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UMTRA Ground Water Project

Tuba City UMTRA Project Site Semi-Annual Performance Evaluation through August 2002

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1.0 Introduction

Ground water at the Tuba City, Arizona, Uranium Mill Tailings Remedial Action (UMTRA) Project site has been contaminated as a result of uranium milling activities that took place between 1956 and 1966. The Tuba City site is located on Navajo Nation land in northeast Arizona (Figure 1). The aquifer underlying the site is referred to as the N-Aquifer (Cooley et al. 1969; Eychaner 1983), which consists of, in descending order, the Navajo Sandstone, the Kayenta Formation, and the Moenave Formation (Cooley et al. 1969). In the study area, a transitional unit referred to as the intertonguing interval lies between the classic Navajo Sandstone and the Kayenta Formation (Middleton and Blakey 1983; DOE 1998). Shallow, unsaturated materials overlie the Navajo Sandstone in the vicinity of the Tuba City site; these consist mostly of loose, fine-grained eolian sands in the uppermost 10 to 20 feet (ft) below ground surface (bgs), which are underlain by alluvial sediments, mostly in the form of sand and gravel with scattered pockets of clay. Under natural conditions, depth to the top of the saturated zone at the site (in the Navajo Sandstone) is approximately 35 to 50 ft.

Mill site-related ground water contaminants of potential concern (COPC) at the Tuba City site include nitrate, molybdenum, uranium, sulfate, strontium, selenium, and cadmium. With the exceptions of sulfate and strontium, environmental standards in the form of maximum concentration limits (MCL) apply to these constituents. The Navajo Nation proposed a secondary cleanup level for sulfate of 250 milligrams per liter (mg/L) (DOE 1998). Though cleanup to this level is not a requirement, the DOE considers the proposed secondary standard to be a target for restoration of the aquifer, and will try to meet this level to the extent practicable.

As part of the effort to restore local ground water quality, a remedial system consisting of extraction wells, a distillation unit (for water treatment), and an infiltration trench, is in operation. These features are placed at various locations surrounding the mill tailings disposal cell at the site (Figure 2). Several injection wells and monitor wells are also located at the site. To date, the injection wells have not yet been used.

This study is the first of a series of semi-annual evaluations of the performance of the Tuba City site remedial system. The evaluation is based on a comparison of site conditions in August 2002 with baseline conditions, which are defined by data collected between 1999 and February 2002, before startup of the remedial system (DOE 2003). Because this study is the first of many, results and conclusions presented herein should be considered with the understanding that it is too early in the evaluation process to discern distinct temporal trends or the long-term effectiveness of remedial efforts. Nevertheless, the evaluation shows that initial remedial efforts are removing ground water contamination from beneath the site and potentially preventing further vertical migration of contaminants.

Because the remedial system had only been in operation for about six months prior to this evaluation, the focus is on the hydraulic aspects of the ground water extraction system rather than the geochemical nature of COPCs in the subsurface, the water treatment system, or the effluent from the treatment system. The effects of ground water pumping tend to be manifested relatively quickly in well water levels and extraction well capture zones. In contrast, significant influences of ground water extraction on measured levels of dissolved contaminants tends to take longer. In the following paragraphs, emphasis is placed on measured hydraulic heads and hydraulic gradients in the ground water system in response to pumping. Accordingly, recommendations for future work focus on ways to improve the ground water extraction system.

Future evaluations will include progressively more detail on assessments of contaminant migration and fate in ground water, design and operation of the water treatment system, and possibly the geochemistry of treatment system effluent returned to the subsurface.

The performance evaluation report is organized as follows. Section 2 describes vertical horizons that have been defined in the N-Aquifer below the site to facilitate descriptions of ground water movement and contaminant plume behavior. Section 3 discusses issues regarding deep monitor wells at the Tuba City site and the data collected from them. Section 4 compares baseline and August 2002 ground water conditions at the site, including horizontal and vertical gradients, and plume geometries. Section 5 discusses extraction system performance relative to system design criteria, and Section 6 summarizes treatment system performance. Section 7 summarizes the performance of the extraction/injection well field and treatment system and Section 8 comprises recommendations for future work.

2.0 Aquifer Horizons

Under pre-remediation conditions, depth to the top of the saturated zone at the Tuba City UMTRA Project site is about 35 to 50 ft. To assess system performance with regard to ground water conditions, the saturated portion of the aquifer (N-Aquifer) beneath the Tuba City site has been vertically discretized into 50-ft intervals, each of which is identified by its approximate bottom and top elevations (Table 1). To simplify discussion, each 50-ft horizon is given a letter designation, starting with the 5,000 to 5,050-ft elevation interval (Horizon A) and ending with the 4,400–4,450-ft elevation interval (Horizon M).

Although not perfectly correlated, Horizons A through C tend to represent conditions in the classic Navajo Sandstone, Horizons D through J represent the intertonguing interval, and Horizons K through M represent the Kayenta Formation. Each well at the site has been assigned to a horizon on the basis of elevation at the midpoint of its well screen (Table 2). Horizontal and vertical hydraulic gradients and contaminant distribution have been analyzed for each horizon where data are available.

3.0 Deep Monitor Wells

Since the early stages of the baseline evaluation, “silting” problems have been encountered at four deep monitor wells installed at the Tuba City site. Deep wells in this case refer to cased boreholes that were advanced to total depths of 500 ft or greater bgs. The silting problems, which have been observed at wells 0253, 0254, 0255, and 0257, are manifested in the form of several feet of fine-grained sediment deposited at the base of each well. There are two potential sources for this fine-grained sediment: (1) bentonite material used to construct surface seals in the annulus of each well and (2) silty materials comprising the Kayenta Formation. If the bentonite is the source, it is possible that the annular seals have been compromised, making it possible for contamination in shallower horizons to migrate to deeper formations via the well filter pack and well-bore interior.

Evidence of contamination in the deep wells listed above has been observed. This observation possibly lends credence to the notion of downward contaminant migration in boreholes rather than transport through N-Aquifer material.

Because it is possible that the grout seals on the four deep wells have been compromised, concentration data collected from them are not considered in this performance evaluation. However, hydraulic data gathered at the deep wells are considered useful and are utilized to help assess vertical hydraulic gradients.

One of the four wells affected by silting (well 0253) has been abandoned. The disposition of the three remaining problem wells will be determined in coming months. Ongoing studies are expected to identify which data from deep wells, if any, can be incorporated in future performance evaluations.

4.0 Ground Water Conditions

4.1 Ground Water Gradients

4.1.1 Horizontal Hydraulic Gradients

Baseline and August 2002 horizontal hydraulic gradients and magnitudes, as calculated for the various horizons using three-point analyses, are summarized in Table 3. V3PP, a computer code developed by Laase et al. (2002), has been used to perform the gradient calculations. To assist the analyses, the calculated gradients are graphically portrayed in V3PP using velocity vector plots. Flow arrows produced by the code show flow directions. Absolute magnitudes of the gradients calculated by the code are not visually discernible; however, relative magnitudes are indicated by the lengths of the gradient arrows in each plot.

Computed horizontal hydraulic gradient directions in Horizon A represent the water table at the site (Figure 3). A comparison of the gradients for baseline and August 2002 conditions shows that, since startup of the treatment system in the spring of 2002, horizontal hydraulic gradients have shifted slightly towards the east and increased in magnitude probably in response to recharge from the infiltration trench.

Comparison of baseline and August 2002 horizontal gradients in Horizon B shows the influence of the extraction wells (Figure 4). In this plot, the gradient south of well 0934 has shifted approximately 180° from the baseline gradient direction, and now points northward, in the direction of nearby extraction wells. The extent of influence of the extraction well field, as depicted by the three-point analysis, compares favorably with the design capture zone predicted by a site ground water flow model, as shown in Figure 5. The model indicates that capture extends to about 400 − 500 ft east and west of the extraction well field, and about 250 ft south of the southernmost extraction wells.

Figure 4 suggests ground water mounding associated with the infiltration trench, as evidenced by a relatively strong southeastward horizontal hydraulic gradient just south of the trench. Relatively consistent gradient directions and magnitudes south of well 0267, which is located about 1,800 ft south of the southwest corner of the disposal cell, indicate that the extraction system appears to have minimal, if any, effect on gradients in this area.

Computed horizontal gradient directions in Horizon C are illustrated in Figure 6. Inspection of this figure shows that only 2 gradient directions have been determined for Horizon C in

August 2002, whereas 9 directions were previously computed for the baseline conditions. This discrepancy occurs because water-level measurements were not taken in the extraction wells screened in this horizon during the most recent sampling effort (August 2002). Despite the limited analysis of recent hydraulic gradients in Horizon C, Figure 6 at least indicates that the extraction wells have minimal influence on ground water flow in the vicinity of a terrace escarpment that traverses the site in a southwesterly direction about 500 to 1,500 ft south of the extraction well field.

Because extraction well water levels would be helpful in assessing general ground water gradients in Horizon C as well as other horizons, monitoring at the Tuba City site now includes the measurement of hydraulic heads in extraction wells while they are pumped. In addition, the pumping rates from individual extraction wells are also being recorded. The combination of measured heads and pumping rates will not only help estimate the general magnitude of hydraulic gradients in the vicinity of the extraction well field, but will also provide better indication of the horizons providing the most water and, accordingly, the greatest amount of contaminant mass to the treatment system.

Water levels were not measured in August 2002 in the extraction wells screened in Horizon D. Consequently, fewer velocity vectors are computed for this horizon than were determined under the baseline evaluation (Figure 7). Nonetheless, the August 2002 horizontal hydraulic gradients show that the extraction wells have minimal to no influence on ground water flow south of the previously mentioned escarpment. As in the case of Horizon C, considerable benefit is expected from the collection of water level and pumping rate information from extraction wells screened over the full thickness of Horizon D.

Figure 8 presents a single horizontal hydraulic gradient calculated for August 2002 conditions in Horizon E, utilizing hydraulic head data from the same three monitor points applied under the baseline evaluation. Though the more recent gradient direction is virtually identical to the baseline direction, the magnitude of the recent velocity vector is smaller than the baseline magnitude. This observation suggests that, while the extraction wells may have minimal effect on ground water flow direction south of the capture zone created by the extraction wells, pumping might reduce the speed with which contaminants in this area migrate away from the site.

Figures 9 and 10, which contain velocity vector plots for Horizons G and I, respectively, show virtually no change in horizontal gradients between baseline and August 2002 conditions. This suggests that the extraction wells exert no noticeable influence on horizontal hydraulic gradients in these deeper horizons. A likely explanation for this observation is that none of the screened intervals in the extraction wells extends into Horizons G or I. In fact, the deepest screened interval in the extraction wells is Horizon E (DOE 2003).

4.1.2 Vertical Hydraulic Gradients

Table 4 presents a comparison of baseline and August 2002 vertical hydraulic gradients between adjacent horizons. In Horizons A through C, located above Horizon D where the majority of the extraction well screens are centered, August 2002 vertical hydraulic gradients are strongly downward. A large downward gradient is also observed in August 2002 between Horizons C and D at well pair 0914−0915. This latter observation contrasts with an upward gradient measured in the 0914−0915 well pair under baseline conditions (DOE 2003). The reversal in vertical gradient at this location is presumably due to pumping from Horizon D. Well pair 0691−1003 shows an upward vertical hydraulic gradient in August 2002. This latter result is not surprising given that this well pair is located in an apparent ground water discharge area associated with a greasewood grove just down-slope from the escarpment south of the disposal cell (DOE 2003). In the baseline evaluation, three well pairs in the vicinity of, and just up-slope of, the greasewood area exhibited upward vertical gradients, all of which were apparently due to ground water discharge to the ground surface in these locales.

The August 2002 vertical hydraulic gradient between the E and I horizons is strongly upward, which differs from the downward gradient observed under baseline conditions (Table 4). The reversal in the vertical gradient direction between the two horizons suggests that operation of the extraction system is preventing further downward contaminant migration.

Vertical hydraulic gradients between Horizons I and M in August 2002 are either downward or neutral; all of the vertical gradients measured between these two horizons under baseline conditions were downward (Table 4). These observations suggest that these horizons are below the influence of the extraction wells.

4.2 Water Table

The top of the saturated zone at the Tuba City site drops several tens of feet between the north end of the disposal cell and the escarpment south of the disposal cell. Consequently, maps of the estimated water table at the Tuba City site must be developed using measured water levels in Horizons A through C. The estimated water table associated with baseline conditions is shown Figure 11a; the corresponding figure for conditions in August 2002 is presented in Figure 11b. Though both figures indicate generally southward flow, significant differences exist between them. Under baseline conditions, the water table gradient is directed mostly toward the south-southeast and its magnitude, except near the escarpment where upward gradients toward the greasewood area occur, is relatively constant. In contrast, August 2002 conditions (Figure 11b) show a significant mound trending east-northeast along the north edge of the disposal cell. This mound corresponds to the previously mentioned increase in Horizon B gradients in the vicinity of the infiltration trench, and is caused by infiltration of treatment system effluent placed in the trench. The mound is not symmetrical about the infiltration trench. Rather it is restricted to the west side of the infiltration trench. This occurs either because (a) most infiltration of treatment effluent occurs on the west end of the trench and is relatively insignificant in other portions of the trench or (b) the resistance to vertical flow in Horizon A is larger below the western part of the trench.

Comparison of Figures 11a and 11b reveals that operation of the extraction wells has produced a decline in the water table near the southwest corner of the disposal cell. This results in the northern migration of the 5,000-ft elevation water table contour relative to ambient conditions. Though extraction wells are also located along the eastern portion of the site (Figure 2), the water table surface shown in Figure 11b does not appear to be affected by them. This apparent lack of effect may be due to a paucity of water table observation wells in the eastern portion of the site. Alternatively, it is possible that less water was being pumped from the extraction wells in this area during the first six months of remedial system operation than was pumped from wells near the southwest corner of the disposal cell.

4.3 Contaminant Distributions

Plume maps showing the distribution of dissolved nitrate in Horizon A during baseline conditions and August 2002, respectively, are shown in Figures 12a and 12b. Similar comparisons are provided for nitrate in Horizons B through E in Figures 13 through 16. Analogous plume maps for sulfate, uranium, selenium, and strontium contamination in Horizons A through E are given in Figures 17 through 35. Other contaminants, such as molybdenum and cadmium, have been detected in ground water, but the detections are sporadic and provide insufficient data points to construct meaningful plume maps.

Tables 5 through 9 present the contaminant concentration data used to construct the plume maps. Water quality data from spring 2002 were primarily used to construct the baseline condition maps; however, 1999–2001 contaminant data were used to augment the baseline data sets in instances where spring 2002 data were absent.

The plume concentration maps indicate that there are generally minimal differences between baseline and August 2002 conditions in Horizons A, B, and C for all constituents evaluated. The most notable differences between baseline and August 2002 conditions occur in the form of concentration decreases in Horizon A in the vicinity of the infiltration trench (Figures 12a, 12b, 17a, 17b, 22a, 22b, 27a, 27b, 31a, and 31b). This observation, made specifically at wells 0686 and 0687, is presumably the result of dilution by inflow of treated water placed in the trench. Though it is possible that related dilution effects occur in Horizons B and C as well, a lack of monitor wells in these horizons near the infiltration trench makes it difficult to discern such effects.

In contrast to Horizons A through C, constituent concentrations and plume geometries in Horizons D and E appear to change more dramatically between baseline and August 2002 conditions. This is particularly true at the extraction wells in Horizon D, where nitrate and sulfate concentrations have been reduced by factors of up to 4 to 5 (Figures 15a, 15b, 20a, and 20b). In Horizon E, concentrations have declined to the extent that nitrate and uranium concentrations at this depth are now below MCLs for these constituents.

While the general decreases in Horizon D constituent concentrations between baseline and August 2002 conditions are encouraging, it is important to note that some uranium concentrations in this horizon have increased since the baseline evaluation (Figures 25a and 25b). These increases are most pronounced at extraction wells 1105, 1106, and 1120. One possible explanation for these observations is that pumping in the extraction well field has drawn uranium contamination from underneath the disposal cell that has heretofore gone undetected.

An additional factor should be taken into account when considering apparent declines in Horizon D contaminant concentrations since the baseline evaluation. In particular, the pumping rates used to collect samples during pre-pumping periods were smaller than the rates currently used to extract water for treatment. Though it is difficult to discern exactly how the change in pumping rates affects measured contaminant levels, the potential for dilution to be enhanced during the pumping of extraction wells for treatment cannot be discounted. Measured concentrations during subsequent semi-annual performance evaluations, wherein pumping rates are expected to be similar to those occurring in August 2002, should help to identify whether the observed contaminant level declines in Horizon D are the result of increased pumping or are indicative of persistent contaminant attenuation.

Commonly observed transport phenomena in ground water media can be used to further elucidate the potential effects of increased pumping on observed contaminant levels. Under ambient, pre-pumping conditions, ground water in the vicinity of the extraction wells, from which most Horizon D samples are collected, moved much slower than has occurred since pumping of all extraction wells began. Because of the slow velocities, contaminant concentrations in the more permeable portions of the aquifer (such as in fracture zones) had time to achieve equilibrium with contaminant levels in the less permeable portions (such as aquifer matrix material). However, this equilibrium may not exist under the faster flow regime associated with pumping, making it possible for pumped ground water to be replaced with less contaminated water rather than more contaminated water in less permeable zones. As a consequence, measured concentrations can be biased towards the lower contaminant levels occurring in the more permeable zones. Accordingly, it is possible that contaminant concentrations will rebound when the extraction well pumps are turned off and ambient ground water velocities return. Recent field analytical data obtained after the treatment system had been shut down for one week indicated that this had been occurring. The potential for such rebound may be even more evident under future performance evaluations.

Regardless of the factors potentially influencing contaminant level changes in Horizon D, August 2002 data clearly indicate that this horizon is most heavily affected by pumping from the extraction wells. This result is somewhat expected because screened intervals at many of the pumping wells include Horizon D (Table 10). This topic is discussed further in the following section regarding extraction system design.

5.0 Extraction System Design

As currently operated, the Tuba City site remedial system consists of 25 extraction wells, a water-treatment distillation unit, and an infiltration trench (Figure 2). The extraction wells are in areas of greatest contaminant mass, both horizontally and vertically. The average total discharge rate from the extraction well field between April 2002 and December 2002 was 84 gallons per minute (gpm); this translates into a cumulative pumped volume of about 100 acre-feet. This rate is somewhat less than the design rate for the well field of 100-120 gpm. The pumping rate from the extraction well field was not constant and fluctuated between 0 and 120 gpm between April and December 2002 (Figure 36). These fluctuations were attributed to down-periods for the treatment system, and, consequently, bear no reflection on the capacity of the wells to produce water.

Pumping rates from individual extraction wells between startup of the remedial system in the spring of 2002 and August 2002 were not available. These pumping rates are now being recorded and are expected to provide valuable information regarding the relative ability of each well to supply water to the treatment system. The combination of individual pumping rates and measured concentrations at individual wells will also help to identify the locales where the greatest reduction in plume mass can be achieved. In addition, when combined with measured ground water levels at extraction wells (as suggested in Section 4.1.1), pumping rates will likely yield useful information regarding the spatial variability of aquifer characteristics.

Though individual well extraction rates for the first semi-annual performance evaluation were not available, some insight to the relative ability of specific horizons to provide flow volume and contaminant mass can be drawn from the plume changes discussed in Section 4.3. In particular, because the greatest reductions in nitrate and sulfate concentrations during the first six months of remedial system operation were observed in Horizon D, this horizon is likely providing more water and mass to the treatment system than Horizons B and C lying above it. Though this result might be partially attributed to the fact that the screened intervals for 22 of the 25 extraction wells are centered on Horizon D (Table 2), it probably does not provide the sole explanation for the dramatic changes in this horizon's plumes as compared to relatively minor changes in Horizon C. The top of screened intervals in all extraction wells is located in Horizon B, and all extraction wells are completely screened across Horizon C (Table 10). Thus, if Horizons B and C were capable of delivering the same quantity of water to the treatment system as Horizon D, reductions in the plume concentration in Horizons B and C would likely be comparable to those of Horizon D.

The relative contributions of water volume and contaminant mass to treatment from Horizons B and C versus Horizon D suggest that Horizon D, which is likely located in the upper portion of the intertonguing interval (Table 2), is generally more permeable than Horizons B and C, which is located in the classic Navajo Sandstone. This is attributed to the fact that, in pumping wells screened across multiple horizons, the largest quantities of water are withdrawn from and, therefore, the largest drawdowns are observed in, the horizon or horizons with the largest hydraulic conductivity. This assessment further suggests that ways should be found to increase the pumping from Horizons B and C within the contaminant plumes delineated for these horizons (Figures 13b, 14b, 18b, 19b, 23b, 24b, 28b, 29b, 32b, and 33b), and balancing this increased pumpage with ground water withdrawals from Horizon D.

The suggestion above to increase pumping from Horizons B and C in contaminated areas also applies to Horizon A. Relatively large concentrations of dissolved nitrate, sulfate, uranium, selenium, and strontium are found in this horizon (Figures 12b, 17b, 22b, 27b, and 31b), yet none of the existing extraction wells is screened in it (Table 10).

Modeling performed as part of the remedial system design process (DOE 1998) predicted approximately 5 ft of mounding adjacent to the infiltration trench. This mounding was expected to occur uniformly along the length of the trench, as the treated water from the distillation system is released to the trench about halfway between its endpoints. Table 11 presents August 2002 drawdown and mounding observations as affected by operation of the extraction well field and infiltration trench. Mounding at the infiltration trench is not symmetrical; rather it is primarily confined to the western end of the infiltration trench. Up to 18 ft of mounding occurs at the western end as opposed to little to none at the eastern end of the infiltration trench.

The apparent localization of mounding beneath the western portion of the infiltration trench raises concerns that shallow groundwater levels in the area might rise as high as the base of the tailings in the disposal cell. Such an occurrence could possibly lead to enhanced loading of tailings constituents to the groundwater system above loading that otherwise occurs with an unsaturated zone separating the tailings from ground water. To assess this issue further, measured ground water levels in Horizon A should be compared to estimated elevations for the base of the tailings pile in the vicinity of the infiltration trench. In the interest of minimizing potentially deleterious effects of focused mounding beneath the infiltration trench, consideration should also be given to utilizing injection wells (Figure 2) to return treated water to the ground water system. Doing so would likely help to dilute dissolved nitrate in ground water beyond the design capture zone for the extraction well field (Figures 14b and 15b).

The numerical modeling (DOE 1998) also predicted drawdowns of approximately 20 to 30 ft in the vicinity of the extraction wells (Figure 37). As shown in Table 11, drawdowns in excess of this value have been observed in Horizon E. For all other horizons, drawdowns are less than the 20- to 30-ft design value. Up to 18 ft of drawdown has been observed in Horizon I at well 0254, which is located nearly 200 ft below the bottom of the extraction wells. It is important to realize that the presence of drawdown at well 0254 is not necessarily indicative of capture by the extraction wells. For example, consider a well field within a valley. Water levels downgradient of the well field will decline everywhere in the valley because there is less ground water through-flow relative to pre-pumping conditions, but this does not mean that the well field is capturing all down-gradient ground water. In an analogous fashion, it is possible that ground water levels in Horizon I at the Tuba City UMTRA Project site decline similarly due to a reduction of ground water through-flow from overlying horizons.

6.0 Treatment System Performance

Evaluation of treatment system performance largely involves a comparison of COPC mass removed by the remedial system with estimated masses occurring in the COPC plumes under baseline conditions. Such comparisons are considered approximate because of numerous uncertainties that affected the baseline mass estimates (DOE 2003). Consequently, the reader is cautioned not to treat estimates of cleanup provided in this section as accurate assessments of remedial system effectiveness.

Treatment system performance in this first evaluation was mostly gauged with respect to treated nitrate and sulfate because these two COPCs comprise most of the contaminant mass dissolved in ground water at the Tuba City site. From April 26 to December 6, 2002 the distillation system treated approximately 27 million gallons of contaminated ground water, and removed 93,062 and 223,327 pounds of nitrate and sulfate, respectively. On the basis of calculations made during the baseline evaluation (DOE 2003), the volume of treated ground water represents approximately 0.79 percent of the total plume volume, and the mass of contamination removed represents approximately 1 percent of the total contaminant mass. Assuming similar operating conditions and influent concentrations, approximately 1.3 percent and 1.7 percent of the initial plume volume and mass, respectively, will be treated each year and removed by the distillation system. It should be mentioned, however, that such projections are overly optimistic because influent concentrations will likely decrease with time. Such a reduction in concentration is typically observed at pump-and-treat operations.

As of December 6, 2002, about 98 pounds of uranium had been removed from ground water at the site. This quantity represents approximately 2.5 percent of the total dissolved uranium estimated under baseline conditions (DOE 2003).

Design specifications stated that the concentrated brine, a by-product of the distillation process which contains all of the dissolved solids, radionuclides, and other nonvolatile contaminants removed from the influent stream, should average about 5 percent of the original volume of influent water (DOE 1998). On average, during this semi-annual performance period, the concentrated brine produced from the distillation process was approximately 5 percent of the influent volume. In addition, the softening pretreatment waste sent to the evaporation pond was approximately 10 percent of effluent volume.

7.0 Performance Summary

Findings from the first semi-annual performance evaluation at the Tuba City site are as follows:

- Three-point analyses show that horizontal hydraulic gradients in the vicinity of the extraction wells and the infiltration trench are being influenced by operation of the remedial system. In Horizon A, mounding associated with the infiltration trench shifts horizontal gradient directions from south to southeast. In Horizon B, operation of the remedial system causes a reversal in gradient direction, with ground water now flowing back towards the extraction well field. The observed horizontal extent of influence is consistent with that predicted by modeling. Away from the extraction wells and infiltration trench, the remedial system minimally influences horizontal hydraulic gradient directions and magnitudes. The observations made regarding the effects of extraction well pumping on horizontal gradients are somewhat limited because ground water levels in individual wells were not recorded in August 2002. Water level measurements in extraction wells are now being made and will assist not only in assessing hydraulic gradients, but also in evaluating the capacity of each well to remove contaminants.

- Vertical hydraulic gradients in Horizons A through C in areas in the vicinity of the extraction well system are strongly downward towards Horizon D, the horizon in which the majority of extraction well screens are centered. A vertical hydraulic gradient calculated using a well screened 200 ft below Horizon D shows a strong upward gradient, suggesting that operation of the remedial system is preventing deep contaminant migration. The remedial system minimally influences vertical hydraulic gradients in the Kayenta Formation, which are represented by Horizons K through M. The hydraulic gradients between Horizons I and M at the end of this first semi-annual evaluation were either downward or neutral. The computed vertical gradients between Horizons I and M suggest that horizons containing the Kayenta Formation are below the influence of extraction wells.

- Comparisons of plume concentration maps prepared for both August 2002 and baseline conditions in Horizons A through C indicate that generally minimal differences occur between the two time periods. In contrast to Horizons A through C, constituent concentrations and plume geometries in Horizons D and E appear to change more dramatically between baseline and August 2002 conditions. These observations indicate that most of the ground water volumes and contaminant masses are being drawn from Horizon D and possibly Horizon E, and that relatively insignificant volumes and masses are taken from Horizons A through C.

- Horizon D concentration declines are observed for all of the COPCs at most wells. However, the concentration of uranium has increased at five wells. Observed decreases in COPC concentrations in Horizon D stem largely from monitoring of extraction wells, which are affected by the larger pumping rates associated with them during remedial system operation than pumping rates utilized during the baseline evaluation.

- The greater volumes of water and contaminant mass removed from Horizon D in comparison to overlying Horizons B and C suggest that Horizon D is more permeable than Horizons B and C. This observation is made despite the fact that all existing extraction wells are screened across all of Horizon C, and much of Horizon B. This in turn suggests that the extraction system could be greatly improved if means were found to increase pumping from Horizons B and C while continuing to remove ground water and associated contamination from Horizon D.

- Horizon A contains relatively high dissolved levels of all COPCs considered in this evaluation, yet none of the existing extraction wells are screened in this horizon. As in the case of Horizons B and C, the effectiveness of the remedial system would likely be improved if means were found to effectively withdraw ground water and associated contaminants from Horizon A.

- The cumulative pumping rate for extraction wells has bearing on the remedial system's capacity to achieve site cleanup. This rate, in conjunction with dissolved COPC levels in the water treatment system's influent, determine the rate at which contaminants will be removed from site ground water. The design total pumping rate for the existing extraction well field is 100 to 120 gpm. The average total pumping rate from this evaluation period was 84 gpm. The discrepancy between the design and actual rates was attributed to treatment system downtime, and bears no reflection on the capacity of the extraction wells to provide pumping rates exceeding 100 gpm.

- Individual well pumping rates for this semi-annual performance evaluation period were not available, but these data are now being collected. Extraction rates at each pumping well will assist in evaluating its capacity to remove contaminants.

- Mounding in the vicinity of the infiltration trench was predicted by modeling to be relatively uniform along the trench's length, and to approach 5 ft in magnitude. Mounding in August 2002 was not uniform and was mostly concentrated at the western end of the infiltration trench, where mound heights of about 18 ft were observed. These observations suggested that nearly all of the effluent placed in the trench infiltrated at the western end of the trench, which in turn suggested that the effective vertical hydraulic conductivity of shallow materials along the north side of the disposal cell is potentially larger in the western portion of the trench than in the eastern portion.

- Drawdowns in the vicinity of the extraction wells were predicted by modeling to approach values of 20 to 30 ft. In August 2002, drawdowns in excess of 30 ft were observed in Horizon E. Computed drawdowns were less than 30 ft in all other horizons. Interestingly, up to 18 ft of drawdown was observed in Horizon I, located nearly 200 ft below the bottom of the extraction wells.

- On the basis of calculations made during the baseline evaluation, the volume of treated ground water at the end of this first semi-annual evaluation represents approximately 0.79 percent of the total plume volume, and the mass of contamination removed represents approximately 1 percent of the total contaminant mass. Assuming similar operating conditions and influent concentrations, approximately 1.3 percent and 1.7 percent of the initial plume volume and mass, respectively, will be treated each year and removed by the distillation system. However, these projections are unrealistic because influent concentrations will likely decrease with time. If such projections were generally reflective of the remedial system's performance, the total time to site cleanup would exceed 20 years.

- The water-treatment distillation system was designed to produce approximately 5 percent of the original volume of influent water as concentrated brine. During this performance period, the concentrated brine produced from the distillation process was, on average, about 5 percent of the influent volume. Additional waste to the evaporation pond from the softening pretreatment step averaged approximately 10 percent of influent volume.

- A general lack of hydraulic head data in the shallowest horizons on the eastern side of the Tuba City site makes it difficult to evaluate hydraulic gradients and water table elevations in this portion of the site. This difficulty suggests that hydraulic performance of the extraction system could be improved through additional shallow monitor wells in this area as well as through the collection of water level data in extraction wells on the east side of the disposal cell.

8.0 Recommendations

Given that this first semi-annual performance evaluation focused on hydraulic characteristics of the Tuba City remedial system, most of the following recommendations for future work are limited steps that would assist in improving the capture and delivery of contaminated ground water to the water treatment system.

- Continue measuring and compiling pumping rates and drawdowns at individual extraction wells so that the efficacy of these wells in removing contaminants can be better evaluated.

- Examine potential methods for increasing the pumping rates from Horizons B and C while continuing to withdraw ground water and dissolved contaminants from Horizon D.

- Develop means of extracting ground water and COPCs from contaminated areas in Horizon A.

- In future evaluations, examine in more detail the chemistry of COPCs at the site as well as the design and performance of the water treatment system.

- Consider returning treated effluent to the ground water system using existing injection wells.

9.0 References

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Figures

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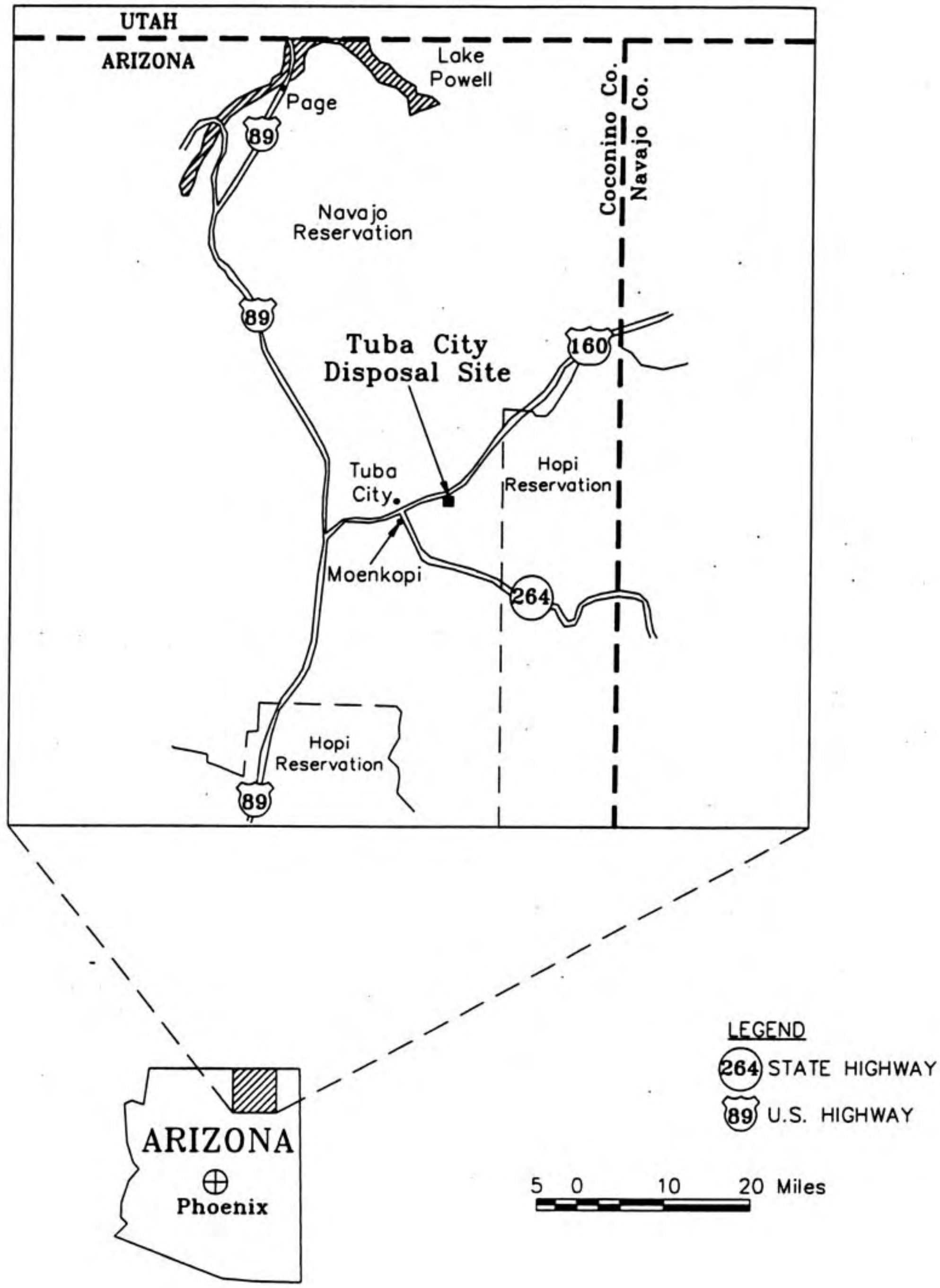


Figure 1. Tuba City UMTRA Project Site Location

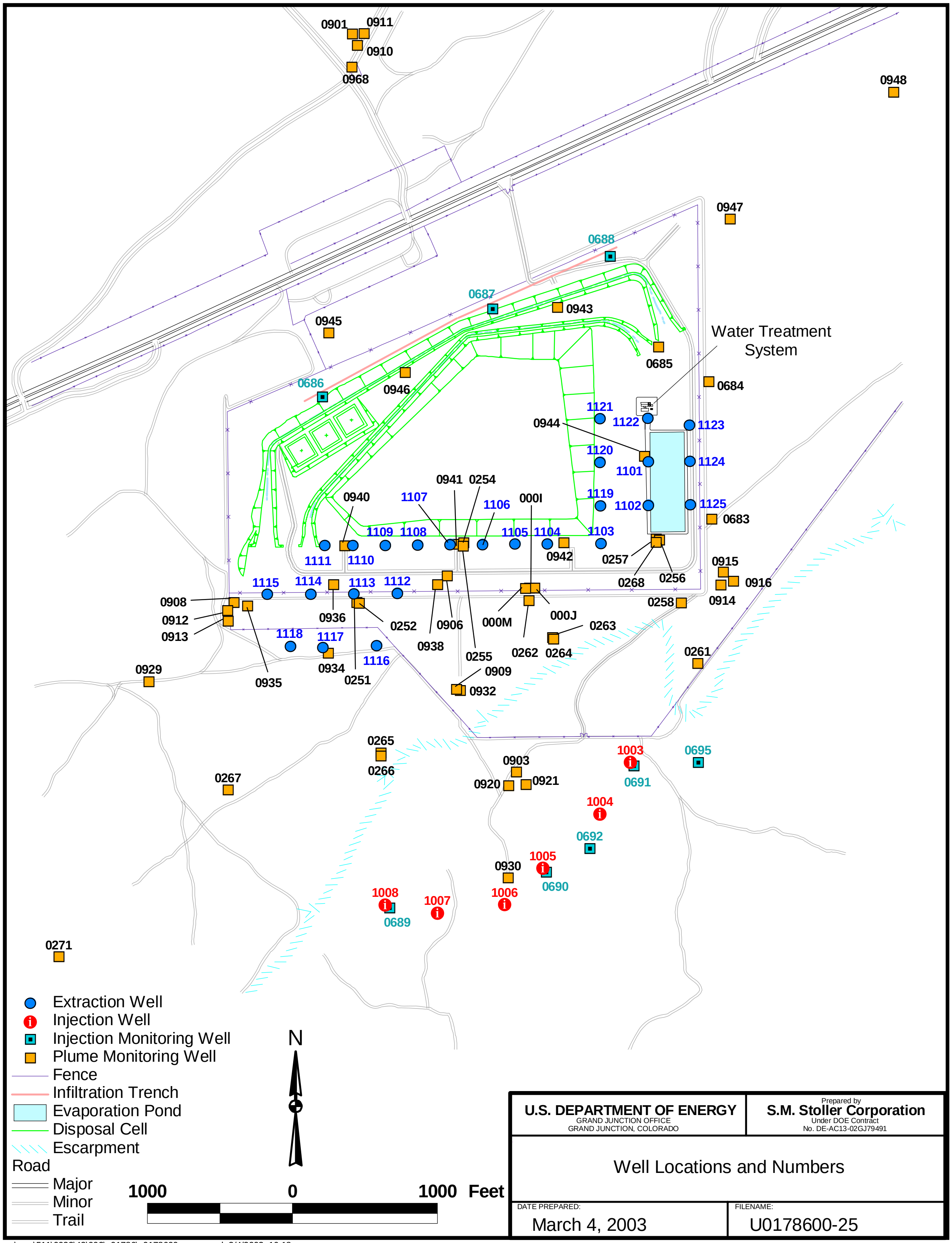
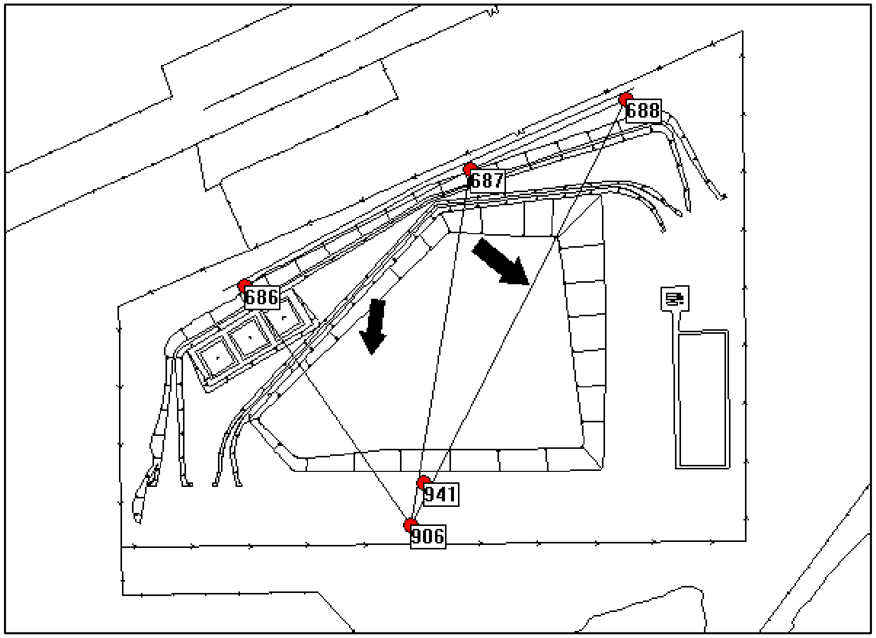


Figure 2. Location of Extraction and Injection Wells and Infiltration Trench



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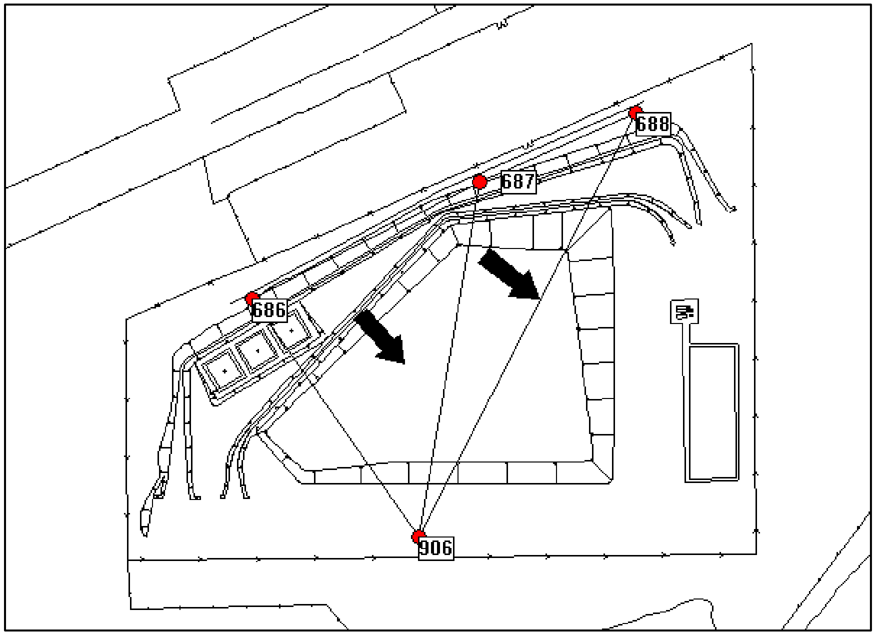
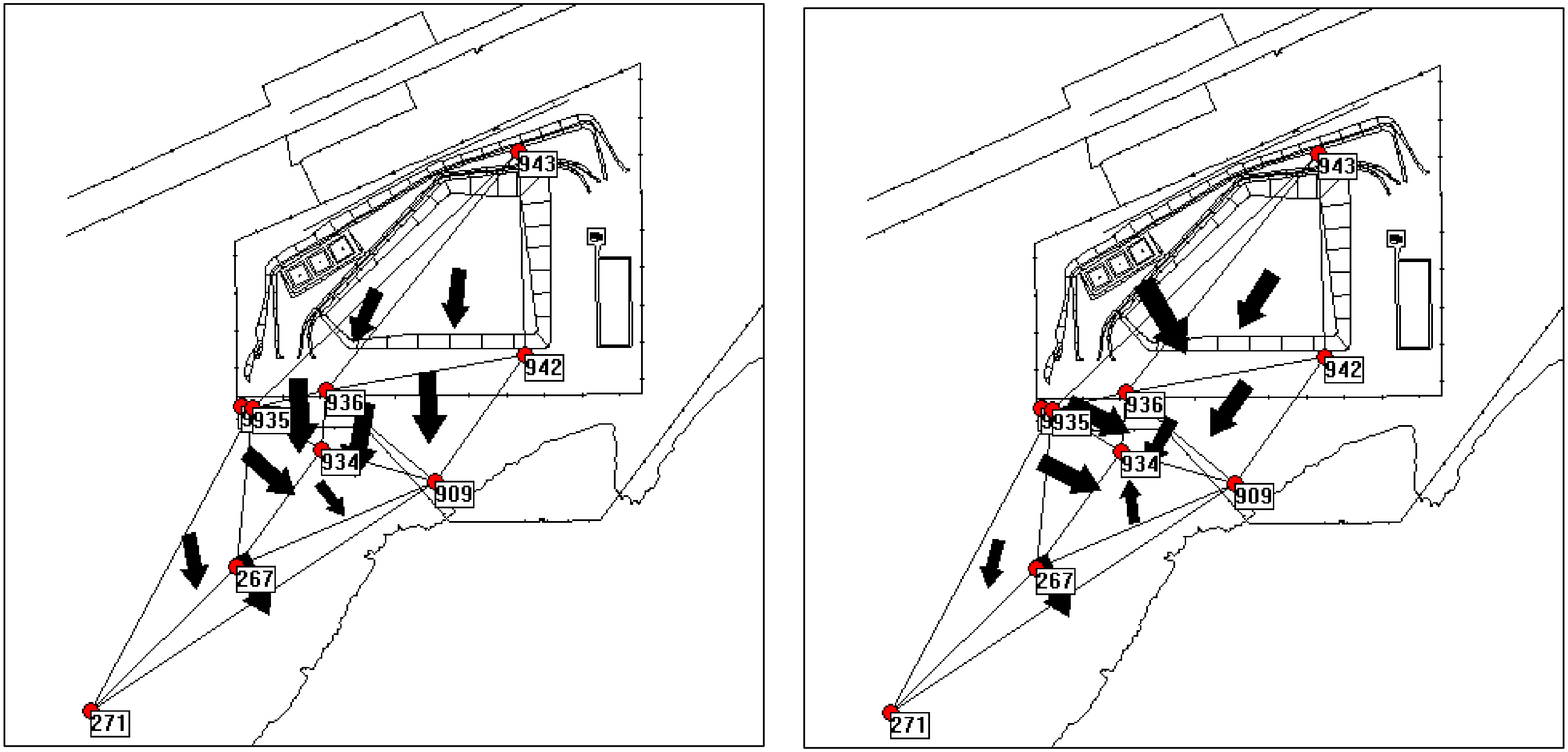


August 2002

Figure 3. Baseline and August 2002 Horizon A Horizonal Hydraulic Gradients



August 2001

August 2002

Figure 4. Baseline and August 2002 Horizon B Horizonal Hydraulic Gradients

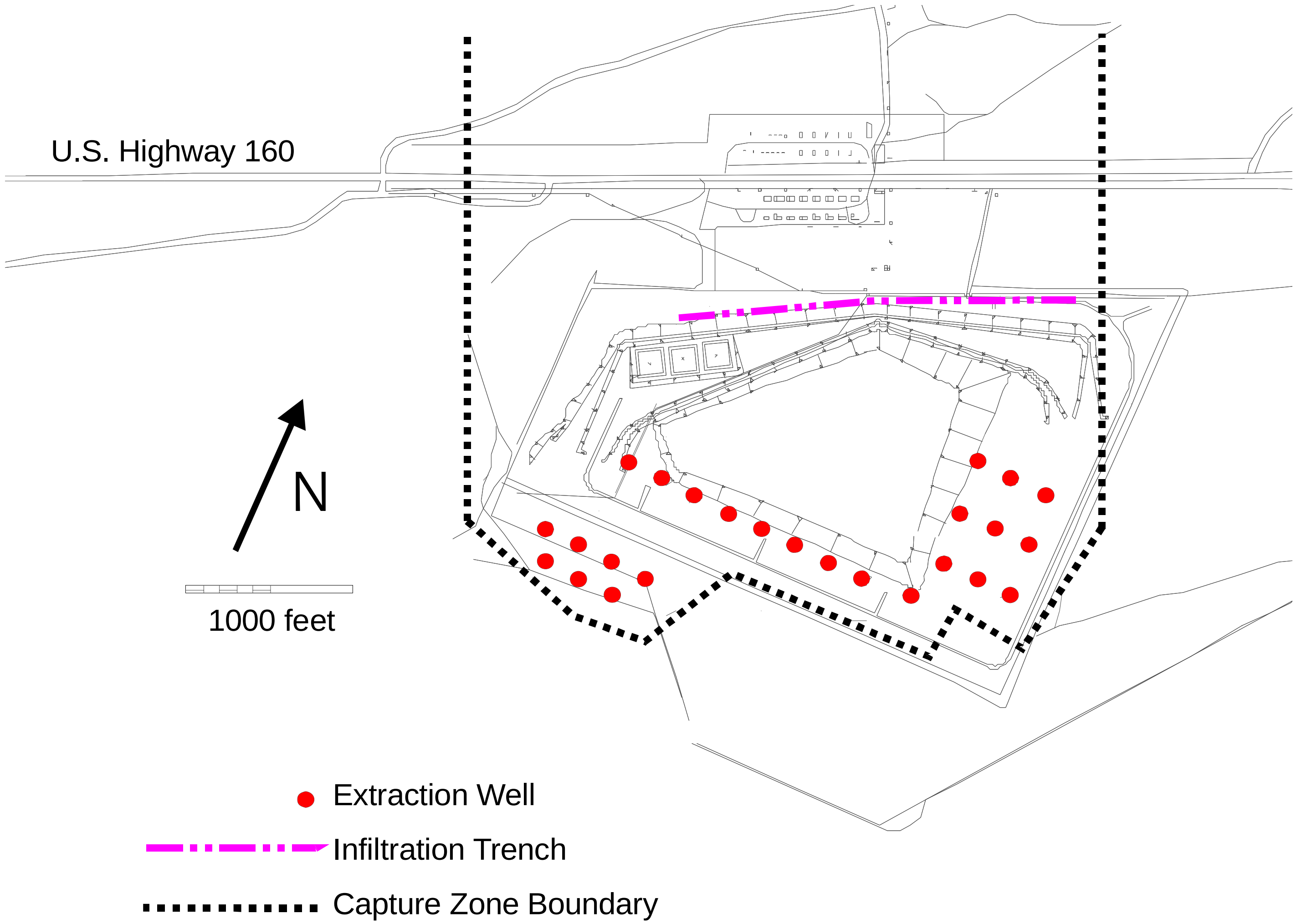
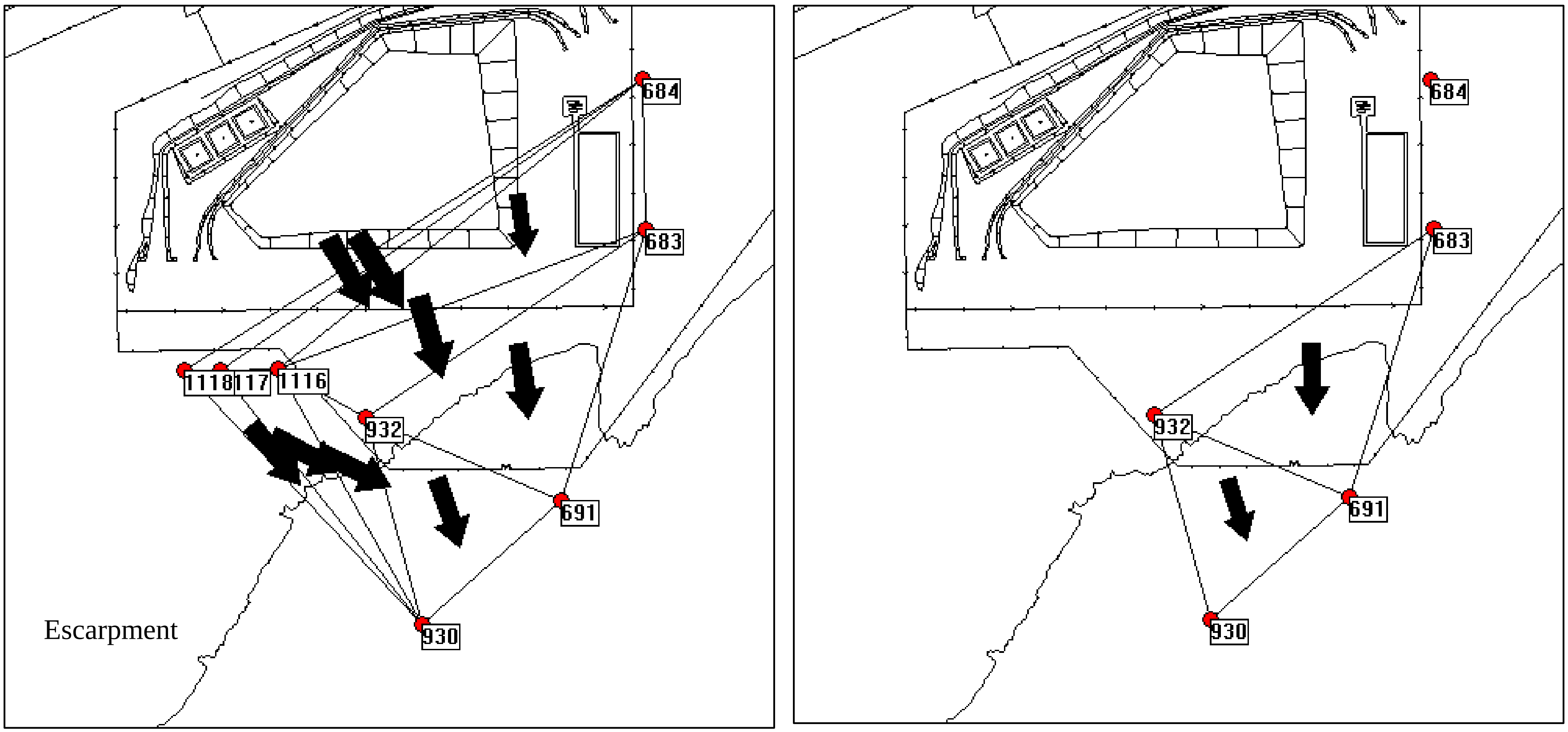


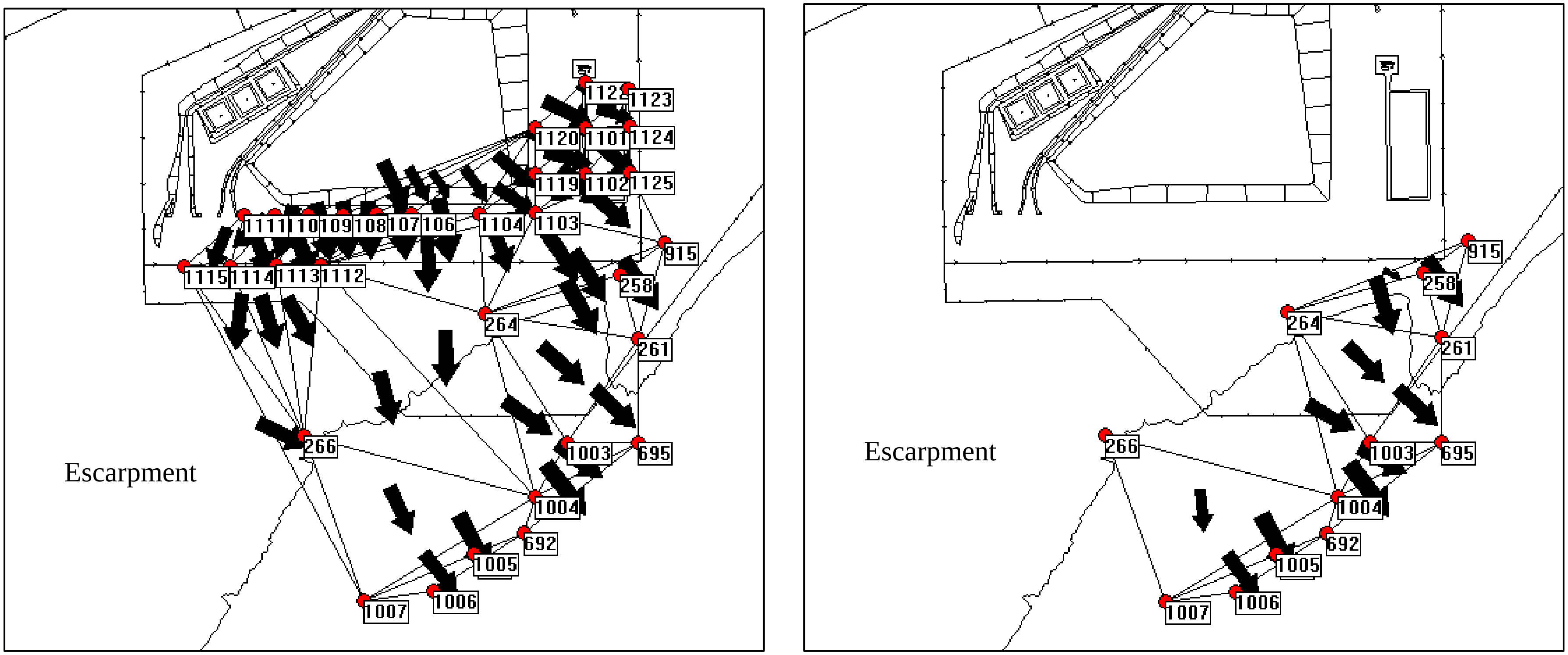
Figure 5. Capture Zone Predicted by the Site Ground Water Flow Model



August 2001

August 2002

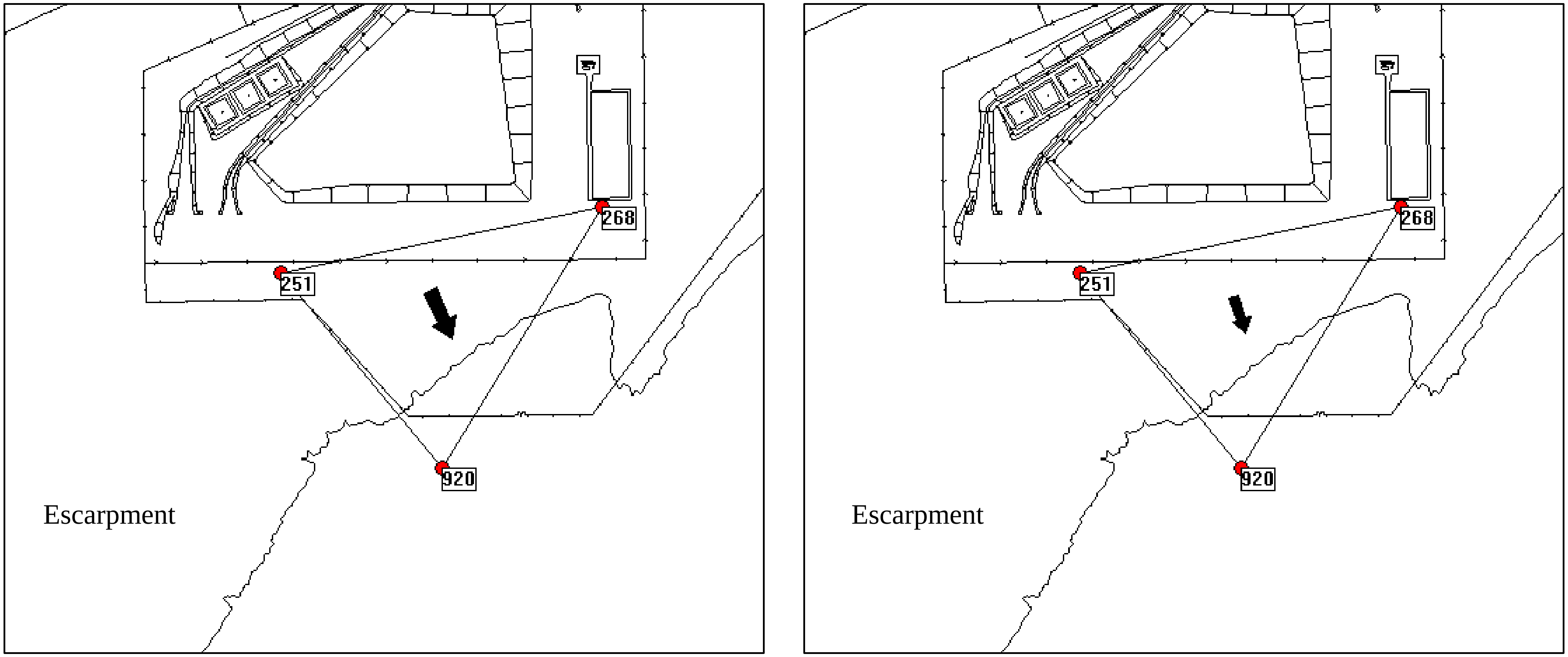
Figure 6. Baseline and August 2002 Horizon C Horizonal Hydraulic Gradients



September 2000

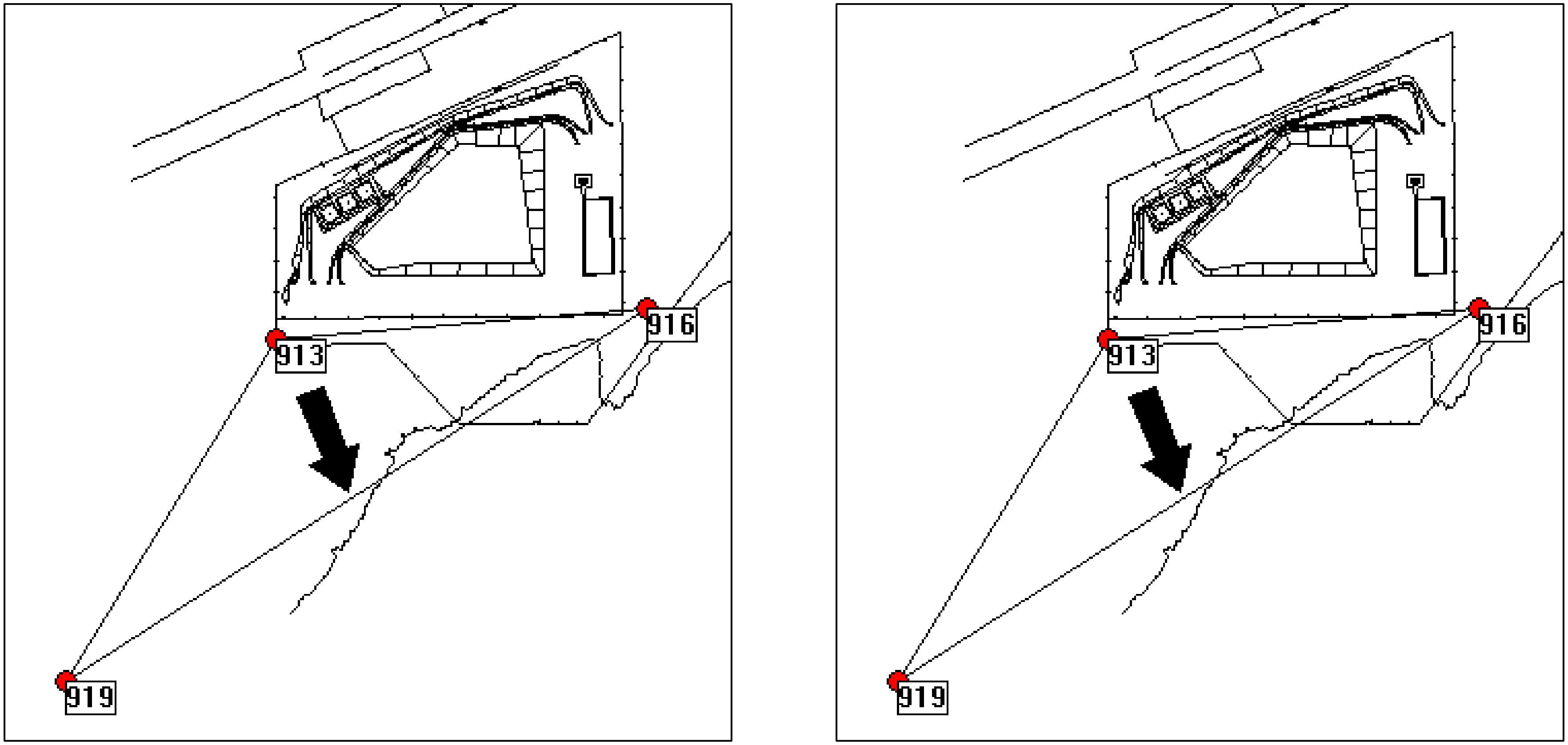
August 2002

Figure 7. Baseline and August 2002 Horizon D Horizonal Hydraulic Gradients



May 2001 August 2002

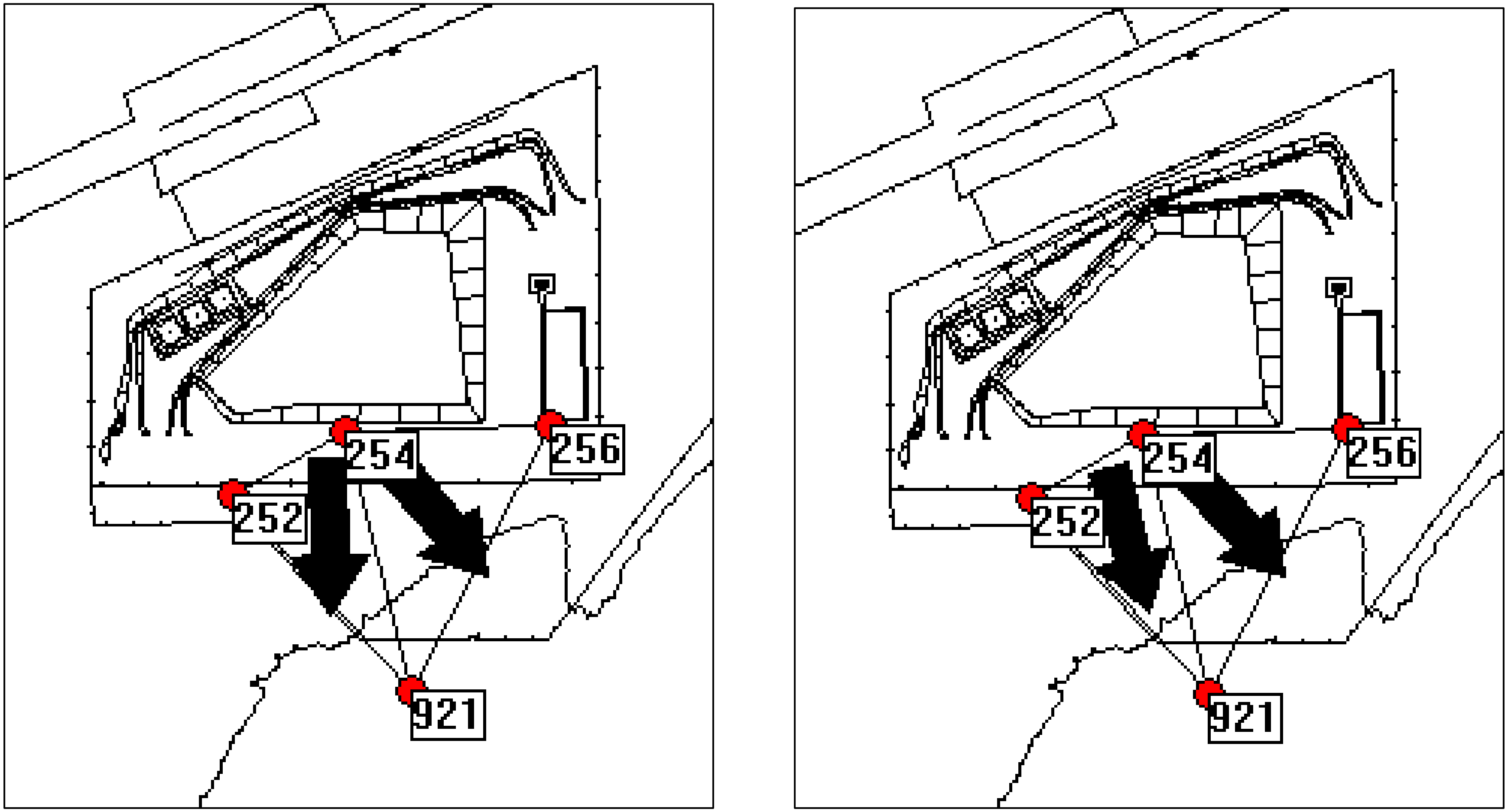
Figure 8. Baseline and August 2002 Horizon E Horizonal Hydraulic Gradients



September 1998

August 2002

Figure 9. Baseline and August 2002 Horizon G Horizonal Hydraulic Gradients



March 2002

August 2002

Figure 10. Baseline and August 2002 Horizon I Horizonal Hydraulic Gradients

Comparison Figures

Baseline Data and August 2002 Data

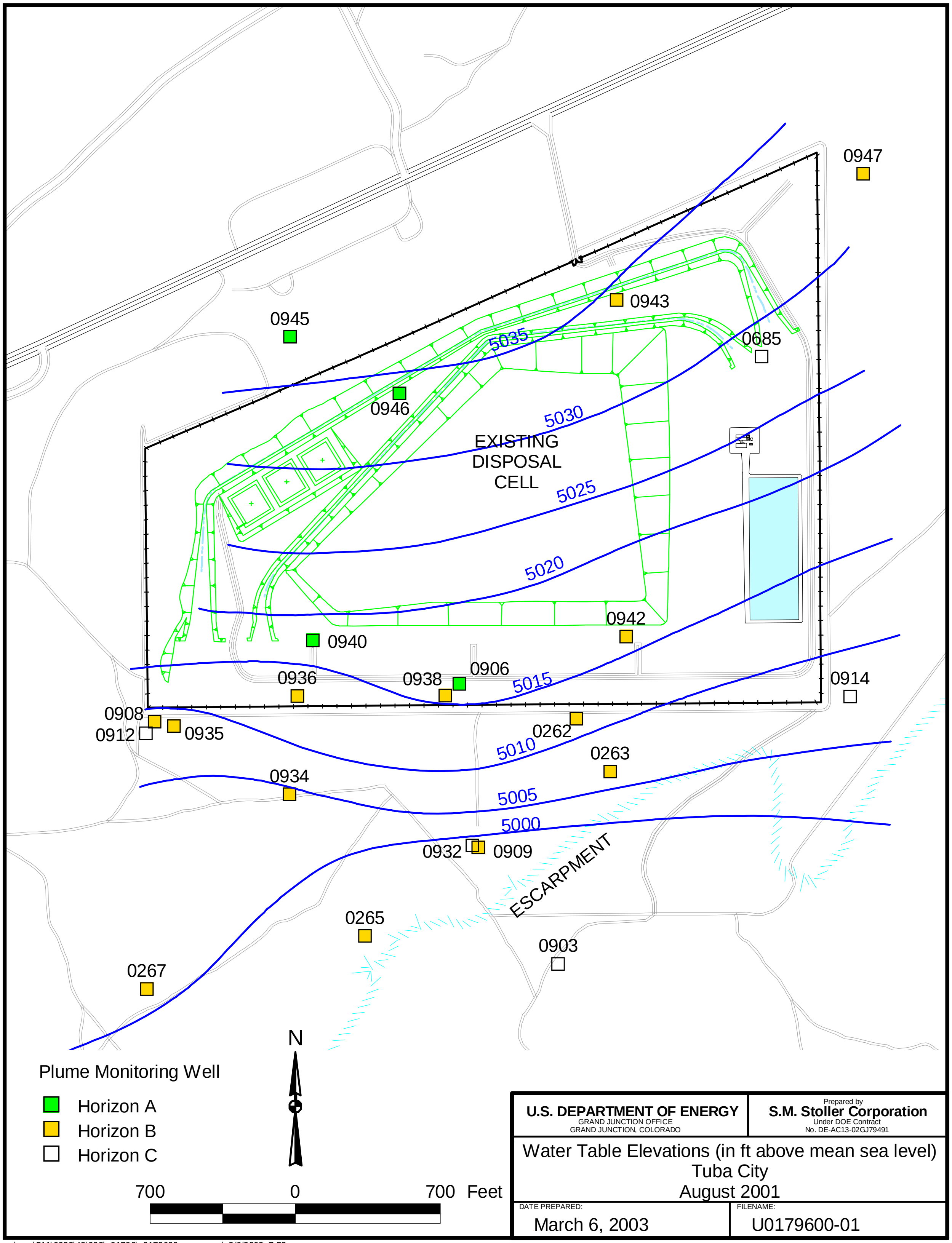


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Figure 11a. Baseline Water Table

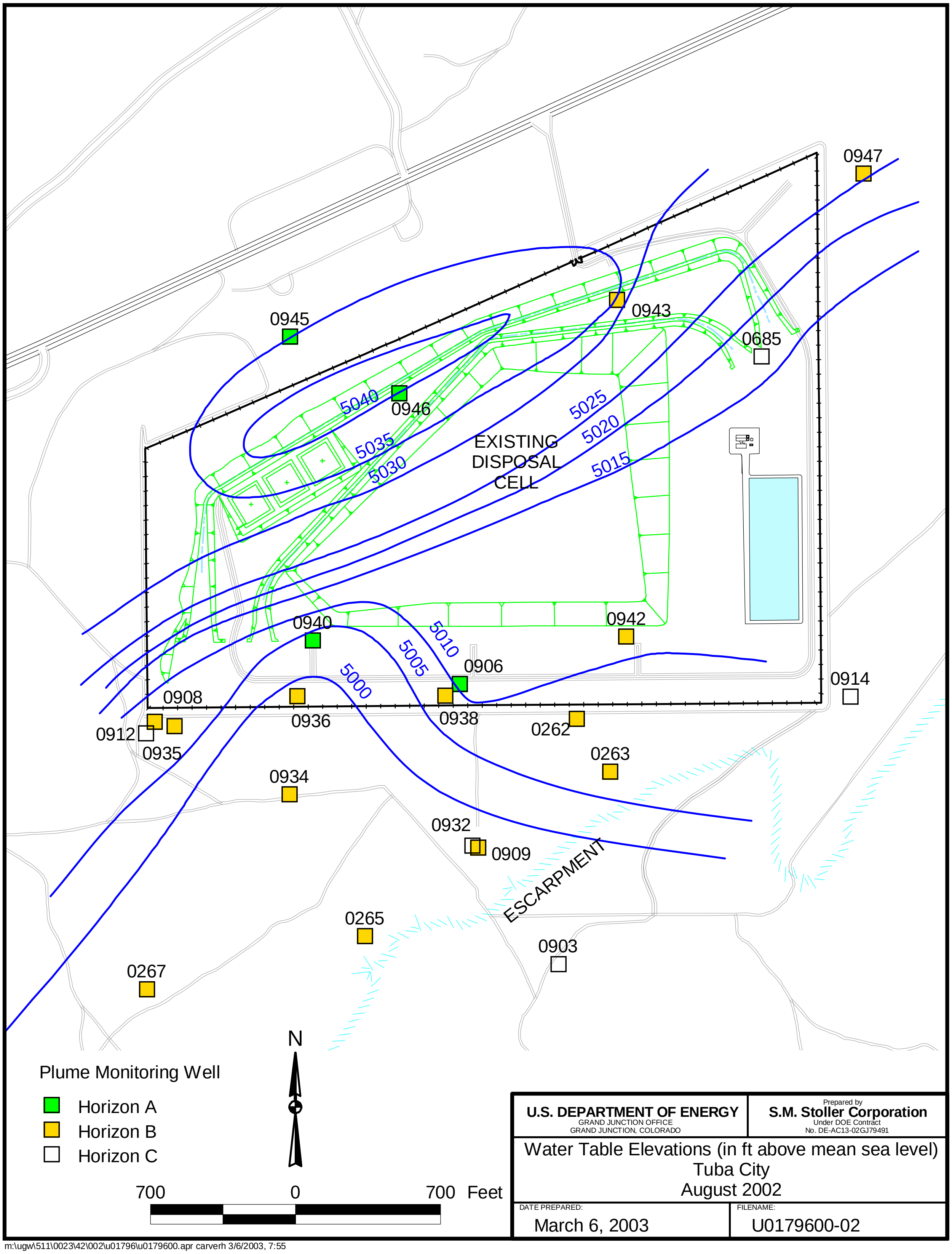

Figure 11b. August 2002 Water Table

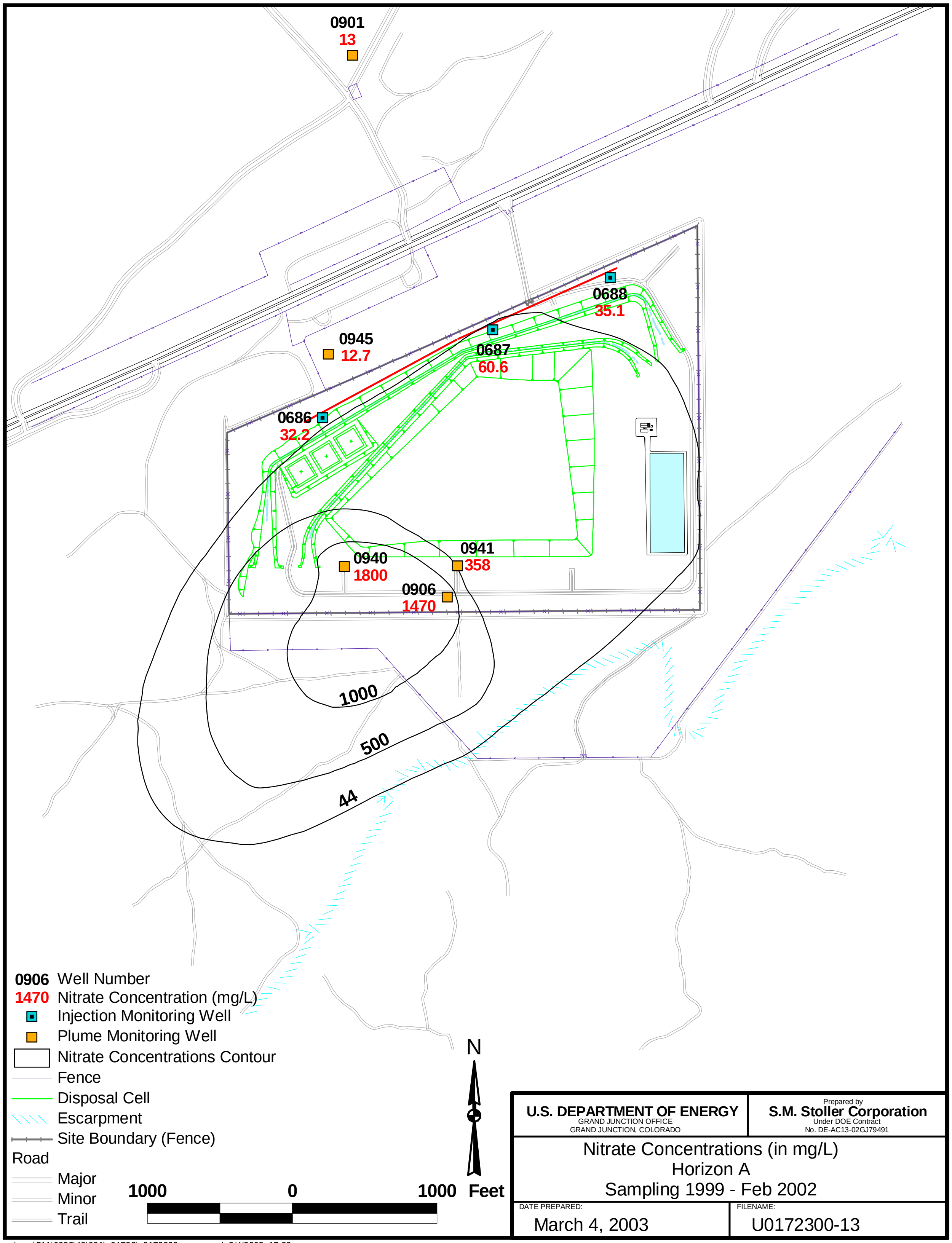

Figure 12a. Baseline Horizon A Nitrate Ground Water Concentrations

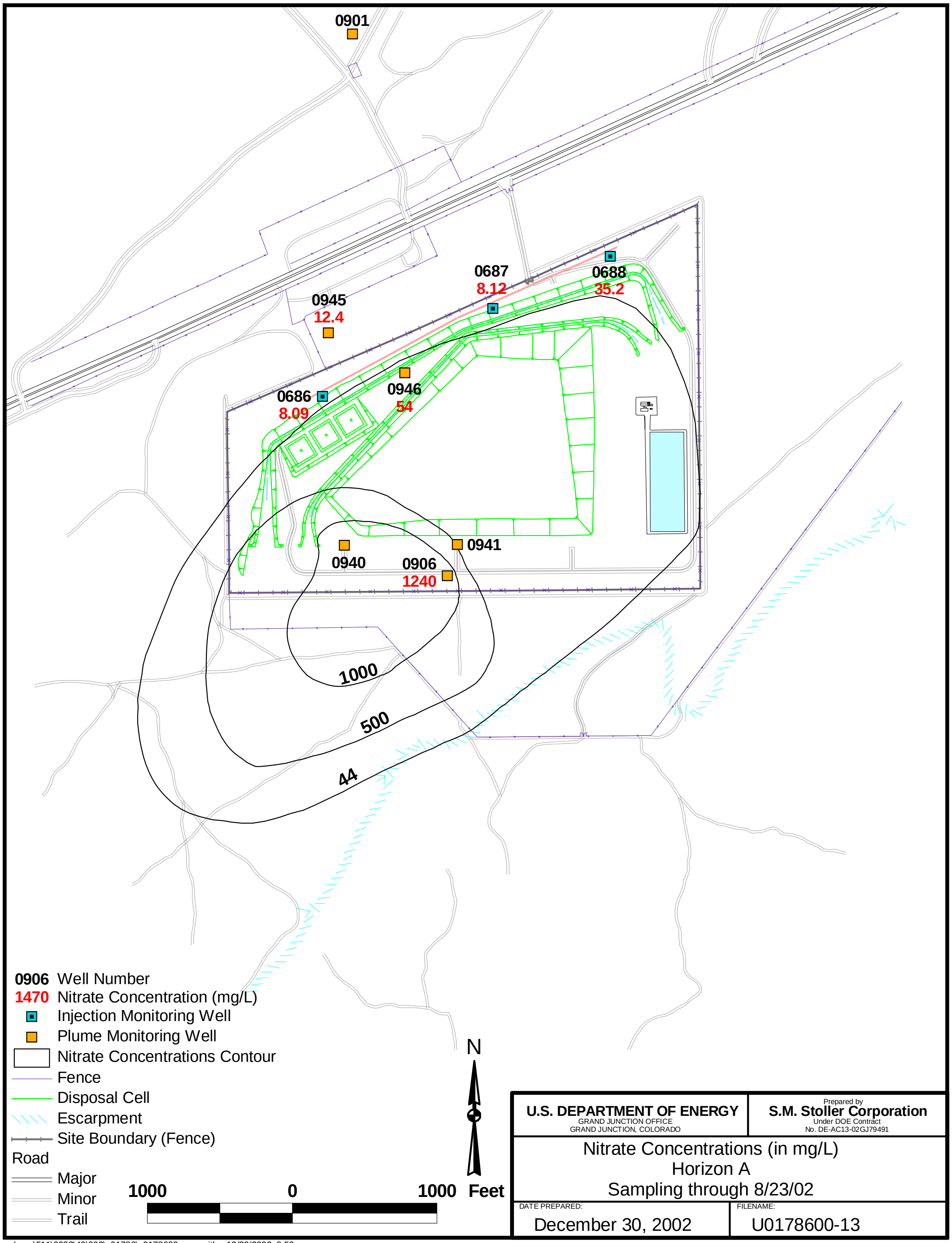

Figure 12b. August 2002 Horizon A Nitrate Ground Water Concentrations

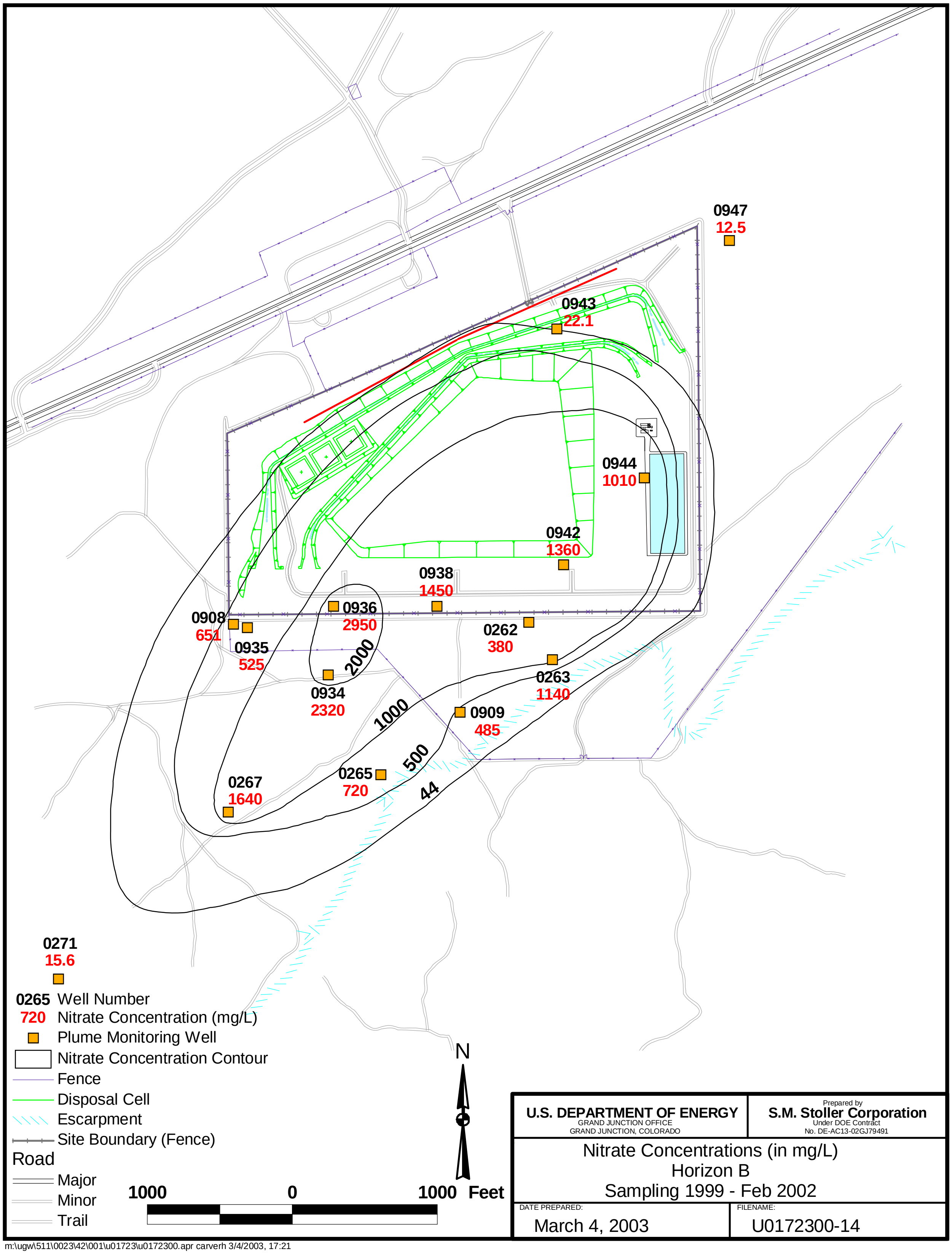

Figure 13a. Baseline Horizon B Nitrate Ground Water Concentrations

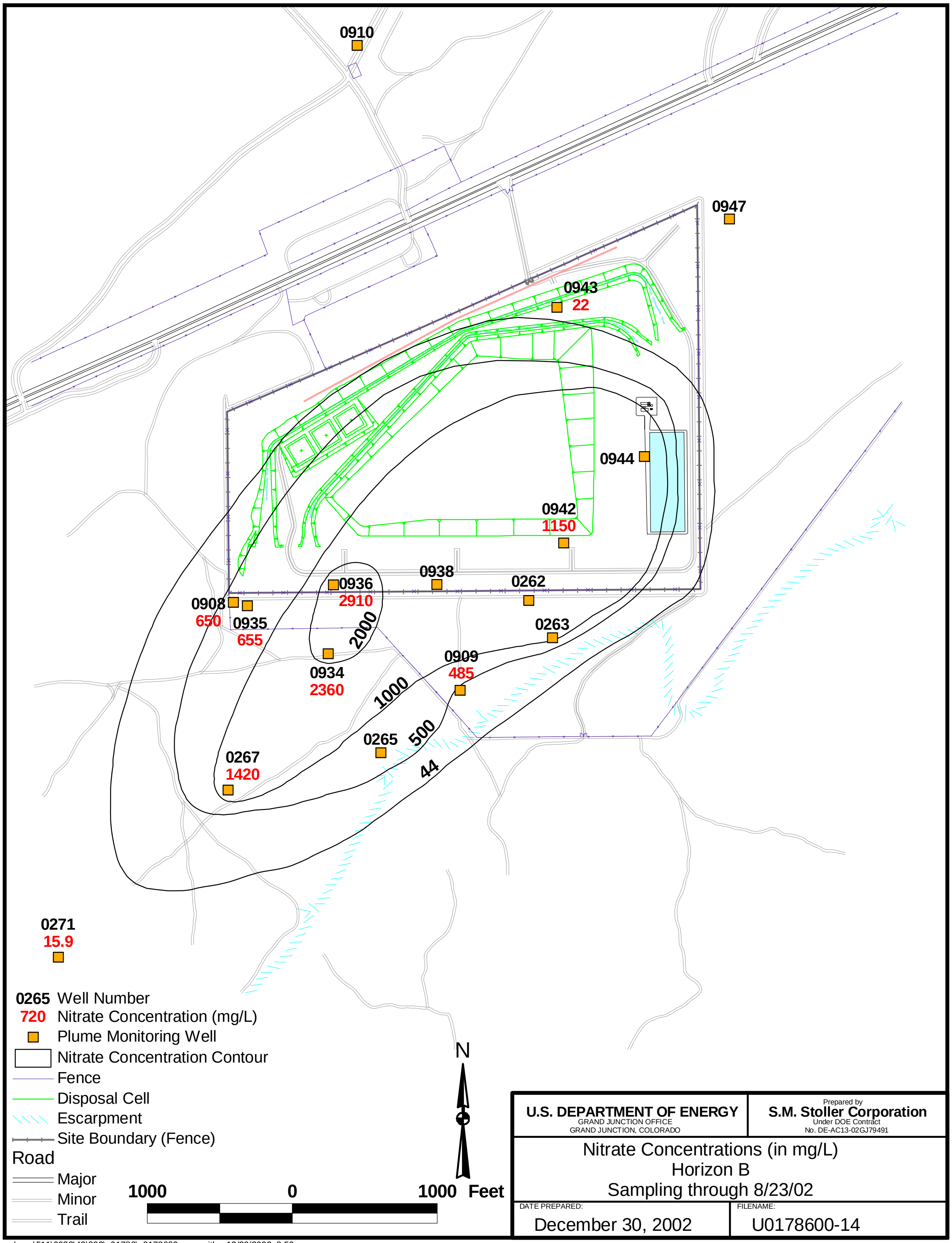

Figure 13b. August 2002 Horizon B Nitrate Ground Water Concentrations

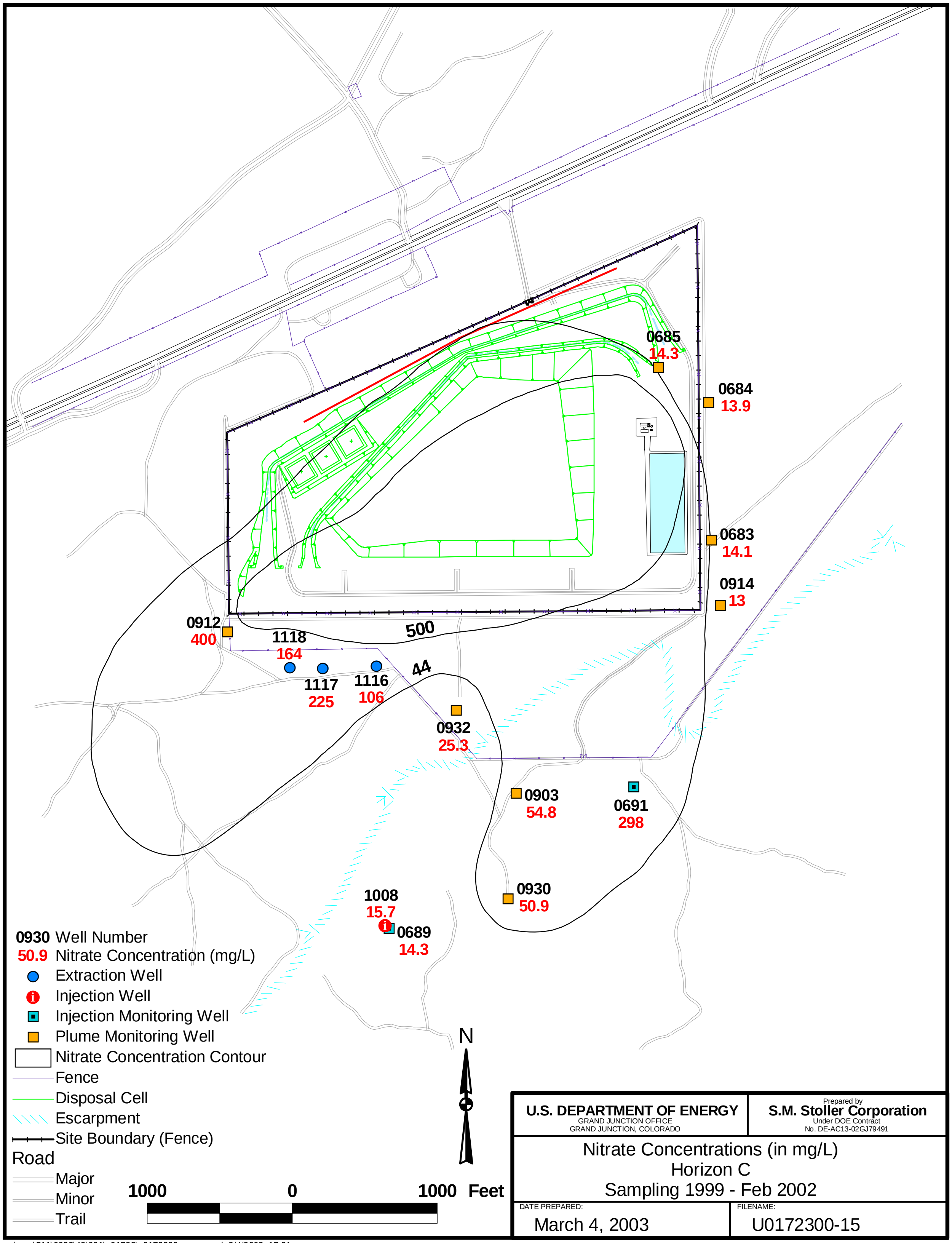

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Figure 14a. Baseline Horizon C Nitrate Ground Water Concentrations

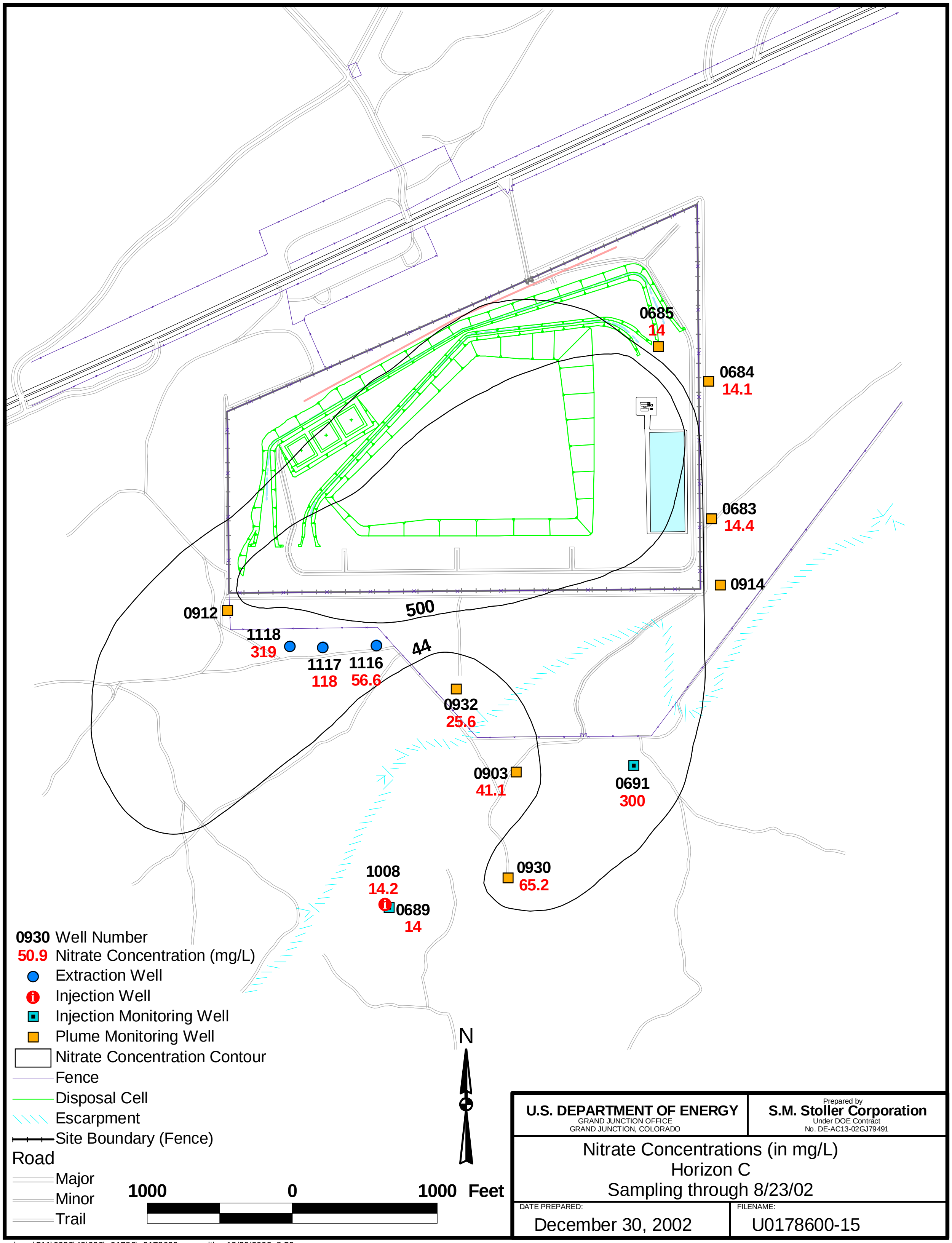

Figure 14b. August 2002 Horizon C Nitrate Ground Water Concentrations

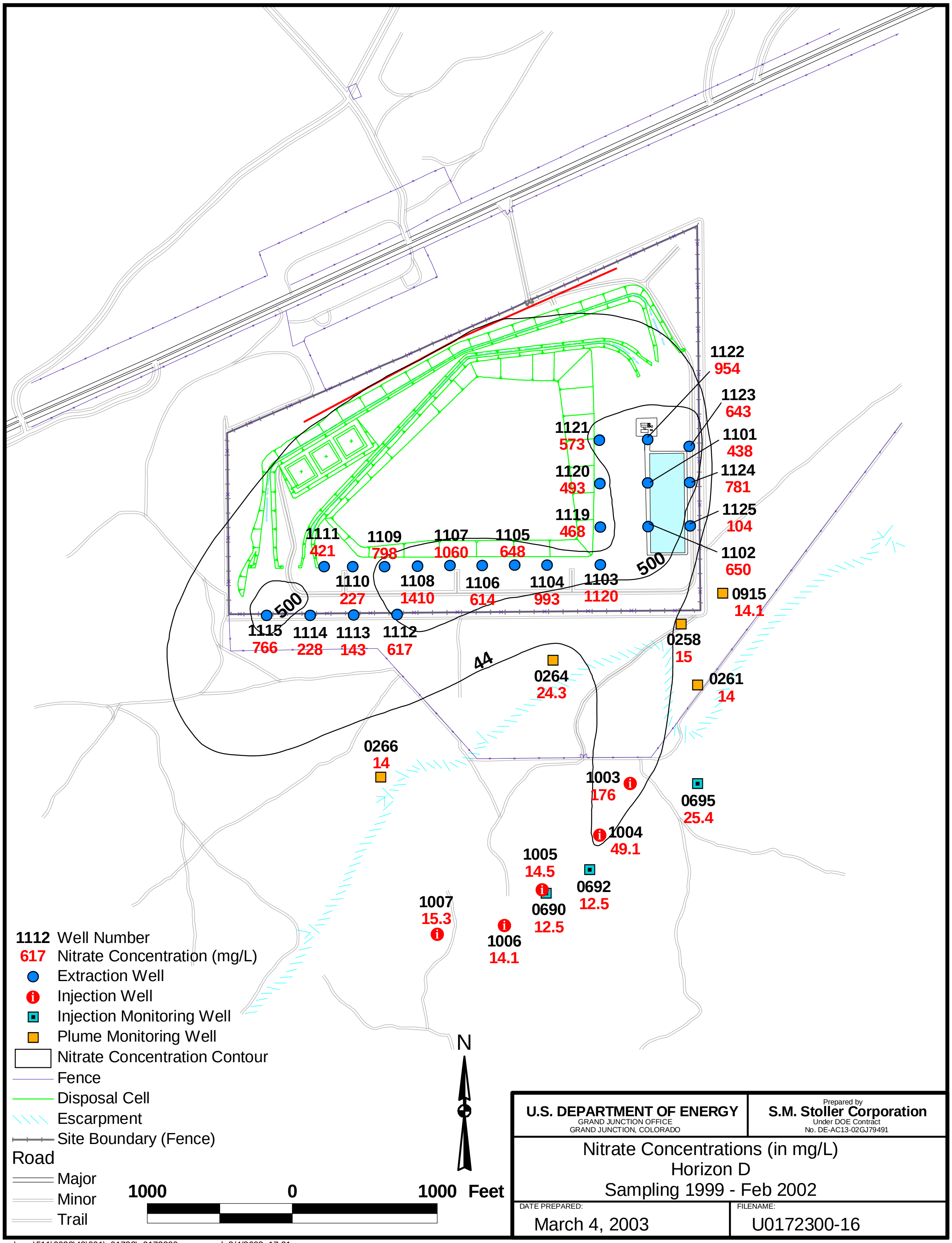

Figure 15a. Baseline Horizon D Nitrate Ground Water Concentrations

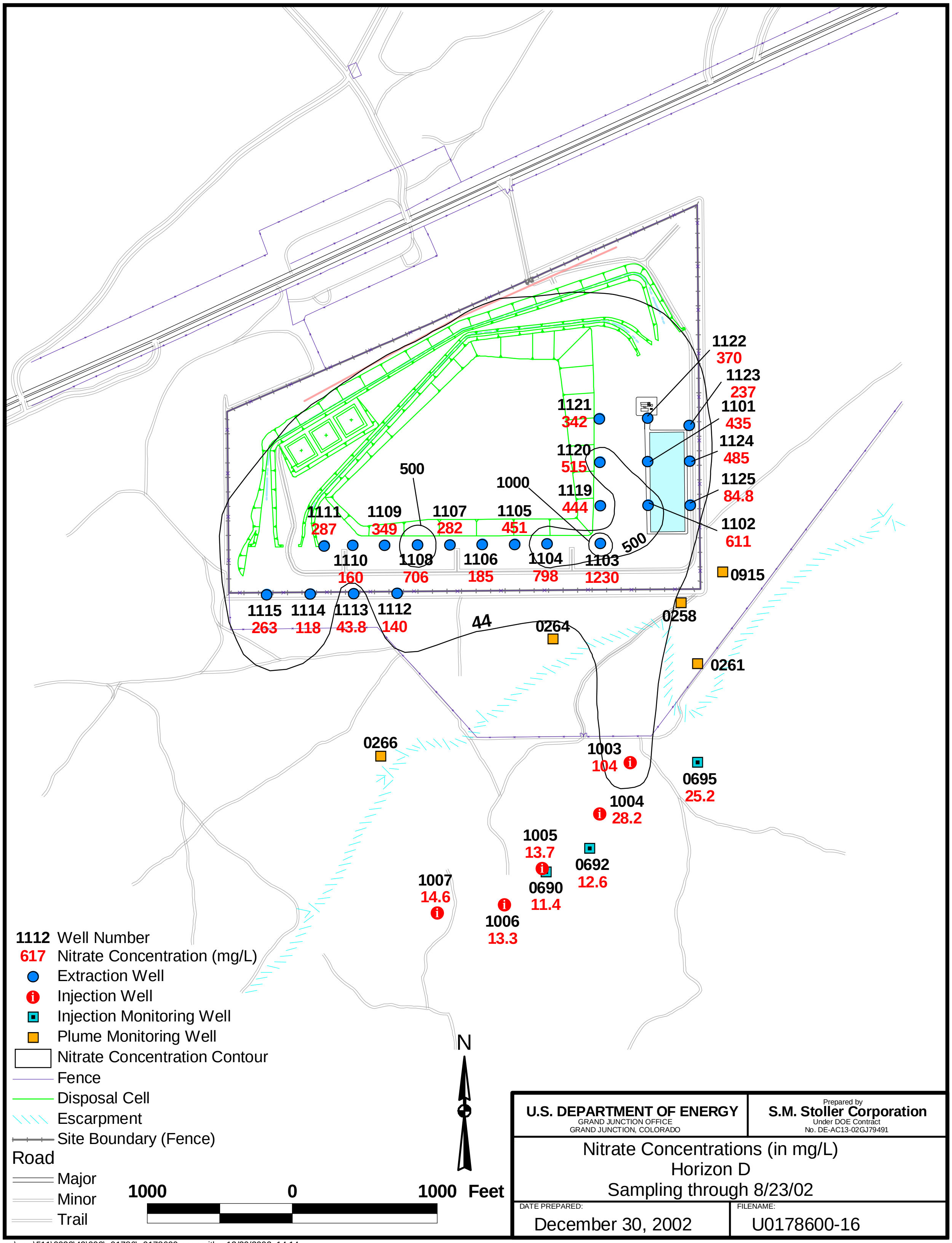

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Figure 15b. August Horizon D Nitrate Ground Water Concentrations

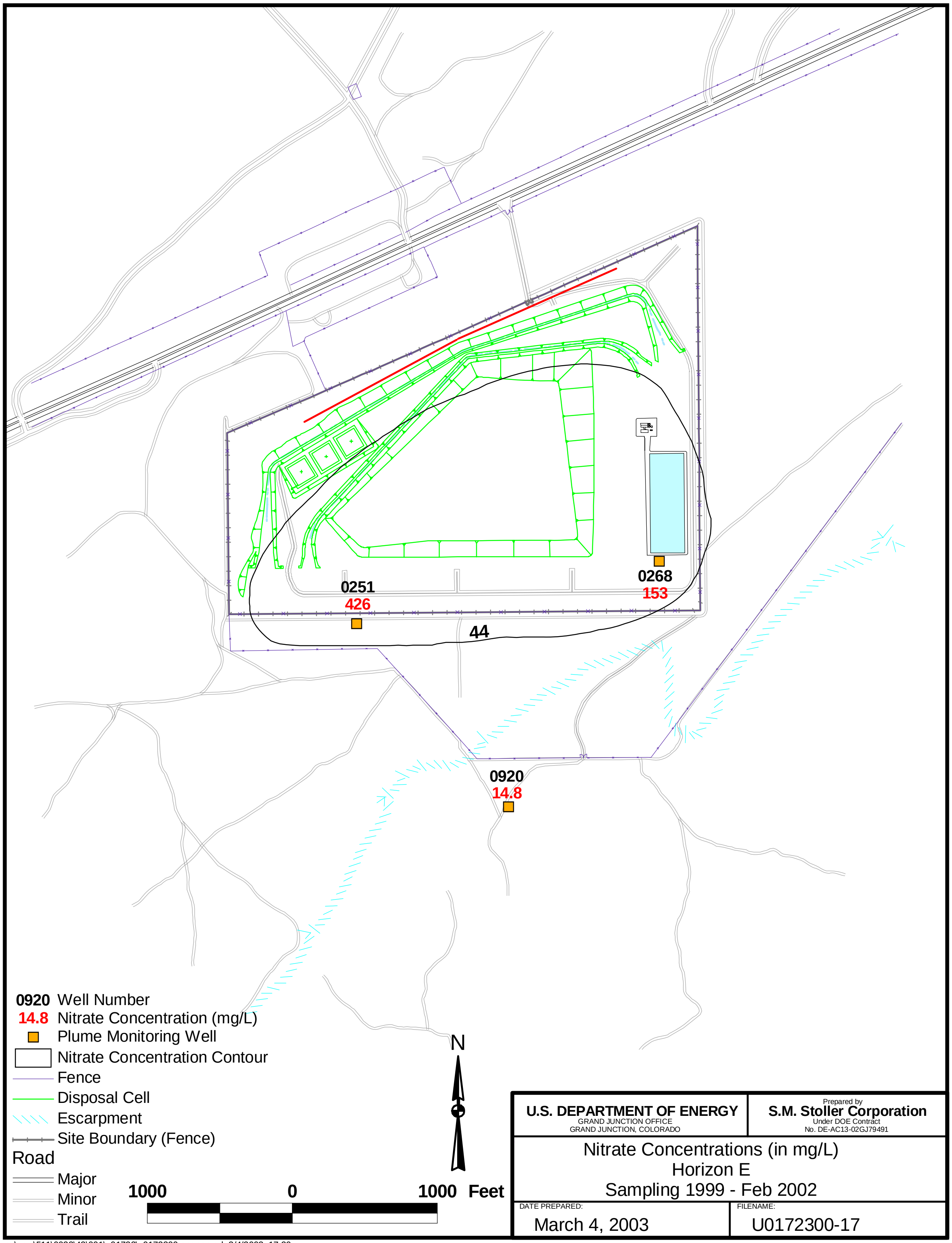

Figure 16a. Baseline Horizon E Nitrate Ground Water Concentrations

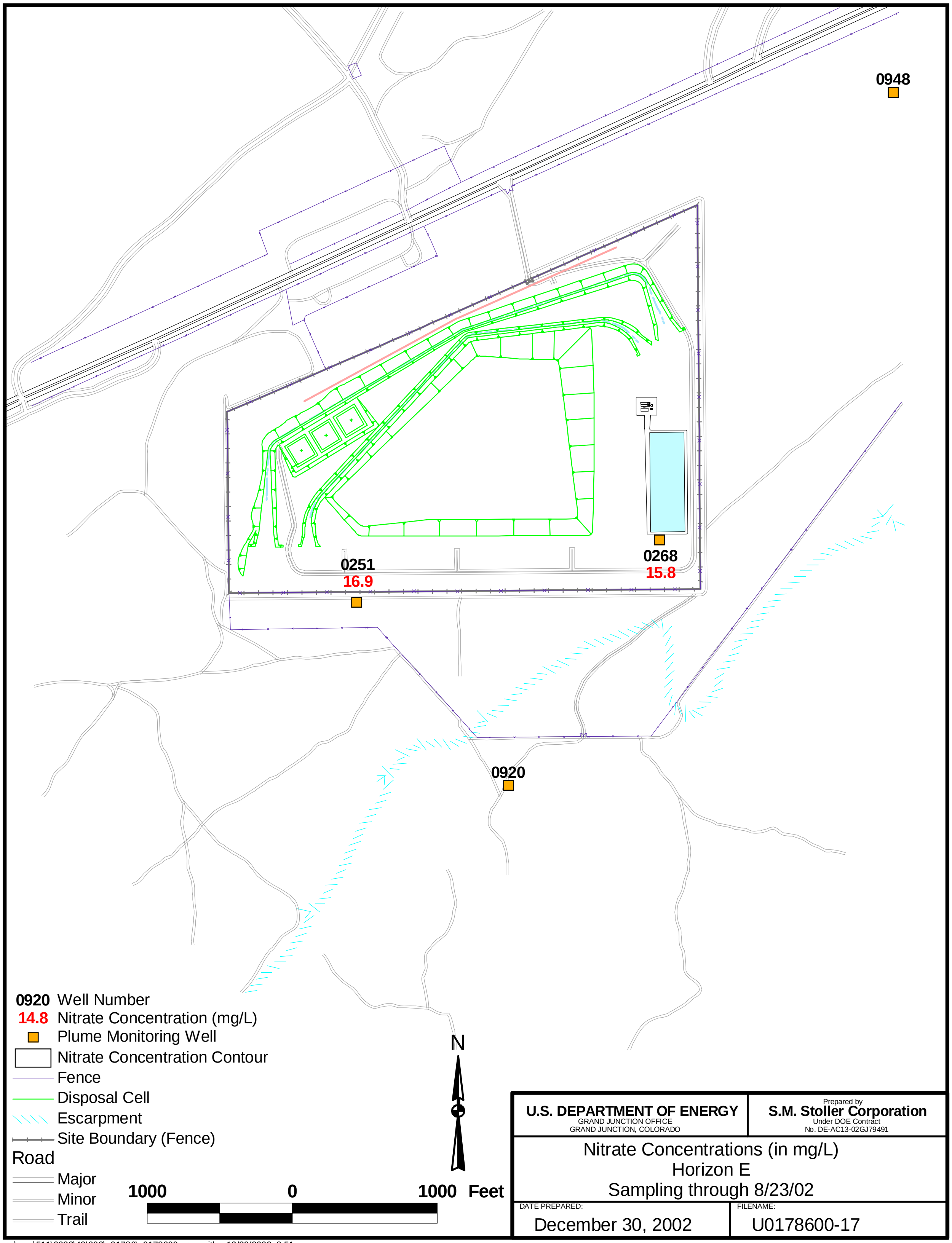

Figure 16b. August Horizon E Nitrate Ground Water Concentrations

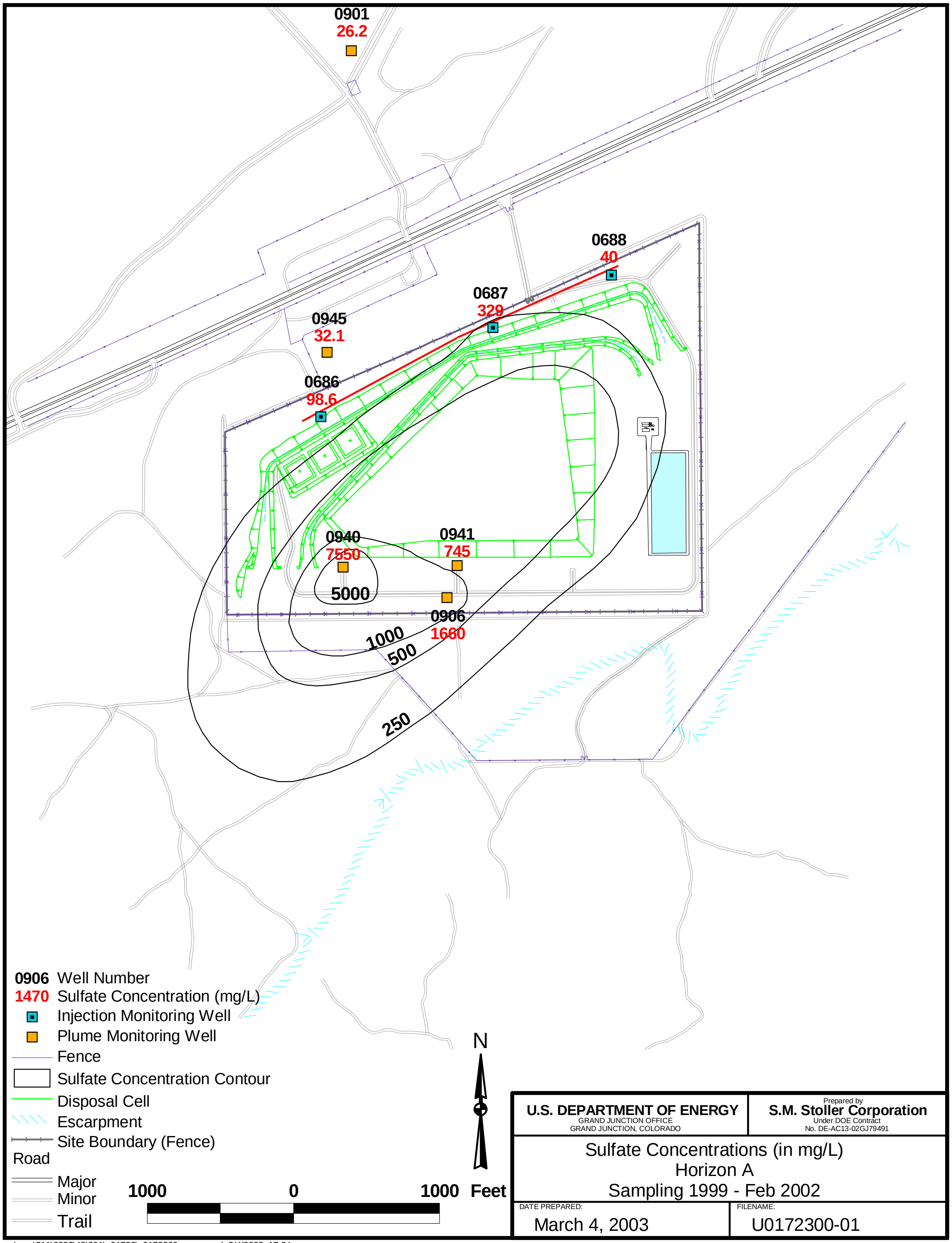

Figure 17a. Baseline Horizon A Sulfate Ground Water Concentrations

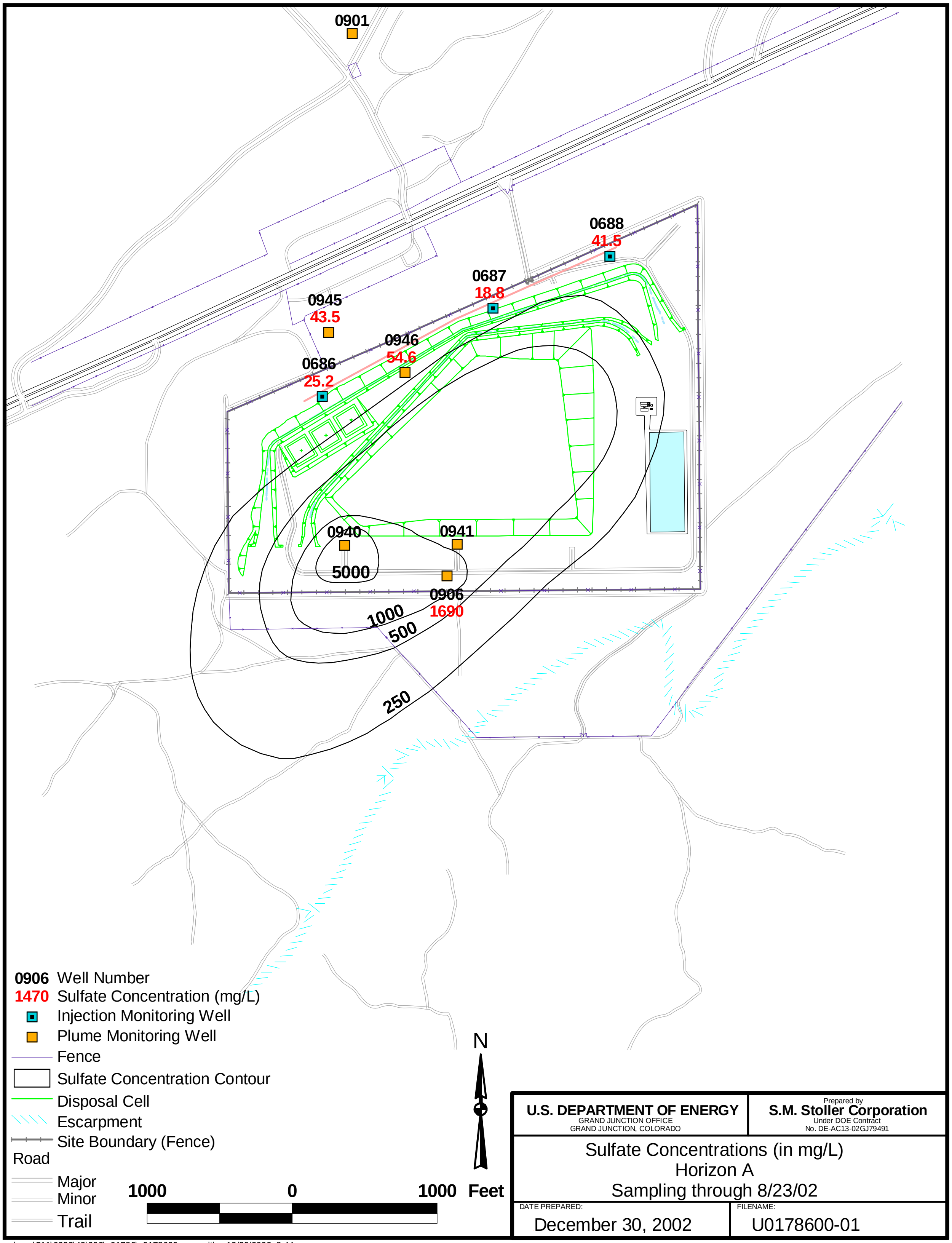

Figure 17b. August Horizon A Sulfate Ground Water Concentrations

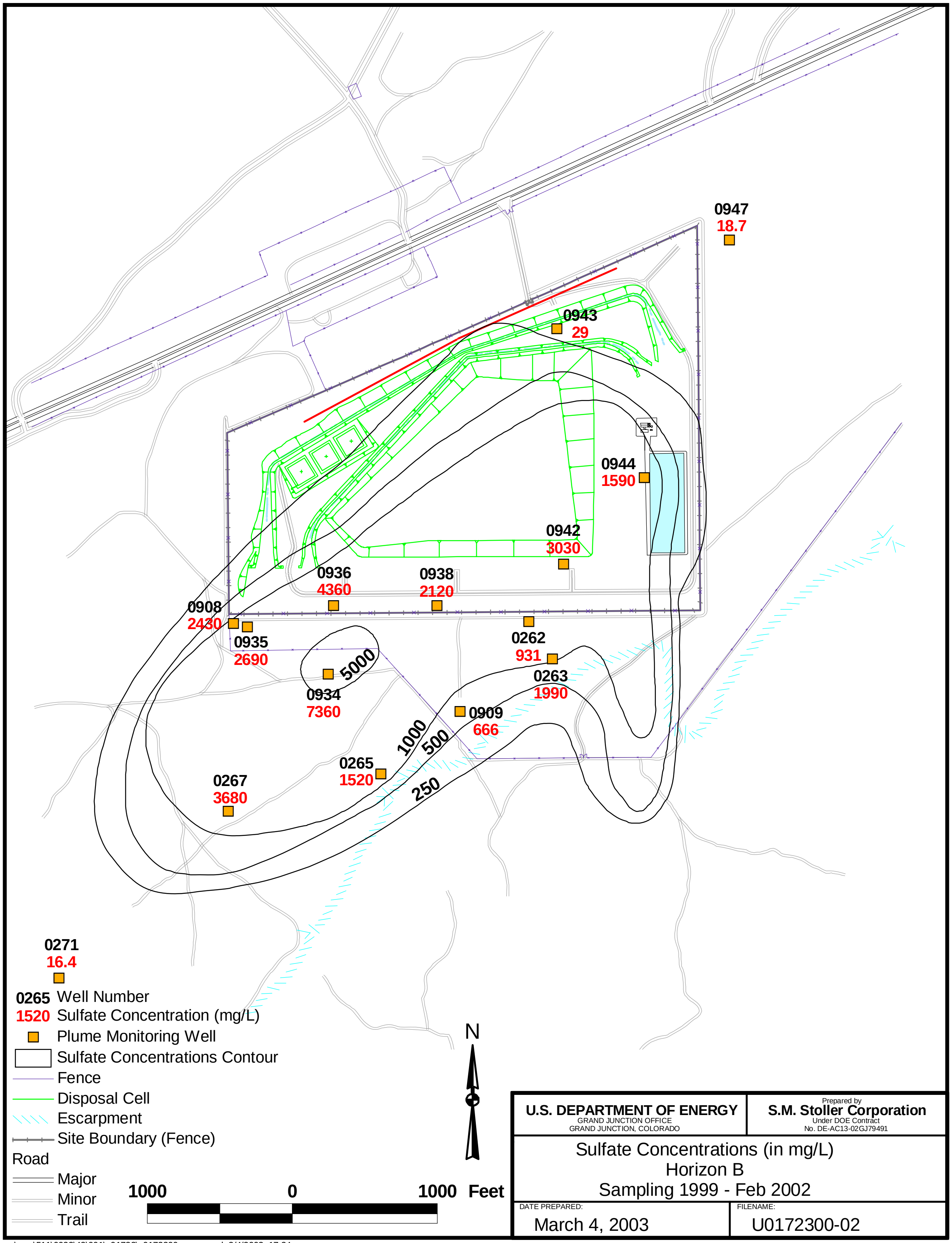

Figure 18a. Baseline Horizon B Sulfate Ground Water Concentrations

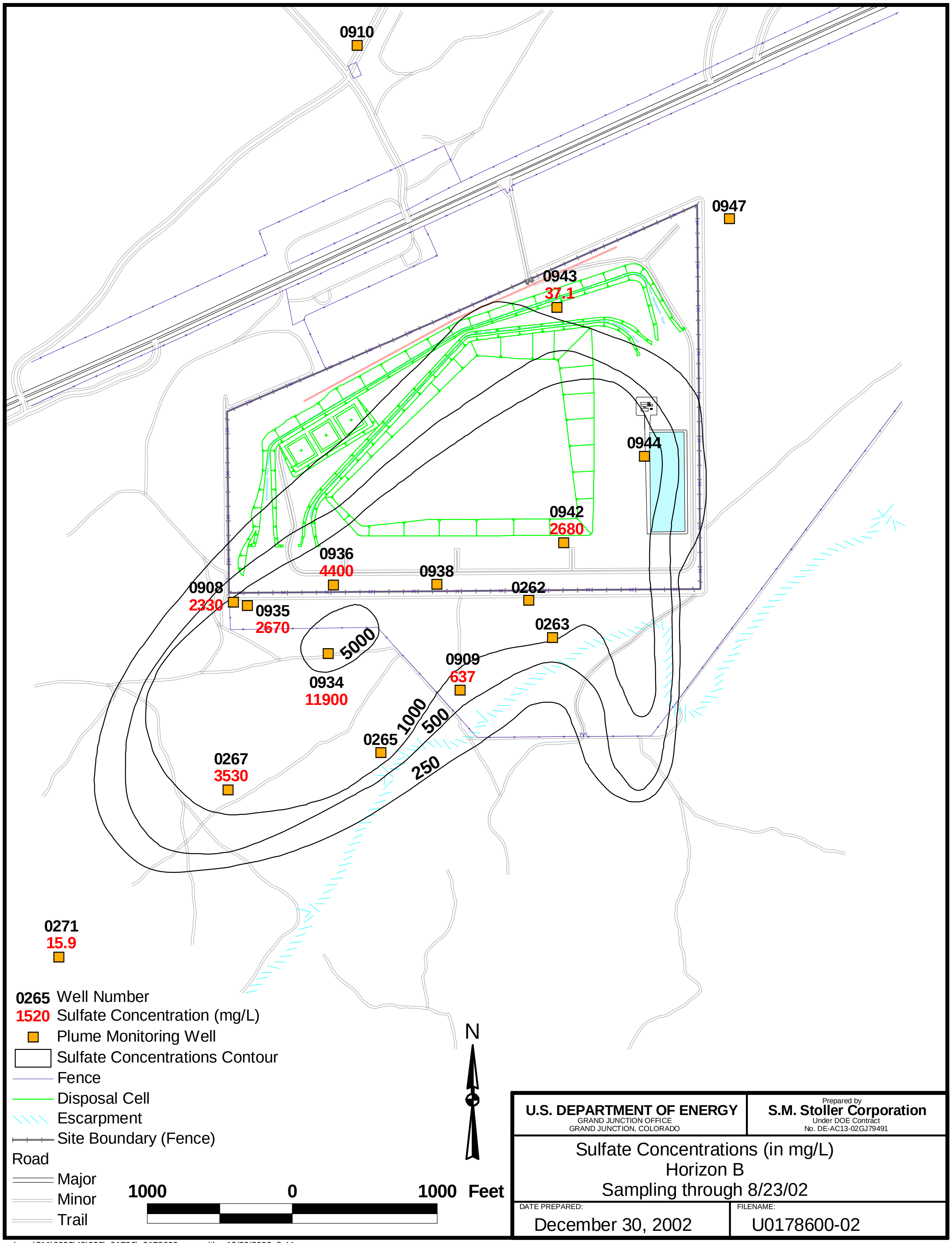

Figure 18b. August 2002 Horizon B Sulfate Ground Water Concentrations

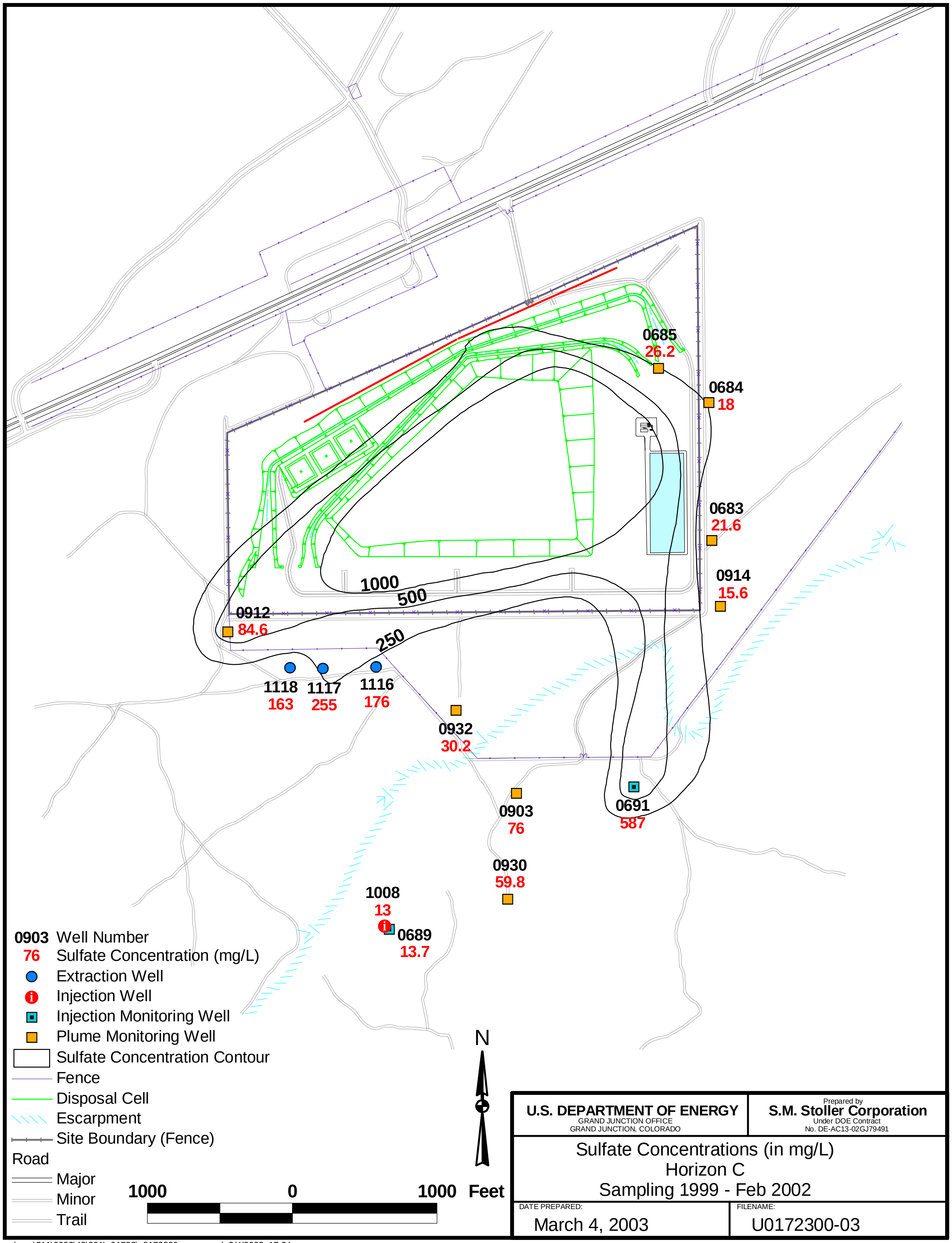

Figure 19a. Baseline Horizon C Sulfate Ground Water Concentrations

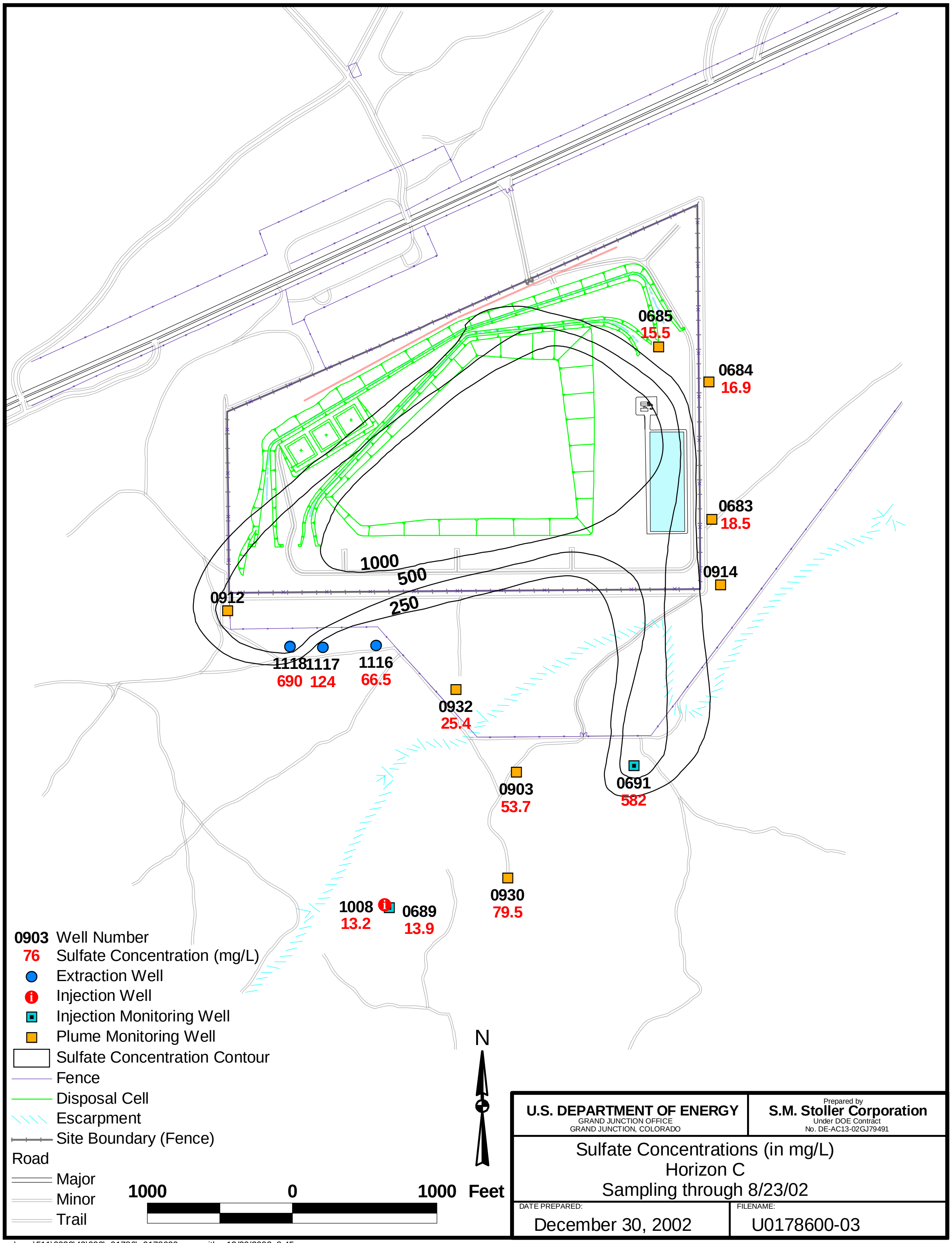

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Figure 19b. August 2002 Horizon C Sulfate Ground Water Concentrations

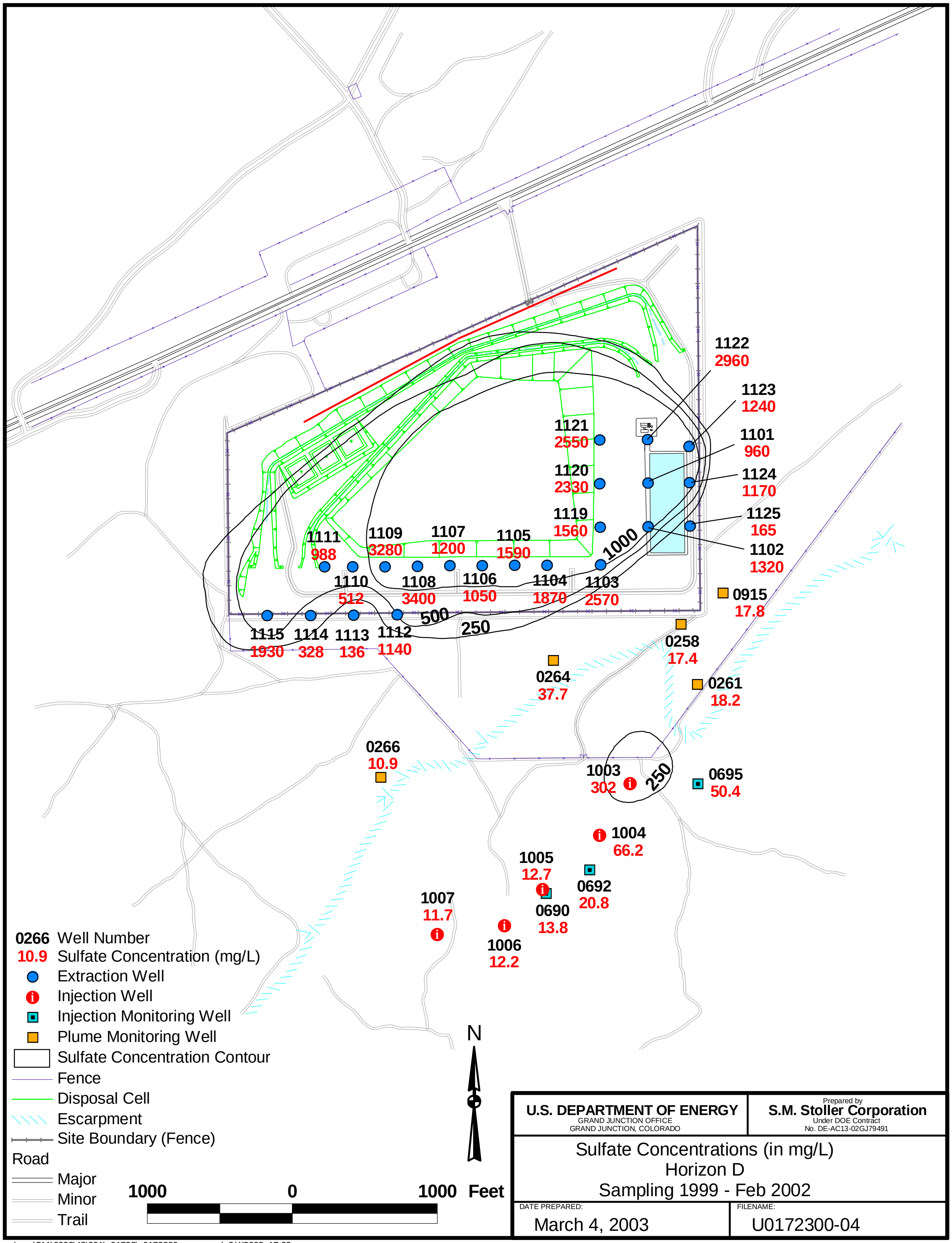

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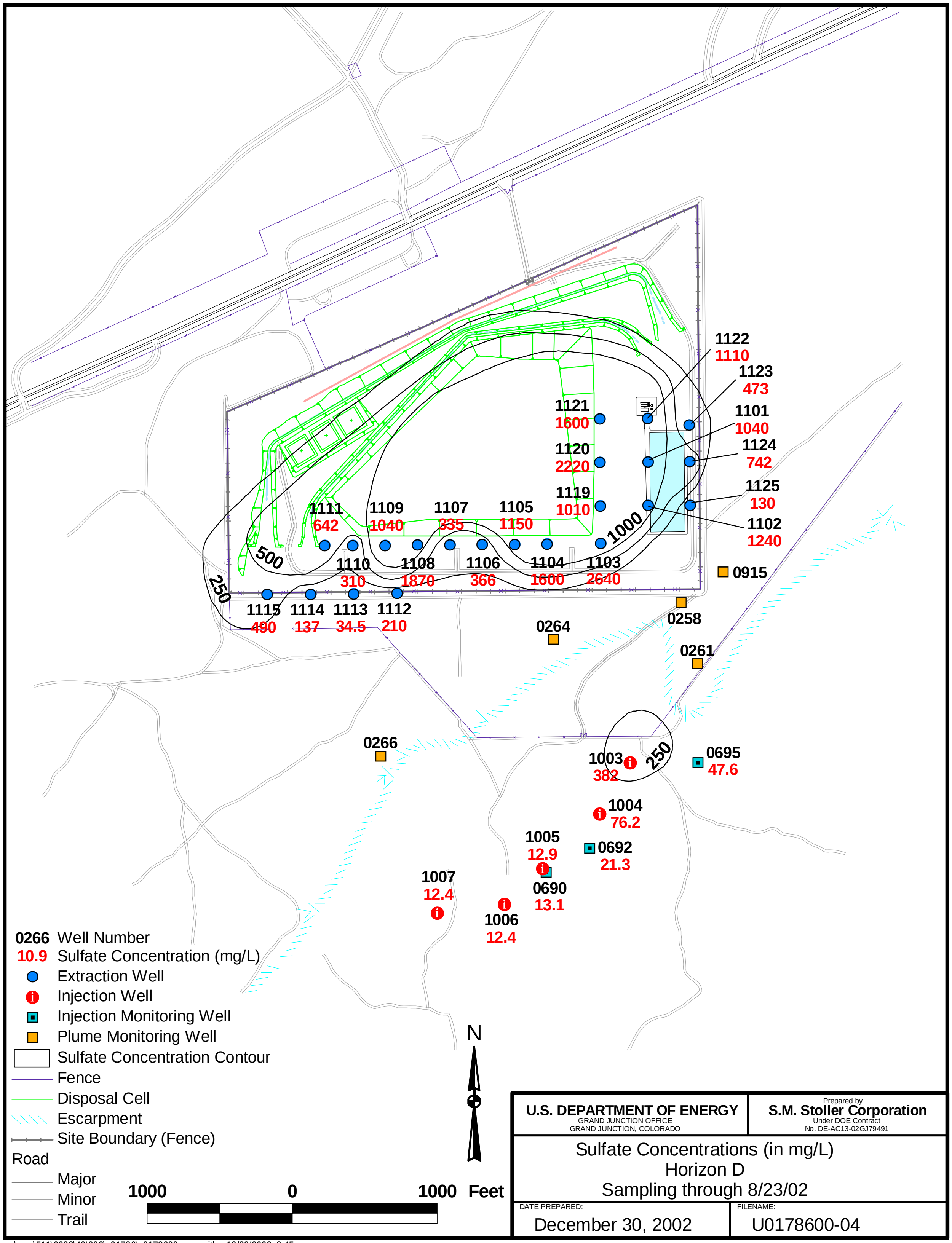
Figure 20a. Baseline Horizon D Sulfate Ground Water Concentrations



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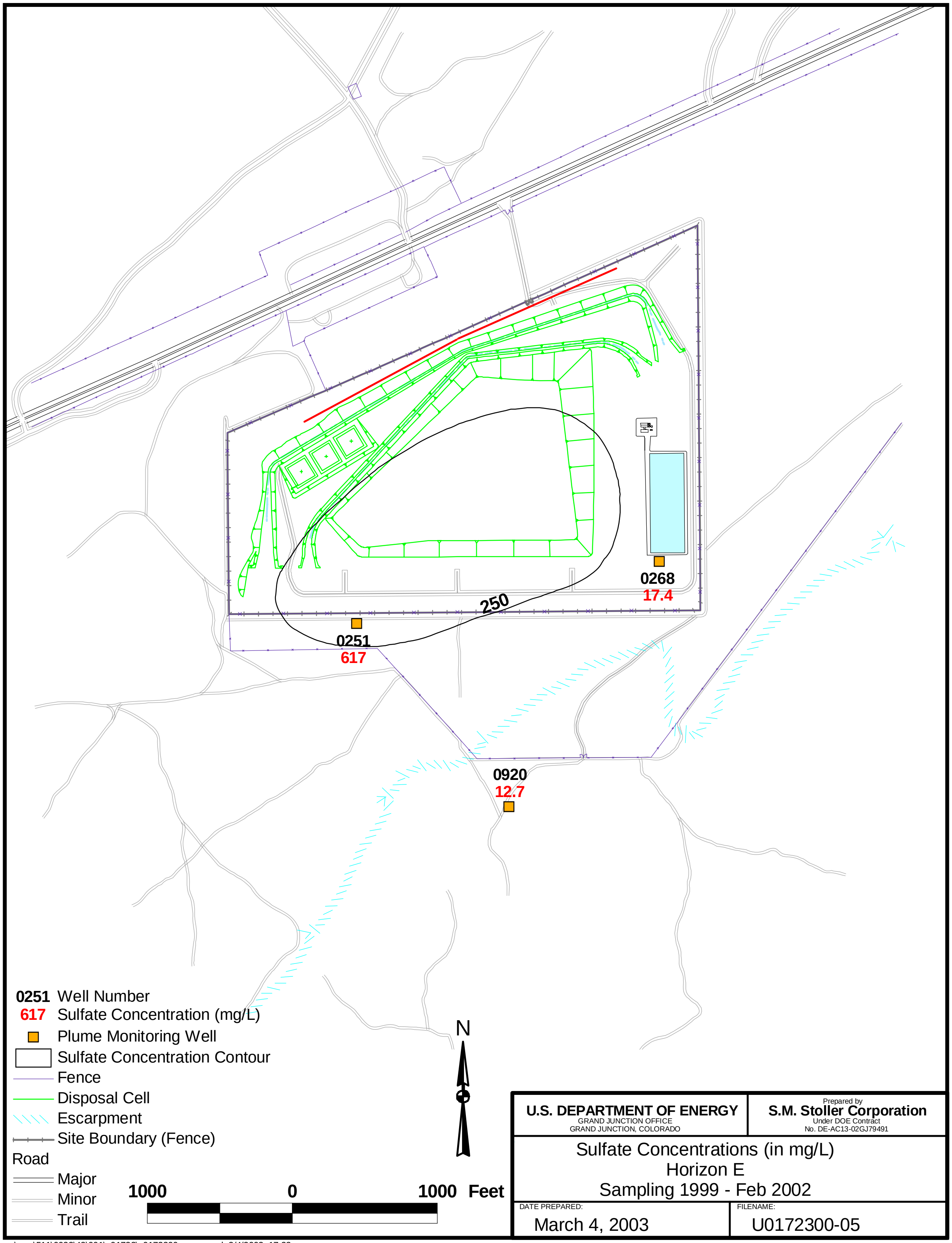

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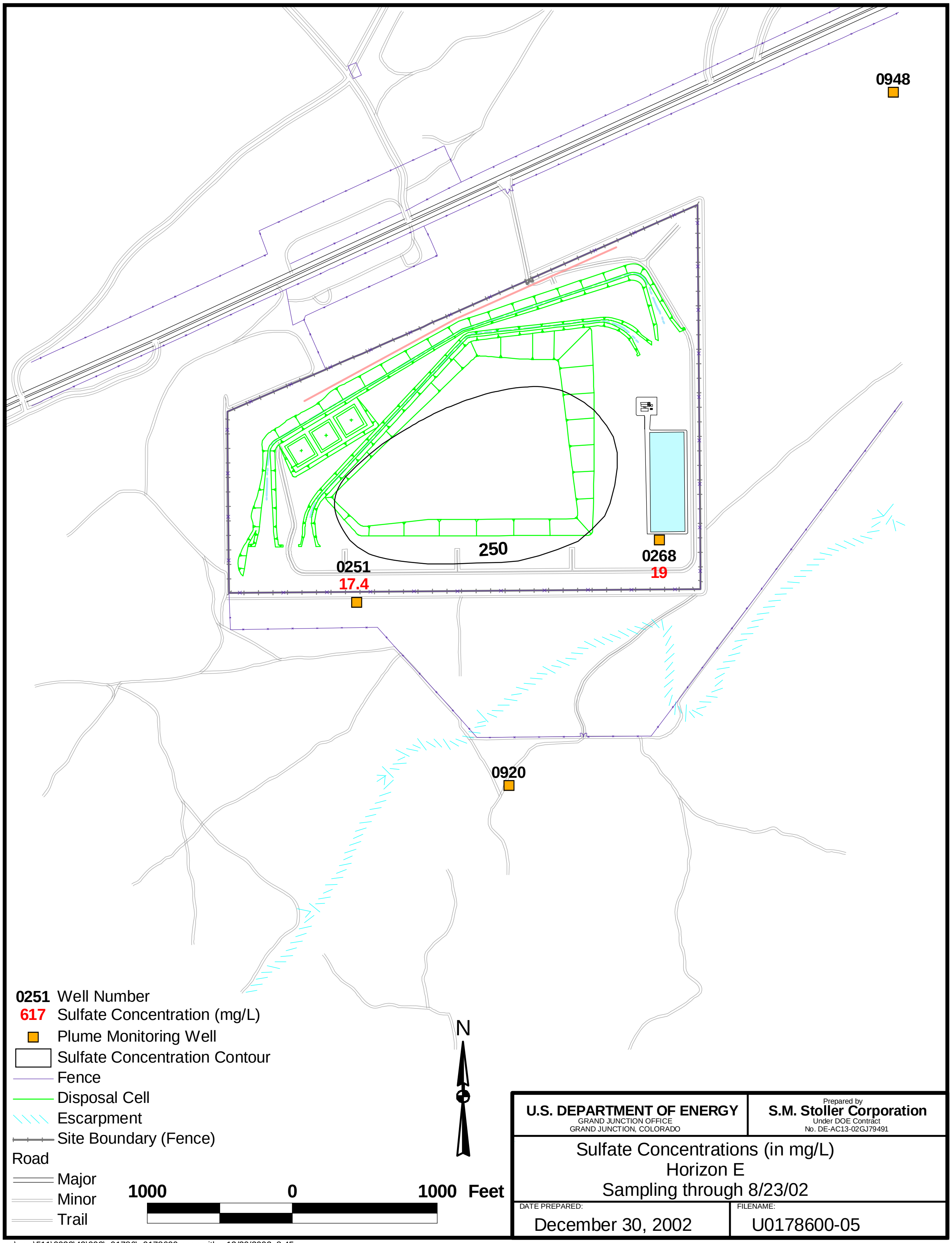

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Figure 21b. August 2002 Horizon E Sulfate Ground Water Concentrations

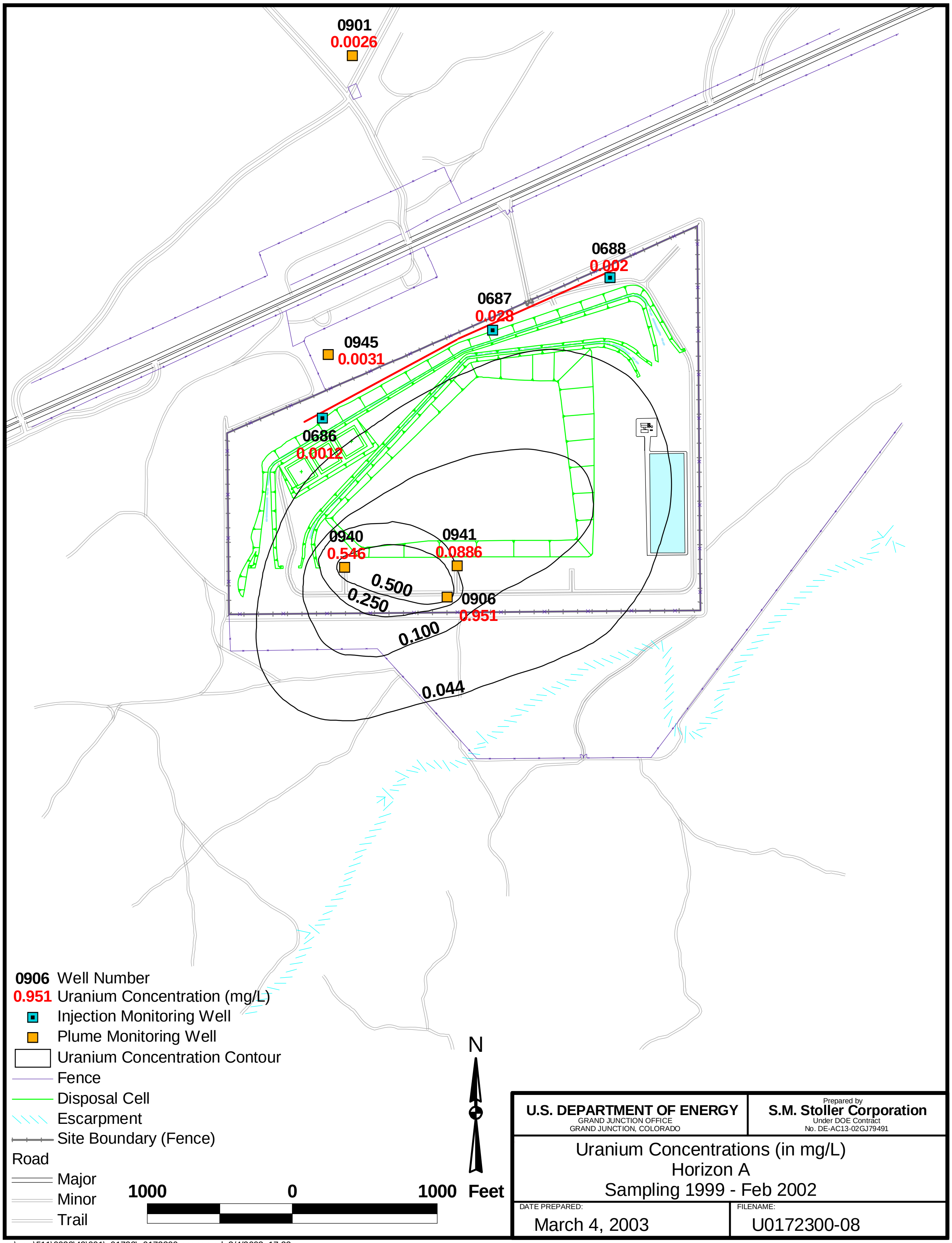

Figure 22a. Baseline Horizon A Uranium Ground Water Concentrations

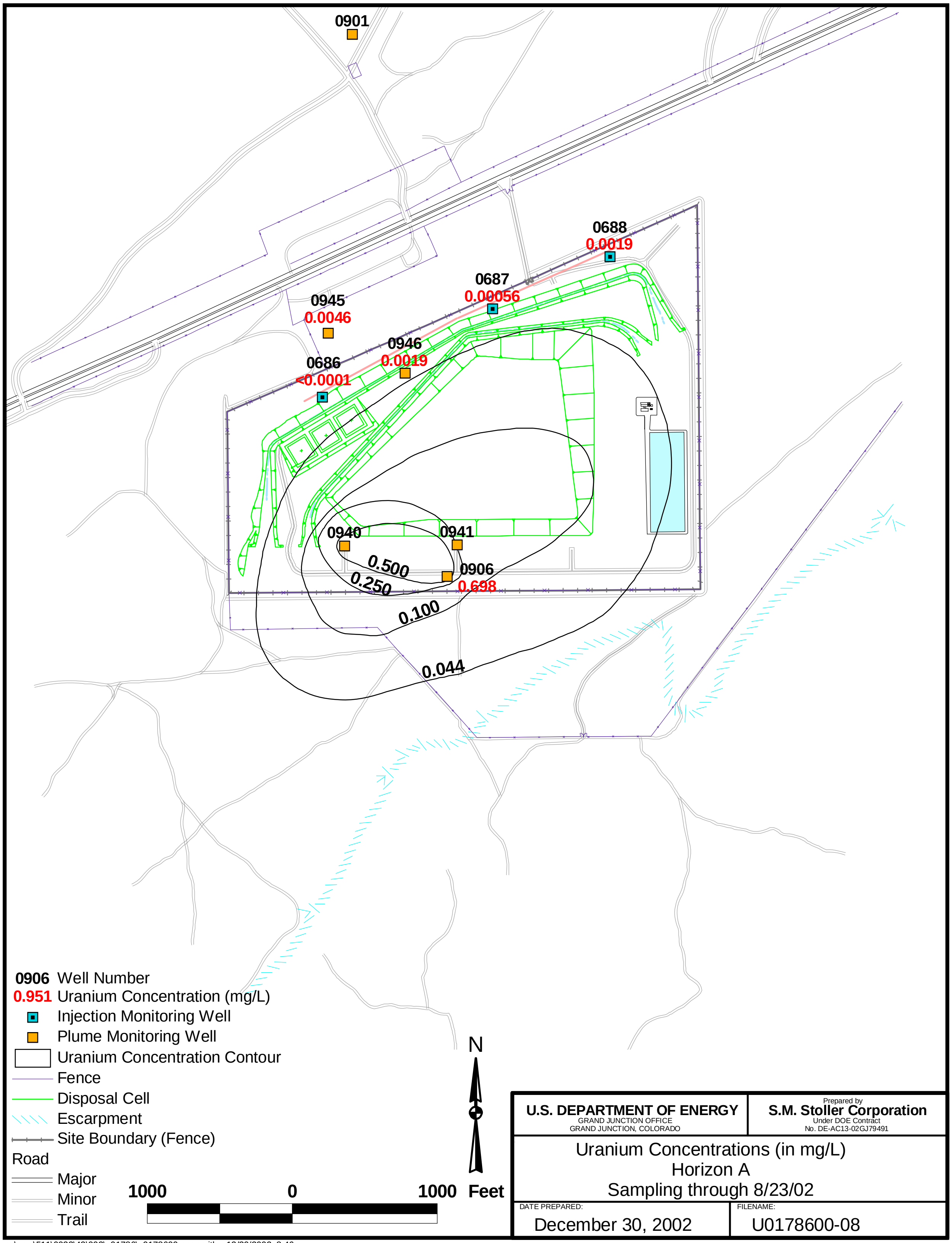

Figure 22b. August 2002 Horizon A Uranium Ground Water Concentrations

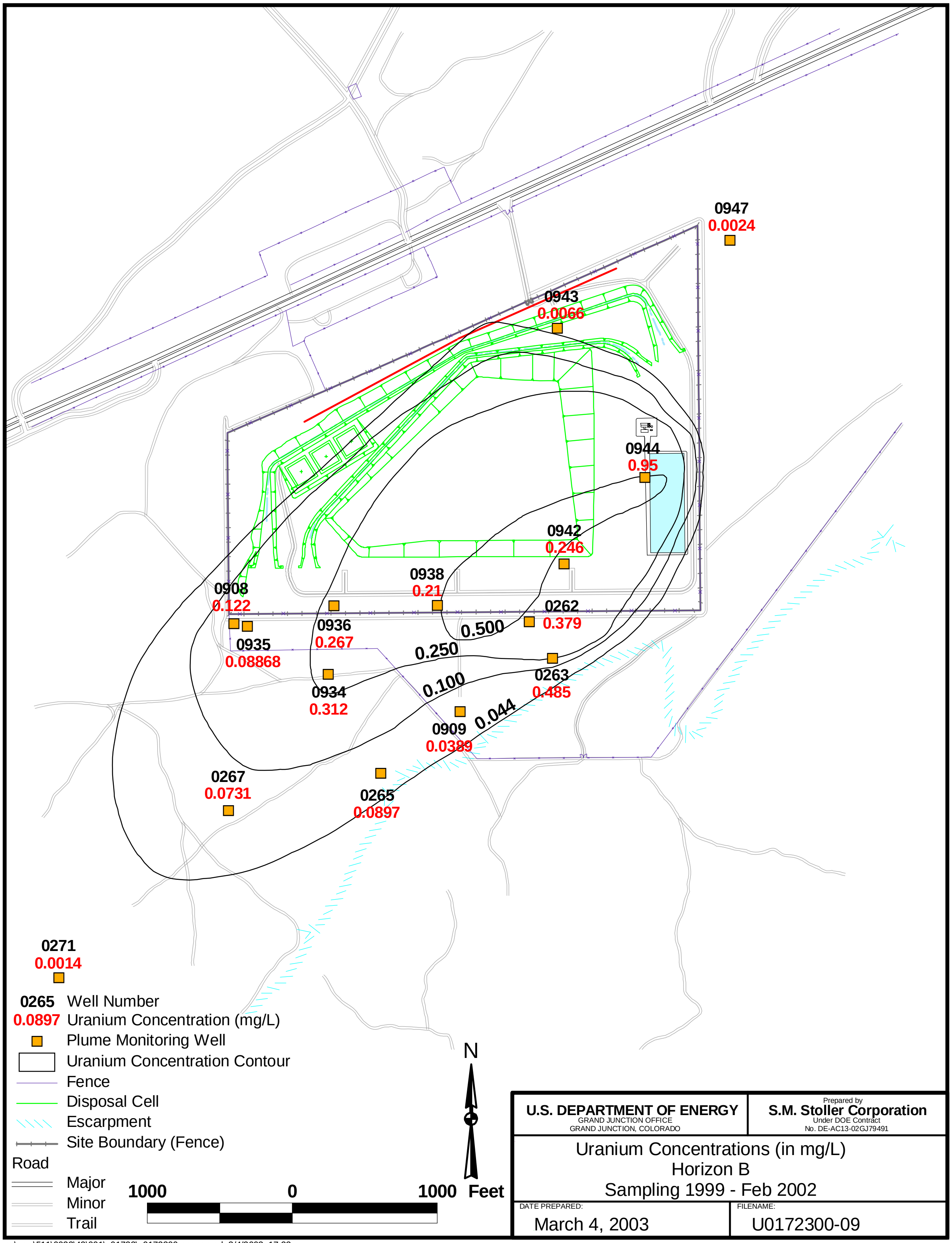

Figure 23a. Baseline Horizon B Uranium Ground Water Concentrations

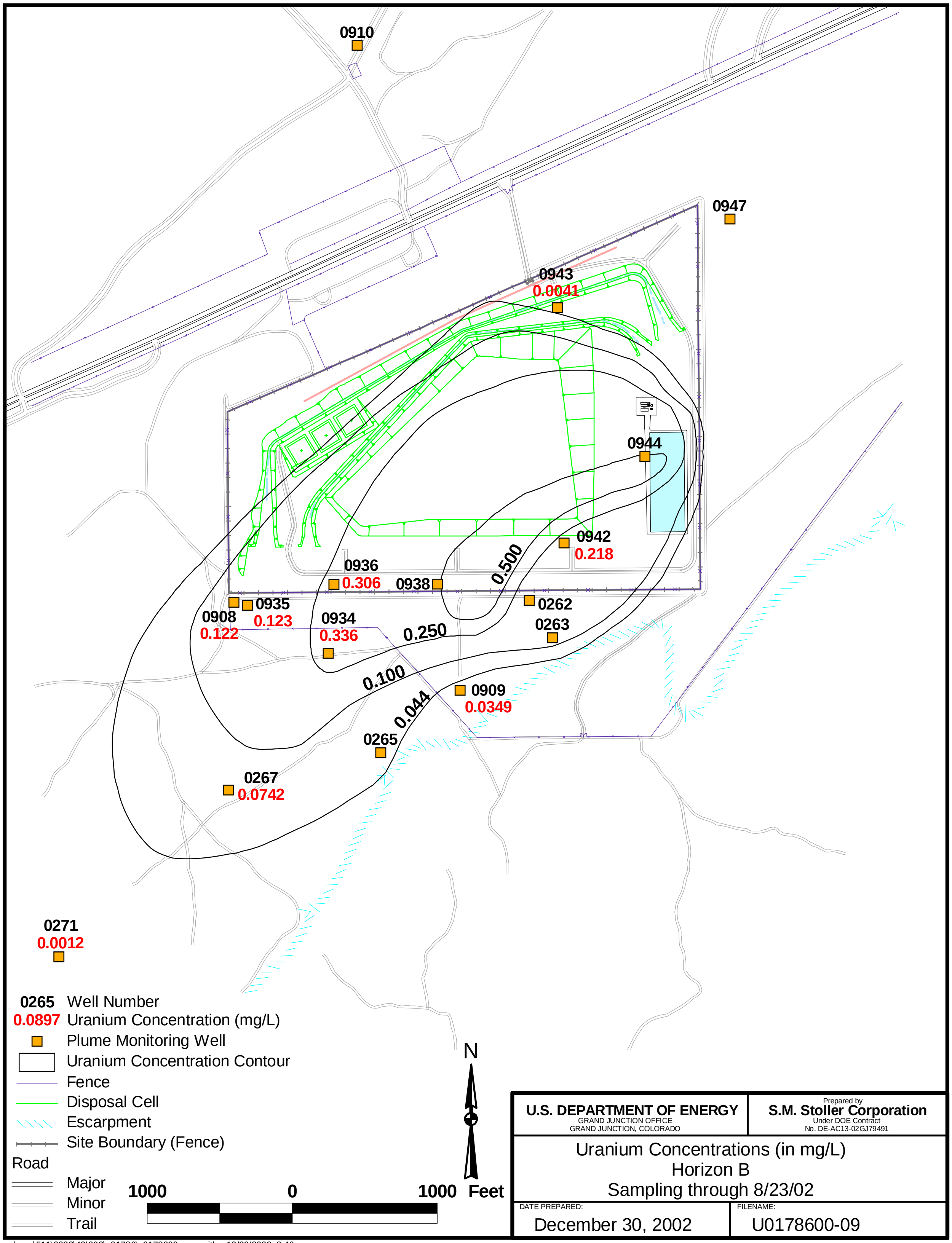

Figure 23b. August 2002 Horizon B Uranium Concentrations

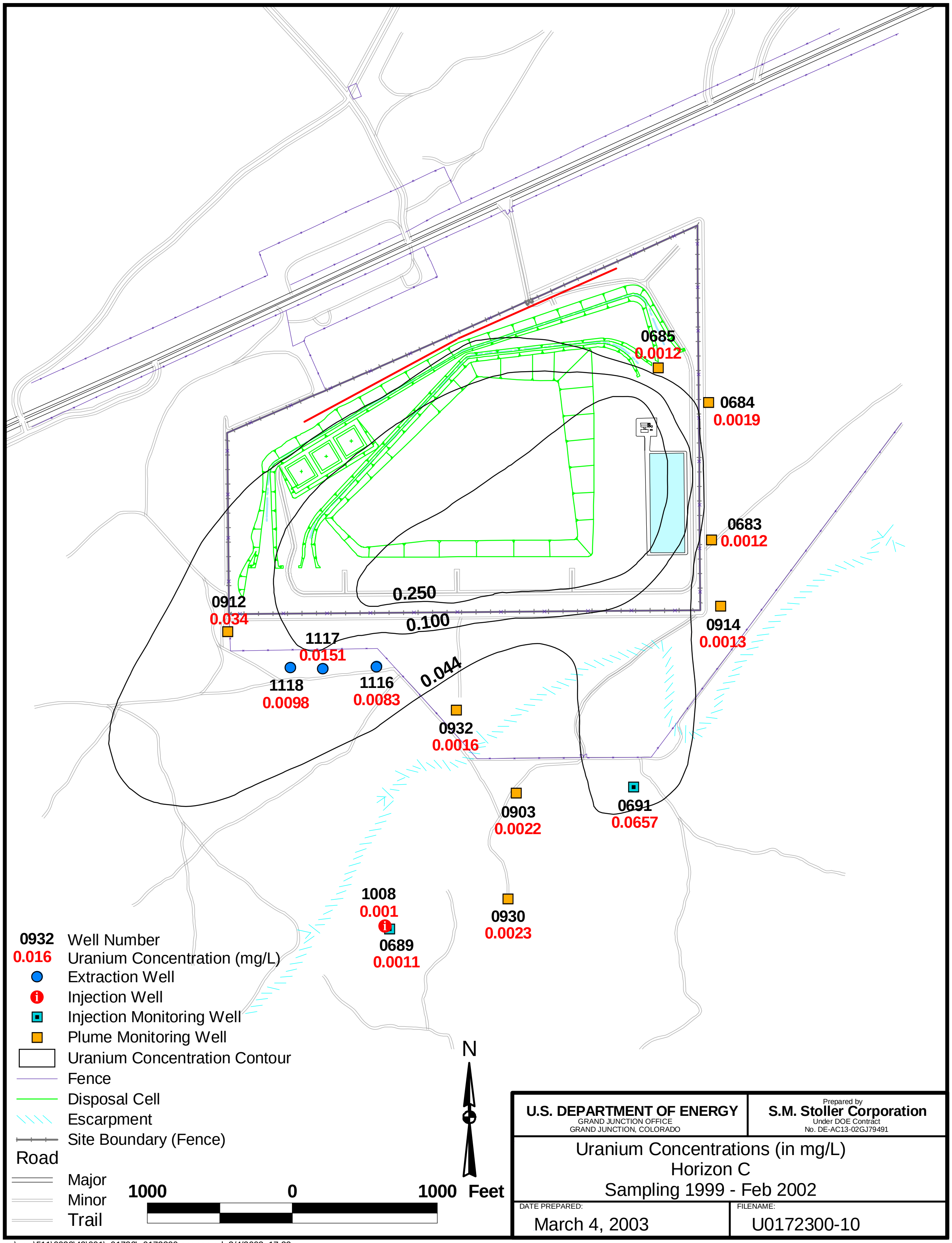

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Figure 24a. Baseline Horizon C Uranium Ground Water Concentrations

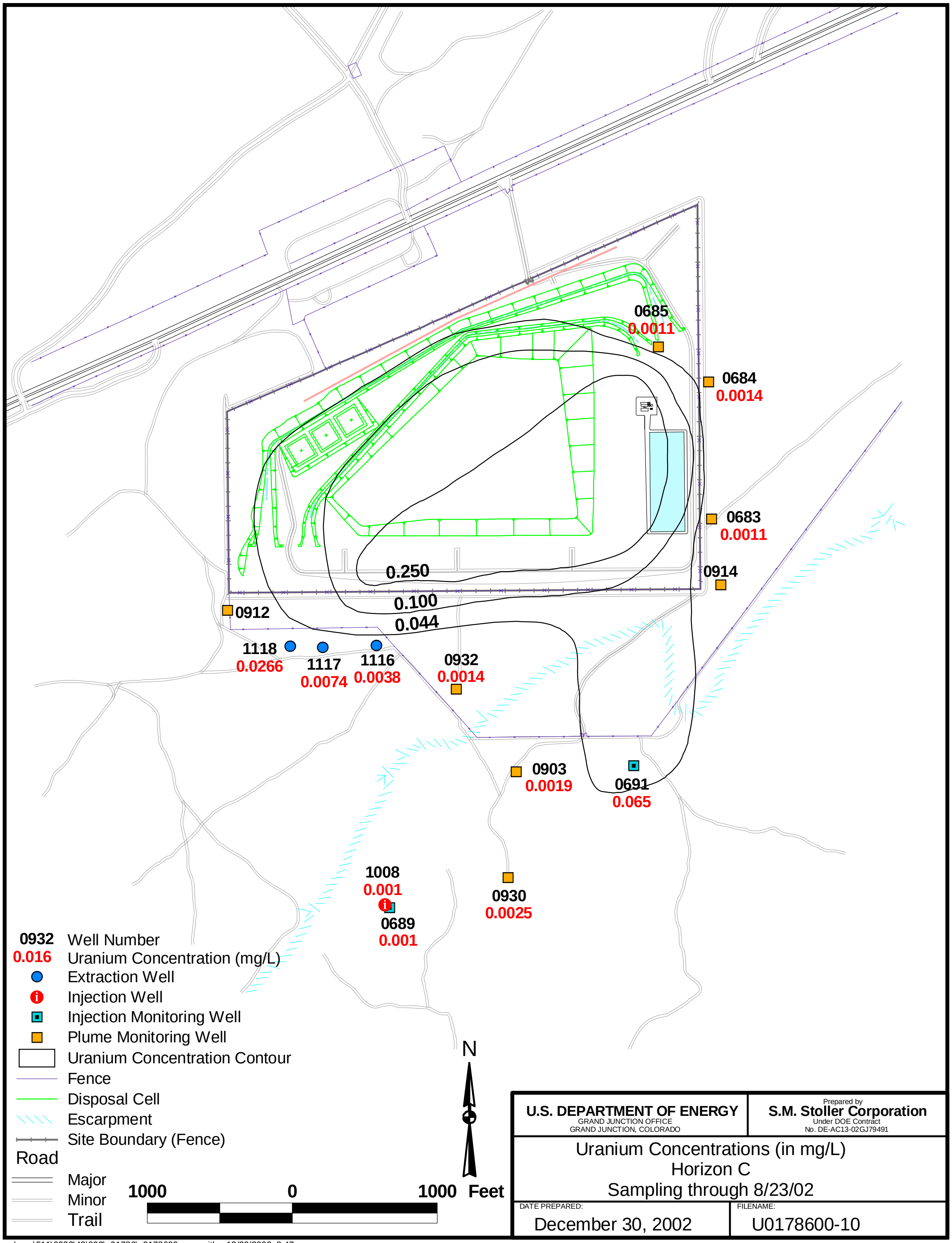

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Figure 24b. August 2002 Horizon C Uranium Concentrations

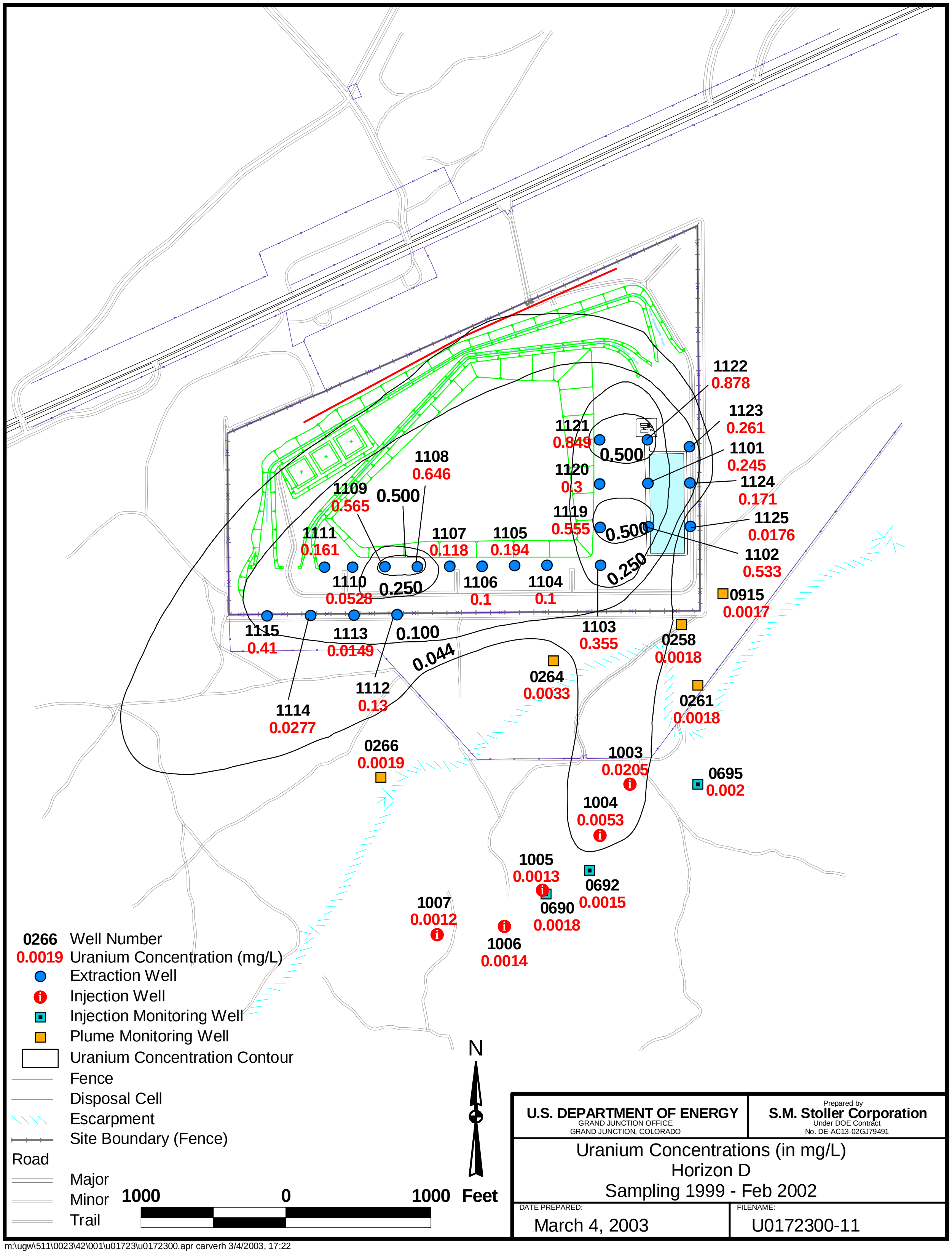
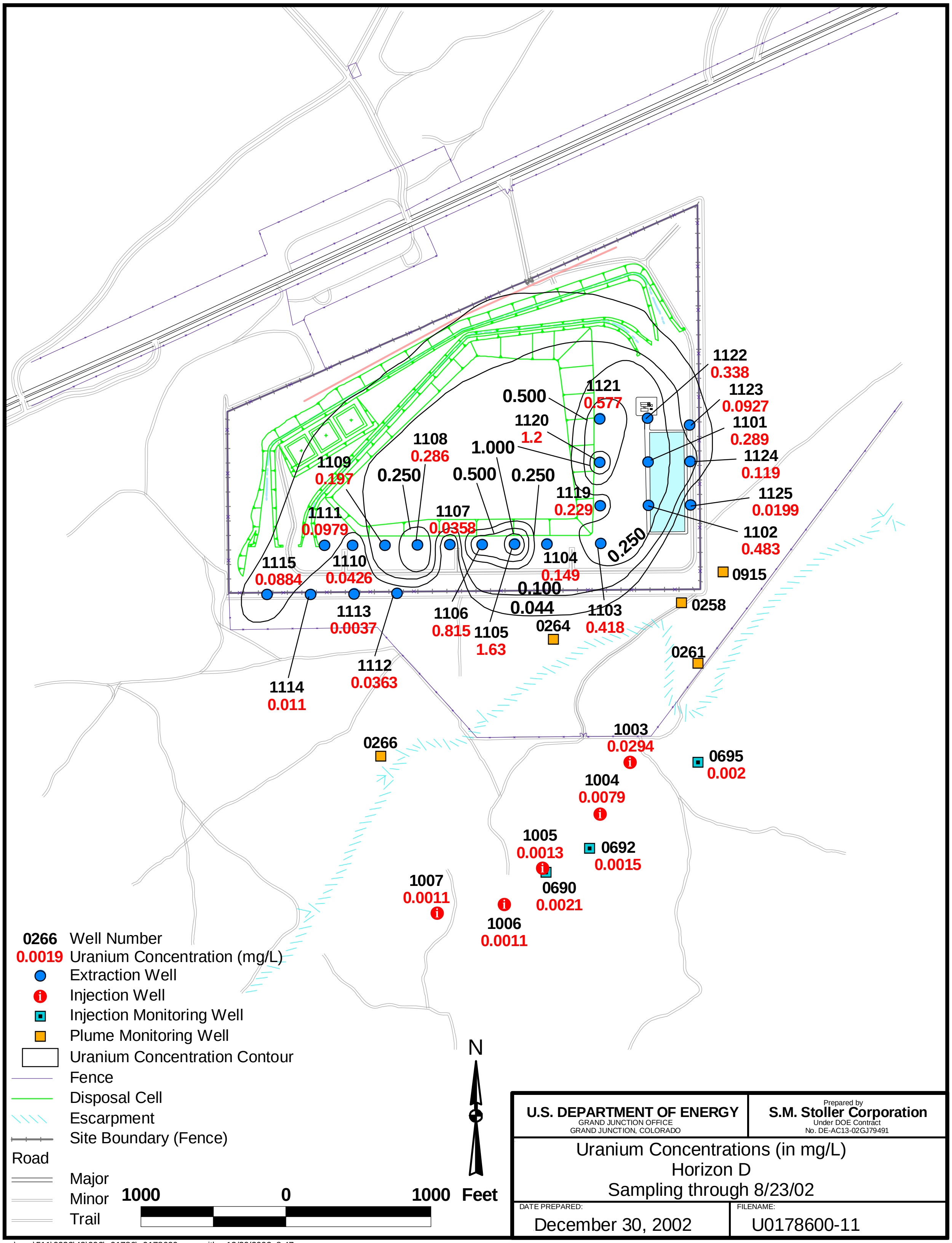


Figure 25a. Baseline Horizon D Uranium Ground Water Concentrations



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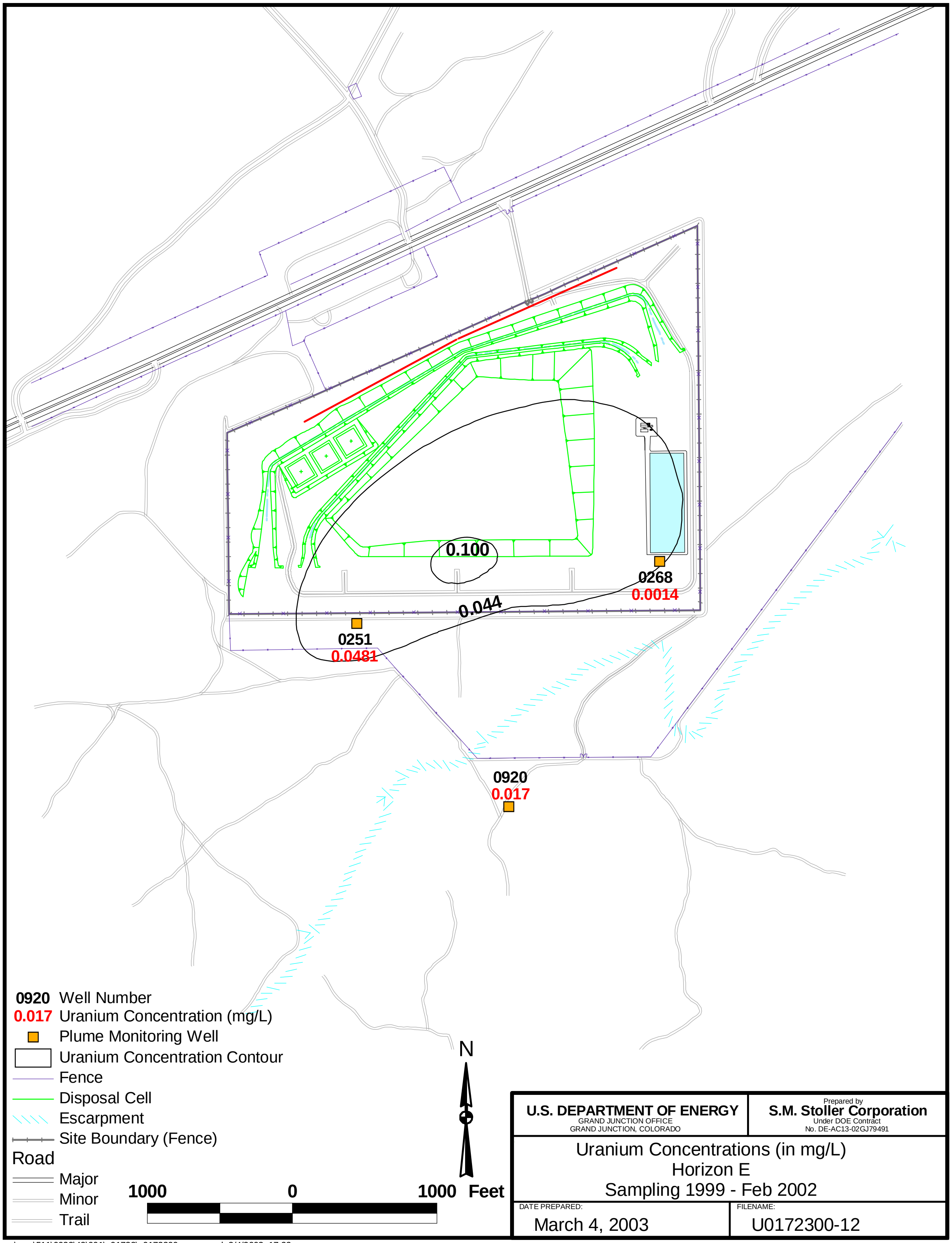

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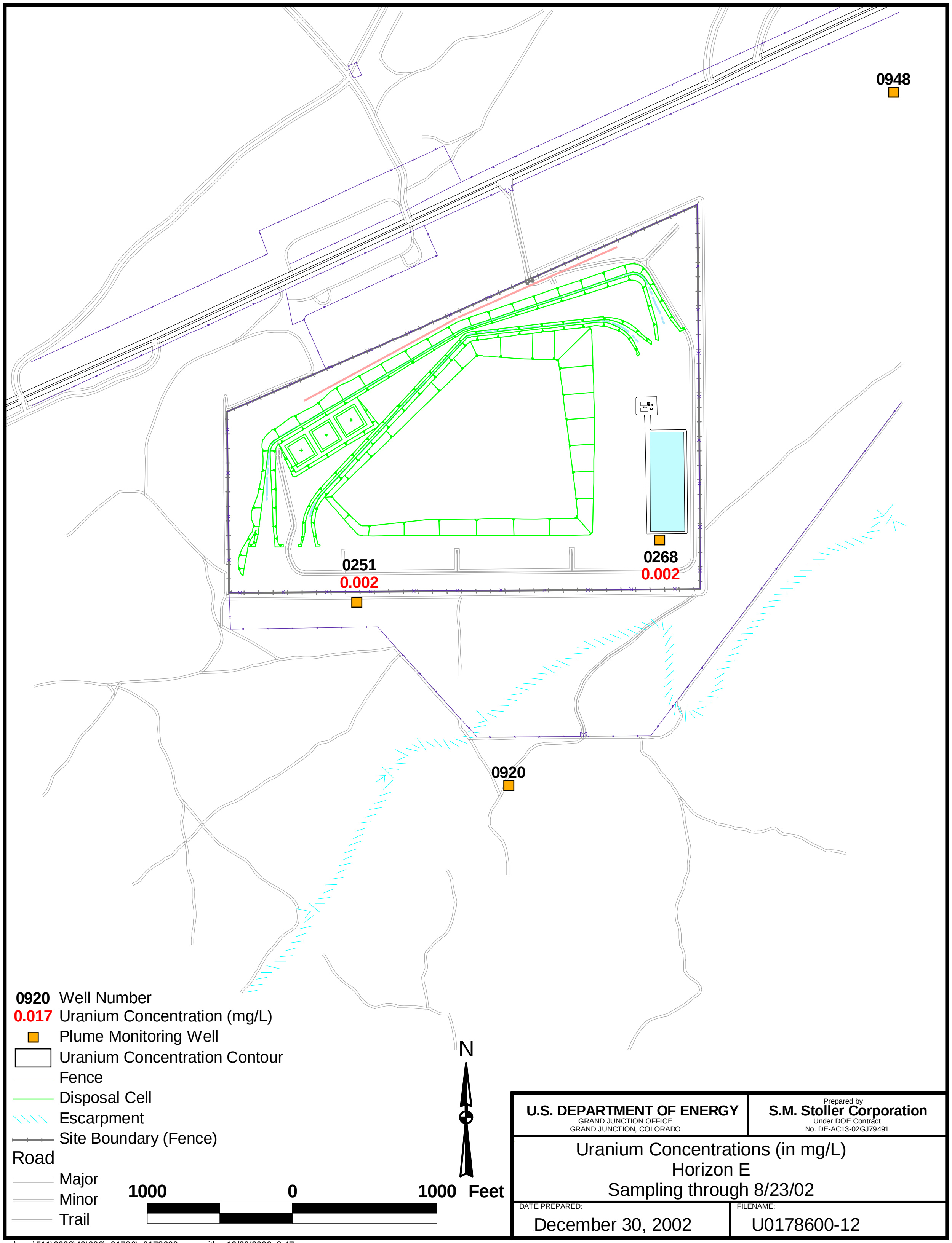

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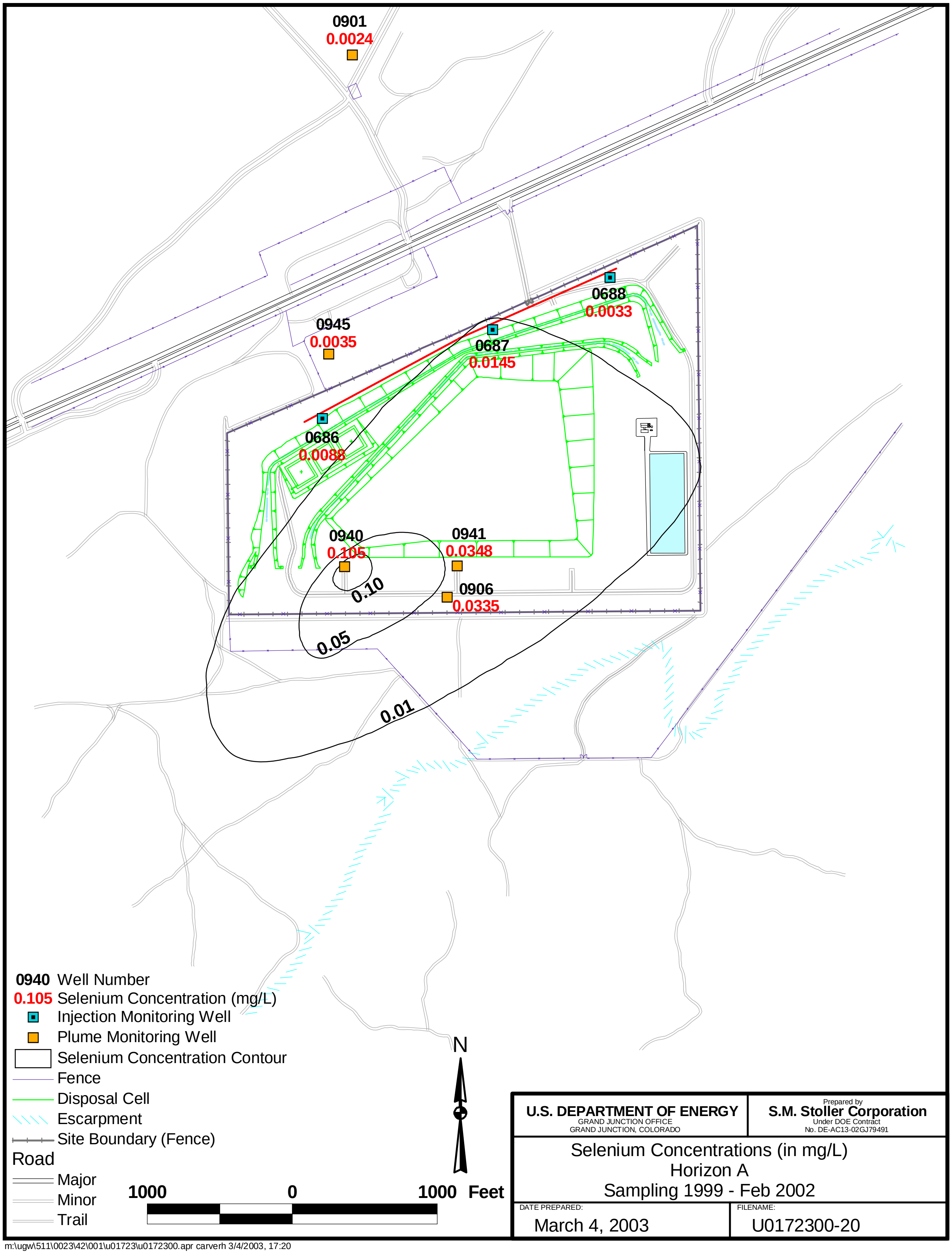

Figure 27a. Baseline Horizon A Selenium Ground Water Concentrations

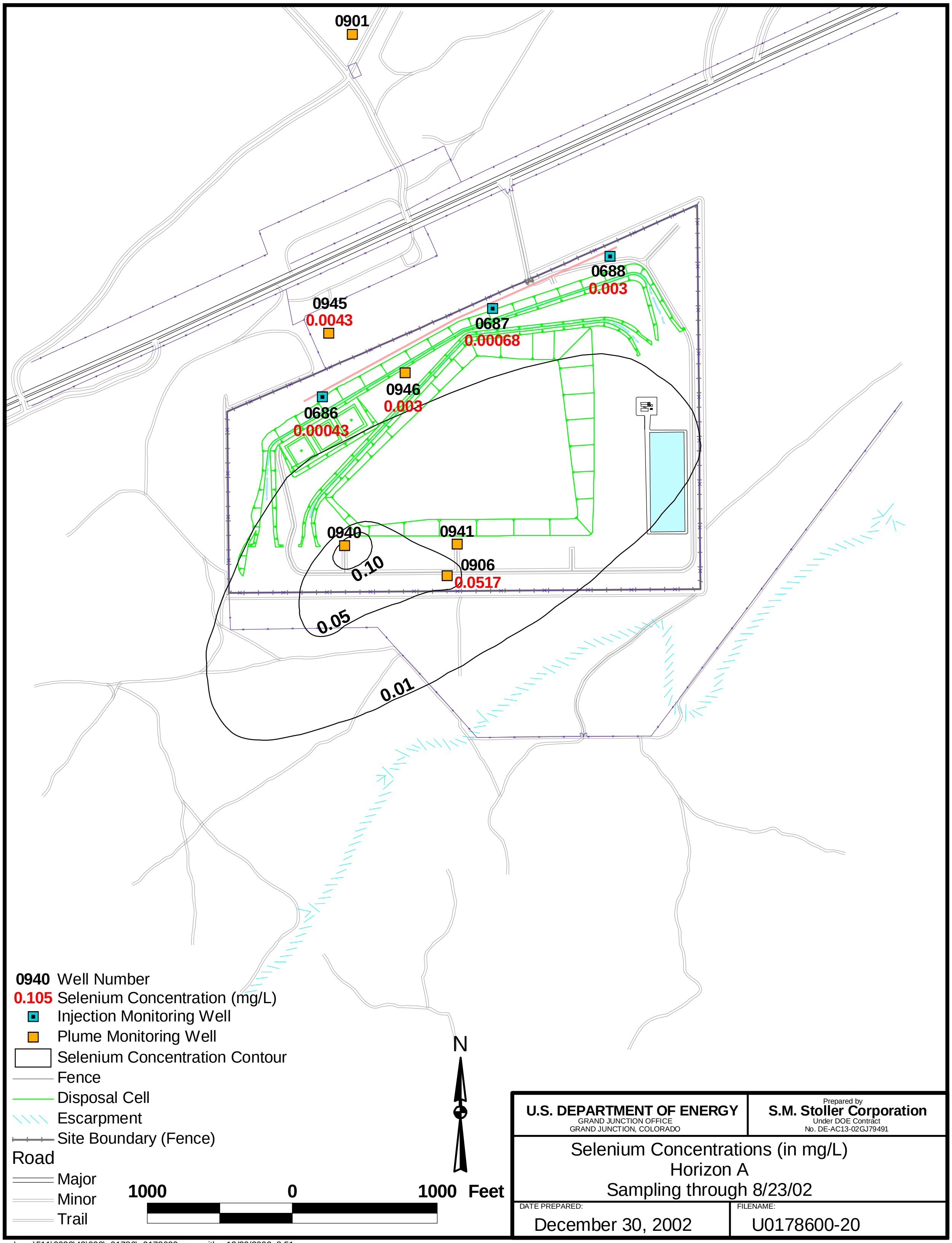

Figure 27b. August 2002 Horizon A Selenium Ground Water Concentrations

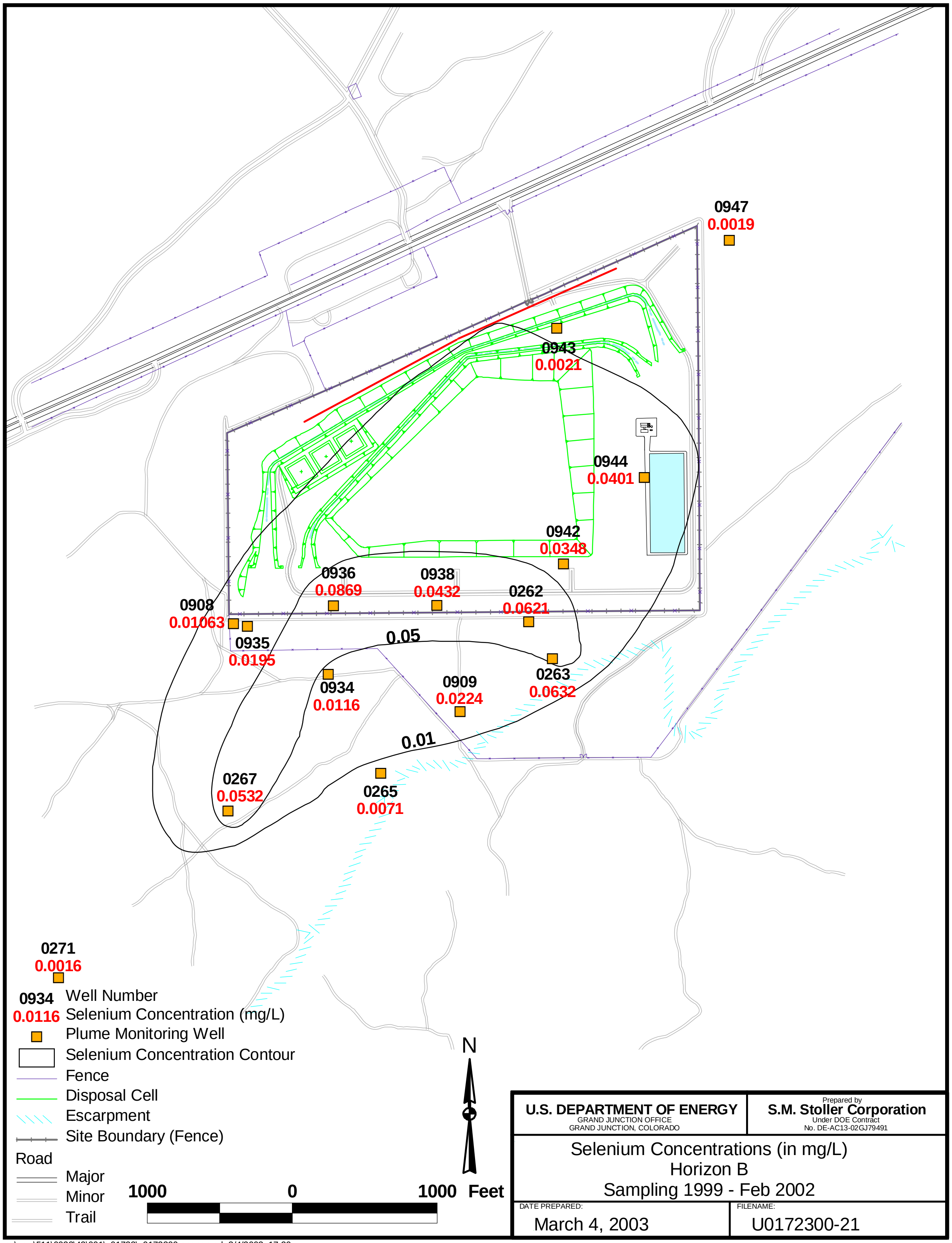

Figure 28a. Baseline Horizon B Selenium Ground Water Concentrations

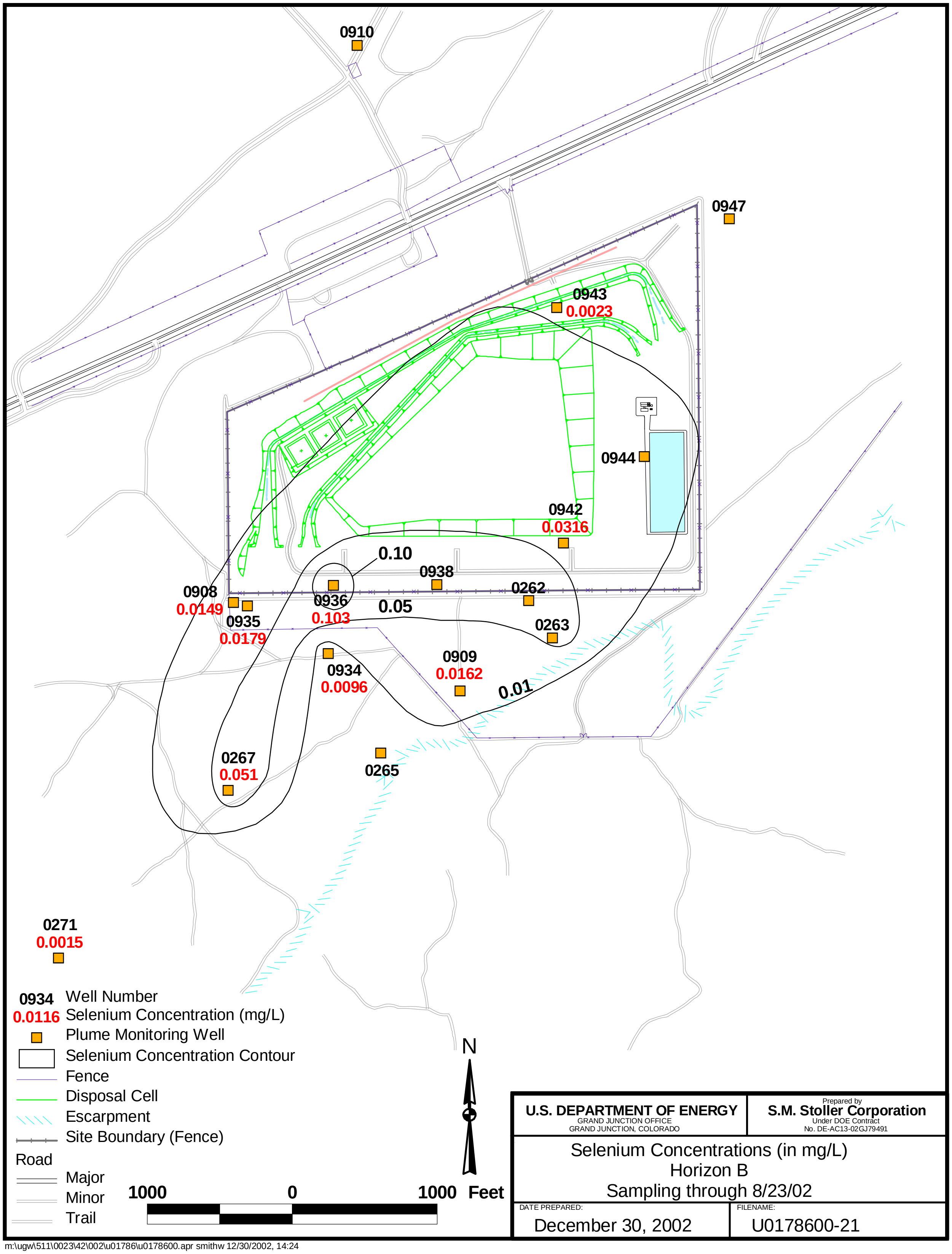

Figure 28b. August 2002 Horizon B Selenium Ground Water Concentrations

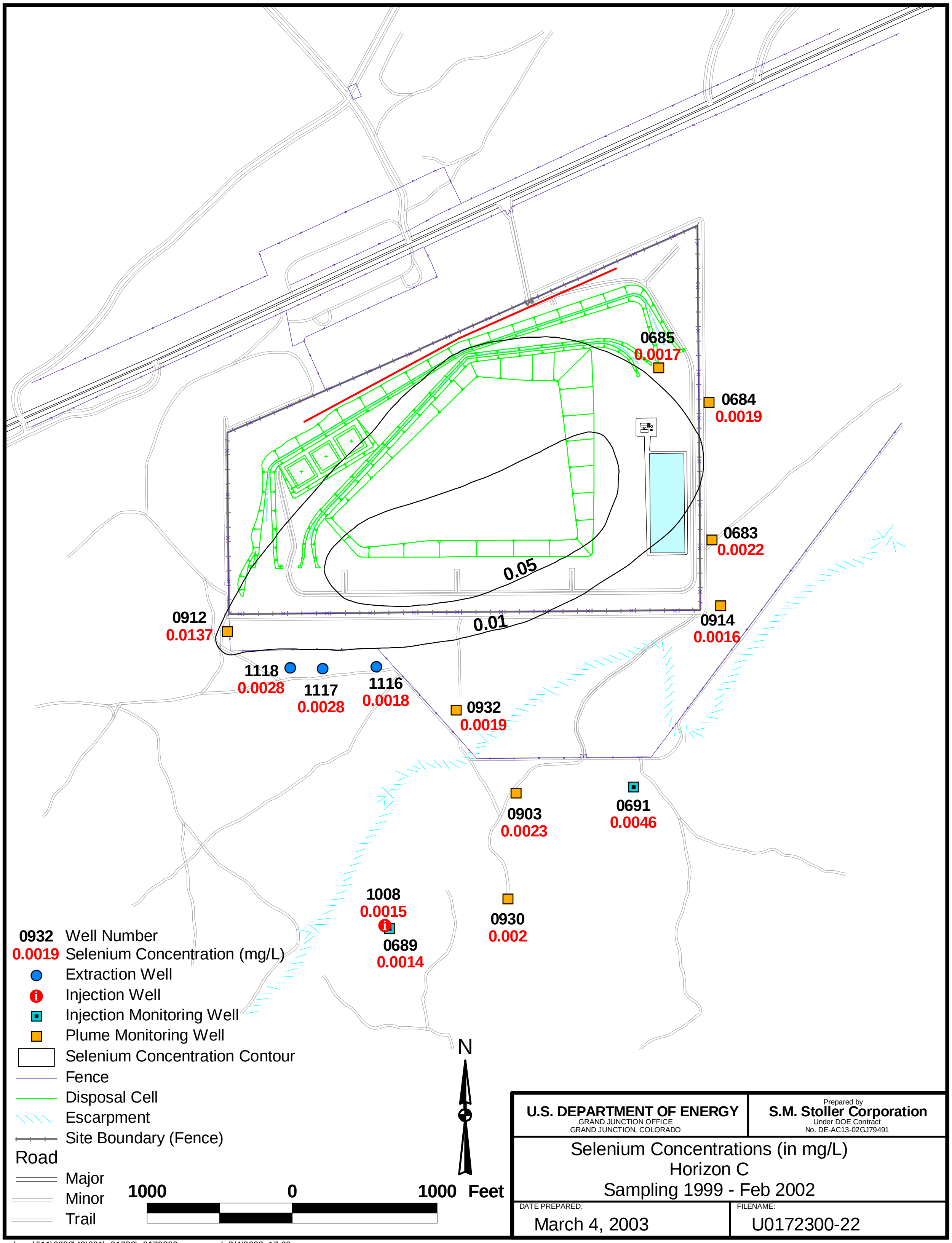

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Figure 29a. Baseline Horizon C Selenium Ground Water Concentrations

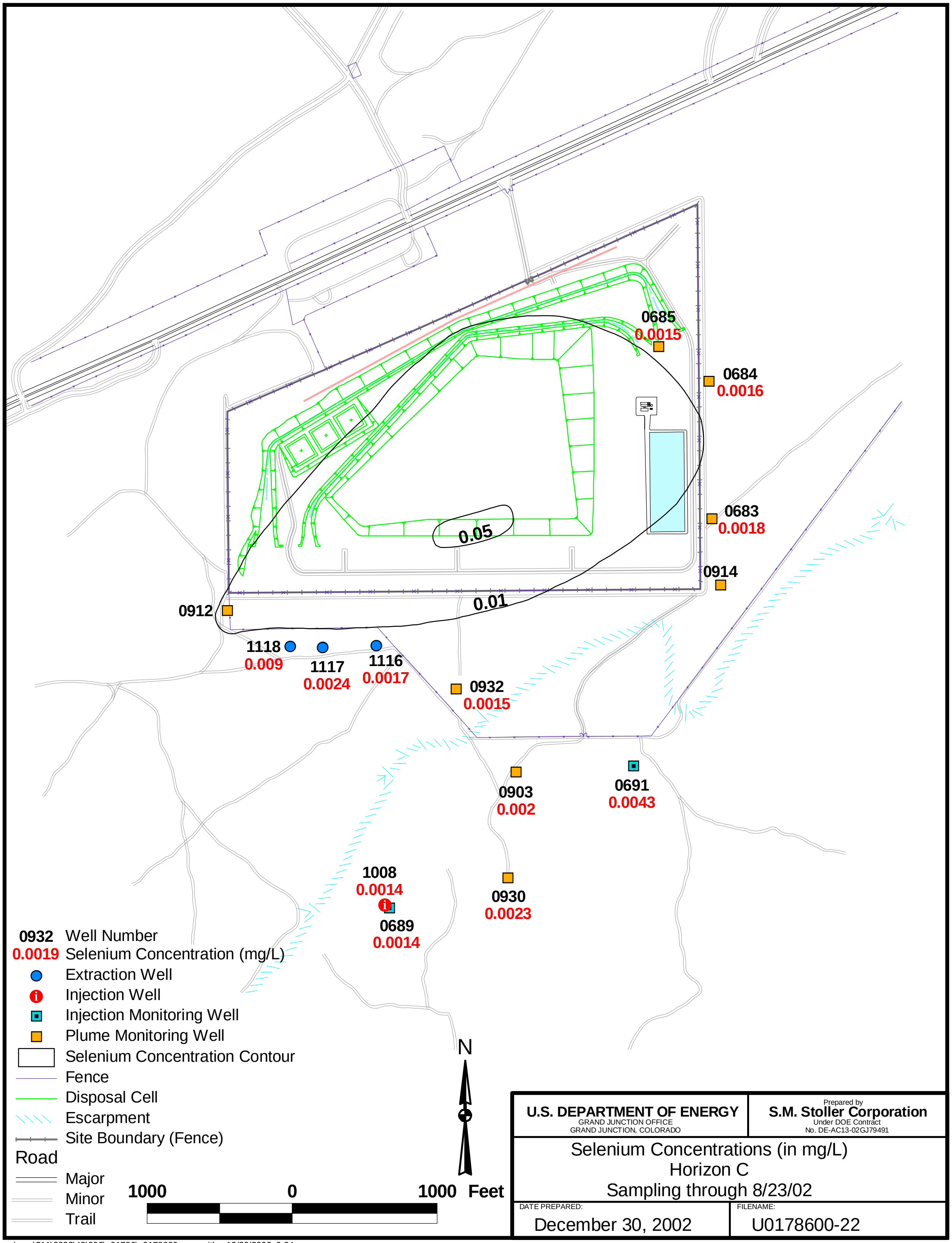

Figure 29b. August 2002 Horizon C Selenium Ground Water Concentrations

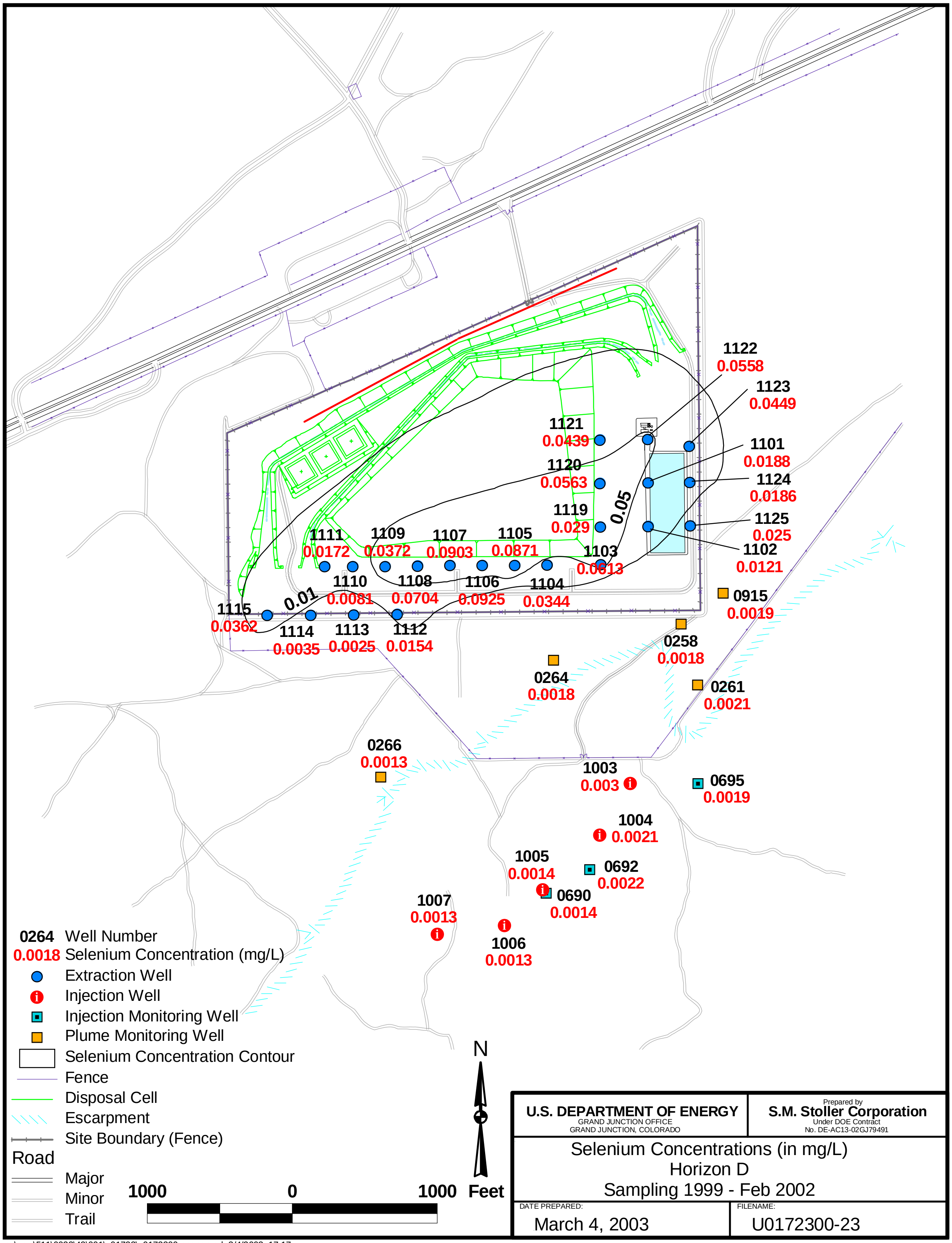

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Figure 30a. Baseline Horizon D Selenium Ground Water Concentrations

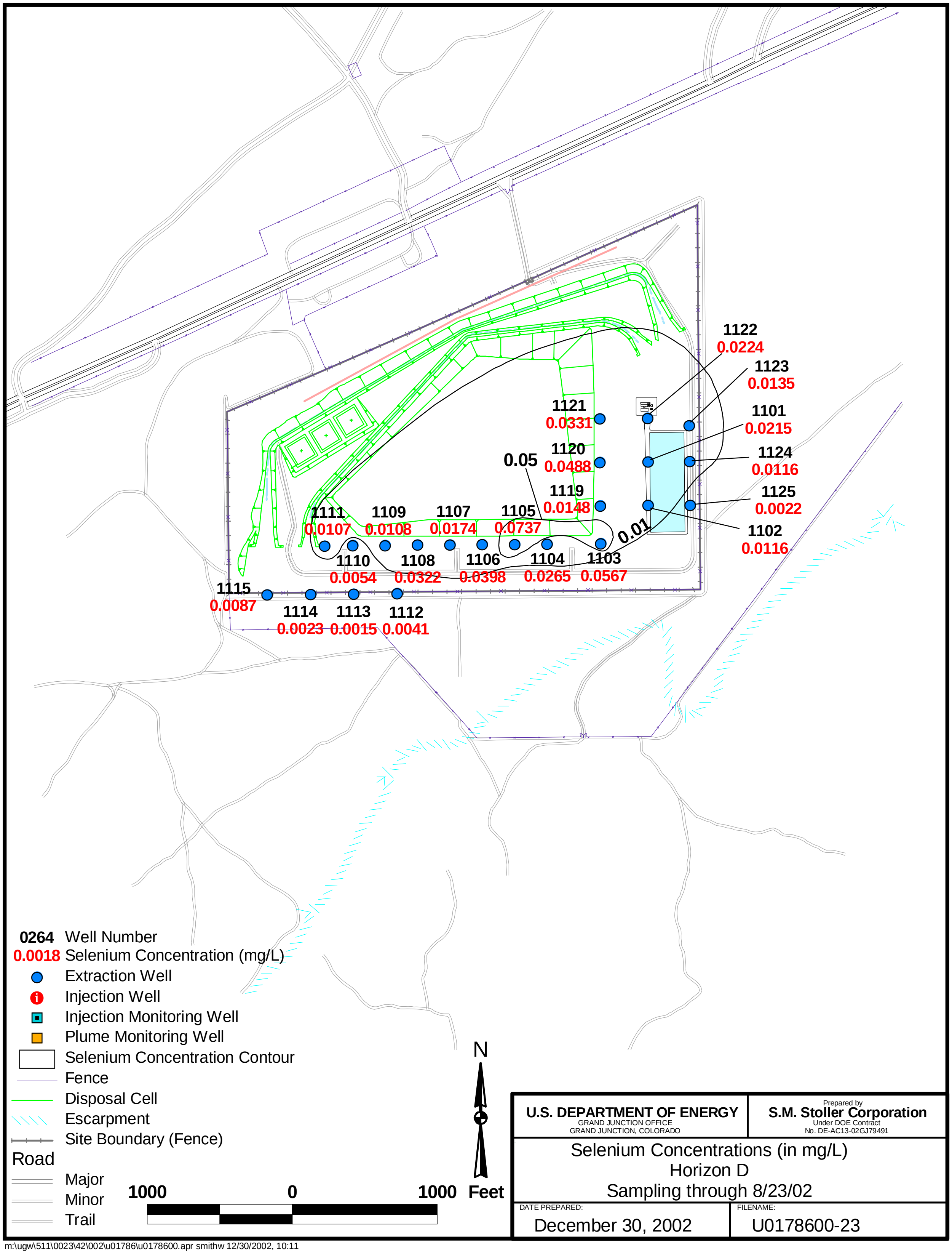

Figure 30b. August 2002 Horizon D Selenium Concentrations

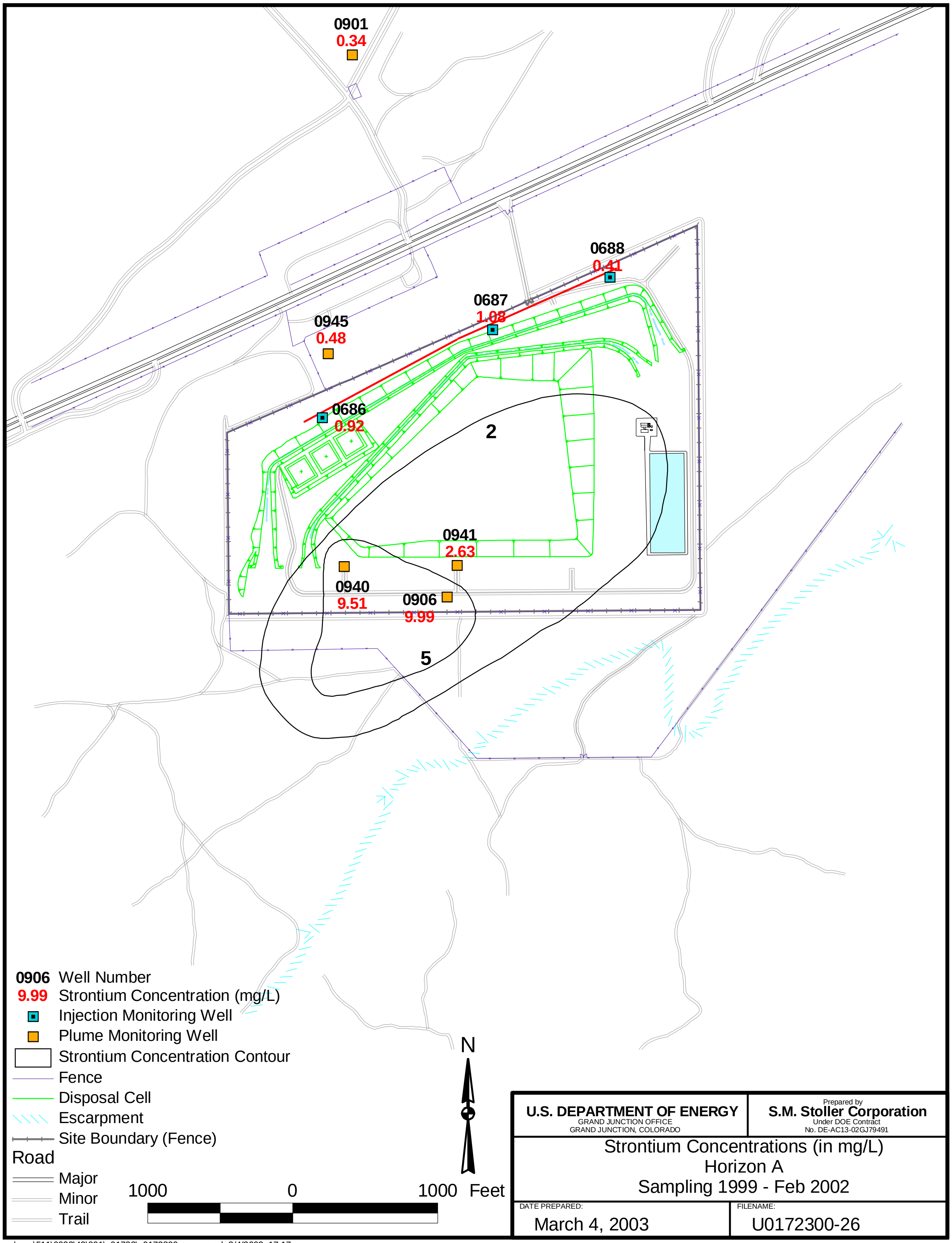

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Figure 31a. Baseline Horizon A Strontium Ground Water Concentrations

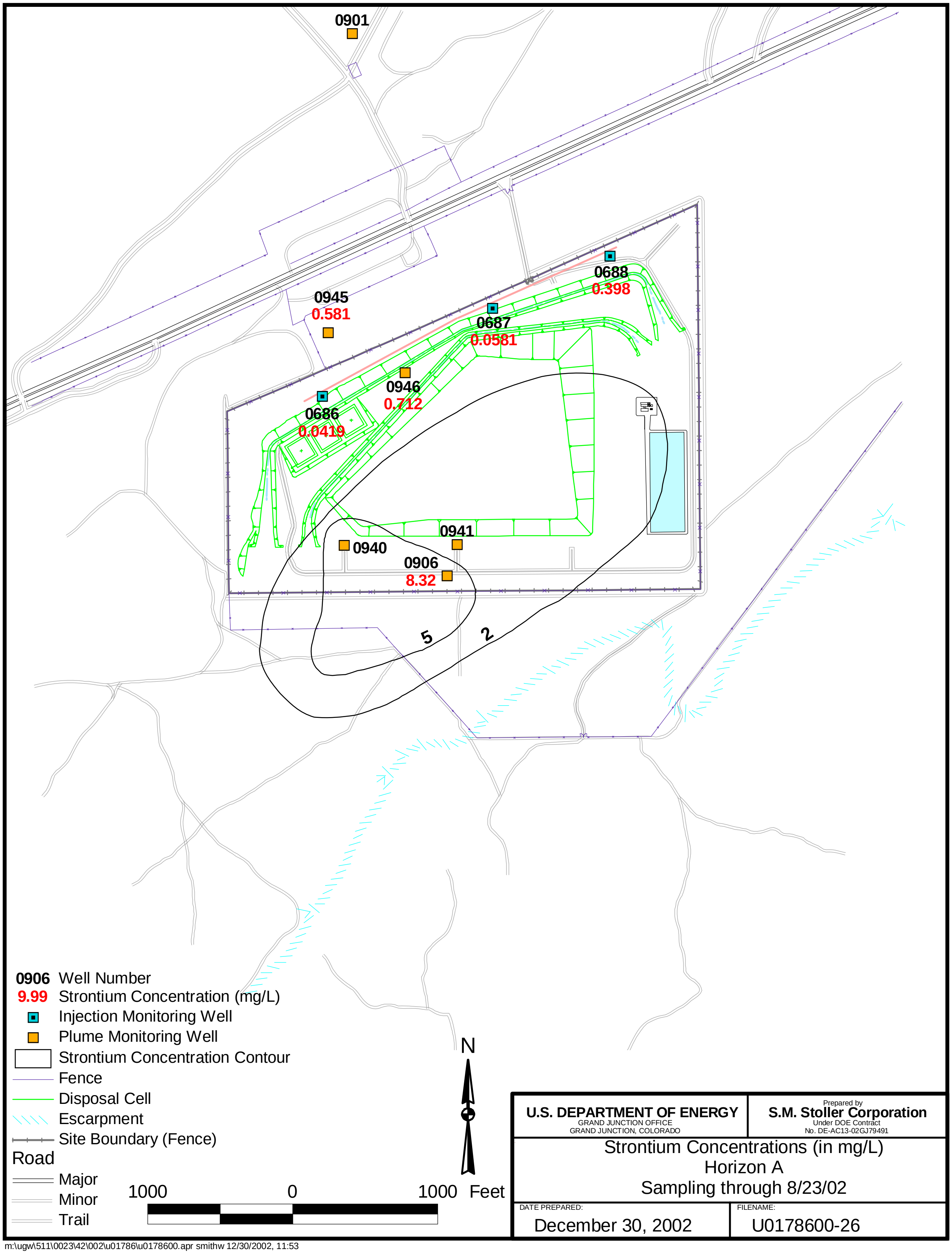

Figure 31b. August 2002 Horizon A Strontium Ground Water Concentrations

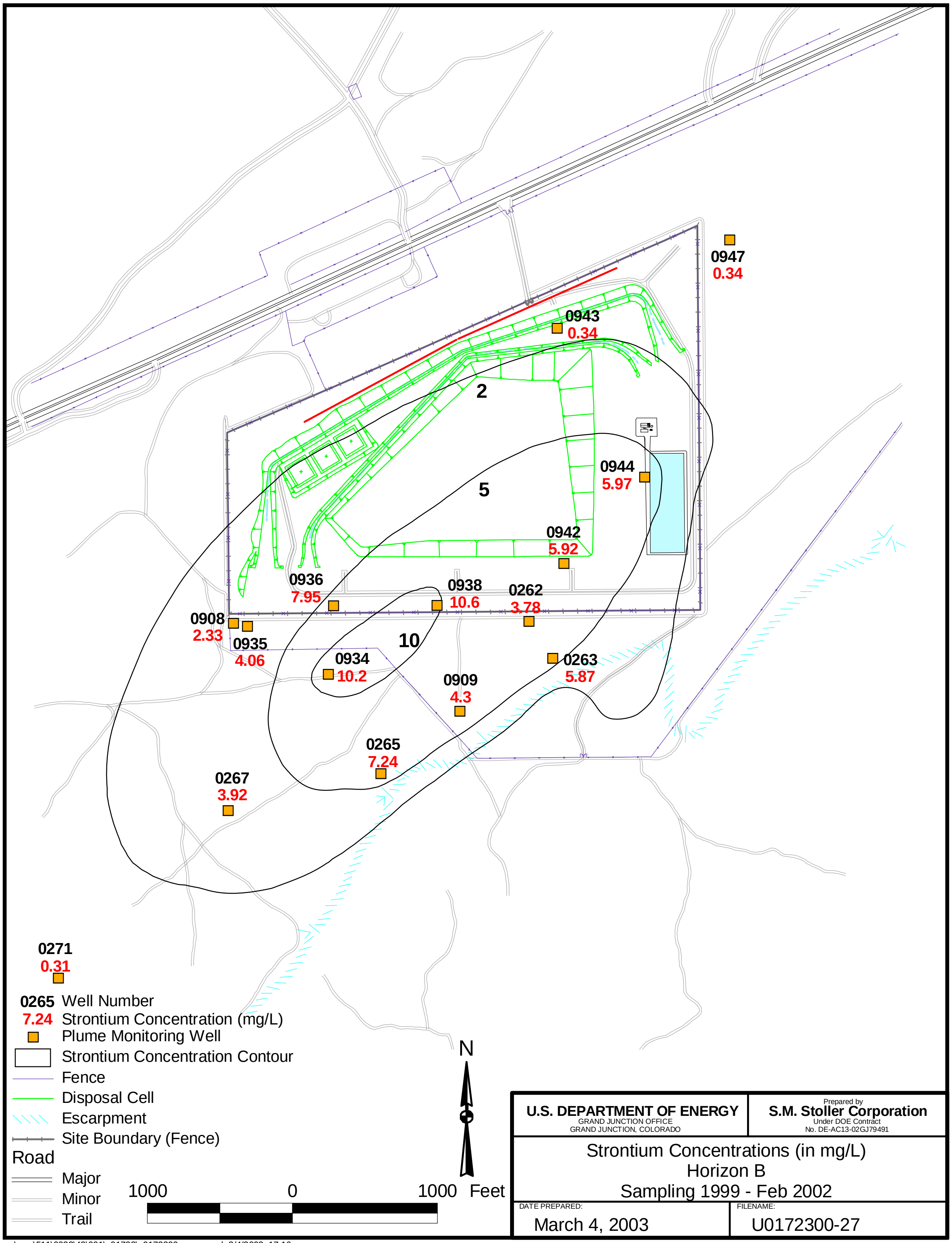

Figure 32a. Baseline Horizon B Strontium Ground Water Concentrations

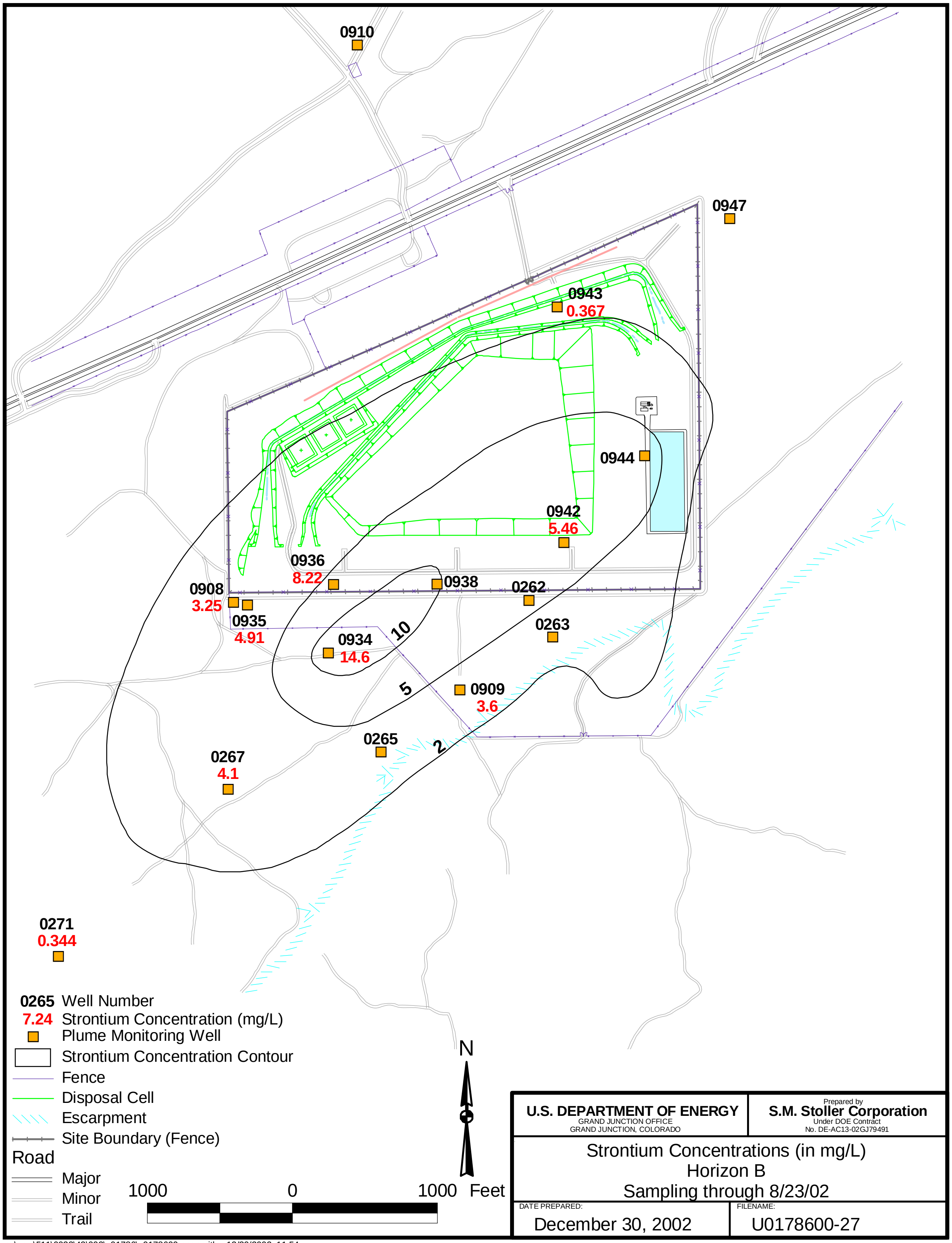

Figure 32b. August 2002 Horizon B Strontium Concentrations

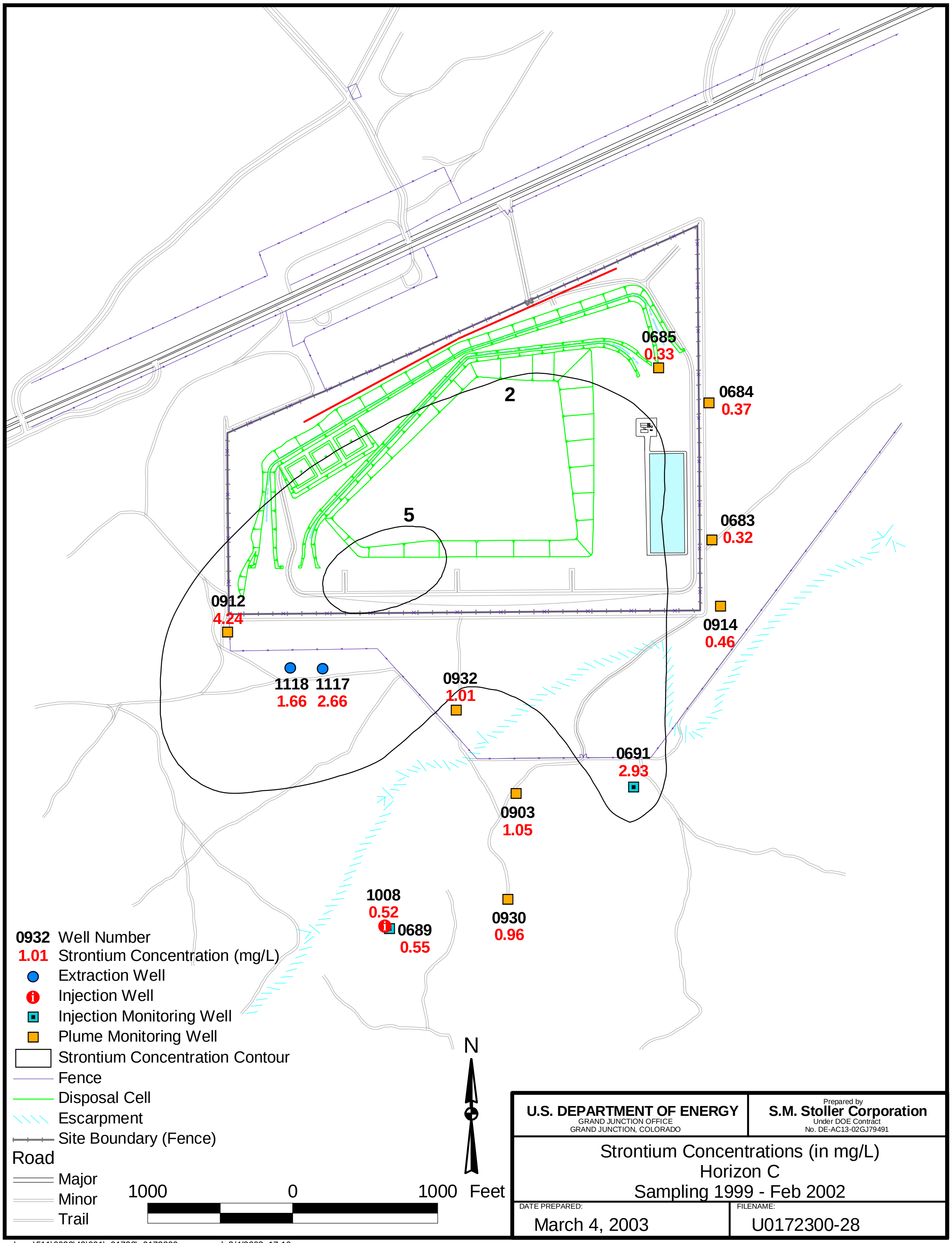

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Figure 33a. Baseline Horizon C Strontium Ground Water Concentrations

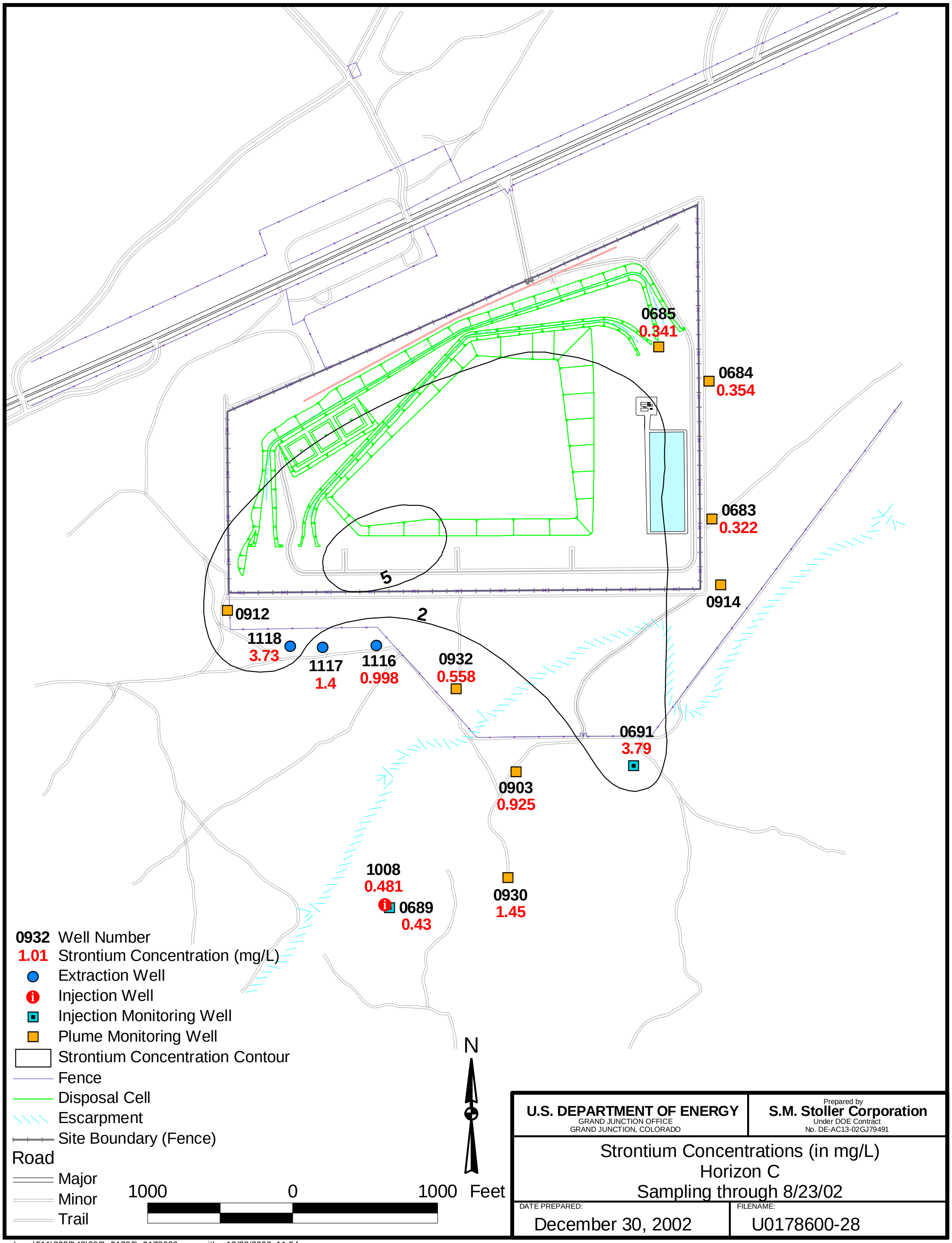

Figure 33b. August 2002 Horizon C Strontium Ground Water Concentrations

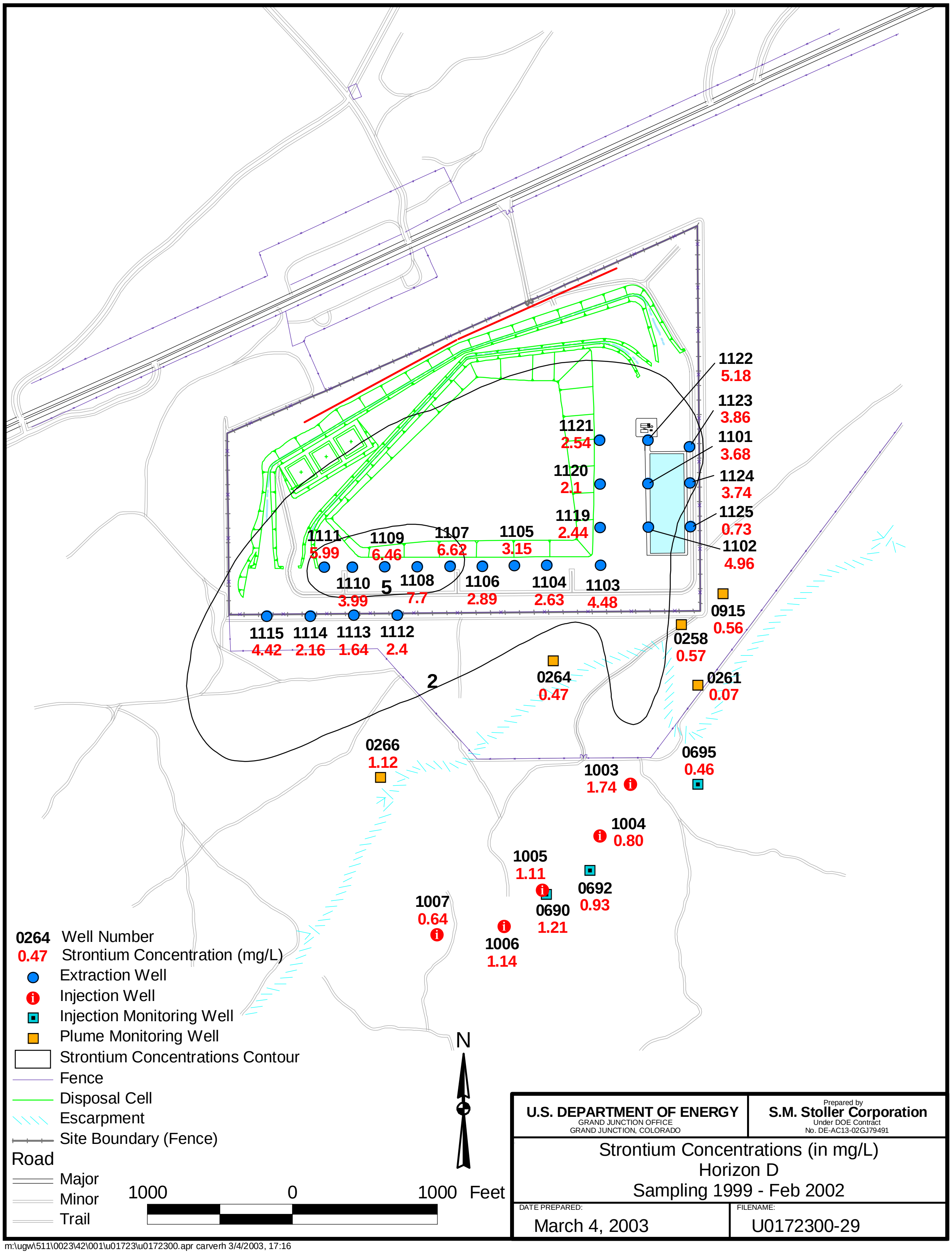

Figure 34a. Baseline Horizon D Strontium Ground Water Concentrations

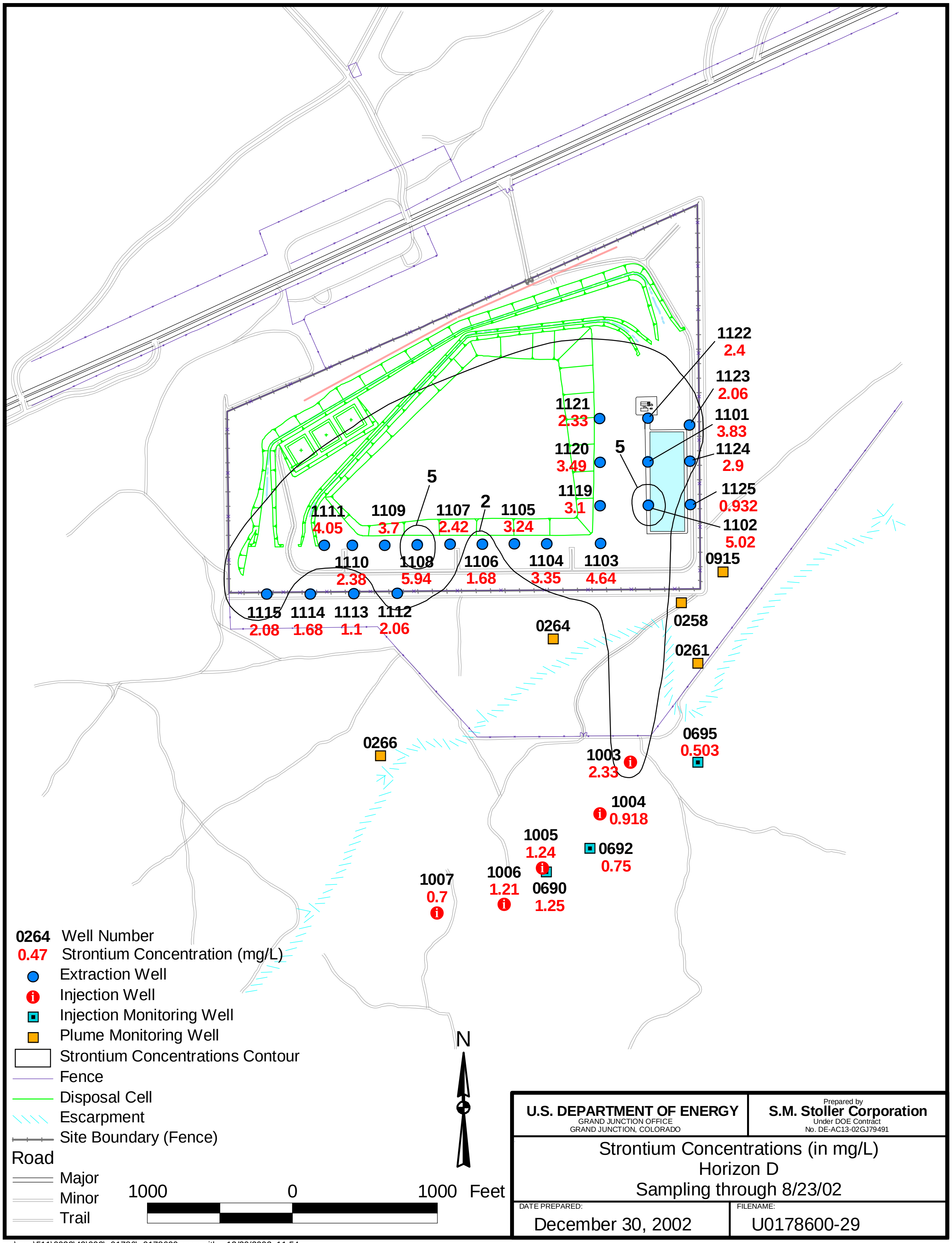

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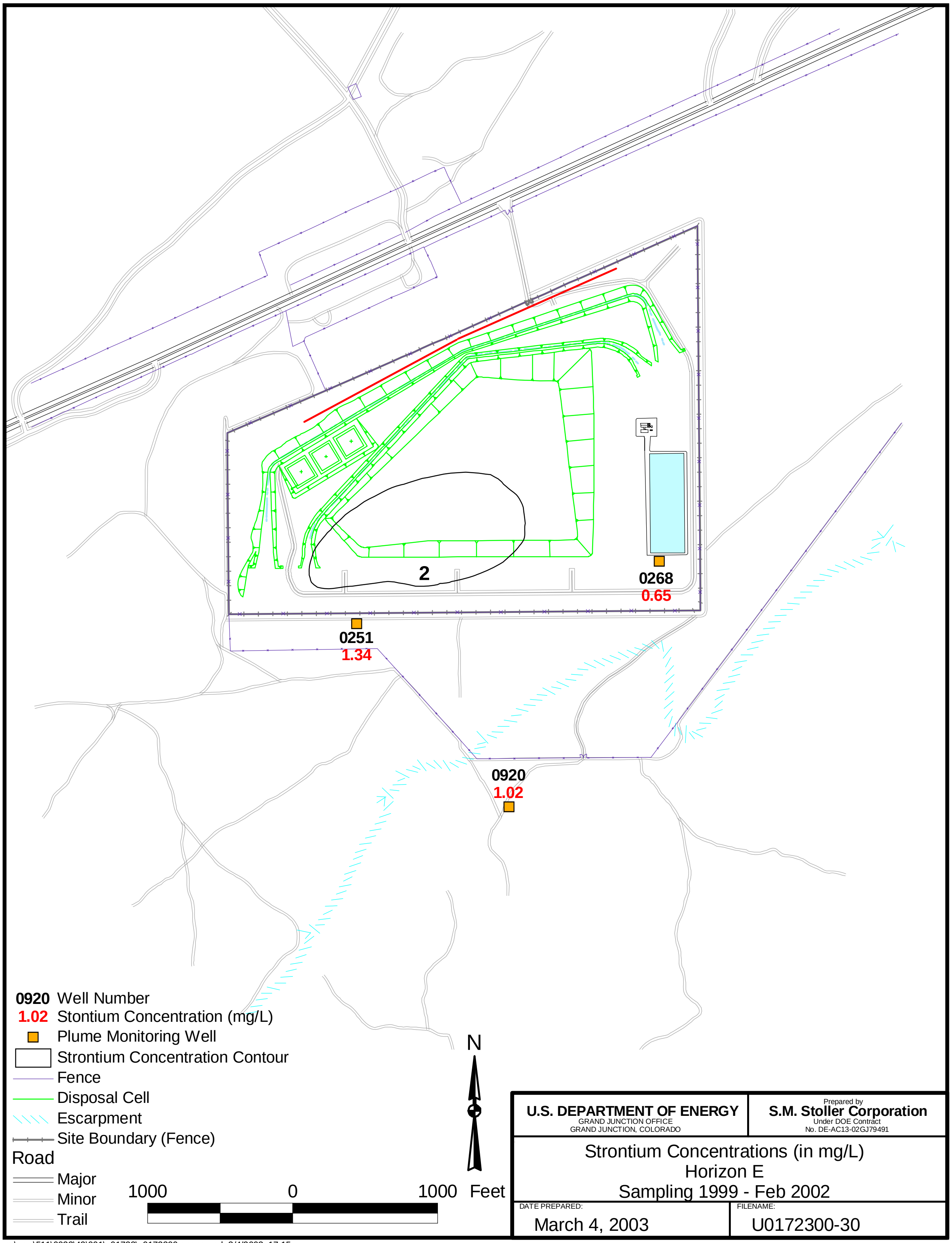
Figure 34b. August 2002 Horizon D Strontium Ground Water Concentrations



m:\ugw\511\0023\42\001\u01723\u0172300.apr carverh 3/4/2003, 17:15

Figure 35a. Baseline Horizon E Strontium Ground Water Concentrations

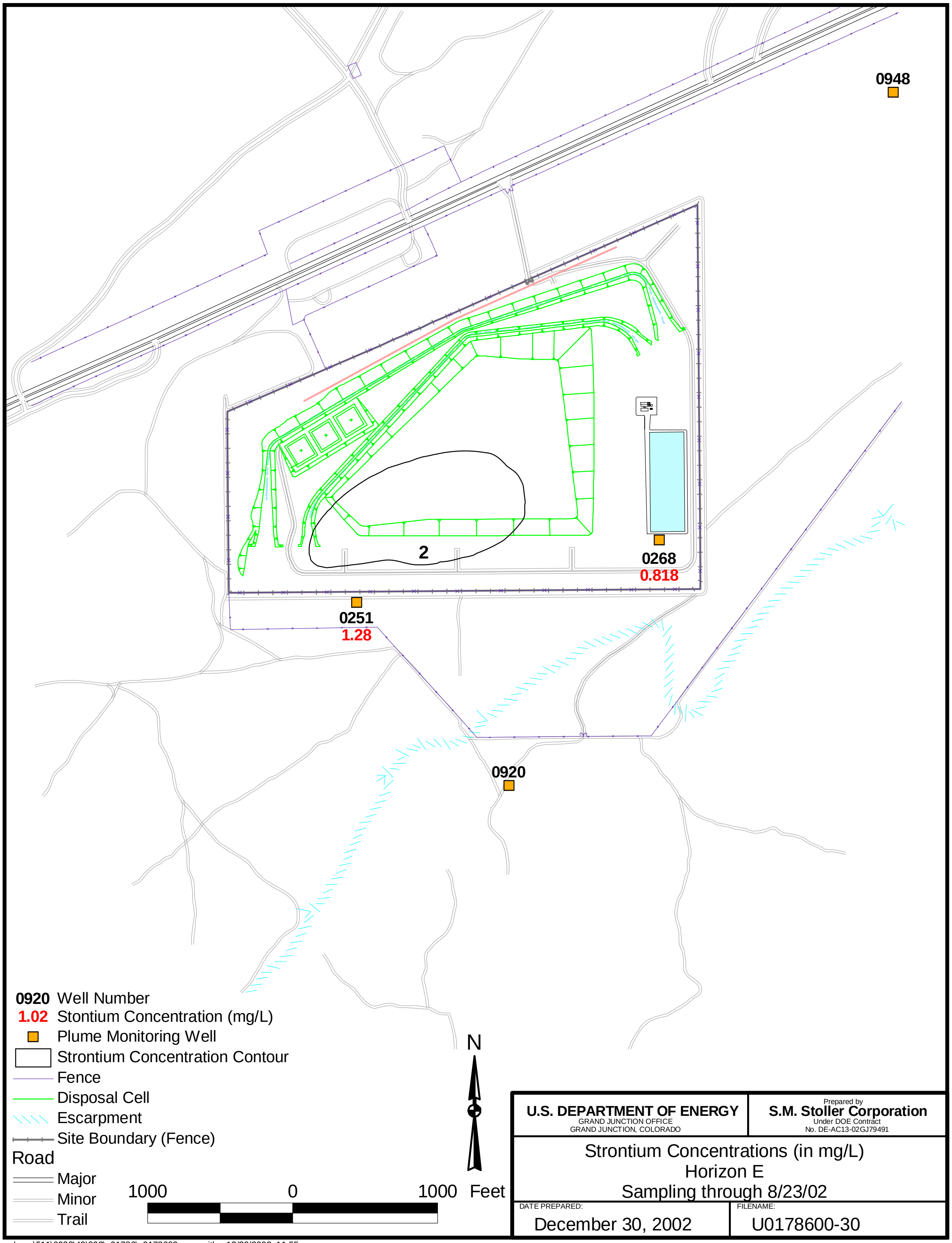


Figure 35b. August 2002 Horizon E Strontium Ground Water Concentrations

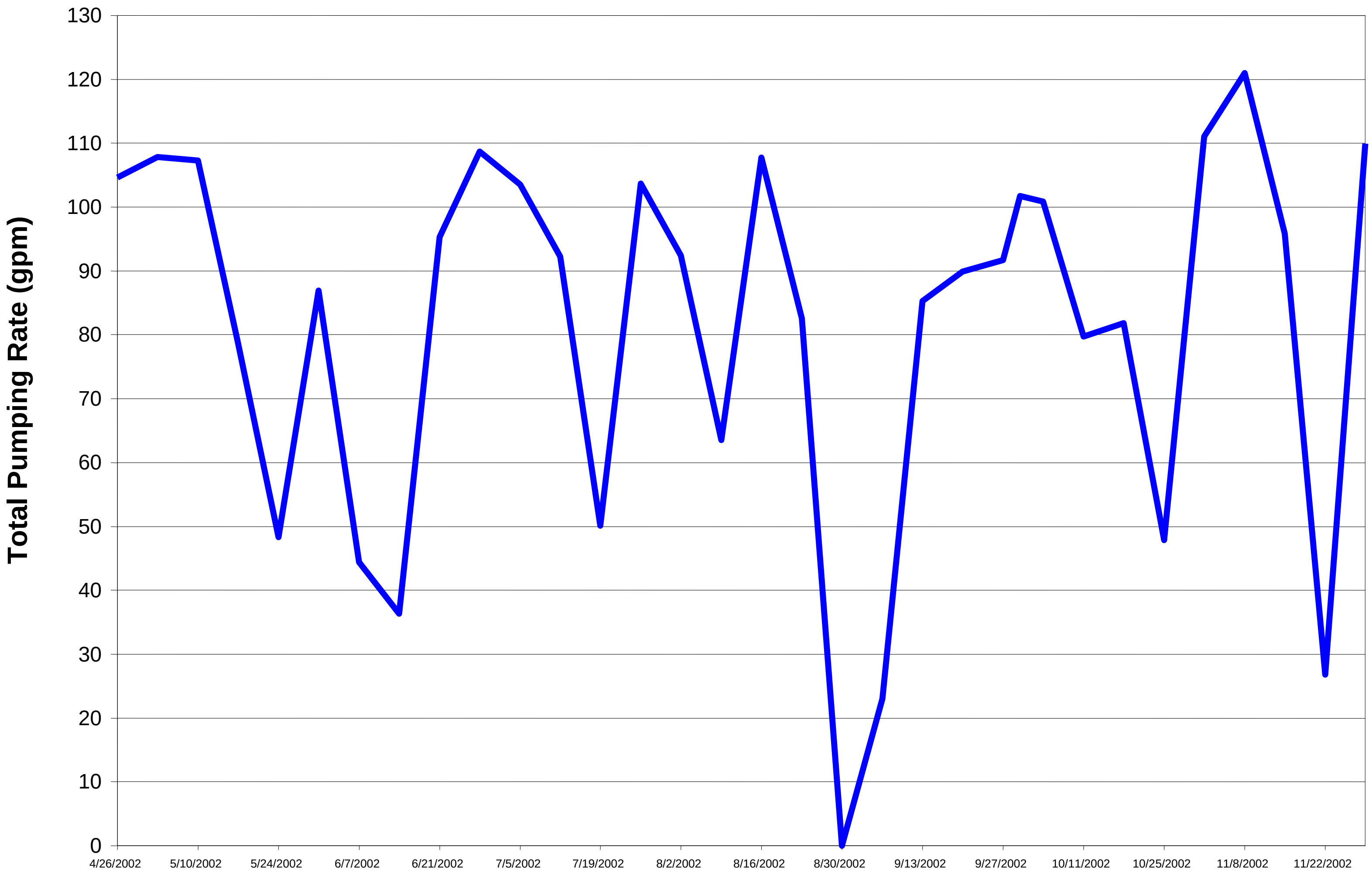


Figure 36. Total Pumping Rate from Extraction Wells

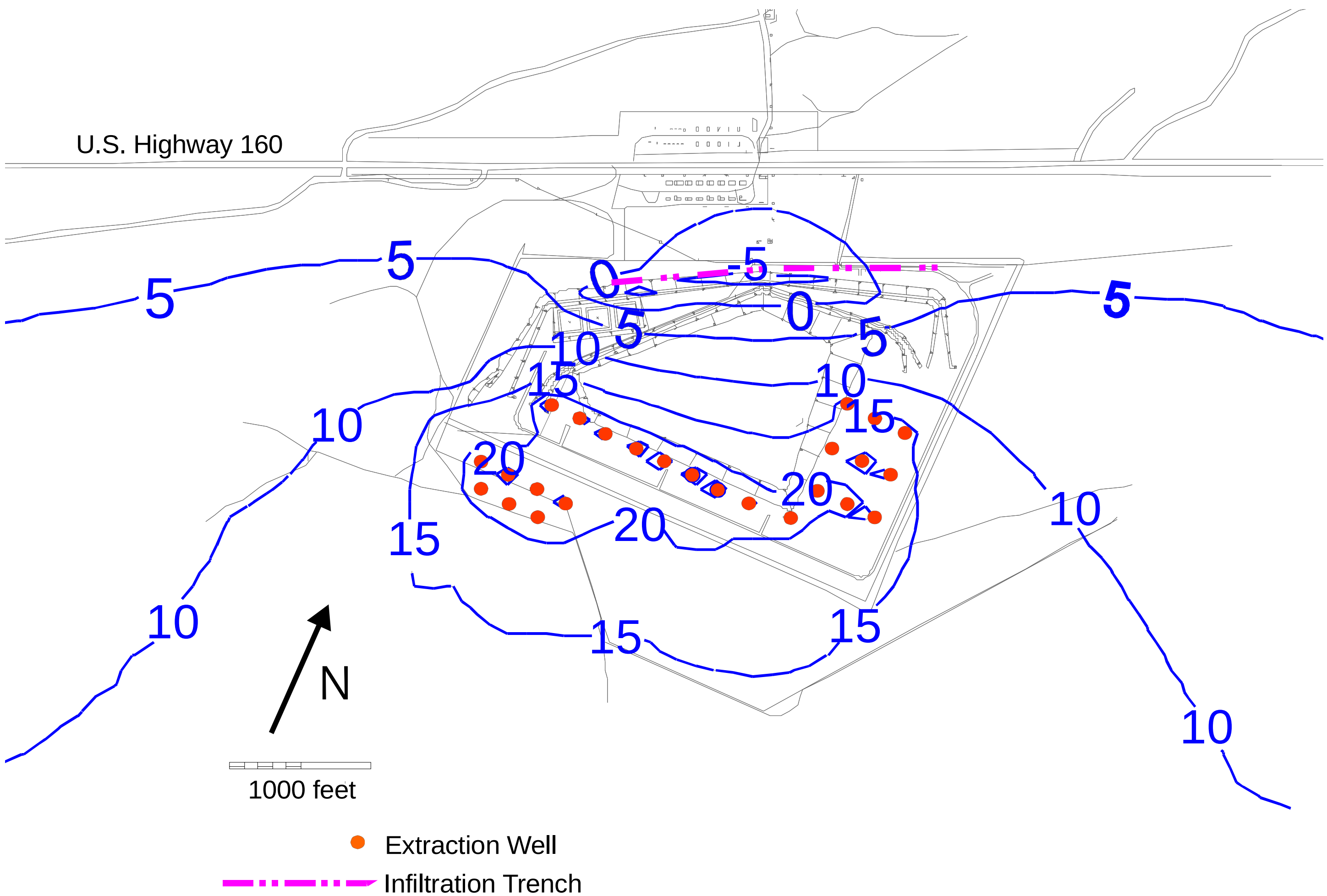


Figure 37. Model-Predicted Drawdowns (feet) in the Navajo Sandstone

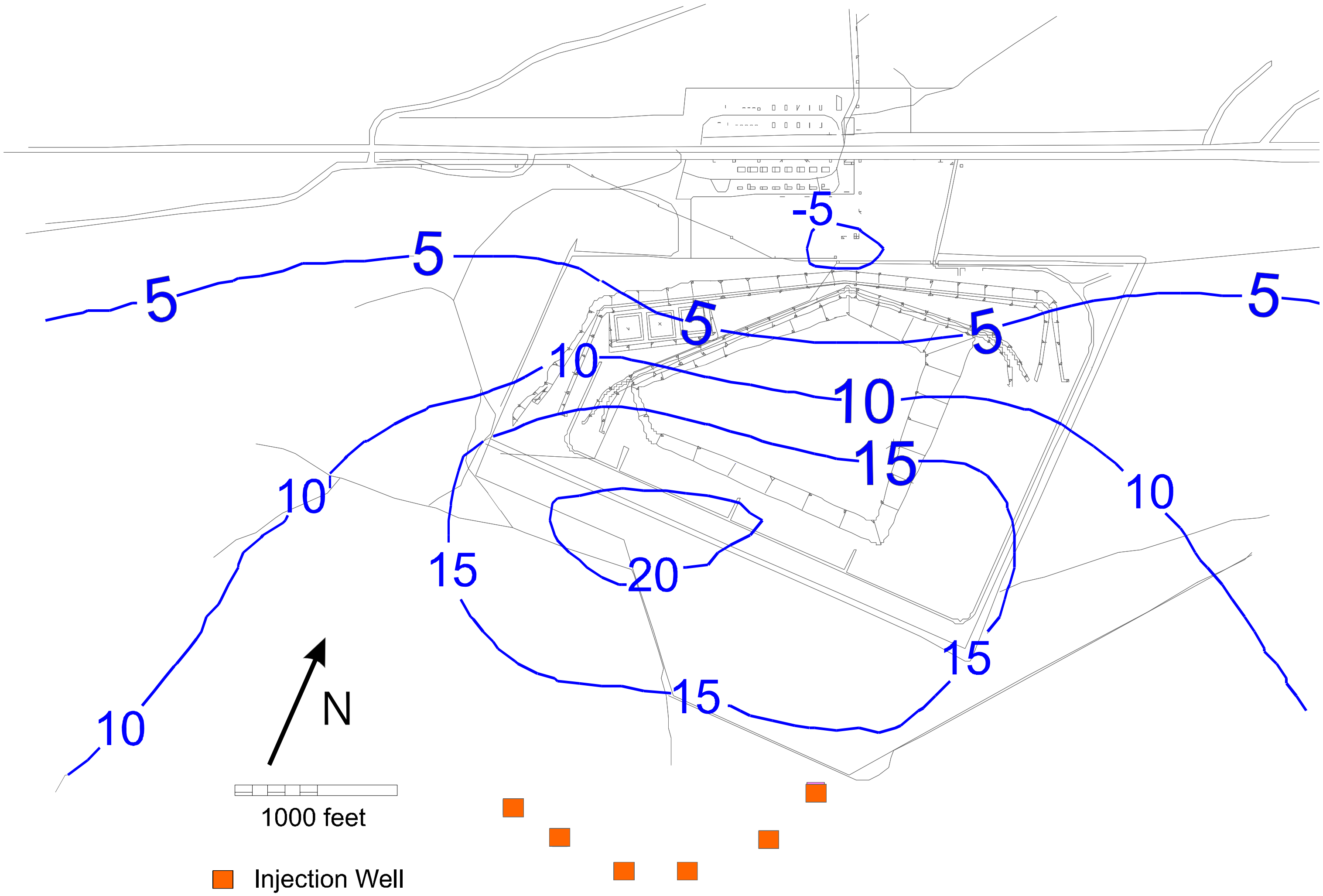


Figure 38. Model-Predicted Drawdowns (feet) in the Intertonguing Interval

Tables

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Table 1. Horizon Elevations

Horizon	Depth Interval, ft above msl[1]	Number of Wells	Lithology
A	5,000 – 5,050	10	Navajo Sandstone
B	4,950 – 5,000	23	Navajo Sandstone
C	4,900 – 4,950	15	Navajo Sandstone
D	4,850 – 4,900	36	Intertonguing Interval
E	4,800 – 4,850	4	Intertonguing Interval
F	4,750 – 4,800	1	Intertonguing Interval
G	4,700 – 4,750	3	Intertonguing Interval
H	4,650 – 4,700	1	Intertonguing Interval
I	4,600 – 4,650	4	Intertonguing Interval
J	4,550 – 4,600	0	Intertonguing Interval
K	4,500 – 4,550	0	Kayenta Formation
L	4,450 – 4,500	0	Kayenta Formation
M	4,400 – 4,450	3	Kayenta Formation

[1] msl = mean sea level

Table 2. Horizons Assigned to Wells

Well Number	Horizon (Center of Well Screen)	Middle of Screen Elevation (ft above mean sea level)	Well Type
686	A	5,025.54	Monitor/Observation
687	A	5,027.55	Monitor/Observation
688	A	5,024.05	Monitor/Observation
901	A	5,035.82	Monitor/Observation
906	A	5,006.89	Monitor/Observation
928	A	5,009.61	Monitor/Observation
940	A	5,010.36	Monitor/Observation
941	A	5,008.00	Monitor/Observation
945	A	5,018.05	Monitor/Observation
946	A	5,047.57	Monitor/Observation
262	B	4,979.22	Monitor/Observation
263	B	4,980.20	Monitor/Observation
265	B	4,971.08	Monitor/Observation
267	B	4,970.80	Monitor/Observation
271	B	4,964.00	Monitor/Observation
905	B	4,998.52	Monitor/Observation
908	B	4,997.82	Monitor/Observation
909	B	4,983.27	Monitor/Observation
910	B	4,957.64	Monitor/Observation
918	B	4,983.67	Monitor/Observation
925	B	4,985.78	Monitor/Observation
926	B	4,993.29	Monitor/Observation
933	B	4,992.28	Monitor/Observation
934	B	4,990.51	Monitor/Observation
935	B	4,988.84	Monitor/Observation
936	B	4,997.87	Monitor/Observation
937	B	4,992.68	Monitor/Observation
938	B	4,992.87	Monitor/Observation
939	B	4,993.60	Monitor/Observation
942	B	4,999.46	Monitor/Observation
943	B	4,984.09	Monitor/Observation
944	B	4,969.90	Monitor/Observation
947	B	4,980.02	Monitor/Observation
683	C	4,948.18	Monitor/Observation
684	C	4,917.44	Monitor/Observation
685	C	4,949.69	Monitor/Observation
689	C	4,903.92	Monitor/Observation
691	C	4,901.90	Monitor/Observation
903	C	4,943.52	Monitor/Observation
912	C	4,914.67	Monitor/Observation
914	C	4,921.80	Monitor/Observation
917	C	4,907.81	Monitor/Observation
930	C	4,917.95	Monitor/Observation
932	C	4,932.28	Monitor/Observation
1008	C	4,901.55	Injection
1116	C	4,912.53	Extraction

Table 2 (continued). Horizons Assigned to Wells

Well Number	Horizon (Center of Well Screen)	Middle of Screen Elevation (ft above mean sea level)	Well Type
1117	C	4,913.66	Extraction
1118	C	4,915.10	Extraction
258	D	4,873.99	Monitor/Observation
261	D	4,887.02	Monitor/Observation
264	D	4,879.62	Monitor/Observation
266	D	4,870.62	Monitor/Observation
690	D	4,873.34	Monitor/Observation
692	D	4,875.59	Monitor/Observation
695	D	4,899.32	Monitor/Observation
904	D	4,868.81	Monitor/Observation
915	D	4,892.77	Monitor/Observation
1003	D	4,898.36	Injection
1004	D	4,893.07	Injection
1005	D	4,879.68	Injection
1006	D	4,878.74	Injection
1007	D	4,890.47	Injection
1101	D	4,896.55	Extraction
1102	D	4,893.84	Extraction
1103	D	4,887.31	Extraction
1104	D	4,894.78	Extraction
1105	D	4,894.60	Extraction
1106	D	4,888.72	Extraction
1107	D	4,893.96	Extraction
1108	D	4,891.12	Extraction
1109	D	4,894.69	Extraction
1110	D	4,891.81	Extraction
1111	D	4,894.73	Extraction
1112	D	4,891.59	Extraction
1113	D	4,891.18	Extraction
1114	D	4,891.01	Extraction
1115	D	4,891.15	Extraction
1119	D	4,893.71	Extraction
1120	D	4,895.96	Extraction
1121	D	4,896.96	Extraction
1122	D	4,896.30	Extraction
1123	D	4,899.19	Extraction
1124	D	4,899.92	Extraction
1125	D	4,897.81	Extraction
251	E	4,808.92	Monitor/Observation
268	E	4,814.47	Monitor/Observation
920	E	4,846.03	Monitor/Observation
948	E	4,803.90	Monitor/Observation
911	F	4,775.16	Monitor/Observation
913	G	4,709.24	Monitor/Observation
916	G	4,716.70	Monitor/Observation
919	G	4,702.90	Monitor/Observation

Table 2 (continued). Horizons Assigned to Wells

Well Number	Horizon (Center of Well Screen)	Middle of Screen Elevation (ft above mean sea level)	Well Type
902	H	4,668.66	Monitor/Observation
252	I	4,608.85	Monitor/Observation
254	I	4,612.69	Monitor/Observation
256	I	4,613.95	Monitor/Observation
921	I	4,643.73	Monitor/Observation
253	M	4,408.75	Monitor/Observation
255	M	4,412.33	Monitor/Observation
257	M	4,413.36	Monitor/Observation

Table 3. Baseline and August 2002 Horizontal Hydraulic Gradients

Well 1	Well 2	Well 3	Date	Baseline Gradients		Date	August 2002 Gradients	
				Direction, degrees	Magnitude, ft/ft		Direction, degrees	Magnitude, ft/ft
Horizon A								
687	686	906	8/2001	188.1	9.44×10^{-3}	8/2002	139.0	2.24×10^{-2}
688	687	906	8/2001	128.0	1.99×10^{-2}	8/2002	128.5	2.94×10^{-2}
Horizon B								
943	935	936	8/2001	205.9	7.81×10^{-3}	8/2002	149.0	3.47×10^{-2}
943	942	936	8/2001	186.1	8.31×10^{-3}	8/2002	211.1	1.21×10^{-2}
936	935	934	8/2001	178.4	2.20×10^{-2}	8/2002	116.0	1.34×10^{-2}
942	936	909	8/2001	177.8	1.67×10^{-2}	8/2002	214.9	1.13×10^{-2}
936	934	909	8/2001	189.4	2.19×10^{-2}	8/2002	209.4	5.41×10^{-3}
935	267	934	8/2001	130.3	1.19×10^{-2}	8/2002	115.6	1.34×10^{-2}
934	909	267	8/2001	142.7	3.01×10^{-3}	8/2002	353.3	3.37×10^{-3}
935	271	267	8/2001	170.4	6.96×10^{-3}	8/2002	192.3	4.55×10^{-3}
909	267	271	8/2001	153.5	1.29×10^{-2}	8/2002	152.5	1.30×10^{-2}
Horizon C								
683	691	932	8/2001	172.4	2.80×10^{-2}	8/2002	179.5	2.14×10^{-2}
932	930	691	8/2001	161.4	2.11×10^{-2}	8/2002	163.1	1.33×10^{-2}
Horizon D								
915	258	264	9/2000	146.5	4.53×10^{-2}	8/2002	119.5	1.10×10^{-3}
258	264	261	9/2000	150.7	5.89×10^{-2}	8/2002	163.2	4.76×10^{-2}
915	261	258	9/2000	145.8	6.03×10^{-2}	8/2002	143.0	5.13×10^{-2}
264	1003	261	9/2000	133.1	4.43×10^{-2}	8/2002	135.0	2.59×10^{-2}
264	1004	1003	9/2000	125.7	4.63×10^{-2}	8/2002	120.0	2.86×10^{-2}
261	695	1003	9/2000	134.2	3.93×10^{-2}	8/2002	132.8	3.29×10^{-2}
1003	695	1004	9/2000	127.3	3.55×10^{-2}	8/2002	120.0	2.79×10^{-2}
1004	692	695	9/2000	142.0	8.32×10^{-2}	8/2002	142.6	8.75×10^{-2}
1004	692	1007	9/2000	151.0	6.90×10^{-2}	8/2002	152.0	7.23×10^{-2}
1007	1006	692	9/2000	141.0	2.67×10^{-2}	8/2002	143.4	2.73×10^{-2}
266	1007	1004	9/2000	155.3	2.43×10^{-2}	8/2002	174.3	9.77×10^{-3}
Horizon E								
251	268	920	5/2001	154.8	2.83×10^{-2}	8/2002	161.4	7.52×10^{-3}
Horizon G								
913	916	919	9/1998	158.3	4.04×10^{-2}	8/2002	157.9	3.87×10^{-2}
Horizon I								
252	254	921	3/2002	178.3	3.92×10^{-2}	8/2002	163.9	3.15×10^{-2}
254	256	921	3/2002	140.1	4.24×10^{-2}	8/2002	137.4	3.57×10^{-2}

Table 4. Vertical Gradients Between Horizons

Well Pair	Horizons	Date	Gradient[1], ft/ft	Date	Gradient[1], ft/ft
901−910	A−B	February 1999	0.024	August 2002	0.49
908−912	B−C	June 2001	0.072	August 2002	0.85
909−932	B−C	August 2001	0.682	August 2002	0.95
914−915	C−D	August 2001	-0.224	August 2002	1.12
691−1003	C−D	August 2001	0.014	August 2002	-0.41
251−252	E−I	May 2000	0.052	August 2002	-0.63
256−257	I−M	May 2000	0.011	August 2002	0.00
254−255	I−M	May 2000	0.073	August 2002	0.09

[1]Positive gradient indicates downward flow; negative gradient indicates upward flow.

Table 5. Background and August 2002 Nitrate Concentrations

Well Number	Horizon	Background Nitrate Concentration (mg/L/Year Sampled)	August 2002 Nitrate Concentration (mg/L)
MCL = 44.0 mg/L			
686	A	32.2/2002	8.1
687	A	60.6/2002	8.1
688	A	35.1/2002	35.2
901	A	13.0/2001	NS
906	A	1,470.0/2002	1,240.0
928	A	NS	NS
940	A	1,800.0/2002	NS
941	A	358.0/2002	NS
945	A	12.7/2002	12.4
946	A	NS	54.0
262	B	380.0/2001	NS
263	B	1,140/2001	NS
265	B	720/2001	NS
267	B	1,640.0/2002	1420.0
271	B	15.6/2002	15.9
905	B	NS	NS
908	B	651.0/2002	650.0
909	B	485.0/2002	485.0
910	B	NS	NS
918	B	NS	NS
925	B	629.0/1999	NS
926	B	994.0/1999	NS
933	B	23.5/1999	NS
934	B	2,320.0/2002	2,360.0
935	B	525.0/2002	655.0
936	B	2,950.0/2002	2,910.0
937	B	1,440.0/2000	NS
938	B	1,450.0/1999	NS
939	B	NS	NS
942	B	1,360.0/2002	1150.0
943	B	22.1/2002	22.0
944	B	1,010.0/1999	NS
947	B	12.5/2002	NS
683	C	14.1/2002	14.4
684	C	13.9/2002	14.1
685	C	14.3/2002	14.0
689	C	14.3/2002	14.0
691	C	298.0/2002	300.0
903	C	54.8/2002	41.1
912	C	400.0/2001	NS
914	C	13.0/2001	NS
917	C	15.7/2001	NS
930	C	50.9/2002	65.2
932	C	25.3/2002	25.6

Table 5 (continued). Background and August 2002 Nitrate Concentrations

Well Number	Horizon	Background Nitrate Concentration (mg/L/Year Sampled)	August 2002 Nitrate Concentration (mg/L)
MCL = 44.0 mg/L			
1008	C	15.7/2000	14.2
1116	C	106.0/2002	56.6
1117	C	225.0/2002	118.0
1118	C	164.0/2002	319.0
258	D	15.0/2000	NS
261	D	14.0/2001	NS
264	D	24.3/2001	NS
266	D	14.0/2001	NS
690	D	12.5/2002	NS
692	D	12.5/2002	12.6
695	D	25.4/2002	25.2
904	D	5.1/2001	NS
915	D	14.1/2001	NS
1003	D	176.0/2000	104.0
1004	D	49.1/2000	28.2
1005	D	14.5/2000	13.7
1006	D	14.1/2000	13.3
1007	D	15.3/2000	14.6
1101	D	438.0/2002	435.0
1102	D	650.0/2002	611.0
1103	D	1120/2002	1,230.0
1104	D	993.0/2002	798.0
1105	D	648.0/2002	451.0
1106	D	614.0/2002	185.0
1107	D	1,060/2002	282.0
1108	D	1410/2002	706.0
1109	D	798.0/2002	349.0
1110	D	227.0/2002	160.0
1111	D	421.0/2002	287.0
1112	D	617.0/2002	140.0
1113	D	143.0/2002	43.8
1114	D	228.0/2002	118.0
1115	D	766.0/2002	263.0
1119	D	468.0/2002	444.0
1120	D	493.0/2002	515.0
1121	D	573.0/2002	342.0
1122	D	954.0/2002	370.0
1123	D	643.0/2002	237.0
1124	D	781.0/2002	485.0
1125	D	104.0/2002	84.8
251	E	426.0/2002	16.9
268	E	153.0/2002	15.8
920	E	14.8/2001	NS
948	E	NS	NS

.

Table 5 (continued). Background and August 2002 Nitrate Concentrations

Well Number	Horizon	Background Nitrate Concentration (mg/L/Year Sampled)	August 2002 Nitrate Concentration (mg/L)
MCL = 44.0 mg/L			
911	F	NS	
913	G	12.4/2001	
916	G	11.6/2001	
919	G	NS	
902	H	NS	
252	I	15.3/2002	
254	I	354.0/2002	
256	I	189.0/2002	
921	I	11.0/2001	
253	M	525.0/2000	
255	M	9.6/2000	
257	M	6.9/2000	

NS – not sampled

Table 6. Background and August 2002 Sulfate Concentrations

Well Number	Horizon	Background Sulfate Concentration (mg/L/Year Sampled)	August 2002 Sulfate Concentration (mg/L)
No MCL for sulfate			
686	A	98.6/2002	25.2
687	A	329.0/2002	18.8
688	A	40.0/2002	41.5
901	A	26.2/2001	NS
906	A	1,660.0/2002	1690.0
928	A	NS	NS
940	A	7,550.0/2002	NS
941	A	745.0/2002	NS
945	A	32.1/2002	43.5
946	A	NS	54.6
262	B	931.0/2001	NS
263	B	1,990.0/2001	NS
265	B	1,520.0/2001	NS
267	B	3,680.0/2002	3,530.0
271	B	16.4/2002	15.9
905	B	NS	NS
908	B	2,430.0/2002	2,330.0
909	B	666.0/2002	637.0
910	B	NS	NS
918	B	NS	NS
925	B	2,630.0/1999	NS
926	B	1,430.0/1999	NS
933	B	97.0/1999	NS
934	B	7,360.0/2002	11,900.0
935	B	2,690.0/2002	2,670.0
936	B	4,360.0/2002	4,400.0
937	B	2,610.0/2000	NS
938	B	2,120.0/1999	NS
939	B	NS	NS
942	B	3,030.0/2002	2,680.0
943	B	29.0/2002	37.1
944	B	1,590.0/1999	NS
947	B	18.7/2002	NS
683	C	21.6/2002	18.5
684	C	18.0/2002	16.9
685	C	26.2/2002	15.5
689	C	13.7/2002	13.9
691	C	587.0/2002	582.0
903	C	76.5/2002	53.7
912	C	84.6/2001	NS
914	C	15.6/2001	NS
917	C	13.9/2001	NS
930	C	59.8/2002	79.5
932	C	30.2/2002	25.4

Table 6 (continued). Background and August 2002 Sulfate Concentrations

Well Number	Horizon	Background Sulfate Concentration (mg/L/Year Sampled)	August 2002 Sulfate Concentration (mg/L)
No MCL for sulfate			
1008	C	13.0/2000	13.2
1116	C	176.0/2002	66.5
1117	C	255.0/2002	124.0
1118	C	163.0/2002	690.0
258	D	17.4/2000	NS
261	D	18.2/2001	NS
264	D	37.7/2001	NS
266	D	10.9/2001	NS
690	D	13.8/2002	13.1
692	D	20.8/2002	21.3
695	D	50.4/2002	47.6
904	D	96.5/2001	NS
915	D	17.8/2001	NS
1003	D	302.0/2000	382.0
1004	D	66.2/2000	76.2
1005	D	12.7/2000	12.9
1006	D	12.2/2000	12.4
1007	D	11.7/2000	12.4
1101	D	960.0/2002	1,040.0
1102	D	1,320.0/2002	1,240.0
1103	D	2,570.0/2002	2,640.0
1104	D	1,870.0/2002	1,600.0
1105	D	1,590.0/2002	1,150.0
1106	D	1,050.0/2002	366.0
1107	D	1,200.0/2002	335.0
1108	D	3,400.0/2002	1,870.0
1109	D	3,280.0/2002	1,040.0
1110	D	512.0/2002	310.0
1111	D	988.0/2002	642.0
1112	D	1,140.0/2002	210.0
1113	D	136.0/2002	34.5
1114	D	328.0/2002	137.0
1115	D	1,930.0/2002	490.0
1119	D	1,560.0/2002	1,010.0
1120	D	2,330.0/2002	2,220.0
1121	D	2,550.0/2002	1,600.0
1122	D	2,960.0/2002	1,110.0
1123	D	1,240.0/2002	473.0
1124	D	1,170.0/2002	742.0
1125	D	165.0/2002	130.0
251	E	617.0/2002	17.4
268	E	17.4/2002	19.0
920	E	12.7/2001	NS
948	E	NS	NS

Table 6 (continued). Background and August 2002 Sulfate Concentrations

Well Number	Horizon	Background Sulfate Concentration (mg/L/Year Sampled)	August 2002 Sulfate Concentration (mg/L)
No MCL for sulfate			
911	F	NS	
913	G	8.43/2001	
916	G	13.5/2001	
919	G	NS	
902	H	NS	
252	I	19.2/2002	
254	I	505.0/2002	
256	I	368.0/2002	
921	I	8.52/2001	
253	M	643.0/2000	
255	M	102.0/2000	
257	M	13.4/2000	

NS – not sampled

Table 7. Background and August 2002 Uranium Concentrations

Well Number	Horizon	Background Uranium Concentration (mg/L/Year Sampled)	August 2002 Uranium Concentrations (mg/L)
MCL = 0.044 mg/L			
686	A	0.0012/2002	<0.0001
687	A	0.0280/2002	0.0056
688	A	0.0020/2002	0.0819
901	A	0.0026/2001	NS
906	A	0.9510/2002	0.698
928	A	NS	NS
940	A	0.5460/2002	NS
941	A	0.0886/2002	NS
945	A	0.0031/2002	0.0046
946	A	NS	0.0019
262	B	0.379/2001	NS
263	B	0.485/2001	NS
265	B	0.0897/2001	NS
267	B	0.0731/2002	0.0742
271	B	0.0014/2002	0.0012
905	B	NS	NS
908	B	0.122/2002	0.122
909	B	0.0389/2002	0.0349
910	B	NS	NS
918	B	NS	NS
925	B	0.127/1999	NS
926	B	0.199/1999	NS
933	B	0.0024/1999	NS
934	B	0.312/2002	0.336
935	B	0.0868/2002	0.123
936	B	0.267/2002	0.306
937	B	0.907/2000	NS
938	B	0.21/1999	NS
939	B	NS	NS
942	B	0.246/2002	0.218
943	B	0.0066/2002	0.0041
944	B	0.95/1999	NS
947	B	0.0024/2002	NS
683	C	0.0012/2002	0.0011
684	C	0.0019/2002	0.0014
685	C	0.0012/2002	0.0011
689	C	0.0011/2002	0.001
691	C	0.0657/2002	0.065
903	C	0.0022/2002	0.0019
912	C	0.034/2001	NS
914	C	0.0013/2001	NS
917	C	0.0013/2001	NS
930	C	0.0023/2002	0.0025
932	C	0.0016/2002	0.0014

Table 7 (continued). Background and August 2002 Uranium Concentrations

Well Number	Horizon	Background Uranium Concentration (mg/L/Year Sampled)	August 2002 Uranium Concentration (mg/L)
MCL = 0.044 mg/L			
1008	C	0.001/2000	0.001
1116	C	0.0083/2002	0.0038
1117	C	0.0151/2002	0.0074
1118	C	0.0098/2002	0.0266
258	D	0.0018/2000	NS
261	D	0.0018/2001	NS
264	D	0.0033/2001	NS
266	D	0.0019/2001	NS
690	D	0.0018/2002	0.0021
692	D	0.0015/2002	0.0015
695	D	0.002/2002	0.002
904	D	0.0044/2001	NS
915	D	0.0017/2001	NS
1003	D	0.0205/2000	0.0294
1004	D	0.0053/2000	0.0079
1005	D	0.0013/2000	0.0013
1006	D	0.0014/2000	0.0011
1007	D	0.0012/2000	0.0011
1101	D	0.245/2002	0.0927
1102	D	0.533/2002	0.483
1103	D	0.355/2002	0.418
1104	D	0.1/2002	0.149
1105	D	0.194/2002	1.63
1106	D	0.1/2002	0.815
1107	D	0.118/2002	0.0358
1108	D	0.646/2002	0.286
1109	D	0.565/2002	0.197
1110	D	0.0528/2002	0.0426
1111	D	0.161/2002	0.0979
1112	D	0.13/2002	0.0363
1113	D	0.0149/2002	0.0037
1114	D	0.0277/2002	0.011
1115	D	0.41/2002	0.0884
1119	D	0.555/2002	0.229
1120	D	0.3/2002	1.2
1121	D	0.849/2002	0.577
1122	D	0.878/2002	0.338
1123	D	0.261/2002	0.0927
1124	D	0.171/2002	0.119
1125	D	0.0176/2002	0.0199
251	E	0.0481/2002	0.002
268	E	0.0014/2002	0.002
920	E	0.017/2001	NS
948	E	NS	NS

Table 7 (continued). Background and August 2002 Uranium Concentrations

Well Number	Horizon	Background Uranium Concentration (mg/L/Year Sampled)	August 2002 Uranium Concentration (mg/L)
MCL = 0.044 mg/L			
911	F	NS	
913	G	0.0016/2001	
916	G	0.0014/2001	
919	G	NS	
902	H	NS	
252	I	0.0024/2002	
254	I	0.209/2002	
256	I	0.0775/2002	
921	I	0.0047/2001	
253	M	0.0765/2000	
255	M	0.0029/2000	
257	M	0.0037/2000	

NS – not sampled

Table 8. Background and August 2002 Selenium Concentrations

Well Number	Horizon	Background Selenium Concentration (mg/L/Year Sampled)	August 2002 Selenium Concentration (mg/L)
MCL = 0.01mg/L			
686	A	0.0088/2002	0.00043
687	A	0.0145/2002	0.00068
688	A	0.0033/2002	0.003
901	A	0.0024/2001	NS
906	A	0.0335/2002	0.0517
928	A	NS	NS
940	A	0.105/2002	NS
941	A	0.0348/2002	NS
945	A	0.0035/2002	0.0043
946	A	NS	0.003
262	B	0.0621/2001	NS
263	B	0.0632/2001	NS
265	B	0.0071/2001	NS
267	B	0.0532/2002	0.051
271	B	0.0016/2002	0.0015
905	B	NS	NS
908	B	0.0163/2002	0.0149
909	B	0.0224/2002	0.0162
910	B	0.005	NS
918	B	NS	NS
925	B	0.0191/1999	NS
926	B	NS	NS
933	B	0.004/1999	NS
934	B	0.0116/2002	0.0096
935	B	0.0195/2002	0.0179
936	B	0.0869/2002	0.103
937	B	0.0765/2000	NS
938	B	0.0432/1999	NS
939	B	NS	NS
942	B	0.0348/2002	0.0316
943	B	0.0021/2002	0.0023
944	B	0.0401/1999	NS
947	B	0.0019/2002	NS
683	C	0.0022/2002	0.0018
684	C	0.0019/2002	0.0016
685	C	0.0017/2002	0.0015
689	C	0.0014/2002	0.0014
691	C	0.0046/2002	0.0043
903	C	0.0023/2002	0.002
912	C	0.0137/2001	NS
914	C	0.0016/2001	NS
917	C	0.0017/2001	NS
930	C	0.002/2002	0.0023
932	C	0.0019/2002	0.0016

Table 8 (continued). Background and August 2002 Selenium Concentrations

Well Number	Horizon	Background Selenium Concentration (mg/L/Year Sampled)	August 2002 Selenium Concentrtion (mg/L)
MCL = 0.01 mg/L			
1008	C	0.0015/2000	0.0014
1116	C	0.0018/2002	0.0017
1117	C	0.0028/2002	0.0024
1118	C	0.0028/2002	0.009
258	D	0.0018/2000	NS
261	D	0.0021/2001	NS
264	D	0.0018/2001	NS
266	D	0.0013/2001	NS
690	D	0.0014/2002	NS
692	D	0.0022/2002	NS
695	D	0.0019/2002	NS
904	D	0.0131/2001	NS
915	D	0.0019/2001	NS
1003	D	0.003/2000	NS
1004	D	0.0021/2000	NS
1005	D	0.0014/2000	NS
1006	D	0.0013/2000	NS
1007	D	0.0013/2000	NS
1101	D	0.0188/2002	0.0215
1102	D	0.0121/2002	0.0116
1103	D	0.0613/2002	0.0567
1104	D	0.0344/2002	0.0265
1105	D	0.0871/2002	0.0737
1106	D	0.0925/2002	0.0398
1107	D	0.0903/2002	0.0174
1108	D	0.0704/2002	0.0322
1109	D	0.0372/2002	0.0108
1110	D	0.0081/2002	0.0054
1111	D	0.0172/2002	0.0107
1112	D	0.0154/2002	0.0041
1113	D	0.0025/2002	0.0015
1114	D	0.0035/2002	0.0023
1115	D	0.0362/2002	0.0087
1119	D	0.0290/2002	0.0148
1120	D	0.0563/2002	0.0488
1121	D	0.0439/2002	0.0331
1122	D	0.0558/2002	0.0224
1123	D	0.0449/2002	0.0135
1124	D	0.0186/2002	0.0116
1125	D	0.0250/2002	0.0022
251	E	0.0035/2002	0.001
268	E	0.0018/2002	0.0016
920	E	0.0014/2001	NS
948	E	NS	NS

Table 8 (continued). Background and August 2002 Selenium Concentrations

Well Number	Horizon	Background Selenium Concentration (mg/L/Year Sampled)	August 2002 Selenium Concentration (mg/L)
MCL = 0.01 mg/L			
911	F	0.005	
913	G	0.00063/2001	
916	G	0.001/2001	
919	G	NS	
902	H	NS	
252	I	0.00092/2002	
254	I	0.0531/2002	
256	I	0.0031/2002	
921	I	0.00091/2001	
253	M	0.0034/2000	
255	M	0.0011/2000	
257	M	0.0013/2000	

NS – not sampled

Table 9. Background and August 2002 Strontium Concentrations

Well Number	Horizon	Background Strontium Concentrations (mg/L/Year Sampled)	August 2002 Strontium Concentrations (mg/L)
No MCL for strontium			
686	A	0.927/2002	0.0419
687	A	1.08/2002	0.0581
688	A	0.413/2002	0.398
901	A	0.349/2001	NS
906	A	9.99/2002	8.32
928	A	NS	NS
940	A	9.51/2002	NS
941	A	2.63/2002	NS
945	A	0.487/2002	0.581
946	A	NS	0.712
262	B	3.78/2001	NS
263	B	5.87/2001	NS
265	B	7.24/2001	NS
267	B	3.92/2002	4.1
271	B	0.318/2002	0.344
905	B	NS	NS
908	B	2.33/2002	3.25
909	B	4.30/2002	3.6
910	B	NS	NS
918	B	NS	NS
925	B	3.43/1999	NS
926	B	7.57/1999	NS
933	B	0.949/1999	NS
934	B	10.2/2002	14.6
935	B	4.06/2002	4.91
936	B	7.95/2002	8.22
937	B	9.87/2000	NS
938	B	10.6/1999	NS
939	B	NS	NS
942	B	5.92/2002	5.46
943	B	0.344/2002	0.367
944	B	5.97/1999	NS
947	B	0.348/2002	NS
683	C	0.328/2002	0.322
684	C	0.375/2002	0.354
685	C	0.339/2002	0.341
689	C	0.555/2002	0.43
691	C	2.93/2002	3.79
903	C	1.05/2002	0.625
912	C	4.24/2001	NS
914	C	0.463/2001	NS
917	C	0.350/2001	NS
930	C	0.966/2002	1.45
932	C	1.01/2002	0.558

Table 9 (continued). Background and August 2002 Strontium Concentrations

Well Number	Horizon	Background Strontium mg/L/Year Sampled	August 2002 Strontium mg/L
No MCL for strontium			
1008	C	0.523/2000	0.481
1116	C	NS	0.998
1117	C	2.66/2002	1.4
1118	C	1.66/2002	3.73
258	D	0.57/2000	NS
261	D	.0719/2001	NS
264	D	0.477/2001	NS
266	D	1.12/2001	NS
690	D	1.21/2002	1.25
692	D	0.931/2002	0.75
695	D	0.463/2002	0.503
904	D	1.20/2001	NS
915	D	0.569/2001	NS
1003	D	1.74/2000	2.33
1004	D	0.804/2000	0.918
1005	D	1.11/2000	1.24
1006	D	1.14/2000	1.21
1007	D	0.648/2000	0.7
1101	D	3.68/2002	3.63
1102	D	4.96/2002	5.02
1103	D	4.48/2002	4.64
1104	D	2.63/2002	3.35
1105	D	3.15/2002	3.24
1106	D	2.89/2002	1.68
1107	D	6.62/2002	2.42
1108	D	7.70/2002	5.94
1109	D	6.46/2002	3.7
1110	D	3.99/2002	2.38
1111	D	5.99/2002	4.05
1112	D	2.40/2002	2.06
1113	D	1.64/2002	1.1
1114	D	2.16/2002	1.68
1115	D	4.42/2002	2.08
1119	D	2.44/2002	3.1
1120	D	2.10/2002	3.49
1121	D	2.54/2002	2.33
1122	D	5.18/2002	2.4
1123	D	3.86/2002	2.06
1124	D	3.74/2002	2.9
1125	D	0.735/2002	0.932
251	E	1.34/2002	1.28
268	E	0.65/2002	0.818
920	E	1.02/2001	NS
948	E	NS	NS

Table 9 (continued). Background and August 2002 Strontium Concentrations

Well Number	Horizon	Background Strontium Concentrtions (mg/L/Year Sampled)	August 2002 Strontium Concentrations (mg/L)
No MCL for strontium			
911	F	NS	
913	G	0.791/2001	
916	G	0.808/2001	
919	G	NS	
902	H	NS	
252	I	0.873/2002	
254	I	0.733/2002	
256	I	0.569/2002	
921	I	0.755/2001	
253	M	2.13/2000	
255	M	0.0919/2000	
257	M	4.30/2000	

NS – not sampled

Table 10. Extraction and Injection Well Design Rates and Screened Horizons

Well Number	Well Type	Design Pumping Rate (gpm)	Screen Length (ft)	Horizon Top of Well Screen	Horizon Bottom Of Well Screen
1003	Injection	1.0	50	C	D
1004	Injection	1.0	50	C	D
1005	Injection	1.0	50	C	D
1006	Injection	1.0	50	C	D
1007	Injection	1.0	50	C	D
1008	Injection	1.0	50	C	D
Infiltration Trench	Infiltration Trench	57.0	NA	NA	NA
1101	Extraction	4.0	155	B	D
1102	Extraction	3.0	150	B	E
1103	Extraction	4.0	150	B	E
1104	Extraction	4.0	155	B	E
1105	Extraction	5.0	155	B	E
1106	Extraction	5.1	155	B	E
1107	Extraction	5.1	154	B	E
1108	Extraction	5.1	150	B	E
1109	Extraction	5.1	155	B	E
1110	Extraction	5.0	150	B	E
1111	Extraction	8.6	154	B	E
1112	Extraction	3.1	155	B	E
1113	Extraction	2.0	155	B	E
1114	Extraction	3.5	155	B	E
1115	Extraction	3.5	155	B	E
1116	Extraction	2.0	103	B	D
1117	Extraction	2.0	103	B	D
1118	Extraction	3.2	106	B	D
1119	Extraction	2.6	155	B	E
1120	Extraction	2.6	150	B	E
1121	Extraction	3.1	150	B	E
1122	Extraction	2.6	154	B	E
1123	Extraction	3.1	154	B	E
1124	Extraction	2.6	158	B	E
1125	Extraction	2.6	150	B	E

Table 11. August 2002 Drawdowns from Baseline Ground Water Levels

Well Number	Baseline Water-Level Elevation (ft above msl[1])	August 2002 Water-Level Elevation (ft above msl[1])	Drawdown[2] (ft)
Horizon A			
686	5028.11	5046.14	-18.03
687	5035.35	5039.18	-3.83
688	5027.11	5027.13	-0.02
906	5017.71	5012.69	5.02
Horizon B			
267	5000.08	4999.61	0.47
271	4993.49	4993.35	0.14
908	5008.12	5005.97	2.15
909	4998.81	4997.94	0.87
934	5001.08	4996.73	4.35
935	5008.66	5005.39	3.27
936	5011.45	4999.06	12.39
942	5015.24	5011.95	3.29
943	5028.63	5028.47	0.16
Horizon C			
683	4990.11	4978.26	11.85
684	5000.85	4985.59	15.26
691	4944.80	4942.01	2.79
930	4935.67	4935.51	0.16
932	4964.01	4953.52	10.49
Horizon D			
258	4975.01	4966.70	8.31
261	4950.28	4946.07	4.21
264	4987.60	4967.41	20.19
266	4967.17	4947.52	19.65
690	4928.09	4926.72	1.37
692	4930.87	4929.24	1.63
695	4931.54	4930.83	0.71
904	4882.55	4882.26	0.29
915	4975.88	4966.54	9.34
1003	4944.72	4942.10	2.62
1004	4943.01	4942.20	0.81
1005	4926.44	4926.43	0.01
1006	4932.76	4930.37	2.39
1007	4939.34	4936.64	2.70
Horizon E			
251	4999.51	4954.50	45.01
268	4985.41	4952.56	32.85
920	4954.53	4942.99	11.54
Horizon F			
911	5057.28	5057.36	-0.08
Horizon G			
913	4995.04	4989.30	5.74
916	4957.55	4948.36	9.19
919	4903.39	4902.86	0.53
Horizon I			
252	4994.81	4985.15	9.66
254	5009.54	4991.53	18.01
256	4968.31	4960.13	8.00
921	4943.98	4937.36	6.62
Horizon M			
255	4974.49	4973.41	1.08
257	4962.07	4959.89	2.18

[1]msl = mean sea level
[2]Drawdown = Baseline water level – August 2002 water level. Positive values indicate drawdown; negative values indicate mounding.

End of current text