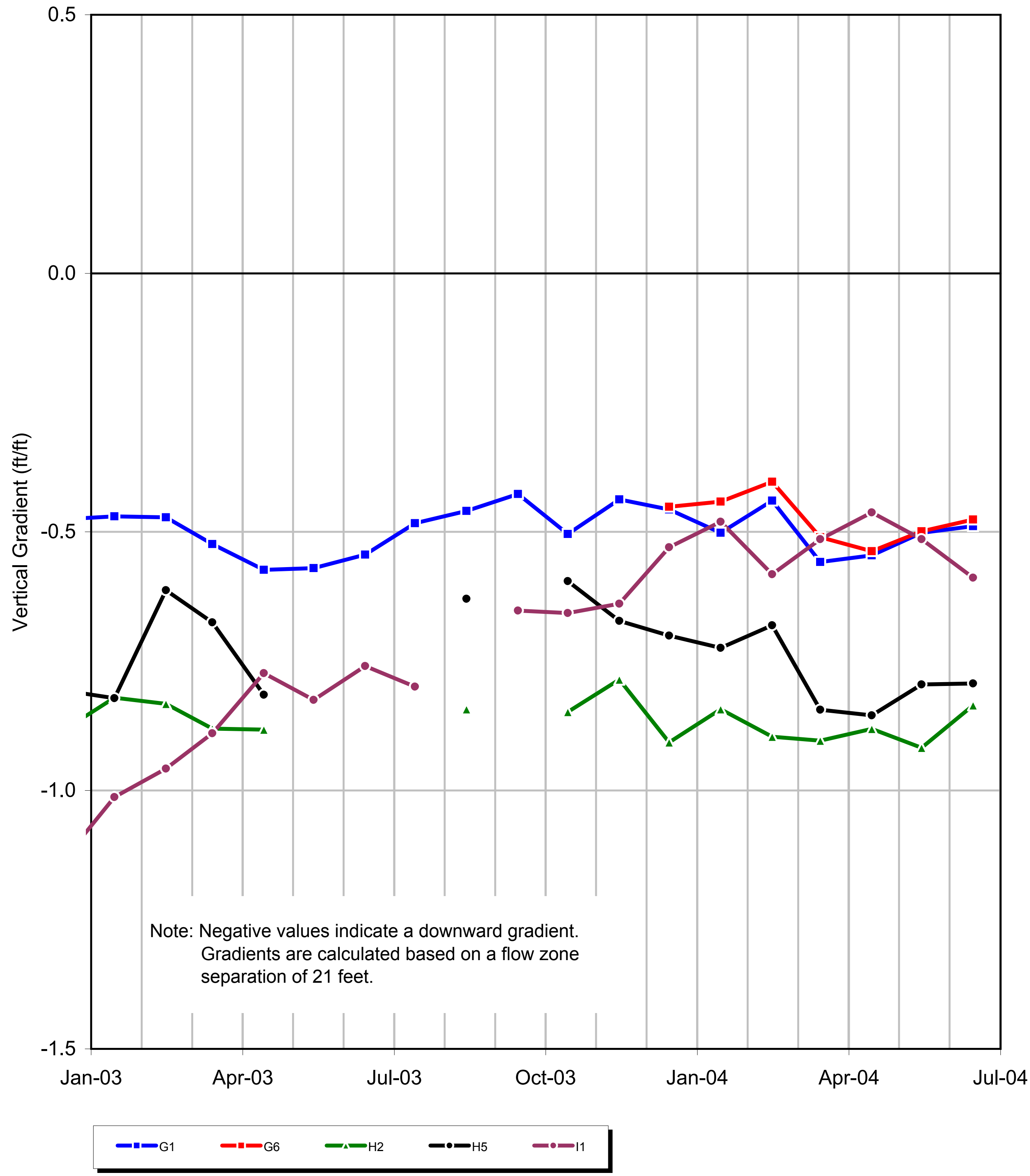



figure E-11
VERTICAL GRADIENTS BETWEEN FZ-01 AND FZ-02
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

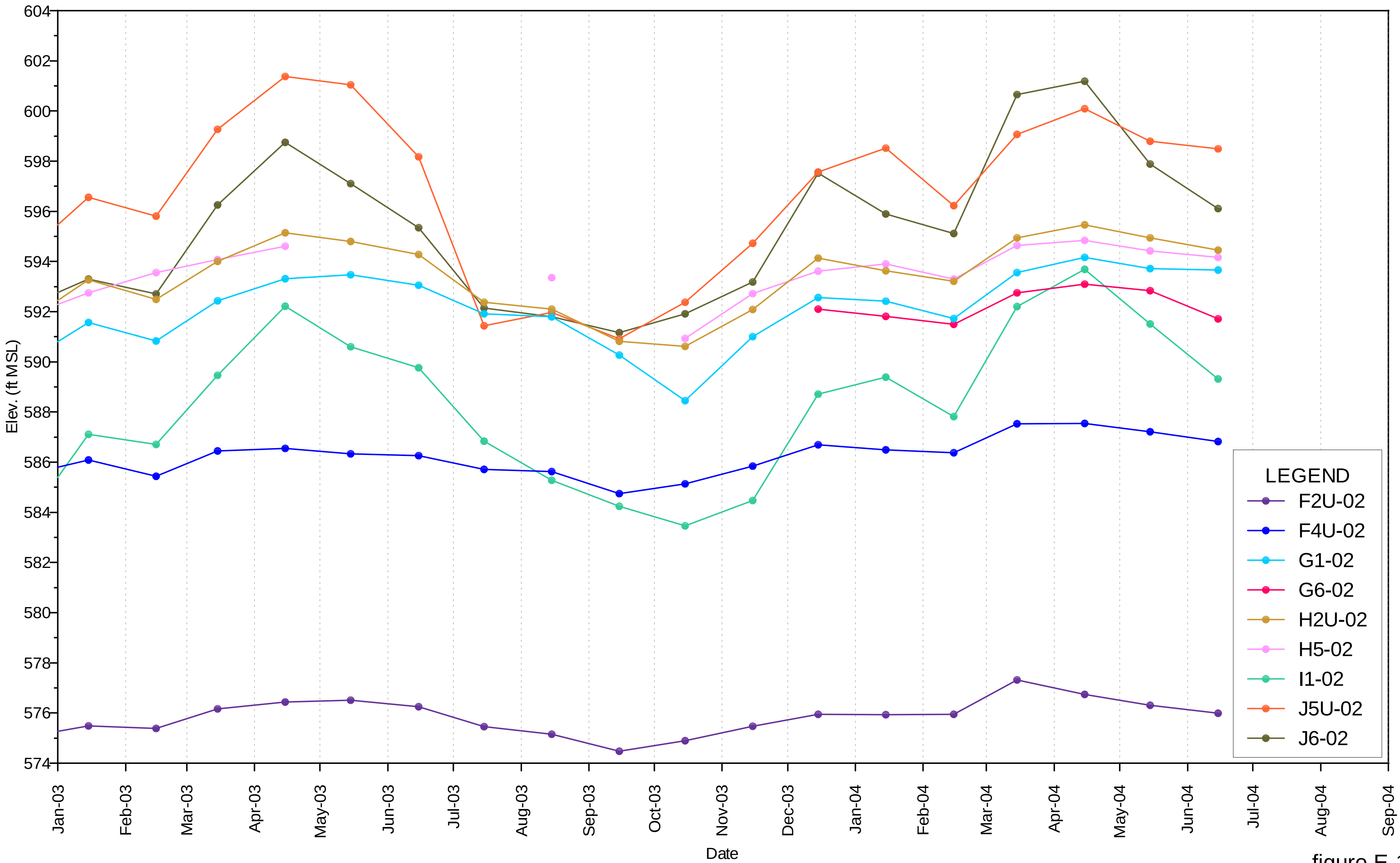



figure E-12
FZ-02 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_12_FZ02_seasonal.grf) AUG 26/2004

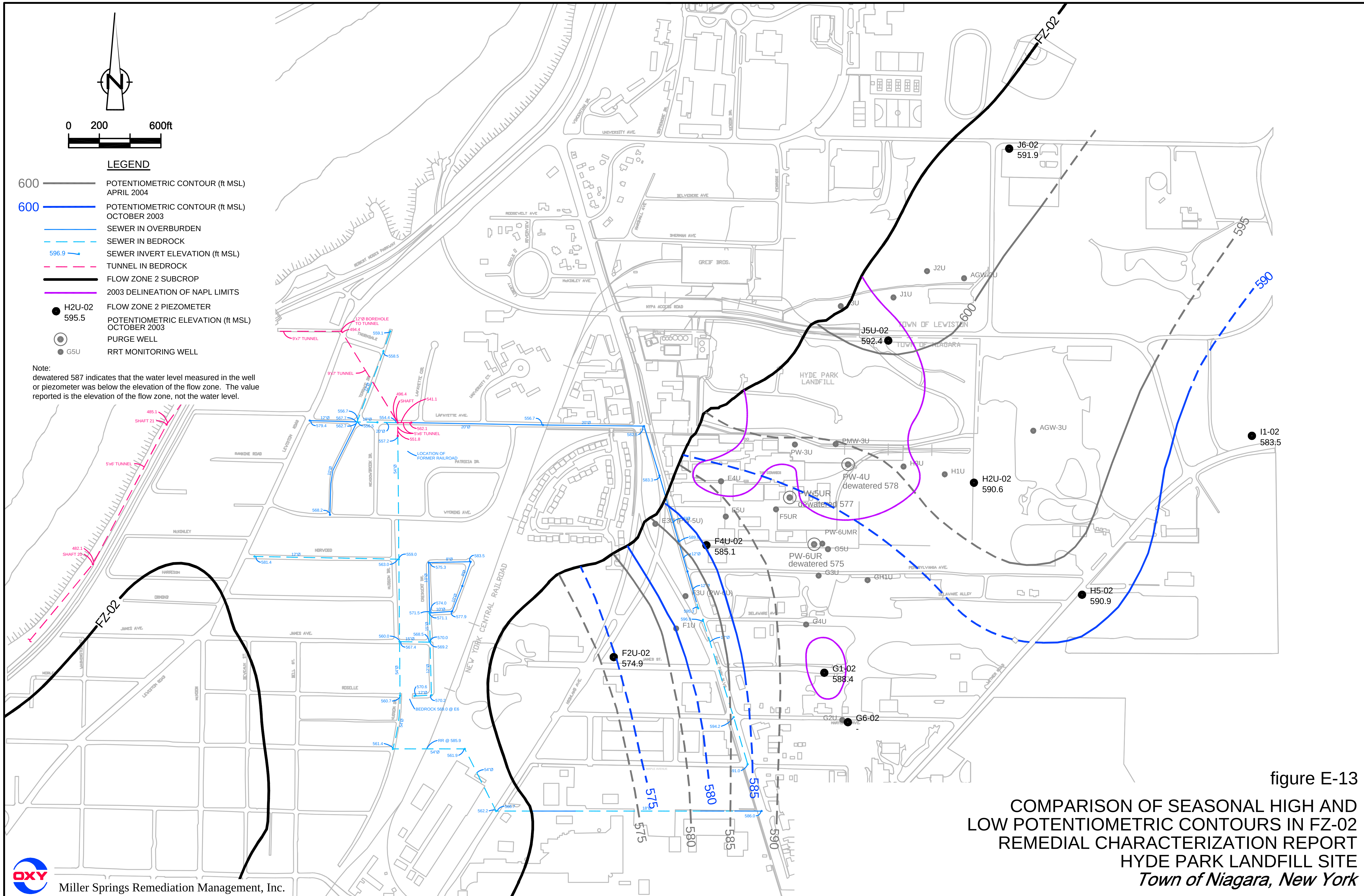



figure E-13

COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-02
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

01069-30(342)GN-WA028 AUG 26/2004

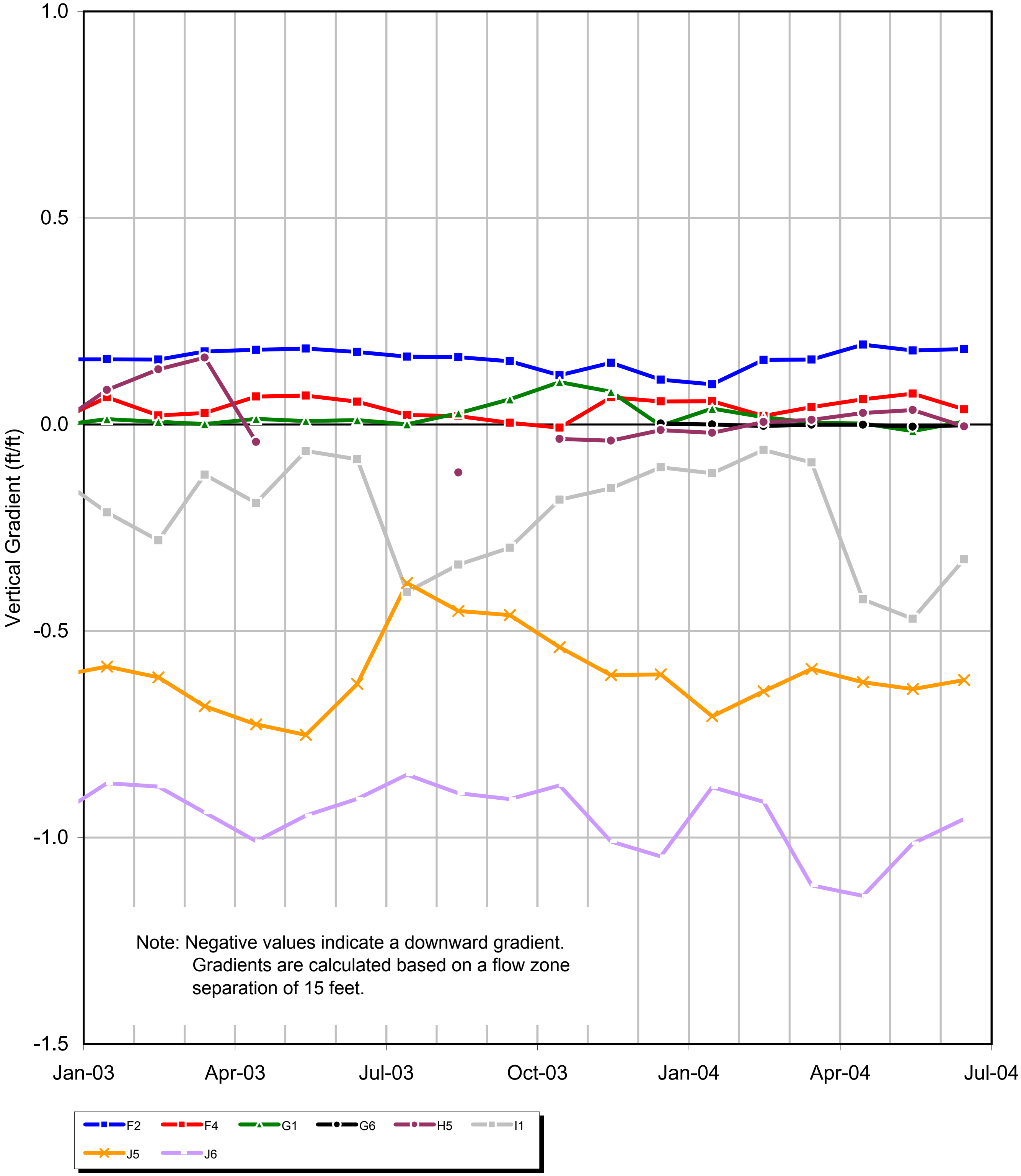



figure E-14
VERTICAL GRADIENTS BETWEEN FZ-02 AND FZ-04
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

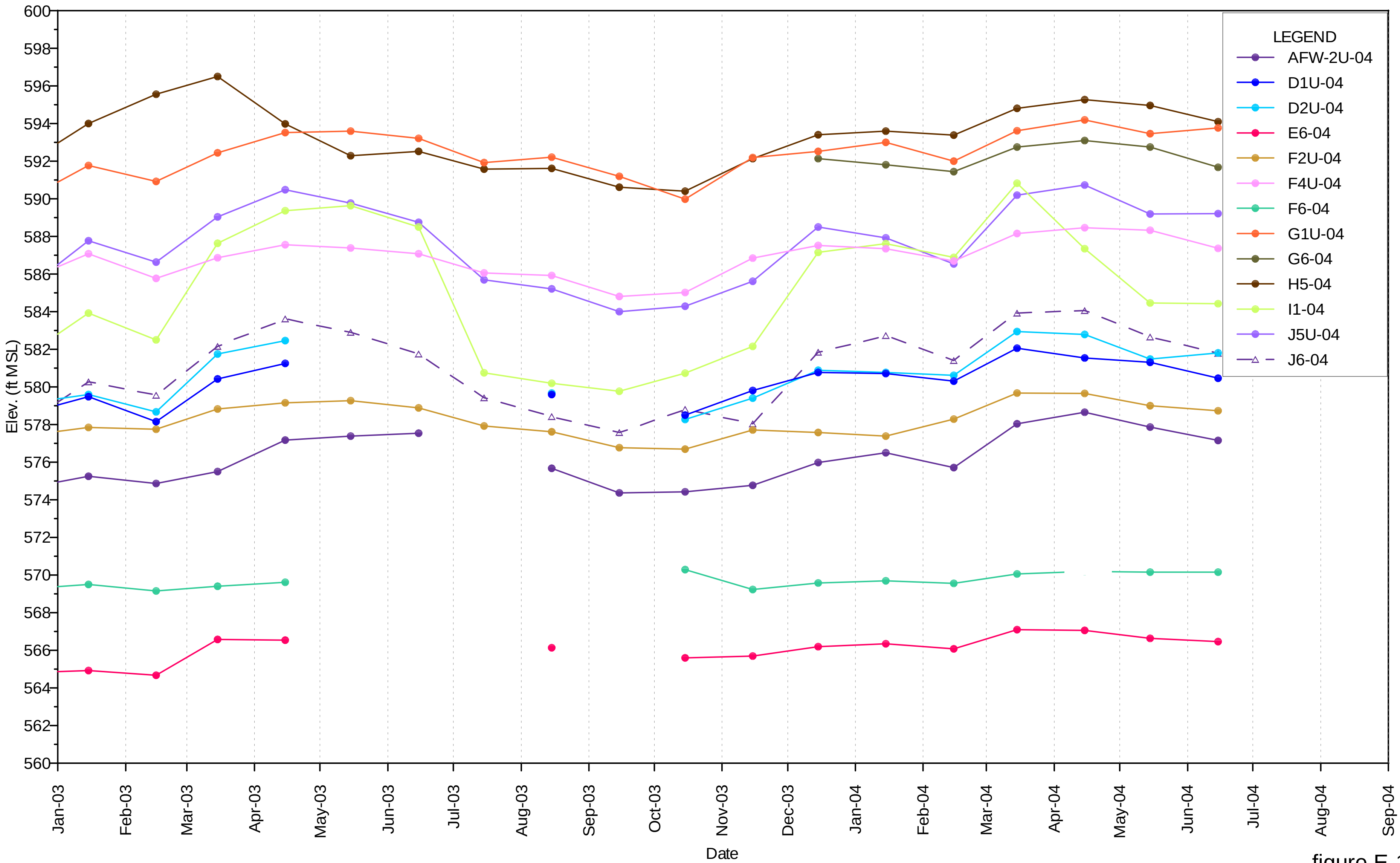



figure E-15
FZ-04 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

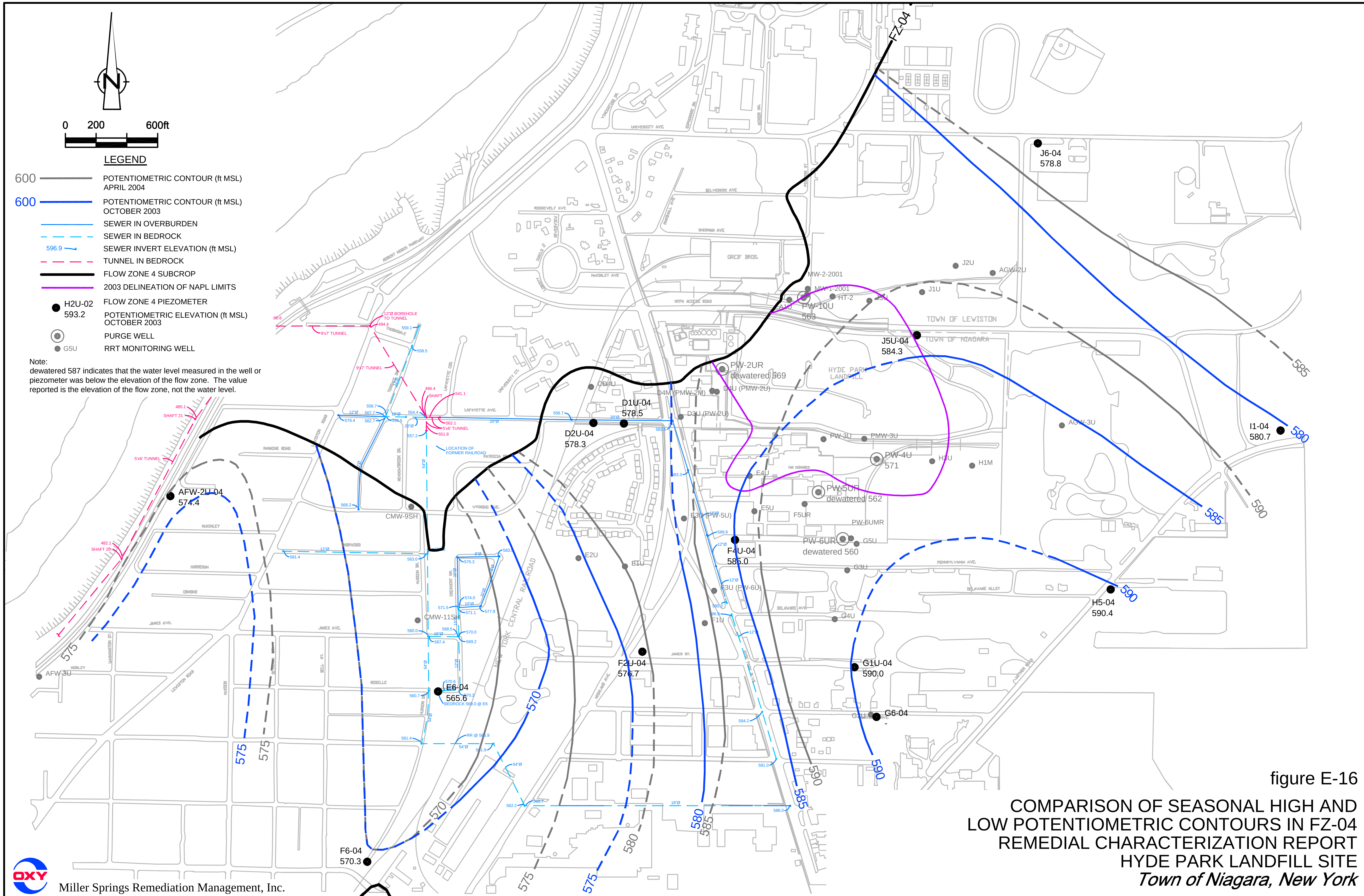



figure E-16

COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-04
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA030 AUG 26/2004

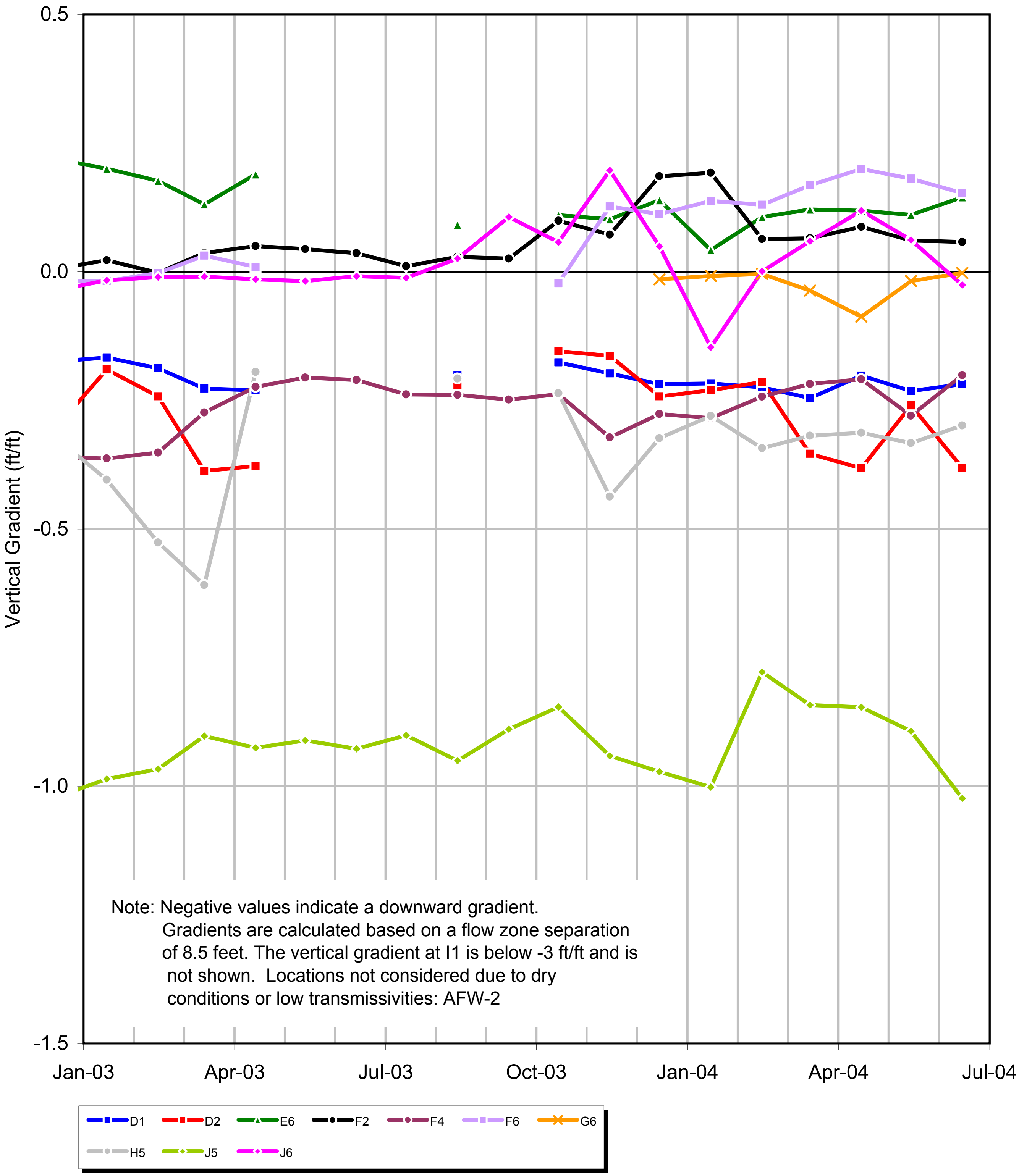



figure E-17

VERTICAL GRADIENTS BETWEEN FZ-04 AND FZ-05

REMEDIAL CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

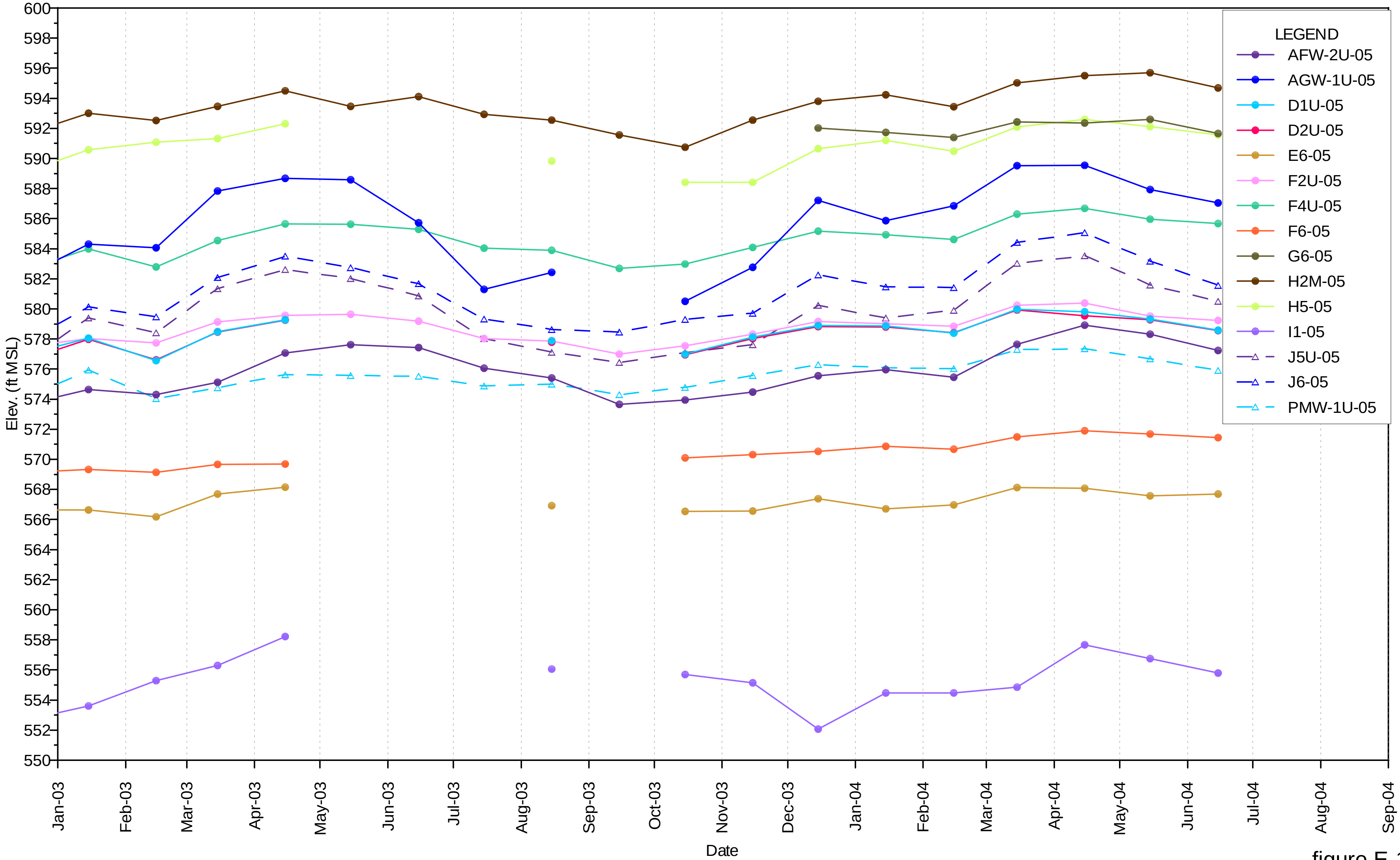



figure E-18
FZ-05 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_18_FZ05_seasonal.grf) AUG 26/2004

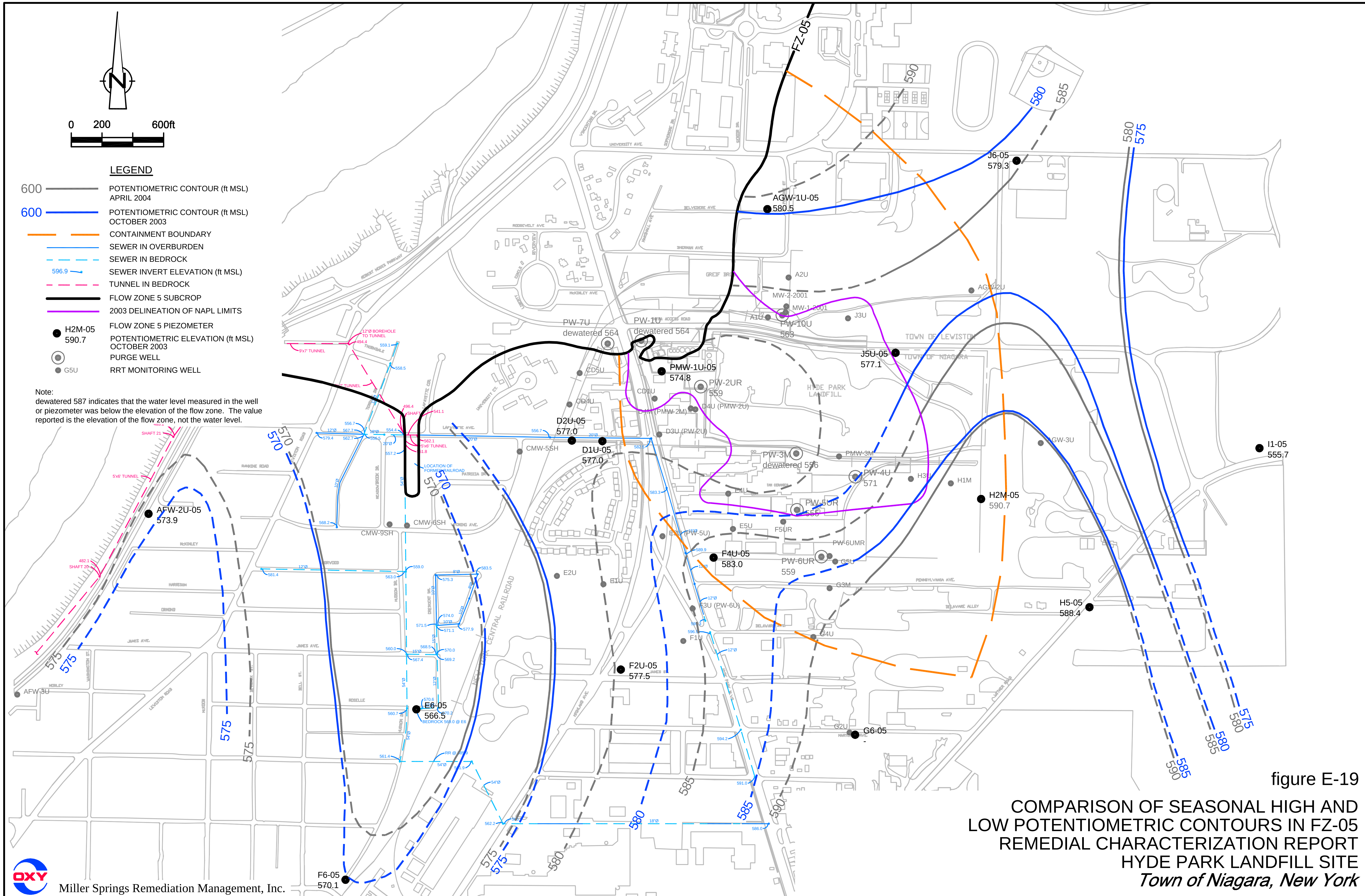



figure E-19

# COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-05
## REMEDIAL CHARACTERIZATION REPORT
## HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA031 AUG 26/2004

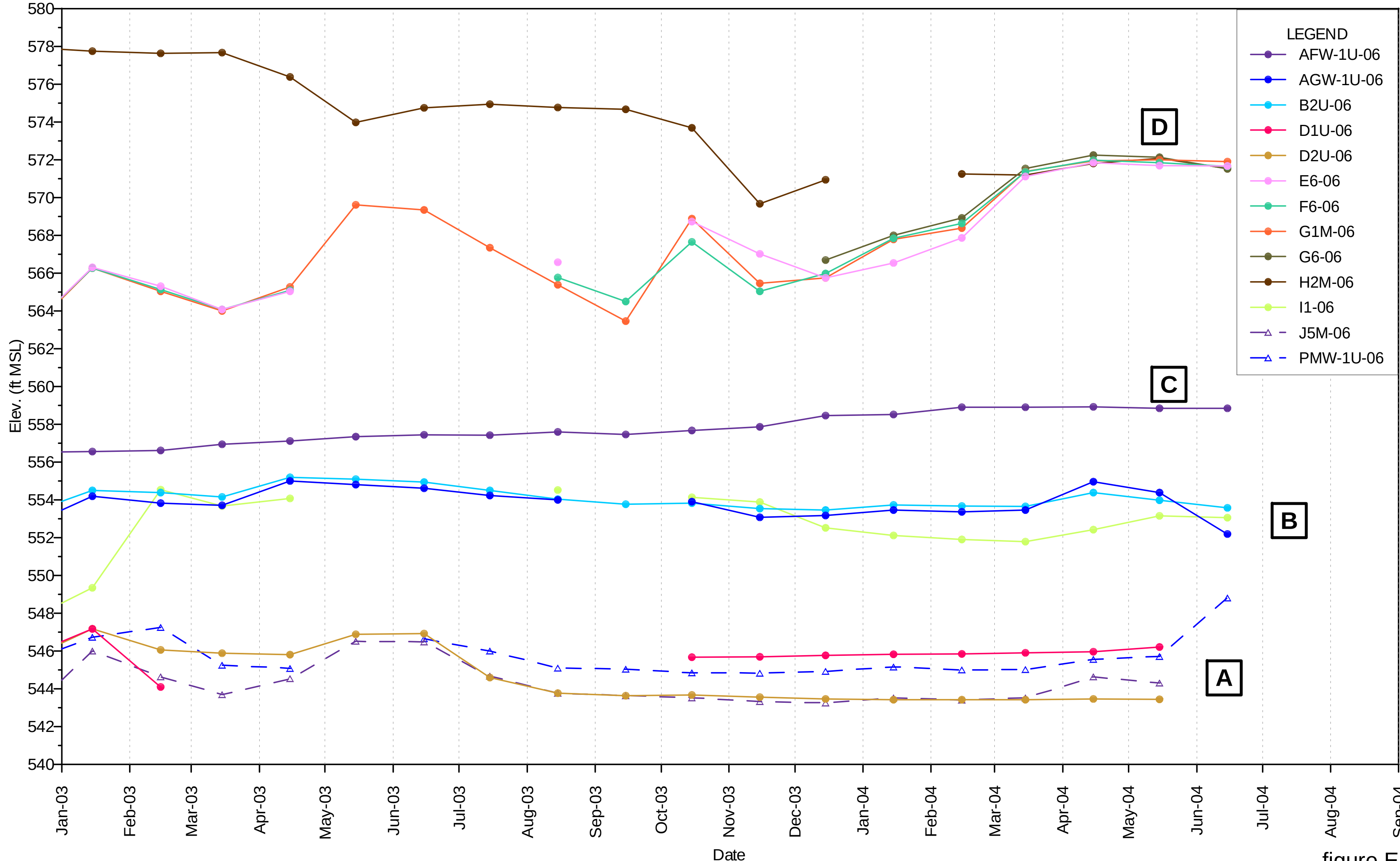



figure E-20
FZ-06 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

NOTE: PIEZOMETER LOCATIONS ABP-7-06, AFW-2U-06, AND C3-06 ARE DRY THROUGHOUT THE MONITORING PERIOD.
PIEZOMETER LOCATIONS F2M-06, F4M-06, H5-06, AND J6-06 ARE EXCLUDED FROM THIS PLOT (SEE TABLE 4-2).

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01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_21_FZ06_seasonal.grf) AUG 26/2004

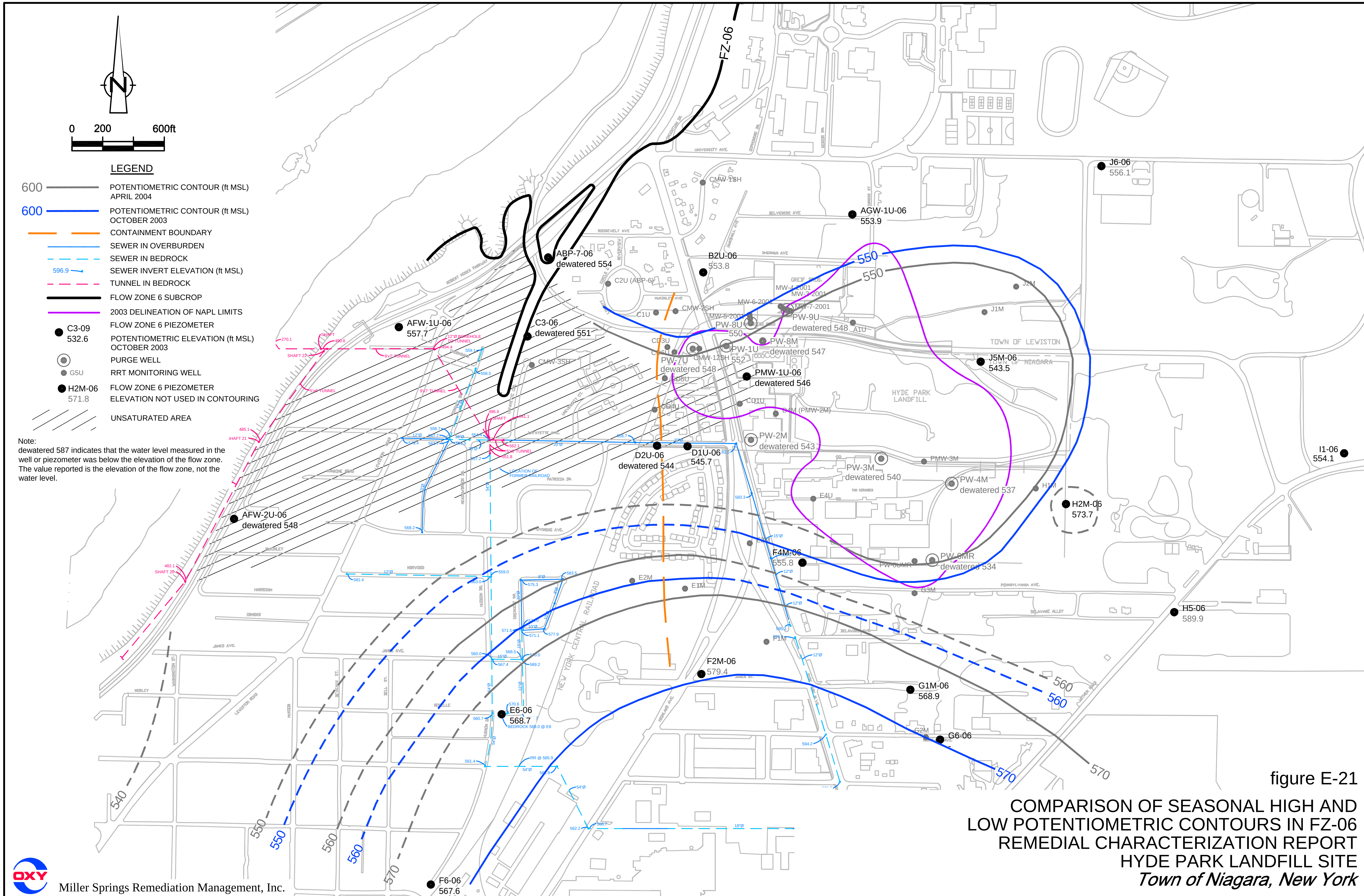



figure E-21

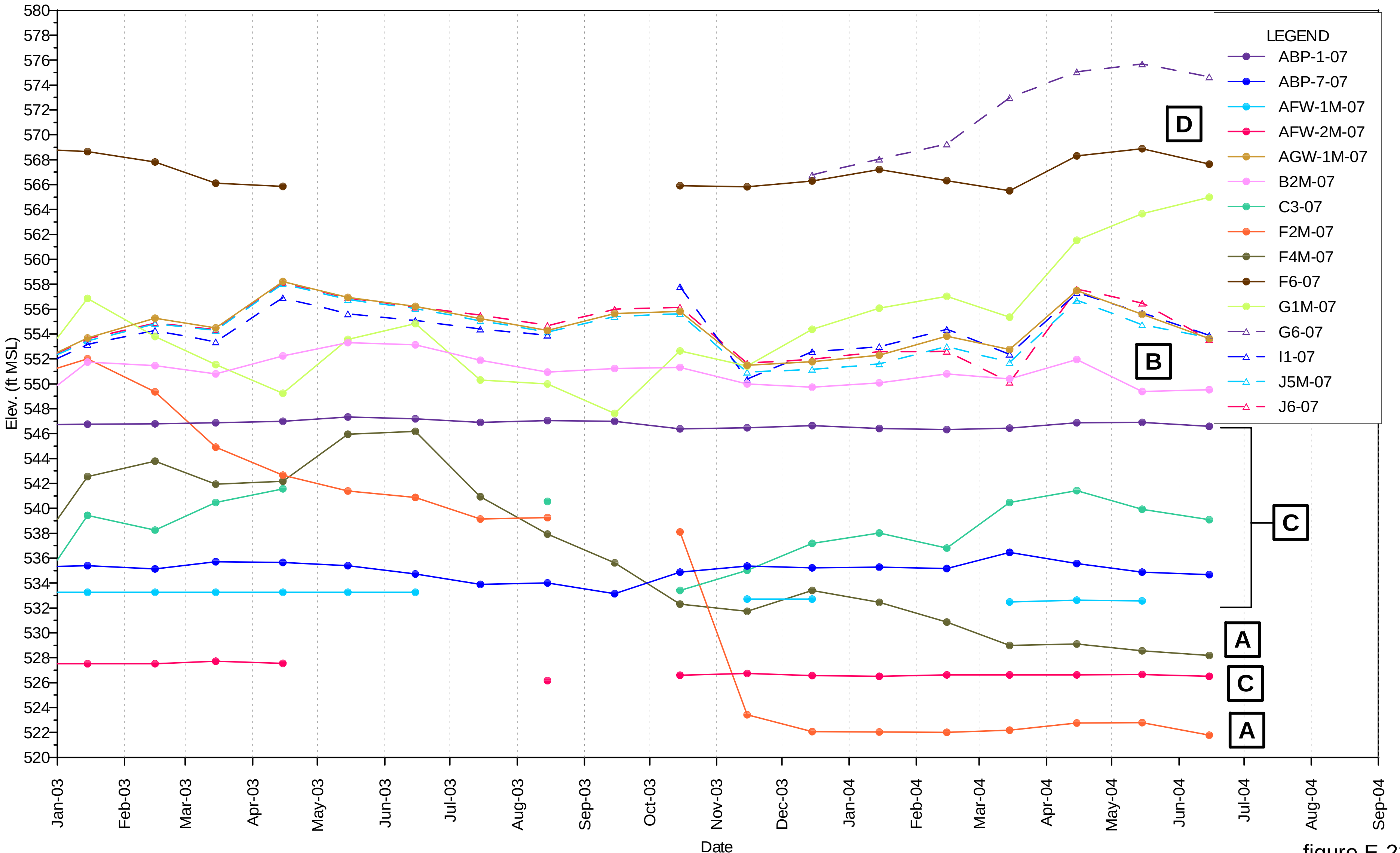
COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-06

REMEDIAL CHARACTERIZATION REPORT

HYDE PARK LANDFILL SITE

*Town of Niagara, New York*

01069-30(342)GN-WA032 AUG 26/2004




NOTE: PIEZOMETER LOCATIONS AFW-1M-07 AND AFW-2M-07 ARE DRY THROUGHOUT THE MONITORING PERIOD.
PIEZOMETER LOCATIONS D1M-07, D2M-07, E6-07, AND PMW-1M-07 ARE EXCLUDED FROM THIS PLOT (SEE TABLE 4-2).

figure E-22
FZ-07 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_23_FZ07_seasonal.grf) AUG 26/2004

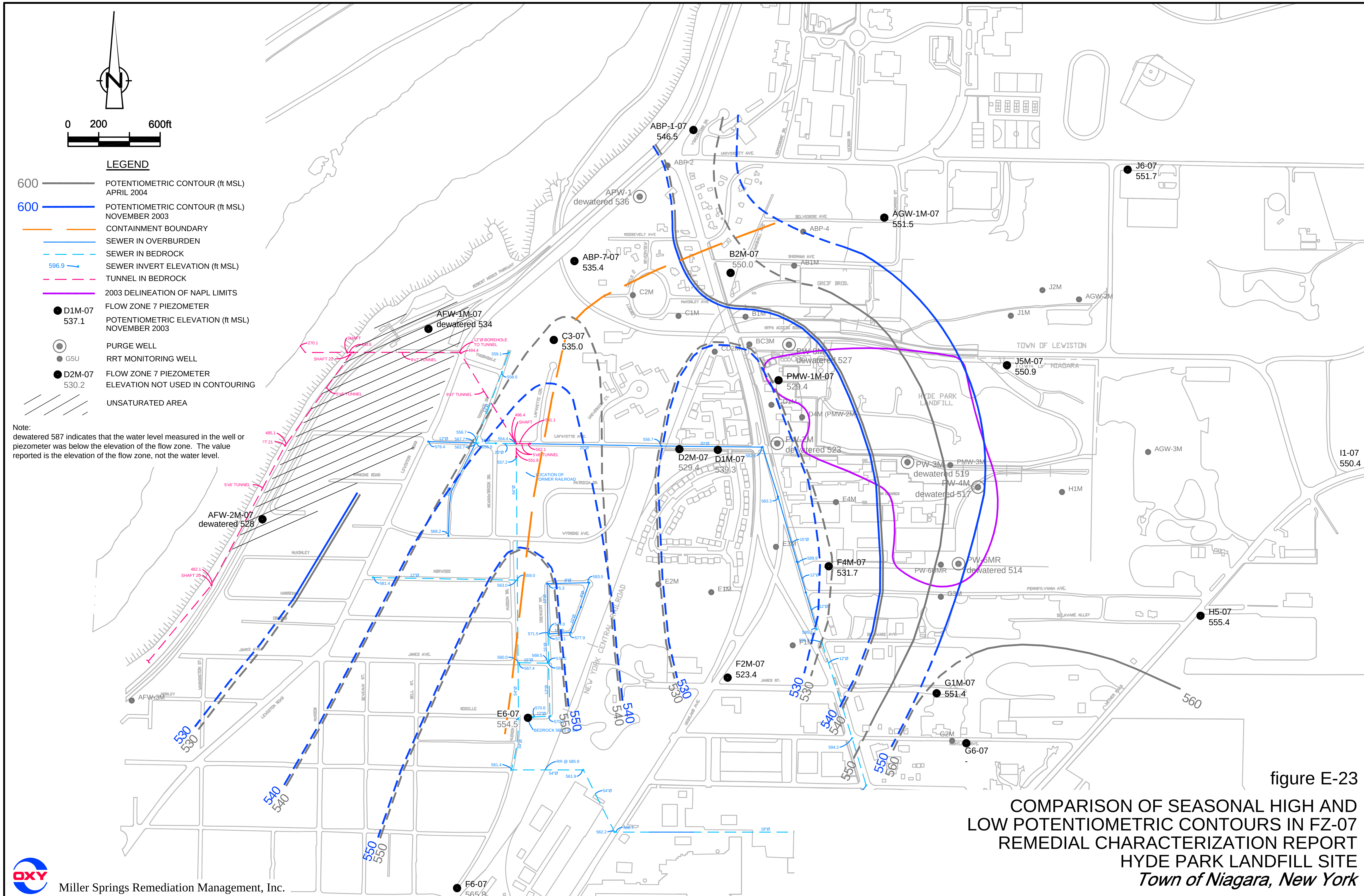
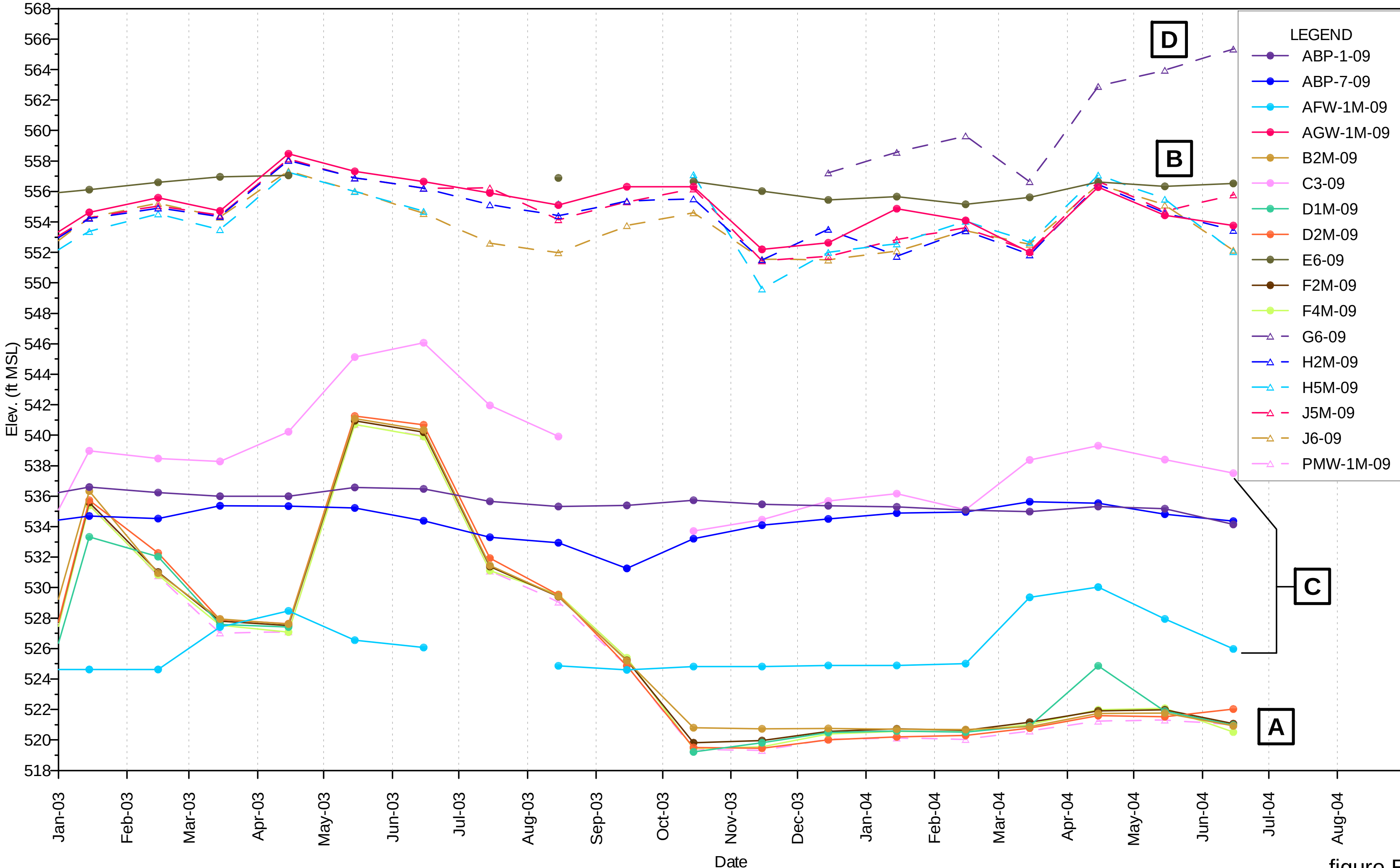



figure E-23

COMPARISON OF SEASONAL HIGH AND LOW POTENTIOMETRIC CONTOURS IN FZ-07
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

01069-30(342)GN-WA033 AUG 26/2004




NOTE: PIEZOMETER LOCATIONS AFW-2M-09, F6-09, G1M-09, AND I1-09 ARE EXCLUDED FROM THIS PLOT (SEE TABLE 4-2).

figure E-24
FZ-09 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

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01069-30(342)GN-WA-HYD (N:\HEG\01069\seasonal_effects\RCR_figures\fA_25_FZ09_seasonal.grf) AUG 26/2004

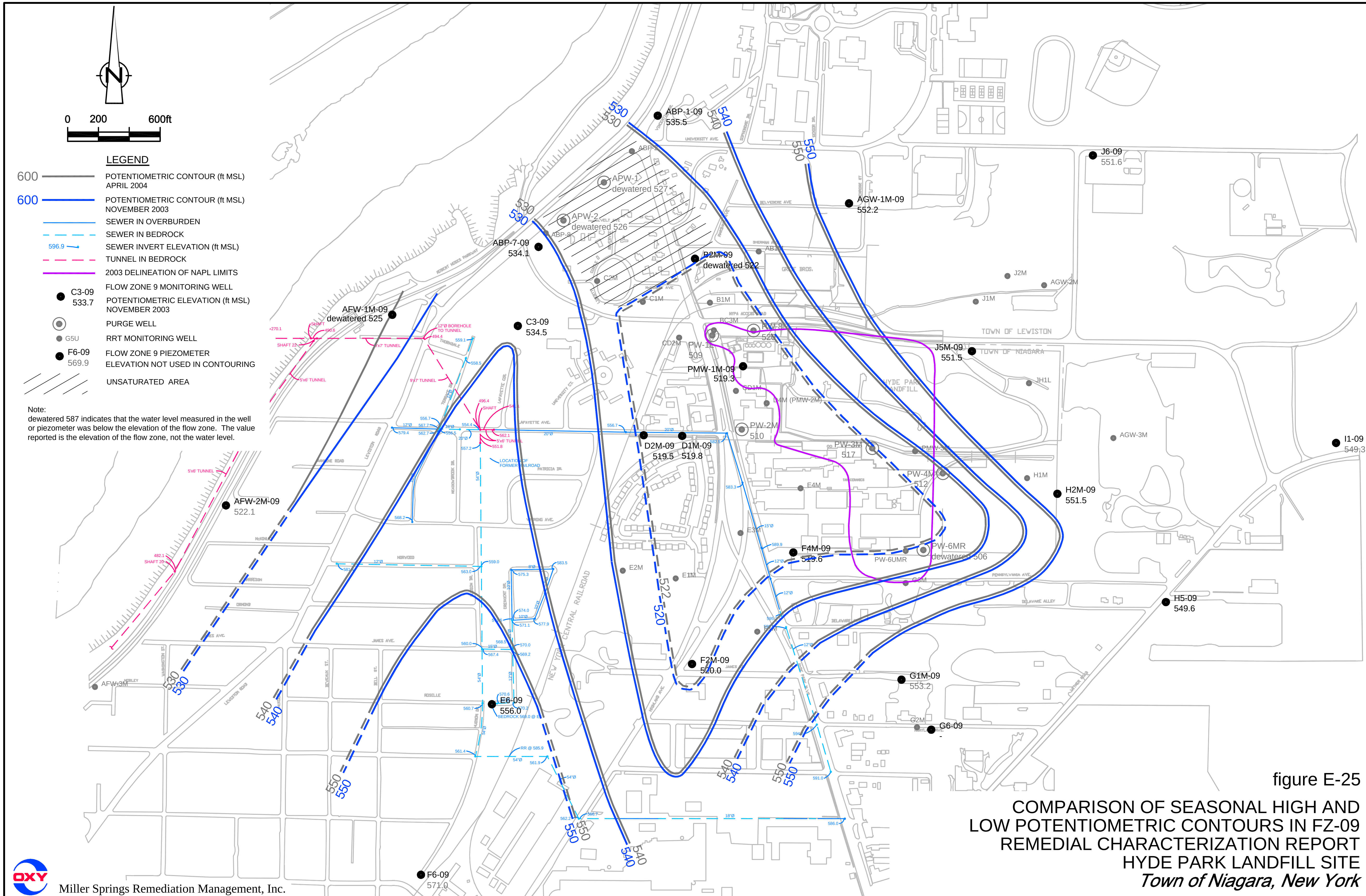
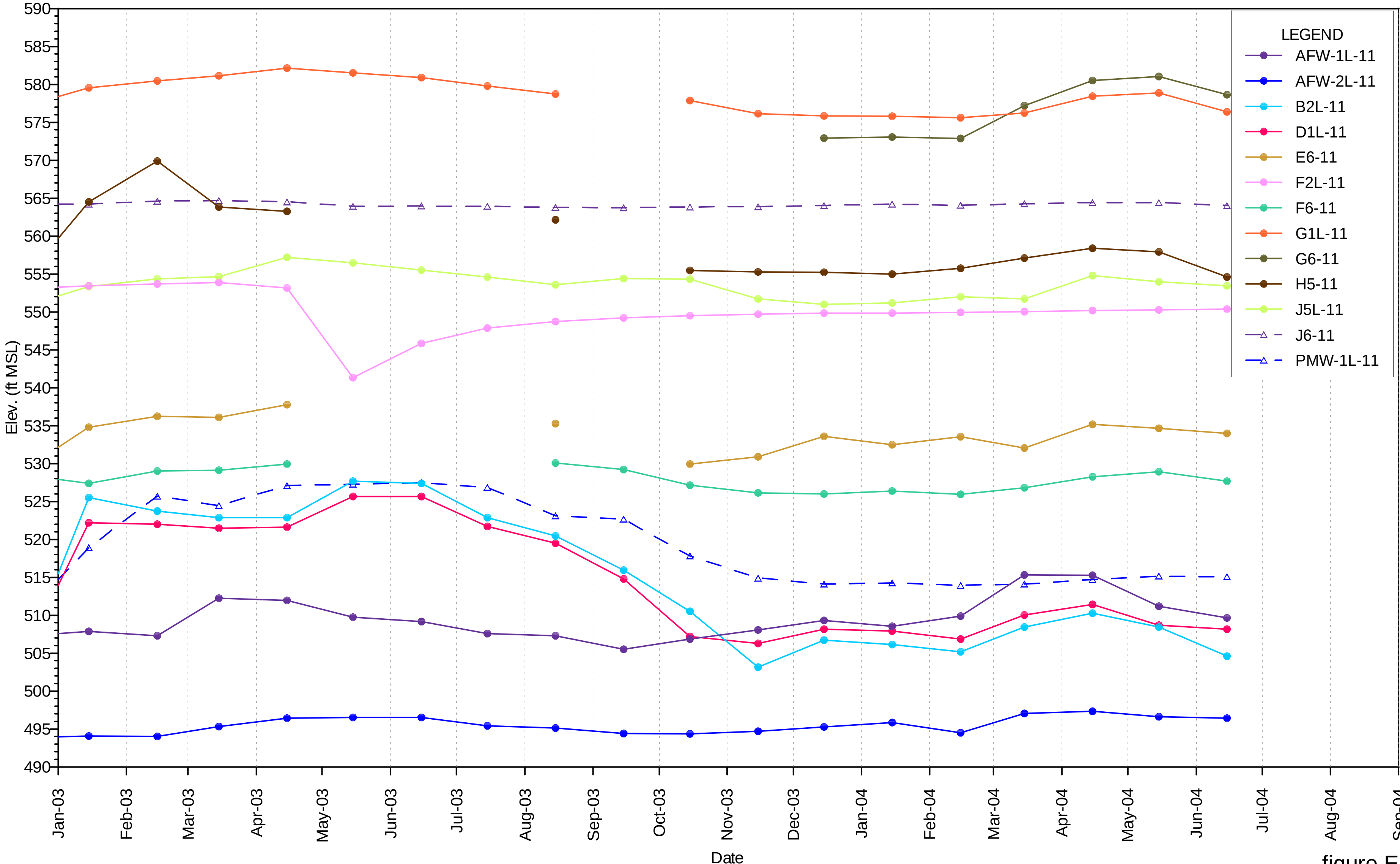



figure E-25

COMPARISON OF SEASONAL HIGH AND
LOW POTENTIOMETRIC CONTOURS IN FZ-09
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA034 AUG 26/2004




NOTE: PIEZOMETER LOCATIONS AGW-1L-11, D2L-11, F4L-11, H2L-11, I1-11 ARE EXCLUDED FROM THIS PLOT (SEE TABLE 4-2).

figure E-26
FZ-11 WATER LEVELS
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE
*Town of Niagara, New York*

OXY Miller Springs Remediation Management, Inc.

01069-30(342)GN-WA-HYD (N:\HEG\01069\piezometer_data\fA_27_FZ11_seasonal.grf) AUG 26/2004

TABLE E-1
ESTIMATION OF EVAPOTRANSPIRATION (THORNTHWAITE)
REMEDIAL CHARACTERIZATION REPORT
HYDE PARK LANDFILL SITE

| (1) Month | (2) Mean Monthly Temperature $T_m$ (°F) | $T_m$ (°C) | (4) Monthly Heat Index $i$ | (5) ET (cm) Unadjusted | (6) Daylight Factor | (7) ET (cm) Adjusted | (8) ET (in) Adjusted |
|---|---|---|---|---|---|---|---|
| Jan-03 | 18.7 | -7.4 | - | 0.00 | 0.82 | 0.00 | 0.00 |
| Feb-03 | 19.7 | -6.8 | - | 0.00 | 0.82 | 0.00 | 0.00 |
| Mar-03 | 32.4 | 0.2 | 0.01 | 0.06 | 1.02 | 0.06 | 0.03 |
| Apr-03 | 42.4 | 5.8 | 1.24 | 2.46 | 1.12 | 2.76 | 1.09 |
| May-03 | 54.9 | 12.7 | 4.11 | 5.98 | 1.26 | 7.56 | 2.98 |
| Jun-03 | 64 | 17.8 | 6.82 | 8.72 | 1.27 | 11.11 | 4.38 |
| Jul-03 | 69.6 | 20.9 | 8.71 | 10.45 | 1.29 | 13.54 | 5.33 |
| Aug-03 | 70.5 | 21.4 | 9.03 | 10.74 | 1.20 | 12.87 | 5.07 |
| Sep-03 | 62.4 | 16.9 | 6.31 | 8.23 | 1.04 | 8.56 | 3.37 |
| Oct-03 | 48.2 | 9.0 | 2.43 | 4.05 | 0.95 | 3.84 | 1.51 |
| Nov-03 | 42.2 | 5.7 | 1.21 | 2.40 | 0.81 | 1.94 | 0.76 |
| Dec-03 | 32.7 | 0.4 | 0.02 | 0.12 | 0.77 | 0.09 | 0.04 |

$$I = \sum_{m=1}^{12} i = 39.91$$

a= 1.1265

Notes: (2): Mean temperature data for Niagara Falls International Airport.

(4)
$$i = \left(\frac{T_m}{5}\right)^{1.514}$$

(5):
$$ET_{month} = 1.62\left(\frac{10T_m}{I}\right)^a$$
where
$$a = 675\times10^{-9} I^3 - 771\times10^{-7} I^2 + 179\times10^{-4} I + 492\times10^{-3}$$

(6) Daylight Factor is based on a Site northern latitude of 43°07'.

(7) Adjusted ET = Unadjusted ET * Daylight Factor