SITE HYDROGEOLOGY
ESTIMATION OF GROUNDWATER TRAVEL TIMES
AND RECOMMENDED ADDITIONAL MONITORING WELLS
FOR PROPOSED TAILINGS CELL 4B
WHITE MESA URANIUM MILL SITE
NEAR BLANDING, UTAH

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January 8, 2008

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1. INTRODUCTION

This report provides a brief description of the hydrogeology of the White Mesa Uranium Mill site (the "Mill" or the "site"), located south of Blanding, Utah, and focuses on the occurrence and flow of groundwater within the relatively shallow perched groundwater zone at the site. Based on available existing hydrogeologic information from the site, estimates of hydraulic gradients and intergranular rates of groundwater movement (interstitial or pore velocities) are provided. These estimates are used to calculate average travel times for a hypothetical conservative solute (assuming no dispersion) from existing tailings cell #3 and proposed cell 4B at the site to a downgradient discharge point. Recommendations for additional perched zone monitoring wells downgradient of proposed cell 4B are also provided. Figure 1 is a site plan showing the locations of perched monitoring wells and proposed cell 4B.

Tailings cell #3 has been in service for many years and a large quantity of groundwater monitoring and hydraulic test data exists for perched monitoring wells completed around the perimeter of the cell. Data from the vicinity of the cell are used in conjunction with data downgradient of the cell to calculate perched zone hydraulic properties and groundwater gradients between cell #3 and the discharge point. Cell 4B is proposed to be installed at the downgradient edge of cell #3. The data from the immediate vicinity and downgradient of cell #3 used to compute rates of movement and travel times for a hypothetical conservative solute will likewise be used to calculate travel times for the hypothetical solute from proposed cell 4B to the discharge point.

2. SITE HYDROGEOLOGY

Titan, 1994 provides a detailed description of site hydrogeology based on information available at that time. A brief summary of site hydrogeology that is based primarily on Titan, 1994, but includes the results of more recent site investigations, is provided below.

2.1 Geologic Setting

The White Mesa Uranium Mill site is located within the Blanding Basin of the Colorado Plateau physiographic province. Typical of large portions of the Colorado Plateau province, the rocks underlying the site are relatively undeformed. The average elevation of the site is approximately 5,600 feet above mean sea level (amsl).

The site is underlain by unconsolidated alluvium and indurated sedimentary rocks consisting primarily of sandstone and shale. The indurated rocks are relatively flat lying with dips generally less than 3°. The alluvial materials consist mostly of aeolian silts and fine-grained aeolian sands with a thickness varying from a few feet to as much as 25 to 30 feet across the site. The alluvium is underlain by the Dakota Sandstone and Burro Canyon Formation, which are sandstones having a total thickness ranging from approximately 100 to 140 feet. Beneath the Burro Canyon Formation lies the Morrison Formation, consisting, in descending order, of the Brushy Basin Member, the Westwater Canyon Member, the Recapture Member, and the Salt Wash Member. The Brushy Basin and Recapture Members of the Morrison Formation, classified as shales, are very fine-grained and have a very low permeability. The Brushy Basin

Member is primarily composed of bentonitic mudstones, siltstones, and claystones. The Westwater Canyon and Salt Wash Members also have a low average vertical permeability due to the presence of interbedded shales.

Beneath the Morrison Formation lie the Summerville Formation, an argillaceous sandstone with interbedded shales, and the Entrada Sandstone. Beneath the Entrada lies the Navajo Sandstone. The Navajo and Entrada Sandstones constitute the primary aquifer in the area of the site. The Entrada and Navajo Sandstones are separated from the Burro Canyon Formation by approximately 1,000 to 1,100 feet of materials having a low average vertical permeability. Groundwater within this system is under artesian pressure in the vicinity of the site, is of generally good quality, and is used as a secondary source of water at the site.

2.2 Hydrogeologic Setting

The site is located within a region that has a dry to arid continental climate, with average annual precipitation of less than 11.8 inches, and average annual evapotranspiration of approximately 61.5 inches. Recharge to aquifers occurs primarily along the mountain fronts (for example, the Henry, Abajo, and La Sal Mountains), and along the flanks of folds such as Comb Ridge Monocline.

Although the water quality and productivity of the Navajo/Entrada aquifer are generally good, the depth of the aquifer (approximately 1,200 feet below land surface [bls]) makes access difficult. The Navajo/Entrada aquifer is capable of yielding significant quantities of water to wells (hundreds of gallons per minute [gpm]). Water in wells completed across these units at the site rises approximately 800 feet above the base of the overlying Summerville Formation.

Perched groundwater in the Dakota Sandstone and Burro Canyon Formation is used on a limited basis to the north (upgradient) of the site because it is more easily accessible. Water quality of the Dakota Sandstone and Burro Canyon Formation is generally poor due to high total dissolved solids (TDS) and is used primarily for stock watering and irrigation. The saturated thickness of the perched water zone generally increases to the north of the site, increasing the yield of the perched zone to wells installed north of the site.

2.3 Perched Zone Hydrogeology

Perched groundwater beneath the site occurs primarily within the Burro Canyon Formation. Perched groundwater at the site has a generally low quality due to high total dissolved solids (TDS) in the range of approximately 1,200 to 5,000 milligrams per liter (mg/L), and is used primarily for stock watering and irrigation in the areas upgradient (north) of the site. Perched water is supported within the Burro Canyon Formation by the underlying, fine-grained Brushy Basin Member. Figure 2 is a contour map showing the approximate elevation of the contact of the Burro Canyon Formation with the Brushy Basin Member, which essentially forms the base of the perched water zone at the site. Contact elevations are based on perched monitoring well drilling and geophysical logs and surveyed land surface elevations. As indicated, the contact generally dips to the south/southwest beneath the site.

Groundwater within the perched zone generally flows south to southwest beneath the site. Beneath the tailings cells, perched water flow is generally southwest to south-southwest.

2.3.1 Lithologic and Hydraulic Properties

Although the Dakota Sandstone and Burro Canyon Formations are often described as a single unit due to their similarity, previous investigators at the site have distinguished between them. The Dakota Sandstone is a relatively-hard to hard, generally fine-to-medium grained sandstone cemented by kaolinite clays. The Dakota Sandstone locally contains discontinuous interbeds of siltstone, shale, and conglomeratic materials. Porosity is primarily intergranular. The underlying Burro Canyon Formation hosts most of the perched groundwater at the site. The Burro Canyon Formation is similar to the Dakota Sandstone but is generally more poorly sorted, contains more conglomeratic materials, and becomes argillaceous near its contact with the underlying Brushy Basin Member. The permeability of the Dakota Sandstone and Burro Canyon Formation at the site is generally low.

No significant joints or fractures within the Dakota Sandstone or Burro Canyon Formation have been documented in any wells or borings installed across the site (Knight Piésold, 1998). Any fractures observed in cores collected from site borings are typically cemented, showing no open space.

2.3.1.1 Dakota

Based on samples collected during installation of wells MW-16 (no longer in service) and MW-17, located immediately downgradient of the tailings cells at the site, porosities of the Dakota Sandstone range from 13.4 to 26 percent, averaging 20 percent, and water saturations range from 3.7 to 27.2 percent, averaging 13.5 percent. The average volumetric water content is approximately 3 percent. The permeability of the Dakota Sandstone based on packer tests in borings installed at the site ranges from 2.71 x 10^{-6} centimeters per second (cm/s) to 9.12 x 10^{-4} cm/s, with a geometric average of 3.89 x 10^{-5} cm/s.

2.3.1.2 Burro Canyon

The average porosity of the Burro Canyon Formation is similar to that of the Dakota Sandstone. Based on samples collected from the Burro Canyon Formation at MW-16, located immediately downgradient of the tailings cells at the site (and no longer in service), porosity ranges from 2 to 29.1 percent, averaging 18.3 percent, and water saturations of unsaturated materials range from 0.6 to 77.2 percent, averaging 23.4 percent. Titan, 1994, reported that the hydraulic conductivity of the Burro Canyon Formation ranges from 1.9 x 10^{-7} to 1.6 x 10^{-3} cm/s, with a geometric mean of 1.1 x 10^{-5} cm/s, based on the results of 12 pumping/recovery tests performed in monitoring wells and 30 packer tests performed in borings prior to that time.

Hydraulic testing of wells MW-01, MW-03, MW-05, MW-17, MW-18, MW-19, MW-20, and MW-22 during the week of July 8, 2002, and newly installed wells MW-23, MW-25, MW-27, MW-28, MW-29, MW-30, MW-31, MW-32, TW4-20, TW4-21, and TW4-22 during

June, 2005, yielded average perched zone permeabilities ranging from approximately 2 x 10^{-7} cm/s to 5 x 10^{-4} cm/s, similar to the range reported by previous investigators at the site (Hydro Geo Chem, Inc [HGC], 2002; HGC, 2005). Downgradient (south to southwest) of the tailings cells, average perched zone permeabilities based on tests at MW-3, MW-5, MW-17, MW-20, MW-22, and MW-25 ranged from approximately 4 x 10^{-7} to 1 x 10^{-4} cm/s Permeability estimates from these tests were based on pumping/recovery and slug tests analyzed using several different methodologies.

A number of temporary (TW4-series) perched zone monitoring wells have been installed at the site to investigate elevated concentrations of chloroform initially discovered at well MW-4 in 1999. Some of the conglomeratic zones encountered within the perched zone during installation of these wells are believed to be partly continuous or at least associated with a relatively continuous zone of higher permeability (International Uranium [USA] Corporation [IUSA] and HGC, 2001). The higher permeability zone defined by these wells is generally located east to northeast of the tailings cells at the site, and is hydraulically cross-gradient to upgradient of the tailings cells with respect to perched groundwater flow. Relatively high permeabilities measured at MW-11, located on the southeastern margin of the downgradient edge of tailings cell #3, and at MW-14, located on the downgradient edge of tailings cell #4, of 1.4 x 10^{-3} cm/s and 7.5 x 10^{-4} cm/s, respectively (UMETCO, 1993), may indicate that this zone extends beneath the southeastern margin of the cells. This zone of higher permeability within the perched water zone does not appear to exist downgradient (south-southwest) of the tailings cells, however. At depths beneath the perched water table, the zone is not evident in lithologic logs of the southernmost temporary wells TW4-4 and TW4-6 (located east [cross-gradient] of cell #3), nor is it evident in wells MW-3, MW-5, MW-12, MW-15, MW-16, MW-17, MW-20, MW-21, or MW-22, located south to southwest (downgradient) of the tailings cells, based on the lithologic logs or hydraulic testing of the wells.

Because of the generally low permeability of the perched zone beneath the site, well yields are typically low (less than 0.5 gpm), although sustainable yields of as much as about 4 gpm may be possible in wells intercepting larger saturated thicknesses and higher permeability zones in the northeast portion of the site. Sufficient productivity can, in general, only be obtained in areas where the saturated thickness is greater, which is the primary reason that the perched zone has been used on a limited basis as a water supply to the north (upgradient) of the site.

2.3.2 Perched Groundwater Flow

Perched groundwater flow at the site has historically been to the south/southwest. Figures 3 through 6 are perched groundwater elevation contour maps for the years 1990, 1994, 2002, and 2007, respectively. The 1990, 1994, and 2002 maps were hand contoured because of sparse data. As groundwater elevations indicate, the perched groundwater gradient changes from generally southwesterly in the western portion of the site, to generally southerly in the eastern portion of the site. The most significant changes between the 2002 and 2007 water levels result from pumping of wells MW-4, TW4-19, TW4-20, and MW-26. These wells are pumped to reduce chloroform mass in the perched zone east and northeast of the tailings cells.

In general, perched groundwater elevations have not changed significantly at most of the site monitoring wells since installation, except in the vicinity of the wildlife ponds and the pumping wells. For example, relatively large increases in water levels occurred between 1994 and 2002 at MW-4 and MW-19, located in the east and northeast portions of the site, as shown by comparing Figures 4 and 5. These water level increases in the northeastern and eastern portions of the site are likely the result of seepage from wildlife ponds located near the piezometers shown in Figure 5, which were installed in 2001 for the purpose of investigating these changes. The increase in water levels in the northeastern portion of the site has resulted in a local steepening of groundwater gradients over portions of the site. Conversely, pumping of wells MW-4, TW4-19, TW4-20, and MW-26 has depressed the perched water table locally and reduced average hydraulic gradients to the south and southwest of these wells.

Perched water discharges in springs and seeps along Westwater Creek Canyon and Cottonwood Canyon to the west-southwest of the site, and along Corral Canyon to the east of the site, where the Burro Canyon Formation outcrops. The discharge point located most directly downgradient of the tailings cells is Ruin Spring. This feature is located approximately 10,000 feet south-southwest of tailings cell #3 and is depicted on the USGS 7.5-minute quad sheet for Black Mesa (Figure 7).

3. PERCHED ZONE HYDROGEOLOGY BENEATH AND DOWNGRADIENT OF THE TAILINGS CELLS

Perched water as of the 3rd Quarter, 2007 was encountered at depths of approximately 57 to 115 feet bls in the vicinity of the tailings cells at the site (Figure 8). Beneath tailings cell #3, depths to water ranged from approximately 77 feet below top of casing (btoc) in the eastern portion of the cell (at MW-25), to approximately 114 feet btoc at the southwest margin of the cell (at MW-23). Assuming an average depth of the base of tailings cell #3 of 25 feet below grade, this corresponds to perched water depths of approximately 52 to 89 feet below the base of the cell, or an average depth of approximately 70 feet beneath the base of the cell. A similar assumption can be made for proposed cell 4B.

3.1 Saturated Thickness

The saturated thickness of the perched zone as of the 3rd Quarter, 2007 ranges from approximately 93 feet in the northeast portion of the site to less than 5 feet in the southwest portion of the site (Figure 9). Beneath tailings cell #3, the saturated thickness varies from approximately 49 feet in the easternmost corner of the cell to approximately 7 feet in the western portion of the cell. South-southwest of the tailings cells, the saturated thickness ranges from less than 1 foot at MW-21 to approximately 26 feet at MW-17. The average saturated thickness south-southwest of the tailings cells, based on measurements at MW-3, MW-5, MW-12, MW-14, MW-15, MW17, and MW-20, is approximately 14 feet. The average saturated thickness based on measurements at MW-5, MW-15, MW-3, and MW-20, which lay close to a line between the center of tailings cell #3 and Ruin Spring, is approximately 12 feet. By projecting conditions at these wells, the average saturated thickness is estimated to be approximately 10 to 15 feet between MW-20 and Ruin Spring.

3.2 Perched Water Flow

Perched groundwater flow beneath the tailings cells has historically been southwest, with the gradient steepening in recent years (since about 1994) and becoming more westerly as perched water levels in the northeastern portion of the site have risen. Perched water flowing beneath the tailings cells eventually discharges in springs and seeps located in Westwater Canyon, to the south-southwest of the cells. The primary discharge point for perched water flowing beneath the tailings cells is believed to be Ruin Spring, located approximately 10,000 feet south-southwest of the cells.

Perched zone hydraulic gradients currently range from a maximum of approximately 0.05 feet per foot (ft/ft) east of tailings cell #2 to approximately 0.01 ft/ft downgradient of cell #3, between cell #3 and MW-20. The average hydraulic gradient between the downgradient edge of tailings cell #3 and Ruin Spring can be approximated assuming the following:

1) The elevation of Ruin Spring, based on the USGS topographic map for Black Mesa, is approximately 5,390 feet amsl.

2) The distance between the downgradient edge of tailings cell #3 and Ruin Spring is approximately 10,000 feet.

3) The average groundwater elevation at the downgradient edge of tailings cell #3 is approximately 5,510 feet amsl.

Using these assumptions, the average perched zone hydraulic gradient between tailings cell #3 and Ruin Spring is approximately:

$$\frac{5510-5390}{10,000}=0.012 ft/ft$$

A hypothetical worst case average perched zone hydraulic gradient can also be estimated assuming the perched water elevation to be coincident with the base of tailings cell #3. The elevation of the base of tailings cell #3, which is also the approximate pre-existing land surface elevation near the center of the cell, is approximately 5,580 feet amsl. Under these conditions, for an unconfined perched zone, the maximum possible average perched zone hydraulic gradient between tailings cell #3 and Ruin Spring would be approximately:

$$\frac{5580-5390}{10,000}=0.019 ft/ft$$

Although the downgradient edge of proposed cell 4B is closer to Ruin Spring (approximately 9,000 feet from Ruin Spring rather than about 10,000 feet), the above hydraulic gradient calculations can also be applied to cell 4B.

3.3 Permeability

The average permeability of the perched zone downgradient of tailings cell #3 can be approximated based on the pumping/recovery test and slug test data obtained from perched zone wells located along the downgradient edge of and south of cell #3. Peel conducted hydraulic tests at perched zone wells MW-11, MW-12, MW-14, and MW-15 in 1992 (UMETCO, 1993).

Results of these tests are provided in Table 1. HGC conducted slug tests at perched zone wells MW-3, MW-5, MW-17, MW-20, and MW-22 in July 2002 (HGC, 2002), and MW-25 in June, 2005 (HGC, 2005).

The HGC slug test results were analyzed using various solution methods including KGS (Hyder, 1994), and Bouwer-Rice (Bouwer and Rice, 1976). Each method yielded slightly different results as shown in Table 2, which is based on Table 1 of HGC, 2002, and Table 1 of HGC, 2005. A range of average permeabilities for the portion of the site south of the tailings cells can be obtained by taking the geometric mean of the Peel test results and the results obtained by the various solution methods used to analyze the HGC data. Averaging the Peel test results for wells MW-11, MW-12, MW-14, and MW-15 with the HGC KGS results for wells MW-3, MW-5, MW-17, MW-20, MW-22, and MW-25 yields a geometric average of 2.3×10^{-5} cm/s, and similarly averaging the Peel test results with the HGC Bouwer-Rice results yields a geometric average of 4.3×10^{-5} cm/s, as shown in Table 2. The "early time" results at MW-5 using the Bouwer-Rice solution (from Table 1 of HGC, 2002) were used in the computations to yield a conservatively high estimate of permeability.

4. EVALUATION OF POTENTIAL FLOW PATHS AND TRAVEL TIMES FOR HYPOTHETICAL SEEPAGE ORIGINATING FROM CELL #3

Although more than 25 years of groundwater monitoring at the site has shown no impact to perched water from the tailings cells, an evaluation of hypothetical transport of a conservative solute in seepage from existing cell #3 and proposed cell 4B is presented assuming a flow path from the base of the existing and proposed cells to the perched water, and thence to Ruin Spring. Average travel times for a conservative constituent moving from the base of tailings cell #3 and proposed cell 4B to the perched water, and then moving with the perched water to Ruin Spring, are computed assuming no dispersion.

The porosities and water saturations used in the calculations were based on measurements reported in Titan, 1994, for samples collected from the Dakota Sandstone during drilling of MW-16 and MW-17, and from the Burro Canyon Formation during drilling of MW-16.

4.1 Estimated Travel Time from the Base of Cell #3 and Proposed Cell 4B to the Perched Zone

Knight-Piésold estimated a maximum volumetric seepage rate for tailings cell #3 based on cell construction and liner characteristics, of approximately 80 cubic feet per day (ft/day) or 0.42 gpm over the entire cell (Knight-Piésold, 1998). Most of this seepage was estimated to be via diffusion through the liner. This rate was estimated to decrease over time as the cell desaturates once the final cover is emplaced. Assuming a cell footprint of 3.38×10^6 ft^2, this rate is equivalent to 2.37×10^{-5} ft/day or 0.0086 feet per year (ft/yr).

The average rate of downward movement of a conservative solute dissolved in the seepage, assuming 1) no dispersion, 2) an average water saturation of 0.20, 3) an average porosity of 0.18, and assuming that this rate of seepage would not significantly raise the average saturation of the underlying materials, can be approximated as:

$$\frac{0.0086 ft/yr}{(.20)(.18)} = 0.24 ft/yr$$

The average time to travel 70 feet to the perched water zone would then be approximately 290 years. This is a conservative estimate because the average water saturations would be likely to increase, thereby reducing the downward rate of travel, and increasing the travel time.

Assuming a similar travel time from the base of proposed cell 4B to the perched water would be even more conservative because the improved liner system to be used for that cell would result in less seepage than from cell #3. However, for purposes of calculation, potential seepage rates and downward rates of movement for a hypothetical conservative solute will be assumed to be the same for cell 4B as those calculated for cell #3.

4.2 Estimated Travel Times from Tailings Cell #3 and Proposed Cell 4B to Ruin Spring

Under current conditions, the average hydraulic gradient between the downgradient edge of tailings cell #3 to Ruin Spring is estimated to be 0.012, as discussed in Section 3.2. Assuming the following:

Average porosity	= 0.18
Average hydraulic gradient	= 0.012
Flow path length	= 10,000 feet
Average permeability range	= 2.3 x 10^{-5} to 4.3 x 10^{-5} cm/s (0.064 ft/day to 0.120 ft/day)

the average rate of intergranular movement of perched groundwater (interstitial or pore velocity) can be approximated to range from 0.0043 ft/day to 0.0080 ft/day (or 1.6 ft/yr to 2.9 ft/yr). The estimated average travel time for a conservative solute, assuming no dispersion, from tailings cell #3 to Ruin Spring would then be approximately 6,250 to 3,450 years over this range of permeabilities. Under conditions of the maximum possible average perched groundwater gradient of 0.019 ft/ft, as estimated in Section 3.2, and assuming the same permeabilities, porosity, and path length as above, the estimated average travel times would range from approximately 4,055 to 2,160 years.

For proposed cell 4B, which is about 9,000 feet from Ruin Spring, the estimated travel times would be approximately 5,625 to 3,100 years using the gradient of 0.012, and approximately 3,650 to 1,950 years using the gradient of 0.019.

4.3 Estimated Total Travel Time from the Base of Tailings Cell #3 and Proposed Cell 4B to Ruin Spring

The total average travel time for a conservative solute from the base of tailings cell #3 or proposed cell 4B to Ruin Spring under current conditions would be the sum of 1) the travel time from the base of either cell to the perched water table, and 2) the time to travel within the perched zone to Ruin Spring. Based on the estimates provided in Sections 4.1 and 4.2, the total average travel time of a conservative solute (assuming no dispersion) over the range of average permeability estimates would be between 6,540 and 3,740 years for cell #3, and between 5,915 and 3,390 years for proposed cell 4B, assuming an average hydraulic gradient of 0.012 ft/ft. As discussed in Section 4.1, because the rate of movement of a conservative solute from the base of cell 4B would likely be slower than for cell #3 because seepage rates would lower, the total travel time would likely be higher than estimated above.

Conditions may hypothetically develop under which travel times may be reduced, such as an increase in average perched zone groundwater gradients between tailings cell #3 or cell 4B and Ruin Spring (as discussed in Section 3.2) or as a result of reduced vadose zone travel times due to development of a relatively large leak in either cell. Under hypothetical conditions in which a relatively large leak were to develop, potentially reducing vadose zone travel times to only a few years, the vadose zone travel time could be ignored, and the total average travel time (assuming no dispersion) would range from approximately 6,250 to 3,450 years for cell #3, and between 5,625 and 3,100 years for proposed cell 4B, assuming an average hydraulic gradient of 0.012 ft/ft. Under hypothetical conditions in which the average perched zone hydraulic gradient between either cell and Ruin Spring reached 0.019 ft/ft, which also implies a negligible vadose zone travel time, the total average travel time (assuming no dispersion) over the estimated range in permeability would be between approximately 4,055 and 2,160 years for cell #3, and between 3,650 and 1,950 years for cell 4B.

Estimates based on hypothetical assumptions of a relatively large leak in tailings cell #3 or an average hydraulic gradient as high as 0.019 ft/ft between either cell and Ruin Spring are considered very conservative because they assume conditions that are unlikely ever to develop. Furthermore the improved construction and leak detection system proposed for cell 4B would make this hypothetical scenario even less likely for cell 4B than for cell #3.

5. RECOMMENDED ADDITIONAL PERCHED ZONE MONITORING WELLS DOWNGRADIENT OF PROPOSED CELL 4B

The current perched groundwater monitoring well network for the tailings cells includes wells that are upgradient, crossgradient, and downgradient of the cells as shown in Figure 10. Most of the wells are located along the margins of the cells and many that are between the cells function as both upgradient wells for the cell located immediately downgradient of the wells and as downgradient wells for the cell located immediately upgradient of the wells. For example, well MW-30 functions as a downgradient well for cell #2 and as an upgradient well for cell #3. Wells MW-5, MW-12, and MW-23 that currently function as downgradient wells for cell #3 would also serve as upgradient wells for proposed cell 4B. The current arrangement of tailings cell perched monitoring wells is conservative with respect to U.S. Environmental Protection Agency (US EPA) Draft Technical Guidance (US EPA, 1992) which generally recommends downgradient wells only along the downgradient margin of the facility which in this case would be the entire complex of tailings cells.

Once proposed cell 4B is installed, an additional well or wells would be needed at the downgradient edge of the cell to be consistent with EPA Draft Guidance (US EPA, 1992). As shown in Figure 10, two additional wells are proposed, one at the southwest corner of proposed cell 4B and one between the southwest corner well and existing well MW-15. These installations would conservatively maintain the approximate existing spacing as defined by the proximity of MW-14 to MW-15 along the downgradient edge of existing cell 4A. Existing wells MW-3, MW-20, and MW-21 would continue to function as distal downgradient wells for the entire cell complex. Once installed, sampling frequencies for the new wells will be based on testing of the wells for perched zone hydraulic properties in the same fashion as for the existing wells.

6. REFERENCES

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7. LIMITATIONS STATEMENT

The opinions and recommendations presented in this report are based upon the scope of services and information obtained through the performance of the services, as agreed upon by HGC and the party for whom this report was originally prepared. Results of any investigations, tests, or findings presented in this report apply solely to conditions existing at the time HGC's investigative work was performed and are inherently based on and limited to the available data and the extent of the investigation activities. No representation, warranty, or guarantee, express or implied, is intended or given. HGC makes no representation as to the accuracy or completeness of any information provided by other parties not under contract to HGC to the extent that HGC relied upon that information. This report is expressly for the sole and exclusive use of the party for whom this report was originally prepared and for the particular purpose that it was intended. Reuse of this report, or any portion thereof, for other than its intended purpose, or if modified, or if used by third parties, shall be at the sole risk of the user.

TABLES

TABLE 1
Peel Hydraulic Test Results [1]

Well	Hydraulic Conductivity (cm/s)
MW-11	1.4×10^{-3}
MW-12	2.2×10^{-5}
MW-14	7.5×10^{-4}
MW-15	1.9×10^{-5}

Notes:
[1] *From UMETCO, 1993*

TABLE 2
Results of July 2002 and June 2005 Hydraulic Tests [2]

Well	Permeability in centimeters per second	
	KGS	Bouwer-Rice
MW-3	4.0×10^{-7}	1.5×10^{-5}
MW-5	3.5×10^{-6}	2.4×10^{-5}
MW-17	2.6×10^{-5}	2.7×10^{-5}
MW-20	--	9.3×10^{-6}
MW-22	1.0×10^{-6}	7.9×10^{-6}
MW-25	1.1×10^{-4}	7.4×10^{-5}

Geometric Average of above test results with Peel[3] test results for MW-11, MW-12, MW-14, and MW-15.

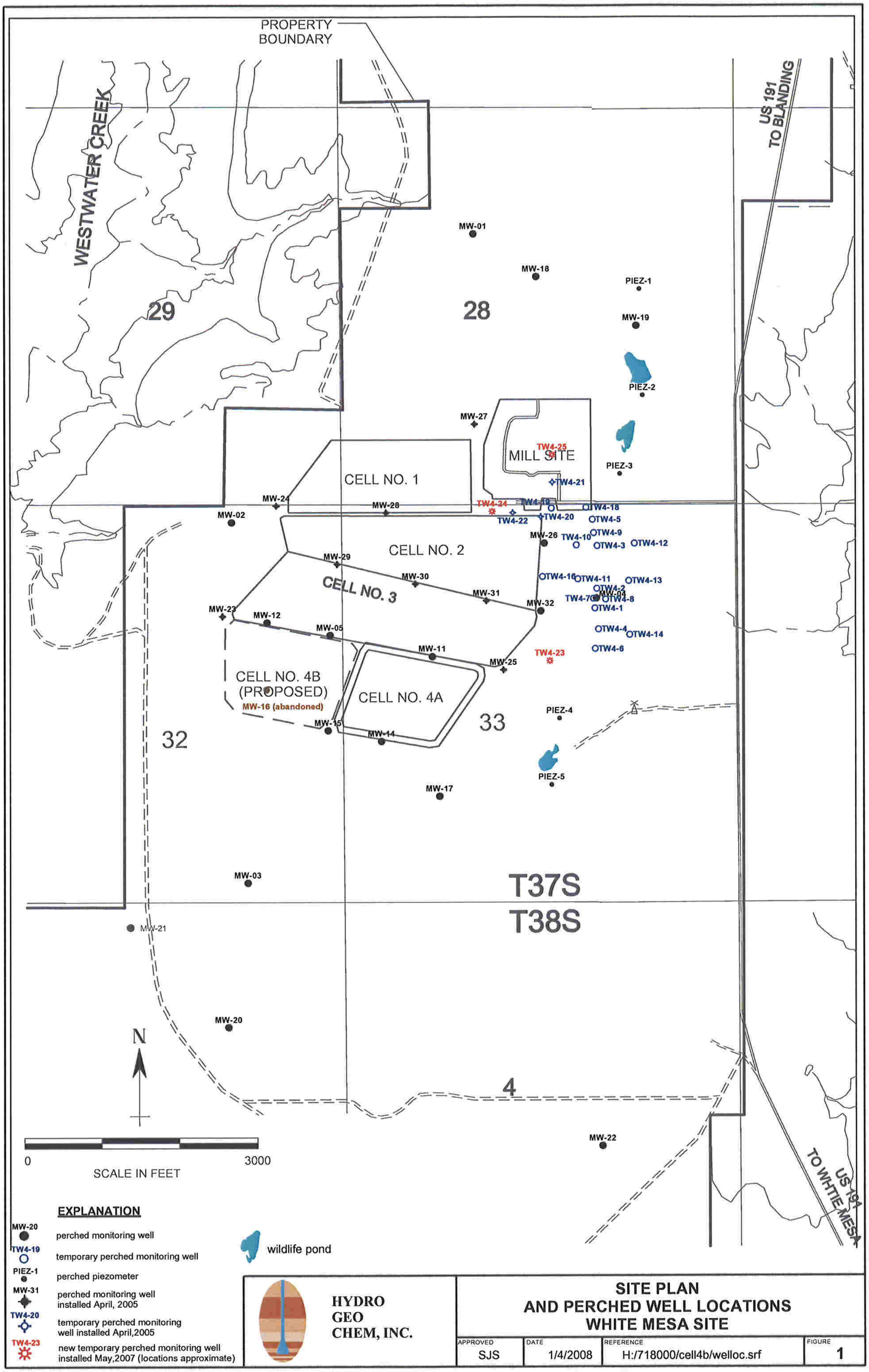
	KGS	Bouwer-Rice
	2.3×10^{-5}	4.3×10^{-5}

Notes:

[2] *From HGC, 2002; HGC, 2005*

[3] *From UMETCO, 1993*

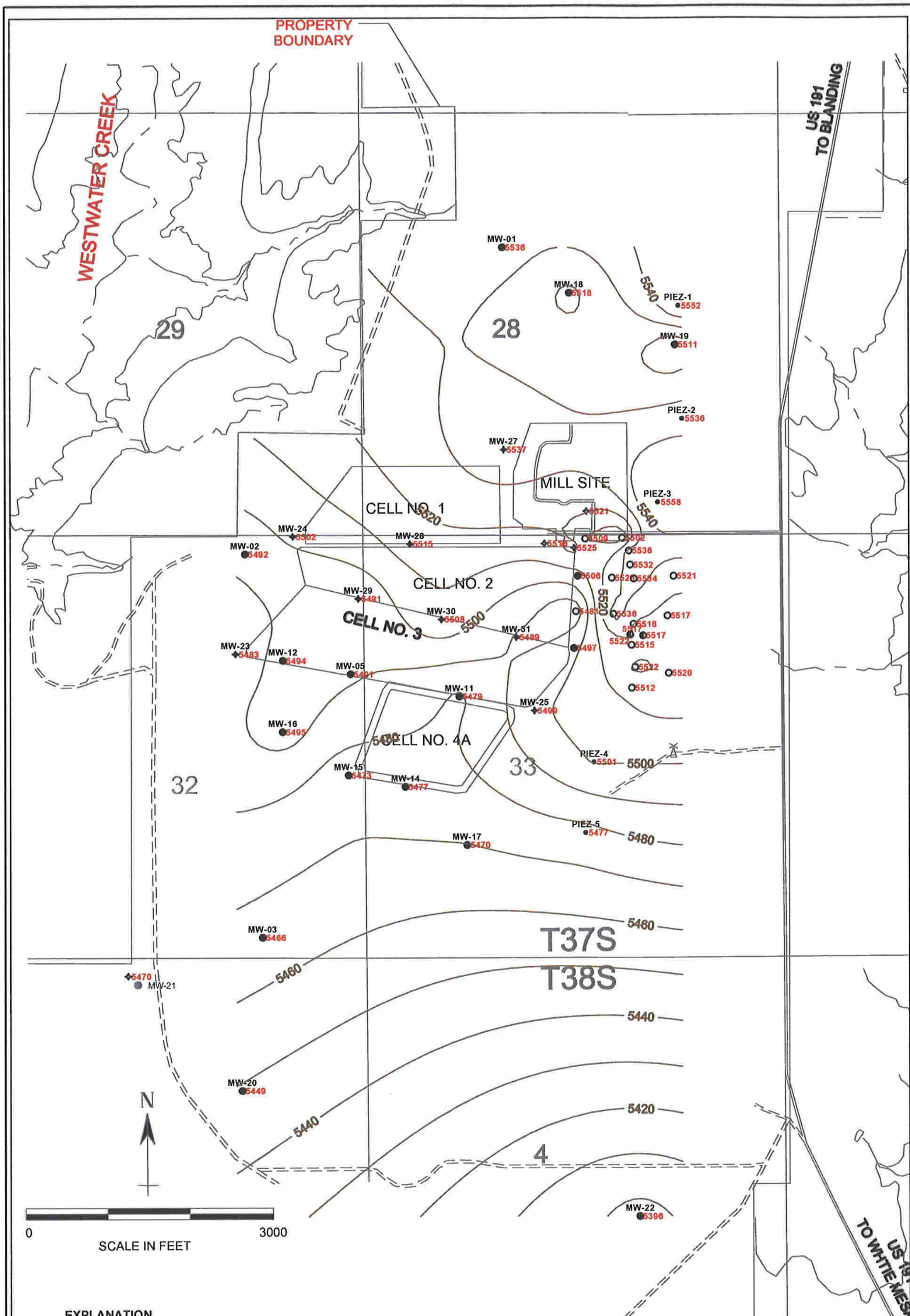
FIGURES



HYDRO GEO CHEM, INC.

SITE PLAN AND PERCHED WELL LOCATIONS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/welloc.srf	1



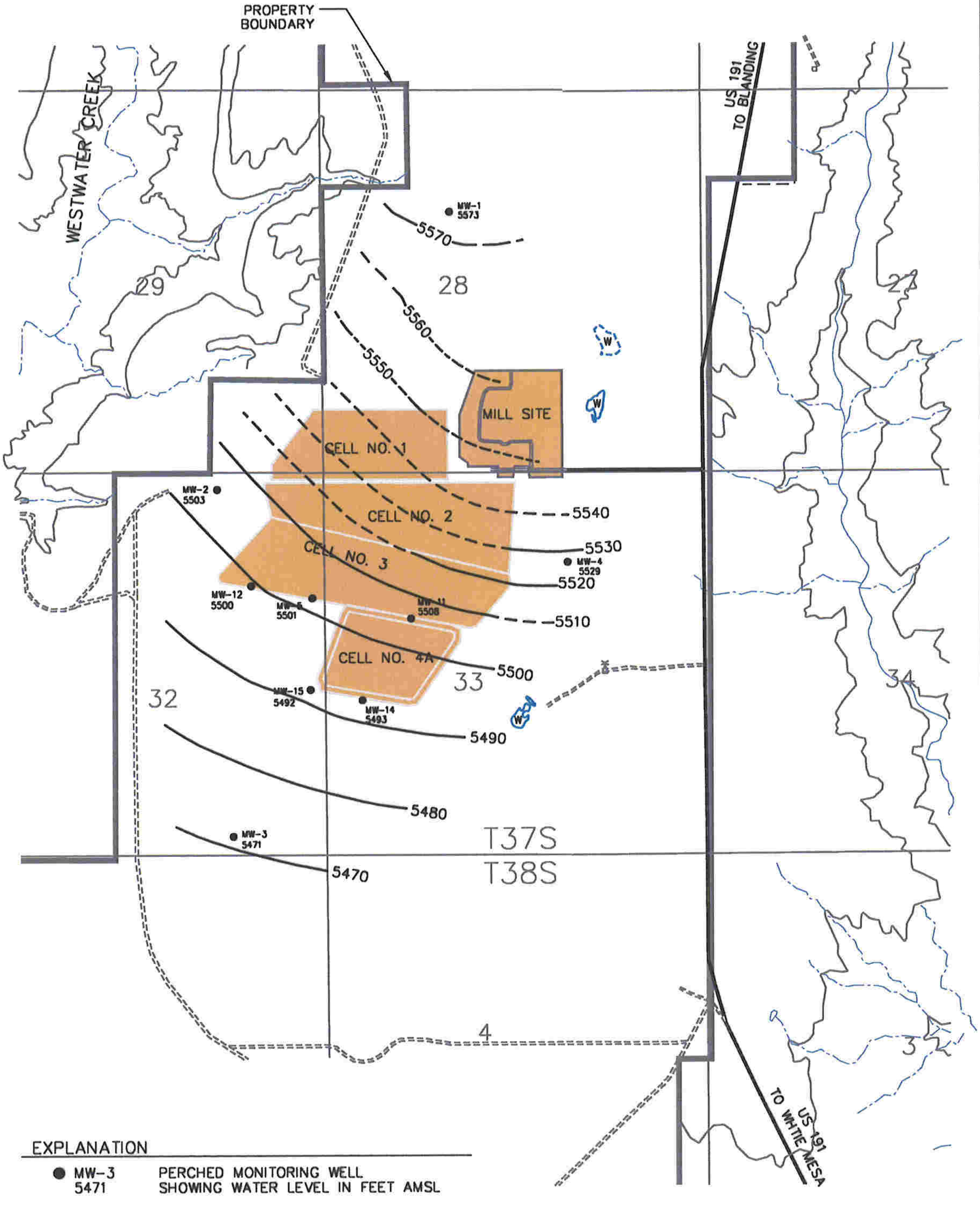
EXPLANATION

MW-20 5449	perched monitoring well showing elevation in feet amsl
5481	temporary perched monitoring well showing elevation in feet amsl
PIEZ-1 5552	perched piezometer showing elevation in feet amsl
MW-31 5489	perched monitoring well installed April,2005 showing elevation in feet amsl
5525	temporary perched monitoring well installed April,2005 showing elevation in feet amsl

HYDRO GEO CHEM, INC.

KRIGED BRUSHY BASIN CONTACT ELEVATIONS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	9/19/2007	H:/718000/cell4b/bbel0705.srf	2



EXPLANATION

● MW-3 5471 — PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL

W — WILDLIFE POND

5580 ——— - - - — WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

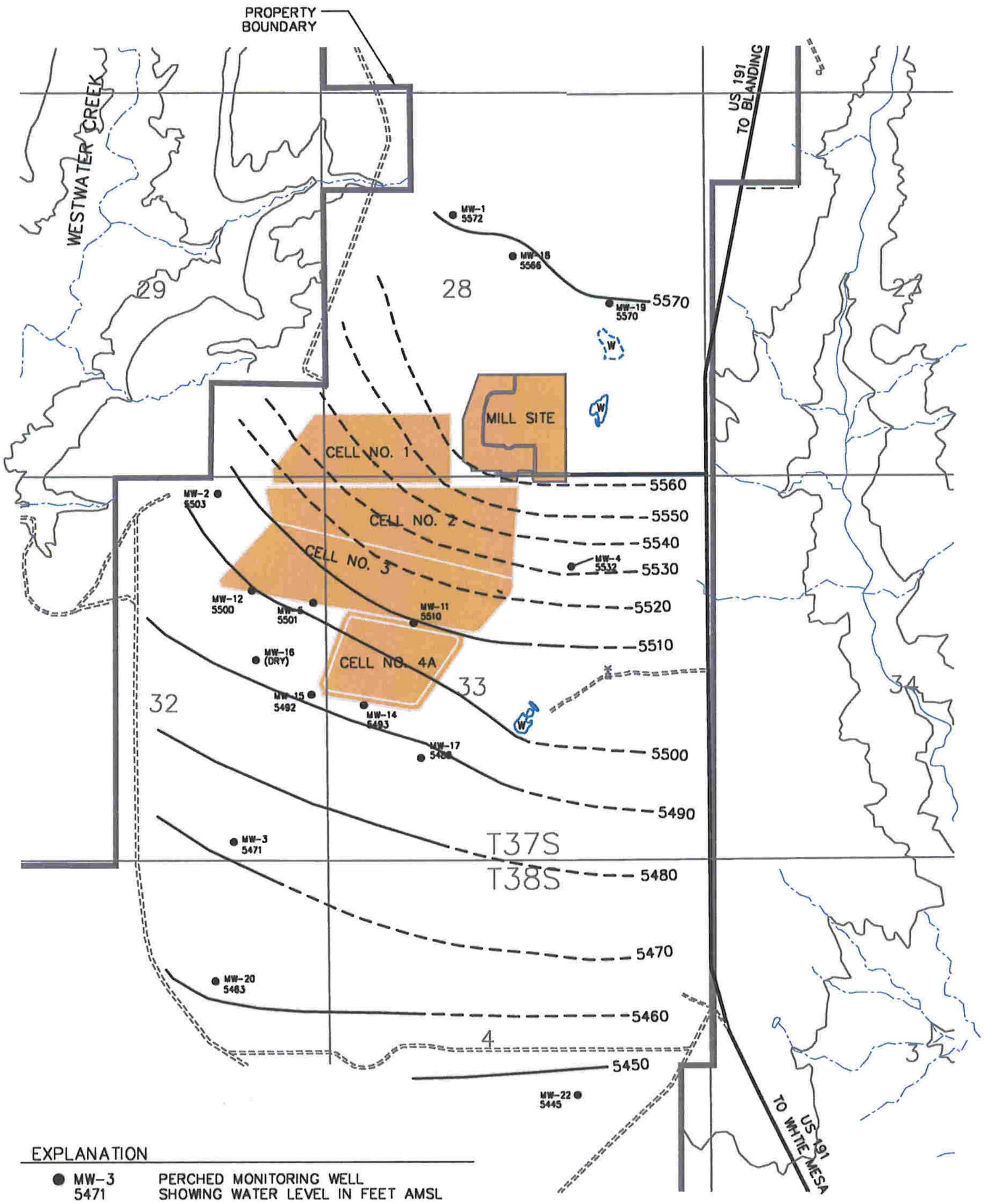
N

0 — 3000
SCALE IN FEET

HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
AUGUST 1990

Approved	Date	Revised	Date	Reference:	FIG:
SS	01/30/03			71800101	3



EXPLANATION

● MW-3 5471	PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL
W	WILDLIFE POND
5580 ——— — —	WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

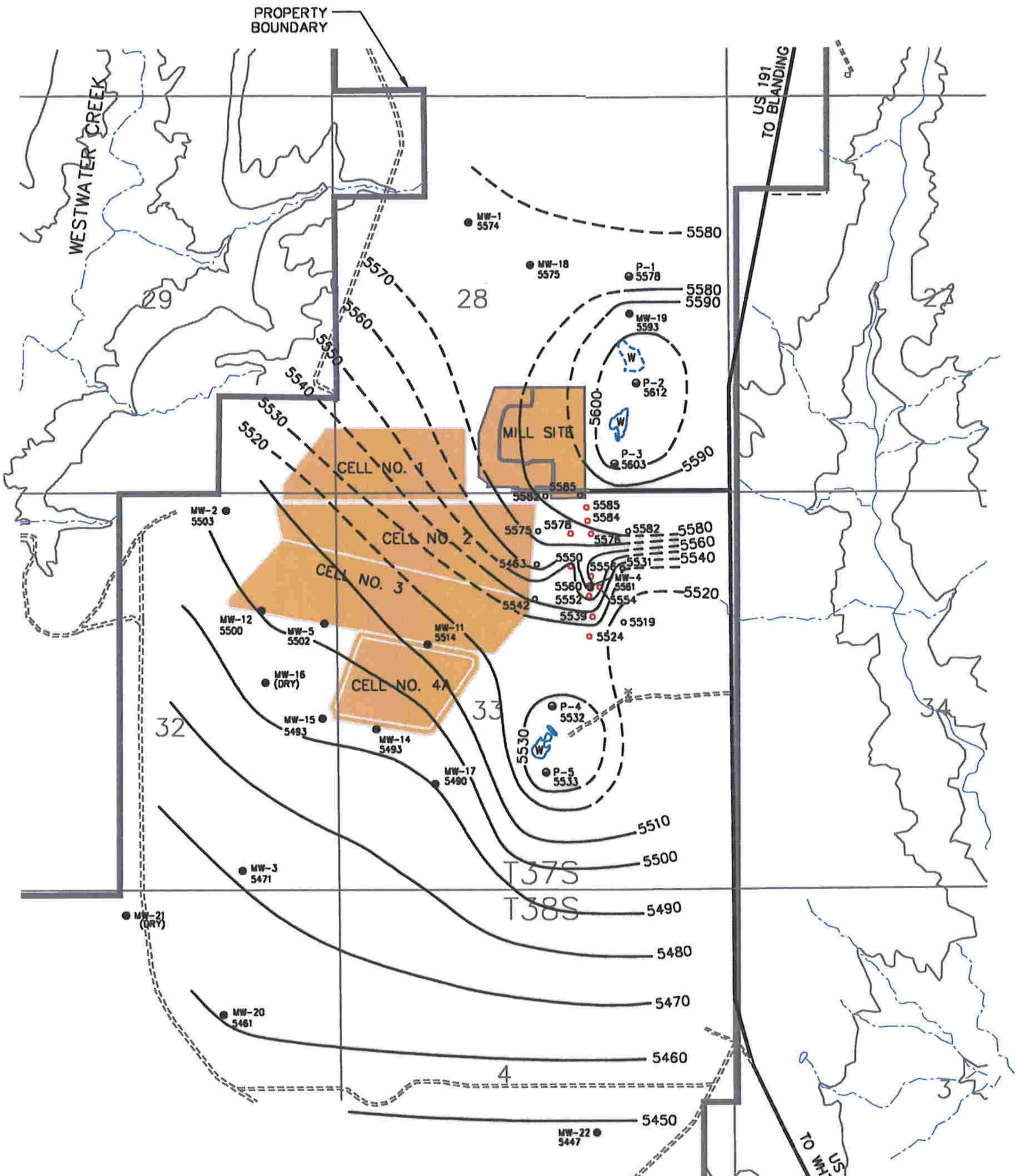
N

0 3000
SCALE IN FEET

HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
AUGUST 1994

Approved	Date	Revised	Date	Reference:	FIG:
SS	01/30/03			71800102	4



EXPLANATION

● MW-11 5514 — PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL

○ 5524 — TEMPORARY PERCHED MONITORING WELL SHOWING WATER LEVEL IN FEET AMSL

◒ P-5 5533 — PIEZOMETER SHOWING WATER LEVEL IN FEET AMSL

5580 ——— – – – WATER LEVEL CONTOUR LINE, DASHED WHERE UNCERTAIN

W — WILDLIFE POND

NOTE: WATER LEVELS FOR PIEZOMETERS ARE FROM AUGUST, 2002

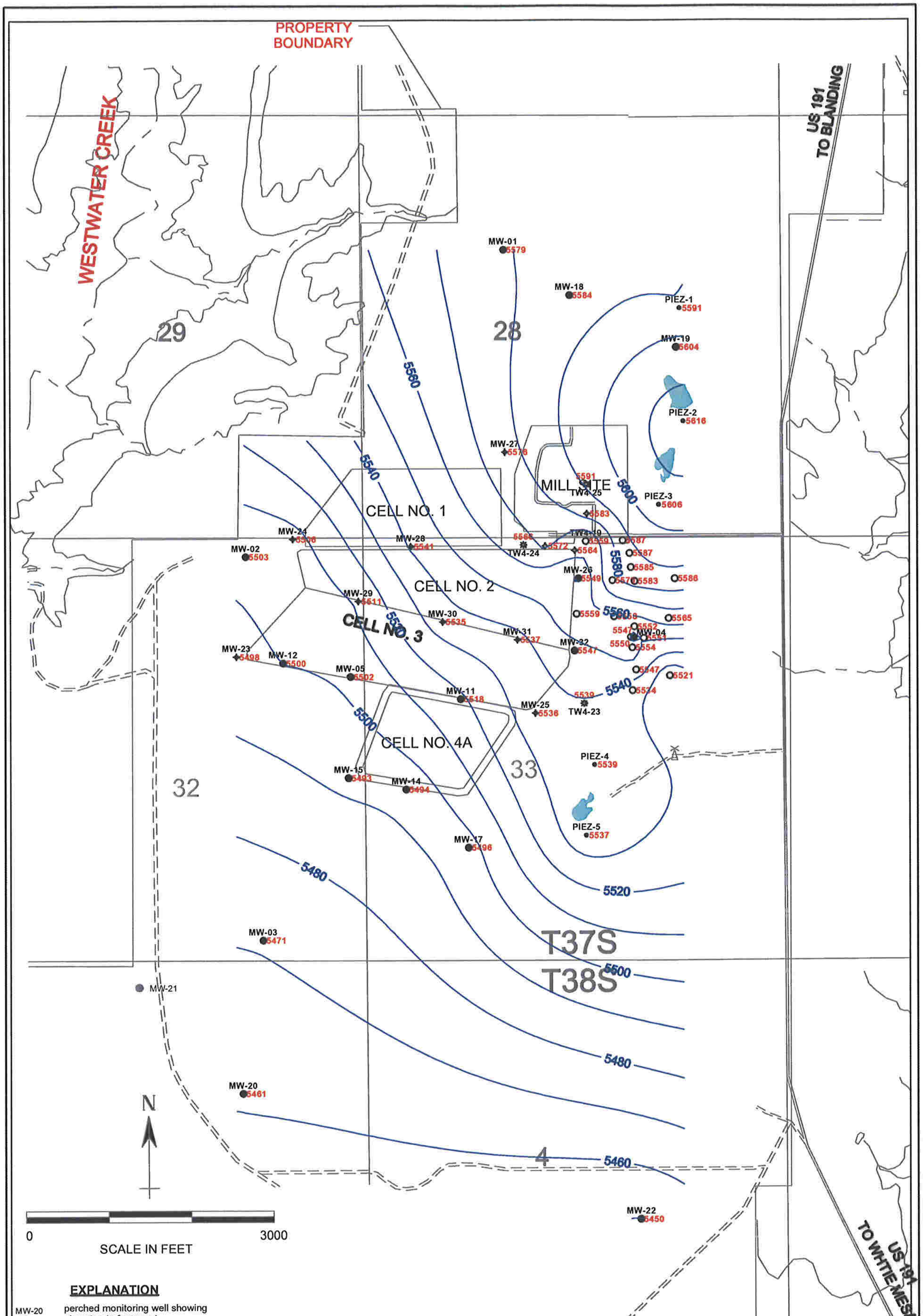
N

0 SCALE IN FEET 3000

HYDRO GEO CHEM, INC.

PERCHED WATER LEVELS
SEPTEMBER 2002

Approved	Date	Revised	Date	Reference:	FIG:
SS	01/30/03			71800103	5



EXPLANATION

MW-20 5461 — perched monitoring well showing elevation in feet amsl

5550 — temporary perched monitoring well showing elevation in feet amsl

PIEZ-1 5591 — perched piezometer showing elevation in feet amsl

MW-31 5537 — perched monitoring well installed April, 2005 showing elevation in feet amsl

5571 — temporary perched monitoring well installed April, 2005 showing elevation in feet amsl

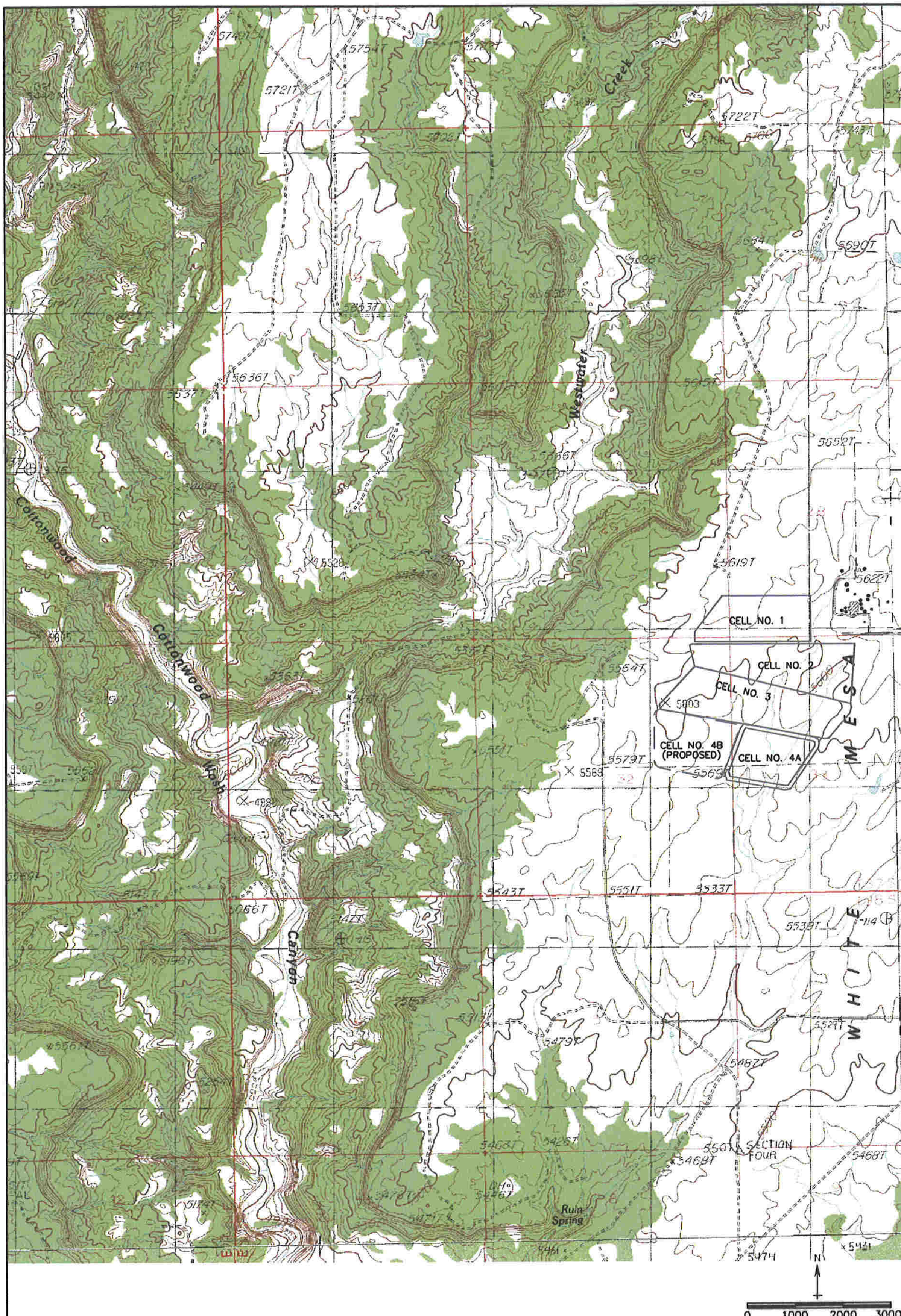
5539 — temporary perched monitoring well installed May, 2007 showing approximate elevation in feet amsl

NOTES: Locations and elevations for TW4-23, TW4-24, and TW4-25 are approximate; Water level for MW-26 (TW4-15) is from the second quarter, 2007

HYDRO GEO CHEM, INC.

KRIGED 3rd QUARTER, 2007 WATER LEVELS
WHITE MESA SITE

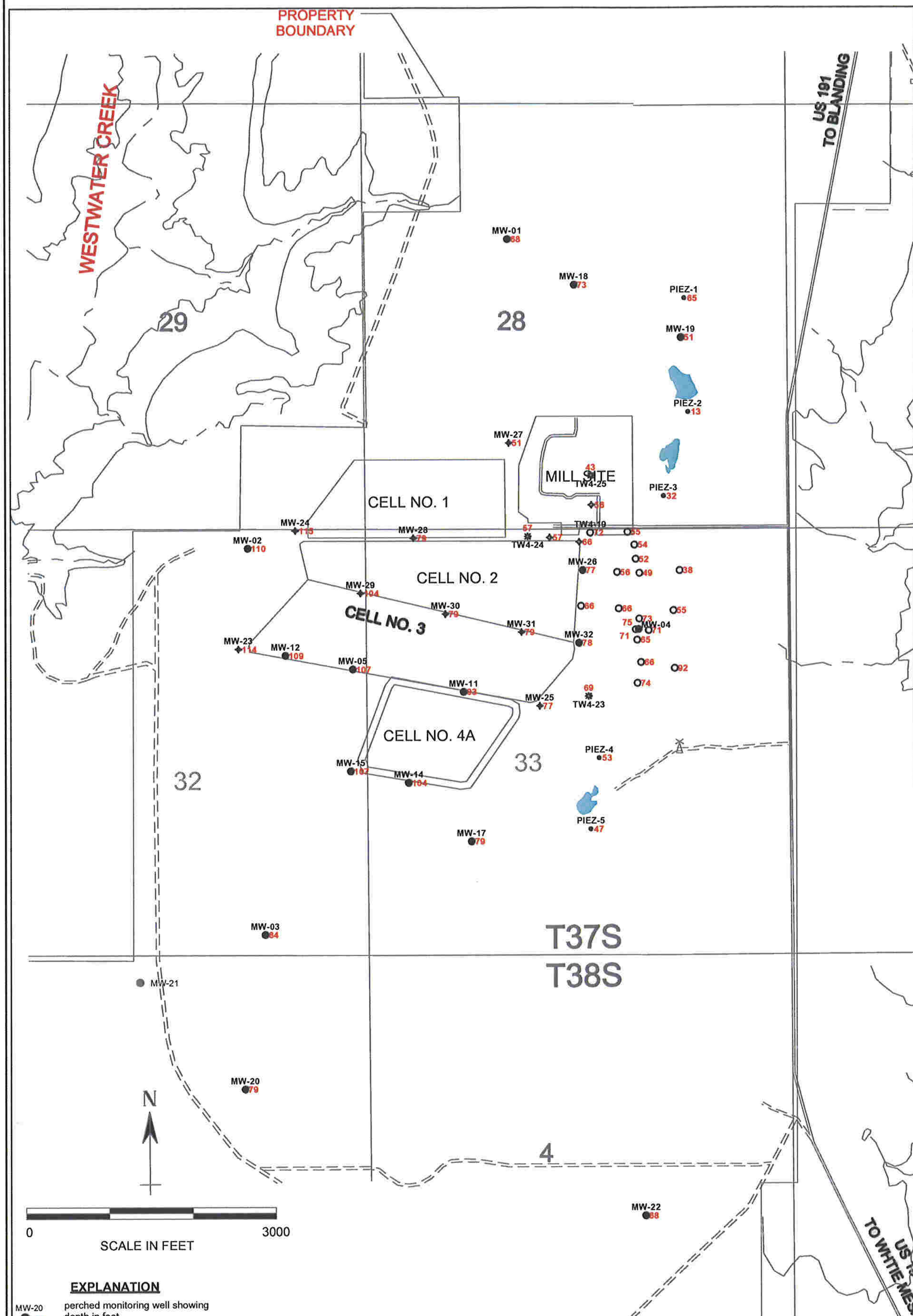
APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/wl0807.srf	6



HYDRO GEO CHEM, INC.

PORTION OF USGS BLACK MESA 7.5' SHEET SHOWING APPROXIMATE LOCATION OF TAILING CELLS IN RELATION TO NEARBY CANYONS AND RUIN SPRING

Approved	Date	Revised	Date	Reference:	FIG:
SS	1/30/03			71800100	7



EXPLANATION

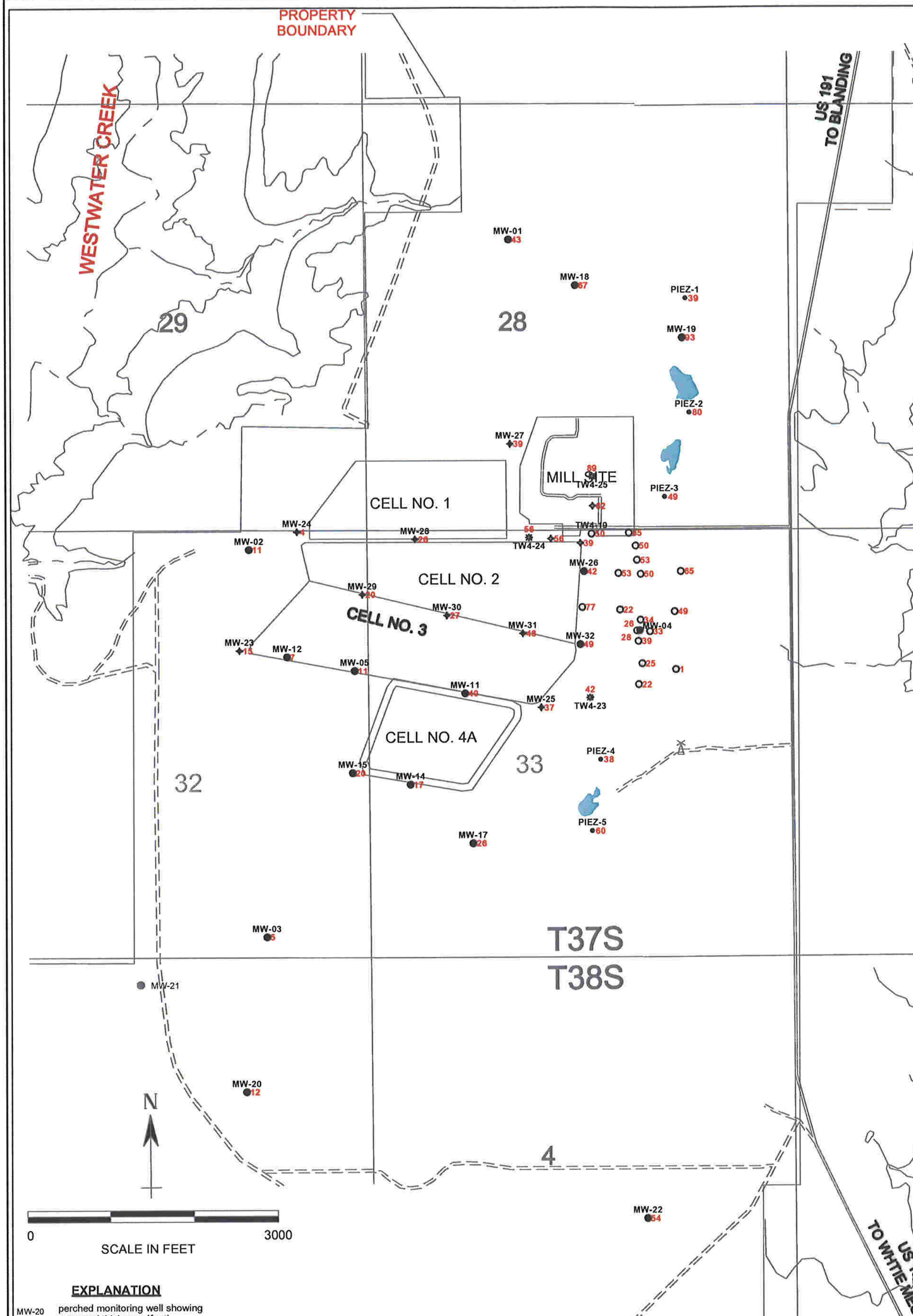
- MW-20 ● 79 — perched monitoring well showing depth in feet
- O 71 — temporary perched monitoring well showing depth in feet
- PIEZ-1 • 65 — perched piezometer showing depth in feet
- MW-31 ✦ 79 — perched monitoring well installed April, 2005 showing depth in feet
- ✧ 57 — temporary perched monitoring well installed April, 2005 showing depth in feet
- ✲ 69 — temporary perched monitoring well installed May, 2007 showing depth in feet

NOTES: Locations of TW4-23, TW4-24, and TW4-25 are approximate;
Measurement for MW-26 (TW4-15) is from the second quarter, 2007

HYDRO GEO CHEM, INC.

DEPTHS TO WATER
3rd QUARTER, 2007
WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/dtw0807.srf	8



EXPLANATION

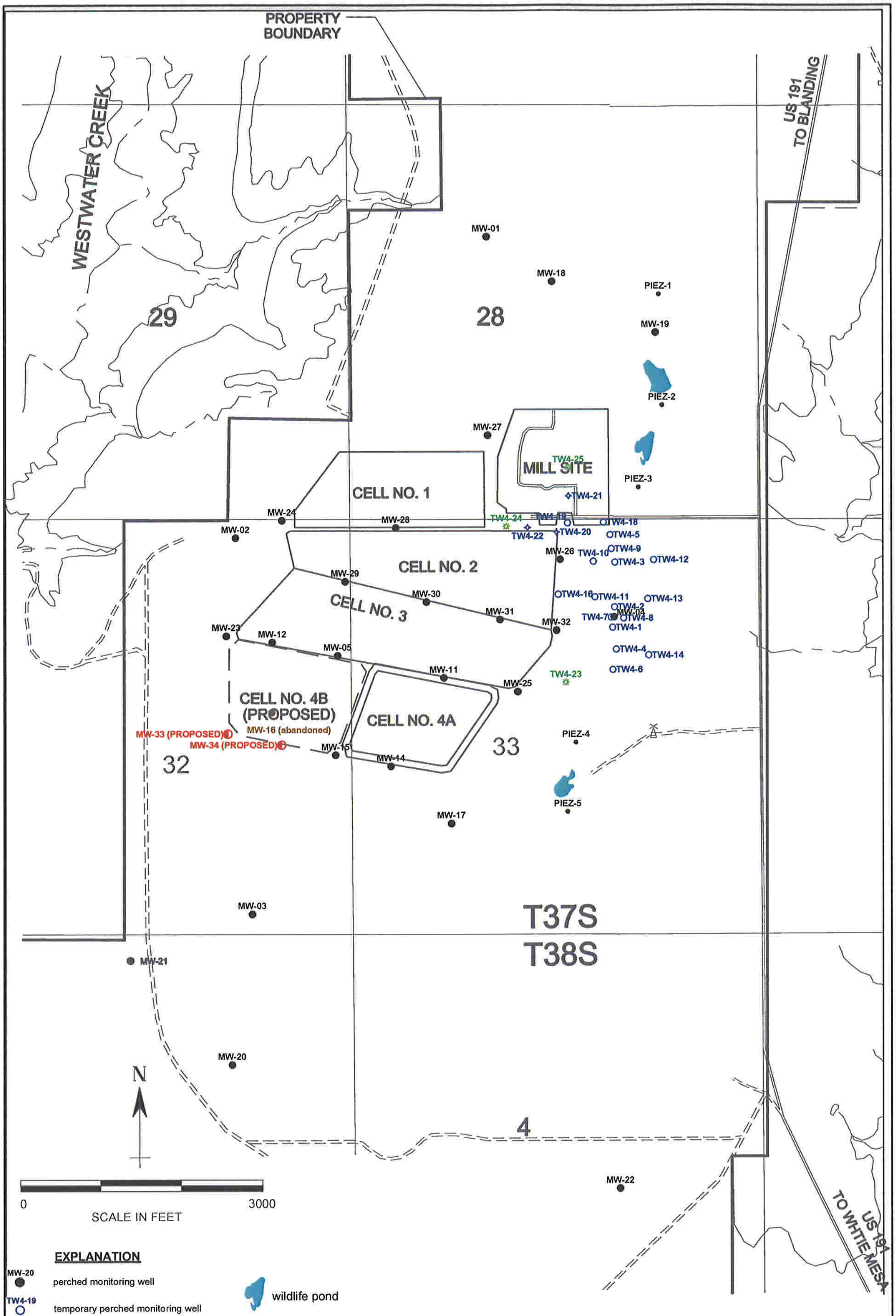
- MW-20 79 — perched monitoring well showing saturated thickness (feet)
- 71 — temporary perched monitoring well showing saturated thickness (feet)
- PIEZ-1 65 — perched piezometer showing saturated thickness (feet)
- MW-31 79 — perched monitoring well installed April, 2005 showing saturated thickness (feet)
- 57 — temporary perched monitoring well installed April, 2005 showing saturated thickness (feet)
- 69 — temporary perched monitoring well installed May, 2007 showing saturated thickness (feet)

NOTES: Locations and values for TW4-23, TW4-24, and TW4-25 are approximate;
Value for MW-26 (TW4-15) is based on the second quarter, 2007 water level

HYDRO GEO CHEM, INC.

**APPROXIMATE SATURATED THICKNESS
3rd QUARTER, 2007
WHITE MESA SITE**

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/satdthck.srf	9



EXPLANATION

MW-20 — perched monitoring well

TW4-19 — temporary perched monitoring well

PIEZ-1 — perched piezometer

TW4-23 — new temporary perched monitoring well installed May,2007 (locations approximate)

MW-33 — proposed temporary perched monitoring well

wildlife pond

HYDRO GEO CHEM, INC.

SITE PLAN SHOWING EXISTING AND PROPOSED PERCHED WELL LOCATIONS WHITE MESA SITE

APPROVED	DATE	REFERENCE	FIGURE
SJS	1/4/2008	H:/718000/cell4b/propwell.srf	10