MALCOLM PIRNIE

HYDROGEOLOGIC ASSESSMENT TECHNICAL MEMORANDUM VOLUME I of III REPORT

FOR THE
SPRING HILL CAMP STUDY AREA
OSCEOLA COUNTY, MICHIGAN

PREPARED FOR
GREAT SPRING WATERS OF AMERICA

OCTOBER 2000

PREPARED BY
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EAST LANSING, MICHIGAN 48823

RECYCLED PAPER

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EXECUTIVE SUMMARY

Great Spring Waters of America retained Malcolm Pirnie in East Lansing, Michigan in June, 2000 to conduct hydrogeologic and environmental investigations of a potential spring water supply source located on the Spring Hill Camp (SHC) property near the city of Evart in Osceola County, Michigan. The evaluation of data from the investigations and other sources shows:

- Three general groups of springs are present on the SHC property (Northern, Central, and Eastern). The most prolific springs are the Central Springs, which occur along the base of a ridge on the SHC property. The flow from the Central and Northern Springs discharge to tributaries of Twin Creek. The Eastern Springs occur in the Chippewa Creek drainage basin and discharge to Decker Ponds.

- A viable spring aquifer exists consisting primarily of fine to coarse sand, with occasional lenses and layers of gravel, silty sand, silt and clay. The stratigraphy associated with the spring aquifer is complex glacial drift and is associated with at least two aquitards, a series of perched aquifers, and a deeper aquifer. At some locations in the SHC study area the spring aquifer is leaky confined and at others it is unconfined.

- The saturated thickness of the spring aquifer ranges from approximately 15 to greater than 80 feet. Based on interpretation of the stratigraphy encountered during well installation, the spring aquifer extends beyond the area studied.

- Groundwater pumped from test wells located adjacent to the springs is chemically identical to the spring water. Pumping of the test wells produced a measurable reduction of the discharge from the springs, indicating that the springs and the wells tap the same aquifer. For these reasons, a well field placed in or near the SHC study area would meet the requirements of FDA regulations for the demonstration of bottled spring water sources. The testing also shows that the SHC study area can be developed as a Type II non-community non-transient water supply under the Michigan Department of Environmental Quality's (MDEQ's) permitting requirements.

- Geochemical analyses of samples collected at groundwater pumped from the spring aquifer and samples collected from the springs meet Federal, State and Perrier Group of America Water quality criteria.

Additional studies will be conducted to provide data to design the well field, to estimate sustainable yield, and to support the process for MDEQ Type II non-transient, non-community water supply well permitting.

1.0 INTRODUCTION

Malcolm Pirnie was retained in June, 2000 by Great Spring Waters of America to conduct hydrogeologic and environmental investigations of a potential spring-water supply source located on the Spring Hill Camp (SHC) property near the city of Evart in Osceola County, Michigan. The investigations were conducted on a portion of the SHC property and on properties located north and south of the property (i.e., the SHC study area). Figures 1-1 and 1-2 show the location of the SHC property and the SHC study area. Great Spring Waters of America had identified the springs on the SHC property prior to the investigations by Malcolm Pirnie.

There are three groups of springs on the SHC property (Figure 1-2). The eastern most springs (Eastern Springs) are located in the central portion of the SHC property and discharge at the base of a ridge adjacent to Decker Pond. Water from the Eastern Springs drains to Decker pond in the Chippewa Creek drainage system. The Central Springs are located along the base of a ridge in the Twin Creek drainage system and discharge along a narrow tributary of Twin Creek. The Northern Springs are located in the northwest corner of the SHC property and also discharge into the Twin Creek drainage system. The Central Springs were the focus of the investigations

The investigations were conducted in two phases during late June through late August of 2000. The intent of the investigations was to determine if the springs at the SHC property could be developed with extraction wells in a manner that meets 21 Code of Federal Registry (CFR) Part 165.110 (a) [Federal Department of Agriculture (FDA) regulations on bottled spring water source demonstration]. This determination was accomplished by evaluating the hydraulic and physical relationship between the springs and the aquifer. As it became apparent that the aquifer would meet FDA requirements, a more extensive investigation was performed. The objectives of the investigations were to:

- Characterize the general physical nature of the spring aquifer (e.g., lithology, and vertical and horizontal extent of the aquifer)
- Determine groundwater flow characteristics
- Estimate the probable recharge area for the spring-water aquifer

- Compare concentrations and relative proportions of dissolved minerals and trace metals in spring water and groundwater

- Identify potential contamination threats to groundwater quality (e.g., underground storage tanks, dairy operations, pesticide applications) in the recharge area

- Develop groundwater level and spring discharge data to serve as a point-of-reference (i.e., baseline conditions) for a long-term monitoring program

The investigations included site reconnaissance, environmental database records search and literature review, stratigraphic evaluation, groundwater geochemistry analyses, and hydrogeologic studies. This report is organized into four remaining chapters. Chapter 2 provides a brief description of the regional setting of the site study area. Chapter 3 describes the investigations conducted to address the objectives listed above. Chapter 4 presents the results of the investigations and their implications. Chapter 5 discusses the findings, identifies data gaps, and provides recommendations.

2.0 REGIONAL HYDROGEOLOGIC SETTING AND GROUNDWATER USE

2.1 REGIONAL HYDROGEOLOGIC SETTING

The SHC study area lies within Hydrogeologic Province 5 (U.S.G.S., 1991), which is characterized by thick (400 to 600 feet) coarse-grained, sandy outwash and glaciofluvial deposits that are underlain by sedimentary bedrock (Jurassic Red Beds, and Pennsylvanian Saginaw Formation). As shown on Figure 2-1, the SHC study area lies on coarse-textured glacial till and is bordered to the south by glacial outwash deposits and to the north by glacial end moraine deposits (Farrand and Bell, 1984). The glacial end moraines are part of an interlobate morainic system that correlates with the Valparaiso and Charlotte moraine systems. Regional groundwater flow is primarily south into the valley of the Muskegon River, which drains the region between the morainal systems. The area receives on average 8.4 inches of recharge per year (estimate based on a 56 year record) as monitored at the USGS streamflow gaging station at the Muskegon River in Evart (also shown on Figure 2-1).

2.2 GROUNDWATER USE

Water well records at the Michigan Geologic Survey were reviewed to identify and locate wells near the SHC study area. A total of 29 water wells were identified within a one mile radius of the SHC study area. The well locations are shown on Figure 2-2. Table 2-1 summarizes information from the well logs. The well logs are presented in Appendix A. Of these wells, 25 supply individual residences, three are public supply wells, and one is used for irrigation.

Most of the residential wells are associated with homes and are found in greatest density east of the SHC study area along 95th Avenue. Two public supply wells, designated 21 and 29 on Figure 2-2, are located south-southeast of the SHC study area at the SHC property. These wells are listed as Type IIb public wells, indicating that the well supplies up to 25 people for at least 60 days each year, but less than 20,000 gallons per day. The third public supply well, designated 10 on Figure 2-2, is located east of the SHC study area at the North Evart United Methodist Church. The record of this public supply well does not include a type use designation, however, it is believed that the well at the church would be considered a Type IIb public well. An irrigation well (designated well number 15 on Figure 2-2) is located east of the SHC study area adjacent to 95th Avenue. Approximate locations for 12 additional residential wells that are known to exist in the area but for which no record was found at the Michigan Geologic Survey are also shown on Figure 2-2.

The City of Evart operates eight wells, approximately 2.2 miles southeast of the SHC study area, for use as public water supply. The wellhead protection area delineated for these wells, at a total combined withdrawal in 1999 of 832.96 million gallons, extends approximately 1,000 ft north of 8 Mile Road into the southern-most portion of the SHC study area.

3.0 INVESTIGATION

3.1 STUDY AREA RECONNAISSANCE

On June 23, 2000, Malcolm Pirnie completed an initial reconnaissance of the SHC study area. Three general groups of springs (Central, Eastern, and Northern) were identified during the initial reconnaissance (Figure 1-2). The greatest density of springs (Central Springs) extends for approximately 800 feet along the southern toe of an east-west trending ridge located near the center of the SHC study area. The Central Springs discharge to a wetland area that drains to Twin Creek to the south of the SHC property west of 100th Avenue (Figure 1-2). The Eastern Springs lie to the east of the Central Springs approximately 700 feet from 100th Avenue and discharge to Chippewa Creek. The Northern Springs lie approximately 2,000 feet northwest of the Central Springs and discharge to a tributary of Twin Creek.

Three springs in the SHC study area are venting in a boil-like manner. One of the venting springs occurs at the bottom of a hillside and boils out through a highly organic muck in a cedar swamp. Another venting spring discharges nearby at a higher elevation from a hillside above an approximately 5-feet-thick clay unit. Both of these springs are part of the Central Springs. The third venting spring is located in the Northern Springs.

3.2 ENVIRONMENTAL DATA BASE SEARCH AND WELL INVENTORY

Environmental Data Resources (EDR) performed a search of various federal and state enforcement database sites for the SHC study area. These lists are compiled from government agency sources and are presented in a consolidated format (Appendix B). The database search did not identify the SHC property on any of the lists and no other sites of environmental contamination were identified within the search radius established by ASTM E 1527-00.

There were, however, ten contamination sites in the county that could not be located (orphan sites). Malcolm Pirnie will attempt to locate these orphan sites during future investigations. The ten orphan sites are:

Site Name	Location	Type
Osceola County Rd	110 th Avenue	UST/LUST
Olon Baldwin	Rt. 3 80 th Avenue	UST
Sears Tire Fire	10977 South M-66	CERCLIS,FINDS
American Logging Tool	302 N. Main St.	SHWS
Rohen Landfill	No Address	SHWS
Robinson Landfill	No Address	SHWS
Schooley Landfill	3 mi S of M-115, M-66	SWF/LF
Evart City Dump	west on US-10	SWF/LF
Joe's Sales & Service/Evart LF	1611 W US-10	SHWS
Kalium Chemicals	PO Box 290	SHWS

UST/LUST – Underground Storage Tank/Leaking Underground Storage Tank
Finds – Facility Index System/Facility Identification Initiative Program Summary Report
SHWS –State Hazardous Waste Site
SWF/LF – Solid Waste Facility/Land Fill
CERCLIS – Comprehensive Environmental Response, Compensation, and Liability Information System

Additionally a search of the State oil/gas well database information identified six oil/gas wells within a 1-mile radius of the SHC study area. Two of these oil/gas wells appear to be on or just south of the SHC study area. The remaining four wells are located to the south and southwest, regionally downgradient of the spring aquifer. Additional investigations will be performed in the future to further assess the two nearest oil/gas wells.

3.3 MONITORING NETWORK

3.3.1 Monitoring Wells

Sixteen 2-inch diameter monitoring wells were installed using 4¼-inch hollow-stem augers at the locations shown on Figure 3-1. Some of the wells were installed in nested pairs to monitor water levels at different depths in the aquifer(s). Monitoring wells are designated as s, i, and d for shallow, intermediate, and deep to denote well depth. Well installation details and post-development water quality measurements made in the field are summarized in Table 3-1.

Split-spoon soil samples were collected approximately every 5 feet in each boring. More frequent soil samples were collected when changes in soil type were observed. The split-spoon samples were logged and these data were used for geologic interpretations. Soil boring and well construction logs are provided in Appendix C.

3.3.2 Test Wells

Three test wells (TW-1, TW-2, and TW-3) were installed for conducting aquifer tests. The soil boring and well construction logs for the test wells are presented in Appendix C. Well construction details and post-development water quality measurements are summarized in Table 3-1. Soil samples of the spring aquifer were collected during the drilling of monitoring wells MW-1, MW-5i, and MW-13 and were analyzed for grain size distribution. The grain size analyses (see Appendix D) were used to design the filter pack and well screen slot size for the test wells.

3.3.3 Stab Wells

Eight stab wells (Seep-1 through Seep-6 and Vent-1 and Vent-2) were installed to monitor shallow groundwater levels adjacent to the springs (Figure 3-1). The wells were installed using a hand auger. Two other stab wells (MW-1s and MW-4s) were installed to monitor a shallow perched groundwater zone located in the vicinity of test well TW-1. The stab wells were constructed of either PVC or stainless steel materials. Additional construction details for the stab wells are provided in Table 3-1 and Appendix C.

3.3.4 Well Development

The monitoring wells and test wells were developed using a combination of air and pumping methods. Stab wells were developed using disposable bailers. The wells were surged several times during development to remove fines from the vicinity of the well screen. During development, water quality parameters (pH, specific conductance, dissolved oxygen, temperature, and turbidity) were measured periodically to assess the status of the development.

Development continued in the wells until the water quality parameters stabilized. The water quality parameter values measured in the wells just after the completion of development are summarized in Table 3-1.

3.3.5 Weirs and Stilling Wells

A network of four 60° V-notch weirs (Weir-1 through Weir-4) were installed across the flowing channels directly downstream from the springs to monitor the influence of pumping on the springs' discharge (Figure 3-1). Discharge across the weirs was determined by measuring the height of water (in inches) above the V-notch and calculating the discharge using a nomogram provided in Driscoll (1986). Measurements of discharge across the Weirs are presented in Table 3-2 and on Figure 3-2.

Two stilling wells (North Twin Creek and South Twin Creek) were installed in Twin Creek to monitor water quality parameters and water levels during and after the pumping test (Figure 1-2). The stilling wells were constructed of 2-inch diameter, 5-ft-long, slotted PVC screens, attached to a metal fence post. The fence post was driven into the bottom of the surface water body until the stilling tube bottom was just above the base of the surface water body. Additional well construction details are provided in Appendix C.

3.3.6 Surveying

Jenema Land Surveyors of Manistee, Michigan surveyed the location easting and northing, and top of casing and ground surface elevations of the wells in early July and early August 2000. Elevations were referenced to a United States Geologic Survey vertical datum and locations were in State Plane Coordinates. The surveyed coordinates and elevations are presented in Table 3-1.

3.4 TESTING

3.4.1 Water Quality Measurements

Three multi-parameter data loggers (In-Situ, Inc. MPTroll 8000 (Trolls®) were installed to measure water quality parameters and water level fluctuations during and after the 7-day well field pumping test. One Troll® was installed in the stab well Vent-1 (located in the Central Springs), one in the South Twin Creek stilling well at 8 Mile Road and one in the North Twin Creek stilling well (Figure 1-2). The North Twin Creek stilling well was moved on August 29, 2000 from the initial location to the final location shown on Figure 1-2. This stilling well was moved based on a recommendation by Midwest Aquatic Services & Design Co. (Great Spring Waters of America's aquatic resources consultant).

The Trolls® were calibrated following the manufacturer's guidelines and then set up to automatically measure and record temperature, water level, pH, conductivity, and dissolved oxygen content. Measurements were collected at 30-minute intervals throughout and subsequent to the test. The data were submitted to Midwest Aquatic Services & Design Co. for detailed analyses and will be used in a forthcoming aquatic resources study. The water quality measurements are discussed further in Section 5.1.7.

3.4.2 Water Level Measurements

Manual and automatic water level measurements (referenced to the top of well casing) were made in the observation wells, the stab wells, the stilling wells and the test wells throughout the investigation. Water levels measured prior to the aquifer tests are included in Table 3-3. Water levels measured during the pumping tests are included in Appendices E and F. The water level of a nearby residential well was also measured prior to, during and after the well field test. The residential well water level measurements are discussed further in Section 5.1.6.

3.4.3 Step Rate Pumping Test

A step rate pumping test was conducted at TW-1 on July 10, 2000. The test consisted of pumping TW-1 at four rates (25, 50, 70, and 90 gpm). The objective of the step rate pumping test was to obtain a preliminary estimate of the specific capacity of the well and well efficiency. These data were used to design the well field pumping test.

During the step rate pumping test, the water level in the pumping well was measured automatically at a logarithmic rate using a pressure transducer and a Hermit™ datalogger. In addition, water levels were measured manually in each of the monitoring wells prior to, during, and after the step test. The step test data are provided in Appendix E.

3.4.4 Well Field Pumping Test

A well field pumping test was performed during August 23 through 30, 2000 to assess aquifer parameters, and to evaluate the effects of sustained pumping by multiple wells on the aquifer. Test wells TW-1, TW-2, and TW-3 were pumped concurrently at constant rates of 200, 227 and 296 gpm (combined rate of 723 gpm) for a seven-day period (10,080 minutes). The test wells were started in a staggered manner with test well TW-1 starting first, test well TW-2 starting 60 minutes later, and test well TW-3 starting 60 minutes after starting well TW-2

The well field test was run for seven days instead of the "standard" 2 or 3 days so that additional late-time data could be collected. The advantage of running a multiple well seven-day pumping test over a single well 2 or 3-day test is that a much larger portion of the aquifer is tested. If aquifer boundaries (barrier or recharge) are present a significant distance away from the pumping well(s) it is more likely that the multiple well, longer duration test would encounter these boundaries because its cone of depression would be more extensive than a single well 2 or 3-day test. Therefore, because a larger portion of the aquifer is tested by the multiple well seven day pumping test, there is greater confidence in the results as compared to a smaller scale test.

Water levels were measured in the wells automatically using pressure transducers and data loggers. Water levels were also measured manually throughout the test using an electronic water level indicator. The well field pumping test water level measurement data are provided in Appendix F. Weir flow rates and the water level in a residential well located on the northwest corner of 8 Mile Road and 100th Avenue (Figure 1-2) were also measured periodically during the test to assess the effects of pumping on spring discharge and on the aquifer water level south of the springs. The weir (i.e., spring) discharge measurements before, during and after pumping are summarized on Figure 3-2. The residential well water level data measured before, during and after the test are summarized on Figure 3-3.

3.4.5 Groundwater Sampling

Water samples were collected from the test wells and from the Central Springs. The analytical results from these samples were used to conduct the geochemical comparison of the spring and the spring aquifer discussed in Section 5-3. Samples were collected and shipped to Arrowhead Quality Services Laboratory in Los Angeles, California for analysis of the following parameters:

Bicarbonate	Chloride	Fluoride	Nitrate
Phosphate	Silica	Sulfate	Nitrite
Bromide	Aluminum	Arsenic	Barium
Cadmium	Calcium	Chromium	Copper
Iron	Magnesium	Manganese	Mercury
Potassium	Selenium	Silver	Sodium
Zinc	Beryllium	Antimony	Nickel
Thallium	Conductivity	pH	Hardness
Total Dissolved Solids	Turbidity Source		

Water samples were collected from Central Springs (Seep), test well TW-1, test well TW-2 and test well TW-3 on August 23, 2000 between 12:00 p.m. and 12:30 p.m. The water sampling analytical data and water quality parameters measured by the laboratory are presented in Appendix G.

4.0 STUDY AREA HYDROGEOLOGY

4.1 HYDROGEOLOGY

Five general hydrogeologic units were identified on the SHC study area during the investigation. These units from uppermost to lowermost are a discontinuous perched aquifer, upper aquitard, spring aquifer, lower aquitard, and lower aquifer (Figures 4-1 through 4-3). The discontinuous perched aquifer consists primarily of sandy sediments above the upper aquitard as exemplified at wells MW-1, MW-4, MW-5, MW-6, and MW-12. Groundwater from one localized perched aquifer discharges to the ground surface as a spring vent near stab well Vent-2 at an elevation of about 1,122 ft above mean sea level (amsl). The saturated thickness of the perched aquifer did not exceed 10 feet where encountered. The aquitard underlying the perched aquifer generally consists of interbedded clay, silty or clayey sand, and sand lenses. Based on water level response during the well field test, this aquitard is leaky. Dry sand of the upper portions of the spring aquifer was frequently observed underlying the upper aquitard.

The shallow (spring) aquifer consists primarily of medium sand, with fine to coarse sand and gravel as secondary constituents. At some locations, repetitive coarsening downward sequences of silty sand to gravel lenses occur within the medium sand deposit. The spring aquifer saturated thickness ranges from approximately 13 ft at well MW-4, to approximately 83 ft at well MW-1.

The spring aquifer is underlain by the lower aquitard, which consists of silt, clay and zones of interbedded sand and fines (silt and clay). The thickness of the lower aquitard measured 8 ft at MW-1d and 15 ft at MW-5d. Based on observations made during well development and during the well field test, the lower aquitard is also leaky. Underlying the lower aquitard is the deep aquifer, which consists primarily of sand with occasional lenses of silt, clay, and gravel. Wells MW-1d and MW-5d are screened in the lower aquifer. Drawdown data collected during the well field pumping test show that there is hydraulic communication between the spring aquifer and both the perched and deep aquifers (Section 5.1.2).

The occurrence of the Central Springs is related to a ridge that extends east to west along the southern perimeter of the test well field. This ridge consists of clay, or interbedded silt, clay, and sand, and appears to restrict flow in the spring aquifer. Boring logs of two observation wells (MW-3 and MW-13) and one production well (TW-2) installed at the crest of the ridge indicate that the upper 60 to 70 ft consists primarily of silt and clay with occasional lenses of sand. North of the ridge, the potentiometric head of the spring aquifer is approximately 1093 ft amsl (MW-3). At the springs south of the ridge, the elevation of the spring water level is about 1082 ft amsl, for a head loss in the spring aquifer of approximately 11 feet over 90 feet horizontally between MW-3 and the closest springs. The rapid change in water levels beneath the ridge show that, although the occurance of the springs is partly controlled by the decreasing topography, the geology of the ridge also contributes to the spring occurance.

4.2 GROUNDWATER FLOW

Groundwater flow in the SHC study area is south toward the Central Springs and wetlands surrounding Twin Creek (Figure 4-4). The average horizontal hydraulic gradient (I) in the spring aquifer upgradient of the test wells (i.e., wells TW-1, TW-2, TW-3) was calculated to be 0.006 based on static groundwater elevations measured on August 4, 2000. Horizontal hydraulic gradients between wells MW-11 and Seep-3 and wells MW-3 and Seep-4 were calculated for the same date to be 0.038 and 0.111.

Vertical hydraulic gradients were calculated at the locations where well clusters were installed. These gradients are presented on Table 4-1. The vertical gradients indicate that recharge to the spring aquifer is occurring upgradient of the well field (downward gradient at well cluster MW-12) and that the aquifer is discharging near the springs (upward gradients at the well clusters MW-1, MW-4, and MW-5).

Linear groundwater flow velocities were estimated to range from 2.1 to 120 ft/day in the vicinity of the Central Springs and 0.32 to 6.4 ft/day upgradient of the test wells. The range of linear groundwater velocities were estimated using high and low hydraulic conductivity values from the pumping test (22 and 279 ft/day per day), the hydraulic gradient values discussed above, and an estimated range of porosity of 0.25 and 0.40 from *Groundwater and Wells*, Driscoll (1986). Table 4-1 presents the hydraulic gradients and Table 4-2 presents the calculated linear groundwater flow velocities.

5.0 HYDROGEOLOGICAL AND GEOCHEMICAL ASSESSMENT

5.1 AQUIFER TEST RESULTS

5.1.1 Step Drawdown Pumping Test

Drawdown measured at test well TW-1 during each of the pumping rate steps was plotted versus elapsed time on a semi-log scale graph to assess specific capacity (Figure 5-1). At a pumping rate of 90 gpm sustained for 140 minutes, approximately 5.3 ft of drawdown was measured in TW-1. The calculated specific capacity at this rate was 17.0 gpm/ft. Higher specific capacities were calculated for the lower pumping rates, ranging from 17.3 to 17.9 gpm/ft. Well efficiency, calculated using the Biershenck and Wilson coefficient method (Biershenk, 1964), was estimated at 96.5 percent. Data from the step drawdown test are presented in Appendix E.

5.1.2 Well Response Curves

Well response curves (i.e., drawdown versus time) were prepared for each test well, monitoring well, and stab well for the purpose of evaluating the response of the wells to pumping during the well field test. Drawdown data were plotted versus time on both a log/log and a semi-log scale. The well response curves are presented in Appendix F.

As discussed in Kruseman and deRidder (1991), the shape of the well response curves are diagnostic of aquifer type (i.e., confined, leaky confined, or unconfined), well geometry (i.e., borehole storage or partial penetration), and aquifer geometry (i.e., barrier or recharge boundaries). In general, most of the wells responded in a "stair step" manner during the first three to four hours of pumping due to the staggered start of the three test wells. During the well field pumping test, test well TW-1 was started first at a rate of 200 gpm, followed 60 minutes later by test well TW-2 at a rate of 227 gpm, and finally 60 minutes after starting test well TW-2, test well TW-3 was started at a rate of 296 gpm. This "stair step" response exhibited by the wells to staggered pumping shows that there was significant interference (i.e., overlapping cones of depression) between the test wells. Another observation of the general shape of the well response curves was that most of the wells responded in a typical unconfined or leaky confined manner. Most of the wells exhibited delayed yield during the middle-time data which is indicative of unconfined or leaky confined conditions. Delayed yield is a phenomenon caused by residual water draining from the dewatered portion of the aquifer into the saturated portion of the aquifer resulting in less drawdown during the middle-time than during the early- and late-time. Delayed yield well response is shown on many of the well response curves presented in Appendix F.

5.1.3 Distance Drawdown Data Analysis (Early-Time Data)

The early-time (i.e., <60 min.) well field pumping test data were analyzed using the Jacob's distance drawdown method (Cooper and Jacob, 1946). A distance versus drawdown plot was prepared for wells in the vicinity of test well TW-1 at an elapsed time of 59 minutes after initiating the well field test (Figure 5-2). This elapsed time was selected because the other test wells (TW-2 and TW-3) had not started pumping at this time, thereby eliminating interference effects from the other test wells. Based on the data presented on Figure 5-2, the aquifer appears to be relatively isotropic in the vicinity of test well TW-1 as indicated by the closeness of fit of the distance/drawdown data to the linear regression line.

As indicated on Figure 5-2, transmissivity (T) is estimated to be 2.75 x 10^4 gpd/ft, hydraulic conductivity (K) is estimated to be 51 ft/day (1.8m 10^2 cm/sec) and specific yield (S_y) is estimated to be 7.1×10^{-4}. These aquifer parameter values are consistent with the aquifer parameter values estimated from the middle and late time well field pumping test data (see Section 5.1.4).

5.1.4 Well Field Test Data Analysis (Middle and Late-Time Data)

A modified Jacob's method was used to analyze the well field test data (Cooper and Jacob, 1946). This method is appropriate for situations in which multiple wells are pumped and can accommodate wells pumped at different or variable rates. This method normalizes the drawdown and time data relative to the distance of the observation well to each test well and the pumping rate at each test well.

The normalized drawdown and time data were plotted on semi-logarithmic scaled graphs and a linear regression line was fitted to the data. The modified Jacob's method plots are presented in Appendix F. The well field test data analyses are summarized in Table 5-1. Transmissivity is estimated to range from 3.85×10^{4} to 2.95×10^{6} gpd/ft. Estimates of hydraulic conductivity range from 22 to 279 ft/day, and S_y estimates range from 5.31×10^{-4} to 4.00×10^{-1}.

5.1.5 Spring Flow

The rate of spring flow was measured across four V-notched weirs prior to, during, and after the well field test (Appendix F). A plot of flow across the weirs versus time was prepared to evaluate discharge from the springs before, during, and after the well field test (Figure 3-2). As shown on Figure 3-2, a reduction in discharge rate occurred at the central springs during the well field test. Discharge across Weir-1, which measures discharge from a perched aquifer, was largely unaffected by the well field pumping.

The weir measurement data show that springs discharging to Weir-2, -3, and -4, are hydraulically connected to the aquifer tested during the well field test and that the well field would meet the FDA requirements for spring water demonstration.

5.1.6 Residential Well Monitoring

The water level in a residential well located at the northwest corner of 8 Mile Road and 100th Avenue (Figure 1-2), approximately 2500 feet southeast of the test wells was measured prior to, during, and after the well field pumping test. Water levels were measured in this well to assess the effects of well field pumping south of the Central Springs. This residential well was selected for monitoring (i.e., water level measurements) because it is the closest residential well south of the Central Springs. Little is known about the construction details of this well because the Michigan Geologic Survey did not have records for it. The initial (pre-well field test) water level in this well was 84.8 feet below ground surface.

The residential well water level versus time measurement data for this well are presented on Figure 3-3. As indicated on Figure 3-3, no measurable drawdown occurred in this well during the well field pumping test. The water level in this well varied up and down during the test from approximately 1048.14 to 1048.21 ft above mean sea level. Minor water level fluctuations in the residential well may be due to periodic water use by the resident, recharge, and/or barometric pressure fluctuation. Additional investigations are needed to further assess hydrogeologic relationships between the spring aquifer and the nearby outwash aquifer utilized by the Town of Evart.

5.1.7 Surface Water Monitoring

Water quality and head data were downloaded from the Trolls® on September 18, 2000 and are presented in Appendix H. As discussed in Section 3.3.1, Trolls® were installed in stilling wells North Twin Creek, South Twin Creek and in stab well Vent-1 (Figure 1-2) to assess the effects of pumping in the spring aquifer on general water quality and water level in Twin Creek and in the Central Springs. The data suggest that in general the pumping test had very little or no effect on the water quality or levels of Twin Creek.

The effects of the well field pumping test were however apparent in the water quality and water level measurements recorded by the Troll® in Vent-1. Changes in DO, conductivity, temperature and water level were apparent during the well field pumping test in stab well Vent-1. The most noticeable effect was 1.6-foot of drawdown measured in the Vent-1 water level at the end of the pumping test. Recovery of the water level in well Vent-1 began shortly after the pumps were shut off. The water level in Stab well Vent-1 recovered to its pre-test level three days after the well field test.

DO in well Vent-1 decreased from 5.9 percent to 5.3 percent during the test and then returned to 5.9 percent after the test. Conductivity in well Vent-1 increased from 335 μS/cm to 367 μS/cm during the test and returned to about 343 μS/cm after the test. Temperature increased in well Vent-1 from about 9.75°C to 11.5°C during the test and then returned to about 10°C after the test. At the beginning of (or just prior to) the well field pumping test there was an increase in pH in well Vent-1 from about 6.9 to between 7.4 and 7.6. This change in pH lasted for the duration of the test.

5.2 AQUIFER – SPRING HYDRAULIC RELATIONSHIP

The hydraulic relationship between the spring aquifer and the springs is demonstrated by both the changes in spring discharge during the pumping tests as well as the drawdown observed in the stab wells. Figure 3-2 shows the changes in discharge across the weirs during the well field pumping test. Further discussion of the Weir discharge measurements are provided in Section 5.1.5 as shown on this figure there is a direct response in the spring discharge to the pumping. This response is further supported by the observed stratigraphic relationship of the spring aquifer and the springs.

5.3 AQUIFER – SPRING GEOCHEMICAL RELATIONSHIP

The groundwater chemical analytical data were evaluated to assess groundwater quality and to determine if groundwater extracted from the aquifer was chemically similar to groundwater seeping from the springs. A summary of the groundwater and spring water sampling geochemical data, along with a list of Federal Maximum Concentration Levels, Michigan Maximum Contaminant Levels, and Perrier Group of America Maximum Contaminant Levels, is presented in Table 5-2. As indicated by the data on Table 5-2, the spring water and groundwater quality meets the federal, state and Perrier Group of America's standards.

Stiff, Piper trilinear, and radial plots of cation and anion concentrations were prepared to compare the geochemical signatures of the groundwater and spring water (Figures 5-3, 5-4, and 5-5). The Stiff and Piper plots present the relative amount of the major cations and anions (i.e., Ca, Na, Mg, HCO_3, and Cl) in the samples. In addition, nitrate and silica were added to the radial plots.

Each of the samples can be characterized as containing calcium, magnesium and bicarbonate as their dominant ions. Furthermore, each of the samples fall within the same general area on the Piper diagram (Figure 5-3) and the shape of the Stiff and radial plots are similar for each sample (Figures 5-4 and 5-5). This demonstrates the chemical similarity of the spring water and the groundwater samples. Therefore, the geochemical data indicates that the spring water is from the same aquifer as is tapped by the test wells.

5.4 GROUNDWATER RECHARGE AREA

A groundwater recharge area was estimated for a hypothetical well field tapping the spring aquifer using data from the U.S.G.S. quadrangle map (Evert, Michigan Quadrangle Map – U.S.G.S., 1993) and the Quaternary Geology of Southern Michigan map (Farrand and Bell, 1984). The groundwater recharge area is shown on Figure 5-6. This area was derived by evaluating the mapped surficial glacial deposits along with geomorphology and apparent surface water drainage patterns. Further investigations should be performed to assess the groundwater recharge area for the spring aquifer.

6.0 FINDINGS, DATA GAPS, AND RECOMMENDATIONS

6.1 FINDINGS

Based on the limited area studied during these investigations the following findings can be made:

- Three general groups of springs are present at the SHC study area (Northern, Central, and Eastern).
- Geological investigations indicate that the spring aquifer consists of sand with some interbedded sand and gravel, silt and clay and extends over at least a 654 acre area. The spring aquifer at the SHC study area is more extensive than the area studied and has a saturated thickness of between 14 to 80 feet. A hydraulically connected aquifer of undetermined thickness lies beneath the spring aquifer.
- The groundwater and spring water quality meets Federal, State, and Perrier Group of America quality standards.
- Pumping in the spring aquifer produces groundwater that is geochemically similar to the spring water and effects the spring flow, thereby meeting the FDA requirements for bottled spring water source demonstration.
- The investigations indicate that production wells can be installed at the SHC study area that are capable of meeting MDEQ Type II, non-community, non-transient well permit requirements.

6.2 DATA GAPS

Evaluation of the data from the investigations have identified additional data that will be necessary to assess sustainable yield of the spring aquifer and to design and manage a well field at the SHC study area. These additional data include:

1. Identify the lateral extent of the spring aquifer west, north and east of the study area.
2. Characterization of the deeper aquifer and its relationship to the springs.

3. Water level measurement data over a greater period of time to assess vertical and horizontal hydraulic gradients.

4. Refinement of the aquifer properties and their distribution within the aquifers (especially on where the well field will be developed).

5. Further study of groundwater discharge to Twin Creek and its tributaries and development of a water budget for the spring aquifer system.

6. Further definition of the relationship between the spring aquifer and the outwash deposits tapped by the City of Evart well field.

7. Demonstration that a well field will meet the FDA regulations and MDEQ Type II, non-community, non-transient well permit requirements (these conclusions were implied by the studies to date but will need to be confirmed for the new well field).

8. Determination of the spring aquifer sustainable yield.

9. Further evaluation of the groundwater recharge area.

6.3 RECOMMENDATIONS

We recommend that additional investigations of the SHC study area be performed to provide data necessary to assess sustainable yield, design and manage a well field, and fulfill the MDEQ Type II non-community, non-transient water supply permitting requirements. We recommend that the following additional investigations be conducted:

1. Drill and install additional monitoring wells to investigate stratigraphy in the well field area, in the recharge/groundwater protection area, in the vicinity of hydraulic boundaries, and near 8 Mile Road (in City of Evart's Well Head Protection Area). Many of these wells should be installed as clusters (one well in the deep aquifer and one well in the shallow aquifer).

2. Drill and install three monitoring well clusters near the anticipated location of the production wells (see 3 below) to assess hydrogeological conditions in this area and to collect aquifer material samples for sieve analyses to design the production wells.

3. Drill and install two 8-inch diameter production wells (i.e., a shallow and a deep production well) at a greater distance north from the Central Spring occurances than test wells TW-1, TW-2, and TW-3. The shallow production well will be

screened in the shallow (spring) aquifer and the deep production well will be screened in the deep aquifer. The location of these production wells will be selected after evaluating the geologic data obtained during drilling of the cluster wells described above. The purpose of these wells is to perform aquifer testing to assess hydraulic communication between the two aquifers and to possibly serve as production wells.

4. Conduct aquifer testing in the newly installed production wells.

5. Install shallow groundwater and surface water monitoring well clusters at five locations in Twin Creek and its tributaries to assess the interaction between shallow ground water and the surface water. The well clusters will consist of a stilling well installed to monitor the water level of the water body along with an accompanying stab well installed approximately five feet below the bottom sediment. These wells will be used to assess hydraulic gradients and to monitor water quality parameters.

6. Develop a database of weekly field measurements including:
   - Surface water flow in Twin Creek and its tributaries.
   - Water levels in the wells.
   - Precipitation and temperature.
   - Groundwater quality.

7. Collect groundwater samples in the production wells and selected monitoring wells and collect spring water samples from near the weirs, and submit the samples for laboratory analysis of drinking water quality parameters. These data will be used to further assess water quality and the chemical similarity of water in the springs spring aquifer, and deep aquifer.

8. Develop a groundwater model to represent the multiple aquifers and aquitards and the estimated recharge area for the spring aquifer. Calibrate this groundwater model with transient data including the well field test and the production well test(s).

9. Conduct predictive simulations with the calibrated model to evaluate the sustainable yield of the aquifer and the recharge area of the well field.

10. Evaluate the necessity, appropriateness, and potential placement of additional production wells.

11. Develop a plan for long-term management of the well field. This plan would utilize field measurements of precipitation, water levels, and surface water discharge in conjunction with the groundwater model to manage the pumping rate of the well field.

After the production wells have been tested, the permit application for a Type II non-transient, non-community water supply should be filed with the Osceola County Health Department.

7.0 REFERENCES

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TABLE 2-1

GSWA
SPRING HILL CAMP STUDY AREA
WATER SUPPLY WELL SUMMARY

Well ID	Ground Surface Elevation[1] (meter amsl)	Ground Surface Elevation[1] (feet amsl)	Use	Screened Interval (feet bgl)	Static Water Level[2] (feet bgl)
1	360	1181.16	Residential	130-134	90
2	379	1243.50	Residential	98-102	78
3	360	1181.16	Residential	144-148	60
4	360	1181.16	Residential	110-114	70
5	357	1171.32	Residential	68-72	68
6	357	1171.32	Residential	NA	NA
7	357	1171.32	Residential	180-185	45
8	366	1200.85	Residential	137-142	65
9	363	1191.00	Residential	111-115	96
10	360	1181.16	Public Supply	111-115	70
11	354	1161.47	Residential	114-118	60
12	351	1151.63	Residential	94-98	70
13	360	1181.16	Residential	105-110	70
14	339	1112.26	Residential	50-54	30
15	342	1122.10	Irrigation	50-54	28
16	342	1122.10	Residential	105-110	40
17	350	1148.35	Residential	79-83	50
18	352	1154.91	Residential	43-47	33
19	357	1171.32	Residential	76-80	60
20	352	1154.91	Residential	53-57	48
21	348	1141.79	Public Supply	190-215	47
22	348	1141.79	Residential	122-127	NA
23	340	1115.54	Residential	71-75	20
24	348	1141.79	Residential	98-102	40
25	348	1141.79	Residential	70-80	40
26	348	1141.79	Residential	86-91	45
27	345	1131.95	Residential	73-77	60
28	330	1082.73	Residential	41-45	21
29	330	1082.73	Public Supply	195-235	24

Notes:

1 - Elevations are estimates based on approximate well locations from USGS topographic map.
2 - Water Elevations obtained from well construction logs
amsl - above mean sea level
bgl - below ground level
NA - Not applicable

TABLE 3-1

GSWA

SPRING HILL CAMP STUDY AREA

WELL INSTALLATION DETAILS AND FIELD WATER QUALITY PARAMETER MEASUREMENTS

Well Installation Details								Water Quality Parameters						
Well ID	Date (s) Drilled	Date (s) Installed	GSE (feet amsl)	TOC (feet amsl)	Easting (feet)	Northing (feet)	Screen Interval (feet bgl)	pH -	Specific Conductance mS/m	Dissolved Oxygen mg/L	Temperature °C	Turbidity NTU	Date Measured	Maximum Drawdown Observed (ft)
MW-1s	06/29/2000	06/29/2000	1097.2	1098.75	1746801.721	227267.5138	3.4-8.4							0.48
MW-1i	06/28/2000	06/29/2000	1098.4	1100.74	1746804.384	227278.4763	33.5-38.5	7.52	0.482	10.60	10.8	959	07/06/00	11.3
MW-1d	06/26/2000	06/28/2000	1097.7	1100.19	1746801.01	227272.6608	103-108	7.84	0.323	2.35	11.3	12.5	07/06/00	5.37
MW-2	06/27/2000	06/28/2000	1101.7	1104.08	1746937.514	227226.8055	55-60	7.76	0.340	7.80	11.1	9.45	07/06/00	9.57
MW-3	06/28/2000	06/28/2000	1107.0	1109.57	1746836.612	227144.8986	81-86	7.63	0.513	11.30	10.7	2.25	06/29/00	8.78
MW-4s	06/29/2000	06/29/2000	1090.1	1091.38	1746649.212	227190.7155	3.7-8.7							1.18
MW-4d	06/29/2000	06/29/2000	1089.5	1096.04	1746646.742	227193.5469	73-78	7.70	0.382	10.75	10.4	1.44	06/29/00	6.44
MW-5i	07/20/2000 - 07/21/2000	07/21/2000	1148.8	1147.09	1747404.049	227274.291	90-100							16.6
MW-5d	07/18/2000 - 07/19/2000	07/20/2000	1149.4	1147.43	1747399.394	227283.8803	153-158							3.49
MW-6	07/17/2000	07/17/2000	1142.4	1139.96	1747396.362	227522.447	70-80							4.85
MW-7	07/18/2000 - 07-19/2000	07/19/2000	1149.2	1147.28	1746900.223	227527.9254	89-99							6.21
MW-8	07/18/2000	07/18/2000	1113.5	1110.52	1746466.405	227562.2683	75-85	8.26	0.345	11.20	10.6	47.7	07/19/00	3.92
MW-9	07/19/2000 - 07/20/2000	07/20/2000	1125.3	1122.97	1747879.516	227063.926	65-75	8.11	0.352	7.36	10	3.68	07/21/00	1.55
MW-10	07/18/2000	07/18/2000	1120.5	1117.67	1747980.125	227478.5681	52-62	7.87	0.455	12.57	10.1	16.5	07/20/00	0.89
MW-11	07/21/2000	07/21/2000	1166.7	1164.08	1746172.819	229202.286	70-80	7.67	0.320	3.04	12.1	6	08/07/00	0.18
MW-12i	07/27/2000	07/27/2000	1162.5	1160.15	1747490.683	229155.2675	52-62	7.64	0.331	-	10.4	17	08/08/00	0.12
MW-12d	07/02/2000	07/25/2000	1163.2	1160.79	1747490.7	229163.1757	105-115	7.94	0.324		10.5	10		0.38
MW-13	07/25/2000	07/25/2000 - 07/26/2000	1120.2	1117.82	1747065.548	227193.1244	95-105	7.62	0.322	5.01	11.2	21	08/07/00	10.17
TW-1	07/05/2000 - 07/06/2000	07/06/2000 - 07/07/2000	1097.4	1099.84	1746816.719	227266.3032	35-85	7.93	0.388	-	9.9	19.5	07/07/00	21.12
TW-2	07/27/2000 - 07/28/2000	07/28/2000 - 08/02/2000	1119.4	1115.92	1747037.406	227206.9858	60-105	7.85	0.329	-	9.4	10	08/08/00	20.42
TW-3	07/26/2000 - 07/27/2000	07/27/2000 - 07/28/2000	1148.6	1145.75	1747420.053	227257.0287	82-122							39.31
Seep 1	06/27/2000	06/27/2000	1086.3	1089.68	1747030.036	227064.7794	4.6-7.6	7.61	0.380	8.25	10.7	48.9	06/29/00	3.39
Seep 2	06/27/2000	06/27/2000	1081.3	1085.83	1746677.594	227061.4627	3.5-6.5	7.57	0.382	6.47	11.9	475	06/29/00	0.69
Seep 3	06/27/2000	06/27/2000	1082.0	1085.66	1746580.683	226991.4502	4.25-7.25	7.52	0.352	8.45	11.8	110	06/29/00	0.82
Seep 4	06/27/2000	06/27/2000	1083.4	1087.62	1746878.653	227063.2613	4.5-7.5	7.38	0.385	7.70	10.8	36.3	06/29/00	1.01
Seep 5	07/20/2000	07/20/2000	1094.5	1090.48	1748096.179	226732.8656	2-7							0.48
Seep 6	07/21/2000	07/21/2000	1106.2	1104.85	1745326.534	229321.7502	2-7							0.23
Vent 1	06/27/2000	06/27/2000	1088.7	1092.79	1747283.458	227025.3271	4.9-7.9	7.43	0.483	8.05	9.7	673	06/29/00	0.78
Vent 2	06/27/2000	06/27/2000	1121.4	1124.28	1747356.447	227170.233	4.8-7.8	7.45	0.434	9.31	11.2	>999	06/29/00	0.17
Weir 1	NA	06/27/2000	1114.9	1113.51	1747349.201	227133.6973	NA	7.76	0.418	9.00	10.6	6.78	06/29/00	NA
Weir 2	NA	06/27/2000	1079.0	1077.67	1746996.986	226968.5191	NA	7.56	0.38	6.50	13	0.67	06/29/00	NA
Weir 3	NA	06/27/2000 - 06/29/2000	1078.7	1077.37	1746985.464	226950.3284	NA	7.79	0.384	9.21	11.1	6.5	06/29/00	NA
Weir 4	NA	06/27/2000 - 06/29/2000	1077.7	1076.36	1746873.712	226996.2516	NA	7.57	0.372	9.48	10.4	1.7	06/29/00	NA

Notes:

amsl - above mean sea level
bgl - below ground level
TOC - top of casing
GSE - ground surface elevation

TABLE 3-2
GSWA
SPRING HILL CAMP STUDY AREA
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
MW-10	07/19/00	12:51	19.78	1120.54	1100.76	
MW-10	07/20/00	7:40	19.78	1120.54	1100.76	
MW-10	07/21/00	9:51	19.79	1120.54	1100.75	
MW-10	07/25/00	15:16	19.80	1120.54	1100.74	
MW-10	07/26/00	17:55	19.81	1120.54	1100.73	
MW-10	07/27/00	19:40	19.80	1120.54	1100.74	
MW-10	07/28/00	14:26	19.81	1120.54	1100.73	
MW-10	07/31/00	10:10	19.82	1120.54	1100.72	
MW-10	08/02/00	18:12	19.84	1120.54	1100.70	
MW-10	08/04/00	7:48	19.87	1120.54	1100.67	
MW-11	07/25/00	14:47	50.83	1166.659	1115.83	
MW-11	07/26/00	11:21	50.84	1166.659	1115.82	
MW-11	07/28/00	14:51	50.85	1166.659	1115.81	
MW-11	07/31/00	14:01	50.84	1166.659	1115.82	
MW-11	08/02/00	19:19	50.87	1166.659	1115.79	
MW-11	08/04/00	9:40	50.85	1166.659	1115.81	
MW-12d	07/28/00	14:41	46.00	1163.21	1117.21	
MW-12d	07/31/00	14:11	46.00	1163.21	1117.21	
MW-12d	08/02/00	19:30	46.04	1163.21	1117.17	
MW-12d	08/04/00	9:54	46.03	1163.21	1117.18	
MW-12d	08/23/00	15:47	46.04	1163.21	1117.17	
MW-12i	07/28/00	14:43	45.13	1162.47	1117.34	
MW-12i	07/31/00	14:16	45.11	1162.47	1117.36	
MW-12i	08/02/00	19:28	45.13	1162.47	1117.34	
MW-12i	08/04/00	9:52	45.14	1162.47	1117.33	
MW-12i	08/23/00	15:48	45.16	1162.47	1117.31	
MW-13	07/28/00	14:09	26.33	1120.17	1093.84	
MW-13	07/31/00	11:39	26.41	1120.17	1093.76	
MW-13	08/02/00	9:50	26.42	1120.17	1093.75	
MW-13	08/03/00	19:36	26.50	1120.17	1093.67	
MW-13	08/04/00	8:15	26.53	1120.17	1093.64	
MW-1d	06/29/00	19:56	3.65	1100.19	1096.54	
MW-1d	07/07/00	7:27	3.71	1100.19	1096.48	
MW-1d	07/07/00	10:53	3.80	1100.19	1096.39	
MW-1d	07/13/00	8:35	3.72	1100.19	1096.47	
MW-1d	07/13/00	19:32	3.71	1100.19	1096.48	
MW-1d	07/14/00	10:09	3.72	1100.19	1096.47	
MW-1d	07/14/00	19:38	3.74	1100.19	1096.45	
MW-1d	07/18/00	11:10	3.78	1100.19	1096.41	
MW-1d	07/18/00	19:34	3.76	1100.19	1096.43	
MW-1d	07/19/00	13:41	3.75	1100.19	1096.44	
MW-1d	07/20/00	8:22	3.76	1100.19	1096.43	
MW-1d	07/21/00	10:20	3.83	1100.19	1096.36	
MW-1d	07/25/00	16:10	3.77	1100.19	1096.42	
MW-1d	07/26/00	18:30	3.77	1100.19	1096.42	
MW-1d	07/28/00	14:20	3.76	1100.19	1096.43	
MW-1d	07/31/00	11:25	3.75	1100.19	1096.44	
MW-1d	08/02/00	18:32	3.81	1100.19	1096.38	
MW-1d	08/03/00	19:24	3.84	1100.19	1096.35	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
MW-1d	08/04/00	8:31	3.83	1100.19	1096.36	
MW-1i	06/29/00	19:54	5.88	1100.74	1094.86	
MW-1i	07/07/00	7:28	5.97	1100.74	1094.77	
MW-1i	07/07/00	10:53	6.01	1100.74	1094.73	
MW-1i	07/13/00	8:33	5.97	1100.74	1094.77	
MW-1i	07/13/00	19:30	5.97	1100.74	1094.77	
MW-1i	07/14/00	10:05	5.99	1100.74	1094.75	
MW-1i	07/14/00	19:37	6.01	1100.74	1094.73	
MW-1i	07/18/00	11:09	6.04	1100.74	1094.70	
MW-1i	07/18/00	19:33	6.03	1100.74	1094.71	
MW-1i	07/19/00	13:40	6.02	1100.74	1094.72	
MW-1i	07/20/00	8:20	6.01	1100.74	1094.73	
MW-1i	07/21/00	10:18	6.05	1100.74	1094.69	
MW-1i	07/25/00	16:08	6.04	1100.74	1094.70	
MW-1i	07/26/00	18:29	6.06	1100.74	1094.68	
MW-1i	07/28/00	14:19	6.02	1100.74	1094.72	
MW-1i	07/31/00	11:23	6.03	1100.74	1094.71	
MW-1i	08/02/00	18:31	6.08	1100.74	1094.66	
MW-1i	08/03/00	19:22	6.11	1100.74	1094.63	
MW-1i	08/04/00	8:29	6.11	1100.74	1094.63	
MW-1s	06/29/00	19:52	5.35	1098.75	1093.40	
MW-1s	07/07/00	10:53	5.81	1098.75	1092.94	
MW-1s	07/11/00	18:25	5.92	1098.75	1092.83	
MW-1s	07/13/00	8:37	6.00	1098.75	1092.75	
MW-1s	07/13/00	19:33	6.02	1098.75	1092.73	
MW-1s	07/14/00	10:11	6.04	1098.75	1092.71	
MW-1s	07/14/00	19:40	6.09	1098.75	1092.66	
MW-1s	07/18/00	11:12	6.25	1098.75	1092.50	
MW-1s	07/18/00	19:35	6.26	1098.75	1092.49	
MW-1s	07/19/00	13:43	6.28	1098.75	1092.47	
MW-1s	07/20/00	8:24	6.30	1098.75	1092.45	
MW-1s	07/21/00	10:22	6.22	1098.75	1092.53	
MW-1s	07/25/00	16:12	6.44	1098.75	1092.31	
MW-1s	07/26/00	18:31	6.48	1098.75	1092.27	
MW-1s	07/28/00	14:18	5.99	1098.75	1092.76	
MW-1s	07/31/00	11:27	5.72	1098.75	1093.03	
MW-1s	08/02/00	10:35	5.90	1098.75	1092.85	
MW-1s	08/03/00	19:26	6.07	1098.75	1092.68	
MW-1s	08/04/00	8:32	6.11	1098.75	1092.64	
MW-2	07/07/00	7:32	9.78	1104.08	1094.30	
MW-2	07/13/00	9:44	9.80	1104.08	1094.28	
MW-2	07/13/00	19:40	9.79	1104.08	1094.29	
MW-2	07/14/00	10:17	9.80	1104.08	1094.28	
MW-2	07/14/00	19:41	9.82	1104.08	1094.26	
MW-2	07/18/00	11:16	9.85	1104.08	1094.23	
MW-2	07/18/00	19:40	9.84	1104.08	1094.24	
MW-2	07/19/00	13:50	9.83	1104.08	1094.25	
MW-2	07/20/00	8:30	9.83	1104.08	1094.25	
MW-2	07/21/00	10:29	9.87	1104.08	1094.21	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
MW-2	07/25/00	15:42	9.85	1104.08	1094.23	
MW-2	07/26/00	10:47	9.90	1104.08	1094.18	
MW-2	07/26/00	18:33	9.86	1104.08	1094.22	
MW-2	07/28/00	14:15	9.84	1104.08	1094.24	
MW-2	07/31/00	11:35	9.85	1104.08	1094.23	
MW-2	08/02/00	18:26	9.91	1104.08	1094.17	
MW-2	08/03/00	19:30	9.03	1104.08	1095.05	
MW-2	08/04/00	8:23	9.95	1104.08	1094.13	
MW-3	07/07/00	7:38	16.36	1109.57	1093.21	
MW-3	07/07/00	9:38	16.87	1109.57	1092.70	
MW-3	07/13/00	8:47	16.37	1109.57	1093.20	
MW-3	07/13/00	19:13	16.37	1109.57	1093.20	
MW-3	07/14/00	10:23	16.37	1109.57	1093.20	
MW-3	07/14/00	19:44	16.40	1109.57	1093.17	
MW-3	07/18/00	11:21	16.43	1109.57	1093.14	
MW-3	07/18/00	19:44	16.41	1109.57	1093.16	
MW-3	07/19/00	13:54	16.42	1109.57	1093.15	
MW-3	07/20/00	8:32	16.40	1109.57	1093.17	
MW-3	07/21/00	10:26	16.44	1109.57	1093.13	
MW-3	07/25/00	16:30	16.43	1109.57	1093.14	
MW-3	07/26/00	18:32	16.44	1109.57	1093.13	
MW-3	07/28/00	14:06	16.41	1109.57	1093.16	
MW-3	07/31/00	11:18	16.41	1109.57	1093.16	
MW-3	08/02/00	18:36	16.46	1109.57	1093.11	
MW-3	08/03/00	19:12	16.51	1109.57	1093.06	
MW-3	08/04/00	8:36	16.51	1109.57	1093.06	
MW-4d	07/13/00	19:23	2.70	1096.04	1093.34	
MW-4d	07/14/00	9:54	2.72	1096.04	1093.32	
MW-4d	07/14/00	19:31	2.75	1096.04	1093.29	
MW-4d	07/18/00	11:03	2.79	1096.04	1093.25	
MW-4d	07/18/00	19:22	2.78	1096.04	1093.26	
MW-4d	07/19/00	13:19	2.74	1096.04	1093.30	
MW-4d	07/20/00	8:11	2.77	1096.04	1093.27	
MW-4d	07/21/00	11:24	2.73	1096.04	1093.31	
MW-4d	07/25/00	16:19	2.82	1096.04	1093.22	
MW-4d	07/28/00	15:42	2.76	1096.04	1093.28	
MW-4d	07/31/00	11:14	2.74	1096.04	1093.30	
MW-4d	08/02/00	18:41	2.80	1096.04	1093.24	
MW-4d	08/03/00	19:18	2.84	1096.04	1093.20	
MW-4d	08/04/00	8:43	2.84	1096.04	1093.20	
MW-4s	06/29/00	19:58	5.60	1091.38	1085.78	
MW-4s	07/13/00	9:29	5.85	1091.38	1085.53	
MW-4s	07/13/00	19:20	5.87	1091.38	1085.51	
MW-4s	07/14/00	9:56	5.91	1091.38	1085.47	
MW-4s	07/14/00	19:33	5.96	1091.38	1085.42	
MW-4s	07/18/00	11:00	6.20	1091.38	1085.18	
MW-4s	07/18/00	19:19	6.21	1091.38	1085.17	
MW-4s	07/19/00	13:16	6.23	1091.38	1085.15	
MW-4s	07/20/00	8:08	6.26	1091.38	1085.12	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
MW-4s	07/21/00	11:21	6.30	1091.38	1085.08	
MW-4s	07/25/00	16:21	6.45	1091.38	1084.93	
MW-4s	07/26/00	14:54	6.48	1091.38	1084.90	
MW-4s	07/28/00	14:04	6.13	1091.38	1085.25	
MW-4s	07/31/00	11:11	5.87	1091.38	1085.51	
MW-4s	08/02/00	10:31	5.90	1091.38	1085.48	
MW-4s	08/03/00	19:15	6.04	1091.38	1085.34	
MW-4s	08/04/00	8:40	6.04	1091.38	1085.34	
MW-5d	07/25/00	15:37	52.19	1149.4	1097.21	
MW-5d	07/26/00	17:07	52.19	1149.4	1097.21	
MW-5d	07/27/00	18:40	52.16	1149.4	1097.24	
MW-5d	07/28/00	15:37	52.19	1149.4	1097.21	
MW-5d	07/31/00	10:36	52.17	1149.4	1097.23	
MW-5d	08/02/00	9:54	52.18	1149.4	1097.22	
MW-5d	08/03/00	18:36	52.26	1149.4	1097.14	
MW-5d	08/04/00	8:07	52.25	1149.4	1097.15	
MW-5i	07/25/00	15:39	52.67	1148.75	1096.08	
MW-5i	07/26/00	17:11	52.67	1148.75	1096.08	
MW-5i	07/27/00	18:43	52.61	1148.75	1096.14	
MW-5i	07/28/00	15:35	52.66	1148.75	1096.09	
MW-5i	07/31/00	10:32	52.68	1148.75	1096.07	
MW-5i	08/02/00	9:57	53.17	1148.75	1095.58	
MW-5i	08/03/00	18:39	54.04	1148.75	1094.71	
MW-5i	08/04/00	8:10	53.97	1148.75	1094.78	
MW-6	07/19/00	12:59	43.58	1142.44	1098.86	
MW-6	07/20/00	7:47	43.60	1142.44	1098.84	
MW-6	07/21/00	10:03	43.65	1142.44	1098.79	
MW-6	07/25/00	15:05	43.61	1142.44	1098.83	
MW-6	07/26/00	16:43	43.61	1142.44	1098.83	
MW-6	07/28/00	13:54	43.62	1142.44	1098.82	
MW-6	07/31/00	10:55	43.63	1142.44	1098.81	
MW-6	08/02/00	18:17	43.71	1142.44	1098.73	
MW-6	08/04/00	7:54	43.82	1142.44	1098.62	
MW-7	07/20/00	9:21	52.83	1149.23	1096.40	
MW-7	07/21/00	10:08	52.87	1149.23	1096.36	
MW-7	07/25/00	14:59	52.85	1149.23	1096.38	
MW-7	07/26/00	16:46	52.86	1149.23	1096.37	
MW-7	07/28/00	13:58	52.84	1149.23	1096.39	
MW-7	07/31/00	11:00	52.85	1149.23	1096.38	
MW-7	08/02/00	10:24	52.86	1149.23	1096.37	
MW-7	08/04/00	7:59	52.94	1149.23	1096.29	
MW-8	07/19/00	13:08	18.09	1113.485	1095.40	
MW-8	07/20/00	7:58	18.10	1113.485	1095.39	
MW-8	07/21/00	10:13	18.11	1113.485	1095.38	
MW-8	07/25/00	14:55	18.10	1113.485	1095.39	
MW-8	07/26/00	16:52	18.12	1113.485	1095.37	
MW-8	07/28/00	14:01	18.06	1113.485	1095.43	
MW-8	07/31/00	11:06	18.05	1113.485	1095.44	
MW-8	08/02/00	19:02	18.10	1113.485	1095.39	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
MW-8	08/04/00	9:20	18.12	1113.485	1095.37	
MW-9	07/21/00	9:57	28.34	1125.29	1096.95	
MW-9	07/25/00	15:24	28.34	1125.29	1096.95	
MW-9	07/26/00	17:51	28.34	1125.29	1096.95	
MW-9	07/27/00	19:45	28.33	1125.29	1096.96	
MW-9	07/28/00	14:30	28.33	1125.29	1096.96	
MW-9	07/31/00	10:21	28.34	1125.29	1096.95	
MW-9	08/02/00	18:08	28.38	1125.29	1096.91	
MW-9	08/04/00	7:43	28.40	1125.29	1096.89	
Seep-1	06/29/00	17:08	2.52	1089.68	1087.16	
Seep-1	07/06/00	13:25	2.52	1089.68	1087.16	
Seep-1	07/11/00	18:36	2.54	1089.68	1087.14	
Seep-1	07/13/00	9:24	2.53	1089.68	1087.15	
Seep-1	07/13/00	19:08	2.53	1089.68	1087.15	
Seep-1	07/14/00	10:45	2.52	1089.68	1087.16	
Seep-1	07/14/00	19:51	2.54	1089.68	1087.14	
Seep-1	07/18/00	11:36	2.54	1089.68	1087.14	
Seep-1	07/18/00	19:55	2.54	1089.68	1087.14	
Seep-1	07/19/00	14:05	2.54	1089.68	1087.14	
Seep-1	07/20/00	9:02	2.55	1089.68	1087.13	
Seep-1	07/21/00	11:13	2.54	1089.68	1087.14	
Seep-1	07/25/00	16:34	2.54	1089.68	1087.14	
Seep-1	07/26/00	17:02	2.55	1089.68	1087.13	
Seep-1	07/28/00	15:12	2.51	1089.68	1087.17	
Seep-1	07/31/00	11:43	2.50	1089.68	1087.18	
Seep-1	08/02/00	10:48	2.52	1089.68	1087.16	
Seep-1	08/03/00	19:02	2.55	1089.68	1087.13	
Seep-1	08/04/00	9:12	2.55	1089.68	1087.13	
Seep-2	06/29/00	19:11	4.51	1085.83	1081.32	
Seep-2	06/29/00	20:06	4.51	1085.83	1081.32	
Seep-2	07/06/00	13:16	4.49	1085.83	1081.34	
Seep-2	07/11/00	18:32	4.50	1085.83	1081.33	
Seep-2	07/13/00	8:53	4.53	1085.83	1081.30	
Seep-2	07/13/00	18:37	4.51	1085.83	1081.32	
Seep-2	07/14/00	10:37	4.52	1085.83	1081.31	
Seep-2	07/14/00	19:49	4.52	1085.83	1081.31	
Seep-2	07/18/00	11:32	4.52	1085.83	1081.31	
Seep-2	07/18/00	19:51	4.51	1085.83	1081.32	
Seep-2	07/20/00	8:38	4.52	1085.83	1081.31	
Seep-2	07/21/00	11:09	4.52	1085.83	1081.31	
Seep-2	07/25/00	16:33	4.52	1085.83	1081.31	
Seep-2	07/26/00	14:58	4.51	1085.83	1081.32	
Seep-2	07/28/00	15:09	4.52	1085.83	1081.31	
Seep-2	07/31/00	11:53	4.52	1085.83	1081.31	
Seep-2	08/02/00	10:44	4.54	1085.83	1081.29	
Seep-2	08/03/00	19:06	4.53	1085.83	1081.30	
Seep-2	08/04/00	8:53	4.53	1085.83	1081.30	
Seep-3	06/29/00	20:03	4.91	1085.66	1080.75	
Seep-3	07/11/00	18:30	4.97	1085.66	1080.69	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
Seep-3	07/13/00	8:50	4.95	1085.66	1080.71	
Seep-3	07/13/00	18:35	4.97	1085.66	1080.69	
Seep-3	07/14/00	10:33	4.95	1085.66	1080.71	
Seep-3	07/14/00	19:48	4.98	1085.66	1080.68	
Seep-3	07/18/00	11:30	5.00	1085.66	1080.66	
Seep-3	07/18/00	19:48	5.00	1085.66	1080.66	
Seep-3	07/19/00	13:59	5.00	1085.66	1080.66	
Seep-3	07/20/00	8:36	4.98	1085.66	1080.68	
Seep-3	07/21/00	11:07	5.02	1085.66	1080.64	
Seep-3	07/25/00	16:32	5.02	1085.66	1080.64	
Seep-3	07/26/00	14:56	5.01	1085.66	1080.65	
Seep-3	07/28/00	15:07	4.92	1085.66	1080.74	
Seep-3	07/31/00	11:51	4.92	1085.66	1080.74	
Seep-3	08/02/00	10:42	4.93	1085.66	1080.73	
Seep-3	08/03/00	19:08	4.95	1085.66	1080.71	
Seep-3	08/04/00	8:50	4.95	1085.66	1080.71	
Seep-4	07/07/00	7:36	4.75	1087.62	1082.87	
Seep-4	07/07/00	9:38	4.71	1087.62	1082.91	
Seep-4	07/11/00	18:34	4.77	1087.62	1082.85	
Seep-4	07/13/00	8:56	4.75	1087.62	1082.87	
Seep-4	07/13/00	18:32	4.75	1087.62	1082.87	
Seep-4	07/14/00	10:40	4.75	1087.62	1082.87	
Seep-4	07/14/00	19:50	4.77	1087.62	1082.85	
Seep-4	07/18/00	11:34	4.78	1087.62	1082.84	
Seep-4	07/18/00	19:53	4.77	1087.62	1082.85	
Seep-4	07/19/00	14:03	4.80	1087.62	1082.82	
Seep-4	07/20/00	9:00	4.77	1087.62	1082.85	
Seep-4	07/21/00	11:11	4.77	1087.62	1082.85	
Seep-4	07/25/00	16:35	4.77	1087.62	1082.85	
Seep-4	07/26/00	17:00	4.77	1087.62	1082.85	
Seep-4	07/28/00	15:10	4.77	1087.62	1082.85	
Seep-4	07/31/00	11:46	4.74	1087.62	1082.88	
Seep-4	08/02/00	10:46	4.74	1087.62	1082.88	
Seep-4	08/03/00	19:04	4.74	1087.62	1082.88	
Seep-4	08/04/00	9:14	4.73	1087.62	1082.89	
Seep=5	07/25/00	15:29	5.63	1094.52	1088.89	
Seep=5	07/26/00	17:47	5.63	1094.52	1088.89	
Seep=5	07/27/00	19:48	5.50	1094.52	1089.02	
Seep=5	07/28/00	14:33	5.52	1094.52	1089.00	
Seep=5	07/31/00	10:15	5.51	1094.52	1089.01	
Seep=5	08/02/00	10:02	5.55	1094.52	1088.97	
Seep=5	08/04/00	7:39	5.55	1094.52	1088.97	
Seep-6	07/25/00	14:40	1.39	1106.222	1104.83	
Seep-6	07/26/00	11:27	1.31	1106.222	1104.91	
Seep-6	07/28/00	14:55	1.21	1106.222	1105.01	
Seep-6	07/31/00	13:52	1.18	1106.222	1105.04	
Seep-6	08/02/00	19:11	1.23	1106.222	1104.99	
Seep-6	08/04/00	9:32	1.23	1106.222	1104.99	
TW-1	07/07/00	7:22	5.20	1099.84	1094.64	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
TW-1	07/07/00	10:54	5.23	1099.84	1094.61	
TW-1	07/13/00	8:39	5.25	1099.84	1094.59	
TW-1	07/13/00	19:35	5.21	1099.84	1094.63	
TW-1	07/14/00	10:13	5.23	1099.84	1094.61	
TW-1	07/14/00	19:39	5.24	1099.84	1094.60	
TW-1	07/18/00	11:13	5.28	1099.84	1094.56	
TW-1	07/18/00	19:37	5.26	1099.84	1094.58	
TW-1	07/19/00	13:45	5.25	1099.84	1094.59	
TW-1	07/20/00	8:26	5.26	1099.84	1094.58	
TW-1	07/21/00	10:24	5.28	1099.84	1094.56	
TW-1	07/25/00	16:14	5.24	1099.84	1094.60	
TW-1	07/26/00	18:27	5.26	1099.84	1094.58	
TW-1	07/28/00	14:17	5.21	1099.84	1094.63	
TW-1	07/31/00	11:31	5.23	1099.84	1094.61	
TW-1	08/02/00	18:33	5.28	1099.84	1094.56	
TW-1	08/03/00	19:27	5.31	1099.84	1094.53	
TW-1	08/04/00	8:34	5.32	1099.84	1094.52	
TW-2	08/02/00	18:23	23.78	1119.41	1095.63	
TW-2	08/03/00	19:33	23.80	1119.41	1095.61	
TW-2	08/04/00	8:19	23.82	1119.41	1095.59	
TW-3	07/28/00	15:33	52.63	1148.57	1095.94	
TW-3	07/31/00	10:26	52.60	1148.57	1095.97	
Vent-1	07/11/00	18:50	3.87	1092.79	1088.92	
Vent-1	07/13/00	9:15	3.86	1092.79	1088.93	
Vent-1	07/13/00	19:00	3.86	1092.79	1088.93	
Vent-1	07/14/00	11:50	3.88	1092.79	1088.91	
Vent-1	07/14/00	20:13	3.88	1092.79	1088.91	
Vent-1	07/18/00	12:13	3.88	1092.79	1088.91	
Vent-1	07/18/00	20:03	3.87	1092.79	1088.92	
Vent-1	07/19/00	14:41	3.87	1092.79	1088.92	
Vent-1	07/20/00	9:10	3.86	1092.79	1088.93	
Vent-1	07/21/00	10:40	3.86	1092.79	1088.93	
Vent-1	07/25/00	17:02	3.88	1092.79	1088.91	
Vent-1	07/26/00	17:18	3.87	1092.79	1088.92	
Vent-1	07/28/00	15:26	3.87	1092.79	1088.92	
Vent-1	07/31/00	13:26	3.89	1092.79	1088.90	
Vent-1	08/02/00	11:05	3.88	1092.79	1088.91	
Vent-1	08/03/00	18:50	3.88	1092.79	1088.91	
Vent-1	08/04/00	9:03	3.89	1092.79	1088.90	
Vent-2	07/11/00	18:56	2.55	1124.28	1121.73	
Vent-2	07/13/00	9:21	2.56	1124.28	1121.72	
Vent-2	07/13/00	19:05	2.55	1124.28	1121.73	
Vent-2	07/14/00	11:40	2.57	1124.28	1121.71	
Vent-2	07/14/00	20:10	2.59	1124.28	1121.69	
Vent-2	07/18/00	12:07	2.60	1124.28	1121.68	
Vent-2	07/18/00	20:00	2.52	1124.28	1121.76	
Vent-2	07/19/00	14:39	2.53	1124.28	1121.75	
Vent-2	07/20/00	9:07	2.52	1124.28	1121.76	
Vent-2	07/21/00	10:33	2.51	1124.28	1121.77	

TABLE 3-2
GSWA
SPRING HILL CAMP
BACKGROUND WELL WATER LEVELS (MANUAL READINGS)

Well ID	Date	Time	DTW (feet)	Well Elevation	Water Elevation	Comments
Vent-2	07/25/00	17:11	2.57	1124.28	1121.71	
Vent-2	07/26/00	17:16	2.58	1124.28	1121.70	
Vent-2	07/28/00	15:31	2.52	1124.28	1121.76	
Vent-2	07/31/00	13:33	2.53	1124.28	1121.75	
Vent-2	08/02/00	11:10	2.52	1124.28	1121.76	
Vent-2	08/03/00	18:43	2.52	1124.28	1121.76	
Vent-2	08/04/00	9:09	2.52	1124.28	1121.76	
Residential-1	08/22/00	17:20	84.81	1133	1048.19	Well Elevation estimated from
Residential-1	08/23/00	9:22	84.82	1133	1048.18	approximate well location from
						U.S.G.S. topographic map.

TABLE 3-3
GSWA
SPRING HILL CAMP STUDY AREA
BACKGROUND WEIR FLOW RATES (MANUAL READINGS)

Well ID	Date	Time	Head of Water (inches)	Flow (gpm)	Comments
Weir-4	06/29/00	8:05	3.63	31.7	
Weir-3	06/29/00	8:58	3.88	37.4	
Weir-2	06/29/00	12:08	3.13	21.9	
Weir-1	06/29/00	12:20	1.50	3.5	
Weir-4	06/29/00	17:50	3.63	31.7	
Weir-3	06/29/00	18:00	3.88	37.4	
Weir-2	06/29/00	18:05	3.19	23.0	
Weir-1	06/29/00	18:20	1.50	3.5	
Weir-4	07/11/00	18:40	3.71	33.7	
Weir-3	07/11/00	18:43	4.00	40.5	
Weir-2	07/11/00	18:46	3.00	19.7	
Weir-1	07/11/00	18:53	1.20	2.0	
Weir-4	07/13/00	9:00	3.56	30.3	
Weir-3	07/13/00	9:08	3.75	34.5	
Weir-2	07/13/00	9:11	3.06	20.8	
Weir-1	07/13/00	9:19	1.25	2.2	
Weir-4	07/13/00	18:40	3.50	29.0	
Weir-3	07/13/00	18:49	3.63	31.7	
Weir-2	07/13/00	18:58	2.94	18.7	
Weir-1	07/13/00	19:03	1.25	2.2	
Weir-4	07/14/00	10:55	3.63	31.7	
Weir-3	07/14/00	11:17	3.81	35.9	
Weir-2	07/14/00	11:25	2.88	17.7	
Weir-1	07/14/00	11:45	1.25	2.2	
Weir-4	07/14/00	19:54	3.75	34.5	
Weir-3	07/14/00	20:00	3.75	34.5	
Weir-2	07/14/00	20:04	2.94	18.7	
Weir-1	07/14/00	20:11	1.31	2.5	
Weir-4	07/18/00	11:43	3.63	31.7	
Weir-3	07/18/00	11:56	3.75	34.5	
Weir-2	07/18/00	11:58	3.06	20.8	
Weir-1	07/18/00	12:12	1.13	1.7	
Weir-4	07/19/00	14:14	3.56	30.3	
Weir-3	07/19/00	14:23	3.75	34.5	
Weir-2	07/19/00	14:27	3.06	20.8	
Weir-1	07/19/00	14:34	1.19	1.9	
Weir-4	07/20/00	8:44	3.50	29.0	
Weir-3	07/20/00	8:52	3.75	34.5	
Weir-2	07/20/00	8:58	3.06	20.8	
Weir-1	07/20/00	9:06	1.19	1.9	
Weir-1	07/21/00	10:37	1.25	2.2	
Weir-2	07/21/00	10:49	3.06	20.8	
Weir-3	07/21/00	10:52	3.75	34.5	
Weir-4	07/21/00	11:02	3.50	29.0	
Weir-1	07/25/00	17:05	1.25	2.2	

TABLE 3-3
GSWA
SPRING HILL CAMP
BACKGROUND WEIR FLOW RATES (MANUAL READINGS)

Well ID	Date	Time	Head of Water (inches)	Flow (gpm)	Comments
Weir-2	07/25/00	16:55	2.94	18.7	
Weir-3	07/25/00	16:50	3.63	31.7	
Weir-4	07/25/00	16:45	3.44	27.7	
Weir-1	07/26/00	19:20-20:15	1.19	1.9	
Weir-2	07/26/00	19:20-20:15	3.00	19.7	
Weir-3	07/26/00	19:20-20:15	3.75	34.5	
Weir-4	07/26/00	19:20-20:15	3.50	29.0	
Weir-4	07/27/00	10:30-10:50	3.44	27.7	
Weir-3	07/27/00	10:30-10:50	3.75	34.5	
Weir-2	07/27/00	10:30-10:50	3.25	24.1	
Weir-1	07/27/00	10:30-10:50	1.44	3.1	
Weir-1	07/28/00	15:20	1.25	2.2	
Weir-2	07/28/00	15:21	3.25	24.1	
Weir-3	07/28/00	15:15	3.88	37.4	
Weir-4	07/28/00	15:17	3.50	29.0	
Weir-4	07/31/00	13:10	3.56	30.3	
Weir-3	07/31/00	13:15	3.94	39.0	
Weir-2	07/31/00	13:18	3.13	21.9	
Weir-1	07/31/00	13:30	1.25	2.2	
Weir-1	08/01/00	15:17	1.25	2.2	
Weir-2	08/01/00	15:33	3.13	21.9	
Weir-3	08/01/00	15:37	3.69	33.1	
Weir-4	08/01/00	15:39	3.50	29.0	
Weir-4	08/02/00	10:57	3.56	30.3	
Weir-3	08/02/00	11:01	3.75	34.5	
Weir-2	08/02/00	11:03	3.06	20.8	
Weir-1	08/02/00	11:08	1.31	2.5	
Weir-1	08/03/00	18:47	1.25	2.2	
Weir-2	08/03/00	18:54	2.94	18.7	
Weir-3	08/03/00	18:57	3.75	34.5	
Weir-4	08/03/00	19:00	3.50	29.0	
Weir-4	08/04/00	8:56	3.50	29.0	
Weir-3	08/04/00	8:58	3.81	35.9	
Weir-2	08/04/00	9:00	3.06	20.8	
Weir-1	08/04/00	9:05	1.25	2.2	
Weir-1	08/30/00			2.7	Post pump test
Weir-2	08/30/00			6.3	Post pump test
Weir-3	08/30/00			9.4	Post pump test
Weir-4	08/30/00			9.4	Post pump test
Weir-4	09/05/00			24.2	Post pump test
Weir-3	09/05/00			23.8	Post pump test
Weir-2	09/05/00			17.5	Post pump test
Weir-1	09/05/00			2.2	Post pump test
Weir-1	09/08/00			2.2	Post pump test
Weir-2	09/08/00			18.4	Post pump test
Weir-3	09/08/00			26.9	Post pump test
Weir-4	09/08/00			22.9	Post pump test

TABLE 4-1
GSWA
SPRING HILL CAMP STUDY AREA
WELL CLUSTER VERTICAL HYDRAULIC GRADIENTS

Well ID	Screen midpoint	Date Measured	Water Elevation	ds	dh	Vertical Gradient	Direction
MW-1s	6.5	06/29/2000	1093.40	99	3.14	0.032	Upward
MW-1d	105.5		1096.54				
MW-1s	6.5	07/26/2000	1092.27	99	4.15	0.042	
MW-1d	105.5		1096.42				
MW-4s	6.2	07/25/2000	1084.93	69.3	8.29	0.120	Upward
MW-4d	75.5		1093.22				
MW-4s	6.2	07/13/2000	1085.51	69.3	7.83	0.113	
MW-4d	75.5		1093.34				
MW-5i	95	08/03/2000	1094.71	60.5	2.43	0.040	Upward
MW-5d	155.5		1097.14				
MW-5i	95	07/27/2000	1096.14	60.5	1.1	0.018	
MW-5d	155.5		1097.24				
MW-12i	57	08/23/2000	1117.31	53	-0.14	-0.003	Downward
MW-12d	110		1117.17				
MW-12i	57	07/31/2000	1117.36	53	-0.15	-0.003	
MW-12d	110		1117.21				

Notes:
dh = difference in hydraulic head
ds = distance in feet between locations

TABLE 4-2
GSWA
SPRING HILL CAMP STUDY AREA
LINEAR GROUNDWATER FLOW VELOCITY - AUGUST 4, 2000

Gradient Location	Water Elevation	dh	ds	I	V_{max} (ft/day)	V_{min} (ft/day)
MW-1i Seep-3	1094.63 1080.71	13.92	364	0.038	43	2.1
MW-3 Seep-4	1093.06 1082.89	10.17	92	0.11	120	6.1
Contour-1114 Contour-1098	1114 1098	16	2781	0.0058	6.4	0.32

Notes:

$V_{max} = K_{max}$(I/effective porosity)

where K_{max} =279 ft/day

effective porosity = 0.25

I = horizontal hydraulic gradient

$V_{min} = K_{min}$(I/effective porosity)

where K_{min} =22 ft/day

effective porosity = 0.4

I = horizontal hydraulic gradient

dh = difference in hydraulic head

ds = distance in feet between locations

effective porosity values are published values for sand taken from Groundwater and Wells (1986)

TABLE 5-1
GSWA
SPRING HILL CAMP STUDY AREA
WELL FIELD TEST AQUIFER PARAMETERS

Parameters	MW-1i	MW-2	MW-3	MW-4d	MW-4s	MW-5d	MW-5i	MW-6
T (m^2/day)	678	678	666	872	1,538	893	523	738
T (gpd/ft)	54,580	54,580	53,588	70,174	123,837	71,886	42,105	59,422
K (cm/s)	3.11E-02	2.84E-02	6.18E-02	4.00E-02	8.13E-02	3.24E-01	2.76E-02	3.90E-02
K (ft/day)	27	24	53	34	70	279	24	34
S_a	1.48E-03	3.39E-03	3.33E-03	2.72E-03	2.52E-01	2.51E-01	5.31E-04	2.65E-02

Parameters	MW-7	MW-8	MW-9	MW-10	MW-13	Seep-1	Seep-3	Seep-4
T (m^2/day)	732	880	1,307	2,025	478	806	3,661	2,326
T (gpd/ft)	58,946	70,849	105,261	163,015	38,477	64,919	294,732	187,250
K (cm/s)	3.87E-02	4.65E-02	6.91E-02	1.07E-01	2.53E-02	4.26E-02	1.93E-01	1.23E-01
K (ft/day)	33	40	60	92	22	37	167	106
S_a	8.12E-03	8.39E-03	5.52E-02	8.23E-02	1.34E-02	1.20E-01	1.03E-01	4.00E-01

Parameters	Maximum	Minimum	Average	Geometric Mean
T (m2/day)	3661	478	1175	985
T (gpd/ft)	294,732	38,477	94,601	79,339
K (cm/s)	3.24E-01	2.53E-02	7.99E-02	5.89E-02
K (ft/day)	279	22	69	51
S_a	4.00E-01	5.31E-04	8.32E-02	2.03E-02

Notes: T = Transmissivity
K = Hydraulic Conductivity
S_a = Storativity

TABLE 5-2
GSWA
SPRING HILL CAMP STUDY AREA
GEOCHEMICAL ANALYTICAL RESULTS

SampleID: / **Date Sampled:** / *Parameter*	Federal Maximum Contaminant Level[1]	Michigan Maximum Contaminant Level[2]	PGA Maximum Contaminant Level[3]	**Central** 08/02/00	**Seep** 08/24/00	**TW-1** 08/24/00	**TW-2** 08/24/00	**TW-3** 08/25/00
Barium	2.0	2.0	0.50	0.015	0.015	0.016	0.019	0.018
Calcium	NR	*	75	47	47	48.6	47	45
Iron	0.3	0.3	0.03	ND	ND	ND	ND	0.01
Magnesium	NR	400	25	16	15.8	16.5	16.1	16.7
Manganese	0.05	0.05	0.005	ND	ND	ND	ND	0.003
Potassium	NR	*	10	0.4	0.6	0.5	0.5	0.5
Sodium	NR	120	21	2	2.2	2.2	2.4	2.5
Zinc	5	2.4	1	ND	ND	0.1	0.01	0.014
Nickel	0.1	0.1	0.1	0.001	ND	ND	0.004	ND
Bicarbonate	NR	*	NR	210	207	212	200	201
Chloride	250	250	50	3	3.6	3.9	2	1
Nitrate	10	10	5	1	1.7	2.7	ND	ND
Sulfate	250	250	50	9.1	9.7	10.2	10	10.3
Silica	NR	*	NR	10	10	10	11	12
Aluminum	0.2	0.05	0.05	ND	ND	ND	ND	ND

Notes:

(1) Federal Drinking Water Standards as reported in analytical report from Quality Services Laboratory

(2) Michigan Department of Environmental Quality Drinking Water Standards

(3) Perrier Group of America Maximum Contaminant Level for Drinking Water

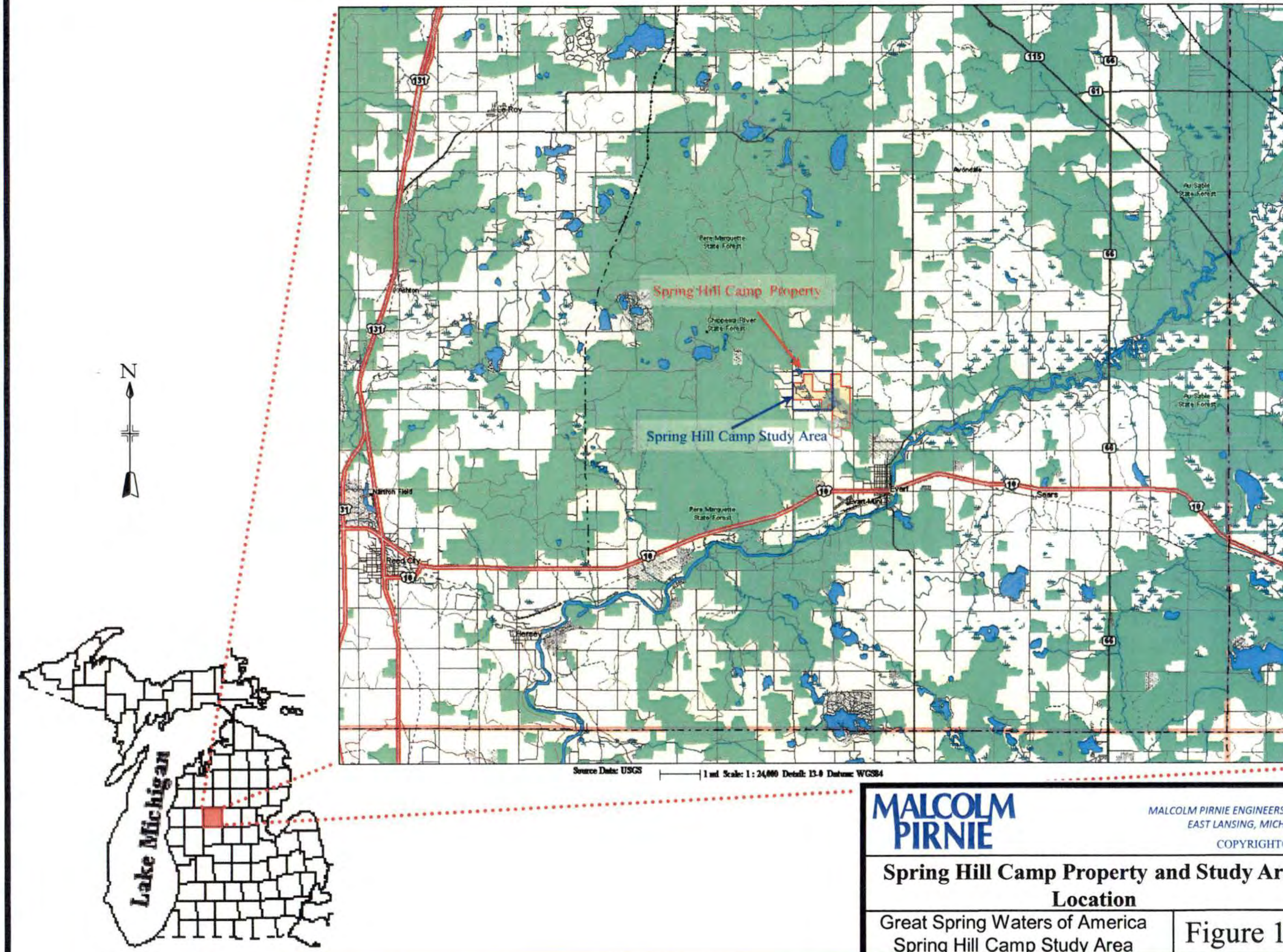
Concentrations reported in mg/L.

No exceedances of federal, state, or PGA maximum concentration levels.

ND - Not Detected

NR - None Required

* - Michigan Maximum Contaminant Level does not exist, per October 10, 2000 discussion with Richard Benzie, Michigan Department of Environmental Quality, Drinking Water and Radiological Protection Division.



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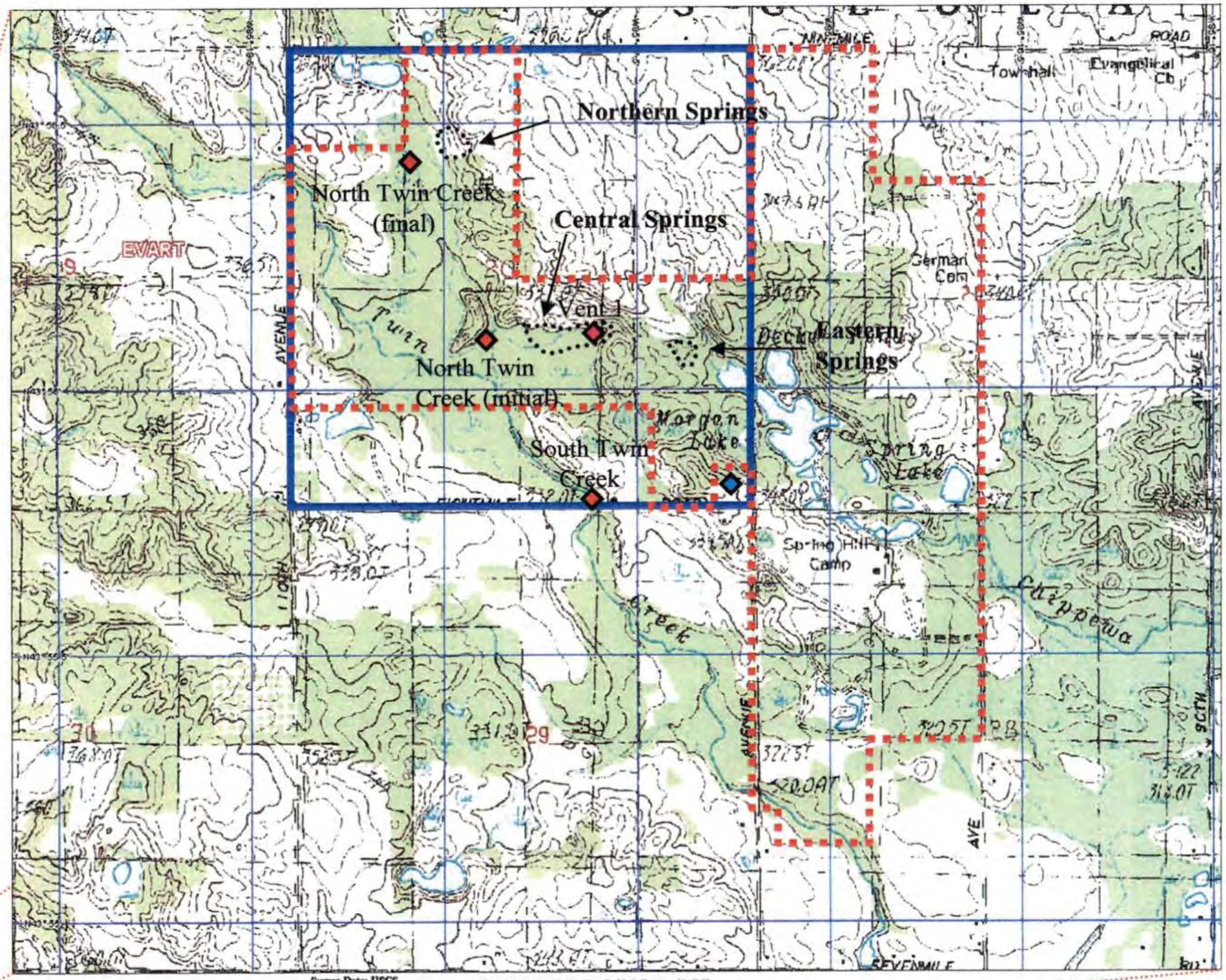
Spring Hill Camp Property and Study Area Location

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 1-1



N

Legend

- Instrumented Stab Well (Vent 1)
- Instrumented Stilling Well
- Residential Well
- Spring Hill Camp Property Boundary
- Spring Hill Camp Study Area
- Spring Locations

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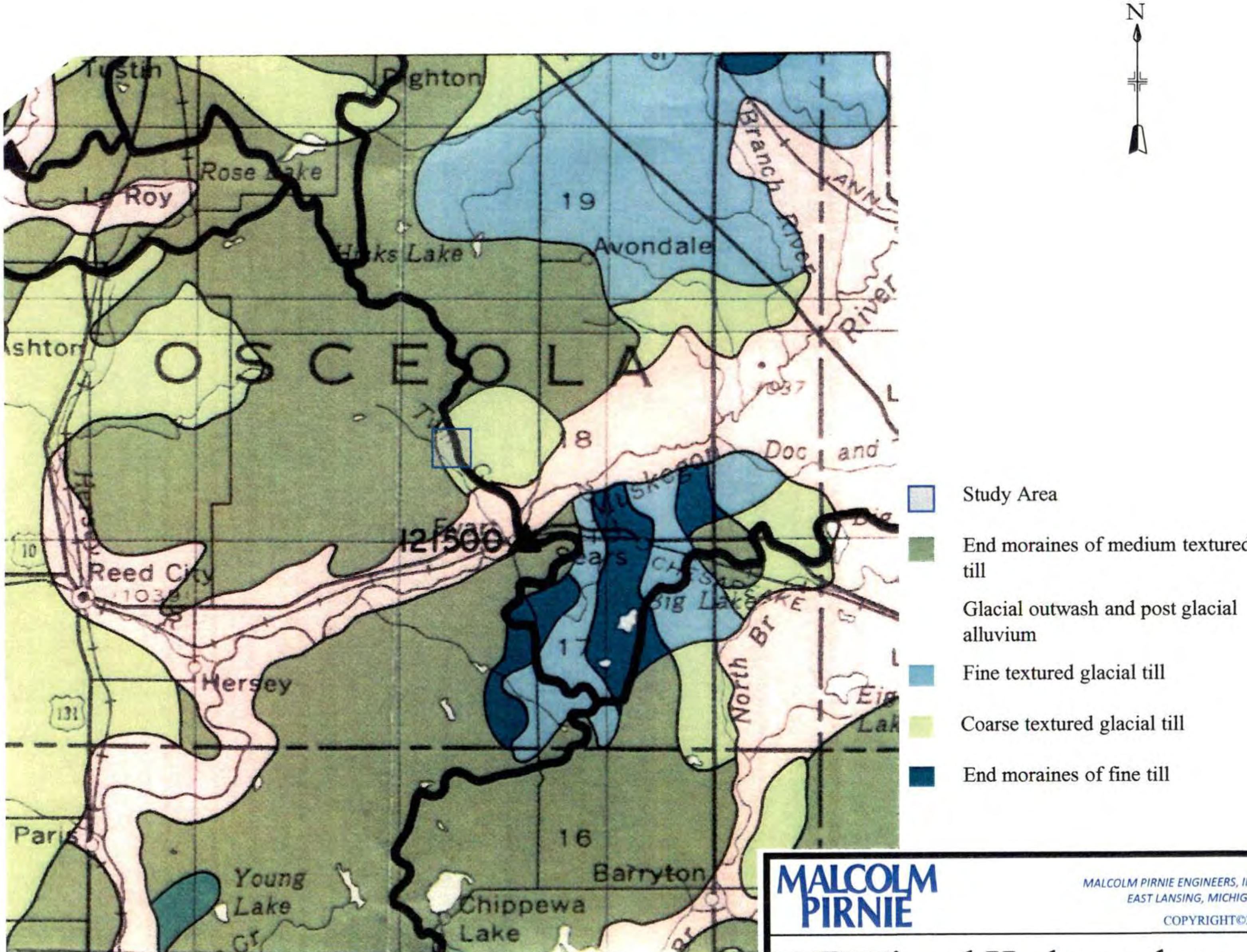
Spring Locations

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 1-2



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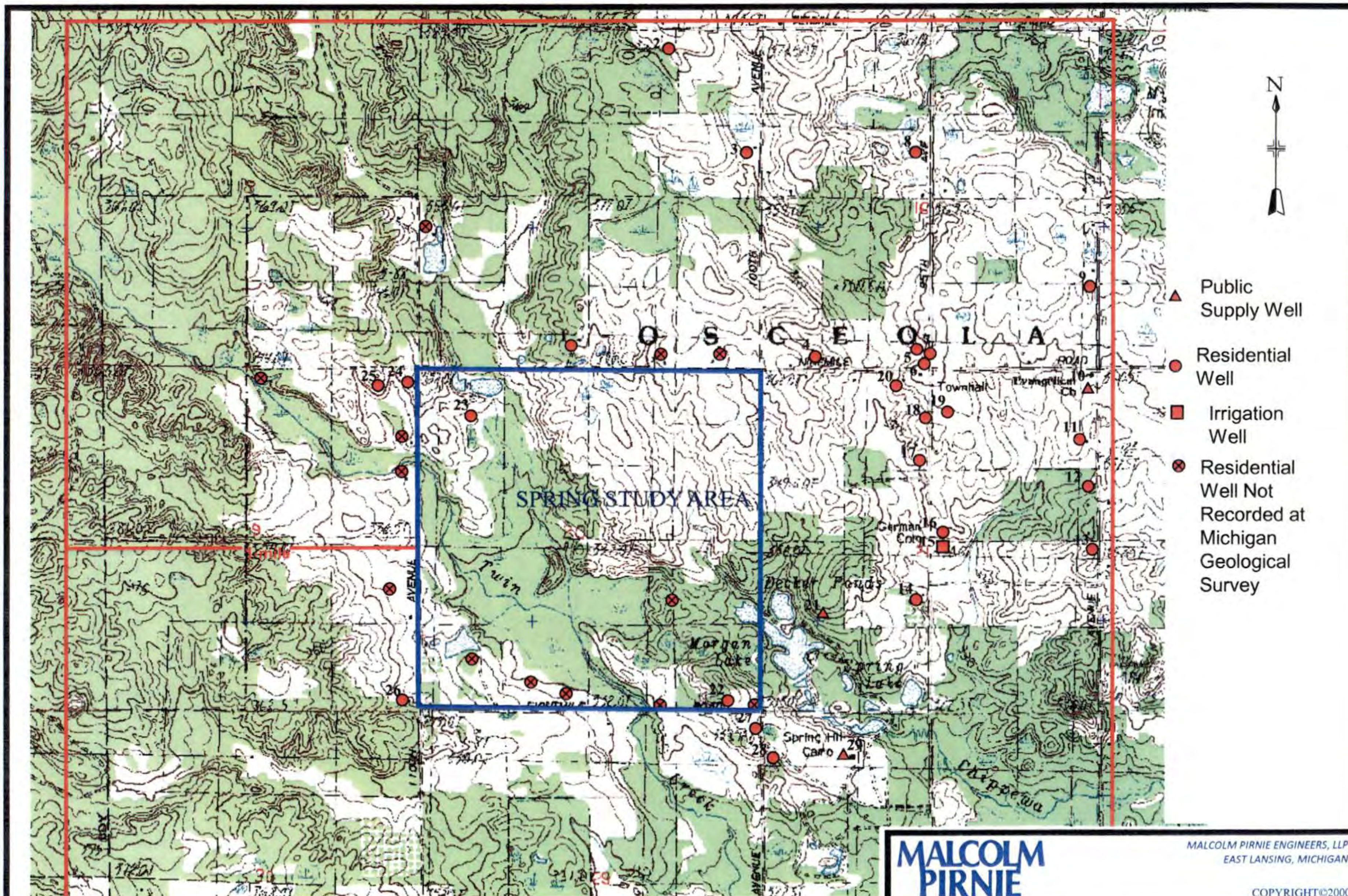
Regional Hydrogeology

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 2-1



0 1000 2000 4000 feet

Notes: Well search limited to one mile from Study Area boundary.
Sources for well locations: USGS, Mecosta County Health Department, and aerial photographs.
All wells shown at approximate locations.
Additional wells not identified by search may be present within a one mile radius of the Spring Study Area.

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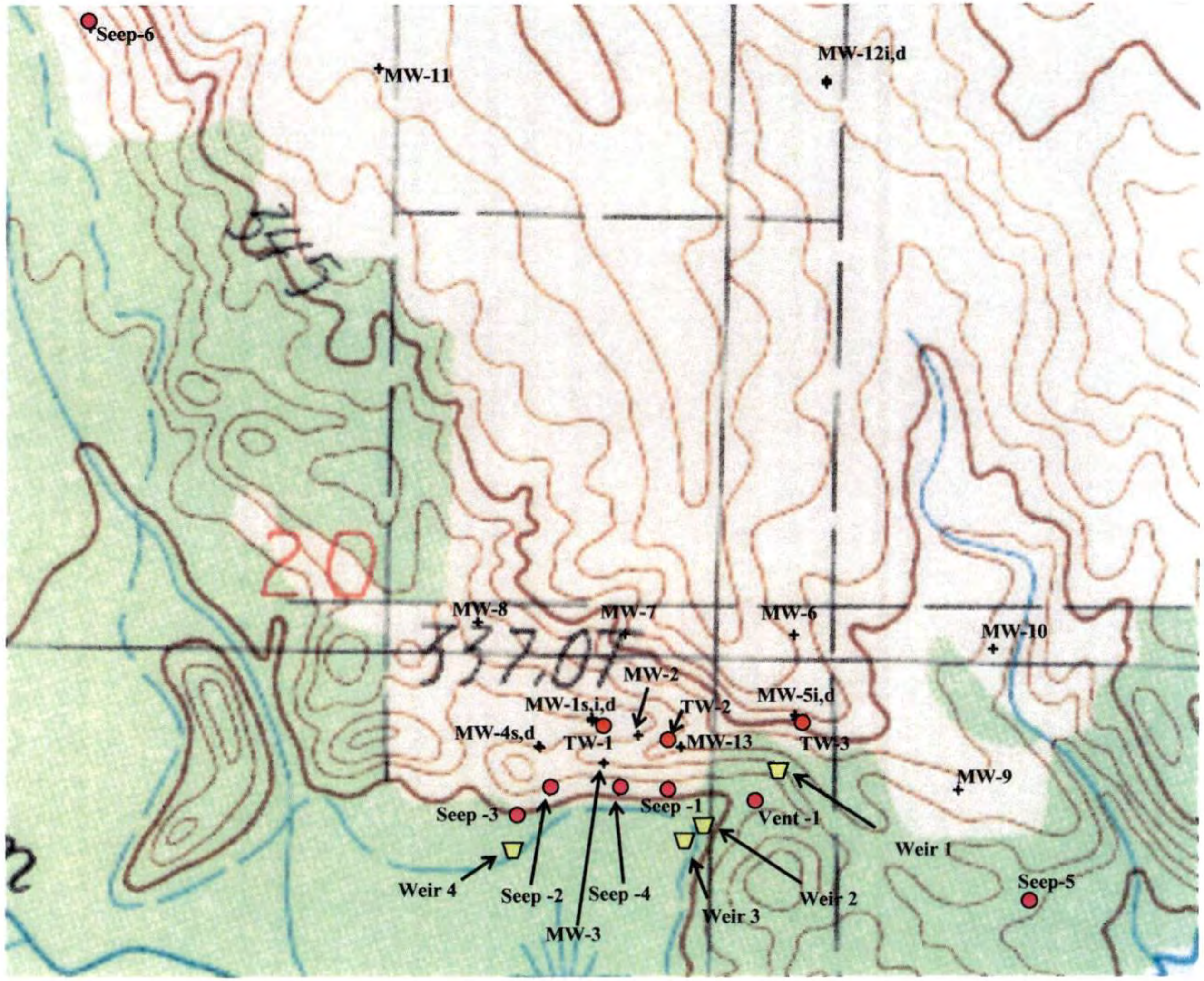
Local Water Supply Wells

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 2-2



Legend

- + Monitoring Well
- s Shallow Well
- i Intermediate Well
- d Deep Well
- ● Test Well
- ● Stab Well
- ▽ V-Notch Weir

N

0 200 400 800 feet

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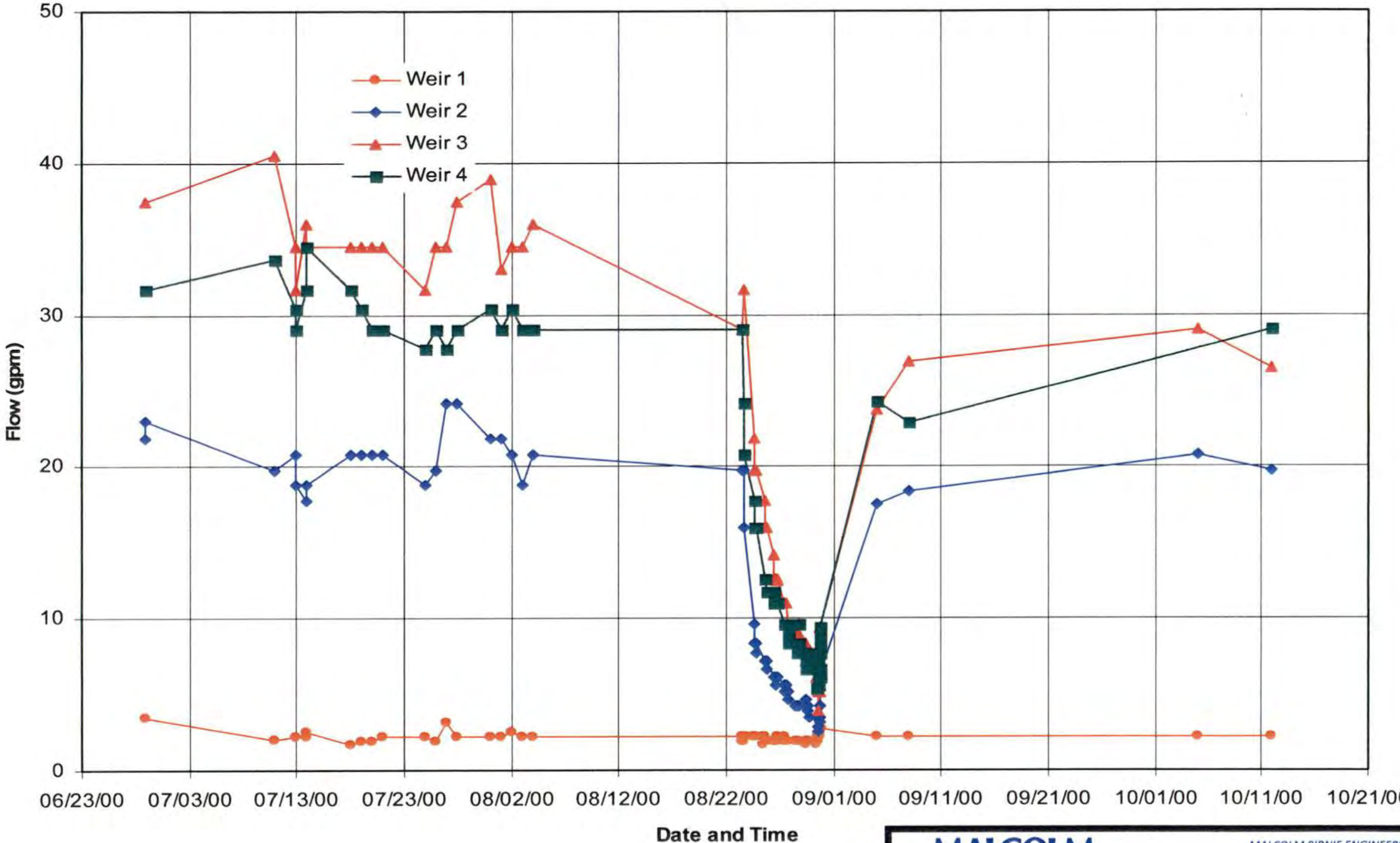
Well Locations

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 3-1



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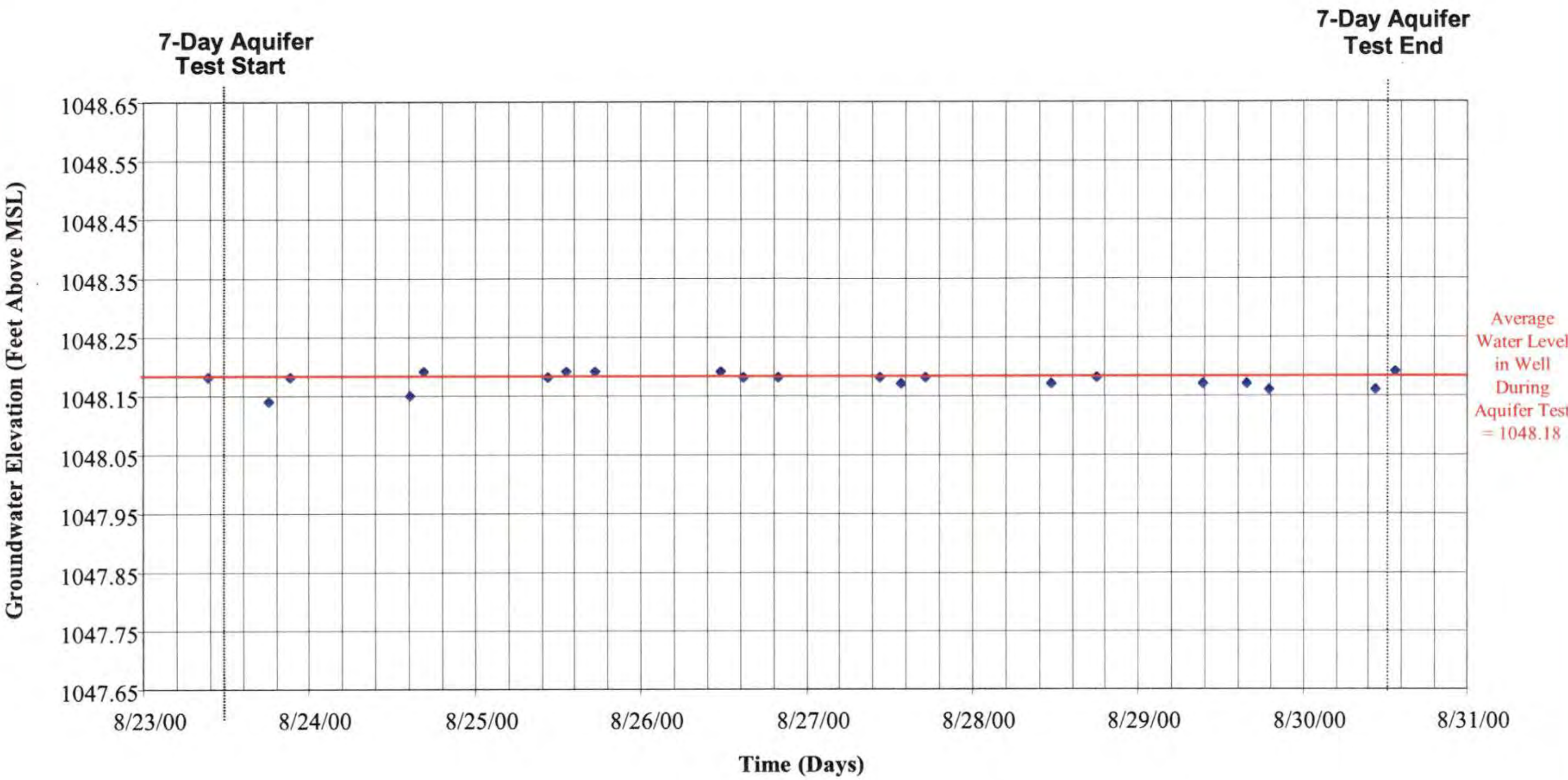
Discharge Across Weir Measurements

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 3-2



Note:

Initial groundwater elevation = 1048.18 feet above mean sea level.

Elevation of residential well estimated from approximate well location on U.S.G.S topographic map.

Residential well located on northwest corner of 100th Avenue and Eight Mile Road.

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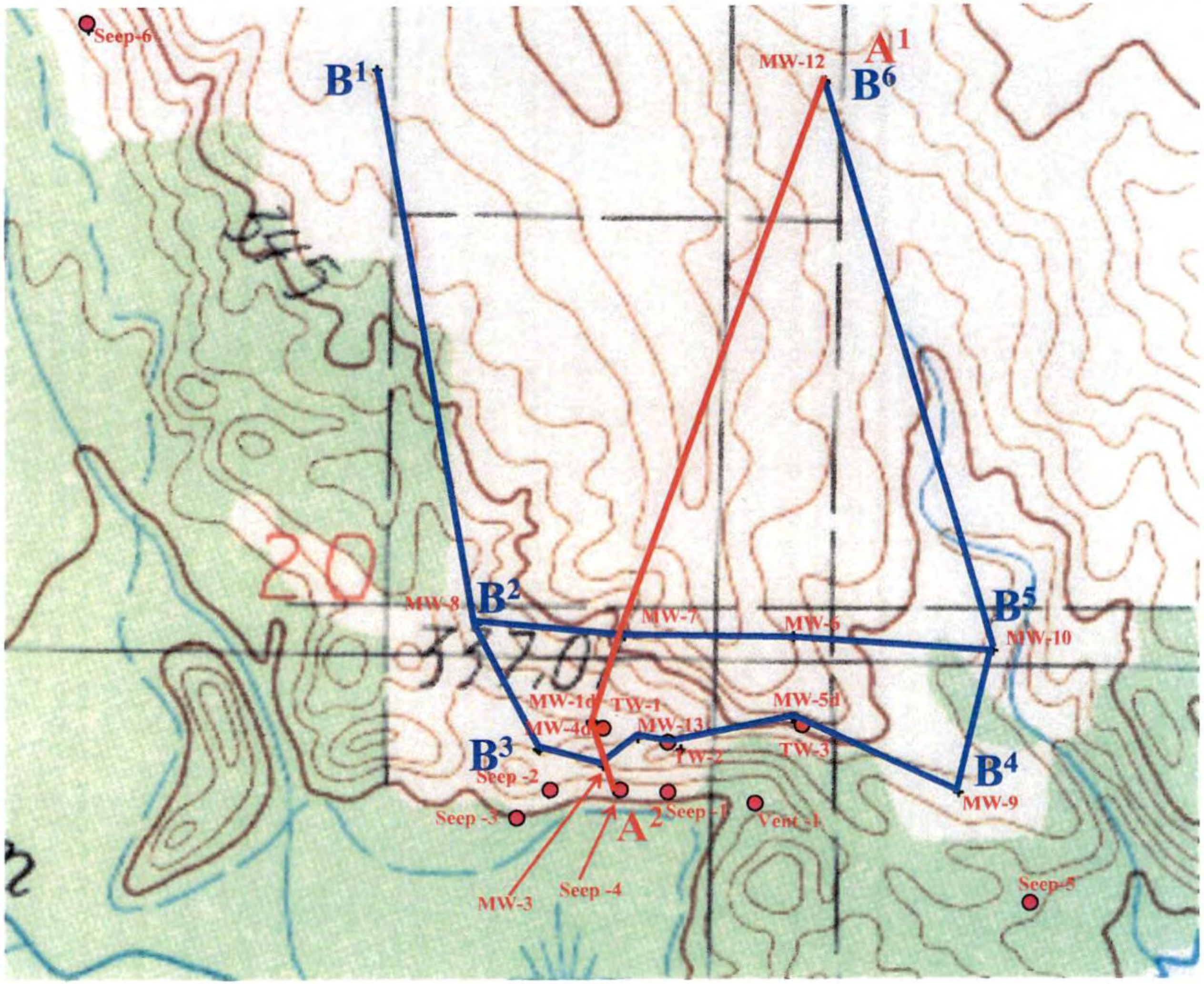
Groundwater Elevation in Residential Well

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 3-3



Legend

- + Monitoring Well
- s Shallow Well
- i Intermediate Well
- d Deep Well
- ● Test Well
- ● Stab Well
- — Cross Section
- — Fence Diagram

N

0 200 400 800 feet

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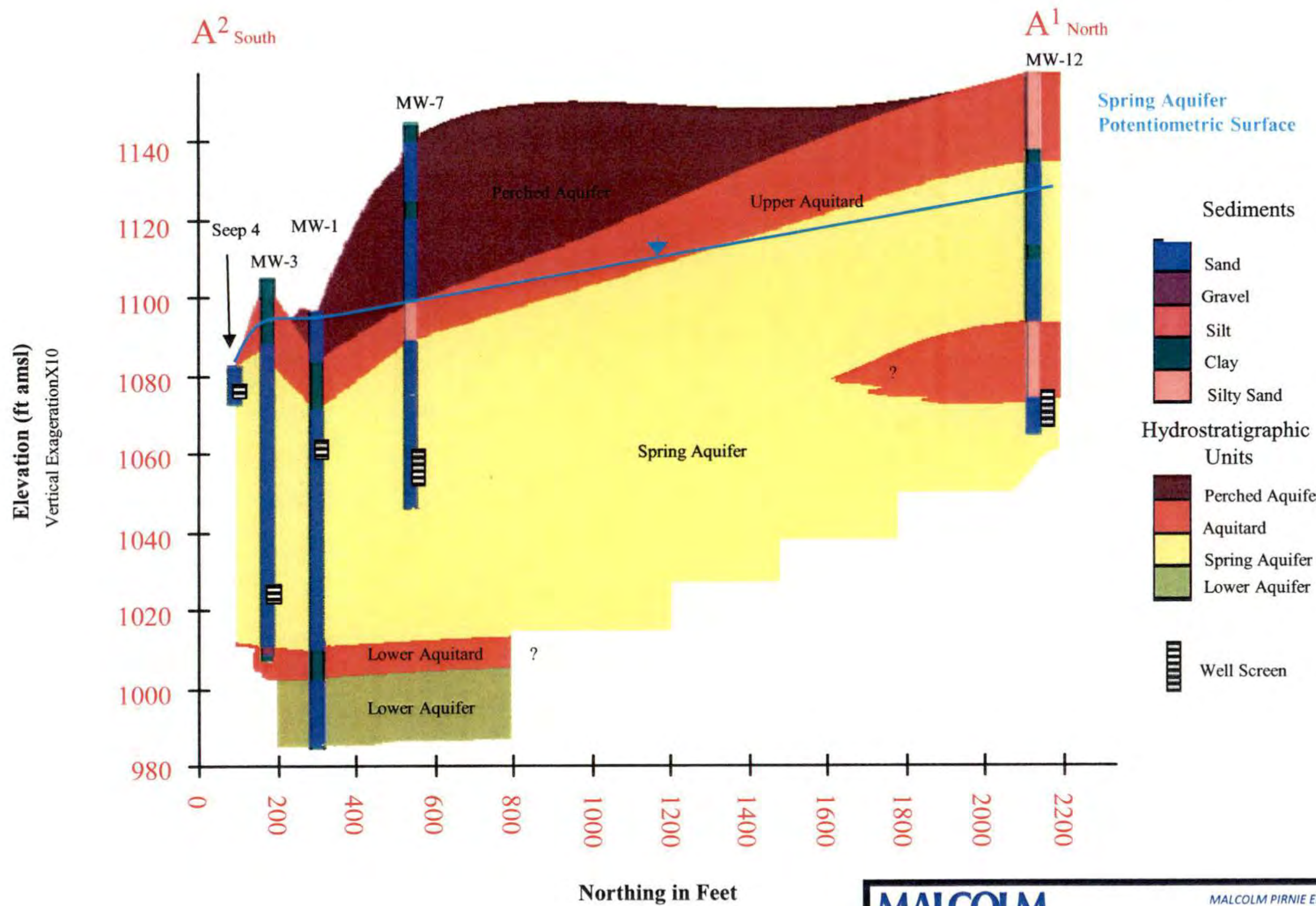
Cross Section and Fence Diagram Locations

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 4-1



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Cross Section A1 – A2

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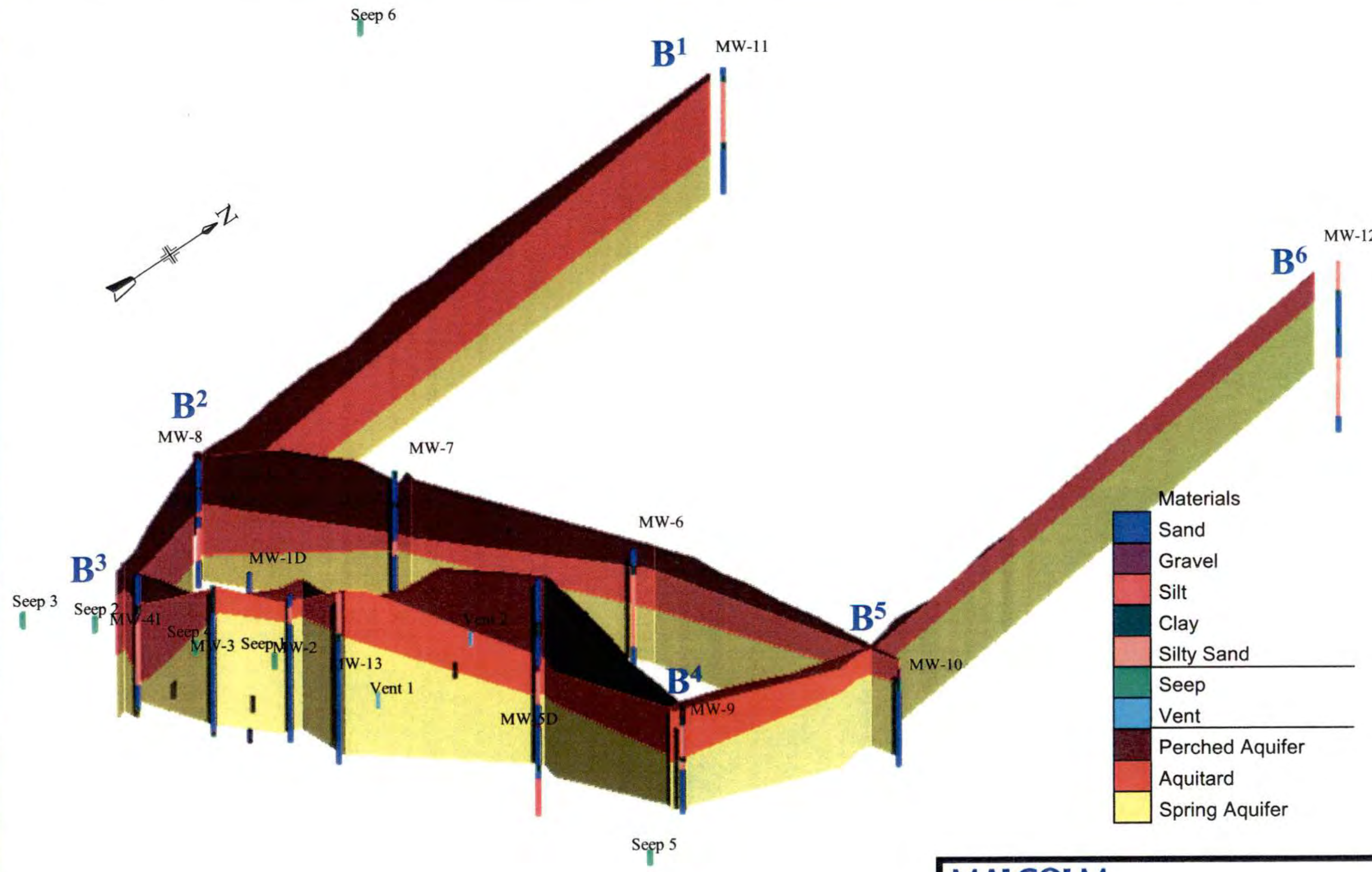
Spring Hill Camp Study Area

Figure 4-2



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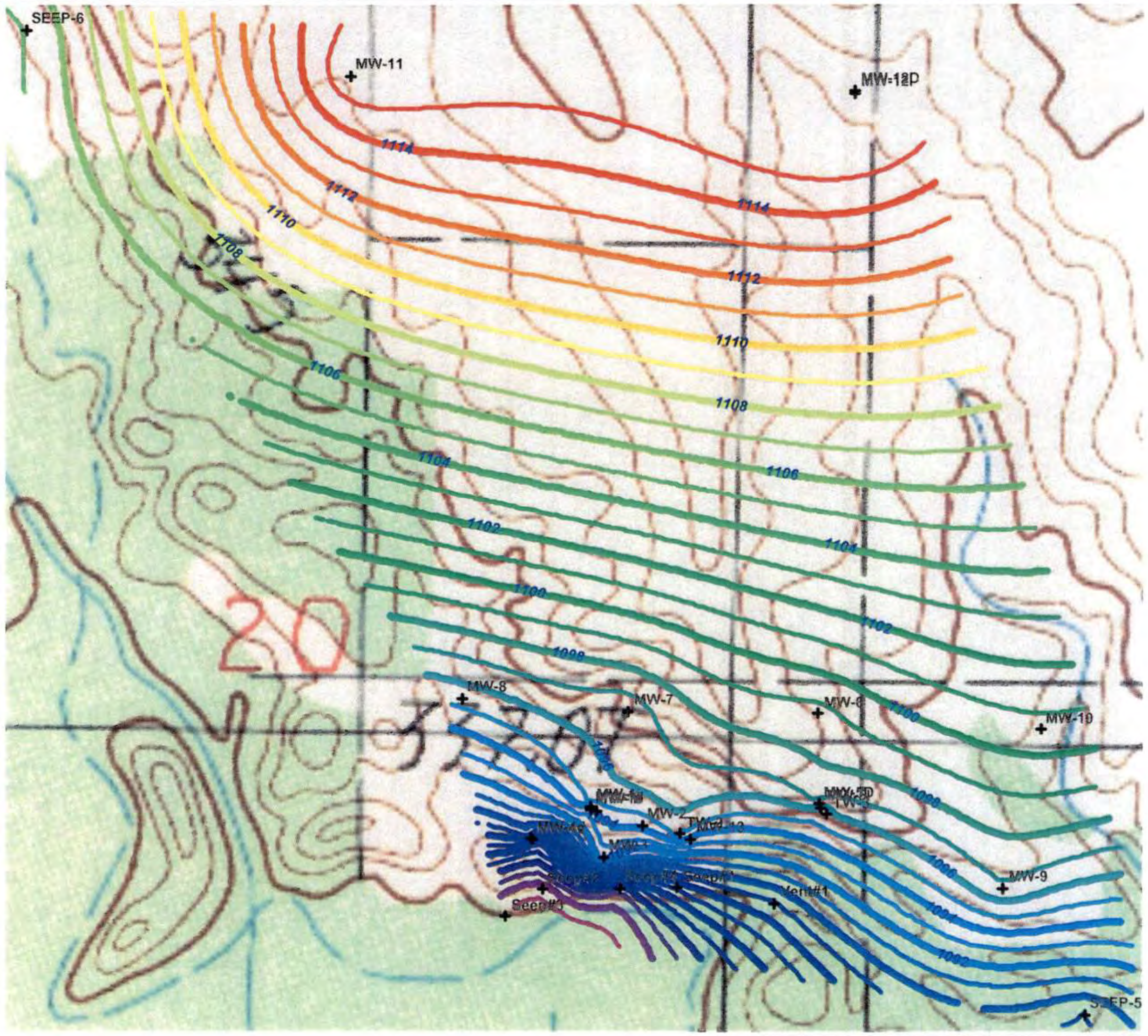
Fence Diagram

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 4-3



N

0 200 400 800 feet

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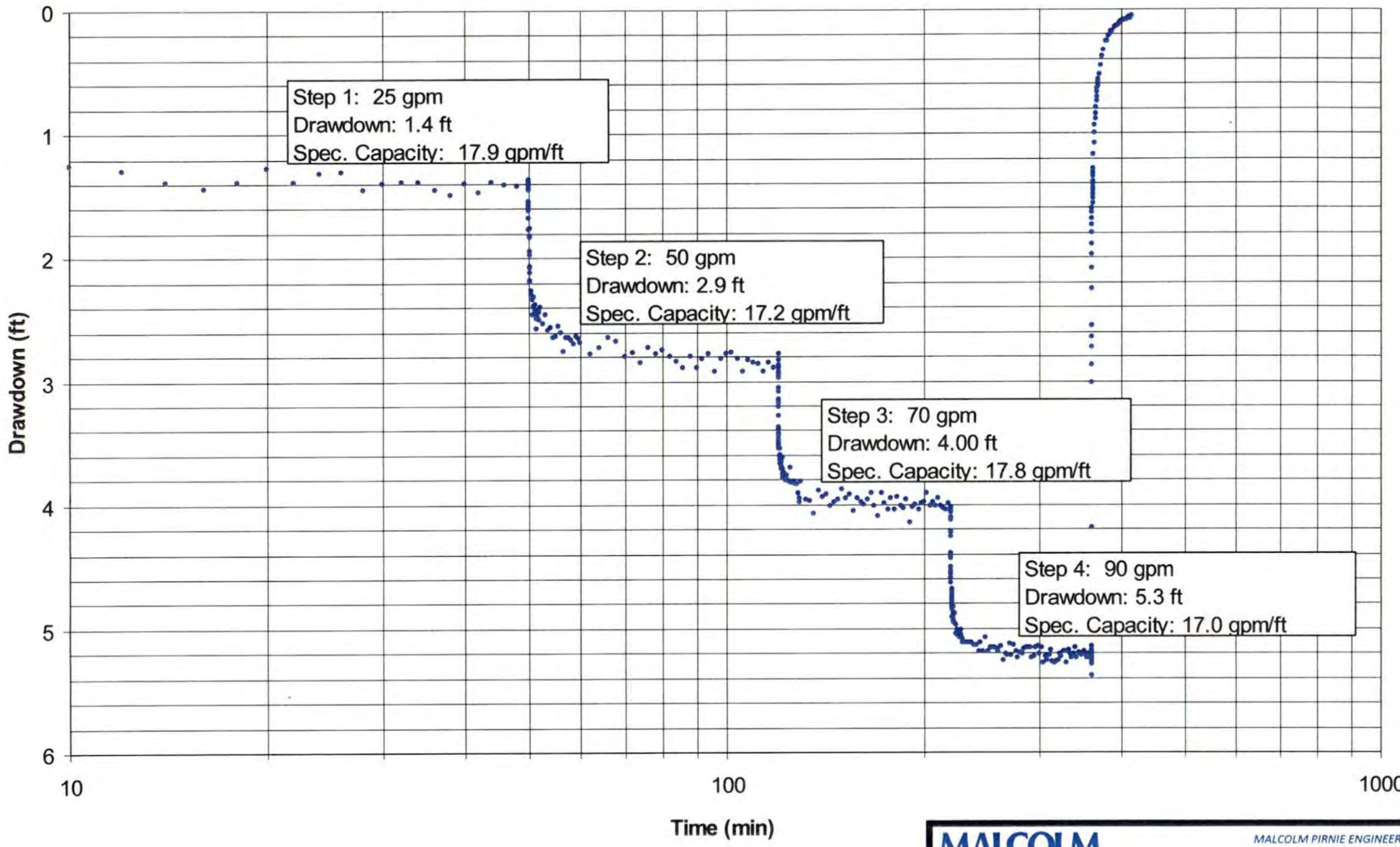
Potentiometric Surface - August 4, 2000

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 4-4



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Drawdown Vs. Time in Pumping Well TW-1
Step Drawdown Test

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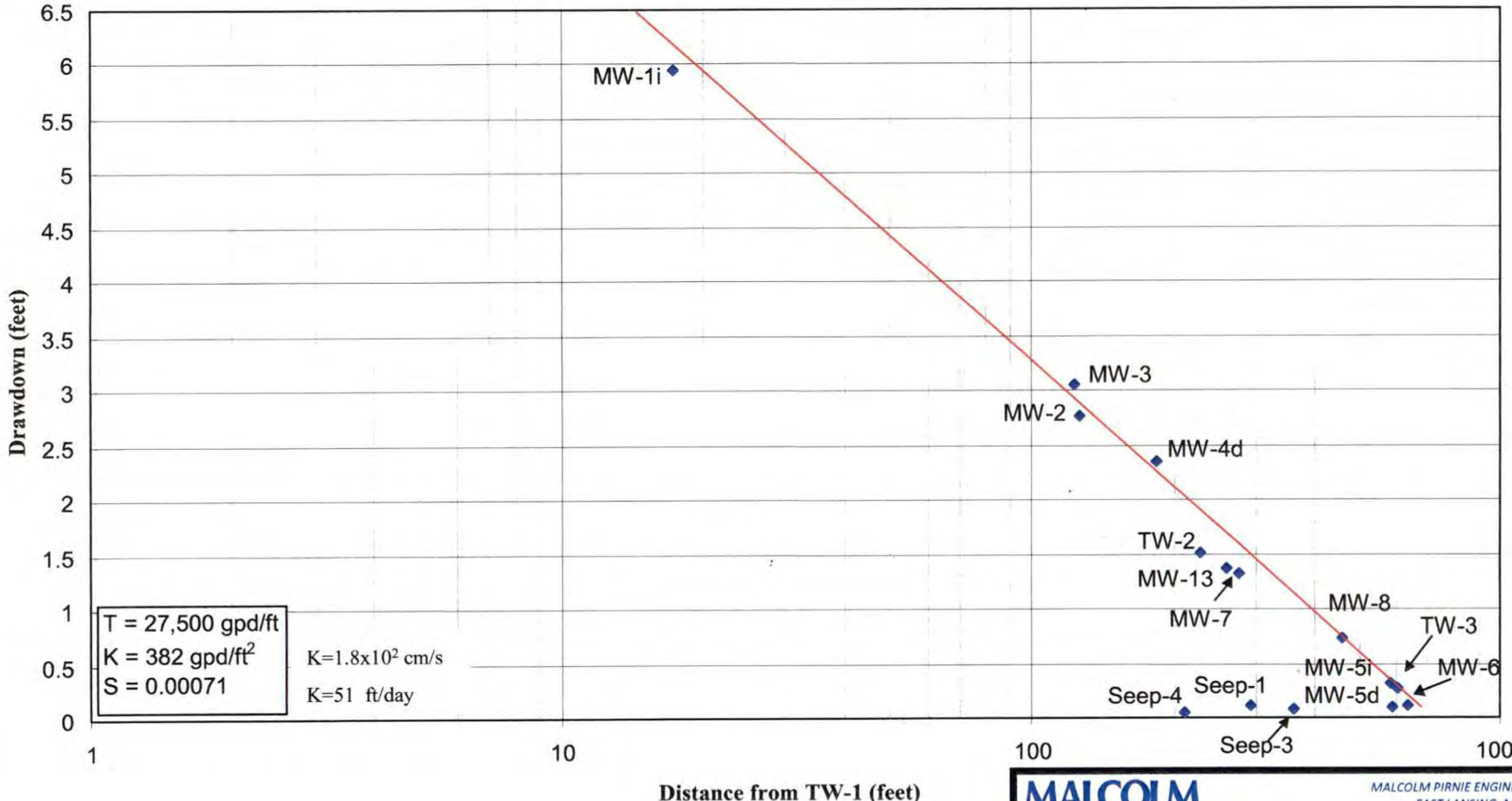
Spring Hill Camp Study Area

Figure 5-1



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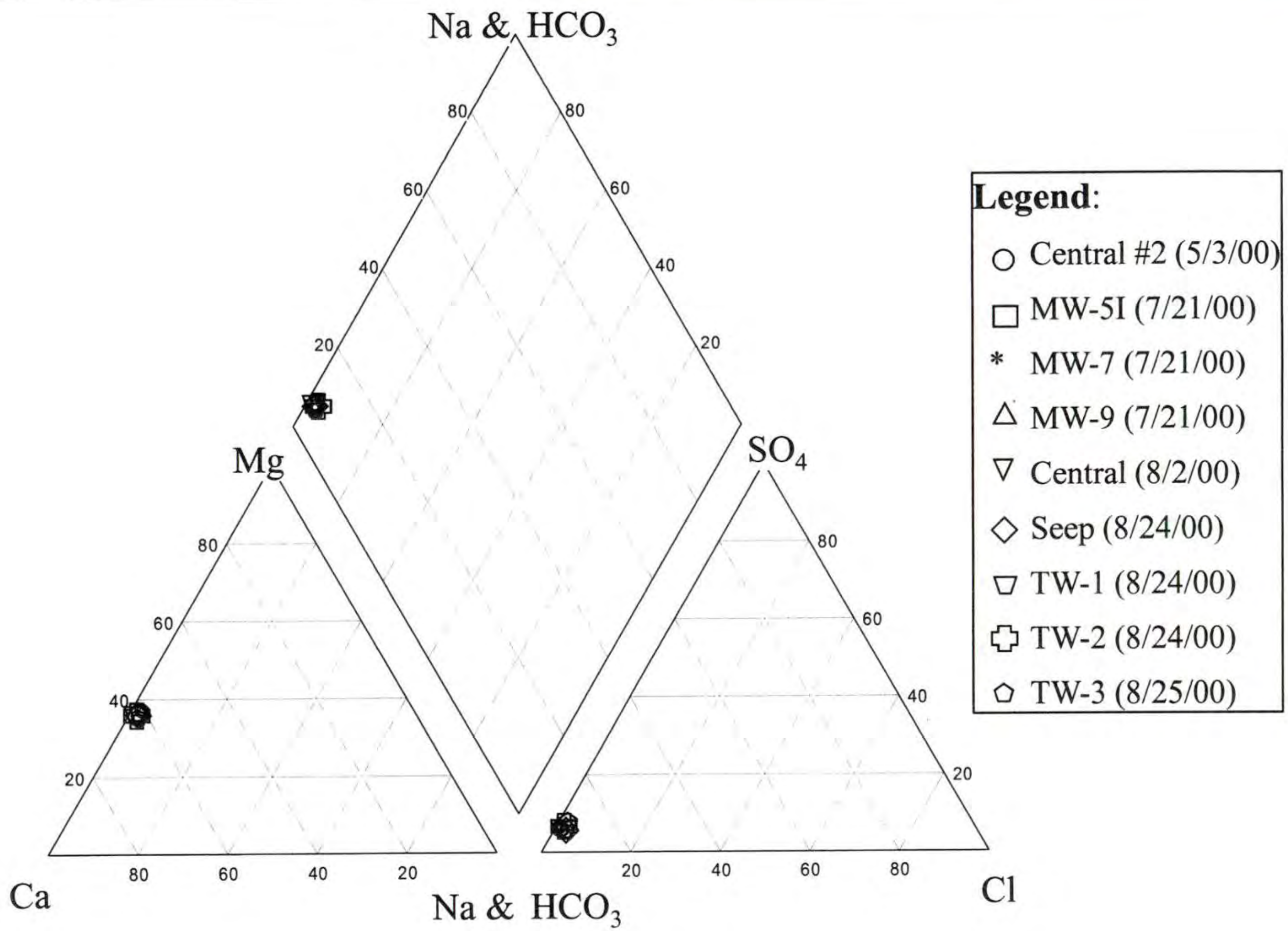
Test Well (TW-1) Distance Drawdown - Pumping 200 gpm 59 Minutes After Test Start

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 5-2

Note: The following wells not shown due to less than 0.01 ft. of drawdown at ΔT=59 min.: MW-1S, MW-1D, MW-4S, MW-9, MW-10, MW-11, MW-12I, MW-12D, Residential-1, Seep 2, Seep-5, Seep-6, Vents 1-2.



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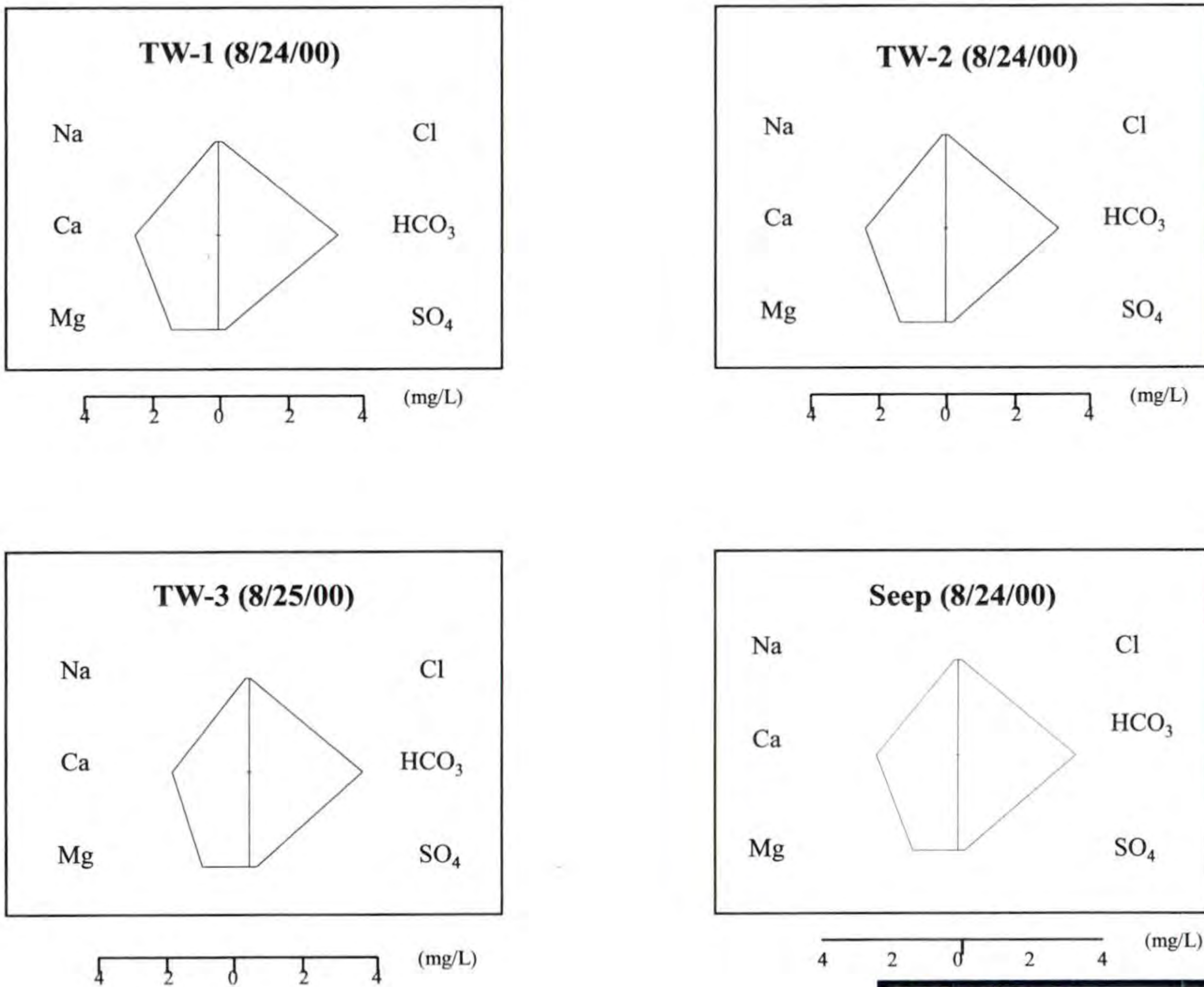
Piper Plot of Groundwater and Spring Water Ion Concentrations

Great Spring Waters of America
Spring Hill Camp Study Area

Figure 5-3



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Stiff Plots of Groundwater and Spring Water Ion Concentrations

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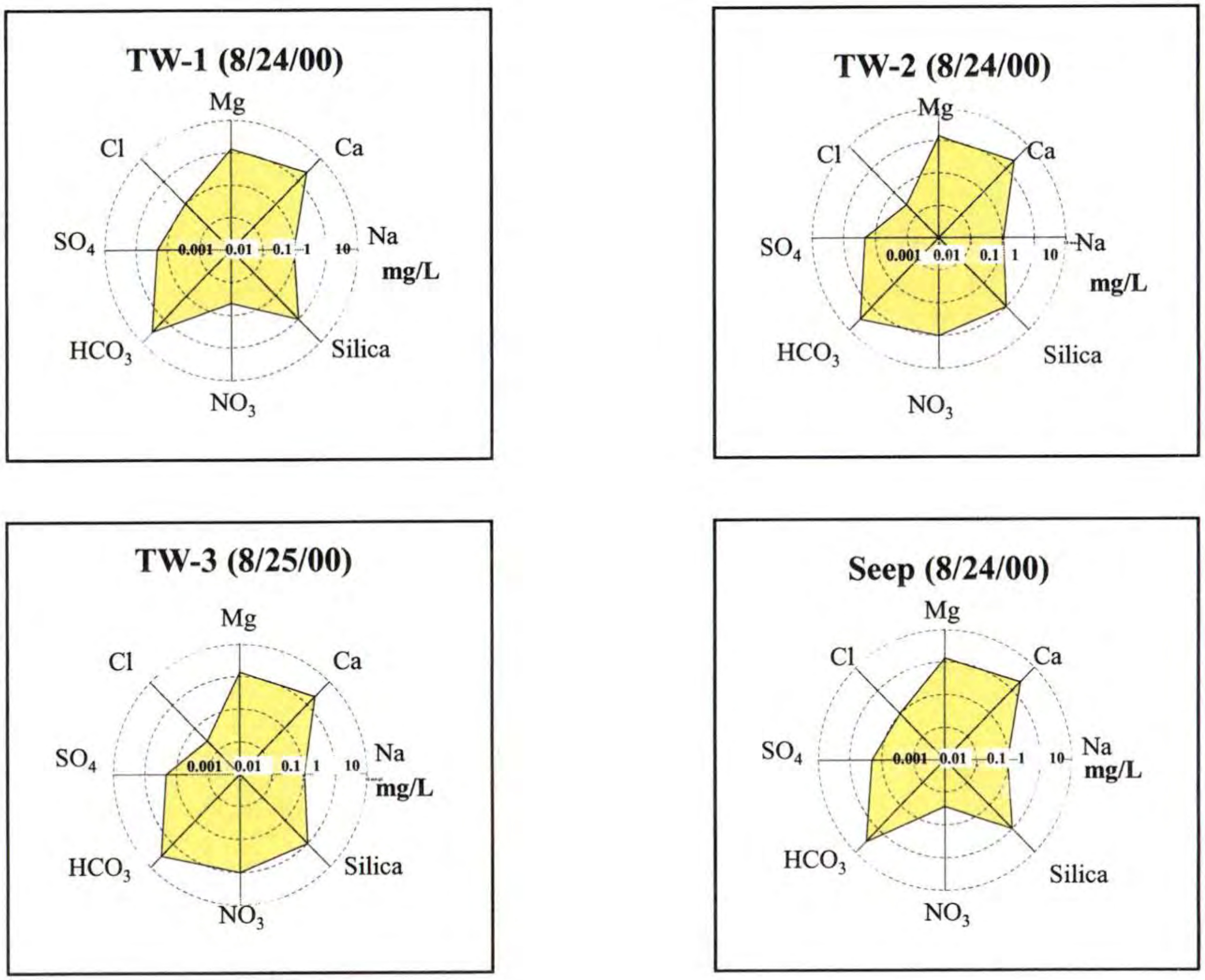
Figure 5-4



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Radial plots of Groundwater and Spring Water Ion Concentrations

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Figure 5-5

N

0 1000 2000 4000 feet

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Groundwater Recharge Area

Great Spring Waters of America
Spring Hill Camp Site

Figure 5-6