CHITTENDEN SOLID WASTE DISTRICT
Williston, Vermont

Evaluation of Bedrock Aquifer in the Vicinity of Martel Hill

November 13, 2009

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Consulting Hydrogeologists, Engineers, and Environmental Scientists

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TABLE OF CONTENTS

PAGE

APPENDICES:

Appendix 1: Figures

Figure 1: USGS Site Location Map
Figure 2: Site Location Map on Orthophoto with Ground Elevations
Figure 3: Surficial Geologic Map of Study Area
Figure 4: Bedrock Geology Map of Study Area
Figure 5: Bedrock Potentiometric Surface Map, Static Conditions, July 2009
Figure 6: Bedrock Potentiometric Surface Map, Pumping Conditions, July 2009
Figure 7: Geologic Cross Section A-A'
Figure 8: Geologic Cross Section B-B'
Subsequent Figures: Graphs of Water Levels and Temperature, Individual Wells

Appendix 2: Data & Tables

Table 1: Summary of Well Data - Study Participants
Subsequent Tables: Summary Tables of Pre- and Post-Study Water Quality Analytical Testing Results, for Individual Wells

Appendix 3: Well Data

H&N Probe Tube Installation Procedures in Drinking Water Wells
Well Completion Reports (Well Logs)
Well Owner Agreements and Questionnaires

Appendix 4: Laboratory Reports

Appendix 5: Photographic Record

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EXECUTIVE SUMMARY

1. In July 2009, Heindel & Noyes, Inc. (H&N), on behalf of the Chittenden Solid Waste District (CSWD), conducted an evaluation of the bedrock aquifer in the vicinity of Martel Hill near the existing CSWD facility in Williston, Vermont.

2. The area near the CSWD facilities and residential wells is underlain by the Cambrian-aged Cheshire Formation (Cc), a dark gray massive, fine to medium-grained quartzite.

3. Regarding surficial geology, the majority of the CSWD facilities are underlain by well-sorted, laminated fine to medium sand, while Martel Hill and nearby areas are underlain by substantial thicknesses of till.

4. Some fracture traces (linear features that may relate to bedrock fracture zones) were identified in the study area. Several moderate to weak fracture traces are noted trending north-south, and some strong fracture traces trend northwest-southeast. Most of the fracture traces were not observed to extend fully between the CSWD area and the bedrock wells on Martel Hill.

5. H&N selected 12 drilled wells in the study area to provide a variety of information regarding bedrock aquifer conditions.

6. Water level measurements were collected from the twelve wells by automatic water level measuring devices (“data-loggers”) which were placed in the wells for approximately 1 week in mid-July 2009.

7. Water quality samples were collected from each well, for laboratory analysis for typical landfill parameters.

8. The directions of groundwater flow in the bedrock aquifer beneath Martel Hill are radial in nature, with flow paths originating at or near the top of the hill and flowing radially outward in all directions. Relative to the CSWD facilities, the flow direction in the bedrock groundwater flow is toward the north, toward the CSWD facilities from Martel Hill.

9. The higher groundwater elevations in the nearby residential wells create a substantial hydraulic gradient in the bedrock aquifer from north to south (from Martel Hill toward the CSWD facilities) which will not be reversed by regular residential use of the nearby wells, or by seasonal groundwater fluctuations, or by the existing or proposed CSWD solid waste management operations.

10. The site-specific geologic conditions, leachate management procedures, and groundwater monitoring results in the vicinity of the CSWD facilities indicate that there is little likelihood of dense high-concentration landfill contaminants being released from the current or future solid waste facilities at CSWD, penetrating through the low-permeability surficial materials to the bedrock aquifer, and following fractures in the bedrock downward (but up-gradient in relation to the potentiometric surface of the bedrock aquifer) to enter the lower elevations of the nearby wells.

11. The water quality analyses of the well samples indicate no signs of any landfill-related impacts on the bedrock aquifer in the vicinity of the CSWD facilities (existing or proposed), or in the vicinity of Martel Hill (Ledgewood Drive) or Old Stage Road.

12. Based on this evaluation, it is our professional judgment that there is no likelihood that groundwater or water quality impacts from the CSWD facilities is now affecting, or will affect in the future, any nearby residential wells including those on Ledgewood Drive, Old Stage Road, or Redmond Road.

13. Several of the water samples collected in July 2009 from the residential wells and CSWD bedrock monitoring wells contained Total Coliform bacteria, although none contained fecal bacteria (*E. coli*) except for the Blankenheim well. In that well, the presence of Total Coliform and *E. coli* bacteria is a known historical condition that the well owner has been addressing through treatment devices since 2004. None of these indications of bacterial contamination are related to the CSWD facilities.

14. **Recommendation:** Based on our evaluation of the bedrock aquifer in the vicinity of the CSWD facilities and Martel Hill contained in this report, H&N does not recommend any further evaluation of the bedrock aquifer with regards to groundwater flow directions, or water quality relating to landfill impacts.

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1.0 BACKGROUND

Heindel & Noyes, Inc. (H&N), on behalf of the Chittenden Solid Waste District (CSWD), has completed an evaluation of the bedrock aquifer in the vicinity of Martel Hill near the existing CSWD facility (the "study area") in Williston, Vermont. Figures 1 and 2 in Appendix 1 show the location of the study area. The objective of this evaluation was to evaluate the bedrock aquifer and the potential interaction between the existing and proposed CSWD Solid Waste Management Facility and the neighboring bedrock water supply wells. The work described in this report was conducted in accordance with H&N's *Bedrock Aquifer Evaluation Work Plan* dated February 26, 2008. The CSWD, the Vermont Agency of Natural Resources (ANR) Solid Waste Management Program (SWMP), and the Water Supply Division (WSD) reviewed of the work plan and provided comments that were incorporated into a final work plan that was approved by all parties in April 2008. The following report summarizes the results of the bedrock aquifer evaluation.

2.0 BEDROCK AQUIFER EVALUATION PROCESS

2.1 Review of Existing Information

H&N evaluated the existing information on the geology and hydrogeology of the area, to aid in the selection of a set of bedrock wells for this study. We reviewed recently released surficial and bedrock geology data for the Town of Williston. We conducted a fracture-trace analysis to identify the presence of linear features that might represent

preferential groundwater migration paths. We also reviewed documents by others regarding studies conducted on the local bedrock geology and water quality. We also reviewed information on the drilled water wells in the ANR *Well Database*. All of this information was used to assist in selecting the appropriate list of wells to be evaluated in the study area. The following sections briefly summarize the existing geologic and hydrogeologic information.

2.1.1 Geologic Mapping Review

A. Surficial Geology: Based on our review of the *Surficial Geologic Map of the Town of Williston, Vermont* (Vermont Geological Survey Open File Report VG07-5, Plate 1; 2007; Springston & DeSimone), the majority of the CSWD facility is mapped as Quaternary Lake Sand of Fort Ann Stage (Qlsfa), which is described as well-sorted, laminated fine to medium sand. The south-southwestern portion of the facility is mapped with a narrow band of Quaternary Thick Till (Qt), described as consisting of poorly sorted "diamict" (a geologic term for poorly-sorted sediments) with abundant angular to sub-angular clasts. The remaining portion of the CSWD facility is mapped as Quaternary Washed Till (Qtw), which is described as similar to Qt, but limited to the upper hill slopes above 500 feet elevation. The surficial geology of Martel Hill is mapped as Qtw on the lower-lying regions, with the upper part of Martel Hill mapped as Quaternary Thin Till (Qtt), which is similar to Qt in description, but with a thickness of generally less than 9 feet. Figure 3 in Appendix 1 depicts the surficial geology map compiled for the study area.

B. Bedrock Geology: Based on our review of the *Bedrock Geologic Map of the Town of Williston, Vermont* (Vermont Geological Survey Open File Report VG07-7, Plate 1; 2007; Kim *et al*), the study area is underlain by the Cambrian-aged Cheshire Formation (Cc), which is described as a light to dark gray, massive, fine to medium-grained quartzite and dark gray argillaceous quartzite. The north-south trending Hinesburg/Lake Iroquois Thrust Fault is located east of the study area, marking the fault contact boundary with the Lower Cambrian to Neoproterozic-aged Pinnacle Formation (CZp). The Pinnacle Formation is described as a gray to greenish-gray quartz-plagioclase-chlorite-sericite, with lesser amounts of magnetite and pyrite phyllitic granofels, pinstriped schist and quartz-pebble conglomerate. Quartz veins and quartz–sulfide veins commonly occur parallel to the dominant foliation. A small area of the Cambrian-aged Dunham Formation (Cdu) is mapped at the south end of the study area south of Mountain View Road. Figure 4 in Appendix 1 depicts the bedrock geology map compiled for the study area.

2.1.2 Fracture Trace Analysis by H&N

As shown on the *Bedrock Geology Map* (Figure 4 in Appendix 1), eight strong fracture traces and nine moderate to weak fracture traces were identified in the study area by H&N geologists, identified by using a stereoscopic viewer with aerial photo pairs. In the study area, several moderate to weak fracture traces are noted trending north-south, and some strong fracture traces trend northwest-southeast. Most of the fracture traces were not observed to extend fully between the CSWD area and the bedrock wells on Martel Hill.

2.1.3 Other Reports

A. Davis, 2007: An Independent Study Project by a Middlebury College student (Leland Davis) conducted during the Fall Term 2007 resulted in a paper entitled "A Geochemical Analysis of Ground Water and Bedrock in Williston, Vermont: An Assessment of Potential Sources of Elevated Radionuclides in Ground Water". Our review of this paper determined that the study area evaluated in this project was located south of Route 2, which is beyond (south of) the CSWD study area. None of the data presented in the Davis 2007 study proved useful to our evaluation of the bedrock aquifer in the CSWD study area.

B. Perry North, 2005: A paper was prepared by a Middlebury College Geology Department student (Katharine Perry North, April 2005) entitled "An Evaluation of Geologic Controls on Elevated Naturally-Occurring Radioactivity in Bedrock Ground Water Wells, Northwest Vermont". For this evaluation, water samples were collected from 14 wells in the Hinesburg and St. George area, and were analyzed for radionuclides. None of the sampled wells, nor this paper's study area, are close to the CSWD study area.

C. KAS Report, 2006: On behalf of CSWD, KAS, Inc. evaluated environmental data provided by CSWD pertaining to the solid waste facilities at Redmond Road (*Landfill Data Analysis, CSWD;* KAS, Inc., May 26, 2006). This report provided general background on the hydrogeologic setting and environmental data of the study area, although none of the monitoring wells referenced in this Report were pertinent to H&N's bedrock aquifer study, since none of them are bedrock monitoring wells. We did not use any specific data from this KAS report.

D. Shaw Report, 2006: On behalf of CSWD, Shaw Environmental, Inc. conducted a hydrogeologic investigation for a new regional landfill in an existing sandpit adjacent to Redmond Rd., southwest of the existing CSWD closed landfills (*Hydrogeologic Investigation Report, Site 21 Regional Landfill*; January 2006). Pertinent to this H&N evaluation, Shaw developed maps of simulated bedrock potentiometric surfaces in the vicinity of Martel Hill and CSWD, using well-drillers' estimated static water levels in wells, and modeled simulations of various hydrogeologic scenarios. These simulations indicated that the bedrock aquifer beneath Martel Hill is significantly higher in elevation than beneath the new regional landfill, and that the bedrock groundwater beneath the new regional landfill will continue to flow AWAY from the wells on Martel Hill.

2.1.4 VDEC Private Wells Database and Locations

There are 71 listings in this State database for drilled water supply wells within the study area. The database does not list the four CSWD bedrock monitoring wells (RW-1 through RW-4). On April 22, 2008, H&N conducted a drive-by survey of the study area to check for wellheads visible from the street against locations mapped on the VDEC well database.

2.2 Bedrock Well Selection

H&N selected 12 drilled wells in the study area to provide information regarding bedrock aquifer conditions. The wells we selected are at scattered locations throughout the study area. The characteristics that we considered in this selection process were location, depth, water level (if available), driller's estimated yield, bedrock type, and location relative to a mapped fracture-trace lineament. The following table summarizes the wells selected for this study. Table 1 in Appendix 2 summarizes the well data and owners' information (per Williston Grand List).

Well Tag No.	Well Report No.	Owner	Property Address
26636	26636	Blankenheim, Robert & Gwen	893 Ledgewood Drive
31801	31801	Ferro, Joseph & Jan	1138 Ledgewood Drive
139 / 1155A	3078	Harvie, Mark & Sanita	18 Ledgewood Drive
none	31	House, Henry & Edith	1514 Old Stage Road
18370	18370	Knight, Stephen Jr. & Beverly	1586 Old Stage Road
10270	10270	Michaud, Jay & Lorna	354 Ledgewood Drive
19106	19106	Poplawski, Henry & Janice	738 Ledgewood Drive
600-A	447	CSWD Office	1021 Redmond Road
RW-1	none	CSWD Monitoring Well	Redmond Road
RW-2	none	CSWD Monitoring Well	Redmond Road
RW-3	none	CSWD Monitoring Well	Redmond Road
RW-4	none	CSWD Monitoring Well	Redmond Road

2.3 Property Access Permission

H&N contacted the selected well owners to gain permission to access their property to conduct an evaluation of their bedrock well. Access Agreement letters were submitted to each well owner with a *Well Questionnaire* requesting additional construction information on their well, water usage habits, and dwelling occupancy/size. A sketch of the well's location on the property was also requested. Each well owner was given the option to have their monitoring "probe tube" remain in the well following the study, and/or to have their well shock-chlorinated at the completion of the study. Signed agreements were received from all well owners with contact information provided. Copies of the agreements are included in Appendix 3.

2.4 Well Monitoring and Sampling Procedures

This study evaluated several components of the hydrogeologic and water quality characteristics the bedrock aquifer in the vicinity of the CSWD facility. Groundwater flow directions in the bedrock aquifer were determined by measuring and mapping its potentiometric surface ("water table elevations"), and then by drawing groundwater flow directions perpendicular to contours of equal potentiometric head. To accomplish this, water level measurements were collected from the twelve wells by automatic water level measuring devices ("data-loggers") which were placed in the wells for approximately 1 week in mid-July 2009. Water quality samples were collected from each well for laboratory analysis for typical landfill parameters.

Water quality samples were collected in two steps:

1. Prior to the installation of a probe tube in each well in which a data-logger was inserted, an initial data collection event was conducted, which included a manual measurement of the depth to water in each well with a hand-held electronic water-level probe, and sampling from each water system as close as possible to the well, for analysis for bacteria and a suite of typical landfill-related parameters;

2. After the week of water-level measurements were completed and the data-loggers and probe tubes were removed, we conducted a post-monitoring sampling round, which consisted of the collection of water samples for bacterial analysis only.

Further details regarding each step in the data collection process are provided in the following sections. Photographs of some of the wells are in Appendix 5.

2.4.1 Initial Well Sampling

On July 14 and 15, 2009, H&N scientists collected the initial water samples from the 8 wells serving buildings, and the 4 monitoring wells. The samples were collected from locations that were identified by the owners as being upstream of water treatment systems. At the wells serving buildings, water from the selected sample locations was allowed to run for approximately 20 minutes to purge the water in the pressure tank and piping, and to cause the well pump to draw in new water from the bedrock aquifer. At the end of the purging period, water samples were collected directly from the spigot into laboratory-prepared sample containers, packed on ice, and hand-delivered to Endyne, Inc. of Williston, Vermont under the appropriate Chain-of-Custody (COC) procedures. These initial groundwater samples were analyzed for Total Coliform Bacteria, *E. coli* Bacteria, volatile organic compounds (VOCs) by EPA Method 8260B, chemical oxygen demand (COD), total sodium (Na), chloride (Cl), dissolved iron (Fe^{+2}) and manganese (Mn^{+2}), and total metals analysis for arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn). Field measurements of pH, temperature, specific conductance (SC), dissolved oxygen (DO), and oxidation-reduction potential (ORP) were also obtained from each water sample at the time of sample collection. Laboratory results for each well sample are summarized in the tables in Appendix 2, and the individual lab reports are in Appendix 4.

The CSWD bedrock monitoring wells do not have permanent pumps in them, so standard sample-collection procedures were used. RW-1 and RW-2 were sampled using disposable bailers after purging several gallons of water from the wells (because the static water levels were below 30 feet). A peristaltic pump was used to purge the water in RW-3 and RW-4, following “low-flow sampling” protocols. Water samples were then collected using the pump. Field parameter measurements were obtained from these wells immediately prior to sample collection. Laboratory results for each monitoring well sample are summarized in the tables in Appendix 2, and the individual lab reports are in Appendix 4.

For Quality Control, trip blank samples were prepared by Endyne on July 10, 2009, and were transported with other samples and returned to the lab for VOC analyses on July 14, 15 and 16, 2009.

2.4.2 Probe Tube and Datalogger Installation

Immediately following the collection of the initial well samples, monitoring "probe tubes" were installed by Spafford and Sons Water Well Drilling (Vermont-licensed well-driller and pump servicer, Jericho, VT) in each well, with the exception of the CSWD bedrock monitoring wells (these are open boreholes, so no probe tubes were needed), and the House residence well (this wellhead was inaccessible due to being buried in the yard; the owner and H&N decided not to excavate the wellhead for water-level monitoring). The depth to water in each well was first manually measured using an electronic water level probe. The probe tubes were 1-inch diameter threaded Schedule 40 PVC pipe in 20-foot lengths. The depths of probe tubes and data-logger placements were chosen by H&N and Spafford personnel, depending upon the depth to water, the functional range of the datalogger to be deployed, and estimated well performance (drawdown) as suggested by the Well Completion Reports, and likely occupant use of the well during the monitoring period. Probe tube depths ranged from 40 feet (Harvie) to 300 feet (Knight). The probe tube installation process is described in detail in the *Probe Tube Installation Procedures in Drinking Water Wells*, H&N, May 13, 2009, found at the beginning of Appendix 3.

After the probe tubes were installed, H&N scientists installed Solinst® Levelogger electronic data-loggers in each well (except for the House well, as explained above) by suspending them on standard inert nylon water-sampling bailer cord. The data-loggers measure the head of the column of water above the logger at programmed time intervals (as well as water temperature) – this head can then be converted to depth below the top of the well casing (or below ground surface), and then to elevation above sea level. For this study, the data-loggers were programmed to record data at 10-minute intervals. A Solinst® Baro-logger was also suspended at a shallow depth (above the water table) in an adjacent CSWD monitoring well (FW-38) located near monitoring well RW-3, to allow corrections to be made in the data-loggers' output for changes in barometric pressure during the study period. This Baro-logger also recorded the air temperature during the study period.

2.4.3 Probe Tube and Datalogger Removal, and Post-Monitoring Samples

On July 22, 2009, (at the end of approximately week), H&N scientists returned to each study well to collect a post-monitoring water sample for bacterial analysis, and then to retrieve the data-loggers and remove the probe tubes. The purpose of the post-

monitoring bacterial samples was to determine whether the probe-tube installation and removal procedures had inadvertently introduced bacteria into any wells. We collected the water samples using the same sample collection procedures as for the initial samples. The water samples were collected in laboratory-prepared containers, packed on ice, and hand-delivered to Endyne, Inc. for analysis of Total Coliform Bacteria and *E. coli* Bacteria. Since no probe tubes had been installed in the CSWD bedrock monitoring wells, no post-monitoring bacteria samples were collected from these wells.

After the samples had been collected, H&N removed the dataloggers and Spafford removed the probe tube from each well. As part of the Access Agreements, the well owners were given the options of having the probe tubes remain or be removed, and of having their wells shock-chlorinated or not. All well owners requested to have the probe tubes removed and their wells shock-chlorinated. Accordingly, Spafford added sodium hypochlorite well-disinfectant to each well prior to closing up the wellhead and leaving the property. A *Notice of Well Chlorination* was left at each property, indicating the potential for chlorine in their well water for a few days, with instructions on how to eliminate the odor from the well water.

3.0 HYDROGEOLOGY OF BEDROCK AQUIFER; RELATIONSHIP OF MARTEL HILL WELLS TO CSWD FACILITY

3.1 Bedrock Aquifer Data

The purpose of evaluating the hydrogeology of the bedrock aquifer in the vicinity of the CSWD facility and Martel Hill region is to determine the groundwater flow patterns and directions between the CSWD facility and the surrounding bedrock water supply wells. Groundwater flow directions in this type of fractured-bedrock aquifer are determined by differences in elevation (“head”) of the bedrock water table (“potentiometric surface”) of the bedrock aquifer. Groundwater flows from areas of higher head (higher elevations of potentiometric surface) to areas of lower elevations of the potentiometric surface. At the scale of hundreds of feet (e.g., between wells on Martel Hill and the CSWD facility), the direction of groundwater flow can be delineated by drawing flow-lines which cross contours of equal elevation of the potentiometric surface at right angles (from higher potentiometric-surface elevations toward lower potentiometric-surface elevations).

Therefore, the steps we took to determine the flow directions in the bedrock aquifer in the study area were as follows:

1. Measure “static water levels” in the wells (depths to water during non-pumping periods);

2. Convert these static water levels to elevations, by determining the elevations of the wellheads, and subtracting the static water levels;

3. Prepare a map showing the static water elevations in the bedrock aquifer;

4. Draw contour lines of equal elevations of static water levels. This is a map of the potentiometric surface of the bedrock aquifer in the static (non-pumping) condition;

5. Draw groundwater flow directions, by drawing arrows crossing each contour line at right angles, and going from higher potentiometric elevations to lower elevations.

The same process can be repeated, using well data during pumping conditions to evaluate whether the normal use of the residential wells will substantially change the hydrogeologic flow regime in the bedrock aquifer.

The following sections describe these steps and their results.

3.2 Potentiometric Surface Maps and Cross-Sections

A. Wellhead Elevations: To prepare the potentiometric surface maps of the bedrock aquifer, we first used elevation data from the Chittenden County Metropolitan Organization (CCMO) 2004 High-Resolution LIDAR Digital Elevation Model (Light Detection and Ranging; DEM) to create a map of the ground surface elevations of the study area. The top-of-casing elevation of each well was then estimated to the nearest foot, by using the interpolated ground surface elevation at each well’s location. Well locations were initially estimated using coordinates obtained from a hand-held Global Positioning System unit (GPS) at each well. The well locations were then further refined on the map using the 2008 NAIP orthophoto image of the study area. A top-of-casing (TOC) elevation for each well was then estimated by adding the field-measured well casing stickup to the interpolated ground surface elevation from the DEM. The TOC elevation of the House well was only estimated, due to its buried wellhead.

B. Topographic Map of Study Area: Figure 2 in Appendix 1 is the resulting topographic map of the study area, showing the TOC elevations for each well. This DEM-generated topographic map shows Martel Hill, with ground surface elevations

sloping downward in all directions from its height. This topographic pattern is in agreement with the standard USGS topographic map of the area (Appendix 1, page 1), and with our general observations made in the field during data collection.

Martel Hill rises to approximate elevation 705 ft. ASL. Top of casing elevations of the highest wells in the Martel Hill housing development (Ledgewood Drive) are in the range of 683 ft. (Ferro; 1138 Ledgewood Drive), 681 ft. (Michaud; 354 Ledgewood Dr.) and 658 ft. (Blankenheim; 893 Ledgewood Dr.). The lowest-elevation residential wells in the study have TOC elevations of 561 ft. (Harvie; 18 Ledgewood Dr., on the south side of Martel Hill, opposite from CSWD), approx. 575 ft. (House, buried wellhead, estimated elevation, at 1514 Old Stage Rd.), and 589 ft. (Knight; 1586 Old Stage Rd.).

The ground surface and top-of-casing elevations at ALL of these private residential wells are higher than the elevations at the CSWD wells, which range from 391 ft. at RW-3 to 510 ft. at RW-4. Further north of the CSWD facility, the Winooski River is at approximate elevation 270 ft.

C. Maps of Bedrock Aquifer Potentiometric Surface: To create the potentiometric surface map, the static (non-pumping) depth to water measured in each well during the week-long monitoring period was determined using the datalogger-derived graphs of water depths below casing over time (Figures 9 to end, in Appendix 1). The static water table depths were subtracted from the TOC elevations calculated above to provide a potentiometric surface elevation for the bedrock aquifer at each well location. The resulting potentiometric elevations were contoured to produce a map of the static potentiometric surface of the bedrock aquifer. Estimated groundwater flow directions are included on this map, by drawing flow-lines which cross the potentiometric contour lines at right angles (see Figure 5 in Appendix 1).

D. Bedrock Aquifer under Pumping Conditions: Water levels were measured during pumping conditions in each well, by the data-loggers. These water levels were converted to elevations (as above, for static conditions), and a potentiometric surface map was developed for the bedrock aquifer under maximum pumping conditions for the monitoring period in mid-July 2009 (see Figure 6 in Appendix 1). Pumping “drawdowns” below static levels (the decline in the water level in a well below its static water level, caused by pumping use of that well) were less than 100 feet, and generally ranged from 4 ft. to 72 feet. None of these pumping water levels brought the bedrock potentiometric surface in any of the wells to an elevation lower than the potentiometric surface beneath the CSWD facility.

E. Groundwater Flow Directions in the Bedrock Aquifer: The resulting maps of the potentiometric surface in the bedrock aquifer show an area of substantially higher groundwater elevations beneath Martel Hill, with a radial pattern of groundwater flowing in all directions away from the highest elevation on Martel Hill. From these maps, it is clear that the bedrock groundwater flows FROM Martel Hill toward the CWSD facilities, and presumably beyond toward the Winooski River. The elevation of bedrock groundwater beneath Martel Hill is in the range of 650 to 670 ft. At the CSWD facilities, the bedrock groundwater is 200 to 300 feet lower in elevation (ranging from 490 ft. at RW-4 down to 359 ft. at RW-3). The bedrock groundwater is also lower in elevation to the east of Martel Hill, along Old Stage Rd. (521 ft. at the Knight well), and we presume it is also lower to the west along Redmond Rd., although there were no wells here to monitor. This pattern of groundwater flow is in agreement with the conceptualized flow model developed by Shaw Environmental as part of their CSWD Site 21 Regional Landfill study in 2006.

Under maximum pumping conditions that were measured in the study wells in mid-July 2009, the potentiometric surface of the bedrock aquifer was in all locations, and at all times, higher beneath Martel Hill and the surround region than beneath the CSWD facilities. That is, the July 2009 pumping measurements indicated that the bedrock aquifer was always flowing from Martel Hill toward CWSD – the flow direction in the bedrock groundwater never reversed.

3.3 Cross Sections

To illustrate the relationships between the ground surface, bedrock surface, bedrock aquifer potentiometric levels (static and pumping), and groundwater flow patterns in the study area, cross sections were prepared to visually show these elements (see pages 7 and 8 in Appendix 1). The lines of cross-section are shown on the Site Location Map in Appendix 1 (p. 2). Cross-section A-A' is south to north through Martel Hill and the CSWD facilities to the Winooski River. Cross-section B-B' is roughly east-west, through Martel Hill from Redmond Rd. to Old Stage Rd. These cross-sections indicate the same hydrogeologic regime as described by the potentiometric maps: that the groundwater in the bedrock beneath Martel Hill flows radially away from the high point of the hill in all directions, and that the bedrock groundwater beneath the CSWD facilities flows northward, away from the neighboring water wells.

3.4 Significance of Well Depths: It is important to note that the depth to the bottom of a drilled well has little significance to the direction of groundwater flow in the aquifer in which it is drilled. Although a drilled well's bottom may be quite deep, the flow

direction of the bedrock groundwater is generally controlled by the elevation at that well of the potentiometric surface in the bedrock aquifer, not the depth of the well's bottom (with one exception that does not likely apply to the CSWD situation, as explained below).

Well depths of the evaluated wells range from 47 feet (Harvie, a sand-and-gravel well, not a bedrock well) to 740 feet (Poplawski), with most of the wells in the range of 300 to 500 feet in depth. Elevations of well bottoms are generally in the range of 119 ft. below sea level to 300 feet above sea level (except for the relatively shallow wells of Harvie and House), which are lower (deeper) than the ground surface at CSWD, or the estimated bottom elevations of the existing closed landfills at CSWD (approx. 360 ft. MSL), or the proposed bottom elevation of the liner system of the new CSWD regional landfill (approx. 370 ft. MSL). However, none of the neighboring wells are down-gradient or within the groundwater flowpath from the existing or proposed CSWD facilities, because the well bottom elevations generally do not control groundwater flow directions. Rather, the potentiometric heads in the bedrock aquifer are generally what controls groundwater flow directions, and these directions are FROM the neighboring wells TOWARD the CSWD facilities, not the reverse.

The exception to the groundwater-flow scenario described above and in Sections 3.2 and 3.3 is the theoretical possibility of what can appear to be an UP-gradient flow in the bedrock aquifer of those groundwater components that are significantly denser than the main body of groundwater. At some highly-contaminated sites, such as at sites with high concentrations of denser-than-water organic compounds or dissolved metals, those dense components of the contaminant plume are known to migrate to the lowest elevations of an aquifer, regardless of where this direction is in relation to the slope of the potentiometric surface of the aquifer. For example, high dissolved concentrations or the pure-product form (called DNAPL, or Dense Non-Aqueous Phase Liquids) of dense organic compounds such as perchlorethylene (and/or its decay daughters) can follow the descending "steps" of bedrock fractures in a direction that appears to be "up-gradient" in relation to the potentiometric surface of the bedrock aquifer.

This phenomenon is relatively rare although not unheard of. It is quite unlikely to occur at the CSWD facilities because of the following site-specific factors:

1. Regarding current potential impacts from the closed unlined landfills (Phases I and II), the areas on which these landfills were originally constructed are likely to be underlain by a thick continuous sequence of low-permeability silts and clays, which

would tend to reduce the likelihood of high concentrations of dense dissolved parameters or DNAPL penetrating through to the underlying bedrock aquifer;

2. Further regarding the closed unlined Phase I and II landfills, given the surficial geology and glacial-lake history of this specific area, the top of this silt-clay layer is likely to slope away from the nearby water wells, toward the northwest, north and northeast. Any plumes of high concentrations of dense dissolved parameters or DNAPL are likely to remain in the overlying sands and follow the sloping silt-clay layer away from the nearby wells, rather than penetrating through to the underlying bedrock aquifer;
3. Further regarding the closed unlined Phase I and II landfills, the on-going twice-yearly groundwater monitoring that has taken place for years in their immediate vicinity gives no indications of a high-concentration plume of landfill leachate emanating from these areas;
4. The closed Phase III landfill (double-lined) has a primary and secondary leachate collection system, and H&N also conducts periodic testing of the soil-gas vapors in the interstitial space between the liners. Nothing in the leachate sampling or soil-gas vapor testing results suggests the release of a high-concentration plume of landfill leachate emanating from Phase III;
5. The Phase III leachate-collection system allows the frequent pumping and removal of leachate from the Phase III liners, so it is very unlikely that a significant release of leachate could occur from the Phase III landfill;
6. The proposed new regional landfill is located in an area underlain by thick and laterally extensive silt-clays, so the site-specific geologic factors described above will also apply to the new landfill;
7. In addition, the new landfill will presumably be constructed with a double-liner system with periodic collection, removal and monitoring of any liquid appearing between the two liners;
8. In the July 2009 water quality sampling of the bedrock wells at the CSWD facilities (CSWD Office Well, and four bedrock aquifer monitoring wells), and the 7 private wells in the study area, no volatile organic compounds (VOCs) were detected. Some of the VOCs that were analyzed are denser than water (such as perchlorethylene and its decay daughters, and other chlorinated solvents), and would be detected in these wells if they occurred in high enough concentrations to induce gravity flow in directions not related to the potentiometric surface of the bedrock aquifer. The fact that no VOCs were detected in any of these wells, including the CSWD wells, suggests that this rare phenomenon of gravity-induced flow of dense parameters is not occurring from the CSWD facilities.

For all of these reasons, it is very unlikely that the bedrock aquifer beneath the CSWD Williston facilities, and Martel Hill and its vicinity, is being impacted or will be impacted by denser-than-water components of landfill parameters from the CSWD facilities.

3.5 Summary of Hydrogeology of Bedrock Aquifer, and Relationship of Martel Hill Wells to CSWD Facility

Based on the potentiometric elevations of the bedrock aquifer beneath the study area, the static water table surface beneath Martel Hill is 150 to 200 feet higher than the bedrock groundwater elevations beneath the CSWD facilities. The groundwater flow directions in the bedrock aquifer beneath Martel Hill are radial. That is, groundwater in the bedrock aquifer flows in all directions away from the area of highest elevation on the hill. To the north of Martel Hill in the direction of CSWD, the bedrock aquifer slopes to the north away from the hill toward the Winooski River. The Winooski River is likely to be the regional discharge zone for the bedrock aquifer in this area. During both static groundwater flow conditions and maximum pumping conditions, the groundwater in the bedrock aquifer beneath Martel Hill flowed away from its higher elevations, radially in all directions, and with sufficient slope to the potentiometric surface to prevent the flow of groundwater “back” toward the wells on the hill, or nearby areas, from regions beneath the CSWD existing or proposed solid waste management facilities.

Relative to the CSWD facilities, the flow direction in the bedrock groundwater flow is toward the north, <u>toward</u> the CSWD facilities from Martel Hill. This is the case both under static non-pumping conditions, and under the maximum pumping conditions recorded in the monitored wells throughout the study period. At all times during the study period, groundwater elevations at the nearby residential wells evaluated were always substantially higher than groundwater elevations in the monitoring wells at or near the CSWD existing and proposed facilities. These higher groundwater elevations in the nearby residential wells create a substantial hydraulic gradient in the bedrock aquifer from north to south (from Martel Hill toward the CSWD facilities) which will not be reversed by regular residential use of the nearby wells, or by seasonal groundwater fluctuations, or by the existing or proposed CSWD solid waste management operations.

The site-specific geologic conditions, leachate management procedures, and groundwater monitoring results in the vicinity of the CSWD facilities indicate that there is little likelihood of dense high-concentration landfill contaminants being released from the current or future solid waste facilities at CSWD, penetrating through the low-permeability surficial materials to the bedrock aquifer, and following fractures in the

bedrock downward (but up-gradient in relation to the potentiometric surface of the bedrock aquifer) to enter the lower elevations of the nearby wells.

Based on this information, it is our professional judgment that there is no likelihood that groundwater or water quality impacts from the CSWD facilities is now affecting, or will affect in the future, any nearby residential wells including those on Ledgewood Drive, Old Stage Road, or Redmond Road.

4.0 WATER QUALITY SAMPLING RESULTS

This section summarizes the water quality sampling results for each well that was included in this evaluation. Where applicable, we compare these results to drinking water and/or groundwater standards (VGES; Vermont Groundwater Enforcement Standards).

4.1 Blankenheim Well (Well Tag #26636)

The Blankenheim bedrock well is located at 893 Ledgewood Drive in the Martel Hill subdivision, at a distance of about 4,200 feet from the existing closed CSWD landfills, and about 2,000 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Blankenheim well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Blankenheim Well Data:	
Well Depth (feet below grade / elevation, MSL)	320 / 336
Ground Elevation at Well (feet MSL)	656
Stick-up / Top of Well Casing Elevation (feet MSL)	1.7 / 658
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	18 / 640
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	22 / 618
Total Coliform Bacteria (pre / post), MPN/100mls	None / 21
E. *coli* Bacteria (pre / post), MPN/100mls	None / 2
Volatile Organic Compounds, µg/L	None in post-treatment sample
Elevated Metals or Inorganics, mg/L	Sodium, Chloride (not landfill related)

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing; MPN/100mls = Most Probable Number per 100 milli-liters.

The initial sample from this well on July 14, 2009 was collected from an external hose spigot, because the homeowner did not initially indicate that they had water treatment systems (a water softener, and ultra-violet disinfection). This initial sample showed

elevated chloride and sodium concentrations that reflect impacts from the ion-exchanging softener. The post-monitoring sample on July 22, 2009 was also collected from the same external hose spigot. When H&N subsequently learned from the well-owner that they had a water softener, we collected a third water sample on August 14, 2009 from a spigot located at the pressure tank upstream of the water softener, in order to evaluate the raw well water.

Bacteria: Neither Total Coliform bacteria nor *E. coli* bacteria were detected in the pre-monitoring sample on 7/14/2009. However, Total Coliform bacteria were detected at 4.0 MPN/100mls in the 7/22/09 post-monitoring sample collected downstream of the softener, and at 21 MPN/100mls in the second post-sample collected downstream of the softener on 8/14/09. The post-monitoring sample collected on 8/14/09 upstream of the softener also detected the presence of E. *coli* bacteria (fecal bacteria) at 2 MPN/100mls. The presence of bacteria in this well was reported by the well-owner as being known to them ever since shortly after the well was drilled, in 2004. This is the apparent reason for the ultra-violet disinfection system that the well-owner indicates that they have on this water system. The source of these bacteria could not be the CSWD facilities because they are far down-gradient of this well, and a long distance away. A possible source of these bacteria could be surface and/or shallow groundwater carrying waste matter from pets or wild animals, since there are bedrock outcrops in the vicinity of the well. Another possible source could be a leaking wastewater disposal pipe (it is our understanding that the wastewater from the Blankenheim residence is piped to a community wastewater disposal field located about 3,500 feet north of, and far downhill from the Blankenheim parcel).

Metals and Inorganics: In the post-monitoring sample that we collected on 8/14/09 upstream of the softener, none of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts. Sodium was detected at 130 mg/l (which is below the VGES of 250 mg/L, but is elevated above what we would expect for non-impacted water), and Chloride was detected at 270 mg/L (which is above the VGES of 250 mg/L, and is also elevated above what we expect for non-impacted water). These elevated sodium and chloride levels could be coming from the backwash of the water softener, if that backwash is discharged on the Blankenheim property, or they could be coming from road salt applications on Ledgewood Drive, which is a steep road with numerous nearby bedrock outcrops.

VOCs: In the analysis of volatile organic compounds (VOCs) in the 7/14/09 pre-monitoring sample (post-softener), one VOC was detected: Acetone, at 19.1 ug/L (micro-grams per liter, or parts per million). However, this chemical was not detected in

the 8/14/09 sample that we collected upstream of the treatment systems. Acetone is a common constituent of household chemicals and cleaning products, and also commercial and industrial solvents. Its Vermont drinking water standard (and VGES) is 700 ug/L, so this detection was far below that standard. The source of acetone in the 7/14/09 pre-monitoring sample might have been some of the components of the two treatment systems on this water system.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from 18 feet BTOC to 40 feet BTOC (elevations 640 ft. to 618 ft. MSL). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding Blankenheim Well: The groundwater analytical results from the Blankenheim well do not suggest any impacts from landfill-related activities. Possible impacts were noticed from the water softener, and/or shallow-to-bedrock conditions near the well, and/or road salt applications on Ledgewood Drive.

4.2 Ferro Well (Well Tag #31801)

The Ferro bedrock well is located at 1138 Ledgewood Drive in the Martel Hill subdivision, at a distance of about 4,800 feet from the existing closed CSWD landfills, and about 2,500 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Ferro well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Ferro Well Data:	
Well Depth (feet below grade / elevation, MSL)	420 / 262
Ground Elevation at Well (feet MSL)	682
Stick-up / Top of Well Casing Elevation (feet MSL)	0.7 / 683
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	24 / 659
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	16 / 643
Total Coliform Bacteria (pre / post), MPN/100mls	27 / 110
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	None

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing; MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: The presence of Total Coliform bacteria was detected at 27 MPN/100mls in the pre-monitoring sample, and 110 MPN/100mls in the post-monitoring sample. No *E.*

coli bacteria were detected (fecal bacteria), so the presence of Total Coliform bacteria does not appear to indicate animal or human wastes. Coliform bacteria in a well could be due to a loose or cracked well cap, incompletely sealed well casing, changes in the water table or other hydrogeologic effects. The source of these bacteria could not be the CSWD facilities because they are far down-gradient of this well, and a long distance away. It may be appropriate for the well-owner to consider re-sampling this well, or shock-chlorinating it and then re-sampling, or having it inspected by a Vermont-licensed well driller.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts.

VOCs: No volatile organic compounds (VOCs) were detected in the Ferro well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 24 feet BTOC to a maximum of about 40 feet BTOC (elevations 659 feet MSL to 643 feet MSL). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding Ferro Well: The groundwater analytical results from the Ferro well do not suggest impacts from any landfill-related activities.

4.3 Harvie Well (Well Tag #139 / 1155A)

The Harvie well (a drilled gravel well) is located at 18 Ledgewood Drive at the southern (“bottom”) edge of the Martel Hill subdivision, at a distance of about 6,800 feet from the existing closed CSWD landfills, and about 4,700 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Harvie well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Harvie Well Data:	
Well Depth (feet below grade / elevation, MSL)	47 / 512
Ground Elevation at Well (feet MSL)	559
Stick-up / Top of Well Casing Elevation (feet MSL)	2.2 / 561
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	1.6 / 559
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	4.2 / 555
Total Coliform Bacteria (pre / post), MPN/100mls	None / >200
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	None

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters (> 200 = more than 200).

Bacteria: No Total Coliform bacteria were detected in the pre-monitoring sample, but they were detected in the post-monitoring sample at more than 200 MPN/100mls. No *E. coli* bacteria were detected in either sample. H&N noticed that the cap on this well was not secured properly, and several bolts were missing. Also, the condition of the cap and well casing suggested that the water level is consistently slightly above grade. This can cause the well to be more susceptible to contaminants. H&N requested that Spafford install a new well cap on this well to improve the seal at the wellhead.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts.

VOCs: No volatile organic compounds (VOCs) were detected in the Ferro well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 1.6 feet BTOC to a maximum of about 5.8 feet BTOC (elevations 559 feet MSL to 555 feet MSL). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 50° F.

Conclusions regarding Harvie Well: The groundwater analytical results from the Harvie well do not suggest impacts from any landfill-related activities. H&N noticed that the cap on this well was not secured properly, and several bolts were missing. Also, the condition of the cap and well casing suggested that the water level is consistently slightly above grade. This can cause the well to be more susceptible to contaminants. H&N requested that Spafford install a new well cap on this well to improve the seal at the wellhead.

4.4 House Well (Well Completion Report #31; no Well Tag)

The House bedrock well is located at 1514 Old Stage Road, east of Martel Hill at a distance of about 5,000 feet from the existing closed CSWD landfills, and about 4,100 feet from the new regional landfill. The following table summarizes the well details and sampling results for the House well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. Water levels and temperatures could not be measured in this well because the wellhead is sealed and buried in the yard, and the well-owner and H&N decided not to dig it up. Therefore, no data-logger or probe tube was installed in the House well, and only one round of water samples was collected (on 7/14/09).

House Well Data:	
Well Depth (feet below grade / elevation, MSL)	90 / 488
Ground Elevation at Well (feet MSL)	578
Stick-up / Top of Well Casing Elevation (feet MSL)	Not Measured
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	Not Measured
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	Not Measured
Total Coliform Bacteria (pre / post), MPN/100mls	>200 / Not Measured
E. *coli* Bacteria (pre / post), MPN/100mls	None / Not Measured
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	None

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters (> 200 = more than 200).

Bacteria: Total Coliform bacteria were detected at more than 200 MPN/100mls in the only sample collected from this well (on 7/14/09; no "post-monitoring" sample was collected on 7/22/09 because this well did not have its water levels measured, as explained above). The source of these bacteria could not be the CSWD facilities because they are far down-gradient of this well, and a long distance away. No *E. coli* bacteria were detected, so it does not appear that the bacteria detected were from human or animal wastes.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts. The sodium and chloride concentrations (9.3 mg/L and 32 mg/L, respectively) are well below their VGES of 250 mg/L, but are slightly elevated above normal non-impacted groundwater, which may be due to road salt impacts.

VOCs: No volatile organic compounds (VOCs) were detected in the Harvie well.

Groundwater Depths: The depths to groundwater in this well were not measured, as explained above.

Conclusions regarding House Well: The groundwater analytical results from the House well do not suggest impacts from any landfill-related activities.

4.5 Knight Well (Well Tag #18370)

The Knight well is located at 1586 Old Stage Road, east of Martel Hill at a distance of about 4,500 feet from the existing closed CSWD landfills, and about 3,700 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Knight well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Knight Well Data:	
Well Depth (feet below grade / elevation, MSL)	605 / -17
Ground Elevation at Well (feet MSL)	588
Stick-up / Top of Well Casing Elevation (feet MSL)	0.5 / 589
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	68 / 521
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	72 / 449
Total Coliform Bacteria (pre / post), MPN/100mls	1.0 / none
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	Sodium, Chloride slightly elevated (not landfill related)

MMSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: The presence of Total Coliform bacteria was just barely detected at 1.0 MPN/100mls in the pre-monitoring sample, but was not detected in the post-monitoring sample. Neither pre- nor post-monitoring samples showed the presence of *E.coli* bacteria.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts. The sodium and chloride concentrations (26 mg/L and 44 mg/L, respectively) are well below their VGES of 250 mg/L, but are slightly elevated above normal non-impacted groundwater, which may be due to road salt impacts. Total arsenic, copper, and lead were detected at 0.003, 0.041 mg/L, and 0.004 mg/L, respectively (all below their VGESs). These parameters at these low levels of detection are not uncommon in bedrock wells in Vermont, due to naturally-occurring metals in the metamorphic bedrock.

VOCs: No volatile organic compounds (VOCs) were detected in the Knight well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 68 feet BTOC to a maximum of about 140 feet BTOC (elevations 521 feet MSL to 449 feet MSL). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding Knight Well: The groundwater analytical results from the Knight well do not suggest impacts from any landfill-related activities.

4.6 Michaud Well (Well Tag #10270)

The Michaud bedrock well is located at 354 Ledgewood Drive in the Martel Hill subdivision, at a distance of about 5,200 feet from the existing closed CSWD landfills, and about 3,100 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Michaud well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Michaud Well Data:	
Well Depth (feet below grade / elevation, MSL)	450 / 229
Ground Elevation at Well (feet MSL)	679
Stick-up / Top of Well Casing Elevation (feet MSL)	2.3 / 681
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	10.7 / 670
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	19 / 662
Total Coliform Bacteria (pre / post), MPN/100mls	none / none
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	COD, Sodium, Chloride, Iron, Lead, Manganese (not landfill related)

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Neither Total Coliform bacteria nor *E. coli* Bacteria were detected in the pre-monitoring or post-monitoring samples.

Metals and Inorganics: Sodium and chloride were detected at 69 mg/l and 170 mg/L, respectively (below their VGESs of 250 mg/L), which suggest either impacts from an ion-exchange water-softener, or road-salt impacts. Iron, Lead and Manganese exceed their VGESs. COD was also detected at 88 mg/L. The elevated concentrations of these metals, and COD, are likely to either be from the local bedrock mineralogy (natural causes), or from a mixture of bedrock and well-casing issues. H&N observed a thick

iron coating/film on the manual water level indicator we used to measure the water level prior to probe tube installation. An iron accumulation was also noted on the probe tube after it was removed (it had been in the well for only about 7 days). H&N also observed three water treatment devices in the basement of this home (sediment filtration, resin filtration, and softening). It is apparent that the water from the Michaud well is high in metals and hardness minerals. None of these impacts are related to landfill activities, since this well is so much higher in elevation than the CSWD facilities, and since groundwater does not flow from the CSWD facility toward the Michaud well.

VOCs: No volatile organic compounds (VOCs) were detected in the Michaud well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 11 feet BTOC to a maximum of 19 feet BTOC (elevations 670 feet MSL to 662 feet MSL). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 50° F.

Conclusions regarding Michaud Well: The groundwater analytical results from the Michaud well do not suggest impacts from any landfill-related activities. It is apparent that the water from the Michaud well is high in metals and hardness minerals.

4.7 Poplawski Well (Well Completion Report #19106)

The Poplawski bedrock well is located at 638 Ledgewood Drive in the Martel Hill subdivision, at a distance of about 3,300 feet from the existing closed CSWD landfills, and about 1,600 feet from the new regional landfill. The following table summarizes the well details and sampling results for the Poplawksi well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

Poplawksi Well Data:	
Well Depth (feet below grade / elevation, MSL)	740 / - 119
Ground Elevation at Well (feet MSL)	621
Stick-up / Top of Well Casing Elevation (feet MSL)	0.6 / 622
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	38 / 584
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	> 52 / < 532
Total Coliform Bacteria (pre / post), MPN/100mls	2.0 / 32
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	None

MSL = Elevation above Mean Sea Level (< = lower than elevation shown);

BTOC = Depth Below Top of Casing (> = greater than depth shown); MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 2.0 MPN/100mls in the pre-monitoring sample, and 32.0 MPN/100mls in the post-monitoring sample. However, no *E. coli* bacteria were detected in either sample so it does not appear that the bacteria detected were from human or animal wastes. The source of these bacteria could not be the CSWD facilities because they are far down-gradient of this well, and a long distance away.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts.

VOCs: No volatile organic compounds (VOCs) were detected in the Poplawski well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 38 feet BTOC to a maximum of greater than 90 feet BTOC (elevations 584 feet MSL to lower than 532 feet MSL; maximum drawdown exceeded the depth of the data-logger, so it could not be measured). These water levels were far above the elevations of the CSWD existing or proposed facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding Poplawski Well: The groundwater analytical results from the Poplawksi well do not suggest impacts from any landfill-related activities.

CSWD Wells: Five CSWD wells were also monitored: the office well, and four bedrock monitoring wells. The results of their sampling and monitoring are described below.

4.8 CSWD Office Well (Well Tag #600-A)

The CSWD Office bedrock well is located at 1021 Redmond Rd., at a distance of about 2,500 feet from the existing closed CSWD landfills, and about 650 feet from the new regional landfill. The following table summarizes the well details and sampling results for the CSWD Office well. Detailed water quality results are summarized in Appendix 2, and the lab reports are in Appendix 4. A graph of the water levels and temperatures in this well during the study period is in Appendix 1.

CSWD Office Well Data:	
Well Depth (feet below grade / elevation, MSL)	375 / 31
Ground Elevation at Well (feet MSL)	406
Stick-up / Top of Well Casing Elevation (feet MSL)	1.2 / 407
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	40 / 367
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	56 / 311
Total Coliform Bacteria (pre / post), MPN/100mls	3 / 1
E. *coli* Bacteria (pre / post), MPN/100mls	none / none
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	None

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 3 MPN/100mls in the pre-monitoring sample, and 1 MPN/100mls in the post-monitoring sample. No *E. coli* bacteria were detected, so it does not appear that the bacteria detected were from human or animal wastes. Coliform bacteria in a well could be due to a loose or cracked well cap, incompletely sealed well casing, changes in the water table or other hydrogeologic effects. The source of these bacteria is not likely to be the CSWD facilities because Coliform bacteria are not a common constituent of landfill leachate. It may be appropriate for CSWD to consider re-sampling this well, or shock-chlorinating it and then re-sampling, or having it inspected by a Vermont-licensed well driller.

Metals and Inorganics: None of the lab results for total metals exceed the VGES, nor did they indicate any signs of landfill impacts.

VOCs: No volatile organic compounds (VOCs) were detected in the CSWD Office well.

Groundwater Depths: The depth to groundwater in this well fluctuated during use, from about 40 feet BTOC to 96 feet BTOC (elevations 367 feet MSL to 311 feet MSL). These water levels are somewhat lower than the bases of the existing and proposed CSWD facilities. The temperature of the water in this well was consistent at 48 - 49° F.

Conclusions regarding CSWD Office Well: The groundwater analytical results from the CSWD Office well do not suggest impacts from any landfill-related activities.

4.9 CSWD Bedrock Monitoring Well RW-1

This bedrock monitoring well is located at the southwestern perimeter of the sand and gravel pit off Redmond Road southwest of the existing CSWD landfill facility. The following table summarizes the monitoring and sampling results for this well. Table 2 in Appendix 2 summarizes the analytical results of the groundwater samples collected

from this well. A graph of the water levels and temperature changes in this well during the study period is included in Appendix 1.

RW-1 Well Data:	
Well Depth (feet below grade / elevation, MSL)	300 / 131
Ground Elevation at Well (feet MSL)	431
Stick-up / Top of Well Casing Elevation (feet MSL)	0.7 / 432
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	45 / 387
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	0 / 387
Total Coliform Bacteria (pre / post), MPN/100mls	10 / Not Sampled
E. *coli* Bacteria (pre / post), MPN/100mls	none / Not Sampled
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	Total Iron, Total Manganese

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 10 MPN/100mls in the pre-monitoring sample. No *E. coli* bacteria were detected. A post-monitoring sample was not analyzed because no probe tube was installed in this well.

Metals and Inorganics: The Total Iron concentration of 22 mg/L far exceeds the VGES of 0.30 mg/L, and the Total Manganese concentration (0.310 mg/L) slightly exceeds the primary VGES of 0.300 mg/L. The dissolved forms of these two metals were non-detected, indicating that the high total concentrations were likely due to particulate matter from the well casing, well sediment or bedrock, and not from direct groundwater impacts.

VOCs: No volatile organic compounds (VOCs) were detected in RW-1.

Groundwater Depths: The depth to groundwater in this well remained stable at about 45 feet BTOC (elevation 387 feet MSL). This elevation is somewhat higher than the base elevations of the CSWD facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding CSWD Monitoring Well RW-1: The groundwater analytical results from RW-1 do not suggest impacts from any landfill-related activities.

4.10 CSWD Bedrock Monitoring Well RW-2

This bedrock monitoring well is located at the southeastern perimeter of the sand and gravel pit off Redmond Road southwest of the existing CSWD landfill facility. The following table summarizes the monitoring and sampling results for this well. Table 2 in Appendix 2 summarizes the analytical results of the groundwater samples collected

from this well. A graph of the water levels and temperature changes in this well during the study period is included in Appendix 1.

RW-2 Well Data:	
Well Depth (feet below grade / elevation, MSL)	345 / 135
Ground Elevation at Well (feet MSL)	480
Stick-up / Top of Well Casing Elevation (feet MSL)	1.0 / 481
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	69 / 412
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	0 / 412
Total Coliform Bacteria (pre / post), MPN/100mls	10 / Not Sampled
E. *coli* Bacteria (pre / post), MPN/100mls	none / Not Sampled
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	Total Iron, Total Manganese

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 10 MPN/100mls in the pre-monitoring sample. No *E. coli* bacteria were detected. A post-monitoring sample was not analyzed because no probe tube was installed in this well.

Metals and Inorganics: The Total Iron concentration of 170 mg/L far exceeds the VGES of 0.30 mg/L, and the Total Manganese concentration (0.97 mg/L) exceeds the primary VGES of 0.300 mg/L. The dissolved forms of these two metals were non-detected (Mn) or detected at a very low concentration (Fe at 0.036 mg/L), indicating that the high total concentrations were likely due to particulate matter from the well casing, well sediment or bedrock, and not from direct groundwater impacts.

VOCs: No volatile organic compounds (VOCs) were detected in RW-2.

Groundwater Depths: The depth to groundwater in this well remained stable at about 69 feet BTOC (elevation 412 feet MSL). This elevation is higher than the base elevations of the CSWD facilities. The temperature of the water in this well was consistent at 47° F.

Conclusions regarding CSWD Monitoring Well RW-2: The groundwater analytical results from RW-2 do not suggest impacts from any landfill-related activities.

4.11 CSWD Bedrock Monitoring Well RW-3

This bedrock aquifer monitoring well is located at the northwestern perimeter of the sand and gravel pit property along the edge of Redmond Road southwest of the existing

CSWD landfill facility. The following table summarizes the monitoring and sampling results for this well. Table 2 in Appendix 2 summarizes the analytical results of the groundwater samples collected from this well. A graph of the water levels and temperature changes in this well during the study period is included in Appendix 1.

RW-3 Well Data:	
Well Depth (feet below grade / elevation, MSL)	500 / -109
Ground Elevation at Well (feet MSL)	391
Stick-up / Top of Well Casing Elevation (feet MSL)	0 / 391
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	32 / 359
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	0 / 359
Total Coliform Bacteria (pre / post), MPN/100mls	10 / Not Sampled
E. *coli* Bacteria (pre / post), MPN/100mls	None / Not Sampled
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	Total Iron

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 10 MPN/100mls in the pre-monitoring sample. No *E. coli* bacteria were detected. A post-monitoring sample was not analyzed because no probe tube was installed in this well.

Metals and Inorganics: The Total Iron concentration of 3.1 mg/L exceeds the VGES of 0.30 mg/L, although Total Manganese was relatively low (0.037 mg/L. The dissolved forms of these two metals were non-detected (Mn) or detected at a very low concentration (Fe at 0.023 mg/L), indicating that the high Total Iron concentration was likely due to particulate matter from the well casing, well sediment or bedrock, and not from direct groundwater impacts.

VOCs: No volatile organic compounds (VOCs) were detected in RW-3.

Groundwater Depths: The depth to groundwater in this well remained stable at about 32 feet BTOC (elevation 359 feet MSL). This elevation is lower than the base elevations of the CSWD facilities. The temperature of the water in this well was consistent at 48° F.

Conclusions regarding CSWD Monitoring Well RW-3: The groundwater analytical results from RW-3 do not suggest impacts from any landfill-related activities.

4.12 CSWD Bedrock Monitoring Well RW-4

This bedrock aquifer monitoring well is located at the southernmost perimeter of the next parcel south of the sand and gravel pit property, southwest of the existing CSWD landfill facility. The following table summarizes the monitoring and sampling results for this well. Table 2 in Appendix 2 summarizes the analytical results of the groundwater samples collected from this well. A graph of the water levels and temperature changes in this well during the study period is included in Appendix 1.

RW-4 Well Data:	
Well Depth (feet below grade / elevation, MSL)	500 / 9
Ground Elevation at Well (feet MSL)	509
Stick-up / Top of Well Casing Elevation (feet MSL)	1.1 / 510
Static Water Depth / Elevation (feet BTOC / Elev. MSL)	20 / 490
Maximum Drawdown below Static (ft BTOC / Elev. MSL)	0 / 490
Total Coliform Bacteria (pre / post), MPN/100mls	5 / Not Sampled
E. *coli* Bacteria (pre / post), MPN/100mls	none / Not Sampled
Volatile Organic Compounds, µg/L	None
Elevated Metals or Inorganics, mg/L	Total Iron

MSL = Elevation above Mean Sea Level;
BTOC = Depth Below Top of Casing;
MPN/100mls = Most Probable Number per 100 milli-liters.

Bacteria: Total Coliform bacteria were detected at 5 MPN/100mls in the pre-monitoring sample. No *E. coli* bacteria were detected. A post-monitoring sample was not analyzed because no probe tube was installed in this well.

Metals and Inorganics: The Total Iron concentration of 3.5 mg/L exceeds the VGES of 0.30 mg/L, although Total Manganese was relatively low (0.049 mg/L. The dissolved forms of these two metals were non-detected, indicating that the high Total Iron concentration was likely due to particulate matter from the well casing, well sediment or bedrock, and not from direct groundwater impacts.

VOCs: No volatile organic compounds (VOCs) were detected in RW-4.

Groundwater Depths: The depth to groundwater in this well remained stable at about 20 feet BTOC (elevation 490 feet MSL). This elevation is higher than the base elevations of the CSWD facilities. The temperature of the water in this well was consistent at 46° F.

Conclusions regarding CSWD Monitoring Well RW-4: The groundwater analytical results from RW-4 do not suggest impacts from any landfill-related activities.

4.13 Quality Assurance / Quality Control Samples

Trip blank samples were prepared by Endyne on July 10, 2009, and were transported with other samples and returned to the lab for VOC analyses on July 14, 15, and 16, 2009. Lab results indicate no detections of VOCs in these samples (see lab reports in Appendix 4). This indicates that the VOC analyses of well samples can be considered accurate.

5.0 SUMMARY OF FINDINGS

Based on the groundwater analytical results from the well samples collected during this study, there are no indications of landfill-related impacts on the bedrock aquifer in the vicinity of the CSWD facilities (existing or proposed), or in the vicinity of Martel Hill (Ledgewood Drive) or Old Stage Road.

The directions of groundwater flow in the bedrock aquifer beneath Martel Hill are radial in nature, with flow paths originating at or near the top of the hill and flowing radially outward in all directions. Relative to the CSWD facilities, the flow direction in the bedrock groundwater flow is toward the north, toward the CSWD facilities from Martel Hill. This is the case both under static non-pumping conditions, and under the maximum pumping conditions recorded in the monitored wells throughout the study period. At all times during the study period, groundwater elevations at the nearby residential wells evaluated were always substantially higher than groundwater elevations in the monitoring wells at or near the CSWD existing and proposed facilities. These higher groundwater elevations in the nearby residential wells create a substantial hydraulic gradient from north to south in the bedrock aquifer (from Martel Hill toward the CSWD facilities) which will not be reversed by regular residential use of the nearby wells, or by seasonal groundwater fluctuations, or by the existing or proposed CSWD solid waste management operations. In addition, the site-specific geologic conditions, leachate management procedures, and groundwater monitoring results in the vicinity of the CSWD facilities indicate that there is little likelihood of dense high-concentration landfill contaminants being released from the current or future solid waste facilities at CSWD, penetrating through the low-permeability surficial materials to the bedrock aquifer, and following fractures in the bedrock downward (but up-gradient in relation to the potentiometric surface of the bedrock aquifer) to enter the lower elevations of the nearby wells. Based on this information, it is our professional judgment that there is no likelihood that groundwater or water quality impacts from the CSWD facilities is now

affecting, or will affect in the future, any nearby residential wells including those on Ledgewood Drive, Old Stage Road, or Redmond Road.

Several of the water samples collected in July 2009 from the residential wells and CSWD bedrock monitoring wells contained Total Coliform bacteria, although none contained fecal bacteria (*E. coli*) except for the Blankenheim well. In that well, the presence of Total and *E. coli* bacteria is a known historical condition that the well owner has been addressing through treatment devices since 2004. The presence of Total Coliform bacteria in the other wells is likely caused by conditions such as a loose or cracked well cap, incompletely sealed well casing, shallow-to-bedrock conditions, or other hydrogeological effects.

There were no indications of any chemical impacts from the CSWD facilities on any nearby residential wells or bedrock monitoring wells (metals, inorganic parameters, or volatile organic compounds).

6.0 RECOMMENDATIONS

Based on our evaluation of the bedrock aquifer in the vicinity of the CSWD facilities and Martel Hill contained in this report, H&N does not recommend any further evaluation of the bedrock aquifer with regards to groundwater flow directions, or water quality relating to landfill impacts.