KRESTOVA IMPROVEMENT DISTRICT

DOMESTIC WATER SYSTEM STUDY

ENGINEERING (2012) LTD.

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Executive Summary

WSA Engineering (2012) Ltd (WSA) has completed a study of the Krestova Improvement District (KID) domestic water system. The purpose of the study is to investigate alternative water sources for the KID and assess the feasibility and cost of capital upgrades to improve the aging system and facilitate the removal of a Boil Water Notice (BWN) that has been issued by Interior Health Authority (IHA).

The current gravity fed surface-water system does not include disinfection or treatment of any kind. The system does not include any provision for fire water storage or fire hydrants. Storage capacity is undersized for current demand and the system cannot service any further development. The distribution network is aging, undersized for demand and significant sections trespass on private property. Finally, existing earthen berms that store surface water are located above the community and pose a risk of flooding.

The priorities that are addressed in this study are:

1. Bring the system into compliance with IHA regulations and remove the BWN
2. Provide fire protection to the community
3. Improve water source quantity and quality
4. Eliminate trespasses of KID infrastructure on private property
5. Facilitate decommissioning of the earthen berms

The recommendations are presented in a three phase approach.

Phase 1 will complete a test well drilling program to identify and establish a groundwater well of sufficient capacity to meet the Maximum Daily Demand of the KID. WSA also recommends that the KID complete a water metering program as part of Phase 1 to confirm community demands prior to completing infrastructure upgrades.

Phase 2 will develop the test well established in Phase 1 as well as a second domestic well for redundancy. Phase 2 will also include the construction of a well pump house, above-ground storage reservoir, reservoir access road, and replacement and/or extension of water mains to increase service capability. Fire hydrants will be installed along new distribution mains to provide fire protection. Trespassing infrastructure will either be abandoned or easements established to allow for KID access and maintenance. The earthen berms will be decommissioned.

Phase 3 will complete upgrades to the distribution network to bring remaining network mains into compliance with Fire Underwriters' Survey recommendations. Fire hydrants will be provided to remaining areas of the KID.

WSA has completed preliminary, Class C (+/- 25%) cost estimates for each of the three phases of improvement recommendations. A summary of the cost estimates for the three phases is illustrated in the table below:

Cost Estimate Summary	Cost Estimate
Phase 1	$112,500
Phase 2	$3,214,250
Phase 3	$476,250
KID Improvement Recommendations Total	**$3,803,000**

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1. Study Overview

1.1 Introduction

The Krestova Improvement District (KID) is a community water utility that serves water users in Krestova, BC, which is located approximately 17 km northeast of Castlegar. The water utility includes 74 service connections, both active and inactive, to supply residents with water for domestic consumption purposes. There is currently no provision of water for fire protection.

Krestova is sited on a bench at the eastern end of the Slocan Valley approximately 1km west of the Slocan River. The community predominantly consists of single family residences located on large rural lots. There are no industrial, commercial, or agricultural water users served by the system.

1.2 Study Objective

The KID water system is old and is in need of significant improvements to meet growing demand and drinking water quality guidelines. The system is currently operating under a Boil Water Notice (BWN) issued by Interior Health Authority (IHA) as there is no treatment or disinfection of the surface water source. The community is growing and the system struggles to meet current demand. There is no spare capacity for more service connections. Pressures vary across the gravity-charged distribution network and the system does not have sufficient storage or sufficiently sized water mains to provide fire protection. It is understood that the KID does not have easements in place for significant portions of infrastructure that trespass on private property. Finally, earthen berms have been constructed to increase the upstream storage capacity of the system and these berms present a flood risk to the community.

The objective of this study is to review the existing water system and investigate improvement options. Specifically, the study considers the following:

- Investigate and identify potential alternate water sources;
- Identify improvements to the distribution network;
- Investigate water storage options;
- Investigate fire protection provisions;
- Investigate disinfection and treatment improvements that will bring the water utility up to current IHA drinking water quality requirements and allow the removal of the BWN;
- Consider ways to eliminate trespasses of KID infrastructure on private property;
- Facilitate decommissioning of earthen berms;
- Provide recommendations and cost estimates for possible upgrades as part of a phased construction project.

An accompanying study, entitled Groundwater Feasibility Assessment for the Krestova Improvement District, has been completed by Western Water Associates Ltd. (WWAL) and is attached to this study (see Appendix B). WWAL is hydrogeology consulting firm that specializes in water source identification and development for water providers. The assessment investigates alternative sources for the KID system and provides recommendations and cost estimates for developing a ground water source.

This study will assist the KID with the planning of future upgrades and will be used to support funding initiatives and grant applications.

1.3 Design Criteria

Guidelines

WSA has employed a number of design guideline documents to assess the water system and inform this study. The following guidelines have been consulted:

- **Design Guidelines for Rural Residential Community Water System**, Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012 (RRCWS)
- **Design Guideline Manual**, Master Municipal Construction Documents Association, 2005 (MMCDA)
- **Water Supply for Public Fire Protection**, Fire Underwriters Survey, 1999 (FUS)

WSA has also reviewed the following reports that have previously been produced on behalf of the KID:

- Geotechnical Assessment of Krestova Improvement District, Langill Lake Water System, WSA Engineering, 2011
- Study of Water Supply, Treatment & Disinfection Options, Mould Engineering, 2003

Demands

System demands include domestic, irrigation and fire flow demands. The KID system does not include flow measurement equipment so system demands presented herein have been estimated.

Domestic demands are quantified in three ways:

- Average Daily Demand (ADD)
- Maximum Daily Demand (MDD)
- Peak Hour Demand (PHD)

The MMCDA recommends that the residential demands be estimated as shown below.

ADD	600 liters/capita/day
MDD	1200 liters/capita/day
PHD	1800 liters/capita/day

Domestic irrigation demand is included in the MMCDA demands above but does not include an allowance for agricultural irrigation. As it is understood that no commercial agriculture is served by the KID at this time, agricultural irrigation is assumed to be negligible.

Fire flow demands have been calculated following recommendations provided by the FUS for wood-framed, one and two story residences with exposure distances of between 10m and 30m (30' – 100'), which are typical conditions for Krestova residences.

System Pressure

The MMCDA guideline indicates that the range for acceptable service pressure is between 140kPa (20psi) to 850kPa (123psi). Minimum residual system pressure under fire flow conditions is 140kPa (20 psi).

The Mould study reported that system pressures vary between 345kPa (50psi) to 931kPa (135psi). WSA has not confirmed these pressures.

Storage

Sufficient system storage is defined as the capacity to balance the fluctuation of domestic demand, provide dedicated fire protection capacity and provide emergency water storage. Sufficient storage is calculated using the following method:

Total Required Storage = A + B + C

(A) = 25% of MDD for Balancing
(B) = Fire Storage Requirement (from FUS)
(C) = 25% of (A +B) for emergency storage

Fire Flows and Hydrants

For a community such as Krestova, the FUS recommends fire flow capability of 3000 Lpm for a duration of 75 minutes. The FUS recommends that system pressure under fire flow conditions is not to fall below 140kPa (20psi). Furthermore flow velocities are recommended to not exceed 3.0 m/s (10 feet per second).

In order to limit the flow velocities, water mains that supply fire hydrants are recommended to be minimum 150mm (6") diameter. The FUS recommends that the maximum hydrant spacing not exceed 180m (600') and the maximum area to be served by a single fire hydrant is 1.5 ha (3.7 ac).

Disinfection and Treatment

Disinfection and treatment guidelines are provided by IHA. Guidelines for water suppliers are to supply disinfection and treatment to meet the 4-3-2-1-0 Drinking Water Quality Objective. That objective is described as follows:

- 4-log inactivation of viruses
- 3-log inactivation of Giardia Lamblia and Cryptosporidium
- 2 – treatment processes for surface water sources
- 1 –1 NTU (nephelometric turbidity unit) or less
- 0 – E. Coli or fecal coliform bacteria

Disinfection and treatment requirements vary from water system to water system based on the water quality of the source. Surface water sources, such as those that currently supply the KID, are considered by IHA to be at high risk of containing pathogens and therefore require treatment and disinfection. Some groundwater well sources, particularly those from deep, confined and protected aquifers, provide water of exceptional quality and may not require additional disinfection or treatment. However, increasingly IHA has encouraged disinfection and treatment of groundwater sources as well.

Additionally, IHA recommends that water distribution mains maintain a residual chlorine concentration of 2ppm to ensure disinfection throughout the network. Water suppliers must regularly test for residual chlorine at various network locations and particularly where water mains dead end.

2. Review of Existing Water System

2.1 Water Sources

Water is supplied to the KID system from two surface-water sources, Langill Creek and East McDermid Creek. A diversion on Langill Creek supplies water to Langill Lake which then follows a natural water course to a man-made reservoir. From there the water follows a natural water course to the system's intake structure and concrete balancing tank. East McDermid Creek follows its natural channel and is diverted to the intake approximately 250m upstream of the tank. The creeks generally supply water between 7-9 months of the year. Each year, typically in July, the creeks run dry and water is supplied solely from the storage volume of Langill Lake and the lower reservoir until fall rains restore flows in Langill and East McDermid Creeks.

Langill Lake is a long, shallow, natural lake with limited water storage. Earthen berms at the north and south ends have been constructed to increase the lake's storage volume to approximately 31,000m^3. Langill Lake is supplied water by both the diversion on Langill Creek and a fresh water spring located beneath the lake. The spring is the only source that replenishes the lake through the months when the Langill Creek is dry.

During the dry months algae will develop in Langill Lake as the water stagnates. A floating siphon in Langill Lake, attached to a raft tethered above the spring, draws fresh water from the center of the Lake. This water is transported from the siphon by a 4" main that travels through the southern earth berm of Langill Lake. The water then follows a natural water course and deposits into the man-made reservoir located approximately 275m to the south.

The reservoir has been constructed in a natural depression and an earthen berm has been constructed at its south end. The reservoir provides a storage capacity of approximately 7000m^3. Water from the reservoir is transported by a 6" main that travels through the berm. This water then flows by a natural water course to the intersection with East McDermid Creek and from there to the system's intake structure. After the intake the water passes through two small plastic settling tanks and from there to the concrete balancing tank. The tank has a volume of approximately 90m^3.

The Lake and reservoir are approximately 100 vertical meters above Krestova. The berms at both locations present flood hazards to the community and require monitoring and maintenance to preserve their integrity. The Deputy Inspector of Dikes with the BC Ministry of the Environment has identified these berms as presenting a flood hazard to the community and has encouraged the KID to develop a plan to decommission them.

Please see Figure 1 of the Appendix A for an illustration of the existing system and infrastructure.

2.2 Current and Future Demands

The system currently has 67 active and 7 inactive residential service connections for a total of 74. The 7 inactive connections have the right to be supplied water but only after the BWN has been removed. Domestic irrigation demand is composed of residential gardens and lawns. There are no commercial or industrial water consumers. The community does not have fire hydrants and does not supply fire flows. The system does not include flow monitoring so accurate consumption data is not available.

A report prepared by Mould Engineering in 2003 estimated that the MDD for the system was 462Lpm (122 USGpm) based on the 81 service connections at the time. The Mould report also anticipated an additional 20 service connections which would result in a future demand of 576Lpm (152 USGpm). This growth has not occurred as the water system is incapable of supplying any increase to demand. However it is expected that once upgrades to the system are completed and supply capacity has increased that more properties will seek to connect to the system. Some of these properties may be existing residences currently supplied by private wells and not by the KID. WSA has used 101 service connections as an estimate of the number of future water users, which represents a 36% increase over current users.

WSA has used the MMCDA to estimate the current and future MDD of the KID and compared those estimates with the estimates presented in the Mould study. WSA has assumed an average of 3.5 people per service connection. The table below illustrates the current and future estimates

Estimate Source	Current MDD (Lpm, 74 Connections)	Future MDD (Lpm, 101 Connections)
Mould Report	462*	576
MMCDA	432	589

*Mould report used 81 current connections

As the table shows, the Mould Report estimates roughly agree with the estimates produced using the MMCDA method. For the purpose of this report WSA will use the MMCDA estimates of 432Lpm current MDD and of 589Lpm future MDD.

As noted in the Recommendations section of this report, WSA strongly advises that, as part of Phase 1 work, the KID seek to confirm demand estimates provided here prior to making final decisions regarding capital upgrades.

2.3 Storage

The system has very limited storage capacity. The 90 m^3 concrete balancing tank provides the only storage downstream from the lake and reservoir described above. The balancing tank is located at the beginning of the distribution network and includes three outlet pipes that supply the three distribution legs of the distribution network. The age of the storage tank is unknown but it has been in service for considerable time. During a site visit in August 2019 the concrete showed evidence of leaching and age.

During wet months the storage reservoir provides sufficient storage to meet the daily consumption demands and is refilled overnight. During dry months the storage capacity is insufficient to meet daily demands and the tank empties through the day and does not completely refill overnight.

The balancing tank is not sealed to the environment and does not prevent animal intrusion. For these reasons it poses a contamination risk to the system.

2.4 Treatment

The system does not include any treatment facilities. As the water is supplied by surface sources it is at perpetual risk of containing harmful pathogens. To protect public health the IHA has issued a Boil Water Notice for water system users.

2.5 Distribution

The gravity distribution system consists of two 100mm (4") PVC mains and one 50mm (2") HDPE main. Each of these mains begins at the concrete balancing tank.

One 100 PVC main is located beside Pine Road and is easily accessible for maintenance. This main travels adjacent to Pine Road to the intersection with Steppe Road where individual 19mm (¾") distribution lines are connected to service properties along Lady Bird Road and Thorpe Road. The 100mm PVC main continues along Pine Road and terminates at Krestova Road where individual 19mm distribution lines are connected to serve properties along Gander Road. This 100mm distribution leg is approximately 1.2km long. The top section of this main from the end of Pine Road to the balancing tank trespasses on private property.

A second 100mm PVC main traverses wooded terrain from the northwest to the southeast and only sections of it are accessible by road. This 100mm main intersects with Krestova Road and continues west to the end of Gage Road. The length of this distribution leg is approximately 2.2km. A 50mm PVC main tees off of the 100mm main at the intersection of Krestova Road and Krestova Cemetery Road and continues north along Krestova Cemetery Road. The 50mm main terminates at Lot 22 and is approximately 360 meters long. The section of this main that traverses the wooded terrain trespasses on private property.

The third main is 50mm HDPE and traverses wooded terrain and private property to the north of Balsam Road and is not easily accessible. The length of the third distribution leg is approximately 520m. The entire length of this main trespasses on private property.

The distribution mains are of varying age as some sections have been replaced. A condition assessment of these mains is outside the scope of this study. As built plans of the distribution network indicate that some of the distribution mains may not have been buried with sufficient ground cover to prevent freezing.

The three distribution mains do not interconnect downstream from the balancing tank and no distribution loops exist. This configuration causes pressure differences between users at different locations along the distribution network. The Mould report indicates that system pressures vary between 345kPa (50psi) to 931kPa (135psi). Although these pressures are within recommended thresholds, the large variance is undesirable. Ideally system pressures are balanced throughout the network.

Generally, distribution loops provide more consistent water quality, balance system pressures, improve system reliability and are beneficial to fire flow delivery as discussed in the next section.

2.6 Fire Protection

The system does not include fire water storage or fire hydrants at this time. The existing network is unsuitable to supply fire flows as the main sizes are smaller than the recommended minimum of 150mm (6") for effective delivery. The small diameter mains make meeting fire flow requirements particularly difficult to achieve due to friction losses caused by large flows through undersized pipes.

The un-looped dead ends in the network also drive up flow velocities as large fire flow volumes must follow a single path. Overall system reliability is reduced when water is delivered through a single main, even if it is sufficiently sized. For these and other reasons, un-looped dead ends are generally avoided in water distribution network design.

3. Improvement Options

3.1 Alternative Source Investigation

As discussed in the accompanying WWAL report (see Appendix B), existing water licences, held by the KID and other water users, for diversions from Langill and McDermid Creeks fully account for the flows provided by these creeks and further water licence diversions are unlikely to be approved by the regulating authority. Furthermore, as the water supplied to the KID from these sources is currently insufficient to meet consumption demand year-round an alternate water source needs to be developed.

WSA understands that the KID is not interested in pursuing a water diversion from the Slocan River. Alternative surface water sources such as Goose Creek are not desirable as, similar to Langill and McDermid Creeks, existing water licences mean that further diversions are unlikely to be approved.

As indicated in the WWAL report, there are numerous ground water wells that provide water to multiple properties in Krestova that are not serviced by the KID. A review conducted by WWAL of some of these wells indicates that it is likely that a test well drilling program will identify a suitable location for a domestic production well to be installed. As surface water sources are either undesirable or unavailable to supply the KID a groundwater source is the best alternative.

Furthermore, groundwater wells that tap into deep, confined and protected aquifers access water that is generally low in turbidity and at low risk of containing pathogens. This can reduce treatment and disinfection requirements for the water system. For example, groundwater is commonly of low turbidity and therefore unlikely to require a filtration system for removal of sediment as surface water sources typically do. Classification of aquifers must be undertaken through careful study by a qualified hydrogeologist and can be completed as part of a test well drilling program. For further details please see the WWAL report.

The WWAL report indicates that an area located at the southeast corner of the community should be considered for test well drilling. There is a vacant property located at the intersection of Krestova Cemetery Road and McKenzie Road that is currently used as a privately operated gravel pit. Improvements discussed in this report assume that a well is developed at this location.

3.2 Water Modeling

WSA has simulated potential upgrades to the system using EPAnet water modeling software. EPAnet is a free, public domain software program developed by the US Environmental Protection Agency and can be used to analyse water distribution networks in both instantaneous and extended duration simulations.

For the modeling exercise it has been assumed that improvements to water supply capacity are available through development of one or more groundwater wells. The model includes improvements to the distribution network to increase the system's capability to supply fire flows. The modeled network includes both new and existing distribution elements. Distribution upgrades included in the model are further described in the Recommendations section below.

Google Earth has been used to provide estimates of local elevation topography and distances. The future MDD demand of 589Lpm (156USGpm) and a fire flow demand of 3000Lpm (793USGpm) have been used to ensure that future growth has been considered in the scenarios described below.

It should be noted that the water modeling conducted for this study is high level and lacks sufficient information to be solely relied on for critical infrastructure decision making. WSA recommends that a more detailed analysis, together with field calibration of the model, be undertaken prior to finalizing any improvement decisions. Furthermore, well capacities can only be confirmed through test well drilling and the completion of well draw down tests.

It should also be noted that, in both scenarios described below, a second domestic supply well and pump should be provided and connected to the distribution network for system redundancy.

Gravity-Pressurized Distribution Network

WSA has modeled a gravity fed distribution network pressurized by a 415m^3 (110,000 USGal) storage reservoir at the balancing tank location which has an elevation of 675m (2200') above sea level (ASL). This site is preferable as there is an existing access road to this location and the KID, by way of the balancing tank, has established use, if not ownership, of this land. The road however is narrow and in poor condition and would need to be improved. Electrical power would need to be extended to the site. Furthermore, the KID would need to have a road easement established and formally acquire the reservoir site land.

The modeled system includes a well located at the intersection of Krestova Cemetery Road and McKenzie Road. A well pump with a duty point of 600Lpm at 170m of head (160 USGpm at 560') supplies the reservoir through the distribution network. A well of this capacity would likely be 200mm (8") in diameter. Within the model some existing sections of the network have been increased in size in order to adequately supply fire flows and maintain minimum system pressures. New sections of the distribution network included in the model are 150mm and 200mm diameter.

The model indicates that, under fire flow conditions, the system pressure is maintained if charged by a reservoir in the location described above and the well pump is operating. Pressure head from the reservoir alone is not sufficient to maintain pressure during fire flows. Therefore well and pump redundancy and provision of emergency backup power will be required to ensure reliable fire protection to FUS recommendations.

The benefits of the gravity-pressurized system include:

- water is available to pressurize the system even during power outages (backup generators would still be required);
- no need for a dedicated fire pump and well
- well and pump can be sized to deliver MDD rather than Peak Hour domestic flows

Extra costs specific to implementing a gravity system include, but may not be limited to, the following:

- cost of building and maintaining the road;
- cost of extending electrical supply to reservoir;
- cost of acquiring the land and building the reservoir

The reservoir would require power for lighting, mixing (to improve water quality and prevent freezing), and communication (alarms). To ensure that the water is not contaminated though the distribution network, chlorine injection would be required to maintain a residual chlorine concentration throughout the system.

This system doesn't require a dedicated well and pump for fire flows. Furthermore it provides domestic water and fire protection even during power outages although backup generators would be required at the well (to power the pump in the event of a fire) and at the reservoir (for chlorine dosing, mixing, and alarms).

It should be noted that, should the well pump not be operable during a fire flow condition, the system will still be capable of supplying water to assist with fire suppression. Our model indicates that with the pump off, but all other network improvements completed, the system can still deliver the required 3000Lpm however the system pressure falls to 35KPa (5 psi) which is below the recommended 140KPa (20 psi) minimum.

Pump-Pressurized Distribution Network

Alternatively, WSA has modeled a pressurized system using two wells and two pumps located at the potential well site described above. In this scenario one well and pump are sized to deliver domestic MDD and the second well and pump are sized to deliver fire flows. This scenario depends on the wells having sufficient capacity and volume to supply these demands so that above-ground storage is unnecessary. The availability of these wells is by no means guaranteed and can only be confirmed through a test well drilling program.

The two pumps are connected in parallel to the distribution network. Under normal conditions only the smaller pump operates. In a fire flow condition both pumps operate concurrently.

The model indicates that a domestic pump capable of delivering 600Lpm at 130m of head (160 USGpm at 427') will supply MDD. Again this will likely require a 200mm diameter well. In order to supply fire flows a dedicated fire pump capable of delivering 3000Lpm at 200m of head (793 USGpm at 656') would also be required. The fire pump well would likely need to be 400mm (16") diameter to accommodate this demand.

The benefits of the pump-pressurized system include:

- no requirement for construction of a reservoir or an access road;
- no requirement for acquisition of reservoir land;
- simplified maintenance as all equipment will be located at well site

Detriments to the pump-pressurized system include:

- increased electrical consumption and maintenance costs as domestic pump runs constantly to maintain pressure
- expense of a dedicated fire pump and well
- no storage of water for emergencies in the event of system disruption or source contamination

- requires a well of sufficient production capacity to supply fire flows

As noted in the WWAL report, existing well logs for the area indicate that most well yields are less than 1/10 the required yield for fire flows. This suggests that it is unlikely that even a large production well could supply the fire flow requirements. This uncertainty of supply diminishes the attractiveness of a pump-pressurized system.

3.3 Storage Upgrades

Storage upgrades will be required if the KID chooses to proceed with a gravity-pressurized distribution system. Should the KID chose to pursue a pump-pressurized system, which WSA does not recommend, then the storage requirements calculated below will be unnecessary.

As noted in the Design Criteria section above, the Fire Underwriters Survey recommends that reservoirs be sized using the following formula:

Total Required Storage = A + B + C, where

A = Balancing Storage	= 0.25*MDD
B = Fire Storage	= (from FUS)
C = Emergency Storage	= 0.25*(A+B)

For rural communities with exposure distances of 10m – 30m between houses (such as Krestova) the minimum fire storage recommended by the FUS is calculated as:

Minimum Fire Storage: = 3000Lpm * 75min = 225,000 L (225 m^3)

The following calculation illustrates the storage requirements for the system using the future MDD estimate of 589Lpm to allow for system expansion:

(A) = 0.25 * 589Lpm *60m/hr *12 hr	= 106,020L
(B) = 3000Lpm * 75 min	= 225,000L
(C) = 0.25 * (A+B)	= 82,755L
Total	**413,775L** (109,000USgal)

We have used a 415,000 liter reservoir for the purposes of this study.

As discussed in the previous section, the reservoir should be located at an elevation sufficient to supply the system by gravity. The water model indicates that with the well pump operating, a reservoir located at 675m ASL will supply fire flows and maintain a minimum residual pressure of 140kPa (20 psi).

3.4 Treatment Upgrades

Interior Health recommends that domestic water suppliers meet the 4-3-2-1-0 Drinking Water Objective (see Section 1.3 Design Criteria above).

Treatment requirements will depend on the nature and quality of the new water source. Groundwater wells tend to supply water that has low turbidity and is at low risk of containing harmful pathogens. However for this to be the case the well must tap into a deep, confined and protected aquifer that is not under the influence of surface water. Classification of aquifers must be completed by a qualified hydrogeologist (see WWAL report.)

Assuming that the test well program is successful and a confined-aquifer groundwater source is established then water treatment requirements may be minimal. In the best case scenario the KID should expect to be required to provide primary treatment by UV disinfection. UV disinfection must occur before the point of entry of groundwater into the distribution network, in this case at the well site.

Furthermore, in-line chlorine dosing equipment will be required to maintain a chlorine residual of 2ppm throughout the network. Chlorine dosing would occur either at the reservoir or at the well site, depending on whether the system is pressurized by gravity or pump. Additional disinfection and treatment equipment may be required depending on the quality of the source water.

These disinfection and treatment requirements are the same for both the gravity and pump-pressurized systems described above. Only the location of the disinfection and treatment equipment may vary.

3.5 Distribution Upgrades

As discussed above the existing system includes three separate water distribution mains, none of which are looped. Looping can improve system operation by limiting pressure variations and can also reduce service disruptions during system maintenance as water services are supplied from more than one direction. Furthermore, fire insurers consider looped systems as more reliable than systems with dead ends.

This study has considered ways to create loops in the system but there are few feasible options available. Dead end roads mean that associated water mains dead end too and private property obstructs looping the dead ends back to the system. Although the distribution upgrades described in the Recommendations section actually create more dead ends in the system, these new dead ends extend fire protection to system users in the near term, which is a priority for the KID. In the medium term, the KID should consider looping these dead ends back to the system as part of future development.

The system does not currently supply fire flows. However if it did the mains would be undersized for that purpose. The FUS recommends that distribution mains that supply fire hydrants be at minimum 6” diameter and 8” diameter for systems where dead ends are likely to exist for the foreseeable future. Delivery of fire flows in smaller mains will result in high flow velocities, high friction losses and premature wear of infrastructure components. Larger diameter mains and distribution loops improve both the capacity and reliability of a system to deliver fire flows effectively.

Portions of the network are difficult to access. Other portions trespass over private property and the KID does not have easements in place to facilitate system maintenance or improvement. In particular this is true of sections of the 100mm main servicing Krestova Road and the 50mm main north of Balsam Road.   Where feasible the improvements presented in this study include the re-use of as much of the network as is practical to keep capital costs down. This includes sections that are currently on private land and/or difficult to access. Improving access and establishing easements for these sections of the distribution network should be a priority for the KID.

Some residences located on McKenzie Road are serviced by connections to the main on Krestova Road that trespass on private property. Elimination of these trespasses has also informed the distribution network improvements presented in this study.

Furthermore, we have assumed that the KID chooses to pursue a gravity-pressurized system and that a storage reservoir is installed at the location of the balancing tank as described in the Gravity-Pressurized Distribution Network section above.

For clarity, discussion of specific upgrades to the distribution network is included in the phased construction approach described in the Recommendations section that follows.

4. Recommendations

The challenges faced by the KID are many and varied. Considering funding restraints it is logical to follow a phased approach to upgrades. As well, the successful completion of earlier phases will impact subsequent phases. For instance, all of the recommendations given here presume that the test well drilling program is successful and that an aquifer of sufficient quality and quality is identified and developed.

With this in mind, WSA recommends the following actions with the caveat that the plan be re-considered after the completion of each.

4.1 Phase 1

Phase 1 will include the following:

- Undertake test well drilling and pumping test program
- Complete water metering program to confirm demands

Phase 1 Discussion:
The test well drilling program is a necessary first step to confirm the availability of a ground water source to supply the KID. All recommendations presented here are predicated on the success of this program. For more information on test well drilling please see the WWAL report.

The system is not well suited to water metering. The only available location to install a single flow meter that will capture all flows is at the outlet of the balancing tank. Installation of a flow meter here would obtain the most accurate flow data. However this would require shutting down the system and draining the balancing tank while the meter is installed. Furthermore, this would require capital investment in infrastructure (the balancing tank) that is soon to be decommissioned.

Alternatively the KID could install residential flow meters at a selection of properties and extrapolate total demand from this sample. Although this would be less accurate that total system metering, residential meters offer the advantage that they could be installed without disruption to the rest of the system. As well, future installation of water meters for all customers would identify leaking pipes, encourage water conservation and allow for a consumption-based fee model. Many communities are moving towards consumption-based fees and the KID should consider the viability of this approach in the future.

Here we have included an allowance of $10,000 to implement a water metering program of whichever method is considered the most appropriate by the KID.

Phase 1 Cost Estimate:

Phase 1	Cost Estimate
Water metering program (allowance)	$10,000
Develop 200mm Test/Production Well & Pumping Test Program	$80,000
Contingency (25%)	$22,500
Phase 1 Total	**$112,500**

4.2 Phase 2

Phase 2 improvements to the system will include the following elements:

- Land acquisition of well and reservoir sites
- Develop second domestic supply well
- Construct pump house
- Connect pump house to distribution network via 150mm main
- Improve access road from end of Balsam Road to reservoir site
- Extend electrical service to reservoir site
- Construct reservoir at concrete balancing tank location and connect (2) existing 100mm distribution legs
- Replace 100mm main on Gage Road with 150mm main
- Replace 50mm main on Krestova Cemetery Road with 150mm main
- Extend 150mm main from Krestova Cemetery Road along McKenzie Road and Mayflower Road and tie to proposed 150mm main on Krestova Road
- Extend 150mm main along Krestova Road from Krestova Cemetery Road to end of Gander Road
- Extend 150mm main from Pine Road along Steppe Road, Lady Bird Road, and terminate at end of Thorpe Road
- Extend 150mm main from Pine Road along Balsam Road
- Abandon 50mm main north of Balsam Road
- Abandon balancing tank, man-made reservoir, Langill Lake siphon and decommission all berms
- Install fire hydrants at 180m intervals along all new mains
- Establish easements for any remaining KID infrastructure that trespasses on private property

See Figure 2, Appendix A, for an illustration of Phase 2 improvements.

Phase 2 Discussion:

Phase 2 will include significant capital expense as it includes the construction of a new pump house and above ground reservoir as well as improvements to the distribution network. Phase 2 will also require land acquisition for the well site and reservoir site and the establishment of easements for the reservoir access road and trespassing water mains. The utility of each of the individual improvements included in Phase 2 is only realized if all elements are operable and working together as a whole. Therefore construction of these elements in a single phase makes the most sense.

After completion of Phase 2 the KID will be compliant with IHA drinking water regulations and will be ready to have the Boil Water Notice removed. Fire protection will be provided to most of the community however one undersized water main will remain, the 100mm main on Pine Road which will be replaced in Phase 3.

Phase 2 also includes decommissioning of the earthen berms at Langill Lake and the man-made reservoir which will remove the threat that these berms pose to the community. Finally, at the completion of Phase 2 all KID infrastructure that currently trespasses on private property will have been abandoned or will be covered by easements.

Phase 2 Cost Estimate:

Phase 2	Cost Estimate
Well site land acquisition (BC Assessment land value)	$80,000
Develop 2nd 200mm domestic well	$40,000
Construct pump house and connect to distribution network (0.3km)	$300,000
Reservoir site land acquisition (assume 5% of BC Assessment land value)	$10,000
Improve reservoir access road (0.8km)	$60,000
Extend electrical service to reservoir site (0.25km, assume 3 spans)	$30,000
Construct 415m^3 reservoir	$585,000
Phase 1 distribution network improvements (5.1km @ $200/m)	$1,020,000
Fire hydrant installation (12 @ $3000 ea)	$36,000
Decommission berms & demolish obsolete infrastructure	$50,000
Establishment of easements for access road and trespassing infrastructure (allowance)	$25,000
Engineering (15%)	$335,400
Contingency (25%)	$642,850
Phase 2 Total	**$3,214,250**

4.3 Phase 3

Phase 3 improvements will include the following:

- Replace 100mm main on Pine Road with 200mm main
- Installation of fire hydrants on Pine Road
- Abandon 100mm main servicing Krestova Road

Phase 3 Discussion:

Replacing the 100mm main along Pine Road with a 200mm main will bring all network pipes up to the recommended standard for fire flow delivery. In addition, by increasing the size of the Pine Road main, the existing 100mm main from the balancing tank to Krestova Road that is inaccessible and trespasses on private property may be abandoned.

See Figure 3, Appendix A, for an illustration of Phase 3 improvements.

Phase 3 Cost Estimate:

Phase 3	Cost Estimate
Phase 3 Distribution Network Improvements (1.3km @ $250/m)	$325,000
Fire Hydrant Installation (2 @ $3000)	$6,000
Engineering (15%)	$50,000
Contingency (25%)	$95,250
Phase 3 Cost Estimate	**$476,250**

4.4 Recommendations Cost Summary & Preliminary Schedule

A summary of the cost estimates for the three phases is shown in the table below:

Cost Estimate Summary	Cost Estimate
Phase 1	$112,500
Phase 2	$3,214,250
Phase 3	$476,250
KID Improvement Recommendations Total	**$3,803,000**

Preliminary scheduling for the project phases is given in the table below.

Preliminary Schedule	Duration
Phase 1	12 – 18 months
Phase 2	24 – 36 months
Phase 3	1 – 2 months

5. Closure

We trust that the information and professional opinions provided in this study are beneficial to the Krestova Improvement District in deciding how best to address the priorities described herein. This study has been prepared for the sole use of the Krestova Improvement District (the Client) for the purposes outlined in the in this study. No responsibility whatsoever for the contents of this study will be accepted to any person other than the Client. WSA Engineering (2012) Ltd takes no responsibility for any damages suffered by any third party for actions taken, or decisions or assumptions made, on the basis of this study.

Should you have any questions with regards to this study please feel free to contact the undersigned.

Sincerely,

Greg Henderson

Greg Henderson, EIT

WSA Engineering (2012) Ltd.

Reviewed By:

PROFESSIONAL ENGINEER
D. R. M. Sahlstrom

Dan Sahlstrom, P.Eng

6. References

Geotechnical Assessment of Krestova Improvement District, Langill Lake Water System, Krestova, BC, WSA Engineering, March 2011

Study of Water Supply, Treatment and Disinfection Options, Mould Engineering, March 2003

Design Guidelines for Rural Residential Community Water System, Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2012

Design Guideline Manual, Master Municipal Construction Documents Association, 2005

Water Supply for Public Fire Protection, Fire Underwriters Survey, 1999

Google Earth images. Retrieved from Google Earth Pro

KRESTOVA IMPROVEMENT DISTRICT

DOMESTIC WATER SYSTEM STUDY

APPENDIX A

FIGURE 1 - EXISTING WATER SYSTEM	DATE: JANUARY 24, 2020	CLIENT: KRESTOVA IMPROVEMENT DISTRICT
KRESTOVA IMPROVEMENT DISTRICT DOMESTIC WATER SYSTEM STUDY	PREPARED BY: GREG HENDERSON	WSA PROJECT NUMBER: C19001-063
	IMAGE SOURCE: GOOGLE EARTH PRO	

WSA ENGINEERING (2012) LTD.
Civil and Structural Engineering
2248 Columbia Ave. Castlegar, B.C. V1N 2X1 Ph:1-888-617-6927

PLAN ROTATION 0°

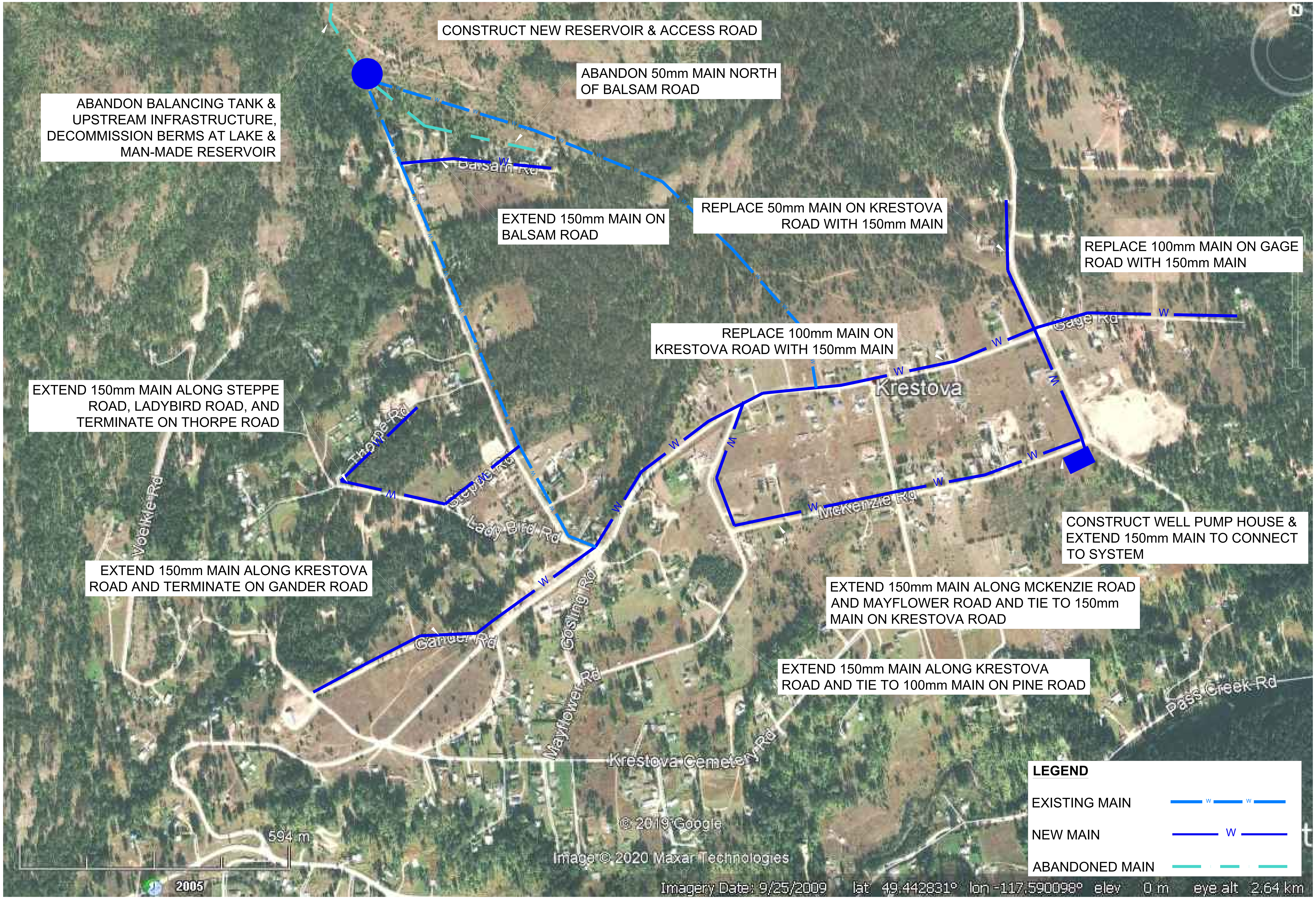

FIGURE 2 - PHASE 2 IMPROVEMENTS	DATE: JANUARY 24, 2020	CLIENT: KRESTOVA IMPROVEMENT DISTRICT
KRESTOVA IMPROVEMENT DISTRICT DOMESTIC WATER SYSTEM STUDY	PREPARED BY: GREG HENDERSON	WSA PROJECT NUMBER: C19001-063
	IMAGE SOURCE: GOOGLE EARTH PRO	

WSA ENGINEERING (2012) LTD.
Civil and Structural Engineering
2248 Columbia Ave. Castlegar, B.C. V1N 2X1 Ph:1-888-617-6927

FIGURE 3 - PHASE 3 IMPROVEMENTS	DATE: JANUARY 24, 2020	CLIENT: KRESTOVA IMPROVEMENT DISTRICT	WSA ENGINEERING (2012) LTD. Civil and Structural Engineering 2248 Columbia Ave. Castlegar, B.C. V1N 2X1 Ph:1-888-617-6927
KRESTOVA IMPROVEMENT DISTRICT DOMESTIC WATER SYSTEM STUDY	PREPARED BY: GREG HENDERSON	WSA PROJECT NUMBER: C19001-063	
	IMAGE SOURCE: GOOGLE EARTH PRO		

PLAN ROTATION 0°

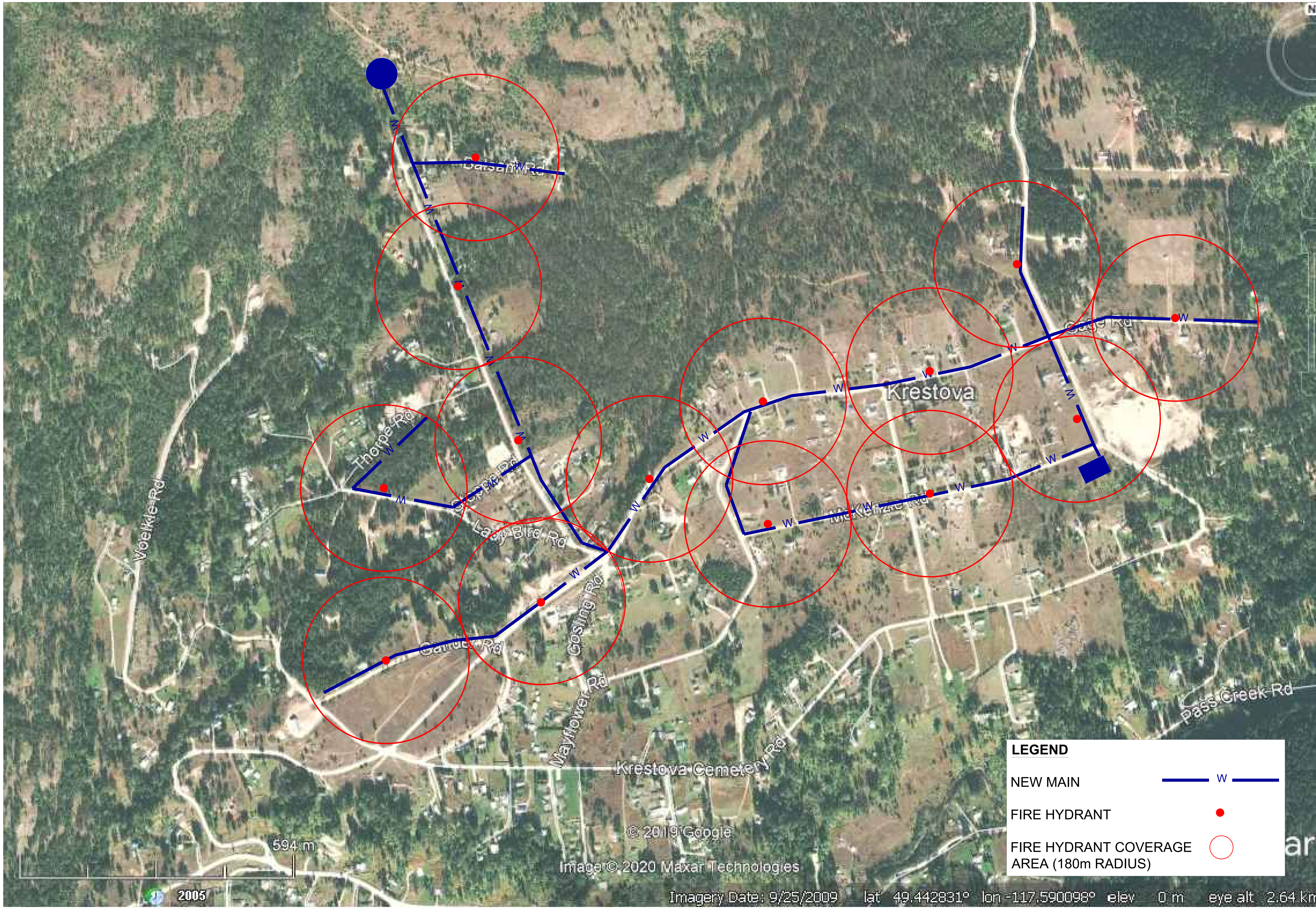

FIGURE 4 - FIRE HYDRANT DISTRIBUTION	DATE: JANUARY 24, 2020	CLIENT: KRESTOVA IMPROVEMENT DISTRICT
KRESTOVA IMPROVEMENT DISTRICT DOMESTIC WATER SYSTEM STUDY	PREPARED BY: GREG HENDERSON	WSA PROJECT NUMBER: C19001-063
	IMAGE SOURCE: GOOGLE EARTH PRO	

WSA ENGINEERING (2012) LTD.
Civil and Structural Engineering
2248 Columbia Ave. Castlegar, B.C. V1N 2X1 Ph:1-888-617-6927

KRESTOVA IMPROVEMENT DISTRICT

DOMESTIC WATER SYSTEM STUDY

APPENDIX B

January 27, 2020 WWAL Project: 19-078-01VR

WSA Engineering (2012) Ltd.
2248 Columbia Avenue
Castlegar, BC V1N 2X1

Attn: Greg Henderson, EIT

Via email: gregh@wsaeng.ca

Re: Groundwater Feasibility Assessment for the Krestova Improvement District, Krestova, BC

Western Water Associates Ltd. (WWAL) is pleased to provide this hydrogeological assessment of the feasibility of developing a groundwater supply for the Krestova Improvement District (KID). The KID is located within the Regional District of Central Kootenay. It is our understanding that the KID currently services approximately 69 lots within the improvement district service area with potable water from a surface intakes on Langill and McDermid Creeks. It is our understanding that the KID is experiencing issues with water availability from their surface water sources in the summer and fall, and has asked WWAL to assess the feasibility of transitioning from a surface water source to a groundwater source. WWAL's main task relates to determining whether sufficient groundwater resources are available to meet KID water system demands. WSA Engineering (2012) Inc. is providing civil engineering expertise to assess the feasibility of this transition from an engineering standpoint.

WSA Engineering provided WWAL with the following water system demands to serve as the basis for our assessment. We understand these water system demands were obtained from a historical water system study/report prepared by Mould Engineering.

- Design Maximum Day Demand of 600 Lpm (159 US gpm)
- Design Fire Flow of 2,000 Lpm (529 US gpm).

Assuming Maximum Day Demand (MDD) is based on a 2.5 peaking factor, current Average Day Demand (ADD) can be assumed to be on the order of 65 US gpm.

The KID holds five surface water licences to supply its current demand and these licences allow for the diversion of water from Langill Creek and McDermid Creek (Table 1, locations shown on Figure 3). McDermid Creek is classified as fully recorded by the Ministry of Forest Lands, Natural Resource Operations and Rural Development (MFLNRORD) and Langill Creek is classified as possible water shortage by the MFLNRORD. When a stream is considered fully recorded by the MFLNRORD, it usually means that no further diversions of surface water (and potentially groundwater that is deemed connected to surface water) within the watersheds of these streams will be considered for approval by the MFLNRORD. Classification of a stream as possible water shortage indicates that periods of water shortage are likely, and new, large water diversion licences are typically not issued.

Table 1. KID Surface Water Licenses

Source	Licence Number	Licence Status	Priority Date	Quantity	Quantity Units
McDermid Creek	C035342	Current	September 17, 1968	33,186	m^3/year
Langill Creek	C035343	Current	September 17, 1968	33,186	m^3/year
Storage Langill Lake	C035344	Current	September 17, 1968	37,004	m^3/year
Langill Creek, Storage Langill Lake, McDermid Creek	C100524	Current	May 1, 1986	147,784 Storage volume 23,436	m^3/year m^3/year
McDermid Creek, Langill Lake	F007903	Current	June 18, 1924	8,297	m^3/year
Total (excluding storage)				222,453 111	m^3/year US gpm

1.0 SITE PHYSIOGRAPHY, HYDROLOGY AND GEOLOGY

The KID is located in the Slocan Valley approximately halfway between Nelson B.C. and Castlegar B.C. The KID is located on gradual hillslopes, bordered by the Selkirk Mountains to the north and west, the Slocan River to the east and the Goose Creek valley bottom to the south (Figures 1 and 2). The largest surface water feature near the KID is the Slocan River, which flows from north to south and discharges to the Kootenay River approximately 5 km southeast of Krestova.

Several smaller creeks flow in the area including McDermid Creek, which originates in the Selkirk Mountains and flows through the western portion of the KID. McDermid Creek drains into Goose Creek, which flows through the valley bottom eastwards and discharges to the Slocan River. Numerous springs and brooks appear to be present in the valley bottom on the north side of Goose Creek, as indicated by the presence of numerous water licenses and points of diversion (Figure 3).

Land within the KID service area slopes mainly southeast with elevations ranging from 650 m asl (above sea level) in the northwest of the KID to 550 m asl near the southeastern boundary of the KID. The Goose Creek valley bottom is at approximately 520 m asl. Figure 1 shows the general location of the KID and the areal extent of the Irrigation District as well as local surface water features are presented in Figure 2.

The closest climate station (Station ID 1141455) to the KID area is located in Castlegar, B.C., approximately 16 km to the south. The recorded average annual temperature and total precipitation from 1981 to 2010 are 8.7°C and 751 mm/year, respectively (Environment Canada, 2019). July and August are typically the warmest months and December and January the coldest. Mean monthly precipitation ranged from 30.4 mm in August to 96.7 mm in November and is fairly consistent throughout the year. Note that these are published climate normals from past decades. Most climate change models for the interior of B.C. predict shifts in the overall seasonal pattern of temperature and precipitation from past “normals.” The main changes expected are warmer, drier summers, and somewhat wetter winters with more precipitation falling as rain (as opposed to snow), particularly in lower elevations. Earlier peak runoff from snowmelt is another outcome of climate change that has already been documented in B.C.

Geological mapping for Krestova, B.C. indicates that the area is underlain by unconsolidated deposits over bedrock with bedrock being largely exposed in areas of higher elevation. Thickness of unconsolidated deposits over bedrock increases with decreasing elevation and consists mostly of colluvial deposits including till in some areas (Jungen, J.R., 1980). Bedrock in the area has been mapped as Nelson Plutonic Rocks mainly comprised of porphyritic granite dated to the Lower Cretaceous 100 to 146 million years before present (Geological Survey of Canada, 1960).

A review of local well driller's logs shows that bedrock is present at shallower depths in the higher elevation areas to the northwest of the KID with the thickness of surficial deposits over bedrock increasing towards the Goose Creek Valley Bottom. Local drill logs indicate that bedrock is generally overlain by sand and gravel with clay lenses in some areas, followed by till over fine sand with varying gravel and silt content.

2.0 HYDROGEOLOGIC SETTING

Provincial mapping shows three aquifers as underlying the project area: Aquifer 513 IIB, Aquifer 1119 IIB and Aquifer 513 IIB (ENV, 2019). Select details for these aquifers are provided in Table 2, below. Figures 4 and 5 illustrate locations of reported water wells in the area labelled with their well tag number and mapped aquifer boundaries, respectively. Figure 6 depicts a cross-section of the expected hydrogeology in the area, created through the interpretation of selected well driller reports for the area. Aquifer mapping and classification in BC uses a three-tiered system to identify the relative productivity, demand and vulnerability to contamination. The first part of the aquifer number refers to the level of development of the aquifer (a factor of yield and demand) and the second letter indicates relative vulnerability. A "IA" aquifer is highly productive, with high demand and high vulnerability to surface contamination. Conversely, a "IIIC" aquifer has a relatively low yield, low usage, and low vulnerability to contamination. More on the BC Aquifer Classification system can be found in the publication by (Kreye et al 1994).

Table 2. Provincially mapped aquifers underlying the subject site

Aquifer Reference Number	Geologic Formation	Overlying Materials	Aquifer Type	Demand	Productivity	Vulnerability
513 IIB	Bedrock	Coarse grained colluvium or glacial till	Partially confined	Low	Moderate	Moderate
515 IIIA	Moderately coarse to very coarse glaciofluvial deposits	Sand and gravel	Unconfined	Low	Low	High
1119 IIB	Sand, gravel or sand and gravel	Clay, silt, sand and gravel	Partially confined	Moderate	Moderate	Moderate

2.1 AQUIFER 513 IIB

Aquifer 513 IIB is mapped as underlying the entire KID, is bounded to the east by the Slocan River and extends between 2 and 3 km west of the Slocan River. To the south the aquifer is bounded by the Goose Creek valley, and from there it extends approximately 7 km north. Aquifer 513 is comprised of fractured bedrock that is overlain by coarse grained colluvium or glacial till. The aquifer is largely confined by silt, clay or till with the thickness of the confining unit decreasing with increasing elevation and ranging from 0 to 122 m. Depth to water in wells completed within the aquifer reportedly range from approximately 17 to 134 m. The aquifer has moderate productivity, with well yields ranging from 0.25 to 50 USgpm, but averaging 10 US gpm. Direct infiltration of precipitation through exposed bedrock within areas of higher elevation is believed to recharge Aquifer 513. Groundwater flow is likely topographically driven, resulting in southward flow from areas of higher elevation towards the Goose Creek valley bottom or eastwards towards the Slocan River.

2.2 AQUIFER 1119 IIB

Aquifer 1119 IIB underlies most of the KID with the exception of some lands in the north and west of the KID boundary. The aquifer overlies bedrock aquifer 513 IIB, extends from north to south from Passmore to Krestova and is bounded by the Slocan River to the east and the Selkirk Mountains to the west. Aquifer 1119 is comprised of glaciofluvial sand, gravel or sand and gravel, and is partially confined by clay, silt or till. Well yields reportedly range up to 100 USgpm with an average yield of 20 USgpm. Depths to water range from 2 to 134 m and well depths range from 9 to 175 m. Recharge to the aquifer likely occurs from mountain block recharge and infiltration of runoff from areas of higher elevation. At Krestova, groundwater flow direction is interpreted to be southeastward, following topography. Where Aquifer 1119 exists adjacent to the Slocan River, the groundwater flow direction may be sub-parallel to river flow.

2.3 AQUIFER 515 IIIA

Aquifer 515 IIIA is a relatively small aquifer, covering approximately 0.8 km^2, with the intersection of Ladybird Road and Krestova Road roughly lying near the centre of the aquifer's mapped extent. The aquifer overlies Aquifers 1119 IIB and 513 IIB, is unconfined and comprised of sand and gravel. Reported well static water levels range from 7 to 11 m and well yields within this aquifer are typically less than 5 US gpm. Recharge to Aquifer 515 occurs through direct infiltration of precipitation and the aquifer is classified as highly vulnerable to surface contamination due to its shallow, unconfined nature.

2.4 LOCAL WELL DRILLER LOGS

WWAL completed a search of the Province's Groundwater Wells and Aquifers database for wells drilled within the KID and its surroundings extending approximately 500 m beyond the KID's boundaries (Province of British Columbia, 2019). Twelve wells are registered within the KID service area and 43 wells are mapped within 500 m of the KID. Reported well yields in the study area are moderate ranging from 0-40 US gpm and two wells were reportedly dry (WTN 401 and WTN55194). We note that most of the logs for deep wells reviewed indicated relatively deep static water levels, especially those in Aquifer 1119 IIB. In our experience, wells with these characteristics can be more productive when pumped with a submersible pump, than the driller's development with compressed air may indicate. Two domestic wells located in the southeast part of the study area are of particular interest as they provide good evidence that there is good groundwater development potential of Aquifer 1119 IIB:

- WTN 105514 was drilled in 2010, and the driller reported at least 17 ft (4 m) of highly productive sand and gravel from a depth of 263-280 ft (80-88 m) and the bottom of the aquifer was not reached; the driller indicated a yield of 40 US gpm based on an airlift test;
- WTN 104167 was drilled in 2009, and the driller noted at least 33 ft (10 m) of highly productive sand and gravel from a depth of 243-276 ft (74-84m), and the bottom of the aquifer was not reached. The driller indicated a yield of 18 US gpm based on an airlift test.

Aquifer 1119 IIB appears to be the main aquifer used in the area. Few wells are reported to be installed in shallow Aquifer 515 IIIA. A summary of select well construction details is included in Table 3 below.

Table 3: Select well construction details for wells located within and near the KID.

WTN	Well Use	Finished Well Depth (ft)	Diameter (in)	Depth to Bedrock (ft)	Depth to Water (ft)	Reported Well Yield (US gpm)	Aquifer
Wells within the KID Service Area							
401	Private Domestic	150	6	-	Dry	-	-
66741	Private Domestic	500	6	485	-	-	513 IIB
66947	Private Domestic	380	6	-	340	4	1119 IIB
77861	Private Domestic	225	6	-			1119 IIB
80305	Private Domestic	367	6	-	290	20	1119 IIB
82178	Private Domestic	457	6	-	344	8	1119 IIB
82179	Private Domestic	46	6	-	30	4	515 IIIA
86180	Private Domestic	390	6	-	340	10	1119 IIB
104221	Private Domestic	316	6	-	276	25	1119 IIB
113186	Private Domestic	160	-	135	120	10	513 IIB
113433	Private Domestic	383	6	-	351	3	1119 IIB
113758	Private Domestic	458	6	-	362	3	1119 IIB
Select wells near the KID							
377	-	267	6	-	210	10	1119 IIB
44089	Private Domestic	258	6	-	127	12	1119 IIB
56157	Private Domestic	192	6	-	143	20 (airlift 10)	1119 IIB
57270	Private Domestic	400	6	269	274	0.5	513 IIB
57429	Private Domestic	60	6	-	37	5	515 IIIA
66196	Private Domestic	315	6	235	160	2	513 IIB
70849	-	242	6	-	210	5	1119 IIB
71637	-	60	5.5	-	27	6.6	1119 IIB
71638	-	60		-	27	5.5	1119 IIB
74697	Private Domestic	580	6	380	440	1	513 IIB
74698	Private Domestic	40	6	-	34	15	515 IIIA
82109	Private Domestic	360	6	239	200	0.5	513 IIB
86199	Private Domestic	403	6	255	340	15	513 IIB
94768	Private Domestic	291	6	-	-	7	1119 IIB

WTN	Well Use	Finished Well Depth (ft)	Diameter (in)	Depth to Bedrock (ft)	Depth to Water (ft)	Reported Well Yield (US gpm)	Aquifer
Wells within the KID Service Area							
104167	Private Domestic	276	6	-	248	18	1119 IIB
105514	Private Domestic	280	6	-	244	40 (airlift 20)	1119 IIB
105615	Private Domestic	715	6	400	250	20	513 IIB
105617	Private Domestic	260	6	-	200	5	1119 IIB
105677	Private Domestic	155	6	35	60	8	513 IIB
109003	Private Domestic	535	6	470	323	20	513 IIB
110785	Private Domestic	520	6	-	167	15	1119 IIB
113449	Private Domestic	755	6	365	356	5	513 IIB
113587	Private Domestic	312	6	-	280	8	1119 IIB
115424	Private Domestic	75	6	-	32	30	1119 IIB

Note: Yellow highlighted wells shown as yellow dots on Figure 4.

We note that there are 12 wells reported on properties within the KID service area, many of them completed in the last 10 years. Until recently, submission of well driller's logs to the province was voluntary, so more wells may be present in the area than the provincial database indicates.

2.5 DISCUSSION

Based on our review, it appears that:

- Bedrock aquifer 513 IIB is likely present under the entire KID service area. Relatively few wells are completed in bedrock, and yields from these wells are variable and dependent on the number and interconnectedness of water-bearing fractures encountered. Reported yields for wells completed in this aquifer are either low (0.5 to 2 US gpm) or moderate (15 to 20 US gpm).
- The majority of the wells in the study area are completed in sand and gravel aquifer 1119 IIB. Well depths vary with the elevation of the drill site, but are typically in the 250 ft to 400 ft range. Static water levels where reported are relatively deep, typically only within ~50 ft of bottom of the well. Driller estimated well yields are variable, ranging from 3 US gpm to 40 US gpm. Of the 21 well logs reviewed in this aquifer, five have driller estimated yields >20 US gpm. A few wells indicated a relatively thick aquifer (5 or more m) that was not fully penetrated.
- Aquifer 515 IIIA is a relatively small unconfined aquifer. Few wells are reported in this aquifer, and those that are have driller estimated yields in the 5 US gpm range.
- Higher yielding wells seem to be predominantly located in areas of lower elevation to the south and southeast of the Irrigation District's boundaries.
- Driller's logs indicate that most wells were only drilled between 4 and 10 ft into the water bearing formation, which is fairly common for private domestic wells as the required yield to service a private dwelling is relatively low and penetrating the entire aquifer is not typically required.

3.0 GROUNDWATER DEVELOPMENT POTENTIAL

Based on our feasibility assessment, it is our opinion that the potential to develop the KID Average Day Demand of 65 US gpm within the bounds of KID service area is good if the relatively thick sand and gravel unit found in wells WTN 105514 and WTN 104167 can be developed. We have noted that the driller-reported yields for wells with deep static levels such as those in Aquifer 1119 IIB may be underestimated. Further, the reported wells are private domestic wells, which are typically constructed to satisfy the modest water needs of a single residence, rather than being constructed to produce maximum possible well yield. Pumping tests would be required to accurately assess the sustainable yield of this type of well. Based largely on the reported lithology of the above mentioned two wells and the fact that other wells did not fully penetrate the aquifer, there is a reasonably good possibility of developing a well (or wells) capable of supplying the design MDD of 160 US gpm or more.

The deign fire flow requirement of 530 US gpm is more than 10 times higher than the most productive reported well in the area. It is unclear at this time whether a well capable of meeting that demand is possible within the KID service area. Drilling and testing of a test / production well to satisfy ADD or MDD demands will provide the information needed to assess the potential of a fire protection well.

Figure 4 depicts the location of reported wells in the Krestova area, and highlights the location of wells completed in Aquifer 1119 IIB with driller estimate yields of 18 US gpm or more. We note that there is a cluster of such wells in the southeast corner of the KID service area that include the wells discussed above that indicate a potentially thick and productive aquifer. In light of the above conclusions, this is the area that should be considered for an exploratory test well. Details on potential test well drilling are found in the report recommendations below.

4.0 GROUNDWATER LICENSING / COMMUNITY WELL APPROVAL PROCESS

Should the KID proceed down the path of pursuing a groundwater source, the source would eventually require a new-use groundwater licence. Licensing of groundwater in B.C. began in 2016 with the introduction of the Water Sustainability Act. Since 2016, all new wells for purposes other than private domestic (one well servicing one home) require a groundwater licence.

The groundwater licence application process can be lengthy, and in our experience the processing time for new-use groundwater licence applications is one year or more. To support a groundwater licence application, a technical assessment of the well is required. The Province has produced a *Guidance Document for Technical Assessment Requirements in Support of Groundwater License Applications* which outlines the information requirements for technical assessments. Technical assessments are typically based on pumping test programs and include evaluating well interference effects, aquifer parameters, water quality and seasonal effects on well yields. In this case, it is likely the technical assessment would also have to address the potential of a new well affecting existing licensed users on springs and brooks in the area.

A review of the B.C. Water Resource Atlas indicates that Goose Creek and its tributaries are fully recorded, meaning no new surface water allocations would be issued. The status of these streams may have an impact on the ability to obtain a licence from a groundwater well, as typically aquifers that are hydraulically connected to fully allocated streams are also considered to be fully allocated. In the case of the KID, a work around is likely possible (assuming the aquifer was hydraulically connected to a stream). This would involve relinquishing some of the KID's surface water licences in exchange for a groundwater licence on a new well, as the surface sources used by the KID eventually report to Goose Creek.

Should a viable community supply well be found, the well would then need to be permitted through the Interior Health Authority (IHA) for use as a potable well. This is a three-stage process including New Source Approval, Waterworks Construction Permit, and Operating Permit. The Waterworks Construction Permit process typically involves the services of a civil engineer who would prepare water system design drawings for the pumping, treatment and distribution system for approval by the IHA public health engineer.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of our assessment, we offer the following conclusions:

C1 Three aquifers are present in the Krestova area, bedrock aquifer 513 and sand and gravel aquifers 1119 and 515. Aquifer 1119 is the most extensive and most productive. The average driller-estimated yield for wells completed in Aquifer 1119 in the study area is ~10 US gpm, while some wells are reported with estimated yields in the 20 – 40 US gpm range.

C2 Considering the KID water demands, there is good potential that a well (or perhaps two wells) capable of producing the KID design Maximum Day Demand of 160 US gpm can be constructed in the general Krestova area if the same aquifer encountered at WTN 105514 and WTN 104167 can be developed. There is a strong likelihood that a well capable of meeting the KID average day demand of about 50 US gpm can be developed in the area.

C3 Should the KID elect to attempt a test well, we would recommend that Aquifer 1119 be the target. If a test well were completed, we would recommend a drill site in the southeast corner of the KID service area, as shown on Figure 4. This area is in and around Cemetery Road, though we note the cemetery is well west of the target drill area. All wells must be at least 30 m from septic systems and 120 m from cemeteries per Health Regulations.

C4 A new use groundwater licence would be required for a new production well, and a groundwater licence application would have to be supported by a technical assessment of the well and aquifer. We believe it is likely the KID could obtain a licence for a new groundwater source, but it would likely involve relinquishing a corresponding volume from their existing surface water rights.

Based on the above conclusions, the following recommendations are made:

R1 Based on input from the KID and the results of the engineering feasibility study, confirm the minimum yield requirement from a groundwater source which would be useful to the KID to replace or augment their surface water supply. If the KID desires a well that can, at a minimum, meet an average day demand of approximately 65 US gpm, a test-production well should be drilled if lands in the vicinity of the target area shown on Figure 4 can be accessed.

R2 In terms of well sizing, there are three options that should be considered:

1) For strictly a test well, which could potentially be converted to a production well capable of meeting the design ADD, a 6-inch diameter well can be considered.

2) For a test well, which if successful, could meet the design MDD of 160 US gpm, an 8-inch diameter well is recommended.

   i. Prior to proceeding with any test well drilling, the lift requirements and pump specifications should be assessed by a civil engineer (i.e., can a pump capable of fitting inside a 6-inch diameter well deliver 65 US gpm to the desired elevation? Can a pump fitting inside an 8-inch well deliver 160 US gpm to the desired elevation).

3) For a well capable of providing the design fire flow requirement of 530 US gpm, a 10-inch diameter well would be required. We do not recommend proceeding directly to 10-inch well in a test well program.

R3 Prior to proceeding with a test well, it may be informative to complete a pumping test on one of the existing, relatively productive wells reported near the southeast corner of the KID service. WTNs 105514, 104167 or 80305 would be good candidates for a pumping test. A pumping test would require permission from the well owner, and the services of a qualified pump contractor to complete the testing. The testing program should be designed by a hydrogeologist who would also evaluate the results.

6.0 COST ESTIMATES

To aid with the overall feasibility study, we provide the following cost estimates for well drilling, pumping tests, and hydrogeological oversight/reporting for various tasks.

Table 4: Cost Estimates for Well Drilling, pumping Test and Hydrogeological Oversight

Task	Cost Estimate
Complete a pumping test on an existing well. Step test and 24-hour constant rate test, completed by a Qualified Pump Installer.	$15,000
Hydrogeological Oversight, Data Analysis, Water Sample and Reporting.	$5,000
Total	$20,000
Complete a 6-inch diameter test well. Assume Depth of 350 ft, 10 ft of well screen.	$25,000
Complete an 8-inch diameter test/production well. Assume Depth of 350 ft, 10-15 ft of well screen.	$35,000 to $40,000
Complete a 10-inch diameter fire protection well. Assume Depth of 350 ft, 20 ft of well screen.	$60,000
Pumping Test Program on a successful test well. Step Test and 48 hour constant rate test by a Qualified Pump Installer.	$20,000
Hydrogeological oversight of test well and pumping test program, water sample, reporting, water licence application.	$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.

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Jan-27-2020

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Hydrogeologist

Attachments: Figures 1 through 6

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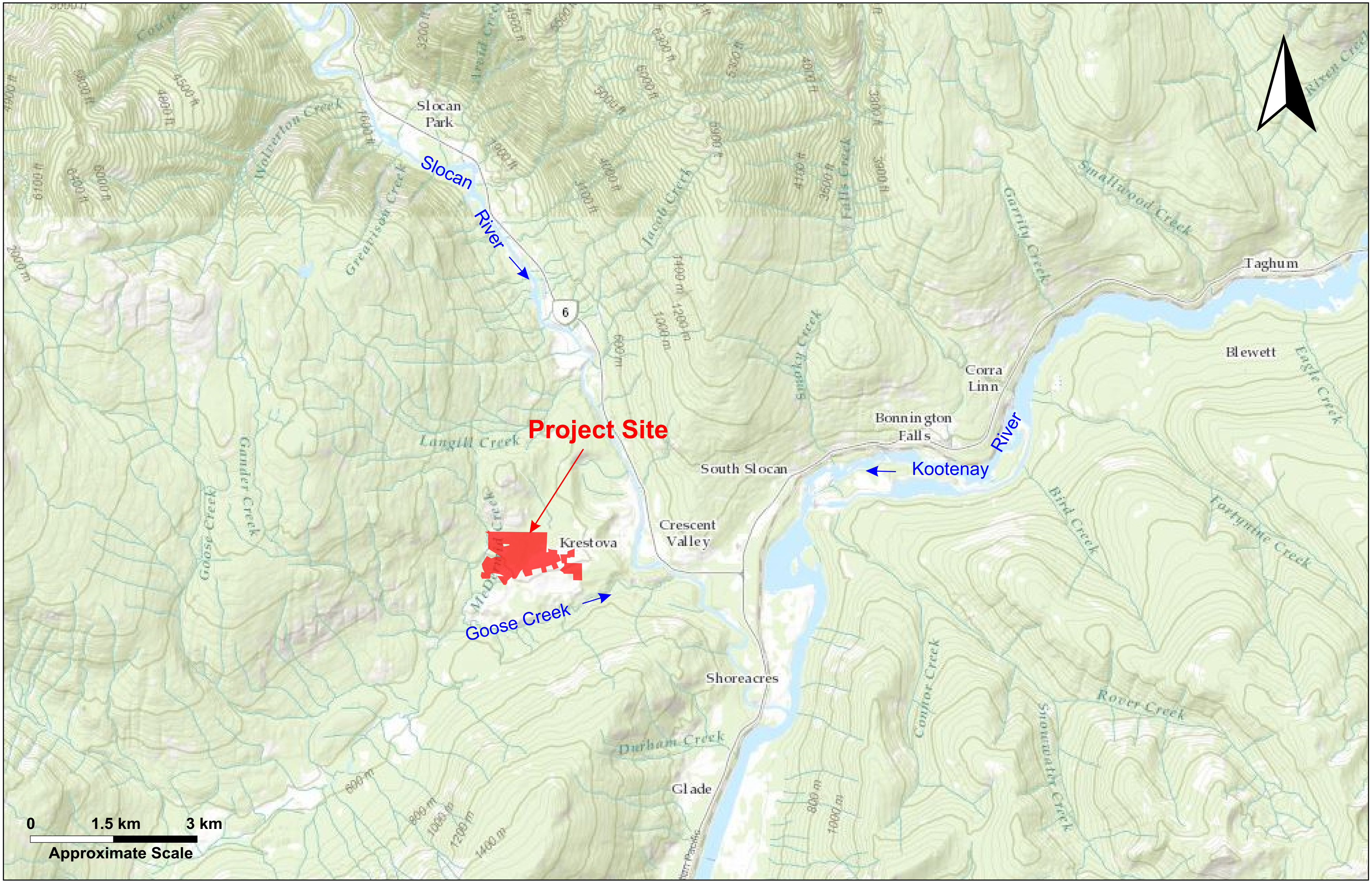

Figure 1: Site Location Plan

Date: September 2019	Image Source: BC Water Resources Atlas		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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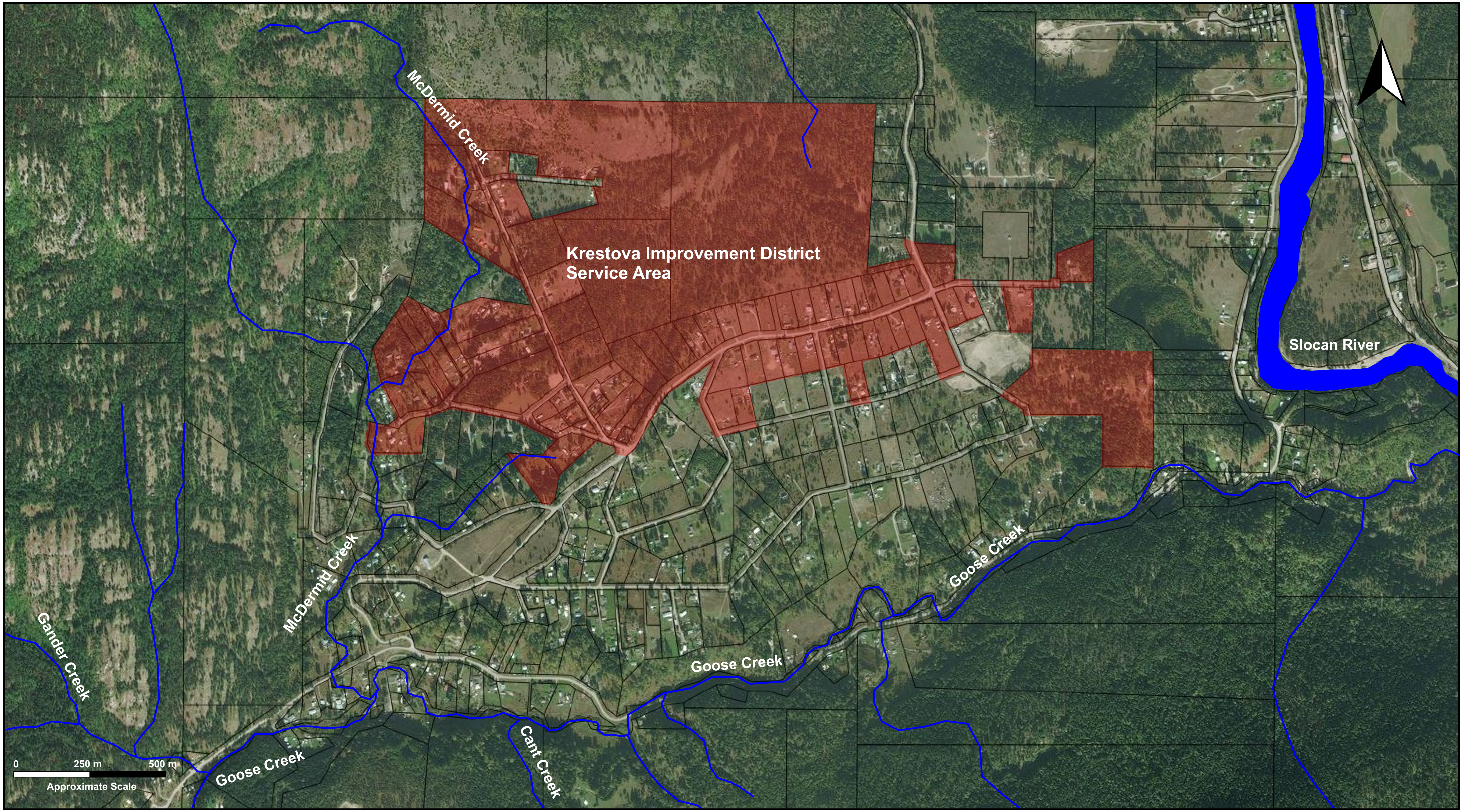

Figure 2: Krestove Improvement District Service Area and Creeks in the Area **KID Service Area Boundary based on maps provided by WSA Engineering.**			
Date: September 2019	Image Source: BC Water Resources Atlas		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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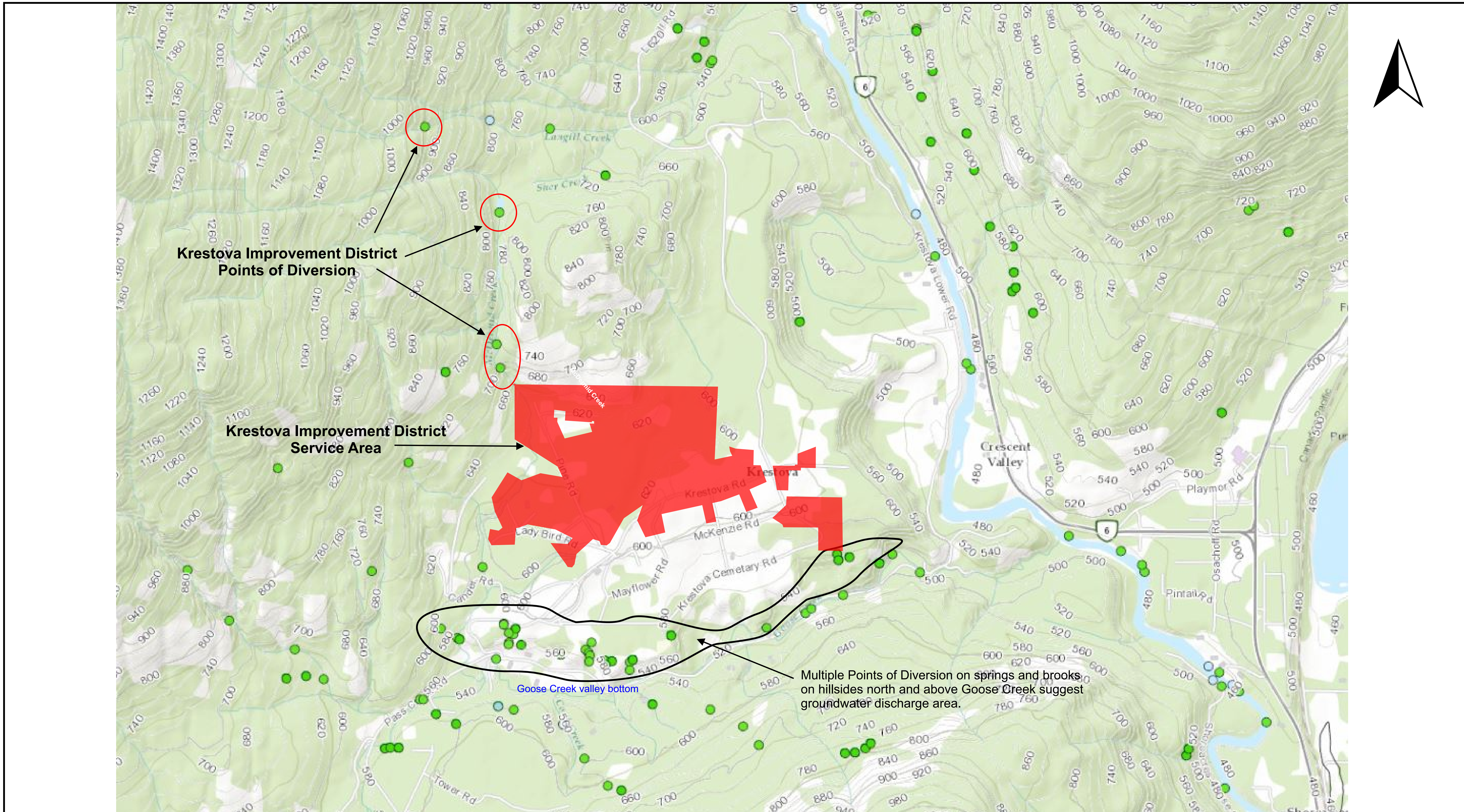

Figure 3: Krestova Improvement District Service Area and Registered Surface Water Points of Diversion (Green dots)

Date: September 2019	Image Source: BC Water Resources Atlas		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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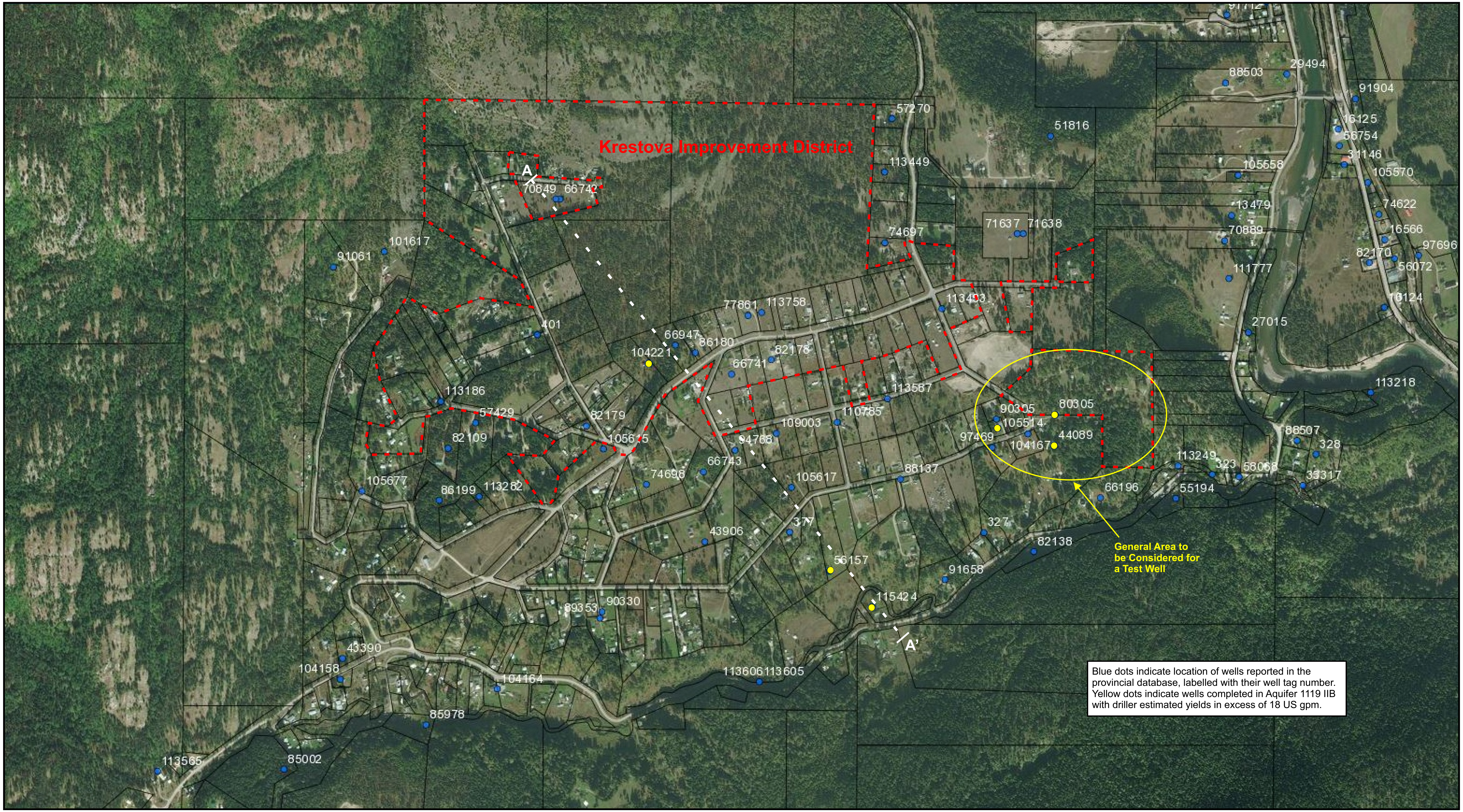

Figure 4: Wells Reported in the Krestova Area and Cross-Section Trace

Date: September 2019	Image Source: BC Water Resources Atlas		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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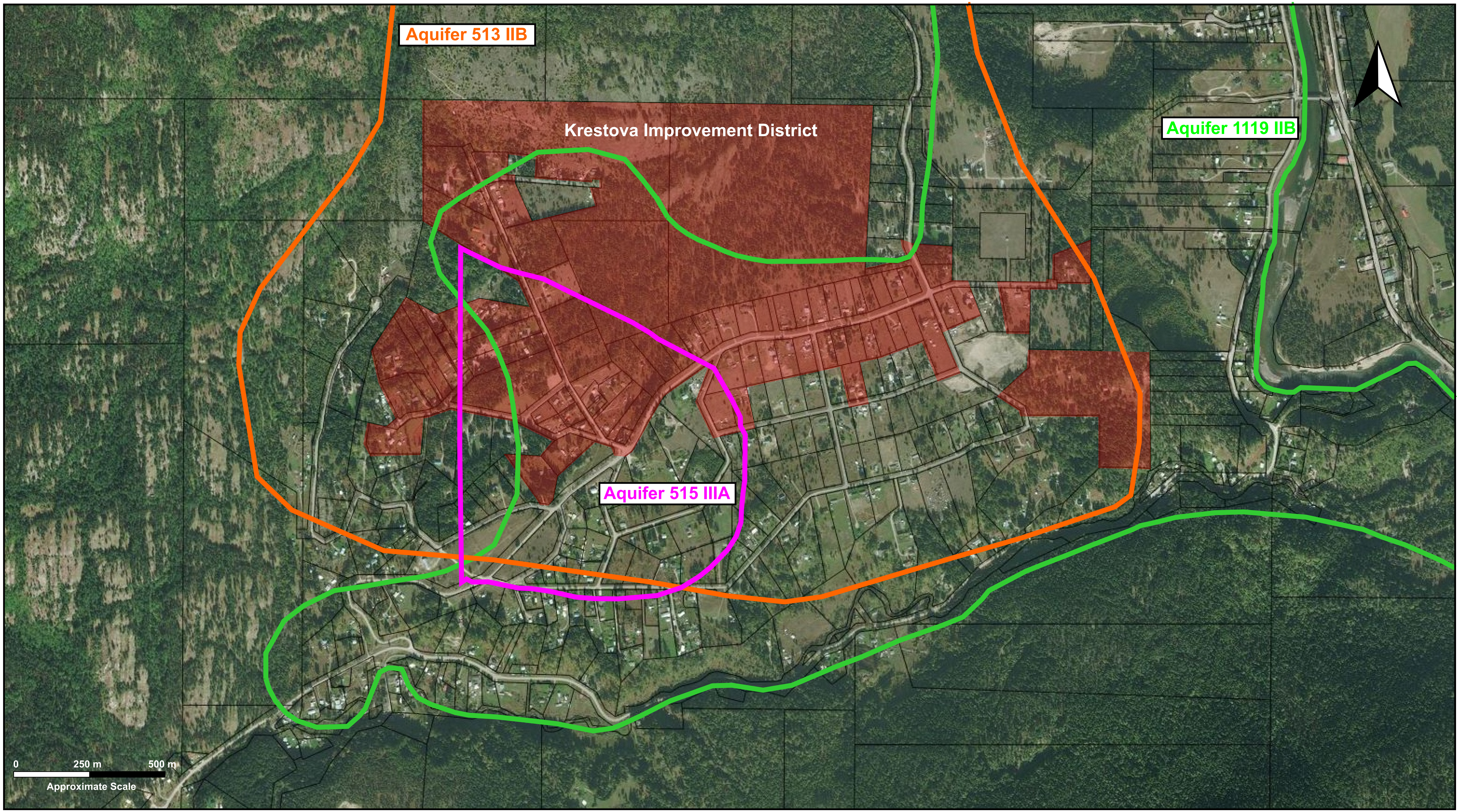

Figure 5: Aquifer Mapping in the Krestova Area			
Date: September 2019	Image Source: BC Water Resources Atlas		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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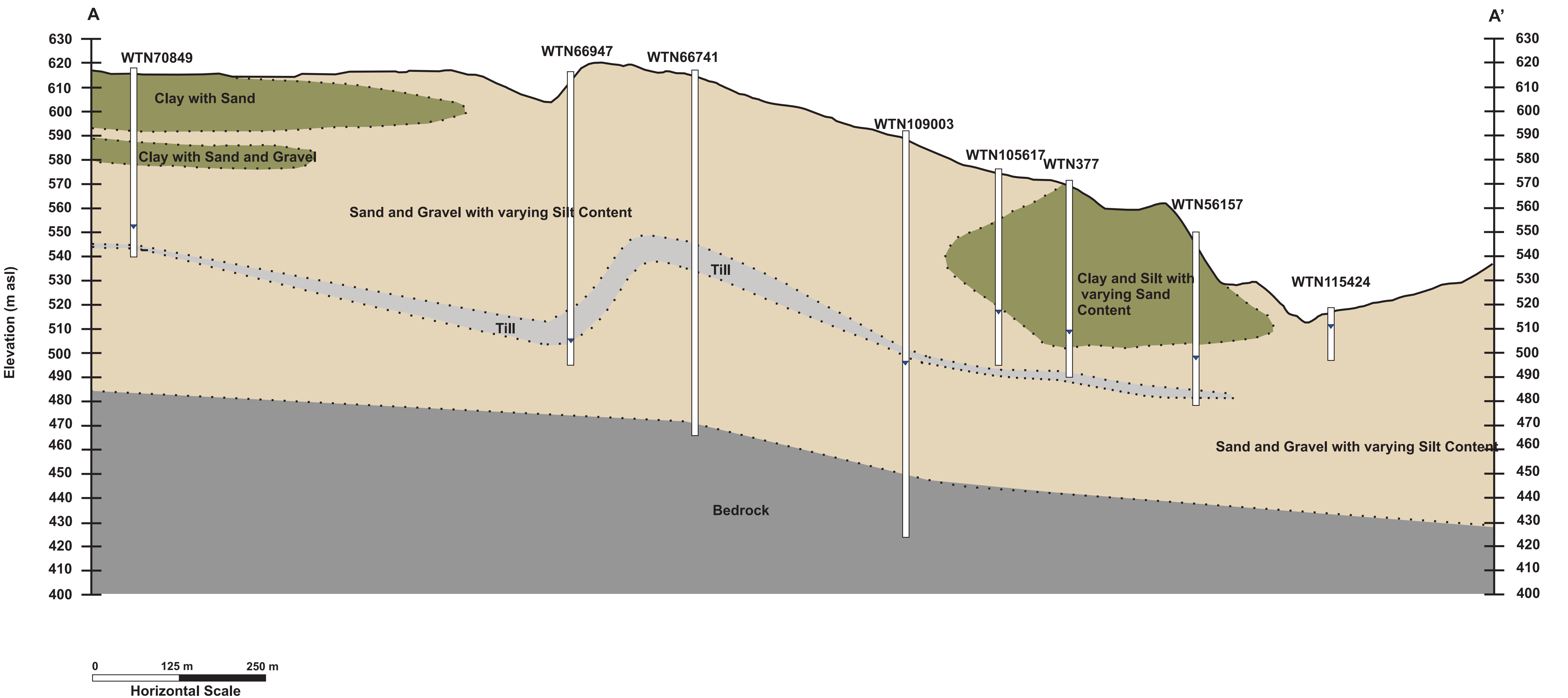

Figure 6: Cross-section A to A' (See Figure 4 for cross-section trace)

Date: September 2019	Cross-Section Transect from Figure 2		WWAL Project: 19-078-01VR
Drawn by: LG	Checked by: RR	Client: WSA Engineering Ltd.	Client Project: N/A

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