western water
ASSOCIATES LTD
Consultants in Hydrogeology and Water Resources Management

February 7, 2023 WWAL Project: 22-153-01VR

Alto Utilities
10397 Lodge Road.
Lake Country, B.C.
V4V 1V6

Re: Assessment of Differing Manganese Concentrations in Groundwater and Recommendations for a Third Production Well: Alto Utilities Production Wells, Lake Country, B.C.

Western Water Associates Ltd. (WWAL) is pleased to provide this hydrogeological assessment of the Alto Utilities production wells located on Lodge Road in Lake Country, B.C.

This assessment was requested by Alto Utilities in support of plans to add a third production well to their system. The two existing production wells, informally referred to the as the North and South wells, produce water with differing geochemistry. Of primary concern to Alto Utilities is the manganese concentrations in the two sources, with the North Well producing water with significantly higher manganese, typically at concentrations around the Guideline for Canadian Drinking Water Quality (GCDWQ) Maximum Acceptable Concentration (MAC) of 0.12 mg/L. The South Well in contrast typically produces water with manganese concentrations in the 0.05 mg/L range.

Our assessment included a review of background information provided, including several historical reports listed in the references section. We also reviewed water quality data from Alto's database, select well performance information from the SCADA system, along with area aquifer mapping and well records. WWAL Hydrogeologist, Ryan Rhodes, P.Geo, also completed a site visit on November 18, 2022.

1.0 BACKGROUND

The Alto Utilities drinking water system is supplied by two wells sourcing water from Provincially mapped, confined Aquifer 344. Select well construction details for the two production wells are included in Table 1 below.

Table 1: Select well construction details for the existing Alto Utilities production wells.

WTN	Informal Well Name	Finished Well Depth (m)	Diameter (mm)	Construction Date	Depth to Water (m)	Screen Construction (mbgs)	Reported Well Yield (US gpm)
83230	North Well[1]	26.2	250 (10 inch)	1977	1.1	19.8 - 25.9m: 100 Slot[2]	588
83017	South Well	34.5	305 (12 Inch	2002	1.5	20.9 - 23.1 m: 60 Slot 23.1 – 27.0 m: blank 27.0 - 30.1 m: 250 Slot 30.1 – 34.1 m: blank	620

[1]-North well has been historically referred to as "West Well". [2]-Slot size is the equivalent of thousandths of an inch.; WTN = Well Tag Number

Historically, an East production well was present at the site but has been abandoned (assumed to be Well Tag Number 23636). Several other test wells and boreholes are reported at the Alto Utilities compound in the BC GWELLS database (Figure 1 - attached).

Both the North and South Wells are licensed for a combined yield of 473,000 m^3/year and select groundwater license details are included in Table 2 below. We note that based on a search of the BC Water Resources Atlas online mapping application in January 2023, Alto Utilities has the only groundwater licence issued in Aquifer 344.

Table 2: Select Groundwater License Details Alto Utilities.

License Number	Wells (WTN)	Priority Date	License Yield	Aquifer	Use/Purpose
50695	83230, 83017	July 7, 1971	473,000 m^3/year	344	Waterworks local provider

Typical water system operation sees alternating use of the wells. The North and South Wells have typical operating rates of 21 L/s and 32 L/s, respectively. We understand that the output from the North Well closely matches water system demands, which results in the North Well running for extended periods of time and providing the bulk of the water to the system. The South Well, which has a higher operating rate, more readily fills the reservoirs to their high-level setting and therefore operates less frequently. We understand both wells are capable of operating at their typical rates simultaneously and do so during summer peak demand periods to meet water system demands.

The water system includes inline turbidity monitoring. We understand that when the North Well operates, turbidity levels are in the 0.3 – 0.4 NTU range, while the South Well produces water with lower turbidity in the 0.04 – 0.05 NTU range.

2.0 WATER QUALITY

Historical laboratory sample results for nuisance parameters including manganese and turbidity were obtained from Wireless Water (Alto Utilities' water quality database provider) and reviewed. Water quality information was available from 2007-2022 for laboratory samples collected by the operator. Manganese was found to be consistently higher in concentration in the North Well, often exceeding the MAC of 0.12 mg/L which was instituted in 2019 (Health Canada, 2019). Manganese in the South Well is consistently lower and typically around 0.05 mg/L. One sample collected from the South Well in 2019 exceeded the manganese MAC and has been attributed to high turbidity observed at the time. A visual comparison of manganese concentrations is included for reference in Figure A below.

Turbidity in the South Well has been variable and, in most cases, is either slightly below or slightly above the water quality guideline of 1 NTU. In 2019, one sample was noted to exceed 4 NTU which appears to be an isolated occurrence. Turbidity in the North Well exceeded 1 NTU on one occasion out of eight reviewed samples. A visual comparison of turbidity observations is included for reference in Figure B below. Note the difference between in-line turbidity measurements (see 1.0 above) and the lab results (Figure B). It is inferred that precipitation of minerals like manganese or iron occur prior to laboratory turbidity analysis and increase the laboratory turbidity readings. In-line turbidity readings taken in the pumphouse are likely lower because the measurements are made before these minerals have precipitated out of solution.

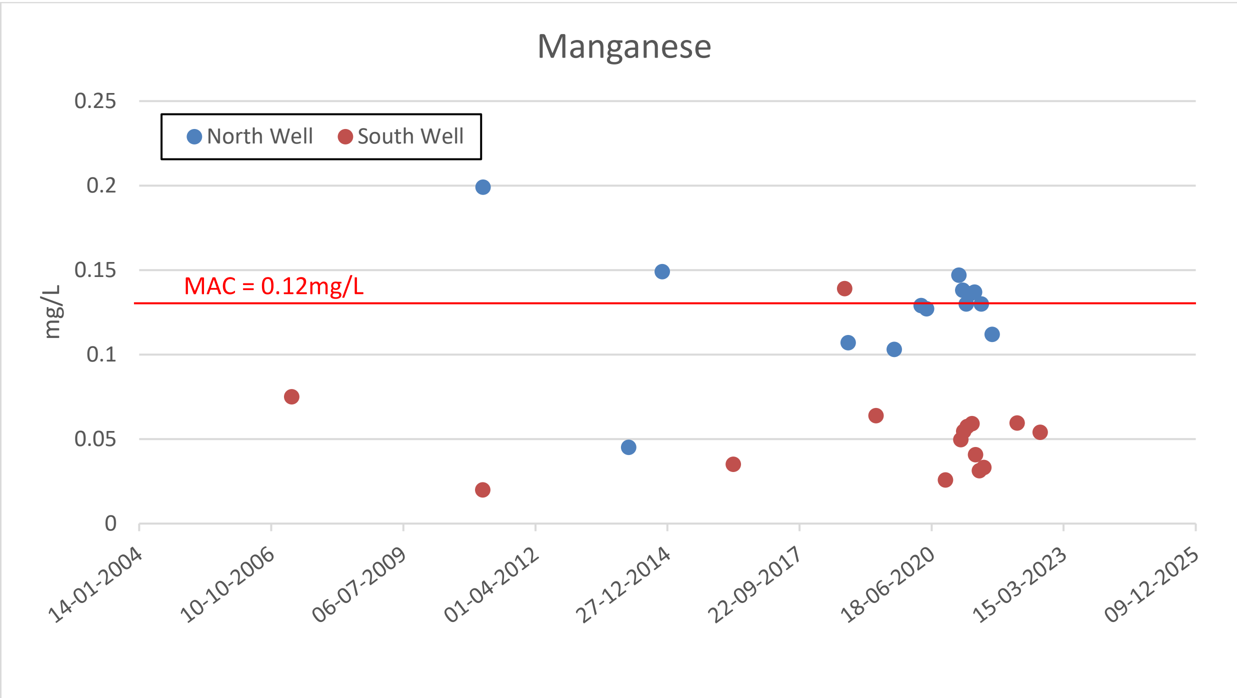


Figure A: Historical manganese concentration for North and South Wells.

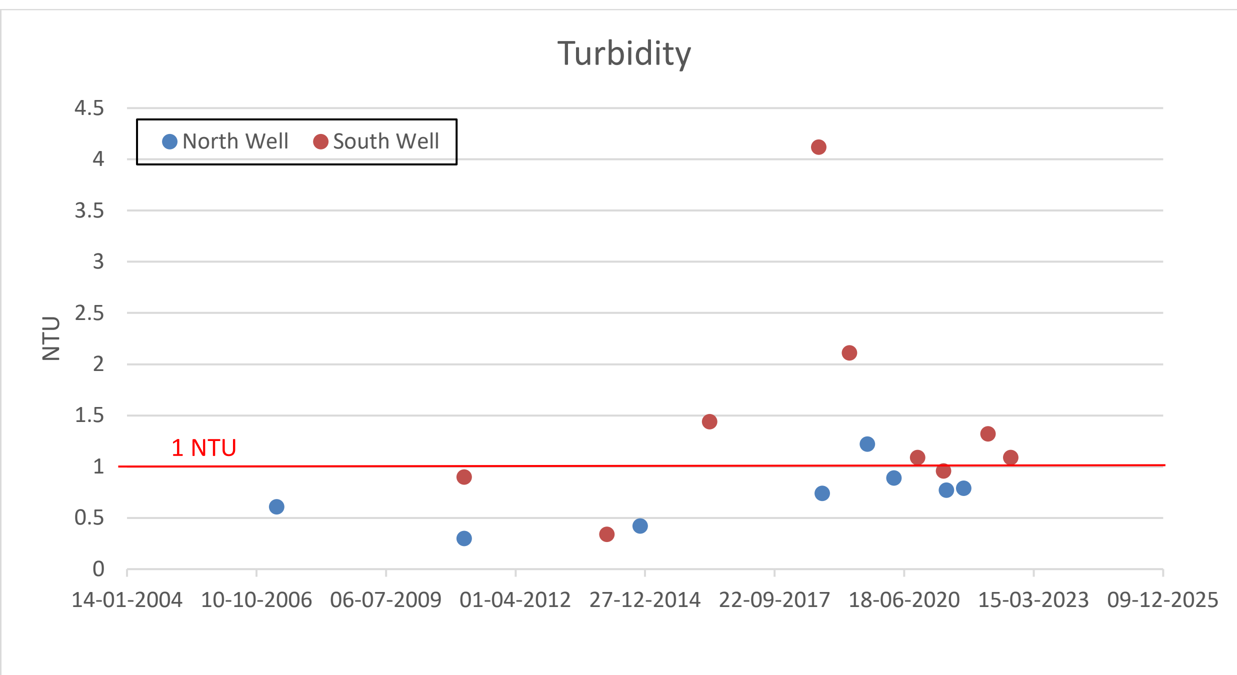


Figure B: Historical turbidity in North and South Wells.

3.0 HYDROGEOLOGIC SETTING

The Alto Utilities wells are completed in Provincially-mapped Aquifer 344, which occupies the valley bottom from Ellison Lake in the south to Wood Lake in the north (ENV 2023). The aquifer is confined, and at the Alto Well site, overlain by 10+ m of silt and clay. In addition, a shallower unconfined aquifer is present over much of the confining layer.

Aquifer 344 is believed to be recharged primarily by infiltrative losses from Vernon Creek, where it emerges from the mountainous area to the east and flows across its alluvial fan. These infiltrative losses create a groundwater mound that causes groundwater to flow northwards, ultimately discharging into Wood Lake.

3.1 Detailed Assessment of North and South Well Construction and Source of Manganese

WWAL reviewed the well completion report for the South Well (Kala 2003). A much briefer and less detailed report on the North Well was included as an appendix to the 1988 Stanley Associates Engineering Ltd. report.

Figure C below provides a completion schematic and lithology for both wells side by side. Well logs for both wells are provided as an attachment.

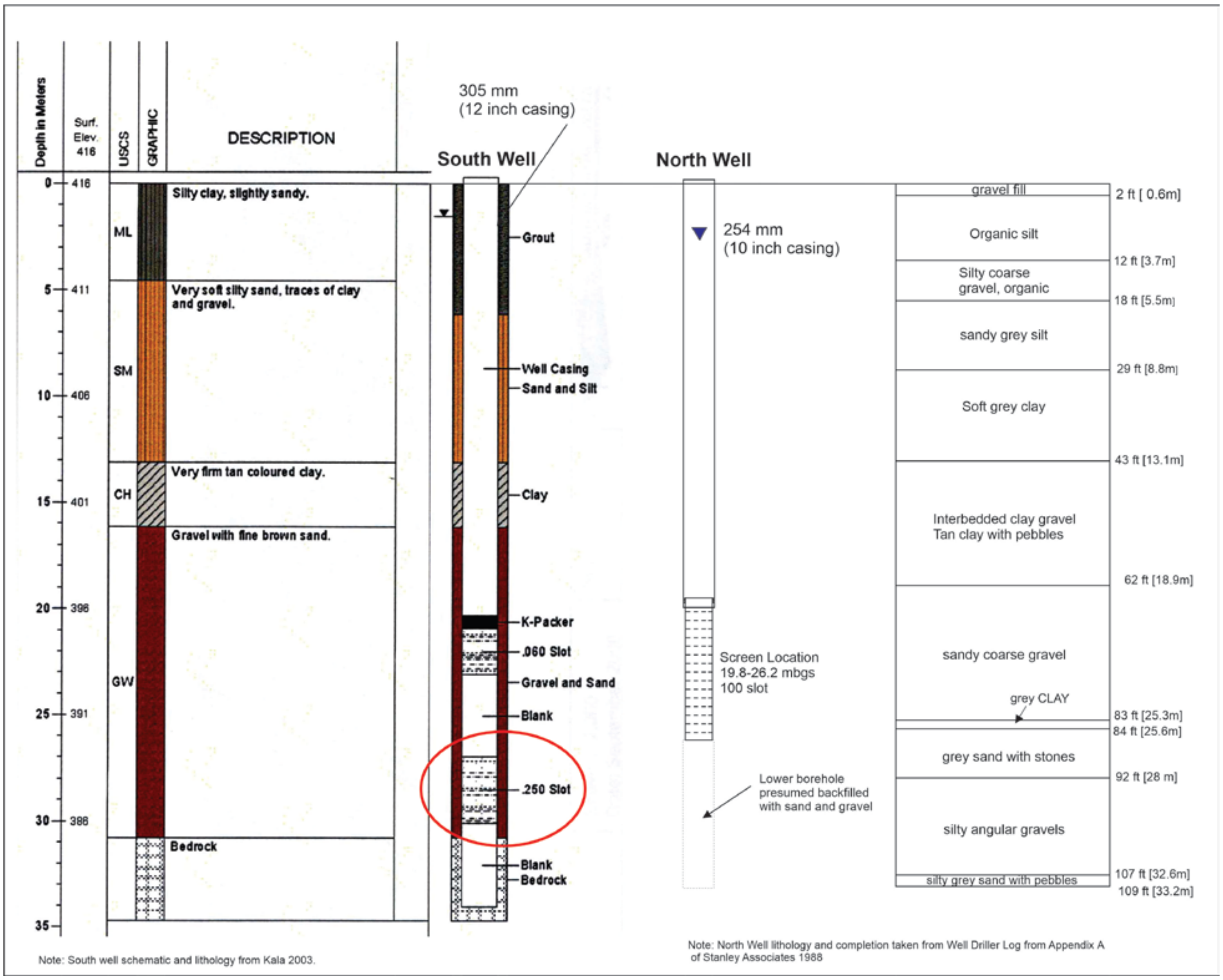
The screen completion in the South Well is complicated and somewhat unusual, consisting of two open screen intervals separated by a blank section. The completion report for the South Well does not explicitly state the reason for the middle blank section, and the lithology reported below 16 m is gravel with fine sand until bedrock was encountered at approximately 31 m. However, grain size analysis completed on formation samples collected from the middle blank screen section indicate less gravel and more fines, and we infer the material present over the middle blank section was too fine grained to be screened.

The North Well has a more conventional completion, with a single continuous screen section.

A grey clay seam is reported on the lithology for the North Well from 25.3 m to 25.6 m, which corresponds with the middle blank in the screen for the South Well. The North Well is screened predominantly above this clay seem, while in the South Well, the screened intervals are both above and below this finer grained zone.

Our interpretation is that there are two zones of Aquifer 344 at the Alto Utilities site, referred to herein as an upper and lower zone. As the North Well only sources water from the upper zone of the aquifer and contains higher manganese, we infer that the upper zone of the aquifer is characterized by higher manganese. The South Well sources water from both the upper and lower zones of the aquifer, and the resulting water quality is a blend of those two zones. Since the South Well has consistently lower manganese, we believe that the lower zone (circled in Red on Figure C) is characterized by lower manganese concentrations that dilute the influence of the upper zone. We recommend that a future well at the site target the lower zone of the aquifer between approximately 26 and 30 m depth.

Figure C: Side by Side Comparison of Lithology and Well Completion for the North and South Wells.



It is interesting to note that for the North Well, the lower zone was drilled through but was not screened. The reason for this is not clear. The North Well was drilled with a cable-tool drilling rig. Cable-tool drill rigs are old technology and relatively slow but result in the collection of accurate and representative formation samples. We infer that the lower zone of the aquifer was not present at the location of the North Well, or if present, comprised of material not suitable for screening (e.g., too fine grained).

We also point out that the completion report for the South Well indicates the well was difficult to develop. Initial development was completed with compressed air from an air rotary drilling rig. A cable-tool rig was subsequently mobilized to site to complete the development process, and it was reported that “large quantities of sand and silt” was removed from the well, ultimately resulting in subsidence around the well casing (Kala 2003). It is not clear from where this material originated, but we suspect it was from the lower section of the screen where relatively large apertures (250 slot) were installed. It is possible that these screens were too large and improperly sized for the formation in that location. For that and other reasons we elaborate on later in this report, we recommend that any future drilling attempts be completed with a cable-tool drilling rig.

4.0 NORTH AND SOUTH WELL SPECIFIC CAPACITY

Specific capacity (defined as pumping rate divided by drawdown) is a simple measure of a well's operational performance or efficiency. Well specific capacity declines over time for many reasons including:

- Physical plugging of the well screen or aquifer around the well screen by fine sediments.
- Chemical encrustation and plugging of well screens resulting from the precipitation of dissolved minerals in groundwater, commonly iron and manganese.
- Biological fouling of the well screen.

Declines in specific capacity, where significant, can result in lost production capacity and the need to reduce pumping rates. Specific capacity of a well can be restored by various well redevelopment techniques including mechanical scrubbing, surging, compressed air or water jetting, or with chemical treatments such as acids and dispersants. Often more than one of these techniques are used. As a rule of thumb, we recommend that well redevelopment be completed when a well's specific capacity has declined by 15%. In most cases, the bulk of lost specific capacity can be restored if redevelopment occurs at this threshold. It has been our experience that the more specific capacity has declined and the longer it has been allowed to decline, the harder it is to reverse these losses through redevelopment.

To the best of our knowledge, neither of the Alto Utilities wells has been redeveloped. To assess the need for redevelopment, we compared specific capacity as calculated during the original pumping tests on the wells (as indicated in the well completion reports) with recent SCADA information obtained during our November 2022 site visit. The pumping rates and drawdown data was utilized to calculate specific capacities of each well to infer if any decline in well efficiency has occurred. The data is provided in Table 3.

Specific capacity normally declines as pumping rates increase due to increasing turbulent flow of water entering the screen (also referred to as "well losses"). In order to make an apples-to-apples comparison, similar pumping rates and durations are required.

The data indicate that a 32% decline in specific capacity has occurred in the North Well over a 46 year period. The magnitude of the decline is likely even higher than that, as the most recent data were for a pumping rate half that of the older data used.

The data indicate that the South Well has experienced an even larger decline in specific capacity of over 77% in the 20 years since the well was put into service. It is worth noting that the specific capacity of the South Well seems to have declined since the pump in that well was replaced in early 2022. Following the installation of the new pump, the well was pumped at a similar rate as previously. In November 2022, water level drawdown occurred to the point where, only 0.6 m of water was present above the transducer, which is likely located at the top of the pump assembly.

Table 3: Summary of pumping test data and specific capacities from North and South Wells.

Test Date	Pumping Duration (minutes)	Pumping Rate (L/s)	Drawdown (m)	Specific Capacity (L/s/m)
North Well				
1977[1]	1450	43.2	9.12	4.73
Dec 1994[2]	1440	44.1	13.01	3.39
Nov 2022[3]	30	21.0	6.49	3.23
South Well				
Oct 2002[2]	1060	39.2	4.79	8.18
Nov 2021 (prior to pump replacement)	30	31.8	13.03	2.44
Nov 2022[3] (after pump replacement)	30	32.5	17.60	1.85

[1]-Source: North Well original drilling report excerpts included in 1988 Stanley Associates Engineering Study (Stanley 1988).

[2]- Source: (Kala, 2008)

[3]-Source: Onsite SCADA information collected during November 2022 site visit.

Based on or review of the specific capacity data, it is our opinion that both wells could benefit from redevelopment to restore lost efficiency. The declines appear to be more pronounced at the South Well, and we would recommend that well be prioritized. The reported issues with sediment production during original development of the South Well bears consideration and is somewhat of a concern. We would recommend a relatively gentle redevelopment program on that well, with close monitoring of sand production and possible subsidence.

5.0 CONCLUSIONS

Based on our assessment we offer the following conclusions:

C1 The differing manganese concentrations in the North and South Well appear to be the result of where the wells are screened. There appears to be an upper and lower zone of Aquifer 344 at the site, separated by finer grained deposits. The North Well sources water from the upper zone, while the South Well sources water from both the upper and lower zones. We infer that the lower zone of the aquifer is characterized by lower concentrations of manganese. The lower zone of the aquifer should be targeted in future drilling attempts.

C2 Review of historical and current specific capacity data indicates that both wells have experienced significant declines in specific capacity since being drilled. The decline appears to be greater and has occurred over a shorter time in the South Well. Both wells would benefit from redevelopment, with priority given to the South Well.

We recommend that well development be completed with a cable-tool drilling rig using the surge and bail method. If possible, simultaneous pumping with a submersible pump to remove silt and fine sand mobilized during the process is recommended. This would require a location to discharge ~90 US gpm of water while development works are being complete. This water could potentially be routed to the ditch on the south side of Lodge Road. A pre- and post-development camera survey is also recommended.

6.0 RECOMMENDATIONS FOR THE CONSTRUCTION OF A NEW WELL

If a third well at the site is desired, we recommend drilling a new production well approximately 10 m west of the existing South Well. The new well should be drilled and developed utilizing a cable-tool drill rig, which will allow for drill cuttings and development water to be contained onsite. A small sump will likely be required adjacent to the drill site. Cable-tool rigs drill much more slowly than air rotary rigs but allow for the collection of more accurate formation samples that aid in screen design. It is also our opinion that cable-tool rigs also provide the best method for well development using the surge and bail technique.

The well screen should target the lower aquifer (approximately 26 – 31 m below ground), which appears to have lower manganese concentrations. A schematic with the recommended well construction is included in attached Figure 2. Note that the final screen design should be based on observations made during drilling and sieve analysis of formation samples. There will likely be an opportunity to confirm our interpretation of the source of the elevated manganese during drilling and prior to screen installation. When drilling reaches the upper zone of the aquifer, we suggest collecting a sample for total and dissolved metals with a small submersible pump, and repeating sample collection when the deeper part of the aquifer is reached.

Drilling of a new well will require permitting through the Interior Health Authority (i.e., New Source Approval, Waterworks Construction Permit and revised Operating Permit). In addition, a new well will necessitate an amendment to Alto Utilities' groundwater licence to add the new well as a new "works" item.

Following the drilling and development of the new well, a variable rate step test and a 24-hour constant rate pumping test should be conducted with water quality samples collected and analyzed for the Interior Health New Source list of parameters. Discharge from the pumping test can be routed through lay flat and/or PVC pipe along the ditch on the south side of Lodge Road, with ultimate discharge to Vernon Creek (a permit for this discharge may be required by the Province). WWAL viewed this discharge pathway and culverts were observed in the ditch; the only crossing of a transportation corridor is the sidewalk on the south side of Lodge Road, near the Alto property. Permission from the District of Lake Country to either temporarily close the sidewalk or to construct a ramp over the discharge will likely be required.

7.0 COST ESTIMATES

To aid with project budgeting, we provide cost estimates for well redevelopment and the drilling of a new well below. These estimates were provided based on a quote obtained from Trinity Valley Drilling of Lumby, B.C. Trinity Valley Drilling is an experienced cable-tool well driller, also capable of completing pumping tests and well redevelopment programs. Note that a contingency has not been applied to the estimates below, and that materials prices (steel well casing, well screens and fittings) have been steadily rising since 2021.

Table 4: Cost Estimates

Task	Cost Estimate
New 12-Inch Well	
Hydrogeological oversight, data analysis, water sample and reporting.	$20,000
12-inch diameter production well. Assume depth of 31 m, 5 m of well screen, 50 hrs development (based on Trinity Valley Drilling pricing January 2023)	$50,000
4 hour variable rate step test, 24 hour constant rate test, 250 m discharge	$10,000
Total	**$80,000**
Well Redevelopment Per Well	
Hydrogeological oversight, data analysis, reporting.	$6,000
Remove Pump, pre &post camera survey, 40 hours development, replace pump	$20,000

CLOSURE

We trust that the professional opinions and advice presented in this document are sufficient for your current requirements. Should you have any questions, or if we can be of further assistance in this matter, please contact the undersigned.

WESTERN WATER ASSOCIATES LTD.

PROFESSIONAL PROVINCE OF R.M. RHODES #32839 BRITISH COLUMBIA GEOSCIENTIST

7-Feb-2023

Ryan Rhodes, P.Geo.
Hydrogeologist

Reviewed by:

Warren Grafton, P.Geo
Hydrogeologist

Attachments:
Figure 1 – Alto Utilities Site and Reported Wells
Figure 2 - Alto Utilities Recommended Well Construction
Well Driller Logs for North and South Wells

REFERENCES

Ministry of Environment and Climate Change Strategy (ENV). 2023. BC Water Resources Atlas online mapping application. https://maps.gov.bc.ca/ess/hm/wrbc/

Health Canada. (2019). Guideline Technical Document - Manganese. *Guidelines for Candian Drinking Water Quality*. Government of Canada.

Kala Groundwater Consulting Ltd. (Kala). Groundwater Supply Investigation Alto Utilities Ltd. Janaury 7, 2023.

Kala Groundwater Consulting Ltd. (Kala). Alto Utilities Ltd. Lake Country BC, Preliminary Aquifer Protection Program Steps 1-3. *Kala Reference R06734*. October 8, 2008

Stanley Associates Engineering Ltd. 1988. Alto Utilities Water Study.

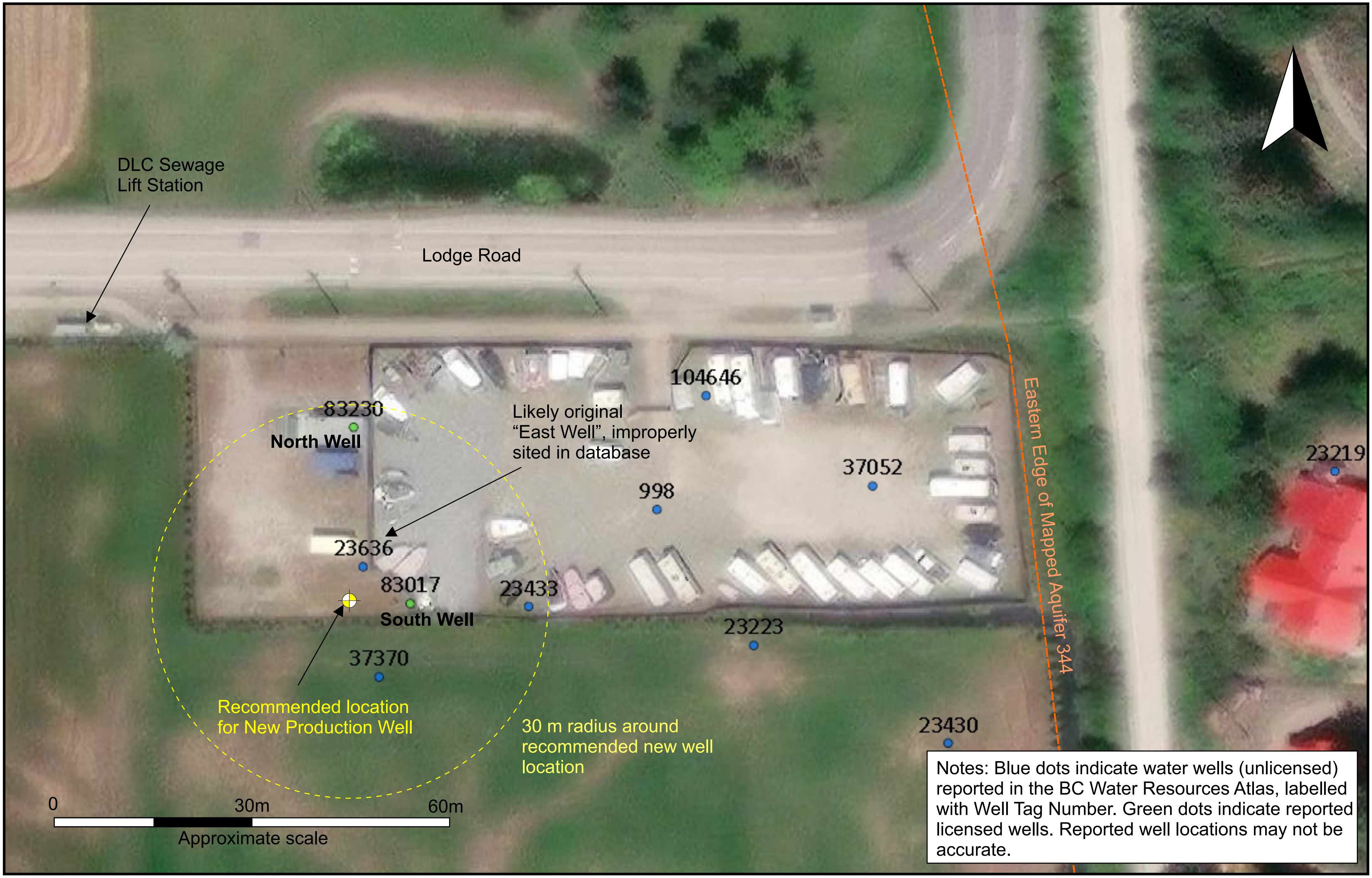


Figure 1 - Alto Utilities Site and Reported Wells

Date: Janaury 2023	Image: BC WRA (ENV 2023)	Client: Alto Utilities	WWAL Project: 22-153-01VR
Drawn by: RR	Checked by: WG	Project: Alto Utilities Well Assessment	

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Figure 2: Alto Utilities Recommended Well Construction
(final depth and screen design to be based on field analysis during drilling)

Date: January 2023	Project: 22-153-01VR
Drawn by: WG	Checked by: RR

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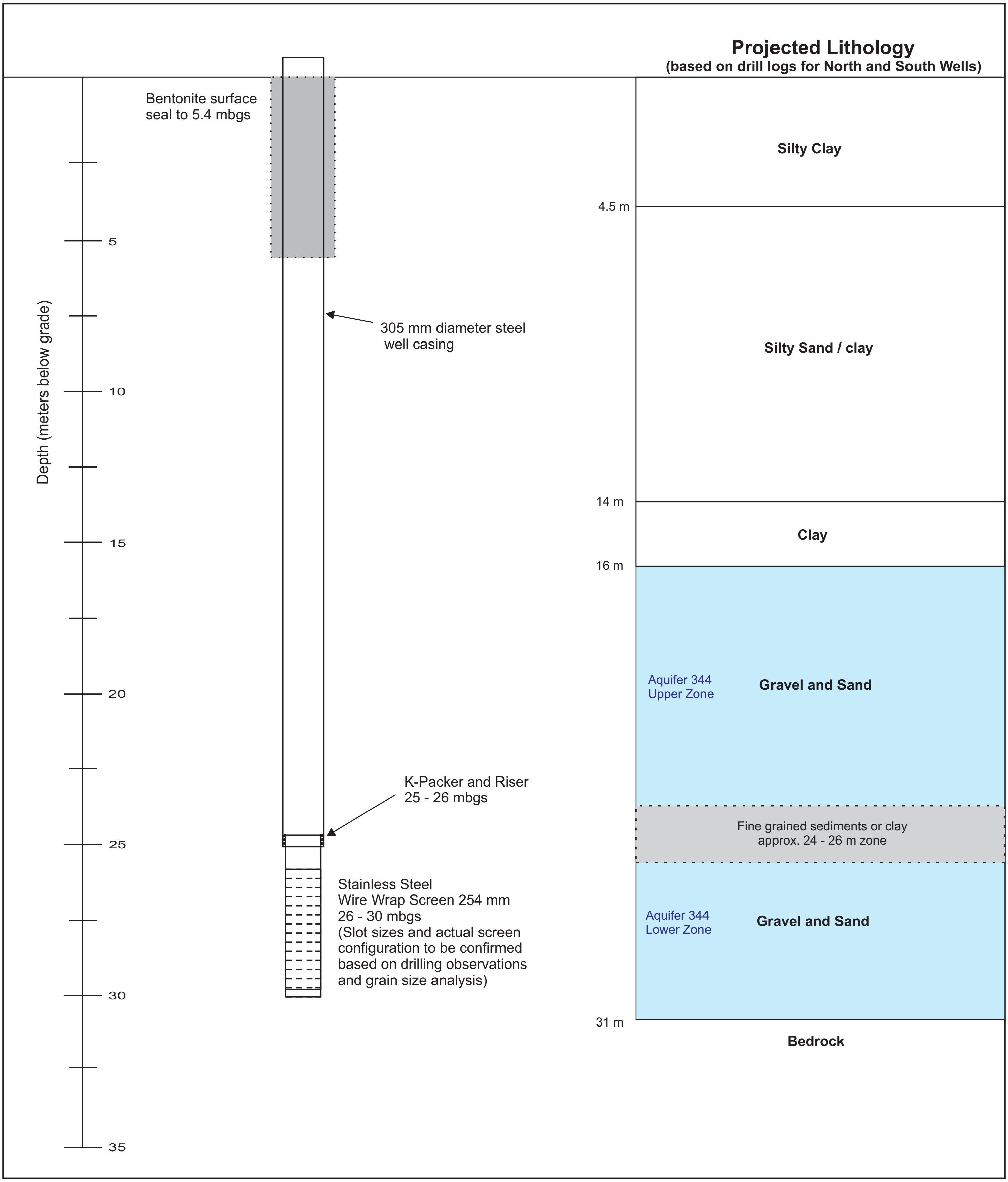


KALA GROUNDWATER CONSULTING LTD.
VERNON KAMLOOPS

1314 McGILL ROAD
TEL. (250) 372-9194
KAMLOOPS, BC, V2C 6N6
FAX (250) 372-9398

LOG OF SOUTH WELL

Alto Utilities Ltd.
Preliminary Aquifer Protection Program

Lake Country, British Columbia
Kala Project Reference: 06734

Date Started	: May 2, 2002	Company Rep.	: Field Drilling
Date Completed	: May 2, 2002	Northing Coord.	: 50° 02' 03.3"
Hole Diameter	: 305 mm	Easting Coord.	: 119° 23' 36.6"
Drilling Method	: Air Lift / Dual Rotation	Survey By	: LCT
Sampling Method	: Grab	Logged By	: LCT

Depth in Meters	Surf. Elev. 416	USCS	DESCRIPTION
0	416	ML	Silty clay, slightly sandy.
5	411	SM	Very soft silty sand, traces of clay and gravel.
10	406		
15	401	CH	Very firm tan coloured clay.
20	396	GW	Gravel with fine brown sand.
25	391		
30	386		Bedrock
35			

Well Construction Information

WELL CONSTRUCTION

Date Compl.	: May 2, 2002
Hole Diameter	: 305 mm
Drill. Method	: Air Rotary
Company Rep.	: LCT

WELL CASING

Material	: Steel
Diameter	: 305 mm
Length	: 21.24 m
Stick - up	: 0.305 m

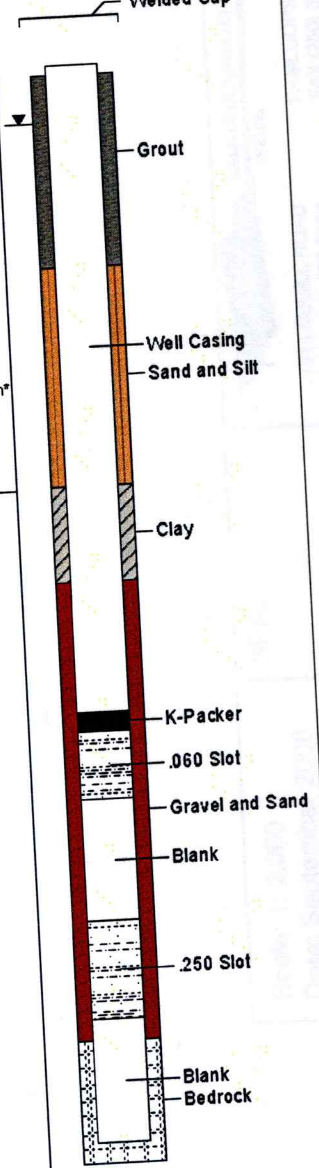
WELL SCREEN

Material	: Steel
Diameter	: 305 mm
Opening	: Varies "See Diagram"
Length	: 13.11 m

MEASUREMENTS

NOTES:

Estimated Yield 10 L/s



Scale: NTS Date: September 2008 Approval: Design By: Drawn By: JB Checked By:	SEAL	KALA GROUNDWATER CONSULTING LTD. VERNON KAMLOOPS 1314 McGILL ROAD TEL. (250) 372-9194 KAMLOOPS, BC, V2C 6N6 FAX (250) 372-9398 ALTO UTILITIES LTD. PAPP, Lake Country, BC Well Completion Diagram – South Well	Ref: 06734 File Ref: 06734Fig7.ppt Fig: 7

North Well

WELL LOG CONSTRUCTION RECORD

OWNER: TOOVEY ENTERPRISES

Address: R.R.#5 TOOVEY ROAD KELOWNA B.C.

Well Location: EAST END LODGE ROAD BY RAILWAY WINFIELD

Date Started: ____ Date Completed: APR. 26/77

A.C. DRILLERS LTD.
RR#1 KEREMEOS
B.C.

Drilling Method: CABLE

Driller: G. MONKMAN Helper: ____

File: ____ Folio: ____

Signed By: [signature]

LOG OF FORMATIONS

Depth		Descriptions
0	to 2	GRAVEL FILL
2	to 12	ORGANIC SILT
12	to 18	SILTY COARSE
	to	GRAVEL ORGANIC
18	to 29	SANDY GREY SILT
29	to 43	SOFT GREY CLAY
43	to 48	INTERBEDDED CLAY
	to	GRAVEL
48	to 62	TAN CLAY WITH
	to	PEBBLES
62	to 83	SANDY COARSE GRAVEL
83	to 84	GREY CLAY
84	to 92	GREY SAND WITH
	to	STONES
92	to 107	SILTY ANGULAR
	to	GRAVELS
107	to 109	SILTY GREY SAND
	to	WITH PEBBLES
	to	
	to	
	to	
	to	
	to	
	to	
	to	
	to	
	to	

GENERAL REMARKS

CASING RECORD

Dia. 10 ins. Wt. 42 #/ft. From 0 to 109

Dia. ____ ins. Wt ____ #/ft. From ____ to ____

Dia. ____ ins. Wt. ____ #/ft. From ____ to ____

Shoe ✓ Welded ✓ Cemented MUD SEAL

SCREEN RECORD

Make: JOHNSTON Material: SS

Slot opening: 100 Length: 20 FT.

Top: 65 ft. Bottom: 86 ft.

Fittings Top: TYPE K Fittings Bottom: BAIL

Gravel Pack ____ Natural ✓

Development Method: SURGE SWAB

ROCK WELL DATA

Open Bore Hole ____ Dia. ____ ins.

From ____ ft. to ____ ft.

PRODUCTION DATA

Static Level: 3.62 ft.

Measured from: TOP OF CASING

Pumping Level ____ ft. at ____ GPM

27.27 ft. at 685 GPM

Bail Test ____ ft. at ____ GPH

____ ft. at ____ GPH

Recommended Pump Setting: 60 ft.

Recommended Max. Pump Output ____ GPM GPH

Duration of Test: 24 HOURS Hrs.

PUMP DATA

Make ____ Type ____

Model ____ Serial No. ____

Size ____ HP ____ Drop Pipe ____ ins.

GPM ____ Head ____ ft. ____ RPM

Motor ____ Volts ____ PH ____

Well Seal ____

Water Analysis — Hardness ____ PPM

PH ____ Iron ____ PPM

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Groundwater Supply Development and Management

Source Water Assessment and Protection

Well Monitoring & Maintenance

Environmental & Water Quality Monitoring

Storm & Wastewater Disposal to Ground

Groundwater Modeling

Aquifer Test Design and Analysis

Geothermal / Geoexchange Systems

Policy and Guideline Development

Applied Research

Rural Subdivision Services

Environmental Assessment & Permitting

Contaminated Sites