District of Lantzville

WATER SUPPLY
&
DISTRIBUTION SYSTEM STUDY

July 2015

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July 16, 2015
1420-01

District of Lantzville
7192 Lantzville Rd
PO Box 100
Lantzville, BC V0R 2H0

Attention: **Mr. Fred Spears**
Director of Public Works

Re: District of Lantzville
Water Supply & Distribution System Study

We are pleased to submit five bound and an electronic (pdf) copy of our District of Lantzville Water Supply & Distribution System Study.

The report provides a comprehensive analysis of the District's water supply and distribution system, and projects water supply requirements to service the properties within the District's OCP Map 7 - Water Service Area that are presently not serviced.

A detailed computer network analysis of the water distribution system was carried out and improvements needed to meet pressure and flow, including fire flow, requirements under existing and future conditions have been identified, including: watermain looping; watermain upgrading; and reservoir storage expansion.

The District's current design water demand per lot is higher than the calculated usage over the past 19 years. A review of design standards for other mid-Island municipalities revealed that the District's design demand is in the middle range compared to the other municipalities and is similar to its closest neighbours (Nanaimo and Parksville).

To date, the District's water supply source has been able to meet the maximum day demand. This is due in part to the very low demands of the system users. The District's average day and maximum day demands per capita are between 60% and 65% of those of its closest neighbor; the City of Nanaimo.

It is essential that, though a review of current demands along with the estimated capacity of the wellfield suggests additional properties can be serviced, the District first carry out the wellfield upgrading works in an effort to increase the pumping capacity of the wells to that of the long-term sustainable yield. Upon confirmation of the increased pumping rates and their sustainability, consideration should then be given to providing service to additional properties.

The provincial government has recently enacted the Water Sustainability Act (Bill 18) which requires the registering and annual licensing of groundwater wells. The District should register the wells as soon as possible.

…/2

District of Lantzille
Mr. Fred Spears

We have enjoyed working on this important study. We would be pleased to discuss implementation of the recommendations with staff and Council and look forward to assisting the District in the further development of its water system.

Yours truly,

KOERS & ASSOCIATES ENGINEERING LTD.

C. M. D. HOLMES
Jul. 17 2015

Chris Holmes, PEng	Rob Hoffman, PEng
Project Engineer	Project Manager

District of Lantzville

WATER SUPPLY & DISTRIBUTION SYSTEM STUDY

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D OCP Map 7 - Water Service Area

1 INTRODUCTION

1.1 AUTHORIZATION

In December 2014, the District of Lantzville authorized Koers & Associates to carry out a comprehensive water study. The study was to assess the present and future capacity of the District's water supply source, analyze the water distribution system, and provide recommendations to maintain an adequate level of service both now and in the future.

1.2 BACKGROUND

<u>1955 - 1969</u>
On November 7, 1955, by Order in Council of the Provincial Government, the Lantzville Improvement District was incorporated under the Water Act. Ten years later, on November 16, 1965, the West Lantzville Waterworks District was incorporated.

On November 13, 1969, the West Lantzville Waterworks District amalgamated with the Lantzville Improvement District (LID).

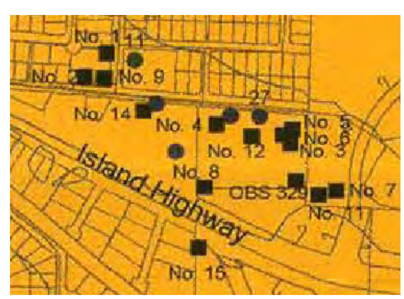
<u>1970 - 2002</u>
By 1984, the water system consisted of two pressure zones; the high pressure zone servicing the Winchelsea subdivision area and the low pressure zone servicing the remainder of the improvement district. There were three water storage reservoirs in the system. The lower pressure zone contained the Harby Road reservoir and the Phillips Road reservoir. The high pressure zone contained the Aulds Road reservoir. The ability of the water system to operate effectively and provide fire flows was assessed using a computer modelling program.

The exact number of wells in use in 1984 is unconfirmed but a 6th well (Well 11) was identified for development to meet increasing demand. Well 11 was constructed around 1988/89 followed by Well 12 in 1990. By 1996, there were five wells in use (Wells 4, 5, 6, 9 and 12).

In 1991, an engineering report for the LID recommended continuous monitoring of water levels at each well in order to understand the capability of the aquifer.

In 1996, an engineering report for the LID identified that a new water source(s) would be needed if all of the properties within the Water Development Area in the RDN's Official Community Plan for the Lantzville area were to be serviced by the LID water system.

In 1998, test well 14 and 15 were developed. Well 14 was developed to assess the potential to increase the withdrawal from the wellfield aquifer. Well 15 was developed to explore the southern boundary of the aquifer and to potentially serve as the supply source for a trailer park affected by the expansion of the Island Highway. Both wells produced lower yields than expected. Well 15 did not encounter a viable aquifer and the casing was pulled.



<u>Wellfield Wells, Past & Existing</u>

In 2002, three water studies were completed for the LID as follows:

- The *Harby Road Wellfield Management* study reviewed water quality, aquifer capacity, and current practices for the Harby Road aquifer. The study conclusions included a caution that under the then discharge rates, the aquifer depletion may be occurring. Further development of the aquifer was discouraged. Close monitoring of the response of the aquifer to water extraction and climatic conditions was recommended.

- The *Hardy Creek Feasibility Study* evaluated the potential of development of a future groundwater supply in the Hardy Creek area with the drilling of a test well at the west end of Southwind Road. The yield was less than anticipated and it was concluded the well was not viable as a sustainable community water supply source.

- The *Water Quality Assessment Project* report reviewed the performance of the water system including well supply, storage capacity, fire flow capability and maintenance procedures; evaluated planned improvements and identified alternatives; evaluated water treatment requirements and options, and assessed the effectiveness of proposed improvements under current and future conditions using a water distribution system computer modelling program.

In 2002/03 Well # 5 was abandoned. It is understood that its operation interfered with Well #6, such that there was little to no increase in overall water production with both wells were running.

<u>2003</u>
After a successful referendum, the Lantzville Improvement District ceased to exist and was replaced by the District of Lantzville, becoming the 155th municipality in BC on June 25, 2003. The population was estimated to be approximately 3,500.

<u>2005 - Present</u>
Since becoming a municipality, there has been a number of significant events within the District, including:

- Development of an Official Community Plan
- Implementation of Subdivision & Development Bylaw and Development Cost Charge Bylaw
- Implementation of water source requirements for new lots
- Construction of municipal sanitary sewer collection system, Phases 1 and 2 (2006-2011)
- Replacement of the Phillips Road reservoir with the Ware Road reservoir and construction of a dedicated supply main (2006)
- Proposed multi-phased Foothills development
- Development of an emergency water service connection with the City of Nanaimo
- Various watermain upgrades and available fire flow improvements
- Signing of water supply agreement with the City of Nanaimo

1.3 PREVIOUS STUDIES

The ongoing need to understand the extent and yield of the District's wellfield aquifer and how to manage it and the water system to meet current and future demands has resulted in a number of water supply and distribution system studies. This has included investigations into additional water supply source(s); both ground and surface. **Table 1** presents a list of water supply and distribution system studies we are aware of that were completed for the District of Lantzville (and the former Lantzville Improvement District).

Table 1
Previous Water Studies

Date	Study	Author
1984	Water Study – Source & Supply	Chatwin Engineering Ltd (CEL)
1984	Distribution System Analysis *	CEL
1988	Water Supply Study	CEL
1991	Reservoir Site Selection Study	CEL
1996	Harby Road Well No. 11	Turner Groundwater Consultants
1996	Arrowsmith Water Service *	CEL
1999	Well No. 14 and 15 Drilling & Testing Program *	Agra Earth & Environmental
2001	Community Water System Report *	unknown
2001	Water Quality & Reservoir Storage Review	CEL
2002	Harby Road Wellfield Management *	EBA Engineering Consultants Ltd (EBA)
2002	Hardy Creek Feasibility Study *	EBA
2002	Water Quality Assessment Project *	Koers & Associates Engineering Ltd
2012	Water Supply Integration Options Study *	Koers & Associates Engineering Ltd.
2014	Technical Memorandum No 1 & 2 – City of Nanaimo & DoL Water Agreement *	Koers & Associates Engineering Ltd.
2014	Phase 1 of Stage 1 Wellfield Management Plan – Wellfield Capacity, Existing and Ultimate, Harby Road Wellfield *	Lowen Hydrogeology Consulting Ltd.
2015	Harby Road Wellfield – Estimation of Well Efficiencies *	Lowen Hydrogeology Consulting Ltd.

Note
* Koers has a copy of the report.

1.4 REGIONAL WATER SYSTEM

The function of a regional water supply system naturally falls under the regional governing municipal authority; the Regional District of Nanaimo (RDN) which was incorporated in 1967.

<u>1972 - 1988</u>
The first regional water study was undertaken in 1972. Three potential future surface water sources where identified with the one closest to the then LID being the Englishman River.

In 1988, after completion of an integrated regional water study focusing on the Englishman River and the Nanaimo River, South Fork – Jump Creek sources, it was decided it would be more feasible for the Greater Nanaimo Water District, which is now the City of Nanaimo, to proceed on its own.

<u>1990 - 1995</u>
With the Greater Nanaimo Water District being developed to service the City of Nanaimo, a referendum was held and approved, in 1990, to carry out a pre-design for a regional water supply system to service the area from Lantzville to Qualicum Beach, focusing on the Englishman River and Bonnel Creek as supply sources. The work, carried out between 1991 and 1993, culminated in a 1995 LID referendum for detailed design and construction of the regional water supply system. The referendum was not successful.

<u>1996 – 2000</u>
In 1996, the RDN, City of Parksville, and Town of Qualicum Beach formed the Arrowsmith Water Service (AWS) and oversaw construction of the Arrowsmith Lake Dam, the first stage of the development of the regional water supply system.

<u>2001 - 2011</u>
Planning and implementation work continued on the AWS project including refinement of the water supply intake location and water treatment requirements.

The Foothills development proposed within the municipal boundaries of the new District of Lantzville was required to develop a water supply source to meet the projected demands which were beyond the understood capacity of the District wellfield aquifer as per the conclusions of the 2002 Harby Road Wellfield Management Report.

In 2011, the Englishman River Water Service (ERWS) venture was formed between the City of Parksville and the RDN as the Town of Qualicum Beach opted out of future capital works related to the regional water intake and treatment system.

<u>2012 - Present</u>
The continued growth of the City of Nanaimo has brought urban development and the City's water distribution system to the eastern boundary of the District of Lantzville.

On September 8, 2014, the District of Lantzville and the City of Nanaimo signed a bulk water sale/purchase agreement. The agreement is the fulfilment of more than 9 years of work since the District and the City signed a Memorandum of Understanding for the supplying of water.

In order to obtain water from the City, the District must construct infrastructure to connect to the City's water system. The agreement includes language on what areas of the District the water is to be used, how many connections per year are permitted and the costs payable to the City's per connection along with an annual consumption fees. A copy of this agreement is presented in **Appendix A.**

1.5 STUDY OBJECTIVES

The objectives of this study are threefold:

Water Distribution System

- Update the computer model of the District's water system and carry out an analysis to identify works necessary to provide peak hour and maximum day plus fire flow demands under current conditions.
- Analyze the water system with respect to storage volume requirements under existing and future conditions, and in relation to the two pressure zones. Identify location options for additional storage.
- Identify options to provide water supply and fire flows to residents in the Northwind/Southwind area.

Water Demands

- Review current water use patterns and demands (annual vs seasonal vs monthly, average day vs maximum day).
- Compare actual demands with other mid Vancouver Island municipalities.
- Compare design demands with other mid Vancouver Island municipalities.

Wellfield Capacity Investigation

- Review previous reports and documents
- Review current production of each well and compare against historical *(by Lowen Hydrogeology Consulting Ltd, LHC)*
- Review well draw down and recovery rates *(by LHC)*
- Assess sustainable yield for each well and for the wellfield. If ability to extract additional water is identified, identify probable location, drill test well and carry-out pumping test *(by LHC)*
- Assess population that can be sustained by the District's well field.

1.6 SCOPE OF WORK

To meet the study objective, the following work plan was adopted:

Project Start-up Meeting, Data Collection & Review

- Meet with District staff to review the project scope and work plan.
- Obtain and review the following documents:
    - Land-use and OCP document and maps
    - Wellfield daily water bulk metering records for the past three years
    - Individual meter records for the past three years
    - Proposed land development information (location, type of, phasing of developments, including year of construction start)

Model Development

- Update in-house model of the District's system to reflect current conditions.
- Re-confirm PRV settings, reservoir control settings (top water level, control valve open and close), and booster pump settings. Enter information into water model.

Population and Demand Projections

- Review population figures from the 2011 Census, BC Stats, anticipated growth rate from the District's Planning Department
- Obtain and review the District's wellfield bulk water daily readings for the past three years.
- Obtain and review the District's individual water meter monthly readings for the past three years.
- Develop existing average day, maximum day and peak hour demands for the entire system based on historical use.
- Compare District's demands with neighbouring municipalities.
- Develop demands based on growth projections.

Modelling Analysis Criteria

- Establish modelling analysis criteria for distribution system (minimum system residual pressures during peak hour and fire flow demands, maximum static pressures, maximum velocities in mains, pipe friction factors) and reservoir storage requirements.

System Analysis

Existing Conditions

- Allocate water demands under existing conditions based on location of individual metered demands. Residential demands will be added in clusters consisting of approximately 10 locations per group. Commercial, Industrial and Institutional will be added based on meter location.
- Run model for existing conditions for three demand conditions; average day; maximum day plus fire flow; and peak hour.
- Check results of each against design criteria.
- Identify system shortcomings (inadequate pressures or fire flows, velocities that exceed design guidelines, dead-end mains) if any.
- Adjust model, re-run as needed to establish extent of required works. Investigate if other upgrading options are possible.
- Using 24 hour extended time modelling feature, confirm system's ability to refill the reservoirs.
- Check reservoir storage capacity against design requirements.
- Develop phasing plan of works.
- Prepare cost estimate (Class D – order of magnitude) of proposed works.

Servicing Northwind/Southwind Area

- Allocate water demands for existing conditions and add watermains.
- Run model under the three demand conditions to confirm watermain sizing.
- Identify potential area for new water balancing storage reservoir to service this area and future development in the area. Run model to assess impact on watermain sizing.
- Using 24 hour extended time modelling feature, confirm the system's ability to refill the reservoirs.
- Prepare cost estimate (Class D) for required works.

Wellfield Sustainable Yield (Capacity) Review

- Review past well drilling reports, wellfield aquifer reports, and other groundwater reports for the general areas.
- Review current production of each well and compare against reported historical information on pumping rates and well yields.
- Review current well draw down and recovery rates. The District has provided these records on file as part of their SCADA system; both historical and current readings.

- Assess sustainable yield for each well and for the wellfield.
- If ability to extract additional water is identified, identify probable location, drill test well and carry-out pumping test.

The hydrogeological investigation work was carried out by Lowen Hydrogeology Consulting Ltd. directly for the DoL. Their findings are presented in the 2014 and 2015 reports listed in **Table 1**. An overview of their findings is presented in Section **3 Wellfield Capacity** of this report.

Draft Report

- Present findings in a bound draft report, complete with plans, illustrations, graphs, tables, discussion, cost estimates, conclusions, and recommendations. A coloured plan drawing showing the District's water system and proposed works will be included.
- A digital (pdf) copy of the draft report will be submitted to the District for review. Upon review, a meeting will be arranged with staff to discuss the report, and agree on modifications or additions.

Final Report

- Submit final report upon receipt of District comments. A digital (pdf) and four bound copies of the report will be provided.

1.7 ACKNOWLEDGEMENTS

Koers & Associates Engineering Ltd. acknowledges with thanks, the assistance provided by District staff, during data collection, analysis and report preparation.

2 WATER SYSTEM

The District of Lantzville obtains it water from four wells. The water from the wells is pumped to one of the District's two reservoirs where it is chlorinated before entering the water distribution system.

A brief discussion of the District's water supply source, treatment, reservoirs and distribution system is presented below.

2.1 SUPPLY SOURCE

The District obtains its water from four groundwater wells (#4, 6, 9 and 12) located along Harby Road East. Three of the wells (#4, 6 and 12) are located in the District's wellfield, an approximately 3.46 ha parcel of forested land. This parcel is located on the south side of Harby Road East, northwest of the intersection of the Island Hwy (Hwy 19) and Ware Road and southeast of the intersection of Harby Road East and Joy Way. The fourth well (#9) is located approximately 200 m to the west on approximately 0.09 ha parcel of land adjacent to Rotary Park on the northeast corner of the intersection of Harby Road East and Peterson Road.

Wellfield & Wells

The approximate location of the four wells is shown in the above photograph.

The existing wells are all 200 mm diameter, and were drilled between 1979 and 1990. It is understood that they were developed in the two areas because of the presence of natural springs. The 1972 design drawing for well 9 is labelled an artesian supply source. It is understood that Well #6 continues to be an artesian well with a static water level 0.5 m above ground level while Well #9 has a static water level that is below the ground level.

The wells have a depth ranging from 16 m to 24 m. The current pumping rate of the wells ranges from 190 m^3/day to 728 m^3/day. The pumping rates vary in response to the diameter of the pump, the well screen opening size and its length, the thickness and porosity of the water baring layer, and the horsepower of the each pump.

2.2 TREATMENT

Water from the wells is pumped into the water storage reservoir on Ware Road. Prior to entering the reservoir, sodium hypochlorite is injected into the watermain, thereby providing adequate contact time before entering the water distribution system and use by the consumers.

2.3 RESERVOIRS

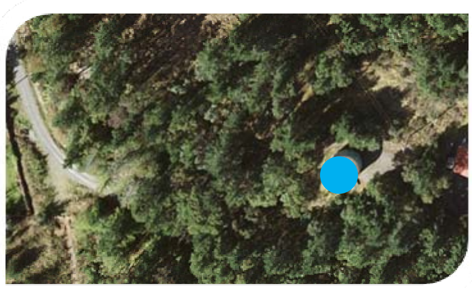
Water from the wellfield is pumped into the water storage reservoir located on the west side of Ware Road at the intersection with Aulds Road. This reinforced concrete structure constructed in 2006 has a storage capacity of 1,887 m^3.

The reservoir was constructed with two cells which can be operated independently, allowing either of the cells to be taken offline for maintenance and cleaning.

Ware Road Reservoir (2006), 1,887 m^3

After treatment, water can either flow by gravity into the distribution system or be pumped up to the District's other water storage reservoir (Aulds Road Reservoir), approximately 200 m to the south, off of Aulds Road at the Phillip Road intersection. This pressure booster pump station is equipped with two 25 hp centrifugal duty pumps and one standby 5 hp jockey pump. The transfer of water from the wellfield to the Ware Road Reservoir and from the Ware Road Reservoir to the Aulds Road Reservoir is controlled by the District's wireless Supervisory Control and Data Acquisition (SCADA) system located in a control room at the Ware Road reservoir. There is a standby emergency power diesel generator located at the Ware Road Reservoir, which will automatically come on in the event of a power outage to provide power to the building, pumps, water treatment system and SCADA system.

Since construction was completed, code requirement for seismic restraint of mechanical piping components have evolved and should be addressed as a future improvement. The reservoir is also approaching the 10 year mark, and previous recommendations to inspect and address the coating of the exterior roof surface should be implemented.



Aulds Road Reservoir (1974), 240 m^3

The Aulds Road Reservoir is a reinforced concrete structure. It is 8.5 m in diameter by 5.3 m tall, providing a storage capacity of 263 m^3.

Access to the reservoir is by way of a road that is located within a Statutory Right-of-Way (SRW) across two private properties. The road also serves at the driveway to the home at 7401 Aulds Road.

Table 2 presents a summary of the characteristics of the District's two water storage reservoirs.

Table 2
Water Storage Reservoir Characteristics

Location	Storage Volume (m^3)	Dimensions (m)	Top Water Level (m)	Type	Year Built
Ware Rd at Aulds Rd	1,887	21 x 33 x 3.3	97.25	Concrete	2006
Aulds Rd at Phillip Rd	240	8.5 dia x 5.3 m	143.6	Concrete	1974

2.4 DISTRIBUTION SYSTEM

2.4.1 Water Mains

The District's water distribution system contains 27 kms of watermain pipe and 885 service connections, all of which are metered. A breakdown by material and diameter is presented in **Table 3.**

Table 3
Pipe Lengths by Material and Diameter

Diameter (mm)	Pipe Length by Material				Total Length (m)
	Asbestos Cement (AC)	Poly Vinyl Chloride (PVC)	Stainless Steel (SS)	Ductile Iron (DI)	
75	-	-	8	-	8
100	5,006	450	14	-	5,470
150	**7,832**	567	7	-	8,406
200	2,521	**7,883**	12	-	10,416
250	-	1,382	5	620	2,007
300	-	742	-	-	742
Total	15,359	11,024	46	620	27,049
Length As Percentage of Total Length					
75	-	-	< 1%	-	< 1 %
100	19%	< 2%	< 1%	-	20 %
150	**29%**	2%	< 1%	-	31 %
200	9%	**29%**	< 1%	-	39 %
250	-	< 5%	< 1%	> 2%	> 7 %
300	-	< 1%	-	-	3 %
	57 %	41 %	< 1%	> 2 %	100%

2.4.2 Pressure Zones

There are two pressure zones in the District; the Lower and Upper pressure zones. The Lower zone is fed from the Ware Road Reservoir with a top water level of 97.25 m. The Upper zone is fed from the Aulds Road Reservoir with a top water level of 143.6 m. The Upper zone contains 226 of the District's 885 service connections (26%). The remaining 659 (74%) are located in the Lower zone.

Ware Road Pressure Reducing Valve (2000)

The Upper zone can supply water into the Lower zone by way of the Pressure Reducing Valve (PRV) station located in a metal kiosk on the south side of Lantzville Road at the Ware Road intersection. The PRV is set to operate (open) when the pressure in the lower zone drops below 621 kPa (90 psi), which would occur during a large system demand, such as a fire flow demand. The PRV station was constructed in 2000.

Characteristics of the PRV station are presented in **Table 4**.

Table 4
PRV Characteristics

Location	PRV Diameter * (mm)	Ground Elevation (m)	Pressure (kPa / psi)	
			Inlet	Outlet
Ware Rd at Lantzville Rd	150	30.5 +/-	1,110 kPa (161 psi)	607 kPa (88 psi)

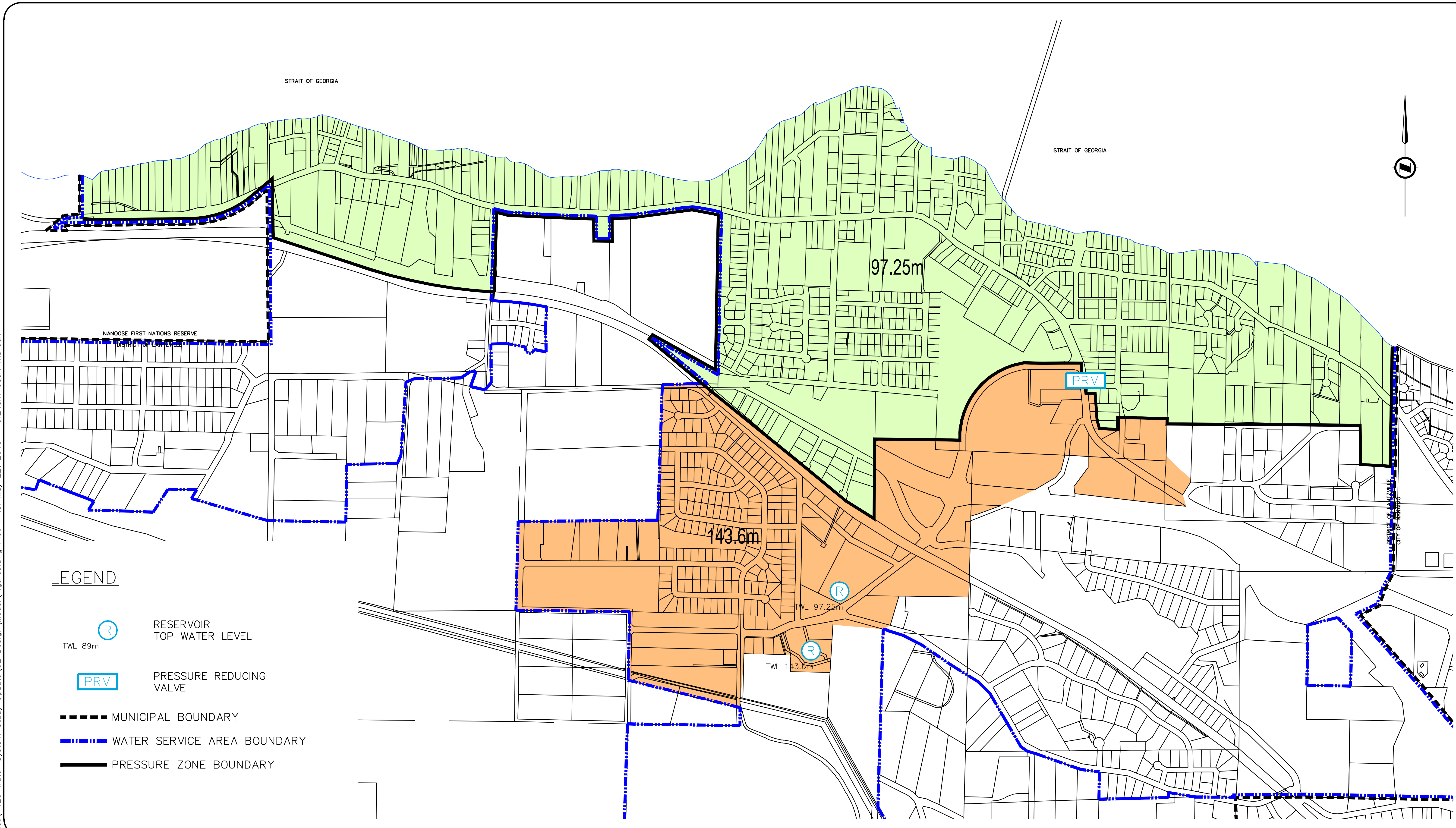
Note

- * The station is equipped with only one PRV. There is a 75 mm diameter pressure relief valve with a drain to the adjacent storm drain catchbasin.

The location of the District's two reservoirs, the PRV station and the service area of the Upper and Lower pressure zones is shown in **Figure 1**.

2.4.3 City of Nanaimo Emergency Connection

The District has the ability to be provided water from the City of Nanaimo under an emergency by installing a temporary connection between two underground flushouts. The two flushouts, the City's and the District's are located at the intersection of Dickinson Road and Schook Road in the northwest boulevard on Dickinson Road. The connection consists of 50 mm diameter galvanized steel piping, a 50 mm diameter flow meter, and a dual check valve assembly with a ball valve on both ends.



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CLIENT	DISTRICT OF LANTZVILLE
PROJECT	WATER STUDY UPDATE

TITLE	EXISTING PRESSURE ZONES		
APPROVED		SCALE	1:12,500
DATE	MAY 2015	DWG No.	Figure 1
PROJECT No.	1420		

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3 WELLFIELD CAPACITY

The study of the capacity of the wellfield vs the pumping capabilities of the existing wells was recently undertaken for the DoL and the findings presented in the following two reports:

- District of Lantzville, Phase 1 of Stage 1 Wellfield Management Plan – Wellfield Capacity, Existing and Ultimate, Harby Road Wellfield, Oct 15, 2014 by Lowen Hydrogeology Consulting Ltd.
- District of Lantzville, Harby Road Wellfield – Estimation of Well Efficiencies, March 31, 2015 by Lowen Hydrogeology Consulting Ltd.

A summary of the findings of each is presented below and a copy of each report is located in **Appendix B** and **Appendix C**; respectively.

3.1 AQUIFER

3.1.1 Water Bearing Layer(s) Soils

The District's four groundwater wells extract water from a sand and gravel aquifer located along Harby Road East. The aquifer is labelled #215 by the Ministry of Environment. The most productive water bearing layer consists of brown or white sand and gravels known as Quadra Sand. The Quadra Sand layer has a reported thickness of 2 m to 10 m; increasing from south to north and from west to east within the DoL wellfield. The well logs indicate it is covered by 5 m to 14 m of either: glacial till; till; sand and gravel; silty gravelly till; sand with till stringers; till with cobbles, sand and gravel, which in turn is covered by 0.3 m to 0.6 m of topsoil.

The aquifer's water table slopes northward towards the ocean. The groundwater level fluctuates throughout the year. Review of water levels revealed up to 3 m of change from the wet winter to dry summer months.

3.1.2 Recharge

For recharging, the aquifer is dependent on precipitation (snow and rainfall) in upland area that infiltrates into the ground and may also be recharged in part by groundwater flowing through the underlying bedrock.

The LHC report noted that changes in the upstream land use within the aquifer recharge area could impact the recharge capability of the aquifer.

3.2 WELLFIELD PUMPING CAPACITY

Presently, there are ten drilled wells in and around the DoL wellfield. Seven (3, 4, 5, 6, 8, 9, 12) are located on lands owned by the DoL, including the four active wells (4, 6, 9, 12). Of the remaining three wells (7, 11, 14), two (11, 14) are located on land owned by the Ministry of Transportation and Infrastructure and the remainder (7) is located on private property. Well 11, is the Ministry of Environment monitoring well #232. The approximate location of the wells is shown in **Appendix B, Figure 1A – Well field Location Plan**. Both well 9 and 12 terminate in bedrock. A schematic cross section of each well is presented in **Appendix B, Figure D1 – Well Construction Logs** and is followed by a summary of the well log record for each.

Pumping tests were carried out in July/August 2014 and again in February 2015. A brief overview and the findings of each pumping test are presented below.

July/Aug 2014 Pumping Tests

The July/Aug 2014 pumping tests served as a means to determine the sustainable yield of the wellfield (determine the safe pumping capacity of the wellfield) and to determine the interference of the operation of each well on the others. The wells were each operated individually and the drawdown of the water level on the other wells was recorded. All four wells were also operated simultaneously as part of the aquifer rating process. It was concluded that while the drilling of additional well(s) was not advisable as a means to increase the overall yield from the aquifer, the existing wells and pumps were not maximizing the wellfield production. The analysis indicated the sustainable yield of the wellfield with all pumps operating simultaneously was 2,424 m^3/day compared to the current maximum simultaneous pumping capability of 2,027 m^3/day. This is a potential increase of 20% (397 m^3/day) from the current pumping capacity.

February 2015 Pumping Tests

The February 2015 pumping tests were carried out to assess the performance and efficiency of each well. The results were compared against data collected during past studies. The test results showed that yield of wells 4, 9 and 12 can be increased by re-development work. It is proposed that well 6 be replaced with a new well because it is operating inefficiently and historical records indicate the rate of pumping has been reduced to stop sand from being pumped out with the water.

The existing and ultimate pumping capacity of each well is presented in **Table 5** below.

Table 5
Well Pump Characteristics and Yield

Well No.	Date Drilled	Well Dia-meter (mm)	Water Level Depth (m)	Well Depth (m)	Well Pump (type)	Well Motor (Hp/Phase/Volts)	Estimated Current Capacity (m^3/day)	Estimated Safe Pumping Yield** Individual (m^3/day)	Simultaneous (m^3/day)	% of Total
4	Aug 1979	200	1.1	21	Berkley	20 / 3 / 230	728	1,019	901	37 %
6	April 1983	200	- 0.5 *	16	Goulds	10 / 3 / 230	543	836	668	27 %
9	Oct 1986	200	3.3	24	Grundfos	5 / 3 / 230	190	352	281	12 %
12	Oct 1990	200	0.5	21	Grundfos	10 / 3 / 230	566	718	574	24 %
						Wellfield Maximum Yield:	**2,027**	**-**	**2,424**	**100 %**
						2014 Maximum Day Demand:	**1,421**		**1,421**	**59 %**
						Difference:	**606 (7 L/s)**		**1,003 (12 L/s)**	**41 %**

Note:

* Indicates well no. 6 is an artesian well with a static water level of 0.5 m above ground.

** Estimates of the safe well yield are based on information presented in the LHC reports referenced above.

3.2 WATER SUSTAINABILITY ACT

The Water Sustainability Act was given Royal Assent on May 29, 2014 and will replace the current Water Act which is over 100 years old. The Water Sustainability Act will manage surface and groundwater as one resource. The current Water Act remains in effect until the Water

Sustainability Act is brought into effect in 2016. Because of the complexity of the new Act and the number of proposed regulations associated with it, it is being implemented in phases starting with water use authorization; water fees and rentals; and regulations needed to authorize and manage groundwater use.

The regulation of groundwater will result in groundwater users having the same rights and responsibilities, including priority rights. In return, the user will be required to obtain a water license which will require payment of an application fee and an annual water rental fee. The application and rental fees vary depending on how the water is being used and who the user (consumer) is. Domestic properties that use groundwater for household needs will be exempt from licensing and fees. Municipalities, like the DoL, will be required to obtain a license and pay the fees.

A review of the application and annual water rental fees rates for 2016 indicate the estimated costs for the DoL for registration of their wells could consist of:

- One Time Application Fee: $5,000 (for 100,000 m^3/yr to < 5,000,000 m^3/yr)
- Annual Rental Fee: $565 ($2.25 per 1,000 m^3)

A copy of the Water Sustainability Act and Table of Fees can be found on the BC government web site.

4 POPULATION

4.1 HISTORIC POPULATION

Since its formation as a District municipality in 2003, the District's population has remained almost unchanged. **Table 6** presents the District's annual population estimates from 2003 to present as published by BCStats along with the population per dwelling unit as calculated during the last three federal censuses.

Table 6
Population Estimates, 2003 – 2014

Year	Population Estimate (BCStats)	Population per Dwelling Unit (Canada Census)
2001	-	2.73
2002	-	-
2003	3,486	-
2004	3,687	-
2005	3,720	-
2006	3,685	2.58
2007	3,721	-
2008	**3,745**	-
2009	3,700	-
2010	3,687	-
2011	3,643	2.46
2012	3,659	-
2013	3,505	-
2014	3,496	-

The resulting stagnation of growth (0%) over the past 11 year is believed to be partly in response to the District's policies and bylaws relating to the capacity concerns of the District's groundwater supply as well as the limited service area of the municipal sanitary sewer collection system. As a comparison, the adjacent communities of City Nanaimo to the south and the City of Parksville to the north, both with community water and sanitary sewer collection systems that have capacity to accommodate growth have experienced significant growth. Nanaimo's population grew by 11,870 (15%) while Parksville's grew by 1,748 (17%) since 2003.

The decline in population per dwelling unit is reflective of components such as: some new home construction; an aging population whereby children are growing up and moving out of the area; and fewer children being born per family. The decline in density is not unusual as it is also occurring in other Vancouver Island municipalities.

The District's 2011 population density of 2.46 capita/dwelling is higher its two neighbouring municipalities of the City of Nanaimo at 2.31 capita/dwelling and the City of Parksville at 2.11 capita/dwelling. With the ongoing aging of the Vancouver Island population being projected by BCStats, it can be expected that this will also apply to the DoL and result in a lowering of the population density per dwelling unit.

4.2 FUTURE POPULATION

While the OCP allows for growth, when growth will occur is unclear as it is subject to a number of variables beyond the District's control, including market and developer influenced criteria. It is understood that the three largest local inhibitors are:

1) Limited extent of the municipal sewage collection system,
2) Limited capacity of the water supply source (the wellfield), and
3) Limited extent of the municipal water distribution system. Approximately 35% of the more than 1,330 homes do not have access to the municipal water system and rely on individual wells.

The District has taken steps towards addressing the water source issue with the signing of a water supply agreement with the City of Nanaimo dated September 8, 2014. A copy the agreement is located in **Appendix A**.

The District's OCP does not provide an estimate of the future population based on the projected land-uses nor at what time in the future when the full land-use potential may be realized. As there are many factors effecting population growth, three growth scenarios have been developed for this report: low; moderate; and high based on a review of historical growth rates in neighbouring municipalities and growth projection data by StatsBC. A time period of 50 years was applied to aide in assessing the ability of the District's current water source to accommodate varying levels of long term growth. **Table 7** presents the population projections in five year increments to Year 2065 for each growth rate. **Figure 2** presents the District's historic population from 2001 to 2014 as published by Stats BC and Census Canada along with the three population growth projection scenarios to year 2065.

Table 7
Population Projections to Year 2065 (50 years)

Year	Total Population		
	Low Growth 0.5%	Moderate Growth 1%	High Growth 1.5%
2014	3,496	3,496	3,496
2015	3,496	3,496	3,496
2020	3,584	3,674	3,766
2025	3,675	3,862	4,057
2030	3,768	4,059	4,371
2035	3,863	4,266	4,709
2040	3,960	4,483	5,073
2045	4,060	4,712	5,465
2050	4,163	4,952	5,887
2055	4,268	5,205	6,342
2060	4,376	5,471	6,832
2065	4,486	5,750	7,360
50 Yr Increase	990	2,254	3,864
(%)	28%	65%	110%

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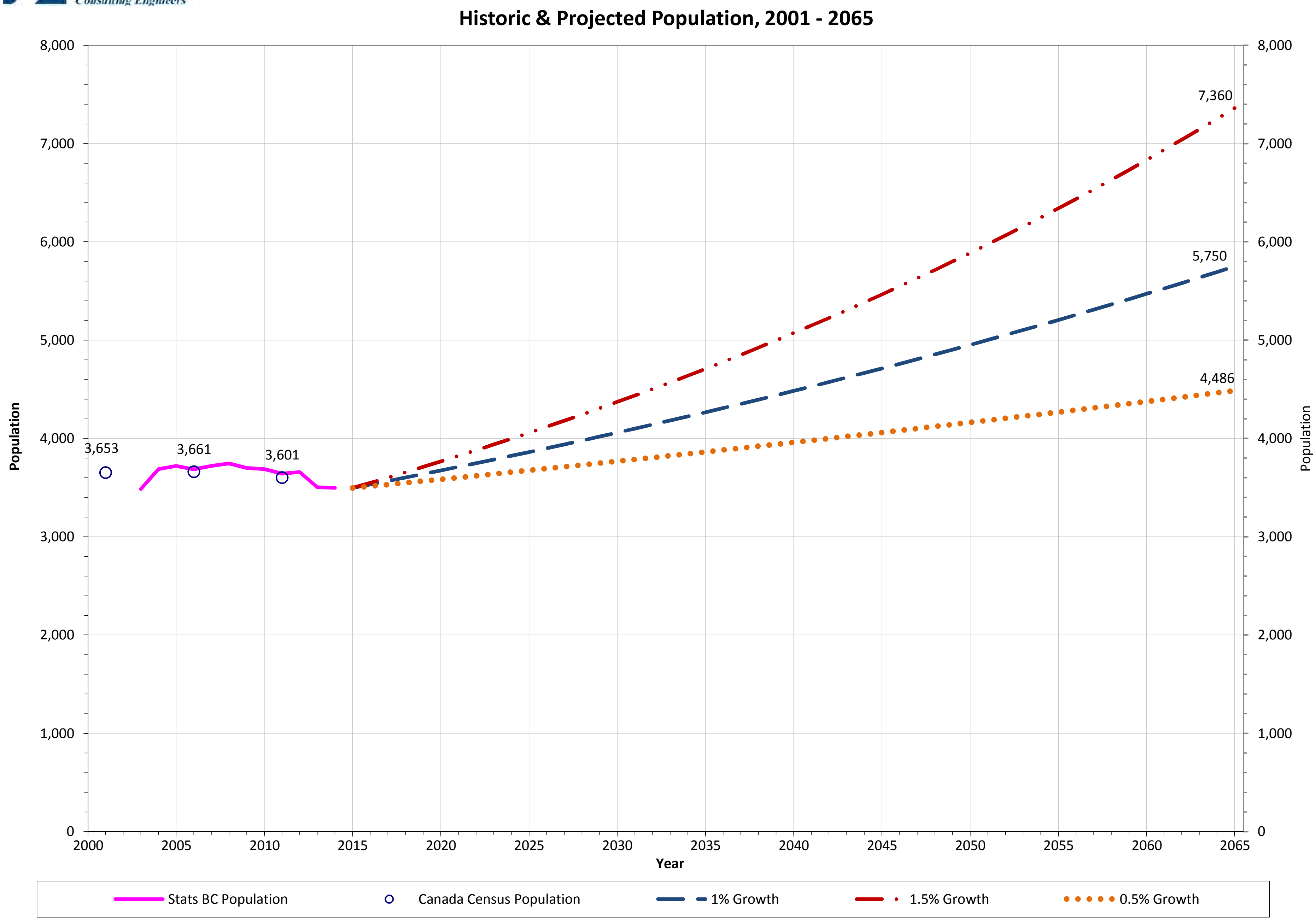


FIGURE 2

While the District's population has remained unchanged over the past 11 years, the population per dwelling unit has decreased, as shown in **Table 6**. This trend is decreasing density is anticipated to continue over the near-term, as previously discussed in Section **4.1 Historic Population**. If the population density over the next 50 years were to average 2.2 capita per dwelling unit, a total of 450 to 1,756 new dwelling units would need to be constructed in order to accommodate the low, moderate and high population growth projections presented in **Table 7**. The required number of new dwelling units in five year increments for each growth scenario to Year 2065 is presented in **Table 8**.

There are two larger land development projects proposed for the DoL which are acknowledged in the OCP as Comprehensive Development Plan Areas (CDPAs).

Table 8
House Construction Projections to Year 2065 (50 years)

Year	New Dwelling Units		
	Low Growth 0.5%	Moderate Growth 1%	High Growth 1.5%
2015	-	-	-
2015 - 2020	40	81	123
2020 - 2025	41	85	132
2025 - 2030	42	90	143
2030 - 2035	43	94	153
2035 - 2040	44	99	165
2040 - 2045	46	104	178
2045 - 2050	47	109	192
2050 - 2055	48	115	207
2055 - 2060	49	121	223
2060 - 2065	50	127	240
50 Yr Increase	450	1,025	1,756

Village (Ware Road)
The Village CDPA is a 23 ha block of land straddling both sides of Ware Road between Hwy 19 and Lantzville Road. While the OCP does not specific a maximum number of dwelling units it does acknowledge that densities are to be higher than the surrounding area to strengthen the vitality of the Village. The adjacent residential development to the west off Peterson Road has a density averaging 6.5 units per ha. It is noted that twenty percent (20%) of all homes are to be single floor type orientated to seniors. Assuming a density of 8 to 10 units per ha, a total of 184 - 230 units could be developed on this site.

Foothills Development
The Foothills CDPA is a 730 ha block of land located in the foot hills of the District, south of Aulds Road. The OCP dictates a maximum of 730 residential units for the development.

Combined, these two developments could accommodate almost all of the projected dwelling units to be constructed over the next 50 years under the moderate growth scenario. For the high growth scenario, subdivision and development of other properties in the District would be required.

5 WATER DEMAND

5.1 CURRENT DEMANDS

Water demands in the District are recorded by three bulk water meters; all located at the Ware Road reservoir. The District's SCADA system records the volume of water flowing through each meter. The first meter records the volume extracted from the wellfield as it enters the Ware Road reservoir. The second bulk meter records the volume of water entering the Lower Pressure zone and the third bulk meter records the volume of water entering the Upper Pressure zone.

The daily readings from the three bulk flow meters for the past four years (2011 – present) were reviewed to assess: year over year trends; seasonal demand changes; maximum and minimum demand months; and average day, maximum day and maximum week demands for the entire system.

Each of 885 properties connected to the water system is metered and the meters are read on a quarterly basis. The data for the past five years (2010 – 2014) was reviewed to assess: year over year trends; seasonal changes; demand by land-use; per service connection demand by land-use; high, average and low demands by land-use; and per capita demands.

5.1.1 Bulk Water Meter

Wellfield vs Upper Zone & Lower Zone Metered Demands

A review of the annual total during the past three years (2012 – 2014) found the wellfield annual recorded volume to be consistently 7.3% lower than the combined total of the Lower and Upper pressure zones as shown in the **Table 9**. The source of the discrepancy is not known but staff suspects it may be a calibration issue with the SCADA system.

Table 9
Wellfield vs Upper & Lower Pressure Zone Bulk Meter Annual Demands, 2011 - 2014

Bulk Meter	Annual Demand, m^3		
	2012	**2013**	**2014**
Wellfield	226,554	225,998	233,786
Upper + Lower Zone*	243,025	242,420	250,929
Difference, m^3	16,471	16,422	17,143
(%)	7.3%	7.3%	7.3%

Note

***** For purposes of this report, the more conservative (higher value) of the combined upper and lower zone flow meters has been used for analysis.

Annual & Monthly Demands

A review of annual demands for the past three years (2012 – 2014) revealed that overall, demands have been relatively stable though for 2014, the total demand was up 3.5% (8,509 m^3) compared to 2013 and was higher than in 2012. This can be traced to a higher cumulative demand for the summer months (June – September) compared to the previous two years. The majority of the increase, 2.3% (5,657 m^3) compared to 2013, occurred in the month of June which has notably less rainfall in 2014 compared to 2013.

A review of the monthly demands showed July or August to have the highest demand and February or November to be the lowest. On average, 25% of the total annual water demand occurs during the two summer months of July and August and a total of 40% for the four month period of June through September.

Demands in January and February of 2015, were significantly higher compared to the previous three years. Their combined total was 25% (8,108 m^3) higher than the 2012 to 2014 average. A review of daily flow records revealed that the increase commenced in December 17 and continued until February 22, 2015. The flow increase occurred only in the District's upper pressure zone. District staff confirmed the increase was the result of a major leak on the Harwood Road watermain that staff were able to locate and repair on February 21, 2015.

Monthly bulk meter demands for the past four year are presented in **Table 10** along with the three year average and annual totals.

Table 10
Bulk Meter Monthly Demands, 2011 – 2015

Month	Total Consumption (m^3)					3 Year Ave (2012 – 2014)	
	2011	2012	2013	2014	2015	(m^3)	L/s
January	-	16,007	18,887	16,865	22,480	17,253	6.4
February	-	16,258	**15,636**	15,554	18,697	15,816	6.5
March	-	17,002	17,735	17,367	16,226	17,368	6.5
April	16,684	16,922	17,233	16,265	16,010	16,807	6.5
May	17,679	21,249	20,808	20,581	25,774	20,879	7.8
June	23,314	20,861	21,319	26,976	-	23,052	8.9
July	27,554	28,904	**32,965**	30,822	-	30,897	11.5
August	**30,343**	**29,741**	27,053	**30,926**	-	29,240	10.9
September	23,778	24,149	19,038	24,981	-	22,723	8.8
October	18,447	17,958	16,151	17,203	-	17,104	6.4
November	16,527	**15,926**	16,126	**15,030**	-	15,694	6.1
December	16,942	18,048	19,469	18,359	-	18,625	7.0
Total	191,268	243,025	242,420	250,929	-	245,458	7.8
Monthly Ave	-	20,250	20,200	20,900	-	20,450	7.8

Notes:

Bold red text indicates **highest** recorded demand for that year.
Bold black underlined text indicates **lowest** recorded demand for that year.

Daily Demands

A review of the water demands for the years 1996 to 2000 as reported in the Lantzville Improvement District Water Quality Assessment Report, May 2002 by Koers & Associates Engineering Ltd. revealed both the total annual and maximum day demands were higher compared to the most recent years (2012 – 2014). The average total annual demand decreased by 19%, while the maximum day demand decreased by 17%.

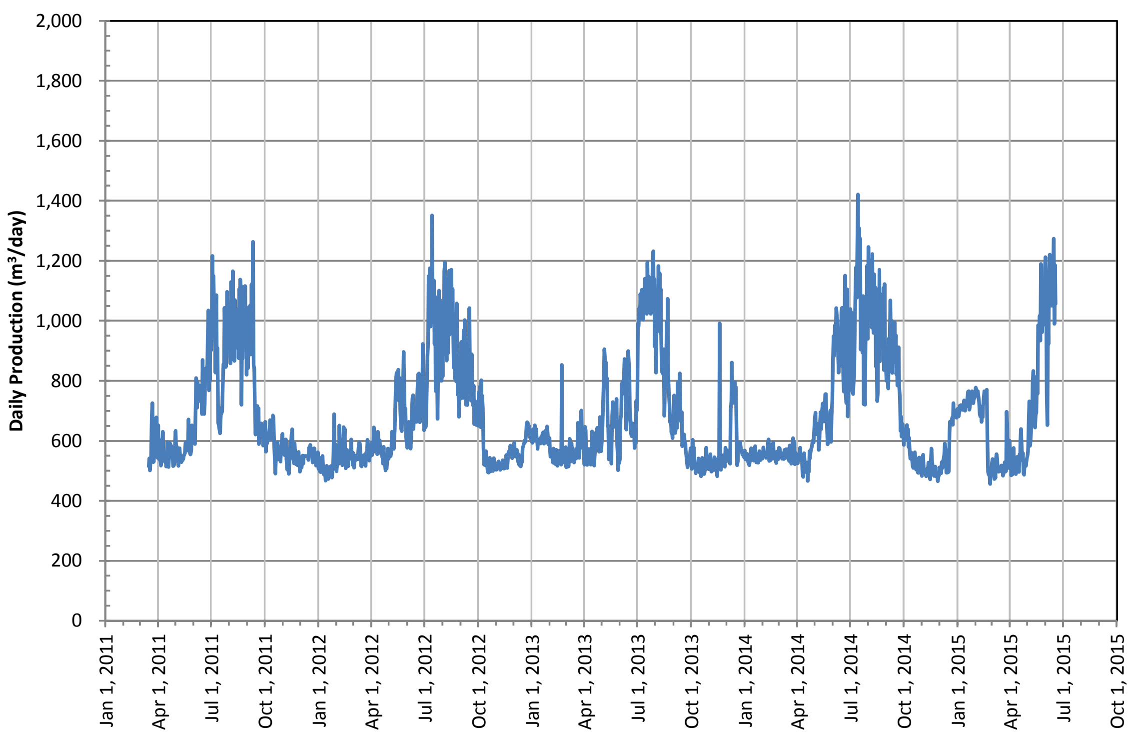
Koers has observed a downward trend in water use in other mid Vancouver Island municipalities over the past 5 to 8 years. The downward trend in these municipalities is believed to be in response to several factors, including:

- public education on the need for water conservation via local programs;
- indirectly through provincial, national and international news/events;
- local water conservation programs; manufacture of lower water use appliances and fixtures; and
- expansion of local water metering programs.

It is suspected the first three factors may also be attributable to the District of Lantzville. The last factor is not associated with Lantzville because the District is already a fully metered system. However, the District's water charge structure of increasing cost with increasing consumption may have contributed to the declining water demand. This inclining block rate water charge structure which has been in place since 2003 and was updated in May 2010 (Bylaw No. 85, 2010).

A review of the daily demands found them to be relatively stable; averaging 550 m^3/day for the seven month period October through April. This time corresponds to cooler temperatures, higher rainfall and a slower growing season compared to the five months of May through September. The maximum day demand most often occurs in July or August and at more than 2.5 times the fall/winter demand. **Figure 3** presents a plot of daily demand (sum of the upper and lower zone bulk meter readings) from March 2011 to June 2015.

Figure 3
Daily Demand (Upper + Lower Zone Bulk Meters), March 2011 – June 2015



The maximum day demand most often occurred in the month of July (5 times), followed by August (2 times), and once each in June and September. The ratio between maximum day and average day ranged from a low of 1.72 to a high of 2.08. This is close to, but at the low end of the expected range of 2 to 2.5 times for a water system of this size. It is suspected that the low peaking ratio is partly in response to the DoL water consumption charge rates and rainwater harvesting program which are designed to reduce demand and encourage water conservation.

The maximum week (7 day) demand all occurred in the month of July for the past four years (2011 – 2014). The maximum day demand all occurred during the maximum week demand, with the exception of in 2011, when a maximum day demand of 1,263 m^3 was recorded on September 11. This was slightly higher than the 1,216 m^3 recorded on July 3, during the maximum week. **Figure 4** presents the daily readings from March 2011 to April 2015 along with a 7 day moving average. The estimated current maximum yield from the wellfield with all pumps operating simultaneously is also shown for reference purposes.

The District's total annual, average day, maximum day and maximum week demands for the years 1996 to 2014 are presented in **Table 11**.

Table 11
Annual, Average Day and Maximum Day Demand, 1996 – 2014

Year	Annual Demand (m^3)	Average Day (m^3/day)	Maximum Day (m^3/day)		Max/Ave Ratio	Maximum Week (m^3/day)	
1996	312,568	854	1,783	July 12	2.09	n/a	
1997	292,421	801	1,563	August 12	1.95	n/a	
1998	329,371	902	1,551	July 28	1.72	n/a	
1999	286,666	774	1,530	June 11	1.98	n/a	
2000	n/a	n/a	1,578	August 15	n/a	n/a	
2001 - 2002	n/a	n/a	n/a		n/a	n/a	
2003	287,983	789	n/a			n/a	
2004	277,804	759	n/a			n/a	
2005	269,840	739	n/a			n/a	
2006	278,737	764	n/a			n/a	
2007	275,844	756	n/a			n/a	
2008	279,628	764	n/a			n/a	
2009	283,078	776	n/a			n/a	
2010	256,568	703	n/a			n/a	
2011	243,380	667	1,263	September 11	1.89	1,060	July 1 – 7
2012	243,025	664	1,351	July 14	2.03	1,095	July 10 – 16
2013	242,420	664	1,232	July 28	1.85	1,114	July 24 – 30
2014	250,929	687	1,421	July 14	2.07	1,227	July 12 – 18

Estimated Demand Per Capita

Year	Service Population Estimate *	Average Day (lpcd)	Maximum Day (lpcd)	Maximum Week (lpcd)
2011	2,143	311	589	495
2012	2,143	310	631	511
2013	2,143	310	575	520
2014	2,143	321	663	573

Notes:

* Based on 2011 Census population density of 2.46 capita per dwelling and an estimated 871 residential dwelling units (serviced from 840 individual water meters).

District of Lantzville
Wellfield Daily Production, 2011 - 2015

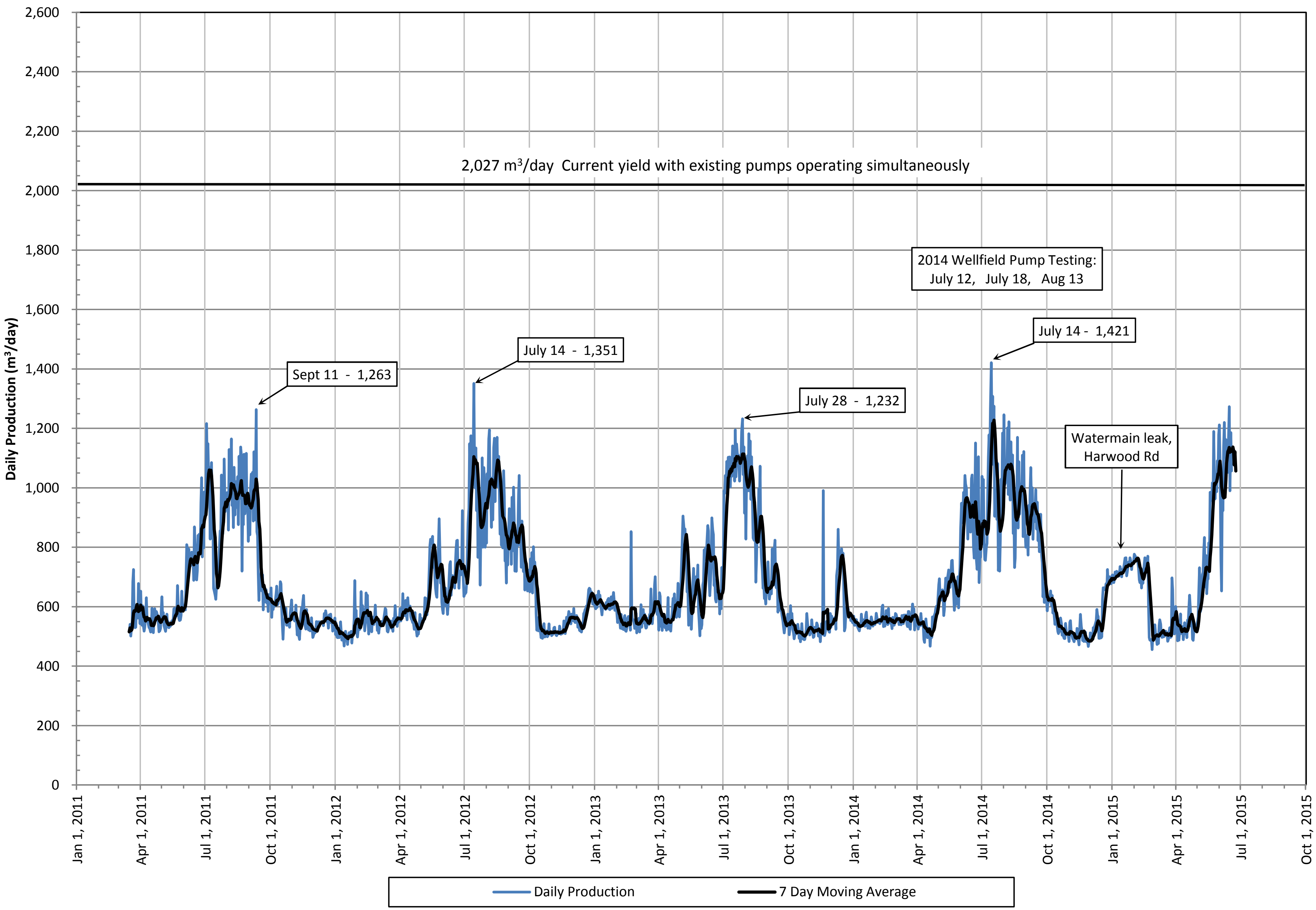


FIGURE 4

Figure 5 graphically presents the total annual, average day, maximum day and maximum week demands from 1996 to 2014. The BCStats population estimate is included on **Figure 5** for reference purposes.

For comparison purposes, the average and maximum day per capita water demands experienced in other Vancouver Island communities is presented in **Table 12**.

Table 12
Average and Maximum Day Demand Per Capita,
Vancouver Island Communities

Community	Study Year	2011 Canada Census Population	Study Per Capita Demand			
			Average Day (lpcd)		Maximum Day (lpcd)	Max/ Total Ave
			Residential	Total		
Gold River	2002	1,267	786 **	866	2,252	2.6
Ucluelet	2012	1,627	996 **	1,270	2,129 ***	1.7 ***
Tofino *	2000	1,876	331	1,008	2,168	2.2
Lantzville *	**2015**	**3,643**	**246 #**	**321 ##**	**663 ###**	**2.1**
Ladysmith *	**2013**	8,691	430		729	1.7
Qualicum Beach	2003	8,687	---	570	1,420	2.5
Parksville *	1995	11,977	---	540	1,180	2.2
Comox	2013	13,627	---	490	840 ***	1.7 ***
Port Alberni *	1995	17,743	366	1,118	1,777	1.6
Courtenay	2003	24,099	---	635	1,417	2.2
Campbell River	2001	31,186	---	635	2,100	3.3
Nanaimo *	1998	83,810	---	540	1,050	1.9
Average (excluding Tofino/Ucluelet)		---	---	703	1,581	---

Notes:

* Indicates municipalities which meter both residential and commercial properties.

\+ Residential average day per capita demands are calculated as the annual sum of all residential metered demands divided by the estimated service population, except where noted otherwise.

Total Average Day per capita demands are calculated as the total demand of the entire water system divided by the estimated service population.

** These are non-metered demand values calculated as the difference between system demand and the commercial/industrial metered demands. As such, they are not solely residential demand but include all system water use excluding commercial/industrial use.

*** Calculated as maximum month demand divided by the number of days in the month as daily demand data was not available. Actual maximum day demand and the resulting peaking ratio would be higher.

\# Based on 2014 individual metering data for 2014. Value is sum of individual residential meters (143,756 m^3) divided by an estimated service population of 2,143.

\## Based on 2014 total system metering demand for 2014. Value is total system demand (154,261 m^3) divided by estimated service population of 2,143.

\### Based on 2014 total system maximum day demand of 1,421 m^3 (August 20, 2014) divided by an estimated service population of 2,143.

The following observations are made of the data presented in **Table 12**:

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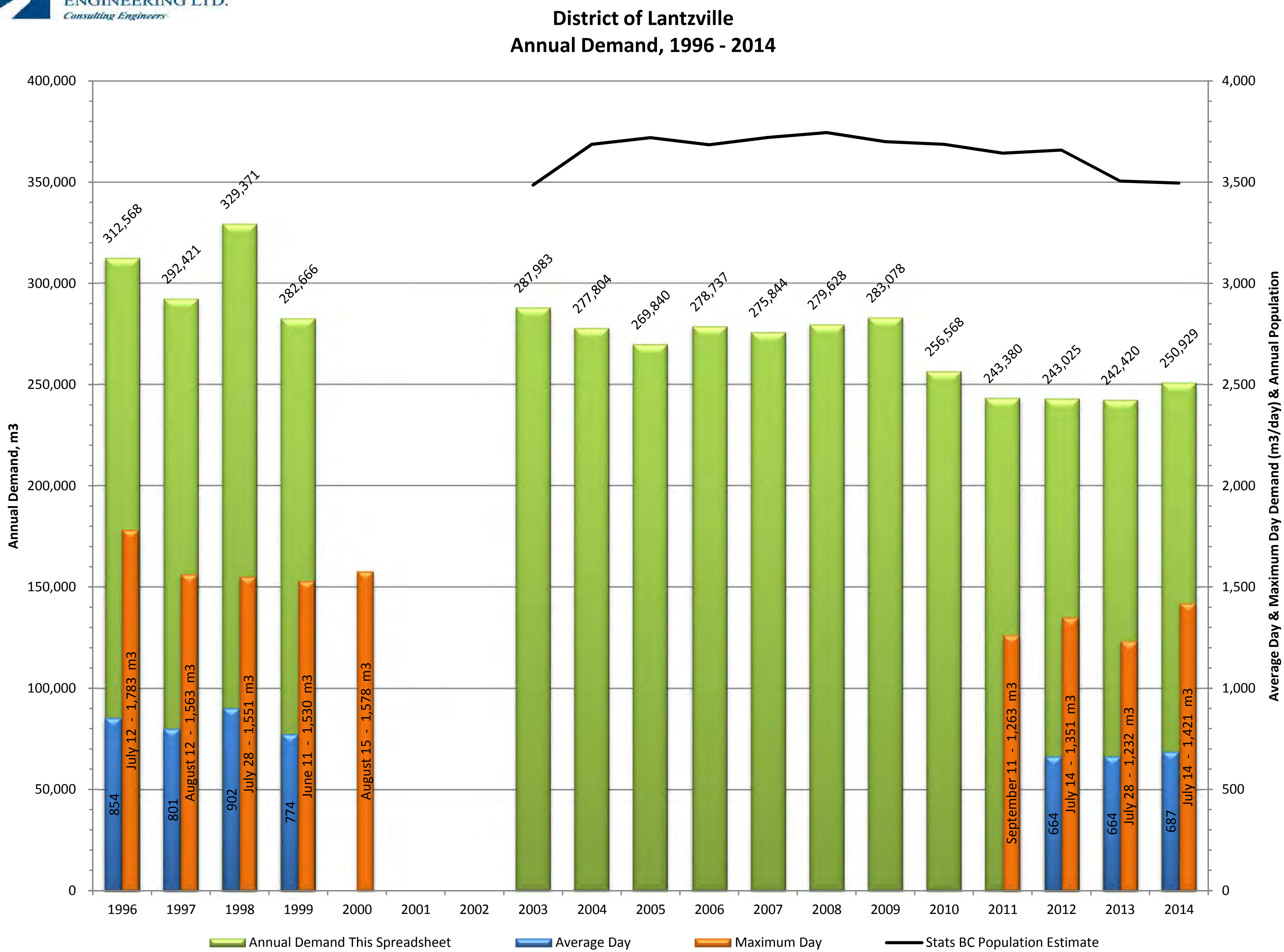


FIGURE 5

- In general, higher per capita demands are experienced with smaller populations compared to large ones.
- Water demands in Tofino, Ucluelet and Parksville are affected by large tourist population increases in the summer months.
- Ucluelet had three processing plants while Tofino has one, which is reflected in the total average and maximum day/month values.
- Domestic water demand for the pulp mill in Port Alberni and Campbell River is supplied by the municipal system, with the exception of the processing water demand at each Mill.
- Lantzville's per capita demands are the lowest of the 12 municipalities reviewed. They are as much as 40% lower than the City of Nanaimo, with whom they share a municipal boundary. It is believed the community awareness of the limited capacity of the wellfield, requirement for new developments to secure their own water supply sources and the inclining block pricing (Bylaw No. 85) are factors contributing to the low per capita demands.

5.1.2 Individual Water Meters

Individual Meters vs Upper & Lower Zone Bulk Meters

The quarterly total of individual meters for the past four years (2011 – 2014) was compared with the combined total of the Upper and Lower pressure zone meters and found to be lower by 16% to 24%. While the difference between the two remained relatively constant from year to year and within each quarter, the first two quarters (Jan – March & April – June) had an average difference of 25% and 28%, respectively, while the difference in the last two quarters (July – Sept & Oct – Dec) was 12% and 14%; respectively, less than ½ the first two quarters. The comparison of the quarterly demands is presented in **Figure 6**.

The volume difference between the sum of the bulk meter totals and the individual metering totals is referred to as "non-revenue" water.

Non-Revenue Water = Upper & Lower Bulk Meters – Individual Meters.

Non-revenue water encompasses unbilled authorized consumption and apparent and real system losses, which may consist of:

Unbilled Authorized Consumption

- Watermain flushing
- Sewer main flushing
- Fire department training and actual fire fighting
- Public boulevard and playfield irrigation

Apparent Losses

- Water theft
- Metering inaccuracies

Real Losses

- Leakage on transmission and/or distribution mains
- Leakage on service connections up to the customer's meter

Total Individual vs Upper & Lower Zone Bulk Metered Quarterly Demand (2011 - 2014)

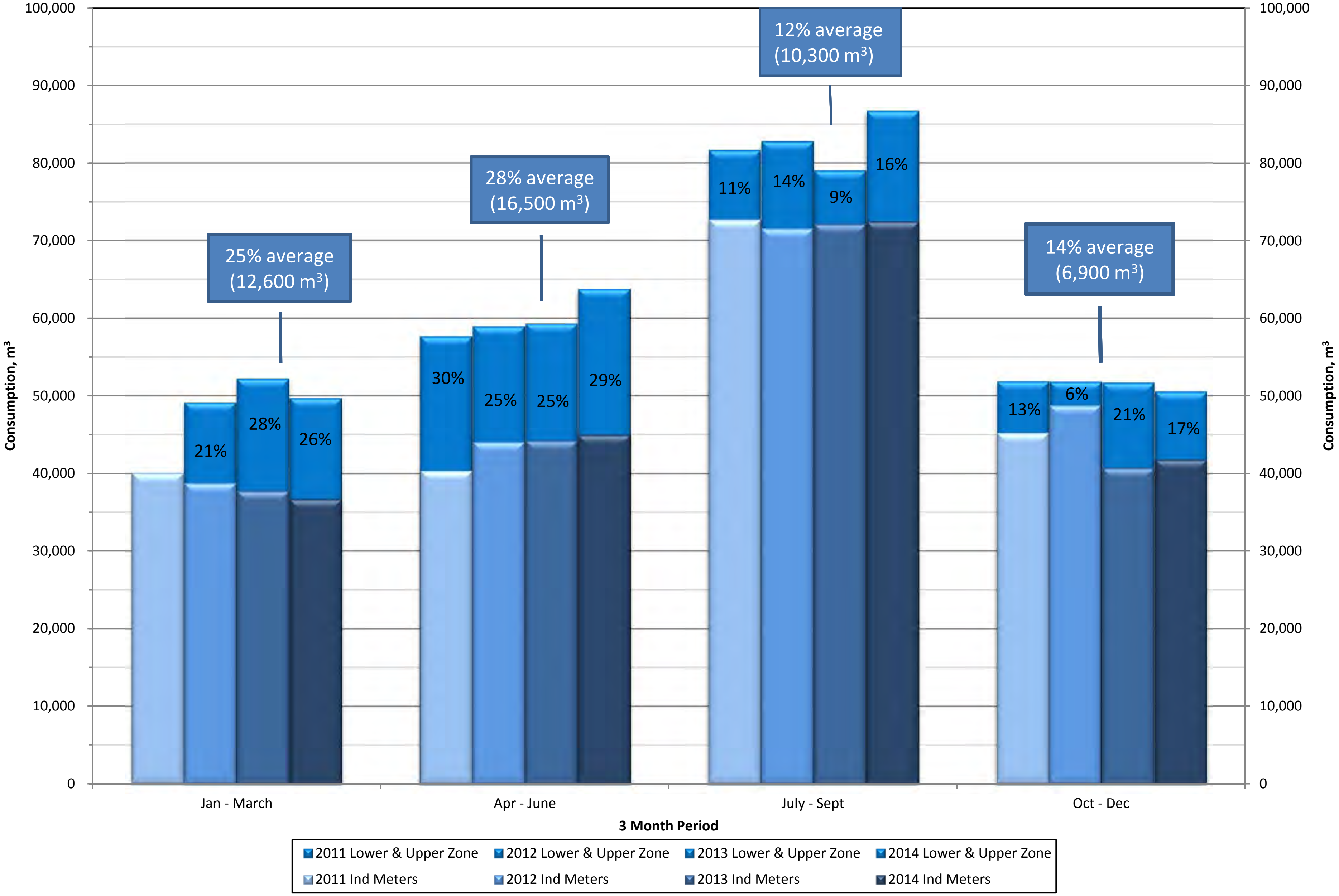
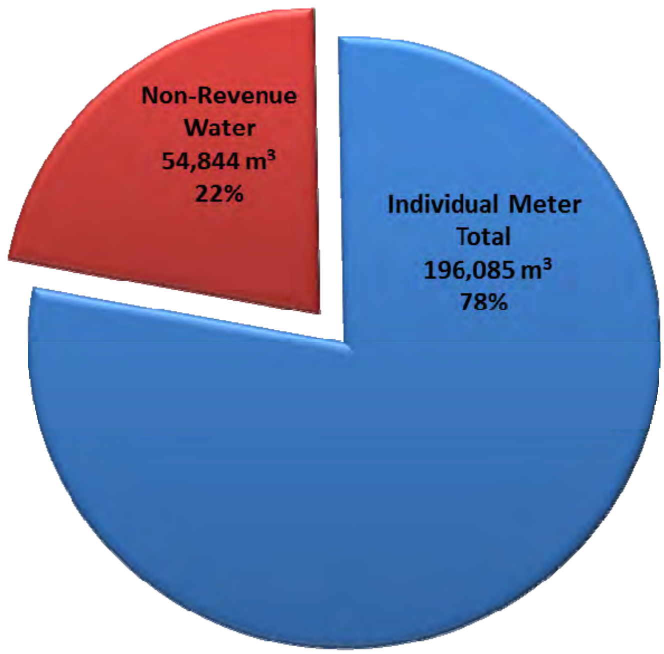


FIGURE 6

For 2014 the "non-revenue" volume totalled 54,844 m^3 as shown in **Figure 7**. While this is a noticeable amount, it is not unexpected or unusual for a water system of this size, age and operating pressures.

Figure 7
Unaccounted for Water, 2014



Land-Use Based Annual Demand

Individual metered demands for the past five years (2010 – 2014) were separated into six (6) land-use categories and the demand per land-use assessed. The analysis revealed:

- The largest user group was Residential with 840 meters (95% of 885 meters) and the group demand accounts for more than 90% of the total individual metered demand.
- The smallest user group was Industrial with 18 meters (2% of 885 meters) and the group demands accounts for 1% of the total individual metered demand. Industrial users had the smallest total demand and the smallest average demand per connection.
- The highest demand per connection was for Commercial/Residential. There are 5 meters (0.6% of 885 meters) and the group demand accounts for 2% of the total individual metered demand.
- The second highest demand per connection was for Commercial properties. There are 14 meters (1.6% of 885 meters) and the group demand accounts for 4% of the total individual metered demand.
- Public use zoned lands have 8 meters (1% of 885 meters) and account for 2% of the total individual metered demand.

Table 13 presents the annual demand, demand per connection and percent demand per land-use category for the past five years along with the 5 year average of each.

Table 13
Annual Demand by Land-Use, 2010 - 2014

Description	Land-Use Category						Total
	Commercial	Com/Res	Public Use	Industrial	Other Res.	Residential	
Number of Meters	14	5	8	18	17	823	885
Total of Individual Meter Demands							
2010	7,818	* 13,007	3,375	3,103	6,834	181,840	215,977
2011	6,195	2,893	3,835	2,781	7,469	175,460	198,633
2012	7,318	3,144	4,454	2,539	6,892	179,066	203,413
2013	7,220	3,639	4,482	2,715	6,468	170,524	195,048
2014	7,101	3,640	5,190	2,312	5,785	172,057	196,085
5 Year Average (2010 – 2014)	7,130	* 3,265	4,267	2,690	6,690	175,789	201,831
Average Demand Per Service Connection							
2010	558	* 2,601	422	172	402	221	244
2011	443	579	479	155	439	213	224
2012	523	629	557	141	405	218	230
2013	516	728	560	151	380	207	220
2014	507	728	649	128	340	209	222
5 Year Average (2010 – 2014)	509	* 653	533	149	394	214	226
Percentage of Total Demand							
2010	4%	6%	2%	1%	3%	84%	100%
2011	3%	1%	2%	1%	4%	88%	100%
2012	4%	2%	2%	1%	3%	88%	100%
2013	4%	2%	2%	1%	3%	87%	100%
2014 (9 months)	4%	2%	3%	1%	3%	88%	100%
4 Year Average (2010 – 2013)	4%	2%	2%	1%	3%	88%	100%

Notes:

* A review of the 2010 data revealed an excessively high demand (10,340 m^3) occurred in the second quarter at a single connection (6690 Dickinson Road) compared to the 202 to 534 m^3 for the same period in other years. The cause of the high demand could not be determined. The 5 year average demand per connection is based on the exclusion of 10,000 m^3 from the second quarter of 2010.

For comparison purposes, Year 2012 per connection demands for three land-uses from several mid-Vancouver Island municipal water systems were reviewed. Data for the same year was used to standardize the comparison as much as possible. The following observations were made from the data which is presented in Table 14;

- Lantzville's single family per dwelling annual demand is lower than its adjoining neighbor, the City of Nanaimo, but higher than the City of Parksville's or the District of Tofino's. However, the DoL per capita demand is lower because of the District's higher per capita per dwelling unit.
- Lantzville's annual demand per commercial unit is lower than the others, but does not appear to be unusual. The high demand for Parksville is reflective of its summertime

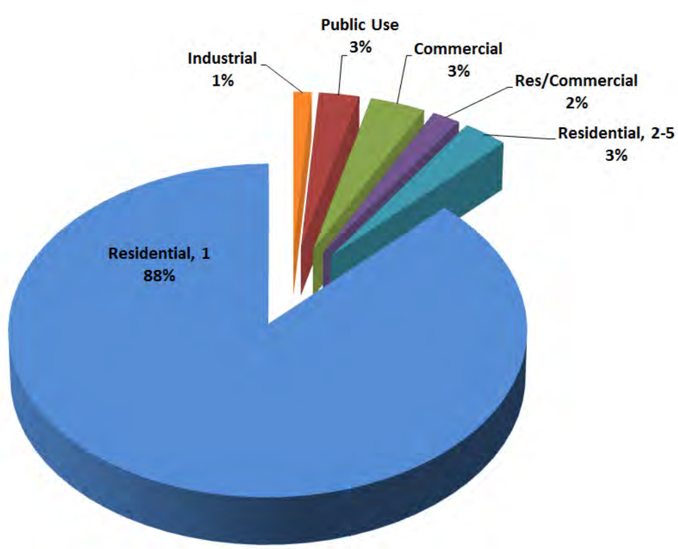
resort destination and the large number of tourist accommodation. The very high demand for Comox is due to a seafood processing business.

Table 14
2012 Annual Water Demand by Land Use, Vancouver Island Communities

Municipality	Annual Metered Water Demand (2012)		
	Single Family (m^3/dwelling)	Multi-Family (m^3/dwelling)	Commercial (m^3/unit)
Tofino	182	110	590
Parksville	199	n/a	2,130
Lantzville	**218**	**n/a**	**523**
Nanaimo	251	165	n/a
Nanoose Bay Water Service Area	256	204	571
Comox	290	150	4,032
Comox Valley Water Local Service Area	382	264	771

Annual demand by land-use has been very stable over the past five years. The percentage demand by each land-use category for 2014 is shown in **Figure 8**.

Figure 8
Percentage of Water Demand by Land-Use, 2014



Largest Users by Land-Use

The five largest water users for each of the six land-use categories were reviewed for 2014. The analysis revealed:

- These 30 properties, representing 3% of the 885 meters, accounted for 12.5% of the sum of all metered demand (24,513 m^3 of 196,085 m^3).
- The 5 Commercial properties had the largest total of these 6 categories, at 6,093 m^3 (3.1% of the sum of all metered demand), followed by Single Family Residential at 5,446 m^3 (2.8% of the sum of all metered demand).
- The smallest total was for the Industrial properties at 1,570 m^3 (less than 1% of the sum of all metered demand).

The 2014 demand for each of the 30 properties is presented in **Table 15** along with the total demand per land-use category and the combined total demand for all categories.

Table 15
Five Highest Water Users by Land-Use, 2014

Customer	Demand (m^3)	Demand ÷ Land-Use Total Demand (%)	Land-Use Total Demand (m^3)
Commercial Property on: (14 meters)			
Lantzville Rd	2,417	34 %	
Lantzville Rd	1,359	19 %	
Lantzville Rd	1,039	15 %	
Lantzville Rd	926	13 %	
Lantzville Rd	352	5 %	
Total:	6,093	86 %	7,101
Commercial/Residential on: (5 meters)			
Dickinson Rd	2,428	67 %	
Lantzville Rd	655	18 %	
Harby Rd W	215	6 %	
Benwaldun Rd	172	5 %	
Fernmar Rd	170	4 %	
Total:	3,640	100%	3,640
Public Use Property on: (8 meters)			
Lantzville Rd	1,863	36 %	
Lantzville Rd	827	16 %	
Lantzville Rd	710	14 %	
Lantzville Rd	704	14 %	
Lantzville Rd	593	11 %	
Total:	4,697	90 %	5,190
Industrial Property On: (18 meters)			
Metro Rd	643	28 %	
Industrial Rd	408	18 %	
Metro Rd	252	11 %	
Mart Rd	147	6 %	
Industrial Rd	120	5 %	
Total:	1,570	68 %	2,312
Other Residential prop. on: (17 meters)			
Lantzville Rd	937	16 %	
McKercher Rd	632	11 %	
Peterson Rd	550	10 %	
Lantzville Rd	489	8 %	
Lantzville Rd	459	8 %	
Total:	3,067	53 %	5,785
Single Family Residential on (823 meters)			
Sunbury Rd	1,267	0.8 %	
Dickinson Rd	1,214	0.7 %	
Lantzville Rd	1,179	0.7 %	
Dickinson Rd	901	0.5 %	
Lantzville Rd	886	0.5 %	
Total:	5,446	3 %	172,057
Combined Total:	24,513	12.5 %	196,085

Single Family Residential Demands

A review of individual demands of the 823 single family meters for the revealed that the single largest user (1/823 = 0.12% of the residential customers) accounted for 0.8% of the total single family metered demand (1,269 m^3 of 172,057 m^3) as shown in **Table 15** on the next page. This was more than 6 times the 209 m^3 per connection average for single family properties for 2014 (**see Table 13**).

The two largest users accounted for 1.4% of the total single family metered demand (2,483 m^3 of 172,057 m^3).

Fifty percent (50%) of all metered demand was used by 35% of the single family residential properties and the top ten percent (10%) of single family properties used 21% of all metered demand as shown in **Table 16**.

Table 16
Single Family Residential Demands, 2014

Description	Value				
Number of SF Residential Meters (out of a total of 823)	10 % (82)	25 % (206)	35 % (289)	50 % (412)	90 % (741)
Demand, m^3	40,823	78,179	98,102	123,030	167,715
Demand as Percentage of Total Demand of Ind. Meters (154,261 m^3)	21 %	40 %	50 %	63 %	86%

The 2014 demand for each single family property from highest to lowest is presented in **Figure 9**.

5.2 FUTURE DEMANDS

5.2.1 Service Area

One of the goals of the District's OCP is to provide clean, potable water for domestic use and water for fire-fighting purposes to all parts of the municipality (OCP 9.2.1 Water Sources and Protection). The ultimate water service area is shown on the OCP Map 7 – Water Service Area, a copy of which is presented in **Appendix D**.

The OCP Water Service Area includes developed, undeveloped and sub-dividable properties. Presently, there are 441 lots within the service area that would require expansion of the District's water distribution system in order to receive municipal water and improved fire protection services. There are two larger parcels within the service area that are slated for development; the Foothills and the Village (Ware Rd) developments. The OCP allows for up to 730 dwelling units within the Foothills development. For the Village (Ware Rd) development, the number of potential dwelling units has been assumed to be between 184 and 230 as previously discussed in **4.2 Future Population**. Combined, these two developments with up to 960 residential units could accommodate almost all of the projected 1,025 dwelling units to be constructed over the next 50 years under the moderate growth scenario as presented in **Table 8**.

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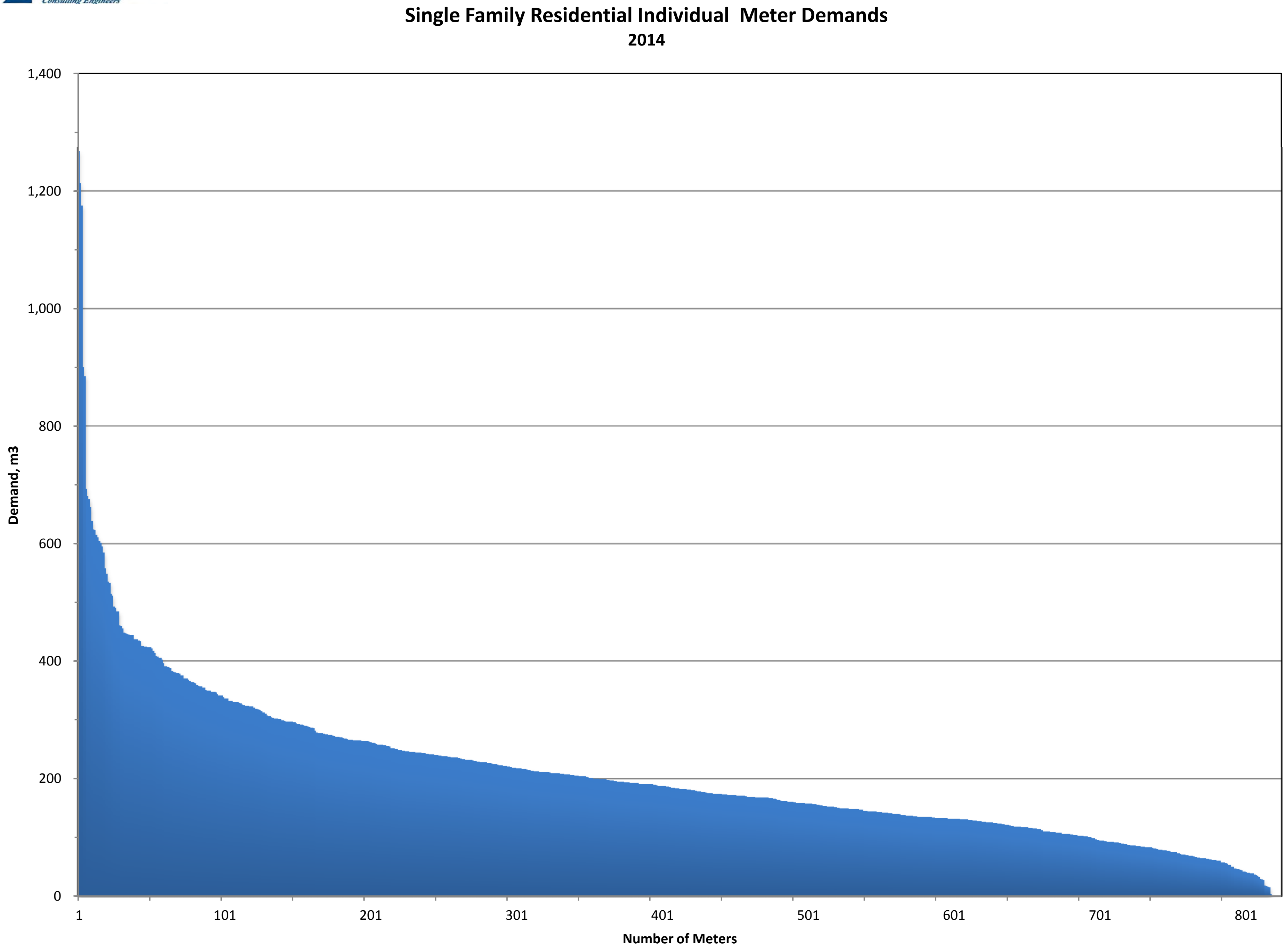

FIGURE 9

5.2.2 Historical Demand Extrapolation

Table 17 presents the average day, maximum day and maximum week demand per service connection based on the combined Upper & Lower zone bulk meter readings for the past three years. The total amount of each and the dates of the maximum day and maximum week events are presented in **Table 11**.

Table 17
Demands Per Service Connection, 2012 - 2014

Description	Demand Per Connection * (m^3/day)		
	2012	2013	2014
Average Day	0.75	0.75	0.78
Maximum Day	1.53	1.39	1.61
Maximum Week	1.24	1.26	1.39

Notes:

* Based on combined demand of the Upper & Lower Zone bulk meters and 885 metered service connections.

Prorating the 2014 average day, maximum day and maximum week demand per service connection to the 441 existing lots yet to be serviced, the projected total system demand if these additional lots were serviced in 2014 would have been 1,029 m^3/day, 2,128 m^3/day and 1,839 m^3/day; respectively. If the projected 960 new residential units had also been serviced in 2014, the total average day, maximum day and maximum week demand are projected to have been 1,775 m^3/day, 3,669 m^3/day and 3,170 m^3/day. The anticipated location of the properties to be serviced is shown in **Figure 10**.

Table 18 presents the extrapolated flows for these developed and undeveloped lands based on the calculated per connection demands for Year 2014. The areas to be serviced are listed based on number of lots to be serviced (highest to lowest). The current pumping capabilities and the estimated safe yield of the wellfield are shown in the table for comparative purposes.

Existing Properties within the OCP Water Service Area Boundary
Presently Not Serviced by the Municipal Water System

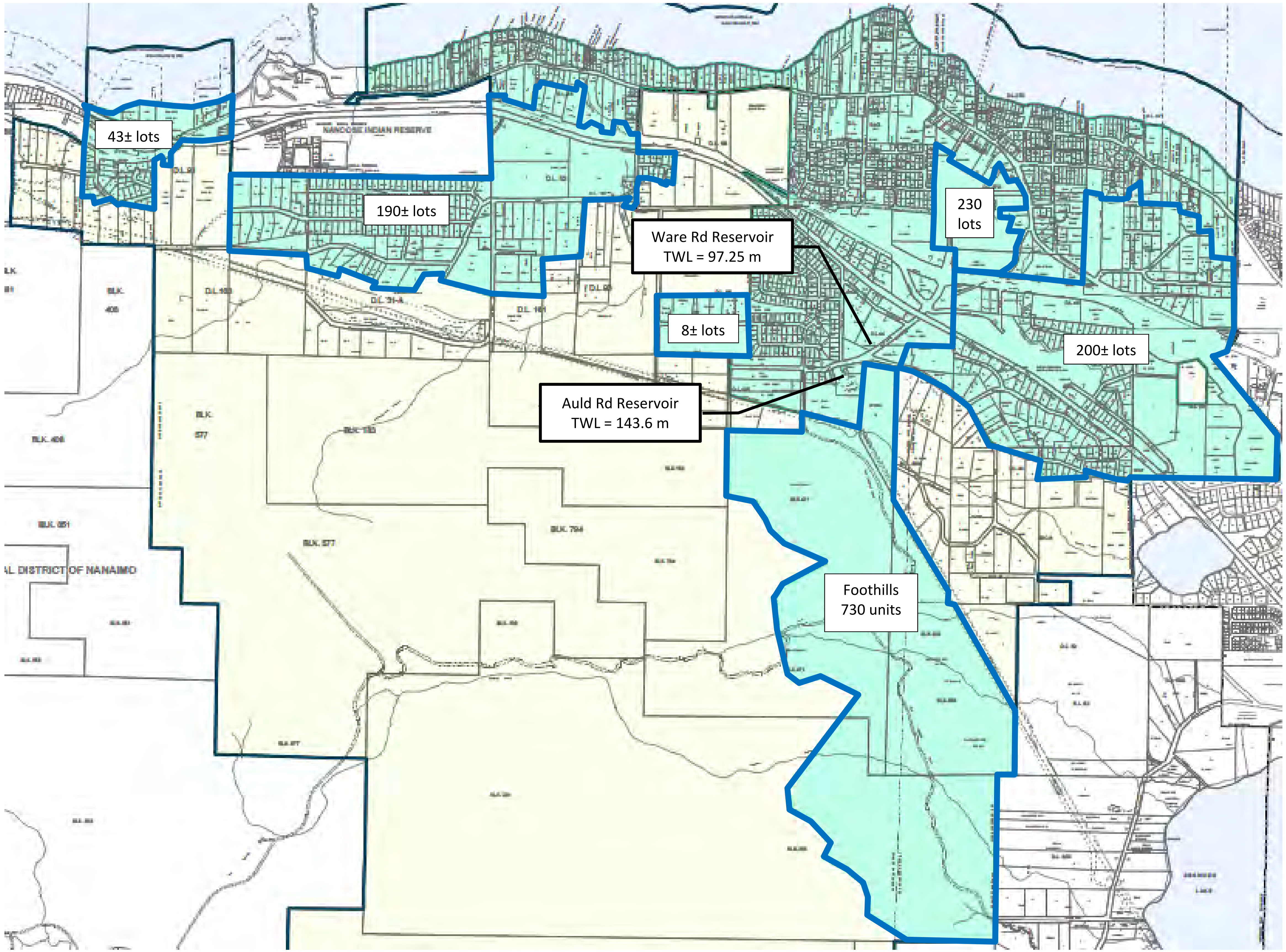

FIGURE 10

Table 18
Service Area Water Demands based on 2014 Per Connection Demands

Description	Number of Connections (#)	Average Day Individual m³/day	Average Day Cumulative m³/day	Maximum Day Ind. m³/day	Maximum Day Cum. m³/day	Maximum Week Ind. m³/day	Maximum Week Cum. m³/day	Wellfield Capacity m³/day* Current Pumps	Wellfield Capacity m³/day* Estimated Safe Yield
YEAR 2014 - Existing System Total:	885	687	687	1,421	1,421	1,227	1,227	2,027	2,424
Extrapolated Demands if all existing properties in Lantzville were serviced (based on Year 2014 average demand per service connection)									
Northwind/Southwind Rd area	190	148	148	305	305	263	263	2,027	2,424
Aulds/Elm Rd area	80	62	210	128	433	111	374	2,027	2,424
Clark/Blackjack Rd area	70	54	264	112	545	97	471	2,027	2,424
Owen Rd area	50	39	303	80	625	69	541	2,027	2,424
Bayview Park/Rumming/Sabre Rd area	43	33	336	69	694	60	600	2,027	2,424
Fernmar Rd area	8	6	342	13	707	11	612	2,027	2,424
Existing Developed areas Extrapolated Total:	441		342		707		612	2,027	2,424
Existing System + Existing Developed areas Extrapolated Total:	1,326		1,029		2,128		1,839	2,027	2,424
Extrapolated Demands for Foothills and Village development (based on Year 2014 average demand per service connection)									
Foothills	730	567	567	1,172	1,172	1,012	1,012	2,027	2,424
Village (Ware Rd) area	230	179	746	369	1,541	319	1,331	2,027	2,424
Foothills + Village Development Total:	960		746		1,541		1,331	2,027	2,424
Existing + Existing Developed + Foothills + Village Extrapolated Total:	2,286		1,775		3,669		3,170	2,027	2,424

Note
* Estimates of the safe well yield are based on information presented in the LHC reports referenced previously in this report.

The data in **Table 18** is graphically presented in **Figure 11**, showing the extrapolated average and maximum day demands for each service area and cumulative total based on the Year 2014 per connection demands. **Figure 12** presents the extrapolated cumulative average day, maximum day and maximum week demand for each individual service area.

The data in Table 18, Figure 11 and Figure 12 needs to be considered in context. While the extrapolated data suggests some, but not all of the additional properties might be able to be serviced by the aquifer if improvements are made to the wellfield, demands will and do vary from year to year. Demands per connection in previous years may not be indicative of future years, and a reasonable factor of safety should be applied. Improvements to the wellfield and storage system should be implemented and the results confirmed before the District considers amending any design standards.

Given the public awareness of the limited capacity of the District's wellfield and the OCP requirement that new development must develop their own water supply to a standard acceptable to the DoL, servicing new lands from the wellfield could result in increased water usage by the current users, as the perception of the need for water conservation could decrease.

5.2.3 Design Standard Extrapolation

The DoL Subdivision and Development Bylaw No. 55, 2005 governs the design of water supply and distribution systems. The Bylaw requires all new properties to connect to the municipal water system and if they are not able, each lot must be provided 3.4 m^3/day of potable water

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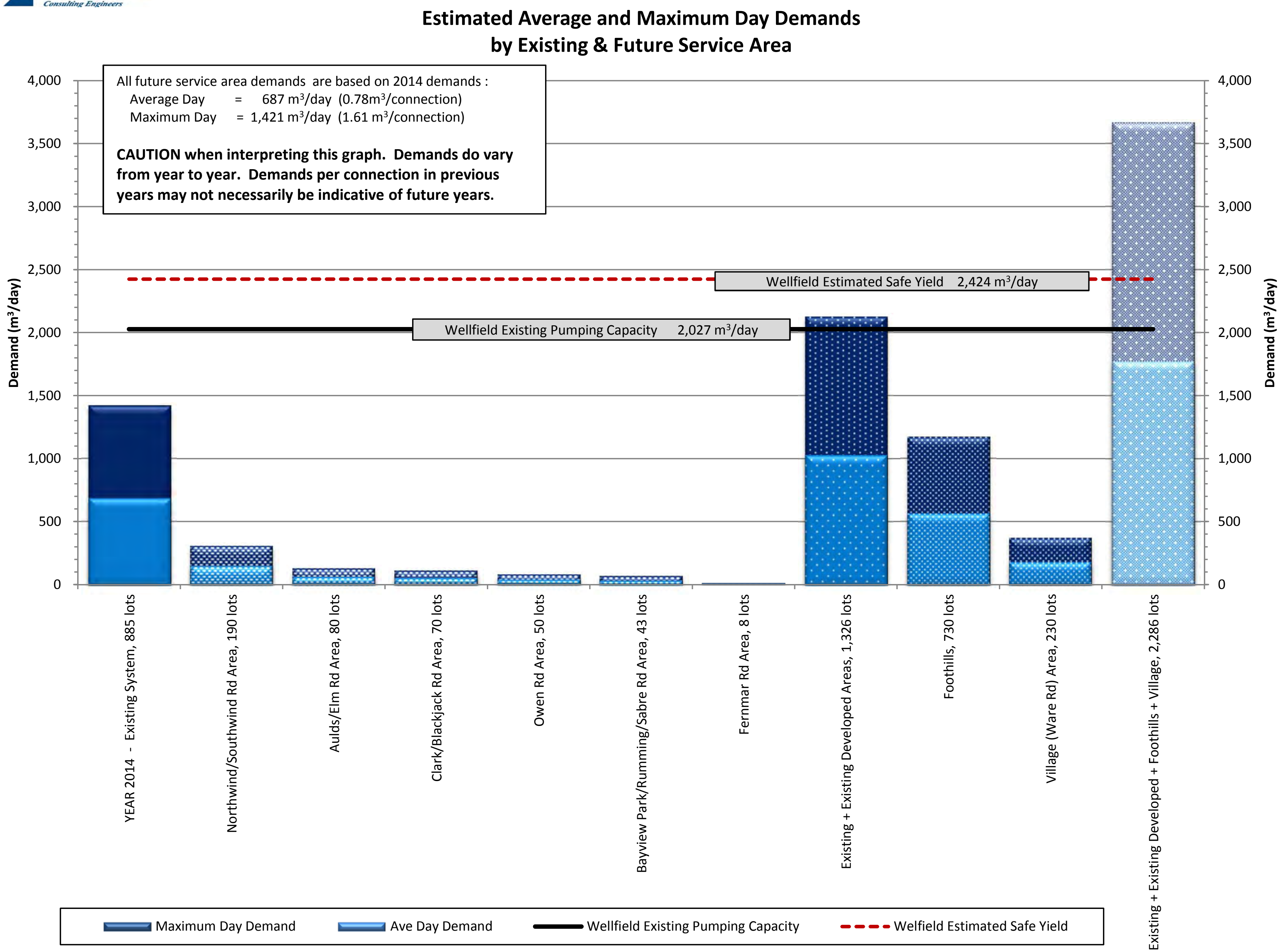


FIGURE 11

Estimated Average & Maximum Day Demands by Existing and Future Service Areas

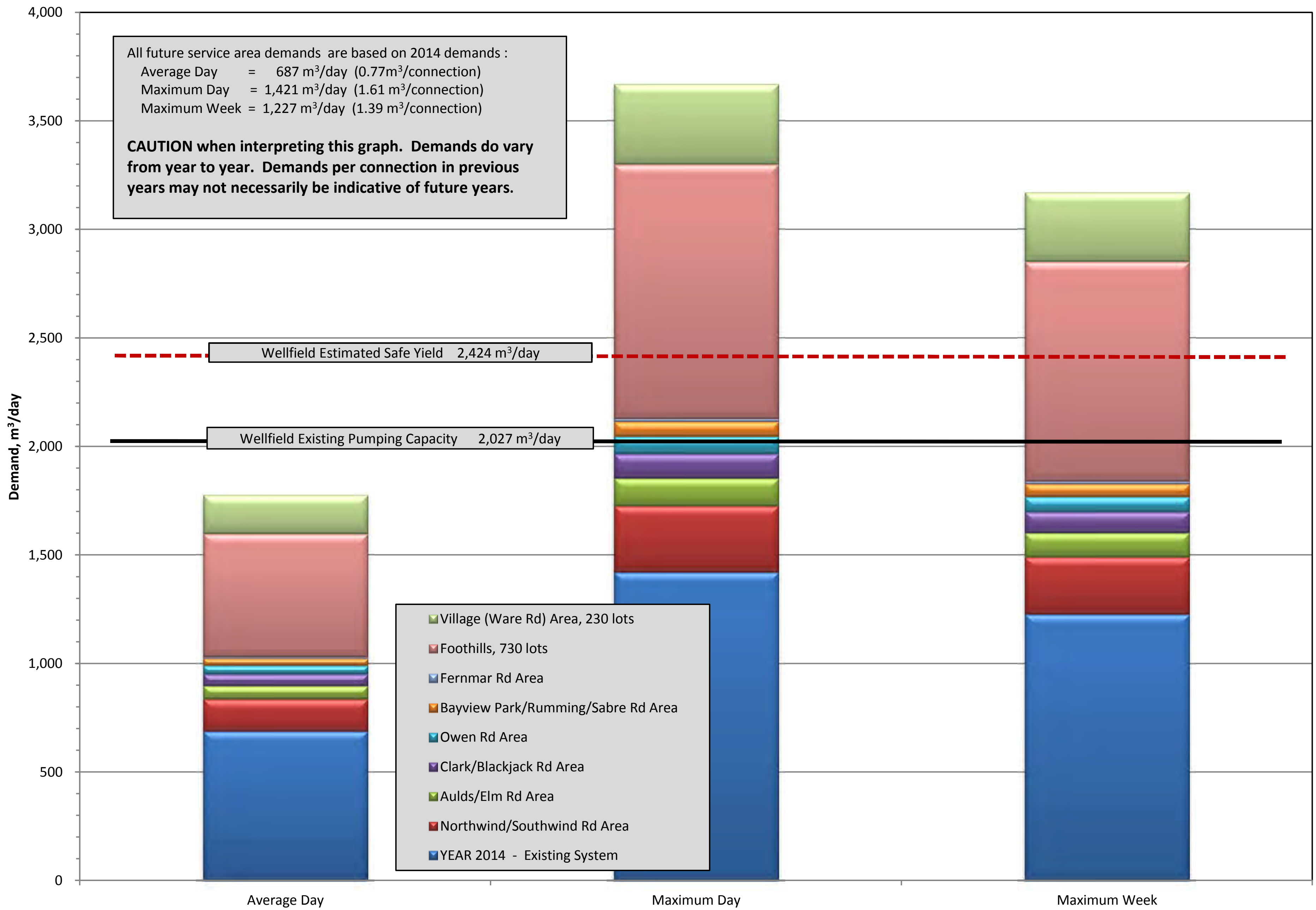


FIGURE 12

from a well. The Bylaw does not provide a design standard for properties connecting to the municipal system.

Water demand design standards for several municipalities on the east coast of mid-Vancouver Island were compared to the DoL standards. The DoL demand design standard was found to be within the range of maximum day demand per capita, but higher than its three closest municipalities of Nanaimo, Fairwinds (Regional District of Nanaimo), and Parksville by 20%, 18% and 1%; respectively. The findings are presented in **Table 19**.

Table 19
Per Capita Design Demands, Mid Vancouver Island Municipalities

Municipality	Municipal Per Capita Demand Design Standards			
	Average Day (lpcd)	Maximum Day (lpcd)	Max/Ave Ratio	Peak Hour (lpcd)
MMCD *	300	600	2	900
Nanaimo	455	1,135	2.5	1,820
Fairwinds		1,168	-	-
Parksville	570	1,364	2.4	1,700
Lantzville	**-**	**1,380 ****	**-**	**-**
Qualicum Beach	-	1,780	-	3,150 ***
Courtenay	635	2,100	3.3	3,000
Comox	635	2,100	3.3	3,000
Campbell River	635	2,100	3.3	3,000

Notes:

* Master Municipal Construction Document, Design Guideline Manual, 2014 where new development is metered. If unmetered, the MMCD design guideline values increase to 450, 900 and 1,350 lpcd, for average day, maximum day and peak hour; respectively.

MMCD recommends these metered and non-metered guideline values only if there are no reliable water consumption records and/or specific municipal requirements. It further states that because maximum day and peak hour demands increase significantly in dry climate areas due to irrigation, the criteria should be adjusted accordingly, based on local water consumption records.

** Based on Lantzville Bylaw 55.1 requirement of 3.4 m^3/day potable water source for a lot not connected to the municipal water supply system. Per capita demand is based on the 2011 Census density of 2.46 capita/dwelling units (3,400 L/day per dwelling ÷ 2.46 capita/dwelling).

*** Based on Qualicum Beach Engineering Standard & Specifications Bylaw No. 545 design of 6.05 m^3/day for single family dwelling, duplex. Per capita demand is based on 2011 Census density of 1.92 capita/dwelling unit (6,050 ÷ 1.92).

The average and maximum day design demands presented in **Table 19**, with the exclusion of the MMCD design guideline values, are almost or more than double the calculated DoL per capita demands for the past three years (2012 – 2014) shown in **Table 11**.

Table 9 of the Lowen Hydrogeology Consulting Ltd. report <u>Phase 1 of Stage 1 Wellfield Management Plan – Wellfield Capacity, Existing and Ultimate, Harby Road Wellfield</u>, dated October 15, 2014 (see copy in **Appendix B**) estimates the long-term safe yield of the wellfield aquifer to be 2,424 m^3/day. Based on the District's current estimated service population of

2,143, this yield would allow a maximum per capita demand of 1,131 lpcd (2,424 m^3/day ÷ 2,143 capita). Only one of the Table 19 Maximum Day per capita design demands is within this limit, the 600 lpcd of the MMCD; though the City of Nanaimo's 1,135 lpcd, is only marginally higher.

Table 20 presents the number of connections that may be accommodated based on the maximum day design demands for the Nanaimo, Fairwinds, Parksville, Qualicum Beach and the District of Lantzville on-site well requirement. Also included is the number of connections based on the DoL recorded maximum day demand of July 14, 2014.

Table 20
Maximum Lots Serviced for Varying Design Demands & Wellfield Yields

Description	**Max Day**	**Municipal Design Demand, Maximum Day**				
Municipality	DoL (July 14, 2014)	(Nanaimo)	(Fairwinds)	(Parksville)	(DoL, on-site well)	(Qualicum Beach)
Maximum Day Demand - Lpcd - Per Connection (m^3) *	 663 1.61	 1,135 2.79	 1,168 2.87	 1,364 3.36	 1,380 3.39	 1,780 4.38
Description	**Number of Lots Serviced based on Maximum Day Design Demand**					
At maximum pumping of 1,426 m^3/day (which equates to 70% of 2,027 m^3/day or 59% of 2,424 m^3/day) **						
Maximum Number of Service Connections:	**886**	511	497	424	421	326
At maximum pumping of 1,630 m^3/day (which equates to 80% of 2,037 m^3/day or 67% of 2,424 m^3/day) **						
Maximum Number of Service Connections:	**1,012**	584	568	485	481	372
At maximum pumping of 1,833 m^3/day (which equates to 90% of 2,037 m^3/day or 76% of 2,424 m^3/day) **						
Maximum Number of Service Connections:	**1,139**	657	639	546	541	418
At maximum pumping of 2,027 m^3/day (which equates to 100% of 2,027 m^3/day or 84% of 2,424 m3/day) **						
Maximum Number of Service Connections:	**1,265**	730	710	606	601	465
At maximum pumping rate of 2,182 m^3/day (which equates to 90% of 2,424 m^3/day) **						
Maximum Number of Service Connections:	**1,355**	782	760	649	644	498
At maximum pumping rate of 2,424 m^3/day (which equates to 100% of 2,424 m^3/day) **						
Maximum Number of Service Connections:	**1,505**	869	845	721	715	553

Notes:

* Maximum Day demand per connection based on 2011 Census density of 2.46 capita/dwelling unit.

** 2,027 m^3/day is the current maximum yield from the wellfield and 2,424 m^3/day is the estimated maximum safe yield subject to successful redevelopment of the wells #4, #9 and #12 and replacement of well #6 as reported in District of Lantzville, Phase 1 of Stage 1 Wellfield Management Plan – Wellfield Capacity, Existing and Ultimate, Harby Road Wellfield, Oct 15, 2014 by Lowen Hydrogeology Consulting Ltd.

Red text indicates the calculated number of potential service connections is less than the current 885.

Bold black underlined text indicates the calculated number of potential service connections is greater than the current 885 service connections.

5.3 BC LIVING WATER SMART PROGRAM

In 2008, the provincial government launched the Living Water Smart program emphasizing water conservation. This program requires 50% of new municipal water needs to be acquired through conservation by Year 2020. The District's current per capita demands are low compared to other mid-Vancouver Island municipalities as shown in **Table 12**. It is not known if this program will be applied to groundwater licensing and if so, what further reduction of DoL (already low) demands can be achieved. The future demand projections in this report have not made any allowances for potential demand reductions.

5.4 CLIMATE CHANGE

Climate change refers to a long-term shift in weather conditions and is measured by changes in a variety of climate indicators (e.g. temperature, precipitation, wind) including both changes in average and extreme conditions.

The following is taken from the Government of Canada climate change website (www.climatechange.gc.ca):

- Over the period 1948 to 2010, the average annual temperature in Canada has warmed by 1.6 °C, a higher rate of warming than in most other regions of the world.
- Future warming will be accompanied by other changes, including the amount and distribution of rain, snow, and ice and the risk of extreme weather events such as:
  - heat waves,
  - heavy rainfalls and related flooding,
  - dry spells and/or droughts, and
  - forest fires.

The recent update to the City of Parksville's Storm Drainage Master Plan, which focuses on winter time storm events, included an assessment of the potential impact of climate change on the City's infrastructure. Some of the key findings were:

- Climate models forecast change in total annual precipitation of between +2% to +11% by 2050s, which is within the historical variability in annual precipitation for the baseline period from 1961 to 1990.
- Models forecast winters that are slightly wetter or about the same as the baseline period (-6% to +14% by 2050s).
- A visual review of the extreme data indicates that Pacific Decadal Oscillation (PDO) cycle could play a role in extreme precipitation in the Parksville Region with the three largest events occurring during cool PDO phase. However, additional records would be required to confirm the statistical significance of this observation.
- The Pacific Decadal Oscillation (PDO) cycles between warm and cool phases about once in every 20 to 30 years. We may have recently shifted from a warm to cool PDO phase, which may have the effect of slowing warming trends in Southwestern BC for the next 20 to 30 years.
- Based on analysis completed by Pacific Climate Impacts Consortium (PCIC), by the 2050s, extreme precipitation in the Parksville Region is forecast to increase by:
  - 5% to 15% for daily maximum, and
  - 15% to 50% for hourly.

The potential impact climate change may have on either the District's water supply source (Aquifer #215) or changes in water demands by the consumers, is not known.

Generally, it is expected that the Vancouver Island region will experience drier summers and wetter winters.

6 WATER MODEL

6.1 COMPUTER PROGRAM

Modelling of the DOL water distribution system was carried out utilizing the computer software program WaterGems, an enhanced version of WaterCAD. This water distribution modelling and management software is in use throughout North America by engineering consultants, municipalities, and utility companies and is used by Koers because of its reliability, versatility, AutoCAD and GIS interface, and support by its creator Bentley Systems Inc.

WaterGems is a powerful, user friendly program created to analyse, design, and optimize water distribution systems. The programs many features include; steady state and extended time modelling, multiple fire flow events modelling while evaluating flows and pressures across the entire system, peak hour pressure analyses, optimization of fixed and variable speed pumps and reservoir storage to minimize energy usage and cost, and automated model calibration. Other analyses features include; system leakage, water loss and unaccounted for water, reservoir mixing, and water-age. Modelling results are presented in tabular and graphical form.

6.2 MODEL UPDATE

6.2.1 Supply & Distribution System

The WaterCAD water model developed for the 2002 water study was updated incorporating water supply and distribution system operational changes and upgrades since completion of that study. These include the construction of the new reservoir and booster pump station on Ware Road, the demolition of the Philip Road reservoir, and a number of watermain replacement/upgrading projects. The existing distribution system is shown on **Drawing 1420-01**.

6.2.2 Pipe Friction Factors

A Hazen Williams friction factor was entered in the model for varying pipe materials, as listed in **Table 21**.

Table 21
Pipe Friction Factors

Pipe Material		Friction Factor, 'C' * (Hazen Williams formula)
HDPE	High Density Polyethylene	145
PVC	PolyVinyl Chloride	140
AC	Asbestos Cement	130
DI	Ductile Iron	130
CI	Cast Iron	110

Note:
* The modeled friction factors are slightly less than those included in the DoL design standards. This takes into account the reduction in capacity that occurs in the distribution system where fittings and service connection points are present and sliming on pipe walls occurs with age.

To better calibrate the friction factors in the DoL system, controlled field testing would be required during times of peak hour flows, where pressure losses in the various pipe types and sizes could be determined. Flow testing was not included in the scope of work for this study. Due to the significant system operators' time required to conduct flow tests, no specific flow testing was carried out. Flow rate and pressure loss determinations along typical sections of the larger supply mains should be carried out when possible, for comparison with the assumed values used in this analysis. In general, except for the oldest pipe sections, the values listed are believed to be conservative.

6.2.3 Allocation of Demands

Water demands were distributed evenly throughout the model at nodal points (pipe intersections, end of mains and pipe diameter changes). The average day demand was used as the base. Maximum day and peak hours demands were modelled by multiplying each individual demand by the appropriate ratio (maximum day to average day, and peak hour to maximum day).

6.3 ANALYSIS CRITERIA

6.3.1 Water Demands

In establishing the capacity of a water supply and distribution system, three levels of water demand are normally considered, in addition to fire flows. These are:

Average Day Demand	=	Total annual consumption / 365 days
Maximum Day Demand	=	Day with highest demand for the year
Peak Hour Demand	=	Highest flow rate maintained for one hour (generally occurring on maximum day of the year)

The system must also be capable of delivering fire flow demands during maximum day demands.

The computer model was used to analyse the existing water distribution system. Average day demand was based on Year 2014. Maximum day demand was based on July 14, 2014, the highest demand recorded during the past four years as graphically shown on **Figure 4**. Peak hour demand was based on a 2 times multiplier of maximum day demand. This multiplier is considered appropriate for a smaller water system of this size.

The 2014 modelled water demands are listed in **Table 22** along with the demands modelled for the previous water study completed when Lantzville was an improvement District (Lantzville Improvement District Water Quality & Assessment Project, May 2002 by Koers & Associates Engineering Ltd.).

Table 22
Modelled Water Demands, 2002 & 2014

Description	Demand, 2002		Demand, 2014		Difference
	(m^3/day)	(L/s)	(m^3/day)	(L/s)	(%)
Average Day	832	9.64	687	7.95	(-17%)
Maximum Day	1,780	20.6	1,421	16.45	(-20%)
Peak Hour (2 x Max Day)	3,335	38.6	2,842	32.89	(-15%)

6.3.2 Fire Flow Requirements

The DoL Subdivision and Development Bylaw No 55, 2005, Engineering Specifications Schedule F specifies that fire flow demands are to be calculated in accordance with the most recent version of the "Water Supply for Public Fire Protection" by the Fire Underwriters Survey (FUS), for existing and anticipated land use. Furthermore, the Bylaw states residual pressures (in the distribution system) the fire flow rate plus average daily demand shall not be less than 240 kPa (35 psi).

The FUS fire flow requirements vary, depending on building design, floor area, number of stories, construction materials, if a fire sprinkler system is installed, fire break walls, and spacing from adjacent buildings (exposure). The duration for which a fire flow is to be provided increases as the flow increases. For example, a fire flow of 33 L/s (2,000 L/minute) or less is to be sustained for at least 1 hour. A fire flow of 667 L/s (40,000 L/minute) or more is to be sustained for 9 hours. The FUS recommends a water system to be capable of providing the design fire flow during maximum day demand while maintaining a minimum residual pressure 150 kPa (22 psi) in the water main.

The application of target fire flows for commercial and industrial applications can vary widely, depending on the building's design, age, size, use, the materials utilized for construction, and whether a sprinkler system has been installed. Typically, the required flow rates are determined using FUS criteria at the time of design, and if necessary, improvements to the municipal system are undertaken to achieve the desired flow if necessary.

It is difficult to determine a specific target number for commercial and industrial land uses, as each building will vary. While the DoL does not publish fire flow requirements by land-use zone, a number of other larger Vancouver Island municipalities do, such as the City of Nanaimo, the City of Parksville, and the City of Port Alberni. Larger municipalities may tend towards larger values, due to the nature and built in redundancy of their systems. However, it is noted that due to the potential impact on future reservoir sizing, the District give careful consideration before adopting specific target criteria. Based on a review of nearby municipalities and their adopted standards, the suggested ranges of fire flow requirements used to assess the DoL water system according to land-use are presented below in **Table 23**.

Table 23
Fire Flow Demand by Land-Use

Land-Use	Minimum Required Fire Flow	
	Flow (L/s)	Duration (hrs)
Single/Two Family Residential	75	2
Low Density Multiple Family Residential	90	2
Medium Density Multiple Family Residential	120	2
High Density Multiple Family Residential	150	2
Light Industrial	150 - 250	2 - 3
Commercial	150 - 300	2 - 4
Institutional	150 - 300	2 - 4

6.3.3 Fire Hydrants

Hydrant Spacing

The DoL Subdivision and Development Bylaw No 55, 2005, Engineering Specifications Schedule F specifies that:

- Distance between hydrants shall be a maximum of 150 m.
- Hydrants shall be located so that every home is within 120 m, but with due regard to the location of existing hydrants.
- Hydrant spacing for school, apartment, commercial, or other high value properties is to be in accordance with the current "Water Supply for Public Fire Protection" by the Fire Underwriters Survey.

Table 24 lists the Fire Underwriters Survey recommended maximum spacing of hydrants based on land-use.

Table 24
Recommended Maximum Distance between Fire Hydrants by Land-Use

Land Use	Recommended Maximum Distance Between Fire Hydrants
Multi-Family Residential	90 m
Commercial, Industrial, Institutional	90 m

Hydrant Type

Fire hydrants are to be equipped with three nozzles:

- two 65 mm diameter hose nozzles, and
- one 100 mm diameter pump nozzle.

Hydrants are to be connected to the watermain by a 150 mm diameter pipe.

Some of the District's older fire hydrants have only the two 65 mm dia. hose nozzles (they do not have a 100 mm dia. pump nozzle), and are usually connected to the main by only a 100 mm dia. pipe. These hydrants are being replaced by the District as funds are available and in conjunction with watermain upgrading projects. The eight remaining hydrants to be replaced are all located in the Lower Pressure Zone and are listed in Table 25.

Table 25
Hydrants to be Replaced

Hydrant No.	Location
23	Huddlestone Rd at park entrance
54	7311 Lynn Rd
57	7305 Millard Rd
59	7339 Rossiter
60	7299 Rossiter
61	7292 Harby Rd East
62	7340 Harby Rd East
72	7032 Leland Rd

6.3.4 Reservoir Sizing

Water reservoirs perform three functions:

- storage for fire fighting
- storage for emergencies (such as a watermain break)
- storage for equalization to manage hourly peaks in demand

The storage volume requirements for the DoL were calculated using the following, generally accepted, formula from the "Design Guideline Manual, 2014" from the Master Municipal Contract Document (MMCD) Association:
Storage Volume = A + B + C

Where:

A = Fire Storage	(from Fire Underwriters Survey Guide)
B = Equalization (Peaking) Storage	(25% of Maximum Day Demands)
C = Emergency Storage	(25% of (A + B))

The requirement for Emergency Storage (C) can be reduced or eliminated based on several factors, including: water source dependability, reliability of the supply system (e.g. gravity vs pumped, duplication of mains and treatment, standby emergency power), multiple sources, more than one storage reservoir, and reservoir water circulation needs. As the DoL water supply is a groundwater source requiring pumps and there are only two water reservoirs in the distribution system, emergency storage volume requirements were included in the calculations. This storage volume calculation has been updated from the one used in the 2002 Water Study which served as the basis for the sizing of the Ware Road reservoir.

6.3.5 Distribution System

The adequacy of the distribution system for various demand conditions is judged by the residual pressure available throughout the system and by the maximum velocity in the mains. The criteria applied to assess the DoL distribution system are listed in **Table 26** and are based on good engineering practise.

Table 26
Distribution System Design Criteria

Parameter	Value	
Under Peak Hour Demand Conditions		
Minimum residual pressure at property line	275 kPa	(40 psi)
Maximum velocity in mains	1.5 m/s	(5 ft/s)
Under Fire Flow Demand Conditions (during Maximum Day Demands)		
Minimum residual pressure at hydrant	138 kPa	(20 psi)
Maximum velocity in mains	3.0 m/s	(10 ft/s)
Minimum residual pressure at property line	35 kPa	(5 psi)
Under Static Conditions		
Maximum service pressure	1,035 kPa	(150 psi)

The DoL Subdivision and Development Bylaw No 55, 2005, Engineering Specifications Schedule F specifies that watermain diameters are to be a minimum of 200 mm diameter, with the exception of the last 90 m of dead-ended watermain in a cul-de-sac can be reduced to 150 mm diameter. Depending on the fire flow demand, and the velocities within the main, and the extent of looping in the system, 150 mm diameter may be sufficient, subject to approval.

7 SYSTEM ANALYSIS

7.1 DISTRIBUTION SYSTEM

The water system was evaluated under steady state conditions to determine the system pressures under peak hour conditions and during maximum day demands plus fire flows for existing and future conditions. The existing water system and pressure zones are shown on **Drawing 1420-01** located in the pocket at the end of this report.

The modeling analyses are discussed below.

7.1.1 Peak Hour Pressures

The system pressures under peak hour demand under existing conditions are shown in **Figure 13**.

Upper Pressure Zone

i) Pressures Less than Minimum Design Standard

Pressures below the acceptable design minimum of 275 kPa (40 psi) occur on properties at an elevation above 115 m geodetic in the upper pressure zone. These encompasses approximately 10 properties located and at the top (southeast) end of Aulds Road (west of Philip Road) and at the top end of Harwood Drive (south of Aulds Rd). The lowest pressure is estimated to be around 207 kPa (30 psi) at the home at 6671 Harewood Road. The highest ground elevation is also on this property at approximately 132 m in the southwest corner.

To provide a minimum design pressure of 275 kPa (40 psi) at the 132 m ground elevation, the top water level of the Aulds Road reservoir could be increased to 160 m geodetic compared to the current 143.6 m. This 16.4 m increase (160 m – 143.6 m) would result in 160 kPa (23 psi) pressure increase throughout the entire Upper Pressure zone. As a result, properties below the 75 m geodetic elevation would experience a static pressure greater than the typical maximum design pressure of 827 kPa (120 psi) and those below 54 m geodetic would experience pressure greater than the recommended maximum design pressure of 1,035 kPa (150 psi). This would impact the following areas encompassing approximately 50 properties:

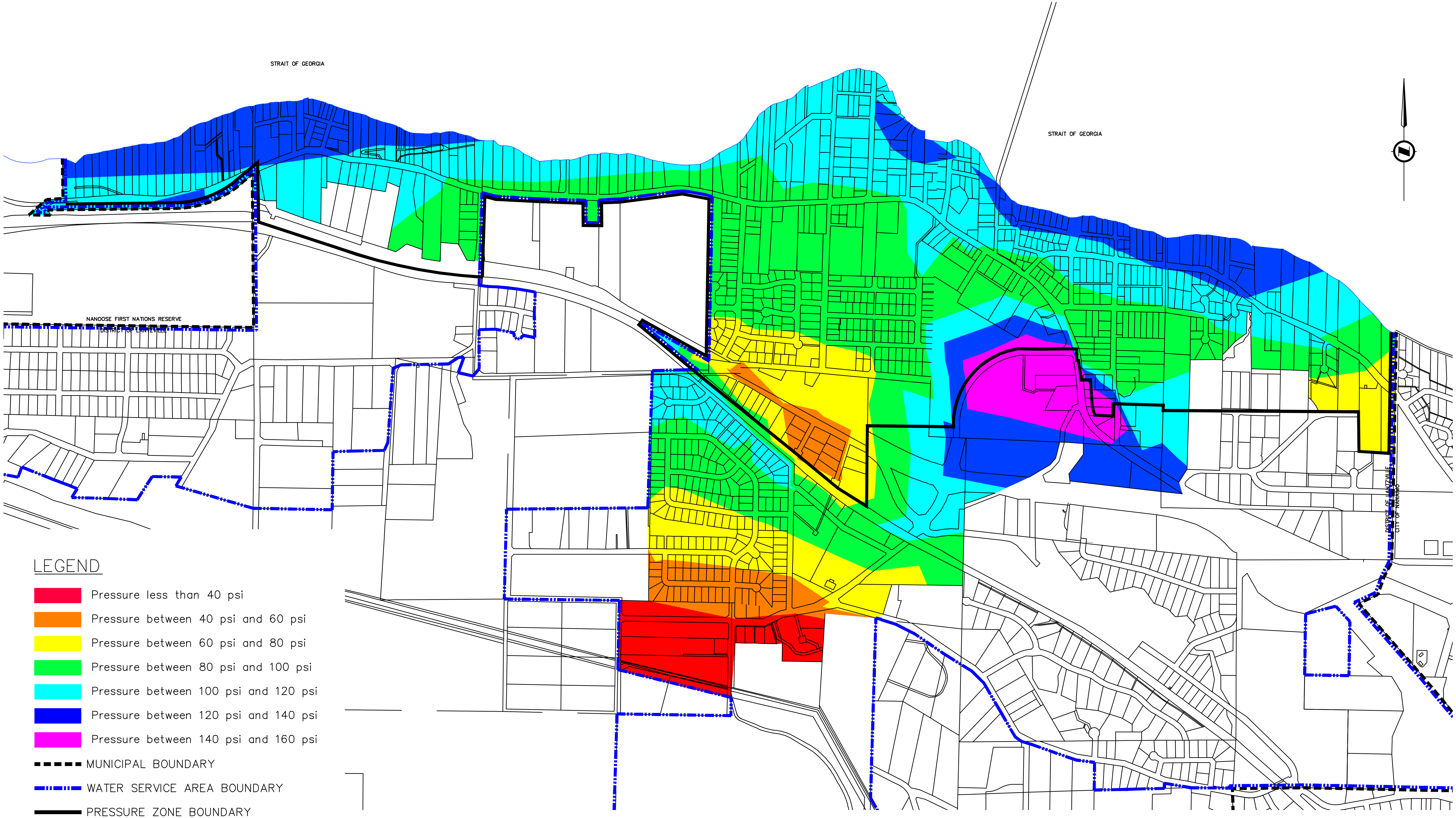
High pressure zone properties below 75 m geodetic (pressures greater than 827 kPA (120 psi) if Aulds Road reservoir elevation increased to 160 m geodetic

- Philip Road properties, north of Ronald Road
- Forest Turn properties,
- Harby Road West properties,
- All properties north of the E&N Railway including:
  - Lantzville Road between Ware Road and Owen Road
  - Stronge Road

Properties below 54 m geodetic (pressures greater than 1,035 kPA (150 psi) if Aulds Road reservoir elevation increased to 160 m geodetic

- Ware Road, (from 110 m north of Hwy 19 to Lantzville Road)
- Lantzville Road between Ware Rd and Maple Glen Mobile Home Park
- Stronge Road

South of the E&N railway, the highest pressures would be experienced on the properties along Forest Turn and Harby Road West where the ground elevation ranges from 68 to 60 m geodetic;



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CLIENT	DISTRICT OF LANTZVILLE	TITLE	EXISTING CONDITIONS PEAK HOUR PRESSURES
PROJECT	WATER STUDY UPDATE	APPROVED	
		DATE	MAY 2015
		PROJECT No.	1420
		SCALE	1:12,500
		DWG No.	Figure 13

File: H:\4254 Lantzville District\1420 Water System Study Update\02 Design\Model\Figures.dwg Plot Time: May 22, 2015 – 9:25am User: mbrook resulting the static pressure increasing from 738 kPa – 820 kPa (107 psi – 119 psi) to 896 kPa – 980 kPa (130 psi – 142 psi).

North of the E&N Railway, the highest pressure would be experienced on Lantzville Road, around the PRV. The pressure at St Philips by the Sea Anglican Church (7113 Lantzville Road) would increase to 1,224 kPa (177 psi) from the current 1,064 kPa (154 psi).

Relocation of the PRV on Lantzville Road to around the 54 m geodetic elevation on Ware Road, which is approximately 110 m north of Hwy 19, would address this issue as discussed in greater detail in the section below. Relocation of the PRV was recommended in the 2002 water study.

An increase in operating pressure will result in an increase in system leakage, which follows a linear relationship, i.e., a 1% increase in system pressure results in a 1% increase in system leakage. It can be expected that a pressure increase would also result in an increase in the number of main breaks, especially on the aging AC mains. The pressure class rating of the AC mains is not known but it is assumed they would be the more common 1,035 kPa (150 psi) and not the less common 689 kPa (100 psi).

ii) Pressures Greater than Maximum Design Standard

Pressures above the recommended design standard of 1,035 kPa (150 psi) occur on properties below an elevation of 38 m geodetic. These encompass the majority of the proposed Village (Ware Rd) development properties. These lands, when developed, should be serviced from the Lower Pressure Zone, which is fed from the Ware Road reservoir. On this pressure zone, the maximum pressure on the property would range from 365 kPa (53 psi) at the Ware Road/Hwy 19 intersection to 659 kPa (96 psi) at Ware Road/Lantzville Road intersection.

The highest static pressure occurs at the PRV station on Lantzville Rd just south of Ware Road intersection, where a pressure of approximately 1,107 kPa occurs (160 psi). If the top water level of the Aulds Road reservoir is raised 16.4 m to 160 m geodetic, in order to provide a minimum operating pressure of 207 kPa (40 psi) to all properties at the top end of Aulds and Harwood Road, the pressure at the PRV station will increase by 160 kPa (23 psi). This would create a maximum pressure of 183 psi at the PRV station, which is greater than the recommended maximum design pressure of 1,034 kPa (150 psi), but may be within the design tolerances of ductile iron. Further study would be needed to determine the phasing and design requirements to implement both improvements.

Those properties along Lantzville Road south of Ware Road intersection are presently serviced by the Upper Pressure zone. Relocating the PRV station as noted above would result in these properties being switched over onto the Lower Pressure zone, which can provide the 275 kPa (40 psi) minimum acceptable design pressure to properties below the 69 m geodetic elevation. This covers all properties in the area except for the following properties above 69 m geodetic and which are presently not connected to the DoL water system because there are no watermains along these roads:

- 6 undeveloped properties along Lantzville Road southeast of Owen Road,
- 15 properties on Rosalyn Crescent and Wayne Place, and
- 2 properties on Schook Road.

If these properties are to be serviced by the DoL water system, they would either need to be serviced from the Upper Pressure Zone, possibly from the potential interconnection line from the Nanaimo system on Dover Road, or from a new localized pressure zone with the construction of a booster pump station fed from the Lower Pressure system.

Lower Pressure Zone
Adequate pressures are maintained throughout the lower pressure zone. The lowest pressures occur in the Industrial Park at the top (south) end of Mart Road and Metro Road at 306 kPa (44 psi).

The highest pressures are along the waterfront. Pressures greater than (827 kPa) 120 psi occur on waterfront properties in two areas:

- Between Seaside Terrace on Dickinson Road and Peterson Road off Lantzville Road (a distance of approximately 2 kms)
- Lantzville Road, between Superior Road and the west end (a distance of approximately 0.7 kms)

These are within the recommended maximum pressure of 1,034 kPa (150 psi).

7.1.2 Available Fire Flows

Figure 14 shows the available fire flows during maximum day demand under existing conditions. Adequate fire flows are available to the majority, but not all, of the properties connected to the water system.

Available fire flows less than recommended minimum 75 L/s for Single Family residential properties generally occur at hydrants connected to 100 mm diameter mains, at the blow-offs located at the end of main, and on the long dead ended 150 mm diameter main on Lantzville Road, west of Superior Road.

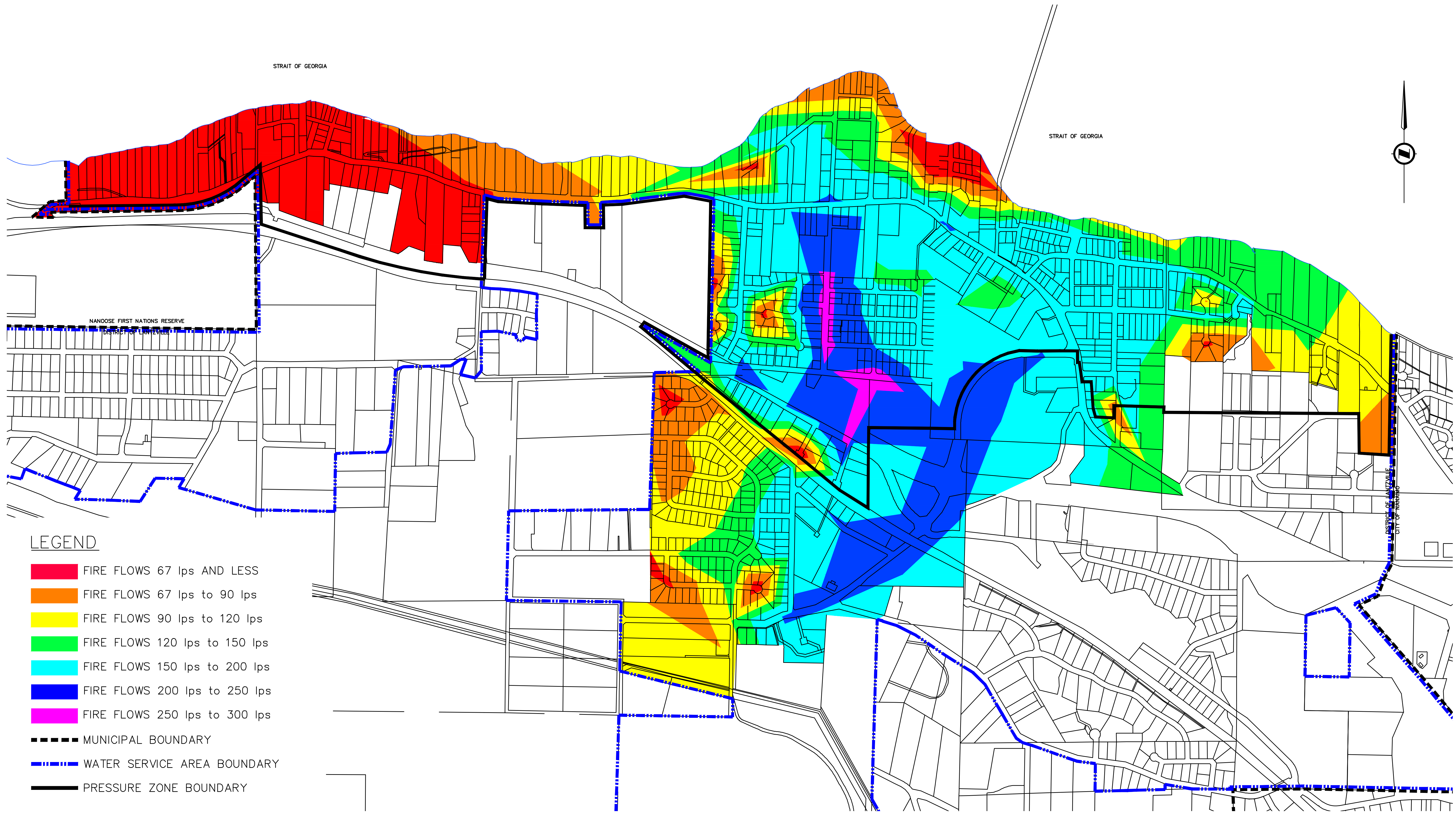
Available fire flows for Commercial and Institutional properties generally range in the 150 to 200 L/s range. Available fire flows for the Industrial properties are generally in the range of 150 to 250 L/s, with the exception of the 100 mm diameter dead end main on Mart Road, where less than 75 L/s is available from the fire hydrant at the end of the main.

Table 27 (overleaf) summarizes the areas with available fire flows less than the recommended minimum design standard.

Replacement of 100 mm Diameter Mains
For the SF Residential areas, upsizing of the 100 mm diameter mains on which a fire hydrant is connected and replacing those hydrants that do not have the 100 mm diameter pump port would generally increase the available fire flows to above the minimum recommended design standard of 75 L/s.

The District standard requires mains to be minimum 200 mm diameter, except for the last 90 m of a dead-ended cul-de-sac main may be 150 mm diameter. Subject to computer modeling confirmation, and a review of anticipated velocities under fire flow conditions, 150 mm diameter for loop mains may be adequate in some cases.

Industrial Area
Installing additional fire hydrants on Mart Rd and upgrading the existing 100 mm diameter main would improve the available fire flows. Replacing the existing 200 mm AC main on Industrial Rd with a new 250 mm dia main between both highway crossings not only improves fire flows within the Industrial area, but the reduced head loss also improves fire flows in the downstream areas of the lower pressure zone.



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CLIENT	DISTRICT OF LANTZVILLE
PROJECT	WATER STUDY UPDATE

TITLE	EXISTING CONDITIONS AVAILABLE FIRE FLOWS		
APPROVED		SCALE	1:12,500
DATE	MAY 2015	DWG No.	Figure 14
PROJECT No.	1420		

Table 27
Areas with Fire Flows less than Recommended Design Standard

Location & watermain diameter (mm)		Fire Flow: Proposed Improvement (mm)	Fire Flow: Recommended Minimum, or Range (L/s)
Upper Pressure Zone			
SF Residential			
Clark Cres (cul-de-sac)	100	150	75
Clark Cres (looped)	100	150 / 200 *	75
Forest Turn (cul-de-sac)	100	150 / 200 *	75
Industrial			
Industrial Road	200	250	150 to 250
Mart Rd (cul-de-sac)	100	200 / 250 *	150 to 250
Lower Pressure Zone			
SF Residential			
Chataway Pl (cul-de-sac)	100	150 / 200 *	75
Geisler Pl (cul-de-sac)	100	150 / 200 *	75
Hall Rd *(future loop)*	100	200	75
Harper Rd *(future loop)*	100	200	75
Huddleston Rd *(future loop)*	100	200	75
Saxon Cross Rd (cul-de-sac)	100	150	75
Lantzville Rd (west of Superior Rd)	150	200	75
Benwaldun & Plover Rds	150	200	75
Shangri-La	150	200	75
North & Alison Rds	150	200	75
Commercial & Institutional			
Lantzville School Rd	150	See Table 31	150 - 300
Lantzville Rd, Tweedhope to Caillet	200	See Table 31	150 - 300

Note
* Larger diameter main to last fire hydrant, then smaller main to end point.

Downtown Commercial/Institution Area
For the Commercial and Institutional properties in the Lower Pressure Zone, fire flows are limited by the 150 mm diameter main on Peterson Road between Lynn Rd and Lantzville Rd and the 150 mm diameter main on Lantzville Rd between Peterson Road and Huddlestone Road. Upsizing these to 250 mm diameter would increase the available fire flows to within the suggested range of 150 - 300 L/s. This requires replacement of a total of 750 m of watermain consisting of 300 m on Peterson Road and 450 m on Lantzville. The existing mains are Asbestos Cement and their replacement would serve as part of the District's Asbestos Cement main replacement program (see **7.4 Asbestos Cement Watermains**).

Additional looping through undeveloped lands adjacent to the downtown core will also strengthen the existing distribution system and increase the fire flows available for the commercial properties. Any opportunity to install these connections should be reviewed in detail as part of the future development review process. Additional replacement and upgrading of the existing Asbestos Cement watermains in the upstream areas of the Lower Pressure Zone on Industrial Road, Joy Way, Rossiter, Millard, Lynn and Lancewood Ave will also improve fire flows in the downtown area, especially if looping opportunities through undeveloped lands are not available in the near future.

For Lantzville School Rd, the dead end 150 mm diameter main near Seaview Elementary should be upsized to minimum of 250 mm dia, if looping through adjacent lands to the east are not available in the near future.

Lantzville Road west of Superior Road
Fire flows along Lantzville Road, west of Superior Road are restricted by the 150 mm diameter (Asbestos Cement) main. To provide the recommended minimum of 67 L/s, approximately 1,400 m of main (550 m east of Superior Road and 950 m west of Superior Road) should be upgraded to 200 mm diameter. This project would also serve as part of the District's Asbestos Cement main replacement program (see **7.4 Asbestos Cement Watermains**).

Figure 15 shows the available fire flows during maximum day demand after completion of the upgrading works noted in the previous paragraphs.

7.2 RESERVOIR STORAGE

The storage volume requirements for the DoL were calculated using formula presented in **6.3.4 Reservoir Sizing** which is based on fire flow and maximum day demand. For smaller municipalities, such as the DoL, the largest factor governing the size of water storage reservoirs is fire storage which varies depending on the design fire flow rate and the duration for which it is applied (see **Table 23**). Storage requirements were therefore calculated separately for District's two pressure zones to account for the differing fire demands and the portion of the maximum day demand within each.

Storage requirements for existing conditions (2014) and in 25 years (2040). Allowance was made for system expansion to service existing developed properties within the OCP Water Service Area boundary along with allowances for new development.

7.2.1 Upper Pressure Zone (Aulds Rd Reservoir)

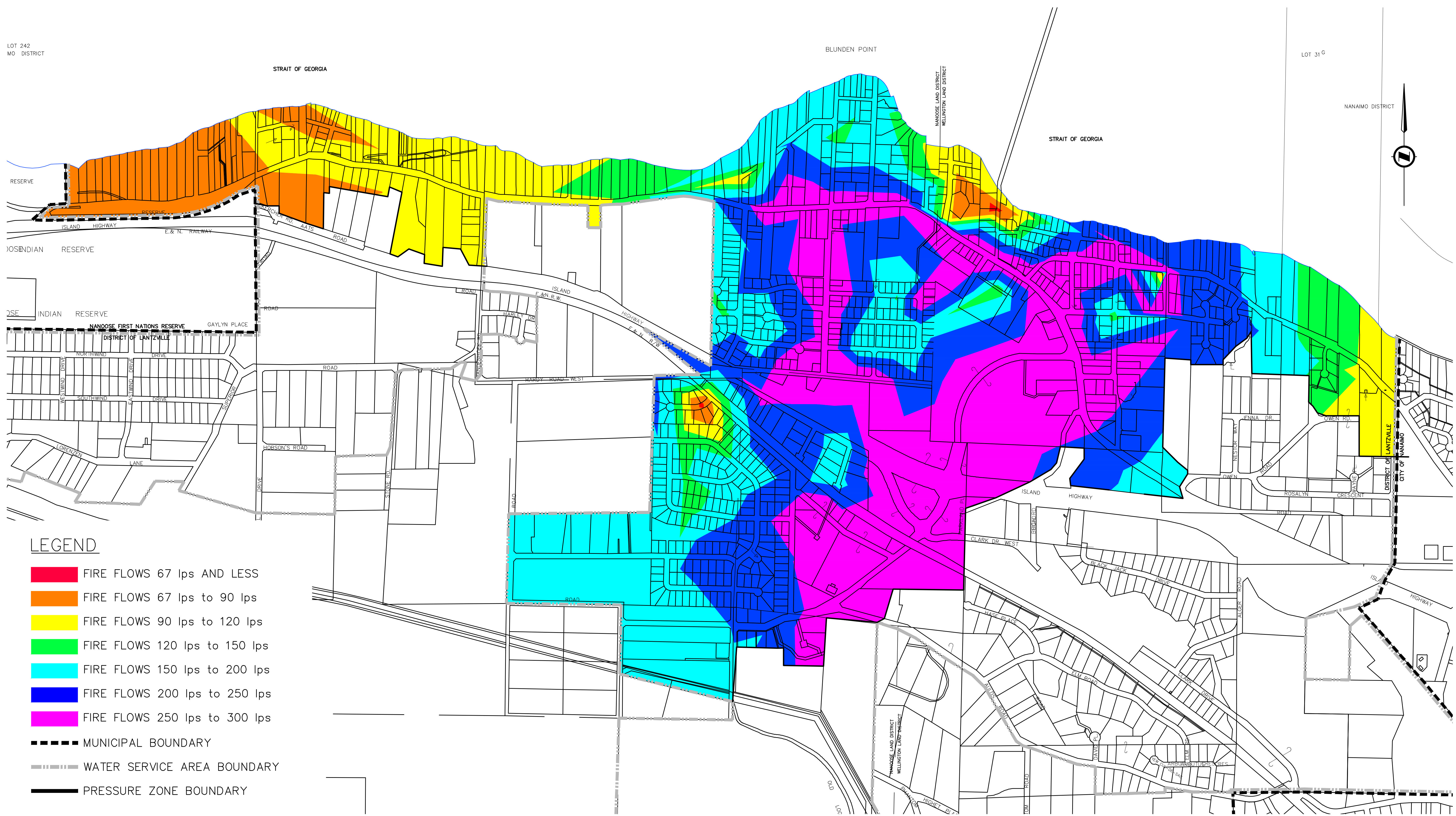
Existing Conditions

A *Fire Storage*:
A fire flow of 75 L/s for 2 hours was used based on single family residential land use. This requires a storage volume of 540 m^3.

B *Peaking Storage*:
Calculated at 25% of maximum day demand. The maximum day demand was estimated based on ratio of water service connections in the Upper Pressure Zone compared to the entire system, which equates to 26% (226 ÷ 885).

Based on the 2014 maximum day demand of 1,421 m^3 for the entire water system, the peaking storage volume requirement for the Aulds Road reservoir is 92 m^3.

C *Emergency Storage*:
Calculated at 25% of (Fire Storage + Peaking Storage). This requires a volume of 158 m^3.



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CLIENT	DISTRICT OF LANTZVILLE
PROJECT	WATER STUDY UPDATE

TITLE	FUTURE DEMAND CONDITIONS AVAILABLE FIRE FLOWS
APPROVED	
DATE	MAY 2015
PROJECT No.	1420
SCALE	1:12,500
DWG No.	Figure 15

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The current storage volume of the Aulds Road reservoir, 240 m^3 (53,000 ig), is almost 1/3 the recommended volume of 790 m^3 (175,000 ig) as summarized in **Table 28**.

Future Conditions (Year 2040)

A *Fire Storage*:

A fire flow of 75 L/s for 2 hours was used based on single family residential land use. This requires a storage volume of 540 m^3.

B Peaking Storage:

Calculated at 25% of maximum day demand. Expansion of the Upper Pressure Zone system to service up to 350 lots over the next 25 years (by Year 2040) was assumed in developing a Year 2040 Maximum Day demand. This number of lots is equivalent to the servicing of those properties shown on **Figure 10** that are within the District's Water Service Area and that should be serviced from the Aulds Road reservoir. These are:

-	Northwind/Southwind area	190 lots
-	Aulds/Elm Rd area	80 lots
-	Clark/Blackjack Rd area	70 lots
-	Owen Road area	50 lots
-	Fernmar area	8 lots
Total		348 lots

No allowance was made for servicing the Foothills development from the District's existing water system. It is understood this development (730 lots) will be responsible for development of its own water supply and distribution system. The elevation of the Foothills development will require a separate pressure zone with a reservoir top water level elevation above 200 m geodetic.

For the Year 2040 maximum day demand, a low and a high value were used for comparative purposes. The low value was based on the DoL's Year 2014 Maximum Day demand per lot of 1.61 m^3/day (1,421 m^3/day ÷ 885 serviced lots). The high value was based on the City of Nanaimo's 1,135 lpcd and an assumed future DoL population density of 2.2 capita per dwelling, resulting in a maximum day demand of 2.50 m^3/day per lot (1,135*2.2). When applied to the total number of existing and future lots (226 + 348 = 574) the resulting required peaking storage volume by Year 2040 is:

- low range = 25% * (1.61 m^3/day per lot * 574 lots) = 231 m^3
- high range = 25% * (2.50 m^3/day per lot * 574 lots) = 359 m^3

C *Emergency Storage*:

Calculated at 25% of (Fire Storage + Peaking Storage).

- low range = 25% * (540 m^3 + 231 m^3) = 193 m^3
- high range = 25% * (540 m^3 + 309 m^3) = 213 m^3

By 2040, the required storage volume ranges from 964 m^3 to 1112 m^3 (213,000 ig to 245,000 ig) based on the range of projected maximum day demands.

The volume calculations for Year 2014 and 2040 are shown in **Table 28**.

Table 28
Upper Pressure Zone (Aulds Rd) Reservoir Storage Requirements

Description	Calculation	Required Volume, m^3 in Year		
		2014	2040	
			Low	High
Fire Storage	75 L/s for 2 hrs	540	540	
Peaking Storage	25% of Max Day	91	231	359
Emergency Storage	25% of (Fire + Peaking Storage)	158	193	213
Total Required Storage Volume:		790	964	1,112
Current Reservoir Storage Volume:		240	240	240
Resulting Storage Surplus/Deficit		**550**	**724**	**872**

Providing the additional storage volume will require replacement of the existing concrete reservoir. Assuming the top water level of the Aulds Road reservoir at its current site is increased to an elevation of 160 m geodetic (from the existing 143.6 m) in order to provide a minimum design pressure of 275 kPa (40 psi) during peak hour demands, the calculated storage volumes require a diameter of 7.8 m and 8.2 m; respectively. This is close to the existing 8.5 m diameter and therefore could potentially be constructed at the existing site, but would first require the removal of the existing reservoir in order to construct the new one.

A preliminary review indicates that the existing booster pumps at the Ware Road reservoir which supply water to the Aulds Road reservoir, may be capable of delivering the Year 2040 range of maximum day demand flows to a higher water elevation. This would require replacing the existing impellers with a larger diameter impeller. Further investigation and updated information from the pump manufacturer would be needed to confirm the design details and potential performance limits.

The Aulds Reservoir is served by a combination inlet / outlet line connecting the tank to the distribution system. Future work on the reservoir should include installing separate in and outlet lines between Aulds Rd and the reservoir. Abandoning the existing reservoir site and constructing a reservoir at a new location, such off at the south end of Harwood Road, and abandoning the existing site is another possible option. Relocating to this area, or other possible sites with adequate elevation would require additional offsite watermain upgrading work.

7.2.2 Lower Pressure Zone (Ware Rd Reservoir)

Existing Conditions

A *Fire Storage*:

An assessment of the DoL fire protection system was carried out by FUS in 2013. This study calculated a maximum fire flow demand of 200 L/s for 2½ hours for the Village core area. A fire demand of 250 L/s for 3 ½ hours for a wooden barn on Lantzville Road between Leland and Superior Road was also calculated. These require a storage volume of 1,800 m^3 and 3,150 m^3; respectively.

As noted previously in **Section 6.3.2**, the application of target fire flow for commercial, institutional, and industrial applications requires careful consideration due to the wide variation of potential design criteria, and the impact on future infrastructure replacement decisions. For the purposes of this study, the 200 L/s flow for a 2 hour duration was used as a lower threshold, while the larger 250 L/s flow for a 3 hour duration was used as a higher value, to highlight the range of potential storage requirements. In addition to reviewing its policies to consider the impact of new commercial, institutional and industrial developments on the existing and proposed water system infrastructure requirements, the District should evaluate the current status of these properties, and assess the appropriateness of the FUS design flow criteria. The two potential fire flow storage volumes are 1,440 m^3 and 2,700 m^3 respectively.

B *Peaking Storage*:
Calculated at 25% of maximum day demand. The maximum day demand was estimated based on ratio of water service connections in the Lower Pressure Zone compared to the entire system, which equates to 74% (659 ÷ 885).

Based on the 2014 maximum day demand of 1,421 m^3 for the entire water system, the peaking storage volume requirement for the Ware Road reservoir is 264 m^3.

C *Emergency Storage*:
Calculated at 25% of (Fire Storage + Peaking Storage).

- low range = 25% * (1,440 m^3 + 264 m^3) = 426 m^3
- high range = 25% * (2,700 m^3 + 264 m^3) = 741 m^3

The required storage for existing conditions in the Ware Road Reservoir ranges from 2,130 m^3 to 3,705 m^3, depending on the selected design criteria. This target range is higher than its current storage volume (1,887 m^3), which was sized based on guidelines prevailing at the time.

The PRV connection at Ware Road, permits storage in the Upper Zone reservoir to augment fire flows in the Lower Zone during a fire event. Thus capacity in the Upper Zone can be credited towards Lower Zone storage requirements. Consideration can be given to increasing the size of the Upper Zone Reservoir to offset or potentially delay future improvements to the Lower Zone Reservoir. Upgrading of the Upper Zone reservoir was recommended in the 2002 study.

Table 29 presents a summary of the reservoir storage requirements for Year 2014 based on various fire flow demand ranges

Future Conditions (Year 2040)

A *Fire Storage*:
A similar fire flow target range of 200 L/s for 2 hours and 250 L/s for 3 hours was used. This required a fire storage volume range from (1,440 m^3 to 2,700 m^3. Further discussion with the District is required to select appropriate targets for planning purposes.

B Peaking Storage:
Calculated at 25% of maximum day demand. Expansion of the Lower Pressure Zone system to service an additional 273 lots over the next 25 years (by Year 2040) was assumed in developing a Year 2040 Maximum Day demand. This allows for the servicing of the existing 43 properties in the Bayview Park/Rumming/Sabre Rd area, at the west end of the District, plus an additional 230 new lots corresponding to the number of lots that may be developed by the Village (Ware Rd) development. Both of these areas are within the District's Water Service Area and are shown on **Figure 10**.

For the Year 2040 maximum day demand, a low and a high value were used for comparative purposes. The low value was based on the DoL's Year 2014 Maximum Day demand per lot of 1.61 m^3/day (1,421 m^3/day ÷ 885 serviced lots). The high value was based on the City of Nanaimo's 1,135 lpcd and an assumed future DoL population density of 2.2 capita per dwelling, resulting in a maximum day demand of 2.50 m^3/day per lot (1,135 * 2.2 = 2.50 m^3/day). When applied to the total number of existing and new lots (659 + 273 = 932) the resulting required peaking storage volume by Year 2040 is:

- low range = 25% * (1.61 m^3/day per lot * 932 lots) = 375 m^3
- high range = 25% * (2.50 m^3/day per lot * 932 lots) = 583 m^3

C <u>*Emergency Storage*</u>:
Calculated at 25% of (Fire Storage + Peaking Storage).

- low range = 25% * (1,440 m^3 + 375 m^3) = 454m^3
- high range = 25% * (2,700 m^3 + 583 m^3) = 1,226 m^3

By 2040, the total required storage volume ranges from 2,270 m^3 to 4105 m^3 (500,000 ig to 900,000 ig) based on the range of projected maximum day demands and potential target fire flow conditions.

Table 29 presents a summary of the reservoir storage requirements for Year 2040 based on a fire flow demand range and a low and high range of projected maximum day demand.

Table 29
Lower Pressure Zone (Ware Rd) Reservoir Storage Requirements

Description	Calculation	Required Volume, m^3 in Year		
		2014	2040	
			Low	High
Fire Storage	200 L/s (for 2 hrs) to 250 l/s (for 3hrs)	1,440 – 2,700	1,440	2,700
Peaking Storage	25% of Max Day	264	375	583
Emergency Storage	25% of (Fire + Peaking Storage)	426 – 741	1,175	1,226
	Total Required Storage Volume:	2,130 – 3,705	2,270	4,105
	Current Reservoir Storage Volume:	1,887	1,887	1,887
	Resulting Storage Surplus/Deficit:	243 – 1,818	383	2,218
	Potential Available Fire Storage in High Pressure Zone:	100 *	540 *	540 *
	Resulting Storage Surplus/Deficit:	**143 – 1,718**	**157**	**1,678**

Note

* Because the Upper Pressure Zone can supply water into the Lower Pressure Zone by way of the pressure reducing valve station on Lantzville Road at Ware Road, the fire storage in the Upper Zone Reservoir could be credited to the Lower Zone reservoir storage requirements. This would provide some reduction to the Low Zone total storage volume requirements.

Space within the existing Ware Road Reservoir property is limited, and expansion would require the District to obtain property from the adjacent land owner. Alternatively, if the District decides to expand the water system to the Northwinds / Southwinds area in the future, a second balancing reservoir at the same top water level could be constructed in the Northwinds / Southwinds area to service the west end of the Lower Pressure zone.

7.3 NORTHWIND/SOUTHWIND AREA SERVICING

The ground elevation of the properties in the Northwind/Southwind roads area are such that the area cannot be serviced from the Lower Pressure Zone but can be serviced from the Upper Pressure Zone. This can be achieved by installing a new main on Harby Road West, Vandenhoek Road and Superior Road along with mains on Northwind Road and Southwind Road with cross ties on Eastwind Road and Westwind Road.

Based on the single family residential land-use of the area, a design fire flow of 75 L/s is anticipated. Providing this flow will require upgrading to a minimum 300 mm diameter, the 120 m of 200 mm diameter main from the Aulds Road Reservoir to Aulds Road and the upgrading of 1,100 m of 150 mm diameter main along Phillip Road and Harby Road West. This is in addition to the installation of 1,700 m of 300 mm of new main along Harby Road West, Vandenhoek Road, and Superior Road, and the installation of 200 mm diameter mains along Northwind, Southwind, Eastwind and Westwind drives. The storage capacity of the Aulds Road reservoir must also be increased, along with offsite improvements to separate the inlet and outlet mains at the reservoir.

The extension of the mains to this area can also serve to strengthen the Lower Pressure zone distribution system and improve fire flows on Superior Road and on Lantzville Road west of Superior Road by connecting the two zones together along Superior Road. A Pressure Reducing Valve station (PRV) would be installed at the connecting point. The valve would be set as per the existing PRV valve, on Lantzville Road at Ware Road, to open only during a large flow demand. If demands in the Northwind/Southwind area are low and water quality is an issue, a small diameter PRV could also be installed in the station to permit a portion of the daily demands in the Lower Pressure Zone to be met. The proposed works are shown on drawing no. **1420-01 Existing System and Proposed Works.**

7.4 ASBESTOS CEMENT WATERMAINS

As noted in **Table 3**, there are 27 kilometers of watermain in the DoL, of which more than 15 kilometers (57%) are Asbestos Cement (AC) piping. The use of AC for watermain construction ceased in the 1970's, indicating these mains are more than 40 years old. The life span of AC mains ranges from 30 to 90 years, depending on many factors, such as: water quality; type of soils; groundwater levels; pipe manufacturer; quality of installation; bedding material; depth of bury; and traffic loading. The major problem experienced with AC pipe, other than wall fractures, is the leaching of the cement mortar binder out of the pipe. This can occur on the internal and the external surfaces, severely weakening the pipe strength. The rate of leaching depends on the aggressiveness of the groundwater and potable water in contact with the AC pipe. Leaching can be highly localized, and vary from pipe to pipe.

The remaining service life in an AC main can be estimated by a series of laboratory tests. This requires the removal of a section of the watermain. The test results along with records of main and service connection repairs should be used in identifying the most problematic areas and prioritizing the work.

During the past six years, the DoL has replaced more than 2,000 metres of AC main, as part of an AC main replacement and fire flow improvement program. The sections of watermain that have been replaced since 2010 are listed in **Table 30**.

Table 30
AC Watermain Replacement, 2010 – 2015

Year	Location	Total Length (m)
2015	Fernmar Road	345
2014	Lancrest Terrace	435
2013	Peterson Road	398
2012	-	-
2011	Lantzville & Tremblay roads	201
2010	Dickinson Road	680
	Total	**2,059 m**

7.5 CITY OF NANAIMO BULK WATER SUPPLY AGREEMENT

On September 8, 2014, the District of Lantzville and the City of Nanaimo signed a bulk water sale/purchase agreement. The agreement is the fulfilment of more than 9 years of work since the District and the City signed a Memorandum of Understanding for the supplying of water.

The agreement identifies the connection to the City's water system is to be made on Dover Road at the intersection of Schook Road onto the existing dead-end of the 200 mm diameter main. The connection to the District's water system is to be made on Lantzville Road onto the existing dead-end of the 200 mm diameter main at 7057 Lantzville Road.

The connection to the City system is fed from pressure zone 20 which has a 183 m hydraulic grade line (HGL). The connection to the District system is to the Upper Pressure Zone which is fed from the Aulds Road reservoir with its 143.6 m HGL. Previous extended time (24 hours) water modelling of this interconnection option carried out by Koers indicated the available HGL from the City ranges from 157.5 m to 179 m as the system demands vary throughout the day.

The proposed raising of the top water level of the Aulds Road reservoir to 160 m geodetic, as discussed in **7.1.1 Peak Hour Pressures, Upper Pressure Zone**, *i) Pressures Less than Minimum Design Standard*, is slightly above the lowest calculated HGL. Further extended time modelling should be carried out as part of conceptual design review of optimizing the reservoirs diameter and height.

The distance between the two connection points noted in the agreement requires the installation of approximately 930 m of 250 mm diameter watermain. The raising of the Aulds Road Reservoir top water level will result in the relocation of the Lantzville Road PRV. This will result in an increase to the overall length of the interconnection main between the City and the District from 930 m to 1,530 m; an increase of 600 m. However, depending on timing, this work can be integrated into the future development adjacent to Ware Road. If the Upper Reservoir replacement project precedes the future connection to the City of Nanaimo, then the PRV locate project can be delayed until the future development work occurs.

The agreement, a copy of which is located in **Appendix A**, includes, among other things: areas of the District the City's water is to be used; how many connections per year are permitted; quantity and quality of water; amount of the one-time and annual fees payable to the City; duration of the agreement (clause 12); and the duties and responsibilities of the City and of the District. It is noted that the District is required to maintain and operate its wells at least Year 2014 levels (clause 6.5).

8 PROPOSED IMPROVEMENTS

Table 31 lists the recommended upgrading works in order of priority to:

- Maximize the yield of the Harby Road wellfield,
- Provide recommended reservoir storage to meet projected future demands,
- Meet recommended fire flow demand standards,
- Strengthen the water distribution system,
- Continue with the replacement of Asbestos Cement watermains, and
- Facilitate the potential servicing of additional areas as well as other existing developed lots within the District's Water Service Area as shown on OCP Map 7.

The locations of the proposed works are shown on drawing no. **1420-01 Existing System and Proposed Works**.

Table 31
Proposed Works

Priority	Description	Quantity	Cost Estimate Class 'D' (excluding GST)
	Water Supply Capacity Improvements		
1	Replace Well No. 6	1	$250,000
2	Redevelopment of Well No. 4, 9 and 12	3	$75,000 (for all)
3	Securing Groundwater License for each Well	n/a	$6,000
	System Storage Improvements		
4	Replace Upper Pressure Zone (Aulds Rd) Reservoir	964 - 1,112 m^3	$900,000 - $1,000,000
TBD	Expand Lower Pressure Zone (Ware Rd) Reservoir Storage	TBD	TBD
	Fire Flow Improvement Projects (Commercial, Institutional & Industrial benefit)		
5	Mart Road and Industrial Road (Metro to Harby Road East) Watermain Upgrade	175 m of 200 mm 475 m of 250 mm	$100,000 $325,000
6	Peterson Rd (Lynn to Lantzville Rd) Watermain Upgrade	300 m of 250 mm dia.	$225,000
7	Lantzville Rd (Peterson Rd to Harper Rd) Watermain Upgrade	450 m of 250 mm dia.	$310,000
8	Harby Road East (Peterson to Joy) Watermain Upgrade	175 m of 250 mm dia	$120,000
9	Joy Way and Rossiter (Peterson to Lancewood) Watermain Upgrade	425 m of 200 mm dia	$240,000

Table 31 (continued)

Priority	Description	Quantity	Cost Estimate Class 'D' (excluding GST)
	Fire Flow Improvement Projects (Commercial, Institutional & Industrial benefit)		
10	Millard Drive (Peterson to Lancewood) Watermain Upgrade	325 m of 200 mm dia	$185,000
11	Lynn Drive (Peterson to Lancewood) Watermain Upgrade	325 m of 200 mm dia	$185,000
12	Lancewood Avenue (Rossiter to Lynn)	250 m of 200 mm dia	$140,000
	Fire Flow Improvement Projects (Residential Area Benefit)		
13	Replace Limited Capacity Hydrants (or in conjunction with main replacements)	8	$3,500 each
14	Lantzville Rd (east and west of Superior Rd) Watermain Upgrade	1,500 m of 200 mm dia	$840,000
15	Huddlestone Rd Watermain Upgrade	175 m of 200 mm dia.	$100,000
16	Harper Rd Watermain Upgrade	200 m of 200 mm dia.	$110,000
17	Hall Rd Watermain Upgrade	150 m of 200 mm dia.	$85,000
18	Saxon Cross Watermain Upgrade	150 m of 150 mm dia.	$75,000
19	Forest Turn Watermain Upgrade	150 m of 150 mm dia.	$75,000
20	Clark Crescent Watermain Upgrade	425 m - 250 mm 100 m – 150 mm	$240,000 $50,000
21	Geisler Pl & Chataway Pl Watermain Upgrade	275 m of 150 mm dia.	$140,000
	Other Watermain Improvement Projects		
22	AC Main Replacement (9 kilometres)	600 m/year for 15 years	$340,000 per year
23	Looping through future development	TBD	Developer Driven
TBD	Relocate PRV on Lantzville Road to Ware Road	1	Developer Driven

The cost estimates are derived from our in-house construction cost data base for watermain construction projects in the mid-Vancouver Island area. All costs are as of June 2015, when the ENR Construction Cost Index was 10,037.

The cost estimates are based on Class 'D' (feasibility study) estimates, made without preliminary design input. The cost estimates include a 25% allowance for legal, construction, financial, administration and engineering costs, with the following exceptions:

- Priority 3, Securing Groundwater License for each Well – Only the estimated costs of the provincial government fees are listed with no contingency allowances.
- Priority 4 Reservoir Storage Costs – Cost estimates include a contingency allowance of 40%.

A discussion of each project is presented below.

1 Replace Well No. 6

It is proposed that well 6 be replaced with a new well because Lowen Hydrogeology Consulting Ltd. (LHC) have determined the existing well is operating inefficiently and that historical records indicate its pumping rate has been reduced to stop sand from being pumped out with the water.

Its current pumping rate is estimated at 543 m^3/day when operating simultaneously with the other pumps. LHC projects the combined pumping rate can be increased to 668 m^3/day; an increase of 125 m^3/day (23%).

When operated by itself it is expected its pumping rate could be 836 m^3/day.

2 Redevelopment of Wells No. 4, 9 and 12

LHC have estimated that the capacity of these well can be increased by re-development. Presently their simultaneous combined pumping capacity totals 1,484 m^3/day. After redevelopment, LHC projects the wells will be able to product a combined total of 1,756 m^3/day when operating simultaneously; an increase of 272 m^3/day (18%).

Upon completion of redevelopment of Well No. 6 and redevelopment of Wells No, 4, 9 and 12, LHC estimates the production of the wellfield could increase from the current 2,027 m^3/day to 2,424 m^3/day; an increase of 397 m^3/day (397 m^3/day).

A budgetary allowance of $25,000 per well has been made for the redevelopment. In general the anticipated work consists of:

- removal of the existing pump, motor and piping,
- surging of the well to loosen sediment that have migrated into the voids in the gravels and sands around the well screen resulting in a decline in the well pumping capacity,
- bailing of the well to remove the sediments loosened by the surging,
- re-instatement of the well pump, motor, and piping, and
- testing wells to confirm new individual and simultaneous pumping rates.

3 Securing Groundwater License for each Well

The DoL is required to obtain a licence from the provincial government for the extraction of water from the ground as per the Water Sustainability Act that was passed in May 2014.

The DoL will be required to pay a one-time application fee of $5,000, in addition to an annual rental fee estimated to cost $565 ($2.25 per 1,000 m^3).

4 Replace Upper Pressure Zone (Aulds Rd) Reservoir

The existing reservoir is undersized to meet existing and Year 2040 storage volume requirements which includes allowances for servicing an additional 348 lots.

The total required storage volume for Year 2040 is estimated to be 741 m^3 based on a maximum day demand of 1.61 m^3/day per connection and 889 m^3 based on a maximum day demand of 2.50 m^3/day per connection.

The reservoir site is very limited and cannot accommodate a larger diameter tank.

The current top water level of the reservoir, 143.6 m geodetic, results in a static operating pressure for below the acceptable design minimum of 275 kPa (40 psi) on the approximately 10 properties located at the top (southeast) end of Aulds Road (west of Philip Road) and at the top end of Harwood Drive (south of Aulds Rd).

The cost estimate is based on removal of the existing 8.5 m diameter concrete reservoir (with a top water elevation of 143.6 m) and constructing a new similar diameter reservoir with a top water elevation of 160 m geodetic. Allowances to upgrade the inlet and outlet piping between the reservoir and Aulds Road have also been identified.

5 Mart Road and Industrial Road (Metro to Harby Road East) Watermain Upgrade

Replace 475 m of 200 mm diameter AC main with 250 mm dia and 175 m of AC main with 200 mm dia. This project is proposed in order to improve firefighting capabilities in and around the Village Core area, and along other downstream areas of the lower pressure zone. It will also result in the replacement of 4% of the District's 15 kilometres m of AC mains.

6 Peterson Rd (Lynn to Lantzville Rd Watermain Upgrade

Replace 325 m of 150 mm diameter AC main with 250 mm dia. This project is proposed in order to improve firefighting capabilities in and around the Village Core area, and along Peterson Road and Lantzville Road (east and west of Peterson). It will also result in the replacement of almost 2% of the District's 15 kilometres m of AC mains.

7 Lantzville Road (Peterson to Harper) Watermain Upgrade

Replace 450 m of 150 mm diameter AC main with 250 mm dia. This project is proposed in order to improve firefighting capabilities in and around the Village Core area, and along Lantzville Road (east and west of Peterson). It will also result in the replacement of 3% of the District's 15 km of AC mains.

8 - **12 Various Watermain Upgrades within the Peterson / Lancewood Area**

Replace 1,500 m of 100 & 150 mm diameter AC main with 200 / 250 mm dia. These projects are proposed in order to improve downstream firefighting capabilities in and around the Village Core area, and along Lantzville Road (east and west of Peterson). It will also result in the replacement of 10% of the District's 15 kilometres m of AC mains.

13 Replace Limited Capacity Fire Hydrants

It is recommended the District continue with its replacement program of the older fire hydrants that have limited firefighting capabilities. These hydrants have the two 65 mm dia. hose nozzles but are missing the 100 mm dia pumper port nozzle, and generally have only a 100 mm diameter service pipe lead, compared to a 150 mm diameter. The eight hydrants to be replaced are located in the Lower Pressure Zone and are listed in **Table 25**. Most of the hydrants are in areas identified for improvements elsewhere. If those watermain upgrades are not scheduled in the near future, then the District should give consideration to replacing these hydrants in advance of the future watermain upgrade project.

14 Lantzville Rd Watermain Upgrade (east and west of Superior Rd)

Replace 1,400 m of 150 mm diameter AC main with 200 mm dia. This project is proposed in order to improve firefighting capabilities. It will also result in the replacement of more than 9% of the District's 15 kilometres of AC mains.

15 - 17 Huddlestone, Hall and Harper Road Watermain Upgrades

Replace 525 m of various sections of small diameter AC main with 200 mm dia. These projects are proposed to improve firefighting capabilities to the properties along Huddlestone, Ellesmere, Bayview, Harper, and Hall Road areas. It will also result in the replacement of more than 3% of the District's AC mains.

18 – 21 Saxon Cross, Forest Turn, Clark, Geisler, and Chataway Pl Watermain Upgrade

Replace 1,100 m of small diameter AC main with 150 / 200 mm dia. These projects are proposed to improve firefighting capabilities in various cul-de-sac and dead-end road areas. They will also result in the replacement of 7% of the District's AC mains.

22 AC Main Replacement

It is recommended the District continue with its AC main renewal/replacement program, preferably in advance of any proposed road rehabilitation requirements within the area. With the completion of priorities noted above, there will be approximately 9 kilometres of AC main remaining in the District. A budget of $340,000per year would allow for replacement of all remaining AC pipe over 15 years.

The cost estimate includes allowances for the installation of a new main; tees; valves; hydrants; reconnecting service connections; abandonment of the existing AC main; removal of tees, valves and fittings; backfilling with imported trench backfill; repaving of the trench surface with 50 mm thickness of asphalt; and a 25% allowance for engineering costs and construction contingency allowances.

23 Looping through Future Development

There are several locations where future development will offer the ability to construct additional looping within the water system which will serve to strengthen the distribution system and improve fire flows throughout the water service area. The specifics of each potential future improvement should be reviewed in detail by the District during the development review process.

(To Be Determined) Relocate PRV on Lantzville Road to Ware Road

Relocation of the PRV is required in order to facilitate the development of the lands in the Ware Road – Lantzville Road area. The PRV should be located onto Ware Road at a ground elevation of approximately 54 m geodetic, creating a maximum inlet pressure of 1,035 kPa (150 psi). It is estimated that this ground elevation is located approximately 110 m north of the Hwy 19A intersection.

The PRV outlet to be set at 380 kPa (55 psi) based on a 54 m geodetic ground elevation.

Relocating the PRV will increase the length of the main required for the District of Lantzville to obtain water from the City of Nanaimo. An additional 600 m will be required, increasing the total length from 930 m to 1,530 m. The relocation of the PRV and the extension to the City of Nanaimo supply system should be the developer's responsibility.

Relocation of the PRV was recommended in the 2002 water study.

(TBD) Expand Lower Pressure Zone (Ware Rd) Reservoir Storage

Depending on the location and nature of future growth, and the target fire flows selected by the District, additional storage volume in the Lower Pressure Zone will likely be needed.

The total required storage volume for Year 2040 is estimated to be in the 2,300 to 4,100 m^3 range, depending on maximum day demand criteria and target commercial flows adopted by the District. Opportunities to expand the existing Ware Road reservoir are limited, and would likely require the District to obtain land from the adjacent owner. Or alternative locations can be reviewed in conjunction with a system expansion review.

9 CONCLUSIONS

Based on the findings of this study, the following conclusions are made:

Water Conservation measures adopted by the District in the past are working, and have been successful in managing system demands.

Water Supply

1. The District obtains its water from four groundwater wells located off of Harby Road East. The current pumping rates range from a low of 190 m^3/day to a maximum of 728 m^3/day. The total capacity of wellfield with all pumps operating simultaneously is 2,027 m^3/day.

2. There are presently 10 wells drilled in and around the wellfield area. One is the Ministry of Environment monitoring well #232.

3. The aquifer from which the District obtains its water is labelled #125 by the Ministry of Environment.

4. Lowen Hydrogeology Consulting Ltd. has estimated the long-term sustainable yield of the aquifer at 2,424 m^3/day, subject to land use changes in the upstream recharge areas of the aquifer. Accessing this will require redevelopment of wells No. 4, 9 and 12 and replacement of well no 6. The pumping rate of well no. 6 has reportedly been lowered to stop sand from being pumped out with the water.

5. The provincial government's Water Sustainability Act (Bill 18) was given Royal Assent on May 29, 2014 and will formally replace the current Water Act in 2016. The new act is being implemented in stages because of its complexity. The new act requires the licensing of groundwater wells. Municipalities that have groundwater sources, as Lantzville does, are now required to obtain a water license which includes paying an application fee. There is also an annual water rental fee that the District is required to pay year. The fee is based on the volume of water used.

Water Treatment

6. Water from the wellfield is pumped directly into the Lower Pressure Zone reservoir on Ware Road. As the water enters the reservoir, it is treated by the addition of sodium hypochlorite. The reservoir provides the required minimum contact time before the treated water enters the water distribution system.

Water Storage & Pressure Zones

7. Water from the Ware Road (Lower Pressure Zone) reservoir is pumped to the Aulds Road (Upper Pressure Zone) reservoir.

8. The Ware Rd (Lower Zone) reservoir is a rectangular concrete structure with a storage capacity of 1,877 m^3 (415,000 ig). The reservoir was built in 2006.

9. The Aulds Road (Upper Zone) reservoir is a circular concrete tank with a storage capacity of 240 m^3. The reservoir was built in 1974.

10. A Pressure Reducing Valve station located on Lantzville Rd at Ware Road links the two pressure zones together. The valve is set to open only when there is large demand, such as during a fire, in the Lower Pressure zone.

11. The water distribution system contains more than 27 kilometers of watermain and 885 metered service connections. Over 15 kms of the watermains are Asbestos Cement material and more than 90% of the service connections are for residential properties.

Population Projections

12. The District's population has remained almost unchanged since its establishment as a municipality in 2003; 12 years ago. Its 2014 population was estimated by BC Stats to be 3,496. During this same time period, the City of Nanaimo and the City of Parksville populations grew by 15% and 17%; respectively. The District's lack of growth is believed to be partly in response to the District's policies and bylaws relating to the capacity concerns of the District's groundwater supply as well as the limited service area of the municipal sanitary sewer collection system.

13. The OCP allows for growth, but when it will occur is unclear, as it will generally be driven by market demands. Based on low moderate and high rates of growth (0.5%, 1.0% and 1.5%), the population of the DoL over the next 50 years would increase by 38%, 65% and 110% (990, 2,254, and 3,864 capita); respectively (**Figure 2**). This would require a total of 450, 1,025 and 1,756 new dwelling units, based on a population density of 2.2 capita per unit (**Table 8**).

14. There are two large proposed developments in the DoL: the 23 ha Village (Ware Rd) development and the 730 ha Foothills development. Combined they could accommodate almost all of the projected dwelling units to be constructed over the next 50 years under the moderate growth scenario (960 units vs 1,025 units).

Water Demands – Annual & Monthly

15. The daily volume of water pumped from the wellfield is recorded as it flows into the Ware Road Reservoir. As the water leaves the reservoir for use in either the Upper and Lower pressure zones is recorded by two meters. A review of the wellfield data compared to the total of the Lower Zone meter plus the Upper Zone meter revealed the wellfield annual volume to be consistently 7.3% lower that the two combined meters. While the discrepancy source is not known, staff suspects it may be a calibration issue with the SCADA system.

16. July and August are the highest demand months. On average, 25% of the total annual demand occurs during the two summer months of July and August and 40% for the four month period of June through September.

Water Demands – Average Day, Maximum Day & Maximum Week

17. The maximum day demand most often occurs in July or August and is approximately 2 times the average day demand.

18. In 2014, the average day demand was 687 m^3/day. The maximum day demand was recorded on July 14 and totaled 1,421 m^3. The demand over the maximum week (7 days)

averaged 1,227 m^3/day for the period July 12 – 18. All of these demands were slightly higher than the demands recorded in 2012 and in 2013.

Water Demands – Per Capita (Per Person)

19. Based on a service population of 2,143 people, the measured DoL per capita demands for 2014 were:
    - Average day = 321 litres per capita per day (lpcd)
    - Maximum day = 663 lpcd
    - Maximum week = 573 lpcd

    These demands are lower than 12 other mid Vancouver Island municipalities including its nearest neighbours of the City of Nanaimo and the City of Parksville (**Table 11 and 12**). Their average and maximum day per capita demands were 540 lpcd and 1,050 lpcd, and 540 lpcd and 1,180 lpcd; respectively.

20. The DoL low per capita demands are suspected to be reflective of the general public's understanding of the limited capacity of the District's water supply source and the DoL policy that an additional water supply source(s) is/are required before any new connections can be supplied; including the Foothills and Ware Road developments.

Water Demands – Unaccounted For Water

21. All water services in the DoL are metered. The annual volume of unaccounted for water ranged from 16% to 24% for the past four years. This unaccounted for water volume is the difference between the sum of the individual meters subtracted from the sum of the upper and lower pressure zone bulk meters, with the bulk meter total being larger than the individual meter total.

22. A review of the unaccounted for water volume on a quarterly basis for the past four years (**Figure 6**) revealed that during the first two quarters of the year (Jan – March and April – June), the difference averages around 26%, while for the last two quarters (July –Sept and Oct – Dec), the difference averaged 12%.

Water Demands – By Land-Use

23. Residential is the largest user group, accounting for more than 90% of the total individual metered demands. This group also has the largest number of water meters at 840 of the 885 in the system. The average annual demand per connection for the past five years (2010 – 2014) was 214 m^3/connection (**Table 13**).

24. Industrial is the smallest user group, accounting for 1% of the total. There are 18 industrial water meters. The demand per connection for the past four years (2010 – 2013) was 155 m^3/connection (**Table 13**).

25. The highest demand per connection is for Commercial/Residential property at 634 m^3/connection. The second highest per connection demand is for Commercial properties at 510 m^3/connection. These two user groups account for a total of 2% and 4% of the total individual metered demand (**Table 13**).

Water Demands – Single Family Largest Users

26. In 2014, the largest Single Family residential land user demand accounted for 0.8% of the total of individual metered demand. This is more than 6 times the per connection average annual demand. The demand by the two highest residential land users, accounted for 1.4% of the total individual metered demand.

27. Ten percent (10 % or 82 properties) of Single Family residential properties used 21% of the total individual metered demand (**Table 16**).

28. Thirty-five percent (35% or 289 properties) of Single Family residential properties used 50% of the total individual metered demand (**Table 16**).

Water Demands - Water Service Area

29. The OCP Map 7 – Water Service Area, identifies the ultimate service of the municipal water system. The purpose of extending the water system to service these properties is to provide potable water for domestic use and water for firefighting. There are presently 441 developed lots yet to be serviced in addition to the Village (Ware Rd) development and the Foothills development which are included in the Water Service Area.

30. The DoL Subdivision and Development Bylaw No. 55, 2005 requires all new properties not able to connect to the municipal water system to be provided with a water source capable of providing 3.4 m^3/day. Based on the DoL population density of 2.46 capita per dwelling, this equates to a per capita demand of 1,380 lpcd. This is very similar to City of Parksville's per capita maximum day of 1,364 lpcd and slightly higher than the City of Nanaimo's 1,135 lpcd. In 2014, the DoL maximum day per capita demand was notably lower at 663 lpcd.

31. Dividing the existing rated pumping capacity of the DoL wellfield of 2,037 m^3/day by the capita maximum day demand of 663 lpcd (July 14, 2014) vs 1,380 lpcd (DoL design standard for on-site wells) and a population density of 2.46 capita per dwelling unit, results in the maximum number of properties that the wellfield may be able to support ranging from a few as 601 properties to a high as 1,265 properties. Presently, there are 885 properties serviced by the wellfield.

32. If the capacity of the wellfield was able to be increased to the estimated long-term safe yield of 2,424 m^3/day projected by Lowen Hydrogeology Consulting Ltd., the number of lots the wellfield may be able to support ranges from 721 properties to 1,505 properties.

    While the extrapolated data suggests some, but not all of the additional properties might be able to be serviced by the aquifer if improvements are made to the wellfield, demands will and do vary from year to year. Demands per connection in previous years may not be indicative of future years. Implementing improvements to the wellfield and storage system and testing with a reasonable factor of safety to confirm the results would be prudent before the District considers amending any design standards.

    Given the public awareness of the limited capacity of the District's wellfield and the OCP requirement that new development must develop their own water supply to a standard acceptable to the DoL, servicing new lands from the wellfield could result in increased water usage by the current users, as the perception of the need for water conservation could decrease.

Design Fire Flows

33. The DoL requires fire flows demand calculations to be done in accordance with the Fire Underwriters Survey (FUS). The demand requirements will vary, depending on the building design, the floor area, the number of stories, the construction materials, the permitted distance from adjacent buildings (existing and future), and whether a fire sprinkler system is installed.

34. For single family residential properties, a minimum design fire flow of 75 L/s is consistent with other nearby local jurisdictions with similar housing styles. For Commercial, Industrial and Institutional uses, the range of design fire flows can vary greatly depending on a variety of factors.

Fire Hydrants

35. Fire hydrants should be equipped with three nozzles, including one 100 mm diameter pump nozzle. The District has been replacing the old fire hydrants that have only two hose nozzles, both 65 mm diameter. There are eight hydrants yet to be replaced; all in the Lower Pressure zone.

36. The DoL maximum spacing for fire hydrants is 150 m, with every home to be located within 120 m of a hydrant. The FUS recommends differing spacing based on land-use. For Multi-Family, Commercial, Industrial and Institutional, a maximum of 90 m is recommended, and subject to building code requirements regulating the distance between the building's sprinkler system connection point and the closet hydrant.

Reservoir Storage Volume

37. Reservoirs should be sized to include storage for:
    - Firefighting,
    - Emergencies (such as watermain break), and
    - Equalization to manage hourly peaks.

38. The Upper Zone reservoir (Aulds Rd) with its storage capacity of 240 m^3 (53,000 ig) is undersized to meet existing conditions design criteria. To meet projected demands over the next 25 years (to Year 2040), a total storage volume between 964m^3 and 1,112 m^3 will be needed. This includes a storage allowance for a fire flow of 75 L/s for 2 hours and the servicing of 348 additional lots. Increasing the size of this reservoir may offset and potentially delay storage improvements needed in the Lower Zone.

39. The Lower Zone reservoir (Ware Rd) has a storage capacity of 1,887 m^3 (415,000 ig). The expanded storage will be driven by the target fire flows the District adopts for its commercial, industrial, and institutional properties. Accommodating future expansion at the existing site will be difficult, but opportunities to increase storage at the higher elevation reservoir, or at future balancing reservoirs within the District can be explored in further detail.

Pressures during Peak Hour Demands

40. During peak hour demands, pressures throughout the system meet the minimum design standard of 275 kPa (40 psi) with the exception of 10 properties at the top end of Aulds and Harwood roads. The lowest pressure is estimated to be 207 kPa (30 psi) or less at the home at 6671 Harwood Rd.

41. Raising the top water level of the Upper Pressure Zone (Aulds Road) reservoir by 16.4 m, to 160 m geodetic, would provide the 275 kPa (40 psi) minimum design standard pressure. As a result of the increase in pressure, the PRV station on Lantzville Road just south of Ware Rd, would need to be reviewed.

42. If Lantzville Projects proceeds with the Village development on Ware Road, then the PRV will need to be re-located (or replaced) at the 54 m geodetic elevation, approximately 110 m north of Hwy 19, in order to not exceed the recommended maximum design pressure of 1,035 kPa (150 psi) for this development.

43. Relocating the Lantzville Road PRV to Ware Road will result in the increasing the length of the watermain required to connect the District of Lantzville to the City of Nanaimo as part of the water supply agreement. The length of the 250 mm diameter main will increase by approximately 600 m, from 930 m to 1,530 m, and should be included in the developer's scope of work.

44. Properties in the Lower Pressure Zone are provided the minimum design standard pressure of 275 kPa (40 psi) during maximum day demands. The existing maximum pressure is approximately 952 kPa (138 psi) at sea level.

Available Fire Flows

45. Fire flows less than the recommended 75 L/s for single family residential occurs in a few areas of the Upper Pressure Zone. Replacement of the small diameter mains with larger diameter mains would resolve this.

46. Fire flows less than the recommended 75 L/s for single family residential occurs along Lantzville Road, west of Superior Road. Replacement of the existing smaller diameter mains larger diameter mains would resolve this.

47. Available Fire flows within the range of 150 L/s to200 L/s for the Commercial and Institutional properties occur in the downtown core area of the Lower Pressure Zone. Various upgrade and looping projects within the Lower Pressure Zone are expected to improve firefighting capability and eventually provide flows in the 250 L/s to300 L/s range.

48. Upgrading of the 100 mm diameter dead-ended main on Mart Road to 200 mm diameter would increase the available fire flows to the recommended minimum of 200 L/s for Industrial properties. A fire hydrant should be installed mid-block.

49. Servicing of the properties in the Northwind/Southwind area requires extension of the High Pressure Zone distribution system and expansion of the storage capacity of the Aulds Road reservoir. To provide adequate fire flows, a 300 mm diameter main would be required from the proposed reservoir to Southwind Road. This improvement would include replacement of 1,800 m of existing mains on Phillip Road and Harby Road West.

50. Almost 60% of the District's watermains are made of Asbestos Cement. The majority are over 40 years old. The life span of AC mains ranges from 30 to 90 years. The District has for each of the past several years replaced sections of the AC mains as funds become available.

General

51. Prevailing science on climate change indicates that the local Vancouver Island region will experience drier summers and wetter winters in the foreseeable future, and other local municipal governments are taking these factors into consideration when developing their long range infrastructure improvement plans.

10 RECOMMENDATIONS

Based on the conclusions listed in this report, it is recommended that the District:

1. Apply for and secure a groundwater licence from the provincial government.

2. Adopt the system improvement projects listed in Table 31.

3. Upgrade the wellfield to improve the yield from the aquifer, and target the long-term safe yield of 2,424 m^3/day calculated by Lowen Hydrogeology Consulting Ltd. by redeveloping well nos, 4, 9 and 12 and carrying out detailed design and construction of a replacement for well no 6.

4. Monitor, test and evaluate the effectiveness of the wellfield improvements to confirm if the target safe water yield is being delivered to the system.

5. Monitor, test and evaluate the impacts of the new wellfield improvement on the aquifer to determine if aquifer levels are being maintained in a sustainable fashion.

6. Review land use activities within the aquifer recharge zone to mitigate potential impacts. Require that a professional hydrogeologist assess the impacts of any proposed development within this area. Maintain and update the low-impact development standards where warranted.

7. Increase the storage capacity of the Upper Pressure Zone reservoir. Raise the top water level of the Upper Pressure Zone reservoir to 160 m from the current 143.6 m and evaluate the impact on the existing PRV station location on Lantzville Road just south of Ware Road.

8. Implement well field improvements and storage upgrades and confirm their effectiveness before considering any changes to the current system design standards.

9. Require the developer to relocate the Ware Road PRV, as part of the Village development on Ware Road. The new location should be approximately 110 m north of the Hwy 19 intersection at around the 54 m geodetic elevation so that the maximum design pressure of 150 psi is not exceeded in the Lower Zone. The work should also include a dedicated supply line that will be needed to connect the Upper Pressure to the potential feed from the City of Nanaimo.

10. Review and adopt appropriate target fire flow criteria for existing and future commercial, industrial, and institutional requirements, prior to finalizing the reservoir storage requirements in the Lower Zone. Review and implement requirements for building sprinkler systems where warranted.

11. Improve available fire flows in the Upper and Lower Pressure Zones by upgrading of mains and replacement of older fire hydrants.

12. Continue with the annual Asbestos Cement watermain replacement program. Laboratory testing of mains should be carried out to assist in determining the remaining service life mains and in prioritizing and budgeting of the work.

13. Obtain looping of the watermain system in conjunction with future development wherever possible.

14. Review and resolve the readings discrepancies between the bulk water meters at the Ware Road Reservoir.

15. Conduct an inspection on the exterior roof surface of the Ware Road Reservoir and review coating options if warranted. Review code requirements and implement seismic restraint improvements for the mechanical piping at the pump station.

16. Update the water study every 5 years, subject to the rate of growth, to review capital project needs based on changes in water demands (per capita, maximum day, peak hour) resulting from population growth.

17. Update the water Development Cost Charge (DCC) for the various land use categories in the DCC Bylaw based on the proposed system improvement projects presented in this report.

18. Keep abreast of ongoing climate change research and its potential impact on aquifer recharge rates, especially when making infrastructure policy decisions.

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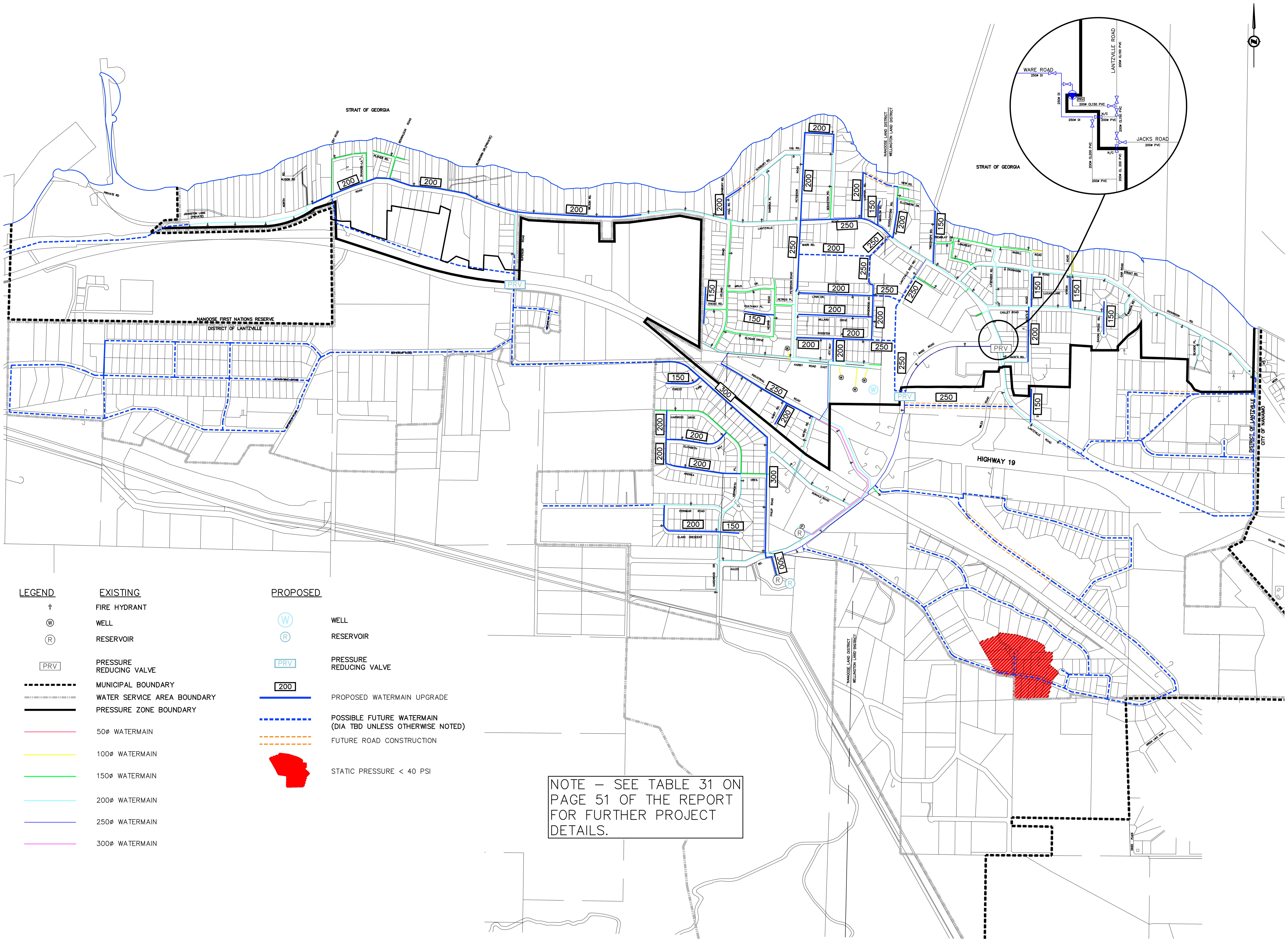


NOTE – SEE TABLE 31 ON PAGE 51 OF THE REPORT FOR FURTHER PROJECT DETAILS.

RECORD OF REVISIONS

REV	DATE	BY	ENG	DESCRIPTION

ISS	DATE	BY	ENG	DESCRIPTION

RECORD OF ISSUE

SEAL

PROJECT NO.	1420
DRAWN	MB
DESIGNED	CH
CHECKED	RH
APPROVED	RH
DATE	MAY 2015
SCALE	1:8000

CLIENT

DISTRICT OF LANTZVILLE

PROJECT

WATER SUPPLY & DISTRIBUTION SYSTEM

TITLE

EXISTING WATER SYSTEM AND PROPSOED WORKS

DRAWING No.	REV.	SHEET
1420–01	–	1/1

File: 1420 Figures Rev 2.dwg Plot Time: Jul 15, 2015 – 10:39am User: mbrook

Appendix A

City of Nanaimo & District of Lantzville
Water Supply Agreement, September 8, 2014

LANTZVILLE/NANAIMO WATER AGREEMENT

THIS AGREEMENT dated for reference this 8th day of September, 2014.

BETWEEN:

CITY OF NANAIMO
455 Wallace Street
Nanaimo, BC V9R 5J6

(hereinafter called "Nanaimo")

OF THE FIRST PART

AND:

DISTRICT OF LANTZVILLE
PO Box 100
7192 Lantzville Road
Lantzville, BC V0R 2H0

(hereinafter called "Lantzville")

OF THE SECOND PART

WHEREAS:

A. Nanaimo operates a water supply system within its boundaries;

B. Lantzville has established facilities for the purposes of constructing, operating and maintaining a water system for the supply and distribution of water within its boundaries and wishes to secure a supply of water in bulk;

C. Under section 23 of the *Community Charter,* S.B.C. 2003, c. 26, a municipal council has the authority to enter into agreements with other public authorities respecting activities and services within the power of a party to the agreement, including agreements respecting the undertaking, provision and operation of activities and services;

D. Lantzville and Nanaimo wish to work together to provide water in bulk from the Nanaimo Water System to serve Lantzville and to strengthen this cooperative relationship through Lantzville's participation in the cost of other services provided through the Regional District of Nanaimo on the terms and conditions set out in this Agreement;

E. Lantzville has consented to Nanaimo providing a supply of water under this Agreement;

NOW THEREFORE in consideration of the premises and the mutual covenants and agreements contained herein, the parties hereby covenant and agree each with the other as follows:

1.0 Definitions

In this Agreement:

(a) "Additional Term" means the additional term as set out in section 12.2;

(b) "Commencement Date" means the date upon which Lantzville certifies the construction of the Lantzville Water System as completed to Lantzville's satisfaction, and notifies Nanaimo with a copy of a Lantzville Council resolution that the Lantzville Water System is ready to accept the Water;

(c) "Connection Fee" means the connection fee for Water payable by Lantzville under article 4.0 (Fees) of this Agreement;

(d) "Connection Point" means the connection points on the Water Main between the Nanaimo Water System and the Lantzville Water System, as identified in Schedule "A" attached to this Agreement;

(e) "Event of Default" means:

(i) a failure by Lantzville to pay a fee, cost or charge payable under this Agreement within thirty (30) days of the date such fee, cost or charge is payable by Lantzville; or

(ii) a breach of sections 6.2, 6.3, 9.1 or 9.3 of this Agreement.

(f) "Force Majeure" means any prevention, delay, stoppage, or interruption in the performance of any obligation of a party due to strike, lockout, labour dispute, act of God, inability to obtain labour or materials, laws, ordinances, rules, regulations or orders of governmental authorities, enemy or hostile action, civil commotion, fire or other casualty or any condition or cause beyond the reasonable control of the party obligated to perform, but shall not include any inability by that party to perform because of its lack of funds;

(g) "Lantzville Water System" means the water system owned and operated by Lantzville to serve Premises within Lantzville boundaries;

(h) "Lower Lantzville Area" means that part of Lantzville identified as such on Schedule "C";

(i) "Nanaimo Water System" means the water system owned by Nanaimo from which it supplies Water under this Agreement and all appurtenant works, facilities and services;

(j) "Premises" means each and every residential, commercial and all other lands and buildings that receive Water from the Lantzville Water System, and in the case of lands and buildings with more than one permitted use, each such use shall constitute a "Premises";

(k) "Term" means the term of this Agreement as set out in section 12.1, and other than in section 12.1 a reference to "Term" is also a reference to the "Additional Term";

(l) "Upper Lantzville Area" means that part of Lantzville identified as such on Schedule "C";

(m) "Water" means water supplied by Nanaimo in bulk under this Agreement for treatment and redistribution by Lantzville;

(n) "Water Main" means the water main or water mains to be constructed by Lantzville to connect the Lantzville Water System with the Nanaimo Water System and service the areas within Lantzville as generally identified in Schedule "A" and includes the Connection Point and all related connections, extensions, upgrades, fire hydrants and appurtenances; and

(o) "Water Shortage" means meteorological or other severe circumstances beyond the reasonable control of Nanaimo (including an event of Force Majeure) resulting in a decline in the availability of Water available to meet the peak Water needs of persons served by the Nanaimo Water System and the Lantzville Water System.

2.0 Water Supply

2.1 Nanaimo agrees to supply Water to the Lantzville Water System for the Term and any extension thereof commencing on the Commencement Date, on the terms and conditions in this Agreement.

2.2 Lantzville and Nanaimo agree that Lantzville shall, at its cost, on or before the Commencement Date, connect the Lantzville Water System to the Nanaimo Water System at the Connection Point for the purpose of supplying Water to the Lantzville Water System pursuant to this Agreement.

2.3 For certainty, Lantzville has no financial liability to Nanaimo under this Agreement until the Commencement Date.

3.0 Conditions Precedent

3.1 It is a condition precedent to the obligations of Nanaimo under this Agreement that:

(a) Lantzville complete construction of the Lantzville Water System including the connection of the Lantzville Water System to the Nanaimo Water System under section 2.2 and any features of the Connection Point necessary to allow the passage of Water; and

(b) approval of this Agreement by the councils of Nanaimo and Lantzville.

4.0 Fees

4.1 Lantzville shall pay to Nanaimo, within thirty (30) days of connection of the Water Main to the portion of the Lantzville Water System serving the Upper Lantzville Area, a Connection Fee in the sum of one million three hundred and thirty thousand, two hundred and fifty-eight dollars and fifty cents ($1,330,258.50) representing two hundred and twenty-five (225) Premises in Upper Lantzville currently connected to the Lantzville Water System; and

4.2 Lantzville shall pay a Connection Fee for each new Connection of Premises to the Lantzville Water System in respect of any of the two hundred and eleven (211) additional Premises in Upper Lantzville served by wells and not currently connected to the Lantzville Water System, in accordance with section 4.6.

4.3 Lantzville shall pay to Nanaimo, within thirty (30) days of connection of the Water Main to the portion of the Lantzville Water System serving the Lower Lantzville Area, a Connection Fee for each existing residential, commercial and industrial Premises connected in the Lower Lantzville Area in accordance with section 4.5, provided that despite anything in this Agreement, including, without limitation, sections 2.2 and 5.1, Nanaimo shall be under no obligation to supply water to any premises in Lower Lantzville until Nanaimo has notified Lantzville in writing that it has secured additional water supply.

4.4 Throughout the Term, Lantzville shall pay a Connection Fee for each new Connection of Premises to the Lantzville Water System in accordance with section 4.5. Lantzville shall pay the Connection Fees on July 1 for connections between January 1 and June 30 of each year of the Term, and January 1 for connections between July 1 and December 31 of each year of the Term. Lantzville shall provide to Nanaimo with respect to each year of the Term a report detailing the number and type of connections made, and such report shall be provided no later than March 31 in the year following the year to which the report relates.

4.5 Except as provided under section 4.6, Connection Fees payable by Lantzville in respect of the Connection of the Premises to the Lantzville Water System shall be equal to the development cost charge payable for comparable premises within the City of Nanaimo pursuant to the City of Nanaimo's Water Supply Development Cost Charge Bylaw 2008 No. 7070, as amended from time to time, or any enactment that may replace it.

4.6 In the case of Connection Fees payable by Lantzville under section 4.2 of this Agreement, the Connection Fees payable during the first five (5) years of the Term shall be those prescribed in Schedule "B". Connection Fees payable by Lantzville during the remaining fifteen (15) years of the Term shall be equal to the development cost charge payable for comparable premises within the City of Nanaimo pursuant to City of Nanaimo's Water Supply Development Cost Charge Bylaw 2008 No. 7070, as amended from time to time, or any enactment that may replace it.

4.7 Lantzville shall pay Nanaimo for all Water supplied under this Agreement in accordance with the rates prescribed from time to time in the City of Nanaimo's Waterworks Rate and Regulation Bylaw 2006 No. 7004, or any bylaw that may replace it, and in accordance with all terms and conditions prescribed thereunder.

4.8 Invoices for water rendered by Nanaimo in a calendar year or an amount of a Connection Fee that remains unpaid at the end of the calendar year will be deemed to be in default and subject to an interest charge equal to the amount applicable to all other users of the Nanaimo Water System.

4.9 Except for the purposes of sections 4.1 of this Agreement, in this article "Connection" means installation of a water pipe and associated plumbing extending from a water distribution line of the Lantzville Water System to the property line of the parcel to be connected to the Lantzville Water System and provided water service.

5.0 <u>Quantity and Quality</u>

5.1 Nanaimo shall, subject to article 7.0 of this Agreement, make available to Lantzville at all times during the Term and any renewal period, sufficient volumes of Water to allow Lantzville to supply Premises connected in accordance with this Agreement through the Lantzville Water System to the Water Main with flows of Water not greater than the average per capita daily flows of Water that Nanaimo supplies to its own residential and commercial consumers.

5.2 Nanaimo shall:

(a) make all reasonable efforts to ensure the Water supplied under this Agreement meets the *Canadian Drinking Water Quality Guidelines* and

(b) comply with all other laws and regulations applicable to the supply of Water under this Agreement.

5.3 Once Lantzville accepts the Water at the Connection Point, Lantzville is, with respect to the Water, the "water supplier" as defined in and for the purposes of the *Drinking Water Protection Act*, and Nanaimo shall not be held liable for the quality of water beyond its own infrastructure in the Nanaimo Water System.

5.4 Lantzville shall at its cost:

(a) monitor the levels of chlorine residuals of Water supplied under this Agreement and at its own cost shall provide treatment to maintain such levels in accordance with all applicable laws and requirements;

(b) conduct all bacteriological water testing and other testing necessary to comply with all applicable laws and requirements, including without limitation the requirements of the *Drinking Water Protection Act,* and all applicable requirements of the Vancouver Island Health Authority, and to otherwise assure itself that it is able to deliver Water that is potable prior to distribution to Premises;

(c) provide any additional treatment necessary to ensure the Water distributed to Premises by Lantzville through the Lantzville Water System meets the requirements of the *Drinking Water Protection Act* (British Columbia) and other applicable law.

5.5 Despite section 6.6 of this Agreement, Lantzville may use Water from the Nanaimo Water System within that part of Lower Lantzville on the low side of the pressure reducing valve that separates the high and low pressure areas of Lantzville for the purpose of firefighting and other emergency purposes.

5.6 Lantzville shall, at its own cost, install a water meter on the low side of the pressure reducing valve referred to in section 5.5 in a location agreed to by Nanaimo, acting reasonably.

5.7 Lantzville shall report to Nanaimo on a quarterly basis on or before the 15th day of April, July, September and January the readings from the water meter installed under section 5.6, and shall pay for any such Water supplied during such quarter in accordance with section 4.7 of this Agreement.

6.0 <u>Lantzville Acknowledgements, Covenants and Agreements</u>

6.1 Lantzville acknowledges, as a principle on which Nanaimo has entered this Agreement, that the amount paid by consumers for Water in Lantzville should not be lower than the amount paid by consumers in Nanaimo.

6.2 Lantzville shall not sell or supply Water from the Nanaimo Water System except to Premises within the boundaries of Lantzville.

6.3 Lantzville shall not sell or supply Water from the Nanaimo Water System to Premises whose owner or occupier is in the business of selling or supplying Water that is not consumed on the Premises, including a bulk water hauler or water bottling plant.

6.4 Lantzville agrees that it shall be a condition of this Agreement that water supplied to Lantzville under this Agreement is not provided to Premises for major agricultural production or golf courses.

6.5 Lantzville shall maintain in operation the existing wells specified in Schedule "D" and shall take reasonable actions to maintain the production of those wells at at least 2014 levels.

6.6 Despite anything in this Agreement, including, without limitation, sections 2.2 and 5.1, until Nanaimo has notified Lantzville in writing that it has secured sufficient additional water supply, connections to the Water Main shall be limited to a total of four hundred and thirty-six (436) Premises located within Upper Lantzville referred to in sections 4.1 and 4.2 of this Agreement, plus connection of 50 Premises per year in Upper Lantzville as a result of new development. For certainty, if less than 50 Premises per year in Upper Lantzville are connected, the remaining Premises connection entitlement will accrue to be used by Lantzville in any future year during the Term or any Additional Term for connection at a time determined by Lantzville.

6.7 For the purpose of this section, "development" means the construction of new Premises or the subdivision of land resulting in the creation of new parcels to create new Premises.

6.8 Lantzville will provide reasonable support to Nanaimo to secure additional water supply.

7.0 Force Majeure and Water Shortage

7.1 Lantzville acknowledges and agrees that Nanaimo is entitled to reduce or temporarily terminate the supply of Water on a basis consistent with other users within an affected distribution area without compensation to Lantzville in the event of a Water Shortage or event of Force Majeure.

7.2 Where Nanaimo anticipates that there will be a Water Shortage, Nanaimo shall advise Lantzville of this circumstance without undue delay and shall appoint representatives to meet with representatives of Lantzville to discuss solutions.

7.3 In reducing the Water supply under section 7.1, Nanaimo shall endeavour to equalize the effect of the water reduction on uses and consumers within Nanaimo and Lantzville.

7.4 Lantzville acknowledges and agrees that Lantzville is at all times responsible for all of its water storage requirements, including without limitation any requirements relating to firefighting or other emergencies whether imposed by an association of fire insurance underwriters or otherwise.

8.0 Watering Conservation and Restrictions

8.1 Lantzville acknowledges, as a principle on which this Agreement is based, that restrictions on Water use in Lantzville should be consistent with those in place in Nanaimo in force from time to time governing the use of the Nanaimo Water System.

8.2 Lantzville shall take reasonable operational measures and consider taking legislative measures at Nanaimo's request to reduce the waste of Water and water consumption within its boundaries consistent with measures taken within the boundaries of Nanaimo.

9.0 Maintenance and Repair

9.1 Lantzville shall repair, operate and maintain the Lantzville Water System in accordance with good engineering practices and all applicable laws.

9.2 To the extent related to the supply of Water in accordance with this Agreement, Nanaimo shall repair, operate and maintain the Nanaimo Water System in a good state of repair in accordance with good engineering practices and all applicable laws.

9.3 Without limiting section 9.1 Lantzville shall maintain all wells connected to the Lantzville Water System in accordance with good engineering practices and all applicable laws, and shall take all reasonable steps to prevent contamination of the Nanaimo Water System.

9.4 Lantzville shall reimburse Nanaimo within thirty (30) days of receiving an invoice for all costs associated with the operation and maintenance of the Water Main and all costs of operating and maintaining any facilities, works or services constructed or located within Nanaimo that are for the sole benefit of the Lantzville Water System.

10.0 Costs of Studies

10.1 Lantzville shall pay the cost of any feasibility studies required to determine the need for additional facilities or modifications or alterations to existing facilities required for the supply of Water to Lantzville, even if such facilities, modifications or alterations would be required to be located, constructed, installed or enlarged within the boundaries of Nanaimo.

11.0 Construction of Main Extension

11.1 Lantzville shall, at Lantzville's sole cost, design, construct, install and replace, as necessary, the Water Main.

11.2 Lantzville shall pay to Nanaimo any actual costs incurred by Nanaimo in relation to the design and construction of the Water Main, including the costs of any staff time appropriately allocated thereto.

11.3 Costs payable under section 11.2 shall include the costs of:

(a) architect, engineering, legal and other professional services in connection with the Water Main project;

(b) the costs of construction;

(c) all land acquisition costs for the purpose of obtaining a statutory right of way or other interest in land necessary for the Water Main, including, if necessary, costs of appraisers and expropriation processes; and

(d) communications infrastructure, programming and electronic monitoring equipment associated with the Connection Point(s) to enable monitoring of water use within Nanaimo's SCADA system;

in relation to the Water Main project.

11.4 Lantzville shall engage the services of a professional engineering consultant acceptable to both parties to determine in consultation with Nanaimo:

(a) the preferred Water Main extension to the Connection Point;

(b) the engineering specifications for the Water Main;

(c) the timing of construction of the Water Main and its connection to the Lantzville Water System;

(d) to oversee the completion of the Water Main; and

(e) to certify the Water Main as having been constructed in accordance with the engineering specifications

and the professional engineering consultant shall be considered Lantzville's agent.

11.5 Nanaimo agrees to cooperate in good faith with Lantzville to secure a design for a Water Main that is both cost effective and meets the standards of good engineering practice, having regard to the effect of the Water Main project on both water systems, and to manage the Water Main project in a manner consistent with its management of similar projects in Nanaimo.

11.6 Subject to agreement otherwise on the timing of the payment of the design and construction costs associated with the Water Main, Lantzville shall reimburse Nanaimo for such costs within thirty (30) days of receiving an invoice for such costs from Nanaimo as work progresses on the construction project.

11.7 Lantzville shall cause the Water Main to be constructed, installed, commissioned and, to the extent the Water Main is within the city limits of Nanaimo, transferred to Nanaimo upon completion and certification by a professional engineering consultant under section 11.4(e) of this Agreement.

12.0 <u>Term</u>

12.1 The Term of this Agreement shall be for a twenty (20) year period commencing on the Commencement Date, and for certainty Nanaimo's obligation to supply Water under this Agreement and Lantzville's obligation to pay Nanaimo only arise from and after the Commencement Date.

12.2 This Agreement may be extended beyond the Term for one Additional Term of twenty (20) years by the District of Lantzville delivering written notice to Nanaimo at least 6 months prior to the end of the Term. The Additional Term shall be on the same terms and conditions as this Agreement except that there shall be no further renewal right.

13.0 <u>Water Supply Advisory Committee</u>

13.1 Lantzville shall be entitled to designate one (1) representative for appointment to the City of Nanaimo Water Supply Advisory Committee.

14.0 <u>Future Nanaimo Water System Capital Costs</u>

14.1 To the extent costs of the design, construction, installation or enlargement of the Nanaimo Water System related to the supply of Water to Lantzville under this Agreement are not otherwise covered by the amounts otherwise paid to Nanaimo by Lantzville, Lantzville shall pay such costs to Nanaimo, within thirty (30) days of receiving an invoice from Nanaimo for such costs.

15.0 <u>Cost Sharing For Other Services</u>

15.1 Lantzville will participate in the following Regional District of Nanaimo services at contribution levels reasonably consistent with other participating areas:

(a) Economic Development Service;

(b) Port Theatre Service; and

(c) Drinking Water and Watershed Protection Service.

16.0 Indemnity

16.1 Nanaimo will indemnify and save harmless Lantzville, its elected officials, officers, employees, contractors and agents against and from any and all actions, causes or action, suits, damages, losses, costs (including costs of professional advisors and solicitors on a solicitor and own client basis), charges, fees, fines, claims or demands arising Nanaimo's breach of this Agreement, or the negligence or wrongful act of Nanaimo its officers, employees, subcontractors, agents or others for whom it is responsible at law except to the extent that such liability arises from the negligence or wrongful act of Lantzville, or others for whom Lantzville is responsible at law.

16.2 Lantzville will indemnify and save harmless Nanaimo, its elected officials, officers, employees, contractors and agents against and from any and all actions, causes or action, suits, damages, losses, costs (including costs of professional advisors and solicitors on a solicitor and own client basis), charges, fees, fines, claims or demands arising from Lantzville's breach of this Agreement, or the negligence or wrongful act of Lantzville its officers, employees, subcontractors, agents or others for whom it is responsible at law except to the extent that such liability arises from the negligence or wrongful act of Nanaimo, or others for whom Nanaimo is responsible at law.

16.3 Without limiting section 16.2 Lantzville shall indemnify and save harmless Nanaimo from any interruption to the service to be provided under this Agreement arising from:

(a) normal maintenance, repair or upgrading of the water system;

(b) failure, breakdown or malfunction of the Lantzville Water System or any act of God or other cause beyond the reasonable control of Nanaimo, except to the extent of negligence by Nanaimo or its officers, employees, agents or contractors.

16.4 Sections 16.1, 16.2 and 16.3 shall survive the expiry or earlier termination of this Agreement.

17.0 Insurance

17.1 Nanaimo and Lantzville shall each:

(a) obtain and maintain during the term of this Agreement Commercial General Liability Insurance including Broad Form Completed Operations Coverage, naming the other party as an Additional Insured and covering losses to third parties for bodily injury or death, property damage and unlicenced vehicles including attached equipment, for a minimum amount of five million dollars ($5,000,000.00) per occurrence with a deductible not greater than ten thousand dollars ($10,000.00);

(b) ensure that all policies where the other party is named as an Additional Insured contain a Cross Liability clause; and

(c) ensure that their respective insurance policy(ies) are not cancelled or materially changed without the insurer giving not less than thirty (30) days' written notice to the other party.

18.0 Assignment

18.1 No party to this Agreement may assign its interest in this Agreement without the prior written consent of the other party.

19.0 Further Documents

19.1 The parties hereto shall execute such further and other documents and do such further and other things as might be necessary to carry out and give effect to the intent of this Agreement, including executing any rights of way or easement agreements.

20.0 Termination

20.1 Nanaimo may terminate this Agreement on six months' written notice to Lantzville in the case of an Event of Default which has not been cured within sixty (60) days of notice of the default being delivered to Lantzville.

21.0 Rights and Powers

21.1 Nothing contained or implied herein shall prejudice or affect the rights and powers of Lantzville or Nanaimo in the exercise of their respective functions under any public and private statute, bylaws, orders and regulations, all of which may be fully and effectively exercised as if this Agreement had not been executed and delivered by the parties, and the interpretation of this Agreement shall be subject to and consistent with statutory restrictions imposed upon Lantzville or Nanaimo under the *Local Government Act* and the *Community Charter.*

22.0 Relationship

22.1 Nothing in this Agreement shall be interpreted as creating an agency, partnership or joint venture relationship between Lantzville and Nanaimo.

23.0 Arbitration

23.1 If a dispute arises under this Agreement, then the parties shall make good faith efforts to resolve the dispute between themselves. If the dispute is not resolved within fifteen (15) days, then the Chief Administrative Officers, or their deputies, shall meet within fifteen (15) days to attempt to resolve the dispute.

23.2 If a dispute arises under sections 9.4, 11 .2 or 14.1 regarding any amounts that may be payable by Lantzville, then such dispute shall, at the request of either party be submitted to arbitration under the *Commercial Arbitration Act,* by a professional engineer selected by the parties. If the parties cannot agree on the choice of the arbitrator, then each party will select a representative who shall jointly select the arbitrator. The costs of the arbitrator shall be shared equally between the parties, and the results of the arbitration shall be binding on the parties.

24.0 Notice

24.1 Unless otherwise specified herein, any notice required to be given under this Agreement by any party will be deemed to have been given if mailed by prepaid registered mail or delivered to the address of the other party set forth on the first page of this Agreement or at such other address as the other party may from time to time direct in writing, and any such notice will be deemed to have been received if mailed, seventy-two (72) hours after the time of mailing and, if delivered, upon the date of delivery. If normal mail service is interrupted by strike, slow down, force majeure or other cause, then a notice sent by mail will not be deemed to be received until actually received, and the party sending the notice must deliver such notice in order to ensure prompt receipt thereof.

25.0 Binding Effect

25.1 This Agreement will enure to the benefit of and be binding upon the parties hereto and their respective heirs, administrators, executors, successors, and permitted assignees.

26.0 Waiver

26.1 The waiver by a party of any failure on the part of the other party to perform in accordance with any of the terms or conditions of this Agreement is not to be construed as a waiver of any future or continuing failure, whether similar or dissimilar.

27.0 Headings

27.1 Section and paragraph headings are inserted for identification purposes only and do not form a part of the Agreement.

28.0 Language

28.1 Wherever the singular, masculine and neuter are used throughout this Agreement, the same is to be construed as meaning the plural or the feminine or the body corporate or politic as the context so requires.

29.0 Law Applicable

29.1 This Agreement is to be construed in accordance with and governed by the laws applicable in the Province of British Columbia. Any reference to an enactment is deemed to be a reference to the enactment as amended from time to time, and any enactment that may replace it.

30.0 Amendment

30.1 This Agreement may not be modified or amended except by the written agreement of the parties.

31.0 Notice of Violations

31.1 Each party shall promptly notify the other party of any matter which is likely to continue or give rise to a violation of its obligations under this Agreement.

IN WITNESS WHEREOF the parties hereto have set their hands and seals as of the day and year first above written.

CITY OF NANAIMO by its authorized signatories this 20th day of August, 2014)

Name: George Anderson - Acting MAYOR)

Name: Chris Jackson Corporate Officer)

DISTRICT OF LANTZVILLE by its authorized signatories this 9th day of September, 2014)

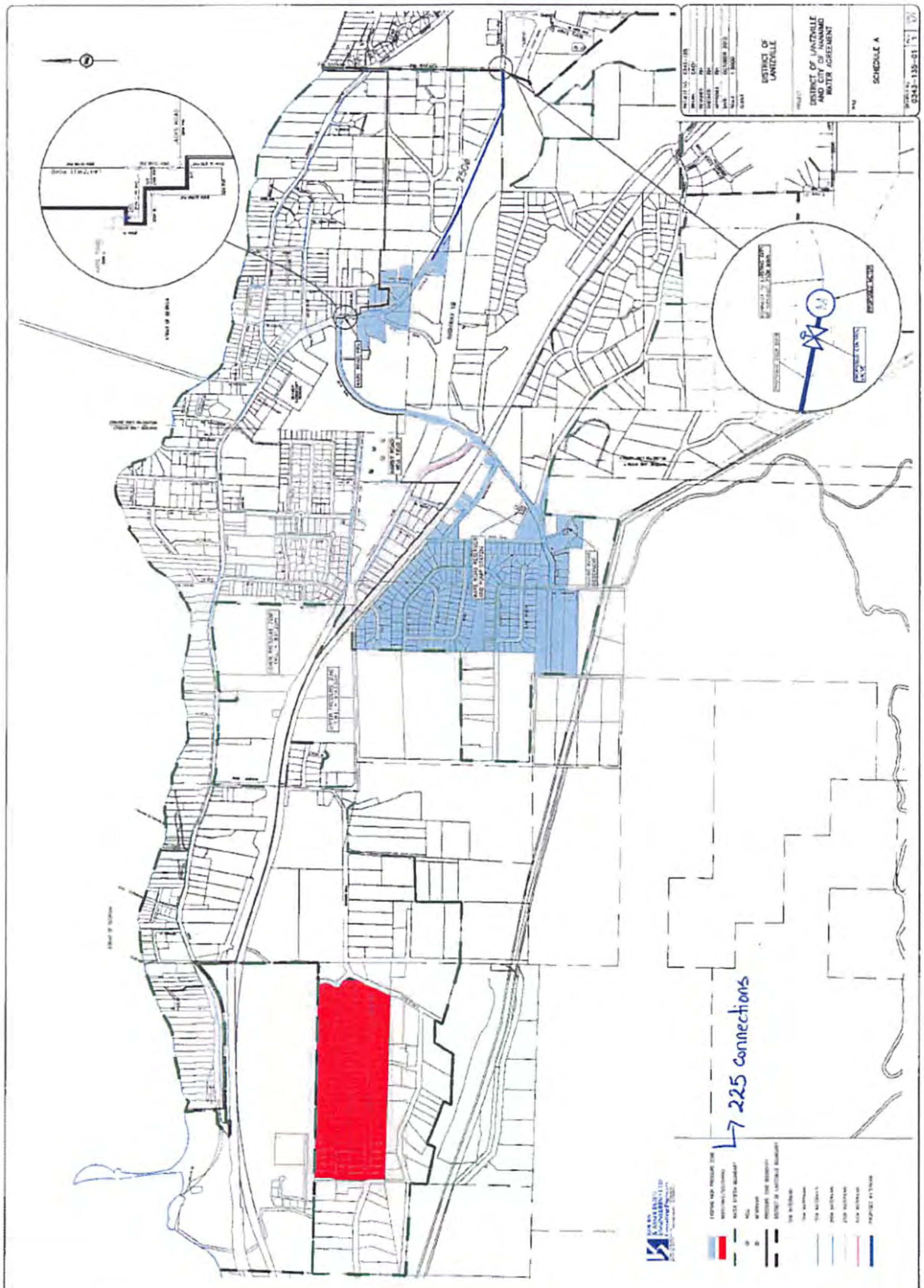
Name: Jack de Jong, Mayor)

Name: Twyla Graff, CAO
Deputy Director of Corp. Admin)

SEAL

SCHEDULE "A"

Connection Points



SCHEDULE “B”

Connection Fees

1. The terms "Single Family", "Dwelling Unit", "Multi-Family", "Gross Floor Area", "Commercial", "Institutional", "Industrial", "Mobile Home Park", "Service Connection" and "Campground" used in this Schedule "B" have the same meaning as provided in the City of Nanaimo's Water Supply Development Cost Charge Bylaw 2008 No. 7070, as amended from time to time, or any enactment that may replace it.

2. The Connection Fees payable by Lantzville are as follows:

   (a) Single Family - $5,912.26 per Dwelling Unit;

   (b) Multi-Family - $35.47 per square metre of Gross Floor Area;

   (c) Commercial- $34.36 per square metre of Gross Floor Area;

   (d) Institutional- $34.36 per square metre of Gross Floor Area;

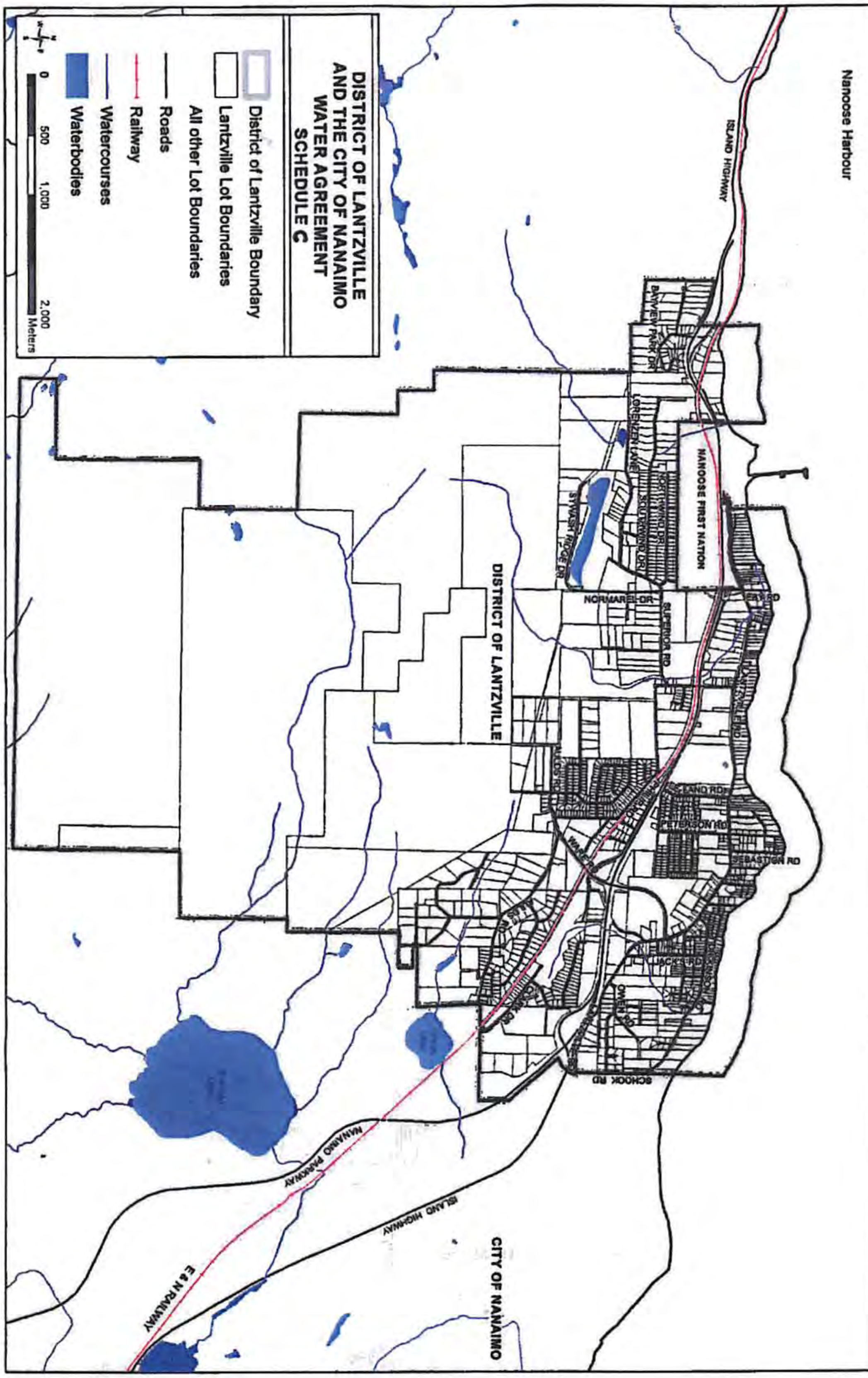
   (e) Industrial - $8.77 per square metre of Gross Floor Area;

   (f) Mobile Home Park - $3,611.38 per Service Connection;

   (g) Campground - $849.74 per Service Connection.

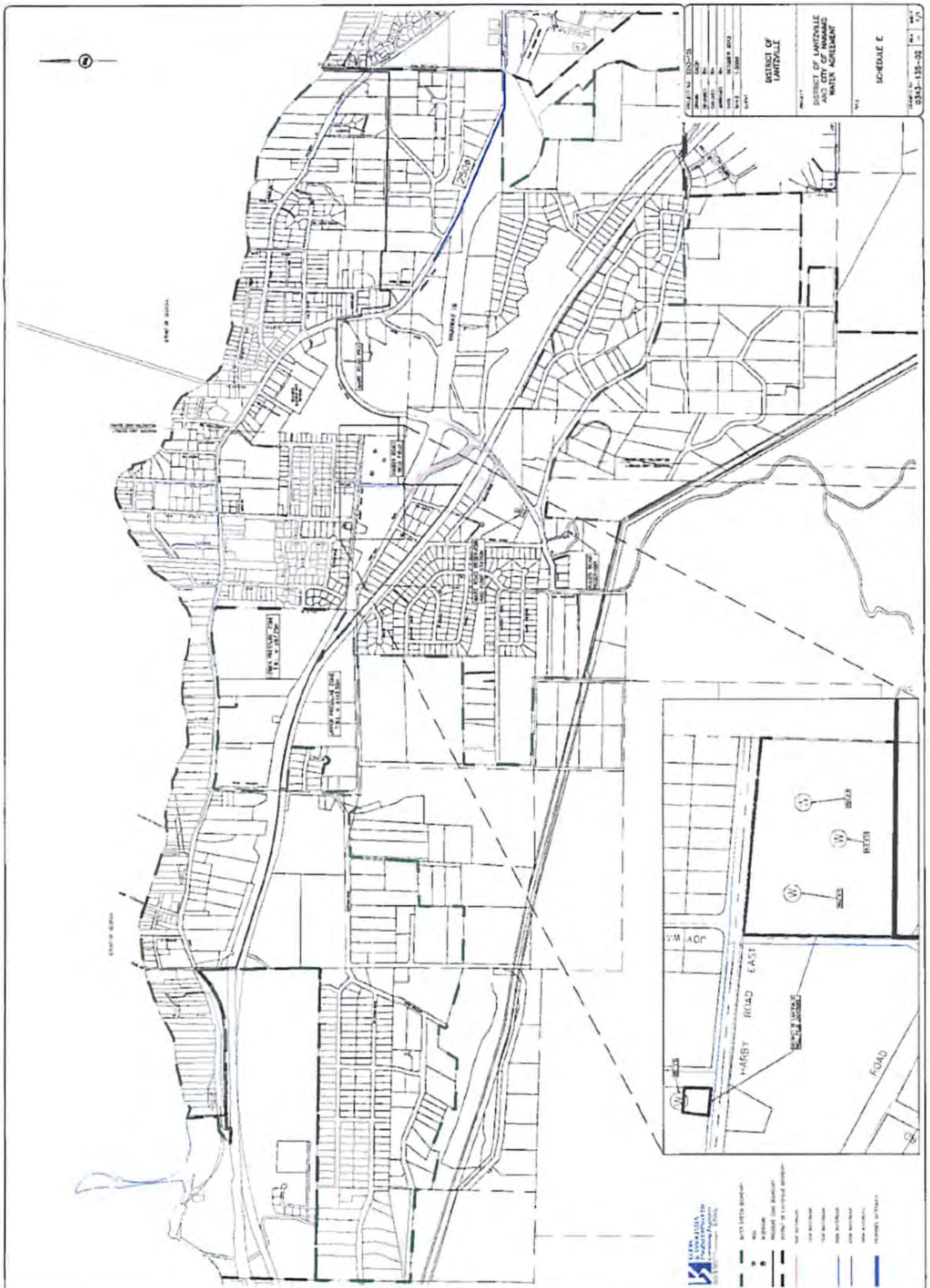
SCHEDULE "C"

Map of Lantzville



SCHEDULE "D"

Existing Lantzville Wells



Appendix B

District of Lantzville
Phase 1 of Stage 1 Wellfield Management Plan – Wellfield Capacity Existing & Ultimate, Harby Road Wellfield
October 15, 2014, Lowen Hydrogeology Consulting Ltd.

Report

District of Lantzville, BC

Phase 1 of Stage 1
Wellfield Management Plan

Wellfield Capacity Existing and Ultimate
Harby Road Wellfield, District of Lantzville, BC

Date: October 15, 2014
LHC Project File: 1412

LHC Lowen Hydrogeology Consulting Ltd.
PO Box 45024 Victoria, B.C. V9A-0C3 Phone: 250 -595-0624 Fax: 1-855 -286-8001 Website: www.lowenhc.ca

SUMMARY

In 2014, the District of Lantzville retained Lowen Hydrogeology Consulting Ltd. (LHC) to conduct a series of pumping tests on the 4 producing wells serving the district. These 4 groundwater sources are located in a wellfield off Harby Road in Lantzville. This Wellfield consists of 4 active wells and 10 inactive test wells completed during previous exploration programs.

The scope of work included a thorough review of previous reports and general work completed on the wells. A large database containing water levels and pumping flows was compiled to establish baseline historical conditions. Staff from the District of Lantzville performed 4 single-well pumping tests using the non-pumping wells as observation points, and one pumping test using the 4 wells simultaneously. LHC processed and analysed the data to assess the well field capacity.

The interference between wells were assessed and taken into account for the final yield calculations. The combined capacity of the wells #4, #6, #9 and #12 is 2,424 m^3/day; 2,424,000 L/d or 28.1 L/s. Considering the combined water level drawdown during simultaneous pumping (all 4 production wells pumping), it is concluded that drilling at additional well sites in the Harby Road well field is not advisable. The well field aquifer is bounded to the south and is not likely to offer a satisfying site for a new production well.

The existing wells and pumping equipment should be reviewed with the objective of maximizing the well field production capacity. The existing wells and pumps cannot produce the ultimate potential yield available. Recommendations are made for: well re-development, well replacement, pump replacement and modifying pump settings.

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Wellfield Management Plan – Wellfield Capacity

Harby Road Wellfield, District of Lantzville, BC

1.0 INTRODUCTION

1.1 Background and Project Implementation

The District of Lantzville relies on 4 groundwater sources, producing an estimated combined flow of 20 L/s. These 4 wells are located in the Harby Road well field (Appendix A – Figure A1). Groundwater levels are subject to seasonal effects and can oscillate up to 3 meters between low and high seasons. Low water levels occur during summer months and are combined with an increase in water demand. The District of Lantzville has estimated in 2013 a water consumption doubling during summer months. Stress on groundwater resources has led to water restrictions in the dry season. Demand growth is projected and an additional water source(s) will be required.

1.2 Scope of Work

In June 2014, LHC was hired by the District of Lantzville to undertake a study of the well field at Harby Road. The tasks were as follows:

- Review all the previous reports on well drilling and testing at the well field since 1996;
- Compute all the flow and water level data collected by the SCADA system at the well field;
- Design large scale pumping tests of the 4 in-use wells, using monitoring wells;
- Rate the well field capacity including well interference effects.

2.0 LOCAL GEOLOGY AND HYDROGEOLOGY

2.1 Aquifer Description

The local sand and gravel aquifer is the aquifer #215, mapped by the BC Ministry of Environment (MOE). The productive layers are mostly composed of brown or white sand and gravel corresponding to the Quadra Sand Formation. The unit is characterized by well sorted sand with silt and gravel (Clague, 1975). This formation is overlain by till, glacio-fluvial sediments and glacio-lacustrine sediments of the Vashon Drift. The underlying unit is the Cowichan Head Formation, composed of a unit of marine clay, silt and sand and a unit of plant-bearing silt, sand and gravel. (Clague, 1975).

The well log records in the region display two types of water-bearing formations; the white or brown sand identified as Quadra Sand, and a grey sand and gravel formation that may belong to the Cowichan Head Formation, or an older unit. These two units are sometimes separated with confining layers of till or clay, but are sometimes juxtaposed.

2.2 Aquifer Thickness

The unconsolidated materials intercalation is very heterogeneous and in most parts randomly alternate from water-producing layers of sand and gravel to low permeability till, silt or clay. A large east-west thrust fault situated south of the subject well field causes the bedrock to drop quickly in elevation, thus the overlying unconsolidated materials along and below this axis are highly disturbed (see Appendix A – Figure A2). The sand and gravel aquifer does not extend south of this thrust and occurs in patches rather than a consistent well-bounded aquifer (Appendix A - Figure A3).

Many well logs suggest the presence of two distinct overlapping aquifer layers, separated by a confining layer. The upper-most layer can be unconfined in some places, and is composed of the white/brown Quadra Sand. A lower sand gravel and silt could be considered as a lower aquifer and is composed of grey materials. The two aquifer have been found to merge in many locations and therefore make the argument of two distinct overlapping aquifers difficult to sustain.

Thicknesses range from less than 0.3 m where the aquifer pinches along the bedrock, to nearly 50 m.

2.3 Recharge / Discharge

The water table has a northward gradient towards the ocean as shown in Appendix A - Figure A4. The recharge occurs along the thrust line on the south boundary of the aquifer. The aquifer is replenished from precipitation and runoff from high topographic areas and infiltration towards productive layers at depth. The aquifer may also be recharged in part by the underlying bedrock. Water table elevation in the recharge zone is up to 65 m.asl (meters above sea level) and drops fairly consistently to sea level at the shore with an average regional gradient between 4 and 10%. The discharge areas are located along the shore.

3.0 WELLFIELD ON HARBY ROAD

3.1 Well Field Features

The well field on Harby Road has a total of 4 active production wells (Well #4, Well #6, Well #9 and Well #12). Furthermore, 6 inactive wells are mapped in the area and some can be used as observation points. The pumping tests performed in July/August 2014 used Well #11 as an observation well. See Appendix A - Figure A1 for the well field plan and Appendix D – Figure D1 for the production well logs.

The 4 production wells are confined with till. The till thickness ranges from 4.3 m (Well #4) to 11.2 m (Well #6). Table 1 provides information on the 4 production wells and the Ministry of Environment Observation Well #11 (MOE #232).

Table 1 - Well Information

WELL LID NAME	WELL ID. PLATE	WELL STATUS	UTM COORDINATES 10 U		ELEVATION (m.asl)	DEPTH (m.bgl.)	STATIC WATER LEVEL (m.bgl)	DEPTH TO TOP OF AQUIFER (m.bgl)
			Easting	Northing				
Well #4	ID.13311	Pumping	421 235.0	5 455 490.4	48.0	21.0	1.12	14.9
Well #6	ID.13309	Pumping	421 361.5	5 455 415.7	46.0	16.0	-0.49	14.6
Well #9	ID.13312	Pumping	421 004.0	5 455 561.0	49.0	24.0	3.31	5.8
Well #12	ID.13310	Pumping	421 300.6	5 455 447.6	48.0	21.0	0.52	10.7
Well #11	ID.126	Observation	421 386.0	5 455 343.0	58.0	28.0	8.3	9.1

asl – Above sea level | **bgl** – Below ground level

3.2 Historical Data

The District of Lantzville has been manually recording cumulative flows at the 4 pumping wells, and the SCADA system in place has been recording water level data since 2007. The data were compiled by LHC and plotted for interpretation. A graph for each well (Graphs B1 to B4 - Appendix B) was produced, displaying the water level at the well correlated with the pumping rate.

The graphs show a clear correlation between the water levels and pumping rates. All the graphs show a 12 months periodicity where the pumping rates increase during summer months and lead to a decrease of the water levels at all the wells.

Generally, the linear trends over the years 2006 to 2014 show an increase of the well water levels linked to a decrease of the volume of water produced. The one exception is well #4 which shows increased water levels despite an increase in flow volume. This can be explained by better management of the water resource and/or a decrease of the population.

Also the BC MOE Observation Well #232 (LID #11) shows water levels increasing in the 2009 – 2013 time frame. See graph B5.

4.0 PUMPING TESTS

4.1 Pumping Test Setting and Schedule

Each well was pumped individually and the other ones shut down and used as monitoring wells. The interference drawdown caused from one well to the others could therefore be assessed and taken into consideration when rating the wells. A pumping test involving all the wells pumping at once was also performed to back-up the data from individual pump tests.

Table 2 gives details on the pumping test schedule as well as key results.

4.2 Aquifer Parameters Calculation

The aquifer transmissivity and hydraulic conductivity are calculated as follows:

Transmissivity (m^2/d): $T = 0.183 \times Q / \Delta s$
Hydraulic Conductivity (m/d): $K = T / e$

The equations used to calculate Δs are shown in the pumping graphs at each well in Appendix C.

Equations without interference effects:

WELL #4: $s(t) = 0.0824 * \ln(t) + 8.8633$
WELL #6: $s(t) = 0.0398 * \ln(t) + 9.3311$
WELL #9: $s(t) = 0.0733 * \ln(t) + 4.2557$
WELL #12: $s(t) = 0.193 * \ln(t) + 5.7349$

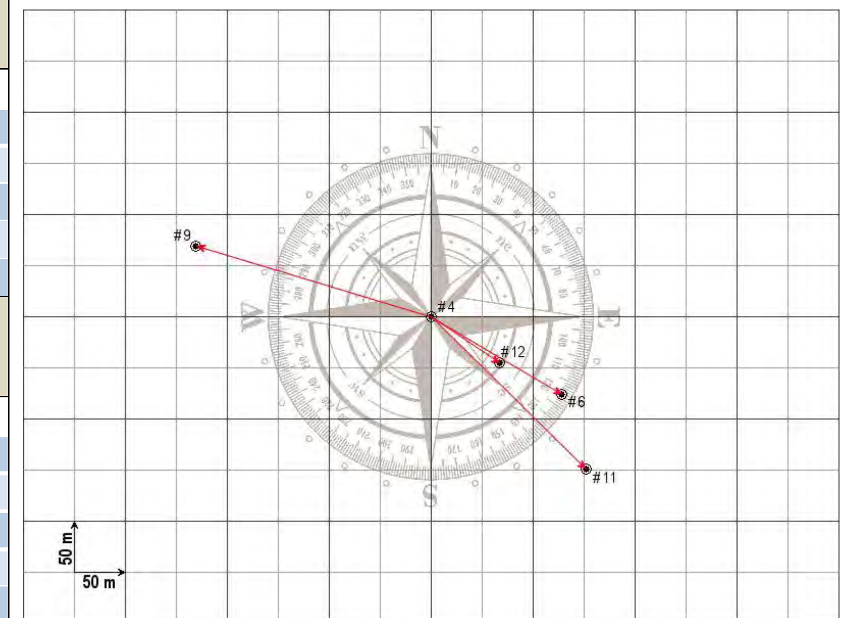
Table 3 – Summary of Calculated Aquifer Parameters

WELL LID NAME	WELL ID. PLATE	PUMPING RATE Q (m^3/d)	DRAWDOWN s (m) 10 min	DRAWDOWN s (m) 100 min	Δs (m)	AQUIFER THICKNESS (m)	TRANSMISSIVITY (m^2/d)	HYDRAULIC CONDUCTIVITY (m/d)
Well #4	ID.13311	728.0	9.0530	9.2428	0.1898	6.4	702	110
Well #6	ID.13309	543.0	9.4227	9.5144	0.0916	1.3	1,085	834
Well #9	ID.13312	190.0	4.4245	4.5933	0.1688	18.0	206	11
Well #12	ID.13310	566.0	6.1793	6.6237	0.4444	9.4	233	25

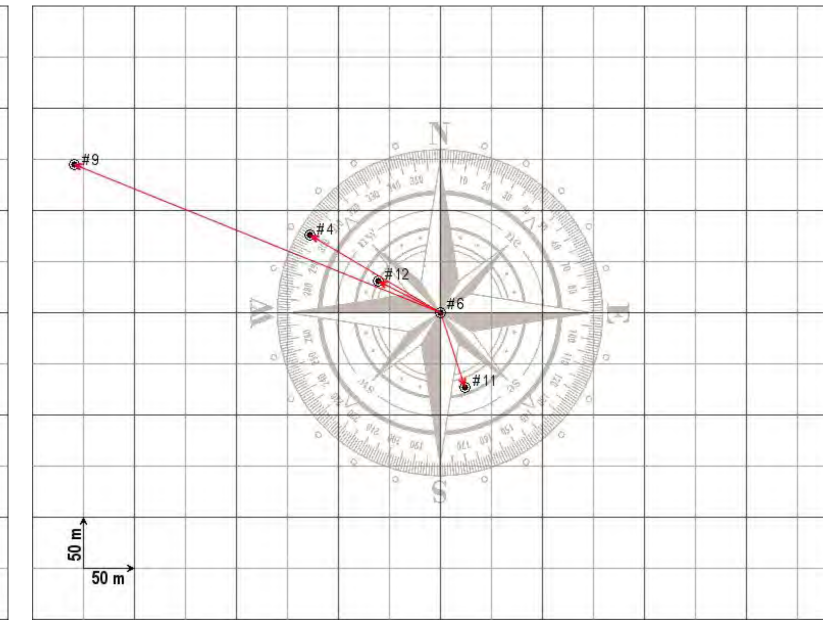
Table 2 - Pumping Test Information

WELL LID NAME	WELL ID. PLATE	WELL STATUS	PUMPING FLOW RATE L/s	PUMPING FLOW RATE (m^3/d)	DISTANCE TO PUMPING WELL (m)	DRAWDOWN AT THE END OF THE TEST (m)	DRAWDOWN AT THE END OF THE TEST (%)	100-DAY EXTRAPOLATED DRAWDOWN (m)	100-DAY EXTRAPOLATED DRAWDOWN (%)
Pumping Test 1 : from 09/07/2014 11:30 AM to 10/07/2014 11:30 AM									
Well #4	ID.13311	Pumping	8.4	728.0	0	9.40	100	9.82	100
Well #12	ID.13310	Observation	-	-	79	0.80	8.5	0.92	9.4
Well #6	ID.13309	Observation	-	-	147	0.40	4.3	0.48	4.9
Well #11	ID.126	Observation	-	-	211	0.11	1.2	0.28	2.8
Well #9	ID.13312	Observation	-	-	241	0.00	0.0	0.00	0.0
WELL LID NAME	**WELL ID. PLATE**	**WELL STATUS**	**PUMPING FLOW RATE L/s**	**(m^3/d)**	**DISTANCE TO PUMPING WELL (m)**	**DRAWDOWN AT THE END OF THE TEST (m)**	**(%)**	**100-DAY EXTRAPOLATED DRAWDOWN (m)**	**(%)**
Pumping Test 2 : from 16/07/2014 3:30 PM to 17/07/2014 3:30 PM									
Well #4	ID.13311	Pumping	8.4	732.0	-	10.60	-	11.20	-
Well #6	ID.13309	Pumping	6.3	492.0	-	10.40	-	11.10	-
Well #9	ID.13312	Pumping	2.2	158.0	-	4.80	-	5.30	-
Well #12	ID.13310	Pumping	6.5	540.0	-	8.90	-	9.60	-
Well #11	ID.126	Observation	-	-	-	0.80	-	1.30	-
WELL LID NAME	**WELL ID. PLATE**	**WELL STATUS**	**PUMPING FLOW RATE L/s**	**(m^3/d)**	**DISTANCE TO PUMPING WELL (m)**	**DRAWDOWN AT 60 MIN (m)**	**(%)**	**100-DAY EXTRAPOLATED DRAWDOWN (m)**	**(%)**
Pumping Test 3 : from 10/08/2014 9:34 PM to 11/08/2014 9:34 PM									
Well #6	ID.13309	Pumping	6.3	543.0	0	9.60	100	9.80	100
Well #12	ID.13310	Observation	-	-	67	0.30	3.1	0.71	7.2
Well #11	ID.126	Observation	-	-	76	0.00	0.0	0.00	0.0
Well #4	ID.13311	Observation	-	-	149	Recovered	0.0	0.00	0.0
Well #9	ID.13312	Observation	-	-	387	Recovered	0.0	0.00	0.0
WELL LID NAME	**WELL ID. PLATE**	**WELL STATUS**	**PUMPING FLOW RATE L/s**	**(m^3/d)**	**DISTANCE TO PUMPING WELL (m)**	**DRAWDOWN AT 70 MIN (m)**	**(%)**	**100-DAY EXTRAPOLATED DRAWDOWN (m)**	**(%)**
Pumping Test 4 : from 13/08/2014 11:20 AM to 14/08/2014 11:20 AM									
Well #12	ID.13310	Pumping	6.5	566.0	0	6.50	100	8.03	100
Well #6	ID.13309	Observation	-	-	68	0.40	6.1	1.45	18
Well #4	ID.13311	Observation	-	-	80	0.10	1.5	0.84	10
Well #11	ID.126	Observation	-	-	133	0.00	0.0	0.49	6.1
Well #9	ID.13312	Observation	-	-	319	0.00	0.0	0.00	0.0
WELL LID NAME	**WELL ID. PLATE**	**WELL STATUS**	**PUMPING FLOW RATE L/s**	**(m^3/d)**	**DISTANCE TO PUMPING WELL (m)**	**DRAWDOWN AT THE END OF THE TEST (m)**	**(%)**	**100-DAY EXTRAPOLATED DRAWDOWN (m)**	**(%)**
Pumping Test 5 : from 18/08/2014 9:25 AM to 18/08/2014 9:25 PM									
Well #9	ID.13312	Pumping	2.2	190.0	0	4.80	100	5.13	100
Well #4	ID.13311	Observation	-	-	241	Recovered	0.0	0.00	0.0
Well #12	ID.13310	Observation	-	-	319	Recovered	0.0	0.00	0.0
Well #6	ID.13309	Observation	-	-	387	Recovered	0.0	0.00	0.0
Well #11	ID.126	Observation	-	-	441	0.00	0.0	0.00	0.0

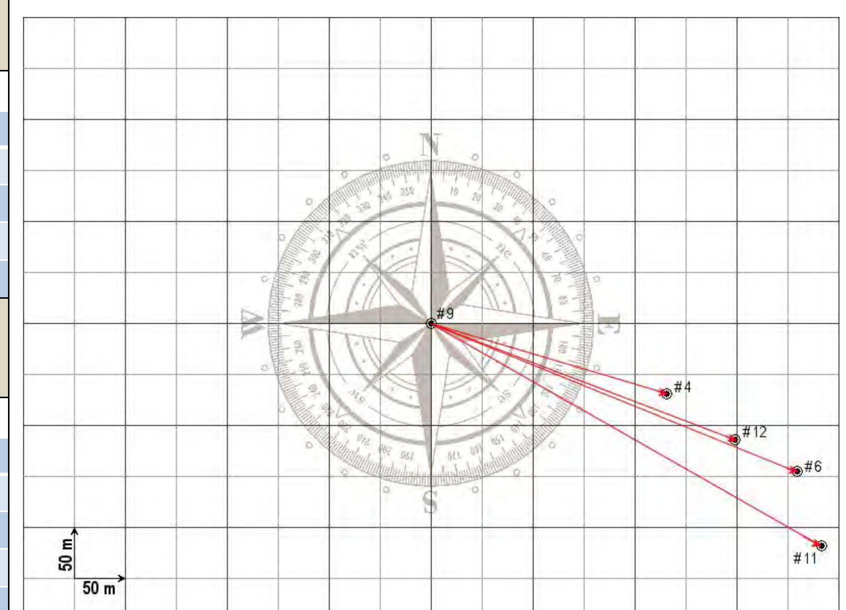
PUMPING WELL #4



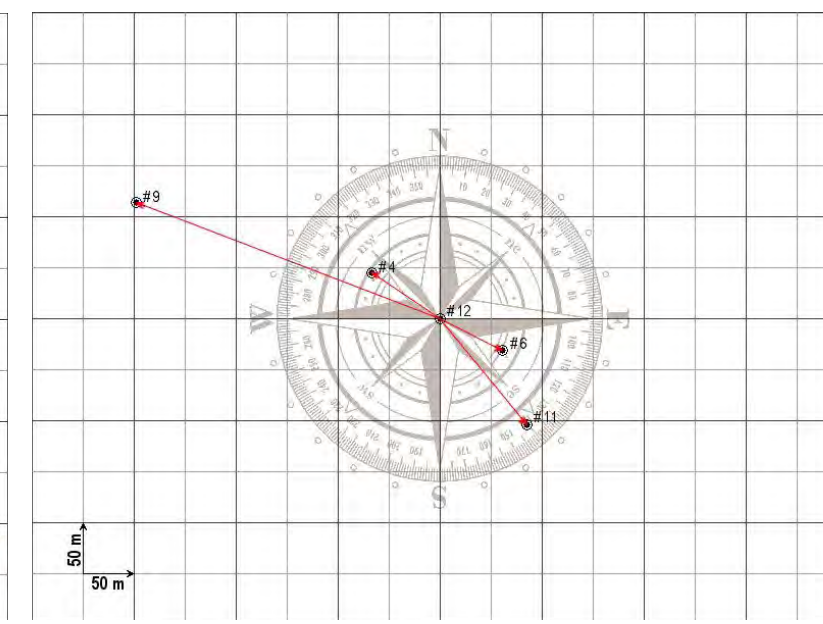
PUMPING WELL #6



PUMPING WELL #9



PUMPING WELL #12



DISTANCE BETWEEN WELLS (m.)

	Well #4	Well #6	Well #9	Well #12
Well #4		149	241	80
Well #6	149		387	67
Well #9	241	387		319
Well #12	80	68	319	

4.3 Well Drawdown Interference

Drawdown interference occurs at each well as the result of pumping of neighbouring wells. The interference caused by each pumping well to the 3 other wells were assessed during the single well pumping. These results are presented in Table 4. Well #9 does not and is not impacted by the other wells because of its remote distance of 241 to 287 m. from the other wells.

Table 4 - 100-day Drawdown Interference in meters

	WELL #4	WELL #6	WELL #9	WELL #12
WELL #4		0.48	0.00	0.92
WELL #6	0.48		0.00	1.45
WELL #9	0.00	0.00		0.00
WELL #12	0.92	1.45	0.00	
Total interference from single wells pumping (m.)	1.4	1.9	0.00	2.4

4.4 Pumping Test Analysis and Well Rating

A well long-term capacity is determined by extrapolating the drawdown information to a 100 days of pumping, calculating the specific capacity at 100 days and utilizing the safe available drawdown. The safe available drawdown depends upon the depth to the top of the aquifer for confined aquifer conditions as is the case here.

The safe available drawdown at the subject wells are defined as follows (also displayed in Appendix D – Figure D1):

Table 5 – Determination of the Safe Available Drawdown in meters

	WELL #4	WELL #6	WELL #9	WELL #12
Static water level	1.12	-0.49	3.31	0.52
Top of the aquifer	14.90	14.60	12.80	10.70
Top of the screen	15.80	14.60	17.40	14.50
SAFE AVAILABLE DRAWDOWN: SAD (m)	**13.78**	**15.09**	**9.49**	**10.18**

Each pump test encompassed the monitoring of 4 wells in the vicinity. The drawdown interferences between the wells were assessed during the tests.

Table 6a gives the maximum capacity of each well when the others are off; therefore, no interference effect applies. Table 6b provides results from the test with simultaneous pumping, and assesses the maximum field capacity when all the wells are pumping simultaneously.

Table 6a – Well Long-Term Yield Assessment without Interference Effects (single pumping well)

WELL LID NAME	WELL ID. PLATE	WELL DIA. (in)	PUMPING RATE (m^3/d)	100d DD (m)	SC 100d ($m^3/d/m$)	TOC (m.agl)	SWL (m.bgl)	SAD (m)	SAFE YIELD (m^3/d)
#4	13311	8	728.0	9.84	73.98	0.86	1.12	13.78	**1,019**
#6	13309	8	543.0	9.80	55.41	0.84	-0.49	15.09	**836**
#9	13312	8	190.0	5.13	37.04	0.26	3.31	9.49	**352**
#12	13310	8	566.0	8.03	70.49	0.85	0.52	10.18	**718**

Table 6b – Well Long-Term Yield Assessment with Interference Effects (all wells pumping simultaneously)

WELL LID NAME	WELL ID. PLATE	WELL DIA. (in)	PUMPING RATE (m^3/d)	100d DD (m)	SC 100d ($m^3/d/m$)	TOC (m.agl)	SWL (m.bgl)	SAD (m)	SAFE YIELD (m^3/d)
#4	13311	8	732.0	11.19	65.42	0.86	1.12	13.78	**901**
#6	13309	8	492.0	11.11	44.28	0.84	-0.49	15.09	**668**
#9	13312	8	158.0	5.34	29.59	0.26	3.31	9.49	**281**
#12	13310	8	540.0	9.57	56.43	0.85	0.52	10.18	**574**
					MAXIMUM FIELD CAPACITY			in m^3/d	**2,424**
								in L/s	**28.1**

TAD = Total available drawdown
SAD = Safe available drawdown
agl = Above ground level
bgl = Below ground level
SC 100d = Extrapolated specific capacity at 100 days
SWL = Static water level
TOC = Top of casing

The well field had previously been assessed and rated by EBA. The conditions have changed, therefore well ratings are different in 2014. Table 6c gives a comparison of the estimated pumping capacities in the past and the current ones.

Table 6c – Comparison of Well Rating Results with Previous Studies

WELL LID NAME	WELL ID. PLATE	INDIVIDUAL PUMPING					SIMULTANEOUS PUMPING				
		EBA (2002)		LHC (2014)			EBA (2002)		LHC (2014)		
		m^3/d	USgpm	m^3/d	USgpm	Change USgpm	m^3/d	USgpm	m^3/d	USgpm	Change USgpm
#4	13311	763	140	1,019	187	+47	567	104	901	165	61
#6	13309	927	170	836	153	-17	927	170	668	123	-47
#9	13312	457	84	352	65	-19	392	72	281	52	-20
#12	13310	491	90	718	132	+42	392	72	574	105	33
Combined pumping rates		**2,638**	**484**	**2,925**	**537**	**+53**	**2,278**	**418**	**2,424**	**445**	**+27**

Table 7 - Well Long-Term Yield Assessment for Different Pumping Configurations

15 pumping options are presented with their respective total combined yields.

WELL LID NAME	WELL ID. PLATE	PUMPING OPTION #														
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12	#13	#14	#15
Well #4	ID.13311	● 901	●916	● 984	● 951	● 984	x	● 951	●1019	x	x	x	●1019	x	x	x
Well #6	ID.13309	● 668	● 729	● 810	x	● 810	● 756	x	x	● 756	● 836	x	x	● 836	x	x
Well #9	ID.13312	● 281	x	● 352	● 352	x	● 352	x	● 352	x	● 352	● 352	x	x	x	● 352
Well #12	ID.13310	● 574	● 551	x	● 653	x	● 615	● 653	x	● 615	x	● 718	x	x	● 718	x
TOTAL CAPACITY (m^3/d)		**2,424**	**2,196**	**2,145**	**1,956**	**1,793**	**1,723**	**1,604**	**1,371**	**1,371**	**1,188**	**1,069**	**1,019**	**836**	**718**	**352**

* See long-term yield in Table 6
● Well pumping
x Well shut off

4.5 Well Efficiencies

The well efficiency is defined as the theoretical drawdown divided by the actual drawdown:

Well efficiency = Theoretical drawdown / Actual drawdown

The theoretical drawdown is extrapolated from observation well data plotted on a distance/drawdown graph. Only the pumping at Well #4 gave exploitable data. The equation given by the three observation wells during the pumping test at Well #4 is as follows:

$y = -0.82 \times \ln(x) + 4.5241$

At x = 0.1 (Well #4), the theoretical drawdown is: $y_{\text{theoretical 100-d}} = 6.41$ m

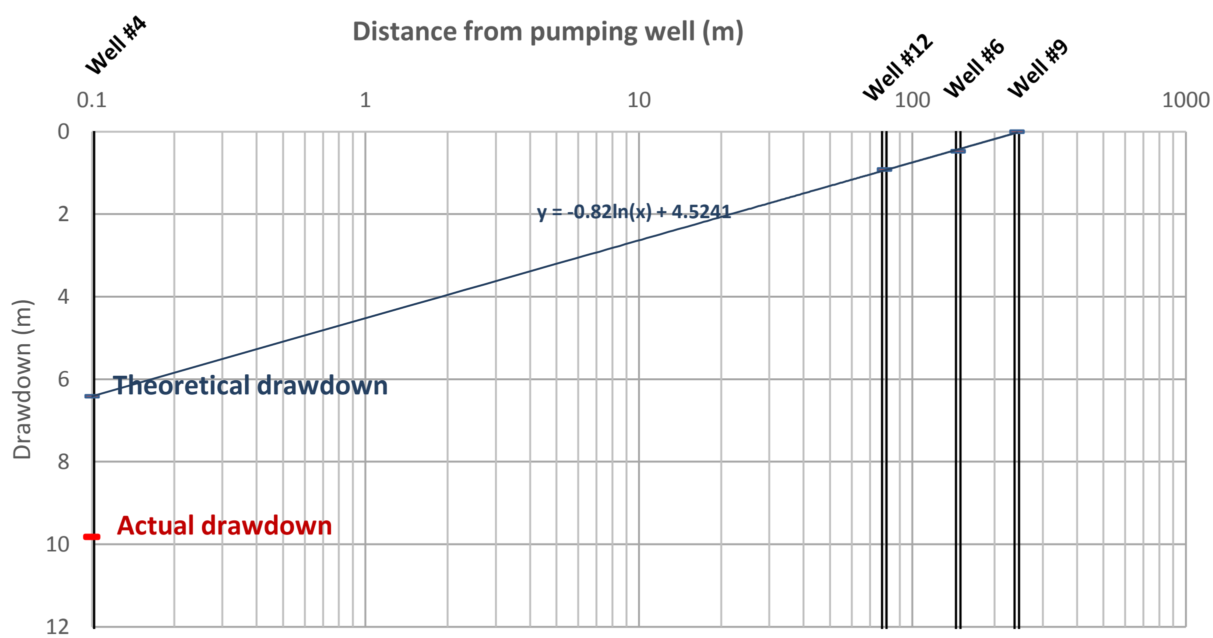
The actual drawdown at 100 day is: $y_{\text{actual 100-d}} = 9.82$ m

Therefore, Well #4 efficiency at 100-day under the conditions of the pumping test is:

Well #4 efficiency = 6.41 / 9.82 = **0.65** *(or 65% efficiency)*

Graph 1 is a distance vs. drawdown graph on a logarithmic scale. The extrapolated drawdown at 100 days was plotted on each well. Theoretically, the line representing the drawdown extended to the pumped well (Well #4) is straight on a log scale. This is represented as the Theoretical Drawdown. In reality, losses occurring at and near the well cause the actual drawdown to be greater. The well efficiency can be assessed based on this theory.

Graph 1 - Distance Drawdown Graph at 100-day



Well efficiency may be partially improved by ensuring that the well is not over pumped (refer to safe estimated yield) and/or by re-development which reduces head loss near the well screen.

5.0 WATER QUALITY

Water quality has not been monitored by LHC during this phase of the project. Previous data and conclusion have however been reviewed and comments regarding potential seawater intrusion are provided in this section. Representative water sample analyses for wells #9 and #12 are attached in Appendix E.

The Harby Road well field lies at an elevation of approximately 50 m above sea level. Well #9 is located off the site at similar elevation. The screen at well #9 is logged at 32 m.asl, with a water table elevation at 47 m.asl. Well #9 is located approximately 800 m. away from the ocean, therefore, the hydraulic gradient under static conditions between Well #9 and the ocean is 6%. Under maximum pumping conditions, where the water level reaches the top of the screen, the hydraulic gradient would be 4% sloping down towards the ocean. This corresponds to a strong gradient that is not believed to be reversible under current pumping conditions. It is LHC's opinion that seawater cannot be drawn into this well by pumping.

The water quality monitoring has shown that alkalinity, chloride, sulphate, calcium, magnesium and sodium slightly increased at Well #9 raising concerns that seawater intrusion may occur. Although the concentrations have marginally evolved at Well #9, they still remain very low, and within common range for fresh groundwater. It is LHC's theory that the pumping at the Harby Road field may have mobilized over time older groundwater bodies which are slowly migrating towards the wells. Well #9 being located at the outskirts of the field has recorded the trace of this groundwater body earlier than the other wells. Alternately well #9 may be drawing an increasing portion of recharge from the underlying bedrock which may contain more highly mineralized water.

Key parameters from analysis performed on September 2014 at Wells #9 and #12 are displayed in Table 8.

Table 8 – Key Water Parameters

PARAMETER	Unit	Canadian Drinking Water Guidelines	WELL #9	WELL #12
Alkalinity	mg/L	-	100	50
Chloride	mg/L	250 **AO**	43.2	21.2
Sulphate	mg/L	500 **AO**	10.9	7.4
Calcium	mg/L	-	33.2	20.8
Magnesium	mg/L	-	9.42	5.81
Sodium	mg/L	-	23.4	7.6
Total dissolved solids	mg/L	500 **AO**	240	130

AO – Aesthetic Objectives
MAC – Maximum Allowable Concentration

6.0 CONCLUSIONS AND RECOMMENDATIONS

1. Well #6 intersects the smallest aquifer thickness (1.3 m.) and it is possible this well was not drilled deep enough.
2. We understand that the flow rate at well #6 was reduced because the well produces sand when pumped at its rated capacity. The well screen design for this well may be faulty.
3. The District's dataloggers record well water levels to the nearest decameter. This accuracy should be increased to the nearest centimeter. Analyzing drawdown graphs would be greatly facilitated by the improved accuracy.
4. The District is keeping good records of cumulative production, this should be continued. Records of production from individual wells should also be maintained.
5. It appears that some wells may benefit from re-development work. This analysis should be refined in the next phase of wellfield work.
6. Considering previous well testing (see sec. 4.4 Table 6c) compared to this study, several options are available to maximize the production capacity of the existing well field. See Table 9.

Table 9 – New Well Yields and Proposed Action to Reach Production Goals

WELL LID NAME	CURRENT PUMPING RATE		WELL LONG-TERM YIELD Single-well pumping		WELL LONG-TERM YIELD Simultaneous pumping		PROPOSED ACTIONS TO REACH WELL LONG-TERM YIELD
#	m^3/d	USgpm	m^3/d	USgpm	m^3/d	USgpm	
#4	728	134	1,019	187	901	165	May need a larger pump
#6	543	100	836	153	668	123	Consider drilling new well
#9	190	35	352	65	281	52	May need re-development and a larger pump
#12	566	104	718	132	574	105	Lower the pump to top of the screen and may need a larger pump
TOTAL	**2,027**	**373**	**2,925**	**537**	**2,424**	**445**	

7. The District of Lantzville should initiate a program to evaluate and carry out the proposed strategies to maximize the production potential of the Harby Road well field.

CLOSURE / DISCLAIMER

This report has been prepared in accordance with generally accepted groundwater engineering practices. The opinions expressed herein are considered valid at the time of writing. Changes in site conditions can occur, however, whether due to natural events or to human activities on these, or adjacent properties. In addition, changes in regulations and standards may occur, whether they result from legislation or the broadening of knowledge. This report is therefore subject to review and revision as changed conditions are identified.

Well yields and water quality can vary over time due to climate change, recharge area modification, or earth movements (earthquakes and blasting). Water quality standards also evolve over time and future revisions of the standards may necessitate changes to the recommendations for water treatment or testing.

In formulating our analyses, conclusions and recommendations we have relied on information supplied by others; well drilling contractors, pumping test contractors and a certified water testing laboratory. The information provided by others is believed to be accurate but cannot be guaranteed. If the recommendations in this report are not implemented, we assume no responsibility for any adverse consequences that may result.

If you have any questions or require any further information, please contact the undersigned.

Respectfully Submitted,

LOWEN HYDROGEOLOGY CONSULTING LTD.

PROFESSIONAL PROVINCE OF D. A. LOWEN BRITISH COLUMBIA GEOSCIENTIST

PROFESSIONAL PROVINCE OF D. A. LOWEN BRITISH COLUMBIA ENGINEER

Dennis A. Lowen, P. Eng., P.Geo.
Senior Hydrogeologist

Marion Dardare, M.Sc.
Hydrogeologist

REFERENCES

Reports

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- AGRA Earth & Environmental Ltd. (1999), *Well #14 and Well #15 Drilling and Testing Program*, District of Lantzville, BC
- Lantzville Improvement District (2001), *Community Water System Report*
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- District of Lantzville (2013), *Annual Water Report*
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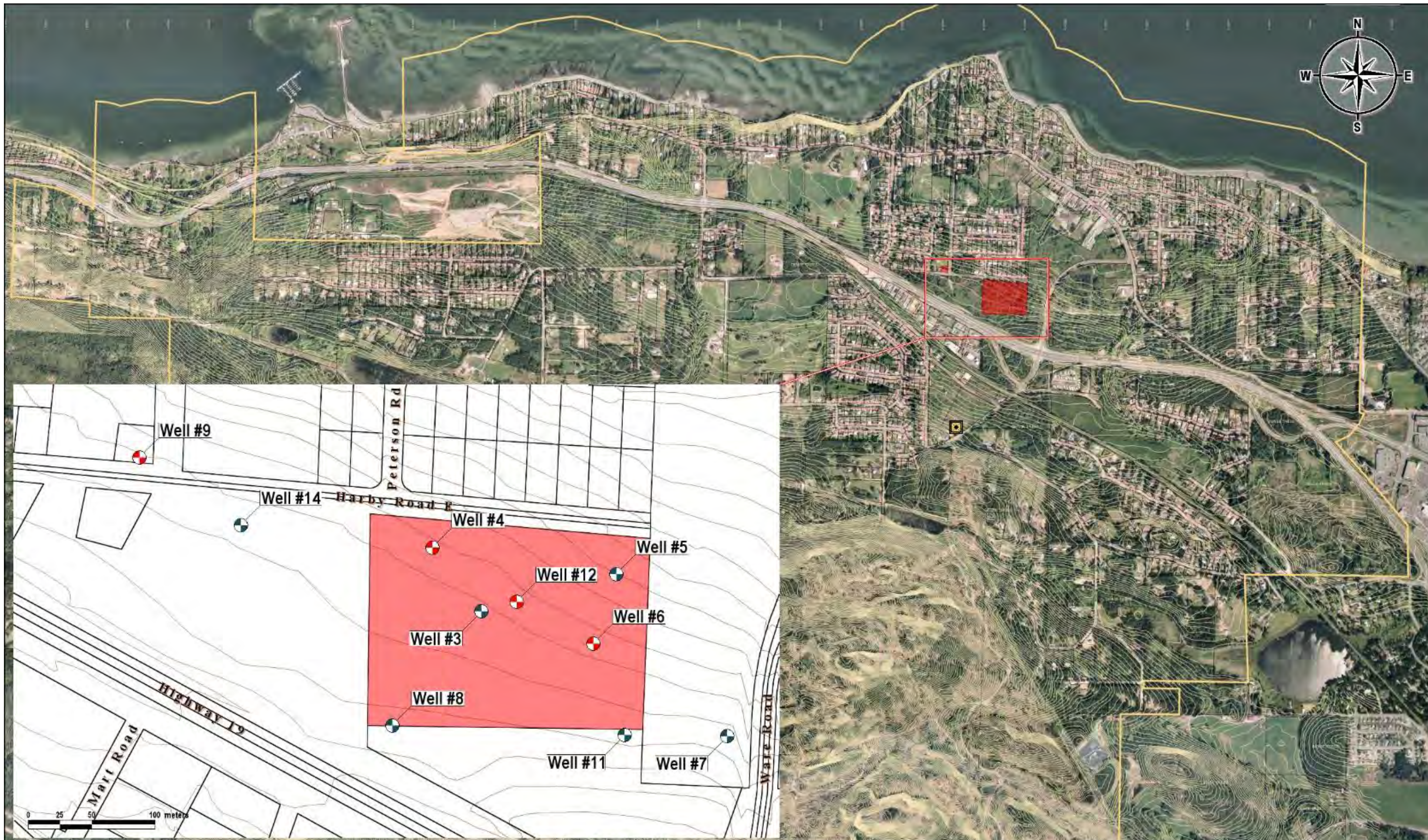
Websites

- Imap BC: http://maps.gov.bc.ca/ess/sv/imapbc/
- Climate Canada: http://climate.weather.gc.ca/
- Statistics Canada: http://www12.statcan.gc.ca/

APPENDIX A

Figures

Figure A1 – Well field location plan



LEGEND

General settings

- Cadastral
- Air Photo 2004
- Topography (2 m. contours)
- District boundary
- Harby Road wellfield

Well field map

- Cadastral
- Water well
- Topography (2 m. contours)
- Pumphouse station / reservoir

Scale

0 200 500 1000 meters.

NOTES

Well #3 = 10 U [421 373.1 ; 5 455 440.3]
Well #4 / ID.13311 = 10 U [421 235.0 ; 5 455 490.4]
Well #5 = 10 U [421 378.5 ; 5 455 470.1]
Well #6 / ID.13309 = 10 U [421 361.5 ; 5 455 415.7]
Well #7 = 10 U [421 465.3 ; 5 455 342.6]
Well #8 = 10 U [421 202.2 ; 5 455 350.8]
Well #9 / ID.13312 = 10 U [421 004.0 ; 5 455 561.0]
Well #11 / ID.126 = 10 U [421 386.0 ; 5 455 343.0]
Well #12 / ID.13310 = 10 U [421 300.6 ; 5 455 447.6]
Well #14 = 10 U [421 082.9 ; 5 455 508.1]

Pumphouse station / reservoir = 10 U [421 051.2 ; 5 454 812.5]

** Data in grey are from EBA, 2002, are believed to be accurate but have not been confirmed by LHC.*

KEY MAP

Harby Road Well Field
District of Lantzville, B.C.

23/07/2014
File No.: 1412
Drawing: MD
Review: DL

LHC Lowen Hydrogeology Consulting Ltd.

Figure A2 – Bedrock Map

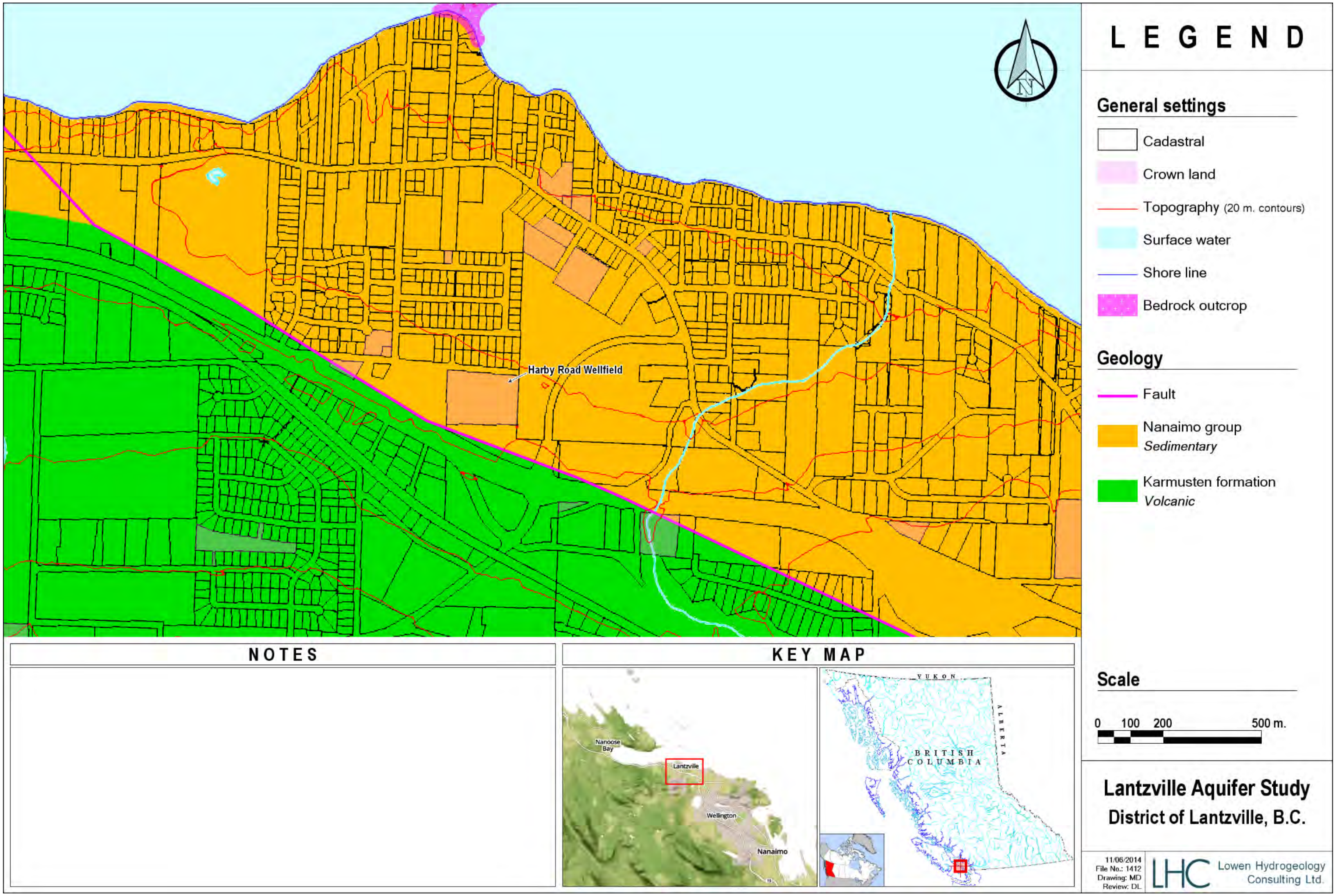


Figure A3 – Aquifer thickness

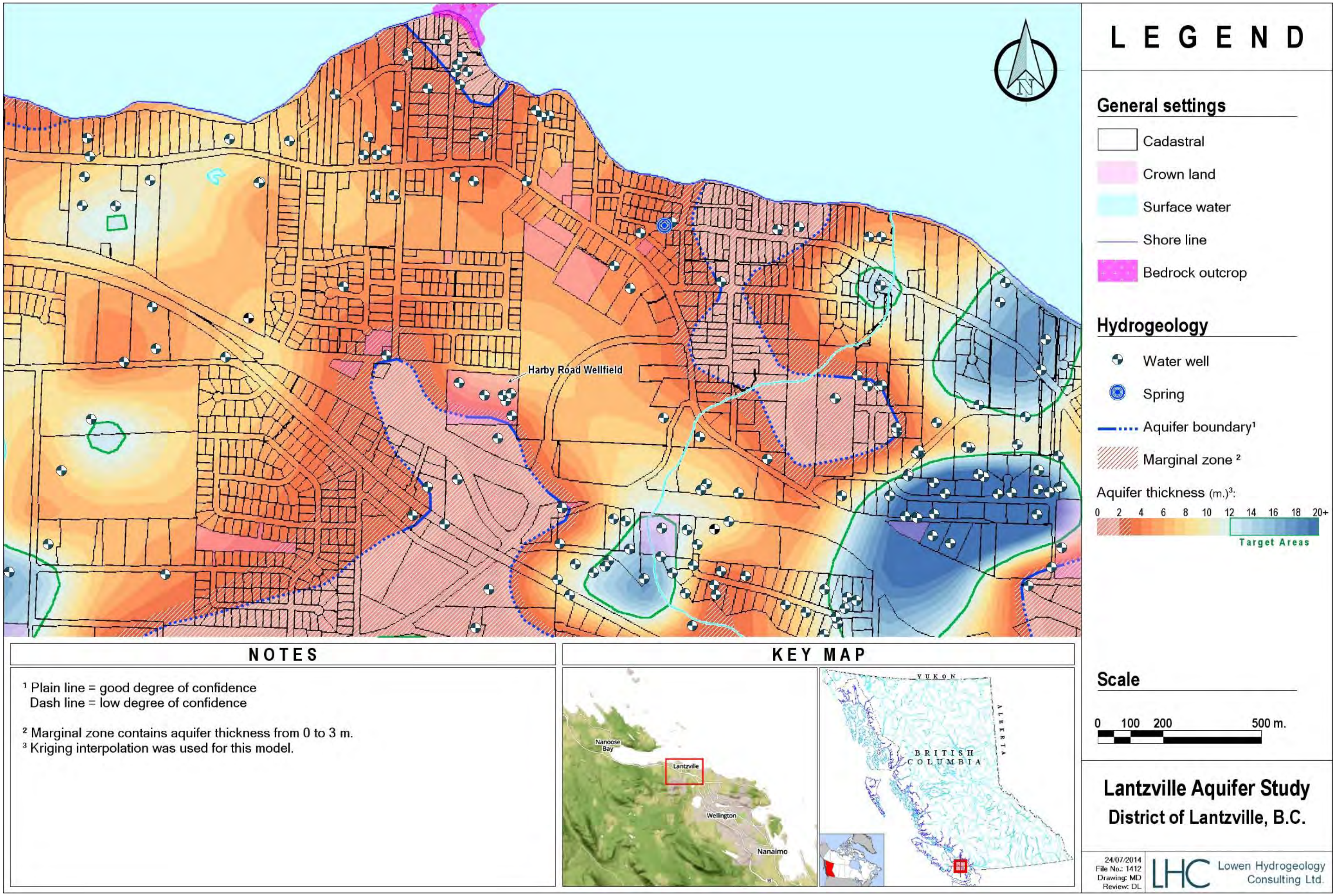


Figure A4 – Water table elevation

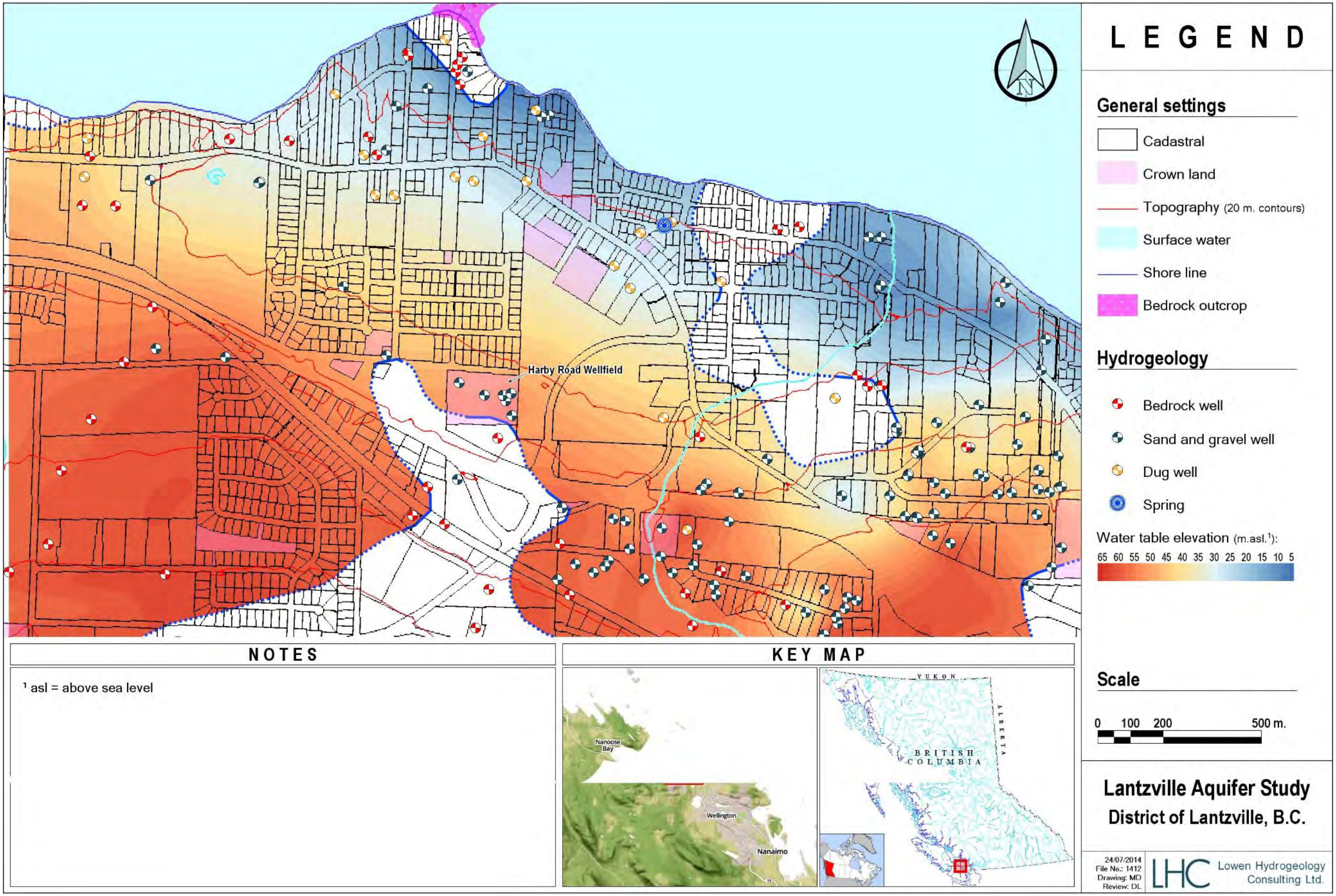


Figure A5 – Well yield

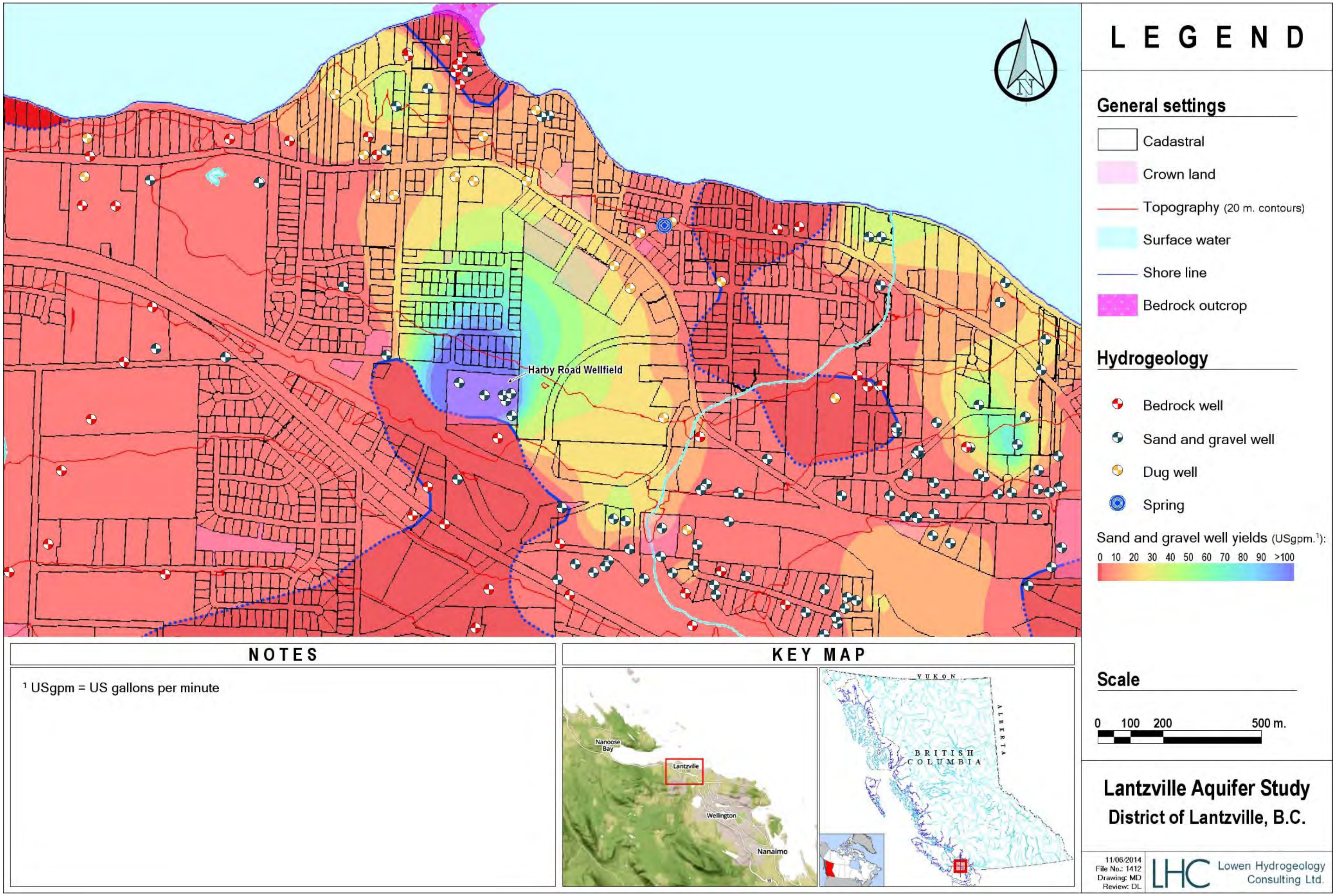
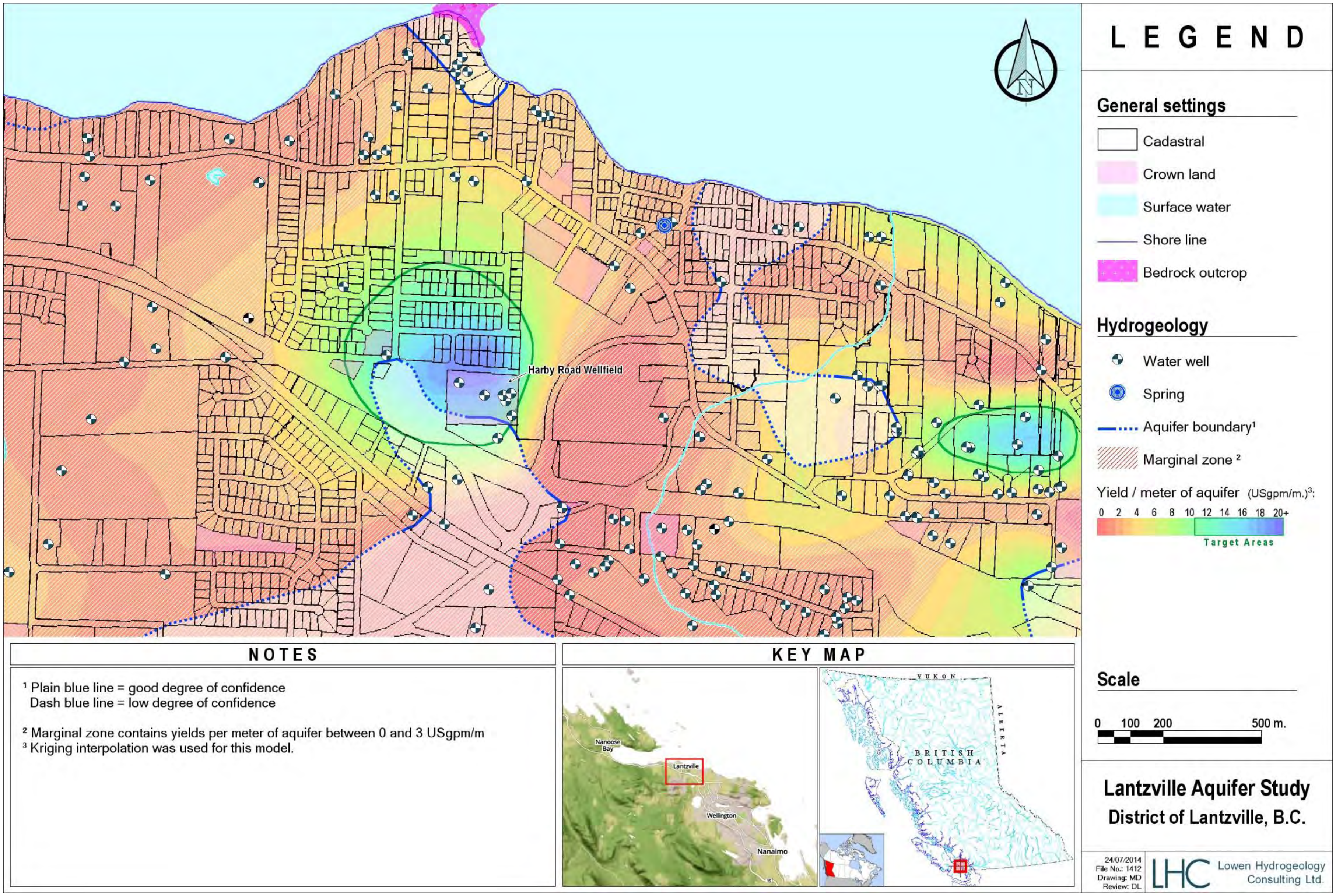


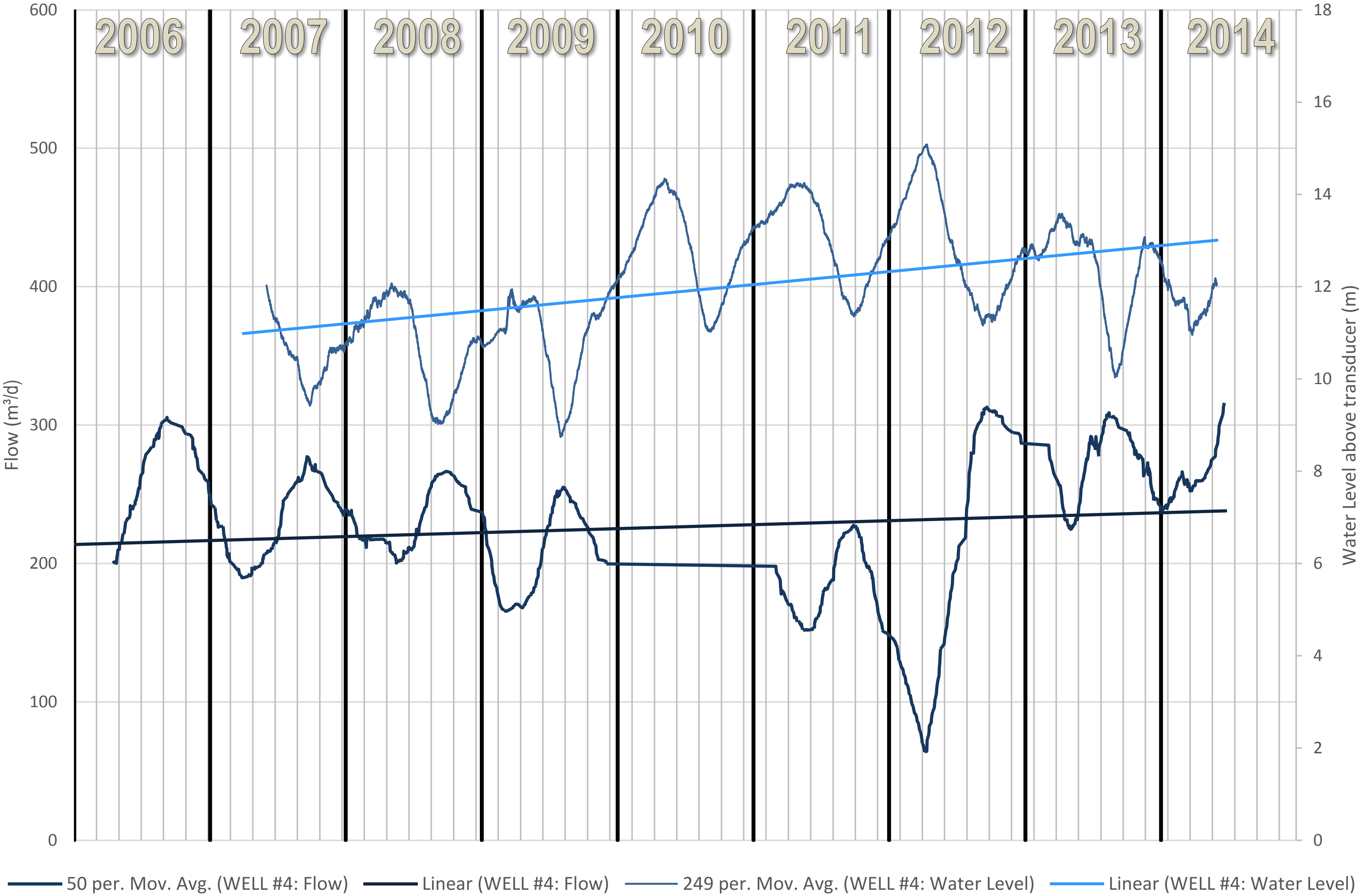
Figure A6 - Yield per meter of aquifer



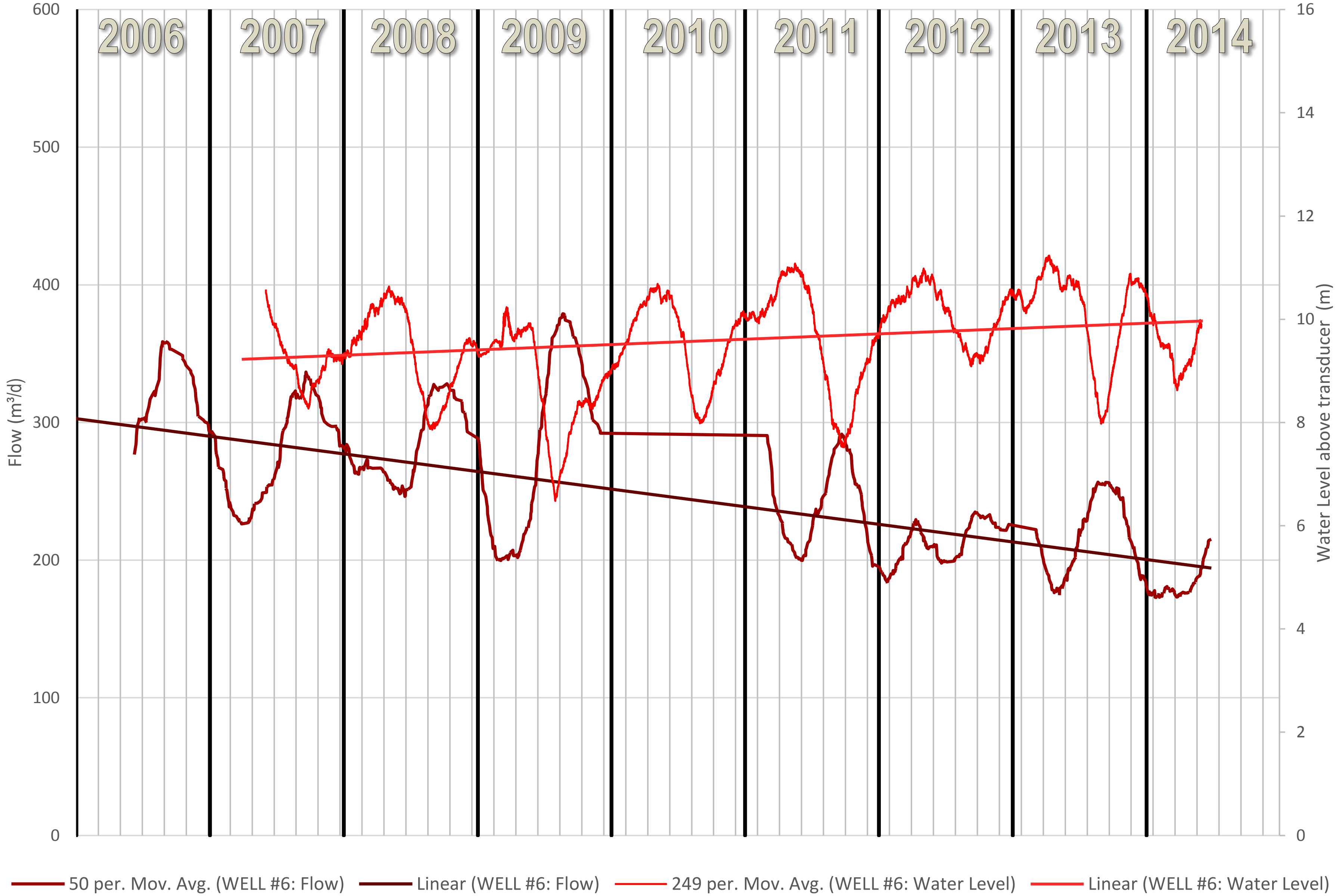
APPENDIX B

Historical Data

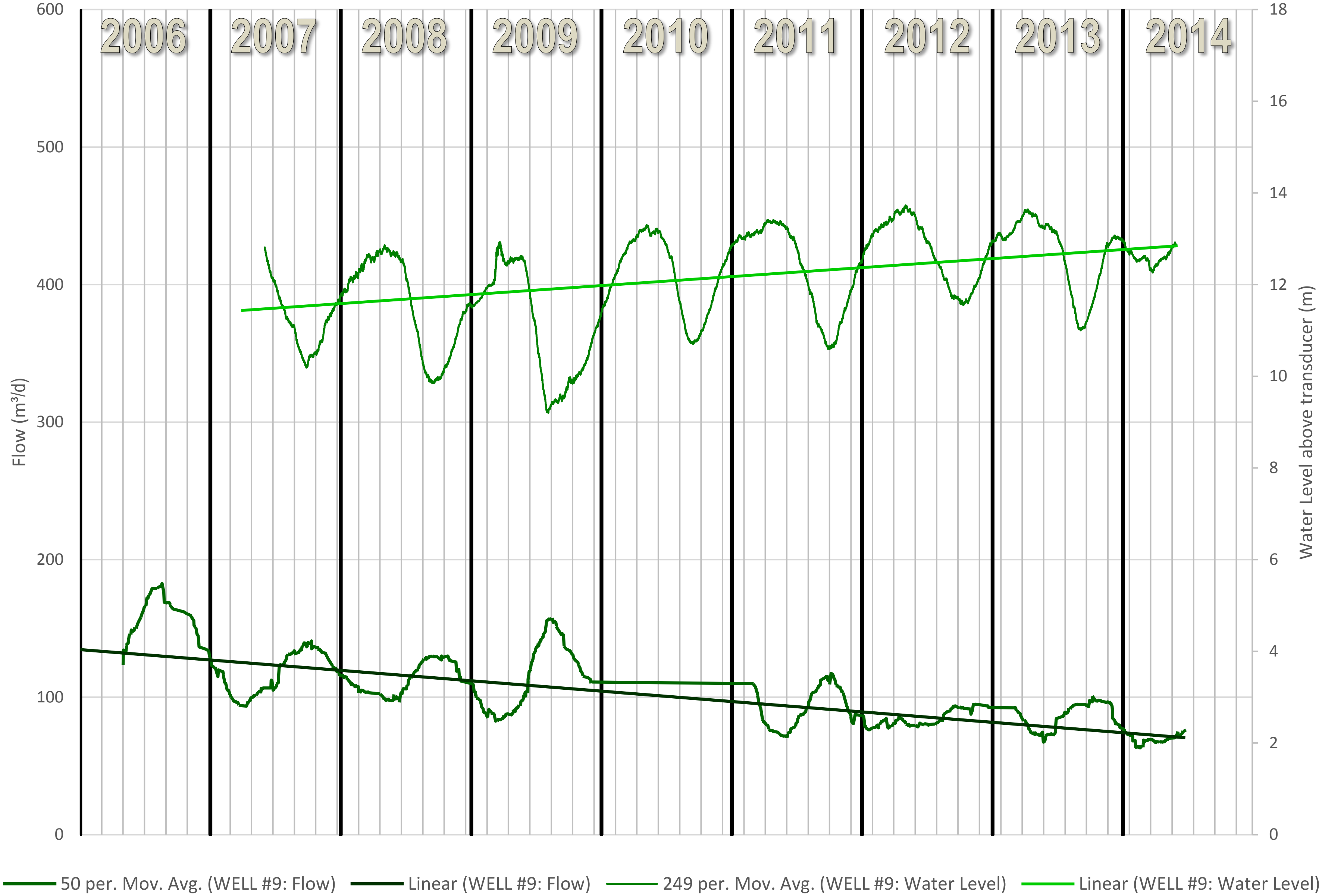
Graph B1 - Water level and pumping rate at Well #4



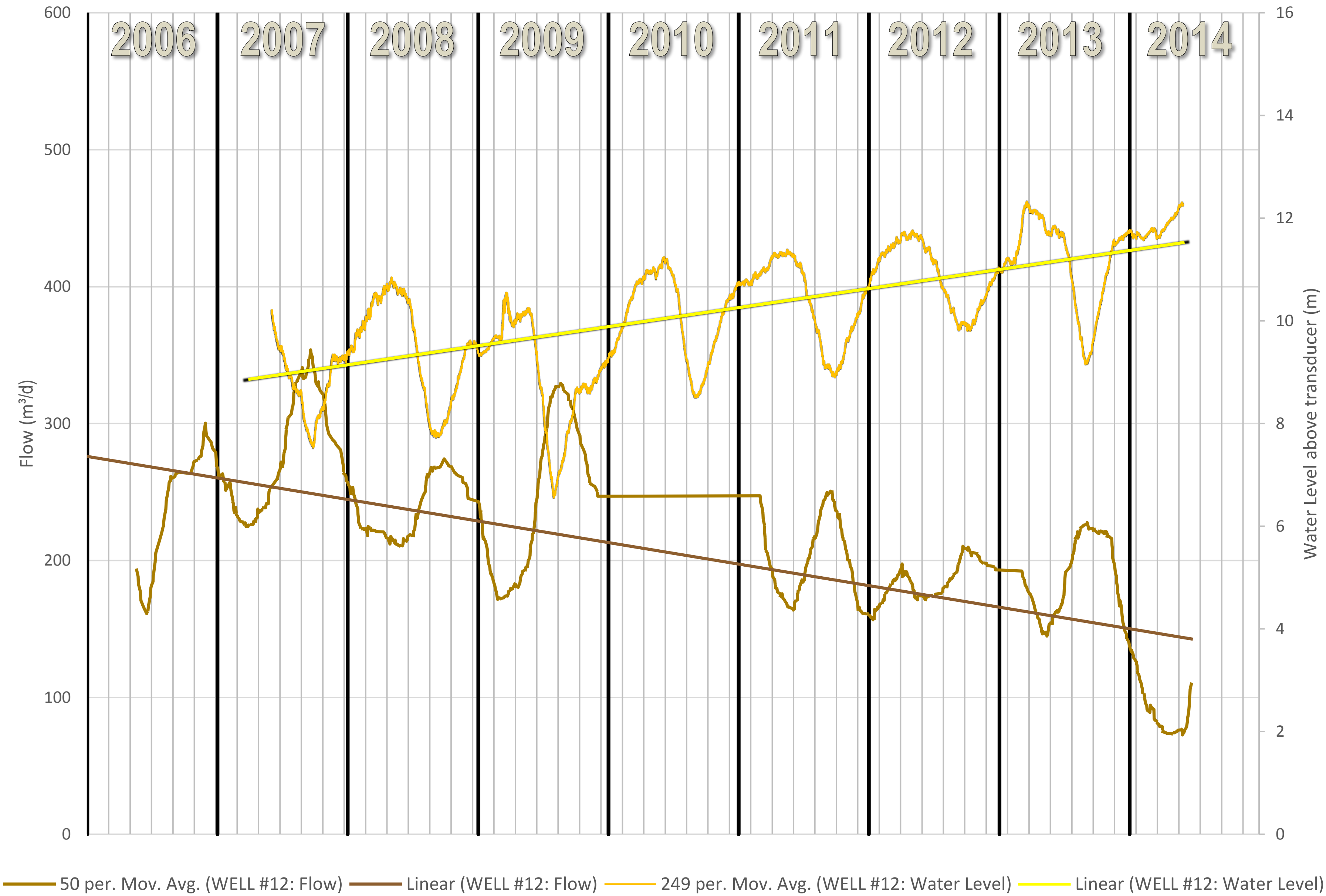
Graph B2 - Water level and pumping rate at Well #6



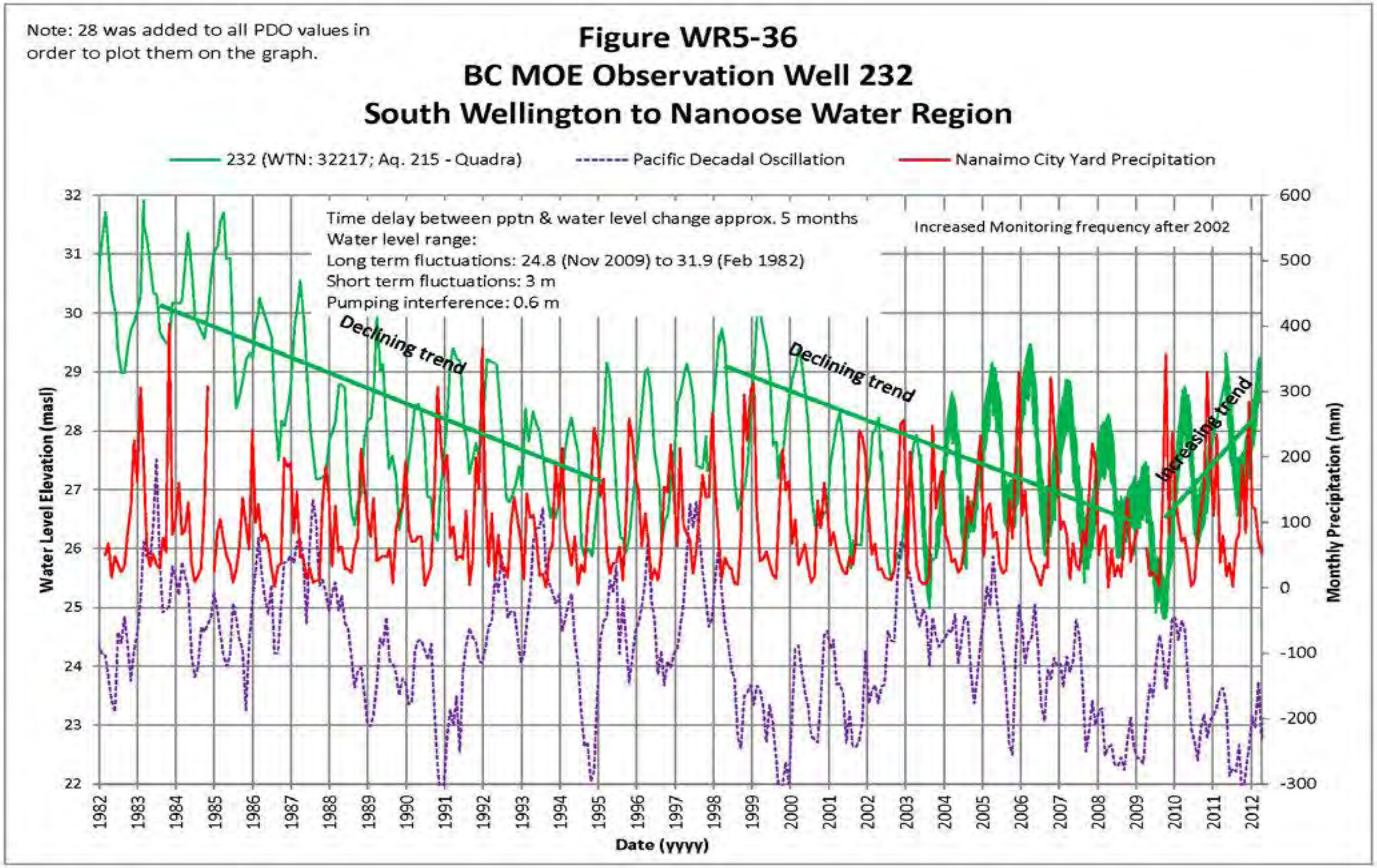
Graph B3 – Water level and pumping rate at Well #9



Graph B4 - Water level and pumping rate at Well #12



Graph B5 – Water Level – BC MOE Observation Well #232

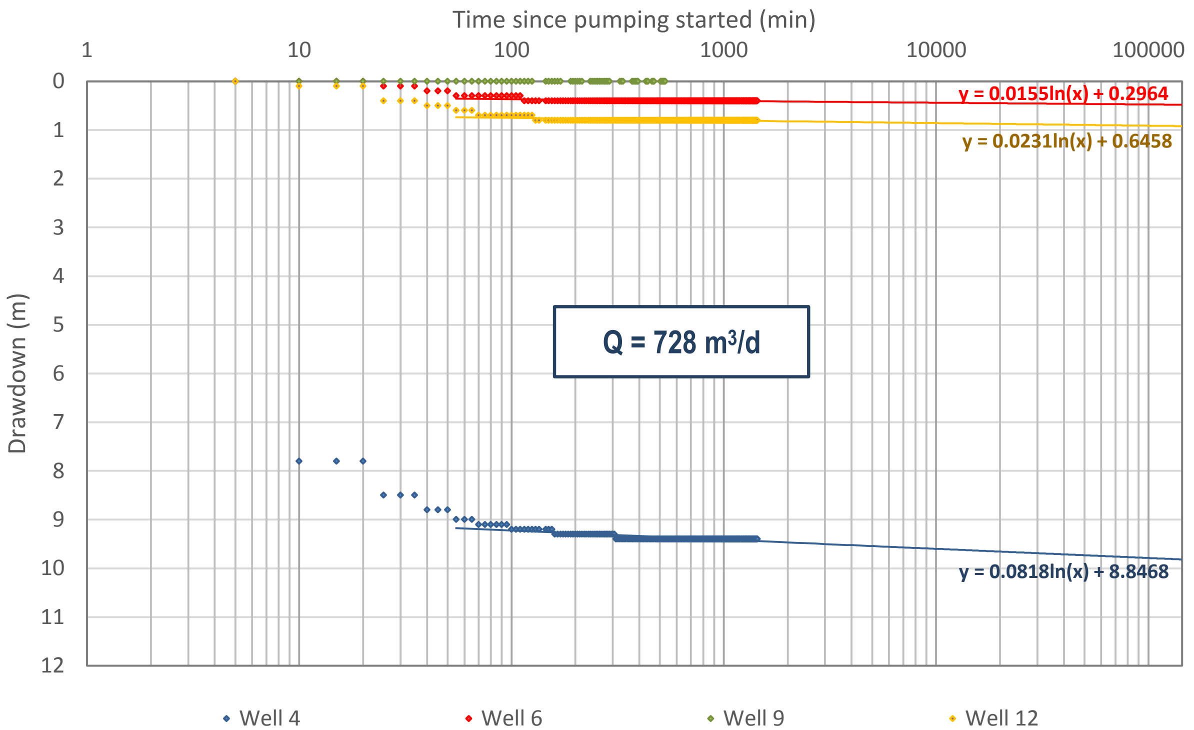


APPENDIX C

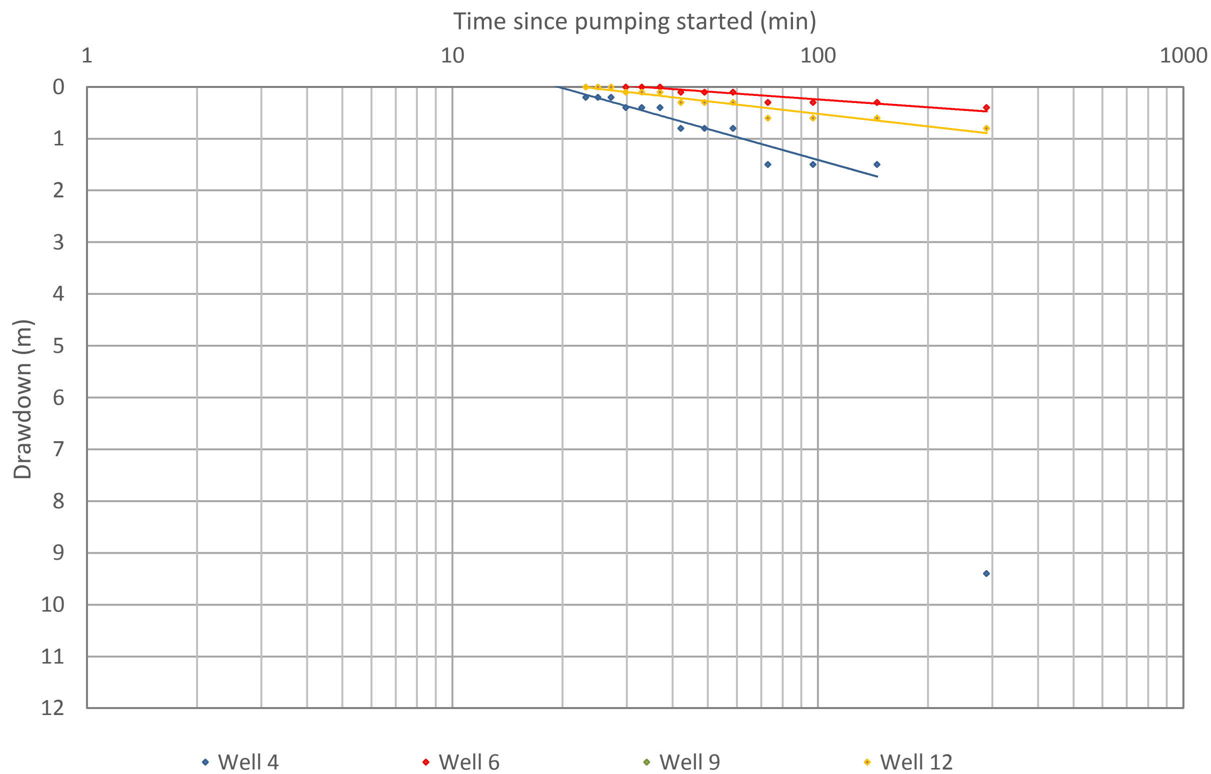
Pumping Test Graphs

WELL #4

Graph C1 - Pumping test at well #4: Drawdown curve

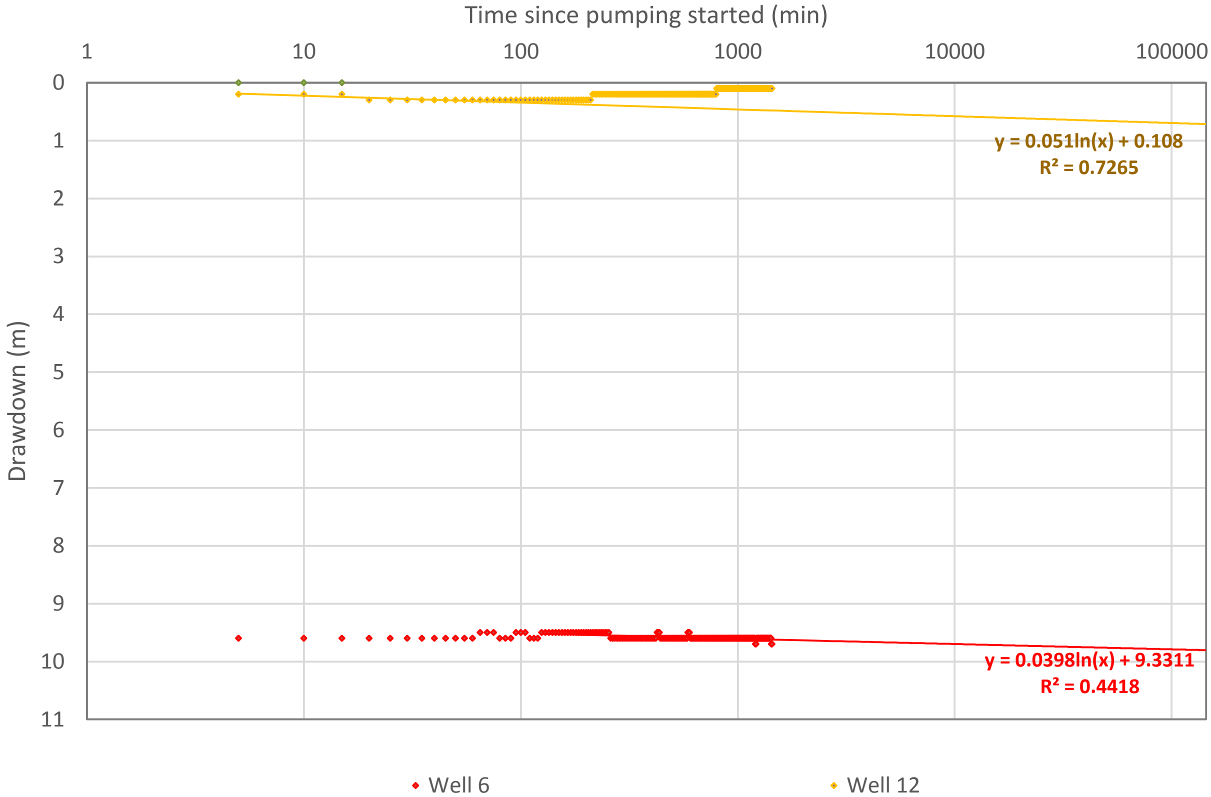


Graph C2 - Pumping test at well #4: Recovery curve



WELL #6

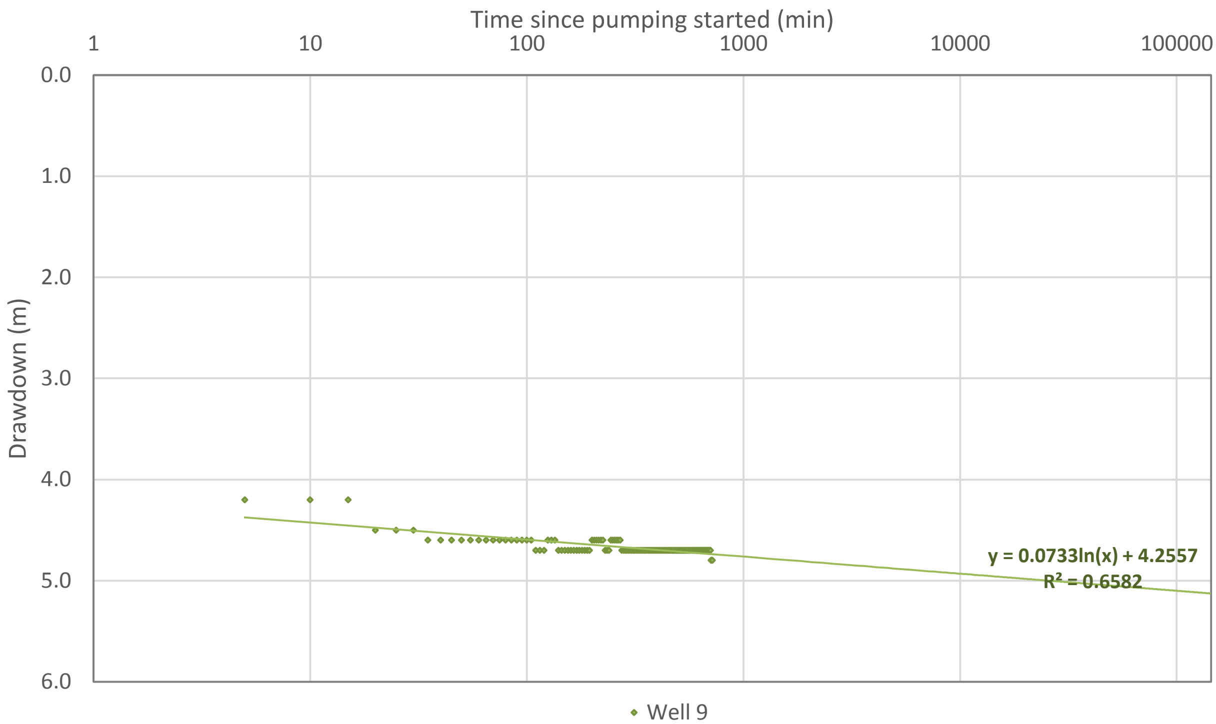
Graph C3 - Pumping test at well #6: Drawdown curve



Wells #4 and #9 did not show any interference.
Both wells recovered immediately after the pump was shut off.

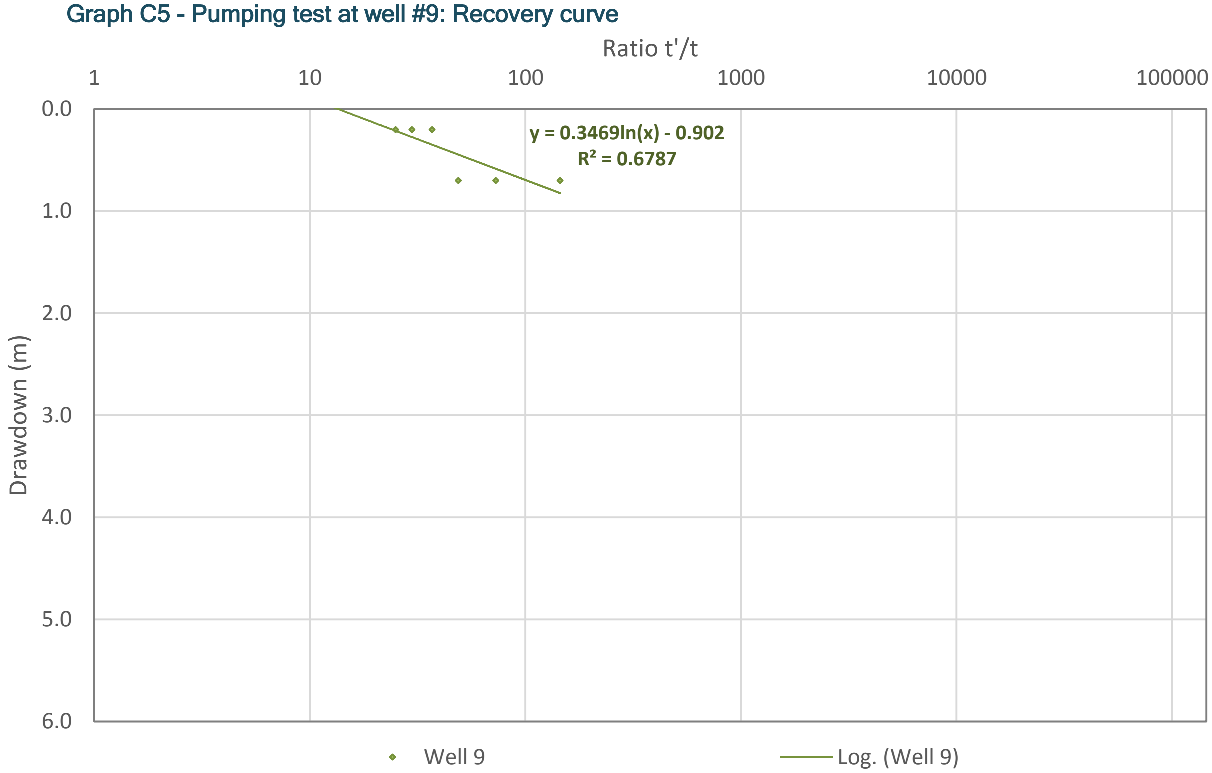
WELL #9

Graph C4 - Pumping test at well #9: Drawdown curve



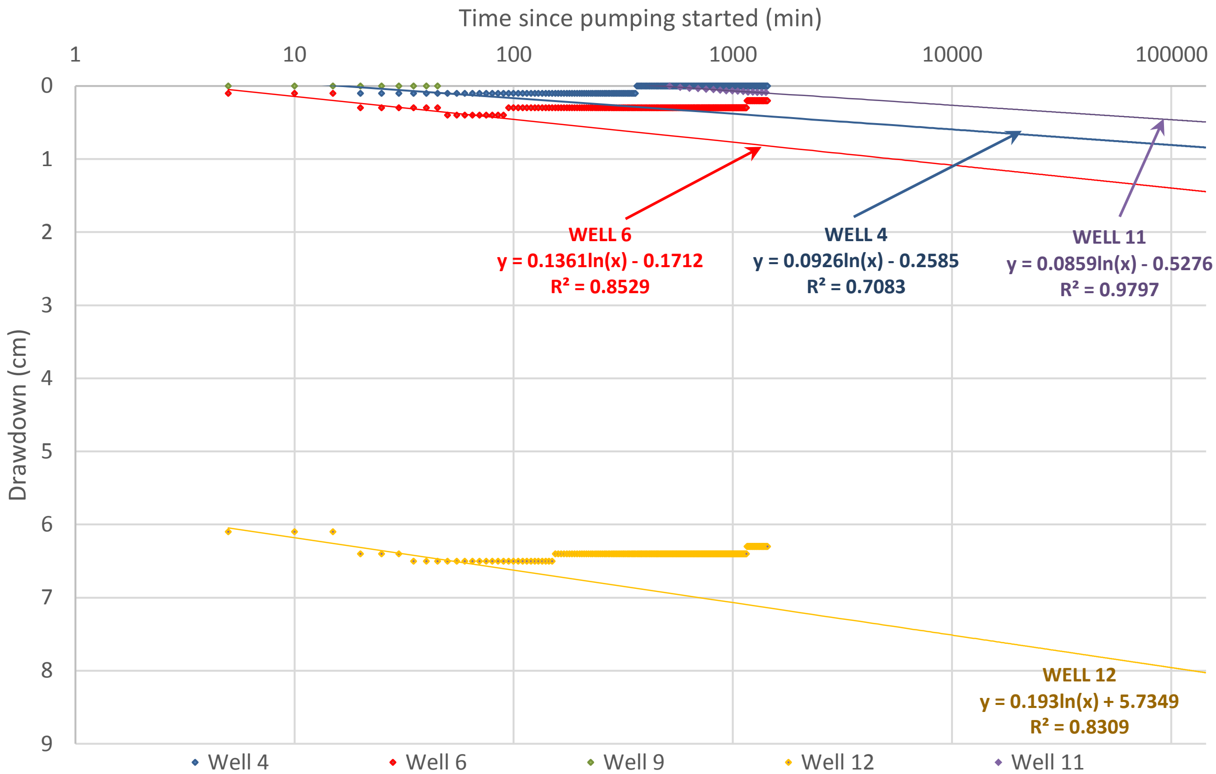
None of the monitoring wells showed any interference.

Graph C5 - Pumping test at well #9: Recovery curve



WELL #12

Graph C6 - Pumping test at well #12: Drawdown curve



Well #9 did not show any interference.
All the wells recovered immediately after the pump was shut off.

SIMULTANEOUS PUMPING
Wells #4, #6, #9 and #12

Graph C7 - Simultaneous pumping test: Drawdown curves

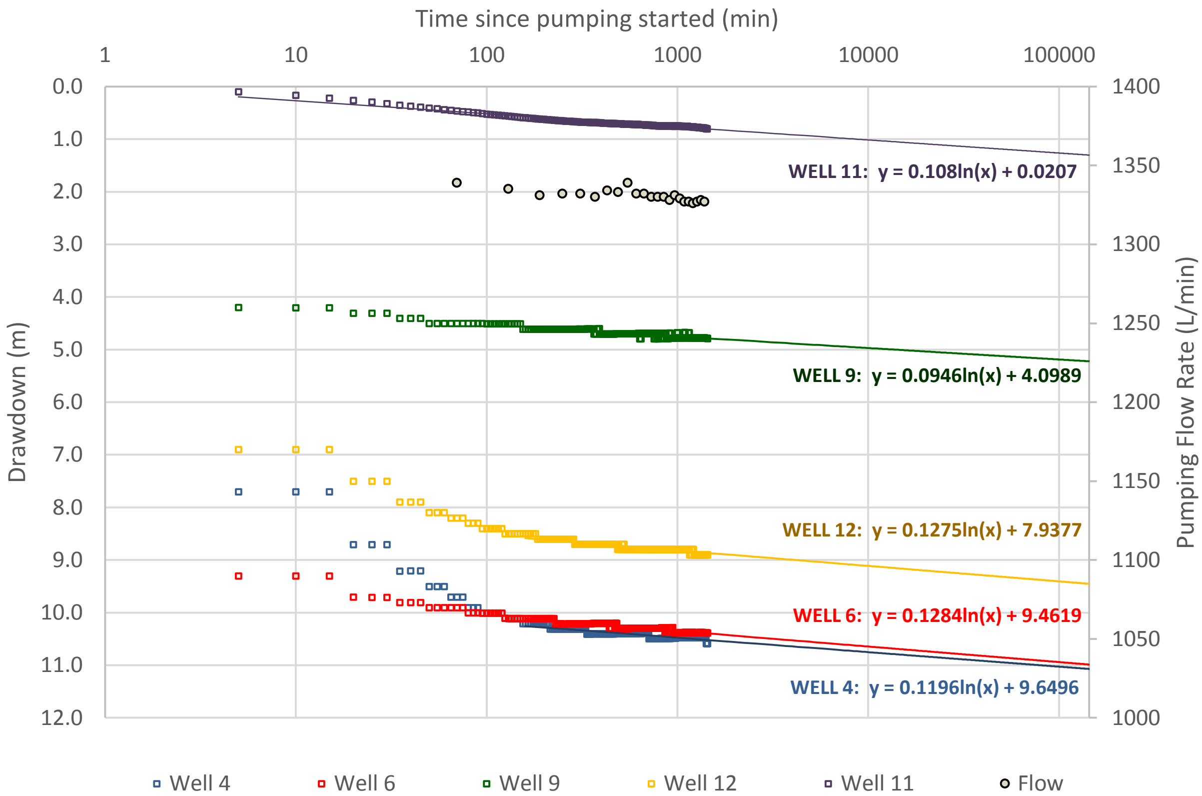
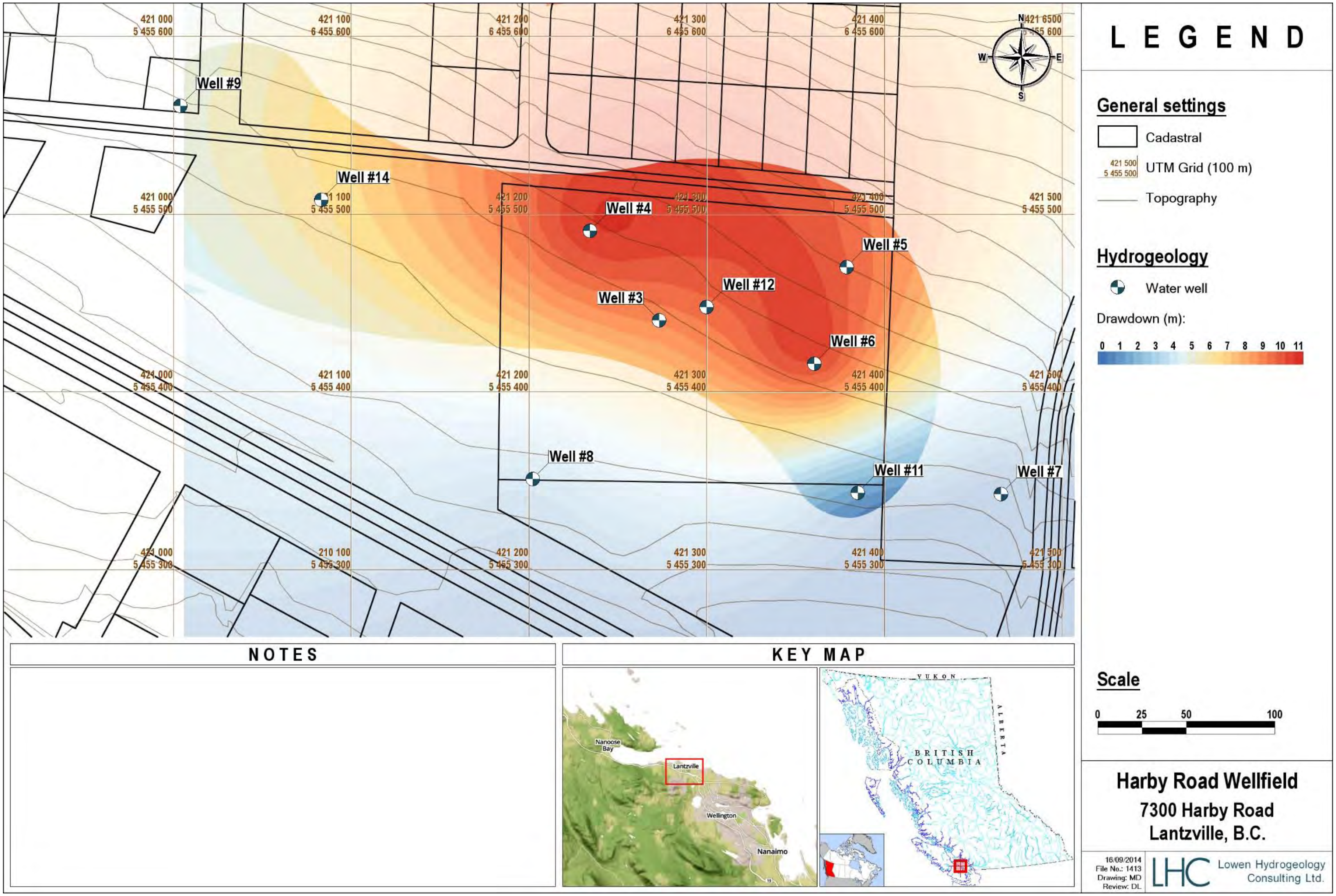


Figure C1 - Drawdown at the well field during simultaneous pumping

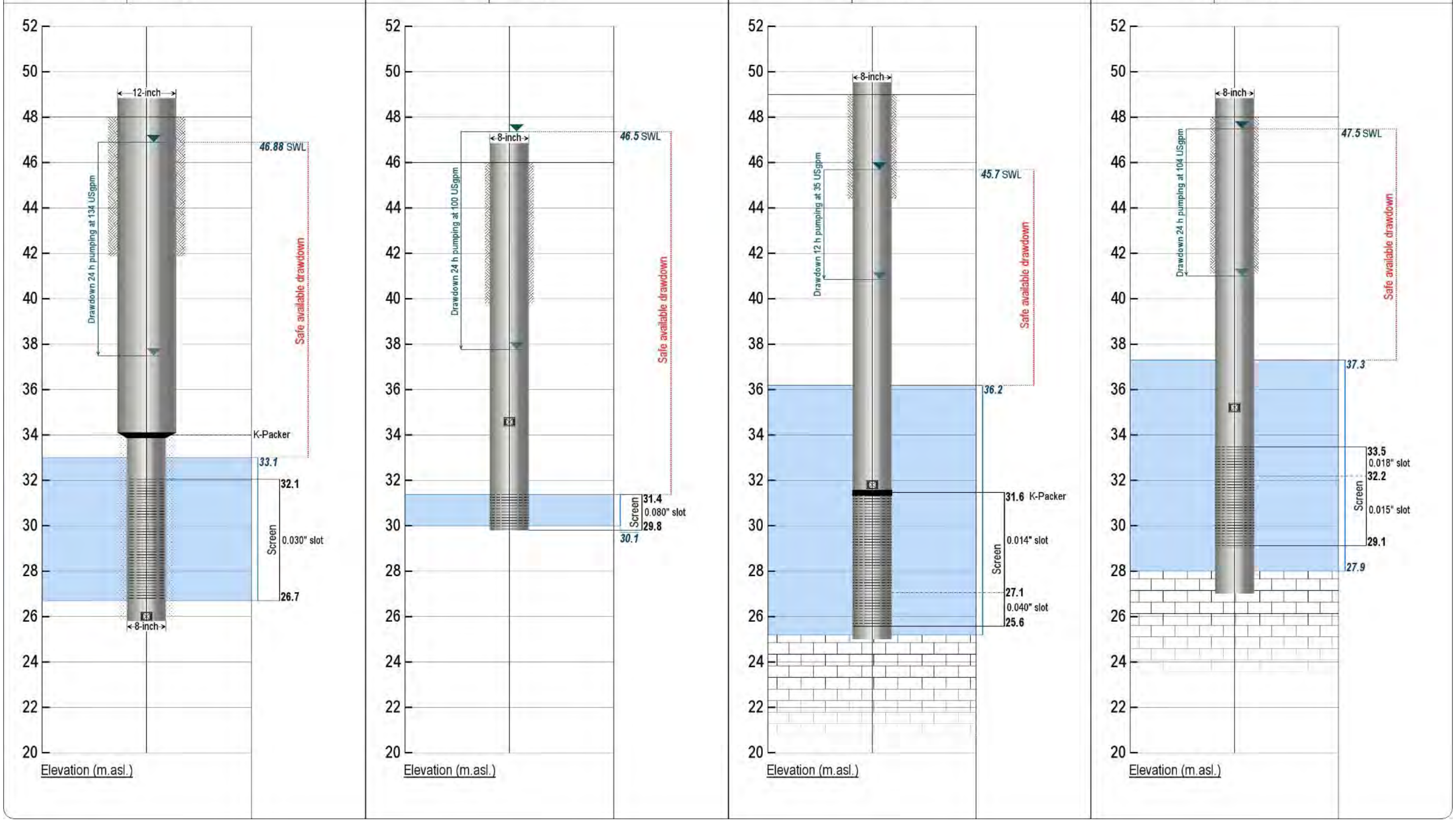


APPENDIX D

Well Log Records

Figure D1 - Well construction logs

Well LID Name:	WELL #4	Well LID Name:	WELL #6	Well LID Name:	WELL #9	Well LID Name:	WELL #12
Well ID. Plate No.:	13311	Well ID. Plate No.:	13309	Well ID. Plate No.:	13312	Well ID. Plate No.:	13310
Static Water Level:	1.12 m	Static Water Level:	-0.49 m	Static Water Level:	3.31 m	Static Water Level:	0.52 m
Yield:	197 USgpm	Yield:	83 USgpm	Yield:	65 USgpm	Yield:	109 USgpm



WELL LOG RECORD

Well ID.:	13311
Well No.:	LID #4
Address:	Harby Road Wellfield, Lantzville, BC
GPS location:	10 U [421,235 ; 5,455,490]
Drilling contractor:	N/A
Static water level:	1.12 m.bgl.
Safe yield:	1,075 m^3/d (197 USgpm)

WELL LOG

From (m.bgl)	**To** (m.bgl)		
0.0	0.6	Topsoil	
0.6	14.9	Glacial Till	
14.9	21.3	Fine to coarse sand and fine gravel	Water bearing
21.3	22.2	Glacial Till	

WELL CONSTRUCTION

From (m.bgl)	**To** (m.bgl)	
+0.86	0.00	12-in diameter stick-up
0.00	14.00	12-in diameter casing
14.00	-	K-Packer
14.00	15.80	Riser pipe – 8-in diameter
15.80	21.30	Screen: 0.762 mm (0.030”) slot (5.5 m / 18 ft) – 8-in diameter
21.30	-	Bail bottom

OTHER

Surface seal:	Bentonite – (6.1 m / 20 ft)

WELL LOG RECORD

Well ID.:	13309
Well No.:	LID #6
Address:	Harby Road Wellfield, Lantzville, BC
GPS location:	10 U [421,361 ; 5,455,416]
Drilling contractor:	Drillwell Enterprises Ltd.
Static water level:	Artesian: 0.49 m.agl.
Safe yield:	454 m^3/d (83 USgpm)

WELL LOG

From (m.bgl)	**To** (m.bgl)	
0.0	0.3	Soil
0.3	3.4	Sand and gravel
3.4	14.6	Silty gravelly till
14.6	15.9	Sand and fine gravel
15.9	16.8	Silty brown sand

WELL CONSTRUCTION

From (m.bgl)	**To** (m.bgl)	
+0.84	0.00	8-in diameter stick-up
0.00	14.60	8-in diameter casing
14.60	16.20	Screen: 0.762 mm (0.030”) slot (5.5 m / 18 ft) - 8-in diameter
16.20	-	Bail bottom

OTHER

Surface seal:	Bentonite - (5.2 m / 17 ft)

WELL LOG RECORD

Well ID.:	13312
Well No.:	LID #9
Address:	Harby Road Wellfield, Lantzville, BC
GPS location:	10 U [421,004 ; 5,455,561]
Drilling contractor:	Fyfe's Well Drilling Ltd.
Static water level:	3.31 m.bgl.
Safe yield:	355 m^3/d (65 USgpm)

WELL LOG

From (m.bgl)	**To** (m.bgl)	
0.0	0.3	Brown till
0.3	4.6	Gravelly grey till
4.6	5.5	Loose sand and gravel, water bearing
5.5	5.8	Till
5.8	8.2	Coarse sand and gravel
8.2	12.8	Fine brown sand, heaves
12.8	18.3	Sand with till stringers
18.3	19.2	Coarse sand and some gravel
19.2	21.6	Fine sand and coarse gravel
21.6	23.5	Coarse sand and pea gravel
23.5	23.8	Angular gravel and fine sand, tight
23.8	-	Bedrock

WELL CONSTRUCTION

From (m.bgl)	**To** (m.bgl)	
+0.54	0.00	8-in diameter stick-up
0.00	17.33	8-in diameter casing
17.33	-	K-Packer
17.33	21.93	Screen: 0.381 mm (0.014") slot (4.6 m / 15 ft) - 8-in diameter
21.93	23.43	Screen: 1.016 mm (0.040") slot (1.5 m / 5 ft) - 8-in diameter
23.43	23.71	Bail bottom

OTHER

Surface seal:	Bentonite - (4.27 m / 14 ft)

WELL LOG RECORD

Well ID.:	13310
Well No.:	LID #12
Address:	Harby Road Wellfield, Lantzville, BC
GPS location:	10 U [421,301 ; 5,455,448]
Drilling contractor:	Drillwell Enterprises Ltd.
Static water level:	0.52 m.bgl.
Safe yield:	596 m^3/d (109 USgpm)

WELL LOG

From (m.bgl)	**To** (m.bgl)		
0.0	0.6	Topsoil	
0.6	2.1	Silty sand and gravel	
2.1	5.5	Grey till with cobbles	
5.5	10.7	Brown silt with layers of till	
10.7	20.1	Brown sand with some stones	Water bearing
20.1	21.6	Bedrock conglomerate	

WELL CONSTRUCTION

From (m.bgl)	**To** (m.bgl)	
+0.52	0.00	8-in diameter stick-up
0.00	14.5	10-in diameter surface casing (removed)
14.5	15.8	Screen: 0.457 mm (0.018") slot (1.3 m / 4.3 ft) – 8-in diameter
15.8	18.9	Screen: 0.381 mm (0.015") slot (3.1 m / 10 ft) – 8-in diameter

OTHER

Surface seal:	Bentonite – (6.9 m / 22.5 ft)

APPENDIX E

Wells #9 & #12 – Water Quality

Well #9 Water Quality

North Island Laboratories
• 2755 B Moray Avenue, Courtenay, B.C. V9N 8M9 Tel: (250) 338-7786 Fax: (250) 338-7553

Certificate of Analysis

Report To:	District of Lantzville Fred Spears PO Box 100 Lantzville, BC V0R 2H0	Lab Number: Date Reported: Date Completed: Date Received:	114092 18 Sep 14 18 Sep 14 8 Sep 14 11:01

114092-01 Well #9 **Well Water**

Sampled By:

Sampling Date: 8 Sep 14 10:20

Test	Result	Units	Drinking Water Guideline
Chloride	43.2	mg/L	250 AO
Fluoride	0.06	mg/L	1.5 MAC
Nitrate (N)	0.94	mg/L	10 MAC
Nitrite (N)	<0.05	mg/L	1 MAC
Sulphate	10.9	mg/L	500 AO
Colour - True	<5	Colour Units	15
pH at 25 C	7.2	pH Units	6.5-8.5
Alkalinity	100	mg/L (CaCO3)	
Turbidity	<0.5	NTU's	5 AO
Total Dissolved Solids (conductivity ca	240	mg/L	500 AO
Total Cyanide	<0.002	mg/L	
d-Aluminium	<0.005	mg/L	
d-Antimony	<0.0002	mg/L	
d-Arsenic	<0.0002	mg/L	
d-Barium	0.008	mg/L	
d-Beryllium	<0.00004	mg/L	
d-Bismuth	<0.001	mg/L	
d-Boron	0.145	mg/L	
d-Cadmium	<0.00001	mg/L	
d-Calcium	33.2	mg/L	
d-Chromium	0.0010	mg/L	
d-Cobalt	0.00006	mg/L	
d-Copper	0.001	mg/L	
d-Iron	<0.005	mg/L	
d-Lead	0.0004	mg/L	
d-Lithium	0.002	mg/L	

AO = Aesthetic Objective; MAC = Max. Allowable Concentration; IMAC = Interim MAC
> = Greater than; < = Less than
Results relate only to samples as submitted. This certificate must not be reproduced, except in its entirety, without written consent from the laboratory.
Canadian Drinking Water Guidelines as listed on Dec. 5th, 2005 and are subject to change. Method uncertainties for specified analyses are available upon request.

9/18/2014 17:00

Page 1 of 4

North Island Laboratories

• 9755 B Moray Avenue, Courtenay, B.C. V9N 8M9 Tel: (250) 338-7786 Fax: (250) 338-7553

114092-01 Well #9 **Well Water**

Sampled By:

Sampling Date: 8 Sep 14 10:20

Test	Result	Units	Drinking Water Guideline
d-Magnesium	9.42	mg/L	
d-Manganese	0.003	mg/L	
d-Molybdenum	<0.00010	mg/L	
d-Nickel	<0.001	mg/L	
d-Potassium	0.6	mg/L	
d-Selenium	<0.0006	mg/L	
d-Silicon	10.8	mg/L	
d-Silver	<0.00001	mg/L	
d-Sodium	23.4	mg/L	
d-Strontium	0.129	mg/L	
d-Thallium	<0.00001	mg/L	
d-Tin	<0.0001	mg/L	
d-Titanium	<0.010	mg/L	
d-Uranium	<0.0004	mg/L	
d-Vanadium	0.00167	mg/L	
d-Zinc	<0.001	mg/L	
Hardness (CaCO3)	122	mg/L	
Total Coliforms (DES)	<1.0	MPN/100mL	<1
E. coli (DES)	<1.0	MPN/100mL	<1
Total Plate Count	3	CFU/ml	

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114092-01

We suggest the following Health Canada website for further information regarding the latest drinking water quality guidelines to help you assess your results:
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/doc_sup-appui/sum_guide-res_recom/index_e.html

Test	Method	Analyst	Date
Alkalinity	Titration to 4.5, APHA 2320 B -modified	NIsL	9/9/2014
Chloride	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Colour - True	Spectrophotometer, APHA 2120 C -modified	NIsL	9/11/2014
d-Aluminium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Antimony	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Arsenic	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Barium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Beryllium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Bismuth	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Boron	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Cadmium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Calcium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Chromium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Cobalt	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Copper	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Iron	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Lead	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Lithium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Magnesium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Manganese	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Molybdenum	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Nickel	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Potassium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Selenium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Silicon	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Silver	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Sodium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Strontium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Thallium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Tin	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Titanium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Uranium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Vanadium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014

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d-Zinc	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
E. coli (DES)	Enzyme Substrate, APHA 9223 B -modified	NIsL	9/8/2014
Fluoride	Ion Chromatography, EPA 300.1 -modified	NIsL	9/9/2014
Hardness (CaCO3)	Hardness by Calculation, APHA 2340 B -modified	EXL	9/12/2014
Nitrate (N)	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Nitrite (N)	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
pH at 25 C	Electrometric, APHA 4500 B -modified	NIsL	9/8/2014
Sulphate	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Total Coliforms (DES)	Enzyme Substrate, APHA 9223 B -modified	NIsL	9/8/2014
Total Cyanide	Exova Subcontract Exova Subcontract	EXL	9/15/2014
Total Dissolved Solids (conducti	Conductivity @25C, APHA 2510 A -modified	NIsL	9/9/2014
Total Plate Count	Membrane Filtration, APHA 9215 D -modified	NIsL	9/8/2014
Turbidity	Nephelometric, APHA 2130 B -modified	NIsL	9/9/2014

Approved By: Catherine Black

Catherine Black, Owner/Operator

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Well #12 – Water Quality

North Island Laboratories
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Certificate of Analysis

Report To:	District of Lantzville Fred Spears PO Box 100 Lantzville, BC V0R 2H0	Lab Number: Date Reported: Date Completed: Date Received:	114094 18 Sep 14 18 Sep 14 8 Sep 14 11:10

114094-01 Well #12 **Well Water**

Sampled By:

Sampling Date: 8 Sep 14 10:15

Test	Result	Units	Drinking Water Guideline
Chloride	21.2	mg/L	250 AO
Fluoride	<0.05	mg/L	1.5 MAC
Nitrate (N)	0.72	mg/L	10 MAC
Nitrite (N)	<0.05	mg/L	1 MAC
Sulphate	7.4	mg/L	500 AO
Colour - True	<5	Colour Units	15
pH at 25 C	6.7	pH Units	6.5-8.5
Alkalinity	50	mg/L (CaCO3)	
Turbidity	<0.5	NTU's	5 AO
Total Dissolved Solids (conductivity ca	130	mg/L	500 AO
Total Cyanide	<0.002	mg/L	
d-Antimony	<0.0002	mg/L	
d-Arsenic	<0.0002	mg/L	
d-Barium	0.008	mg/L	
d-Beryllium	<0.00004	mg/L	
d-Bismuth	<0.001	mg/L	
d-Boron	0.057	mg/L	
d-Cadmium	<0.00001	mg/L	
d-Calcium	20.8	mg/L	
d-Chromium	0.0007	mg/L	
d-Cobalt	0.00002	mg/L	
d-Copper	<0.001	mg/L	
d-Iron	<0.005	mg/L	
d-Lead	0.0004	mg/L	
d-Lithium	0.002	mg/L	
d-Magnesium	5.81	mg/L	

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114094-01 Well #12 **Well Water**
Sampled By:
Sampling Date: 8 Sep 14 10:15

Test	Result	Units	Drinking Water Guideline
d-Manganese	<0.001	mg/L	
d-Molybdenum	<0.00010	mg/L	
d-Nickel	<0.001	mg/L	
d-Potassium	0.3	mg/L	
d-Selenium	<0.0006	mg/L	
d-Silicon	11.8	mg/L	
d-Silver	<0.00001	mg/L	
d-Sodium	7.6	mg/L	
d-Strontium	0.064	mg/L	
d-Thallium	<0.00001	mg/L	
d-Tin	<0.0001	mg/L	
d-Titanium	<0.010	mg/L	
d-Uranium	<0.0004	mg/L	
d-Vanadium	0.00141	mg/L	
d-Zinc	0.002	mg/L	
Hardness (CaCO3)	76	mg/L	
Total Coliforms (DES)	<1.0	MPN/100mL	<1
E. coli (DES)	<1.0	MPN/100mL	<1
Total Plate Count	<3	CFU/ml	

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114094-01

Test	Method	Analyst	Date
Alkalinity	Titration to 4.5, APHA 2320 B -modified	NIsL	9/9/2014
Chloride	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Colour - True	Spectrophotometer, APHA 2120 C -modified	NIsL	9/11/2014
d-Antimony	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Arsenic	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Barium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Beryllium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Bismuth	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Boron	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Cadmium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Calcium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Chromium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Cobalt	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Copper	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Iron	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Lead	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Lithium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Magnesium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Manganese	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Molybdenum	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Nickel	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Potassium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Selenium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Silicon	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Silver	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Sodium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Strontium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Thallium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Tin	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Titanium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Uranium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Vanadium	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
d-Zinc	Exova Subcontract, ICP-AES, EPA 6010C -modified	EXL	9/12/2014
E. coli (DES)	Enzyme Substrate, APHA 9223 B -modified	NIsL	9/8/2014
Fluoride	Ion Chromatography, EPA 300.1 -modified	NIsL	9/9/2014

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Hardness (CaCO3)	Hardness by Calculation, APHA 2340 B -modified	EXL	9/12/2014
Nitrate (N)	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Nitrite (N)	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
pH at 25 C	Electrometric, APHA 4500 B -modified	NIsL	9/8/2014
Sulphate	Ion Chromatography, EPA 300.1 -modified	NIsL	9/10/2014
Total Coliforms (DES)	Enzyme Substrate, APHA 9223 B -modified	NIsL	9/8/2014
Total Cyanide	Exova Subcontract Exova Subcontract	EXL	9/15/2014
Total Dissolved Solids (conducti	Conductivity @25C, APHA 2510 A -modified	NIsL	9/9/2014
Total Plate Count	Membrane Filtration, APHA 9215 D -modified	NIsL	9/8/2014
Turbidity	Nephelometric, APHA 2130 B -modified	NIsL	9/9/2014

Approved By: Catherine Black

Catherine Black, Owner/Operator

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Appendix C

District of Lantzville
Harby Road Wellfield, Estimation of Well Efficiencies
March 31, 2015 Lowen Hydrogeology Consulting Ltd.

District of Lantzville, BC

Harby Road Well Field

Estimation of Well Efficiencies

REPORT

Date: March 31, 2015
LHC Project File: 1501

LHC Lowen Hydrogeology Consulting Ltd.
PO Box 45024 Victoria, B.C. V9A-0C3 Phone: 250 -595-0624 Fax: 1-855 -286-8001 Website: www.lowenhc.ca

SUMMARY

Four pumping tests have been carried out on the District of Lantzville's production wells #4, 6, 9 and 12. The tests were performed to better assess well performance and efficiency. The test results were also compared to historical test data to determine if performance / efficiency is stable or diminished. Estimated well efficiencies for the four wells range from 28 to 73%. Specific capacities have also diminished in wells #6 and #9 significantly. All of the wells could benefit from re-developing work and this is recommended for wells #4, 9 and 12. A new well should be constructed at the Well LID #6 site as the existing well is inefficient plus historical records indicate the pumping rate was reduced at this well due to sand pumping. Well #6 has a design or construction fault that precludes maximum production at this site.

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LIST OF TABLES

Estimation of the Well Efficiencies

1.0 INTRODUCTION

The subject well field is located at 7300 Harby Road W. in Lantzville, B.C. The District of Lantzville currently relies on 4 active wells (Wells #4, #6, #9 & #12) to supply the district. A re-assessment of the combined well capacities was undertaken in July/August 2014 and a Well Field Management Plan was produced by Lowen Hydrogeology Consulting Ltd. (LHC). The combined capacity of the 4 wells pumping simultaneously was estimated at 2,424 m^3/d or 28.0 L/s.

LHC also provided some recommendations to optimize and potentially increase the well efficiencies and production. This report constitutes the second phase of the Well Field Management Plan by focusing on the well efficiencies. An additional round of pumping was undertaken to assess well efficiencies. The testing was designed to determine aquifer characteristics (mainly Transmissivity) and then to determine the theoretical yields from 100% efficient wells in the subject aquifer. Comparing the theoretical yields to actual yields provides an indication of well efficiency. The results will allow the well field management team to prepare and prioritize a scope of actions to enhance the capacity of the active wells by well development work designed to maximize efficiency.

2.0 SUBJECT WELLS

The 4 subject wells are Wells #4, #6, #9 and #12. Their main characteristics are summarized in Table 2. Wells #4, #6 and #12 are located close to each other within the boundaries of the Harby Road well field. Well #9 is more remote and usually does not interfere with any well in the Harby Road well field. A well field plan showing well locations is provided in Appendix A. The 4 subject wells were used successively as observation wells.

Table 1 - Distance between pumping and observation wells

	PUMPING WELL #4		
	Well #12	Well #6	Well #9
Distance to PW (m.)	78	147	242

	PUMPING WELL #6		
	Well #12	Well #4	Well #9
Distance to PW (m.)	69	147	386

	PUMPING WELL #9		
	Well #4	Well #12	Well #6
Distance to PW (m.)	242	318	386

	PUMPING WELL #12		
	Well #6	Well #4	Well #9
Distance to PW (m.)	69	78	318

Table 2 - Pumped Well Characteristics

Well	Well Diameter	Static Water Level[2]	Long-term Capacity[1] Single Pumping Simult. Pumping		Aquifer Location & Thickness	Screen Location & Length	% of Aquifer Screened	Aquifer Formation	Formation Overlying the Aquifer	Formation Underlying the Aquifer
			Single	Simult.						
#	[in]	[m.bgl.]	L/s		[m.bgl.] / [m]	[m.bgl.] / [m]	%			
#4	8	1.12	11.8	10.4	[14.9 – 21.3] 6.4	[15.8 – 21.3] 5.5	86	Fine to coarse sand and fine gravel	Glacial till	Glacial till
#6	8	+0.49	9.7	7.7	[14.6 – 16.8] 2.2	[14.6 – 16.2] 1.6	73	Sand and fine gravel to silty brown sand	Silty gravelly till	N/A
#9	8	3.31	4.1	3.3	[5.8 – 23.8] 18.0	[17.3 – 23.4] 6.1	34	Coarse sand and gravel to fine sand	Till	Bedrock
#12	8	0.52	8.3	6.6	[10.7 – 20.1] 9.4	[14.5 – 18.9] 4.4	47	Brown sand with some stones	Brown silt with layers of silt	Bedrock

[1] cf. Well Field Management Plan, (August 2014) - Lowen Hydrogeology Consulting Ltd., Long-term capacity = Rated Well Capacity.
[2] When drilled

3.0 PUMPING TESTS

The 4 subject wells were pumped in February 2015 according to the schedule displayed in Table 3. The goal of these pump tests was to catch early pump test data, until the drawdown was almost stabilized. Water level data were recorded at a sampling interval of 10 seconds for a period of 3 hours. Drawdown and recovery graphs are displayed in Appendix D.

Table 3 - Pumping Schedule

Date	Well	Pumping Rate	Start Time	End Time
dd/mm/yyyy	#	L/s		
16/02/2015	Well #4	8.98	10:40 am	1:40 pm
17/02/2015	Well #6	6.39	9:26 am	12:26 pm
18/02/2015	Well #12	7.59	11:23 am	2:23 pm
20/02/2015	Well #9	2.22	11:06 am	2:06 pm

4.0 DERIVATIVE ANALYSIS

4.1 Methods

The derivative analysis is employed to interpret the flow regimes in a pumping test and *facilitate the identification of an appropriate conceptual model* (Renard et al., 2008) to best estimate the aquifer parameters. The log derivative enhances the subtle variations otherwise difficult to detect on the regular drawdown vs. time curve.

The standard derivative often produces noise that makes the data interpretation challenging, especially at larger values of time (t). Smoothing methods can be applied to filter the noise and extract useful information. The Bourdet derivative method is used in this report; both derivative methods are as follows:

$$\text{Derivative}_{\text{Standard}} = \delta s / \delta \ln t$$

$$\text{Derivative}_{\text{Bourdet}} = (\delta s_1 * \delta \ln t_2 / \delta \ln t_1 + \delta s_2 * \delta \ln t_1 / \delta \ln t_2) / (\delta \ln t_1 + \delta \ln t_2)$$

With δt_1 and δt_2 regularly spaced on a log scale. Greater δ values can lead to over smoothing, therefore the loss of information.

4.2 Flow Regimes Identification

The use of a catalog of derivative plots allows comparison between the field data and the plots of typical flow regimes. Drawdown graphs from all the subject wells display the behaviour of a leaky aquifer. A leaky or semi-confined aquifer occurs when the aquifer's upper and/or lower boundaries are aquitards, with water flowing downwards and/or upwards through the aquitard(s) to the aquifer (Kruseman and De Ridder, 1991). A "leaky" aquifer is one that receives recharge water from overlying or underlying geologic units that have lower permeability(ies) than the aquifer. The low permeability layers are called aquitards.

Some wells in the Harby Road well field show that the aquifer lies directly over the bedrock (Wells #9 & #12). It is believed that the pumping mobilized groundwater from the bedrock, flowing upwards into the sand and gravel aquifer. This assumption is also backed up by the observed evolution of the groundwater chemistry over time, with the increase of chemical elements typical of older and/or deeper groundwater type.

5.0 ESTIMATION OF THE AQUIFER PARAMETERS

5.1 Determination from the Walton Method

The Walton Method is used to determine the parameters of a leaky aquifer, with pumping test data from the pumped well and observation wells under transient-flow mode. The leakage parameter (L) is a function of the hydraulic conductivity (permeability) and thickness of the aquitard layer. The Walton method is being used here as it provides the most accurate estimate of the aquifer transmissivity (T). Using this calculated T we can calculate theoretical well capacities for 100% efficient wells. Comparing the theoretical to actual (measured) capacities we can determine well efficiencies. Table 4 is a summary of the calculated parameters. Details and graphs are given in Appendix C.

Table 4 - Aquifer Parameters from the Walton Method

	PW: Well #4	OW: Well #12	OW: Well #6
Pumping rate, Q [m^3/d]	776	776	776
Aquifer thickness, b [m]	6.4	9.4	2.2
Distance from pumping well, r [m]	0	78	147
r/L	0.025	0.7	0.5
[x_{exp} ; y_{exp}] *[x_{th} = 100 ; y_{th} = 0.1]*	[0.59 ; 0.12]	[1350 ; 0.07]	[1020 ; 0.038]
Transmissivity, T [m^2/d]	**51.5**	**88.2**	**162.5**
Specific Storage, S [-]	**N/A**	**0.783**	**0.307**
Hydraulic Conductivity, K [m/d]	**8.0**	**9.4**	**73.9**
Leakage Factor, L (dimensionless)	**N/A**	**111.4**	**294.0**

Table 4 Continued

	PW: Well #6	OW: Well #12	OW: Well #4
Pumping rate, Q [m³/d]	552	552	552
Aquifer thickness, b [m]	2.2	9.4	6.4
Distance from pumping well, r [m]	0	69	147
r/L	0.85	0.3	0.7
[x_{exp} ; y_{exp}] [x_{th} = 100 ; y_{th} = 0.1]	[9.6 ; 1.05]	[320 ; 0.0175]	
Transmissivity, T [m²/d]	**N/A**	**251.0**	**162.7**
Specific Storage, S [-]	**N/A**	**0.675**	**0.295**
Hydraulic Conductivity, K [m/d]	**N/A**	**26.7**	**25.4**
Leakage Factor, L	**N/A**	**230.0**	**210.0**

	PW: Well #12	OW: Well #6	OW: Well #4
Pumping rate, Q [m³/d]	656	656	656
Aquifer thickness, b [m]	9.4	2.2	6.4
Distance from pumping well, r [m]	0	69	78
r/L	0.85	0.3	0.3
[x_{exp} ; y_{exp}] [x_{th} = 100 ; y_{th} = 0.1]	[20 ; 0.7]	[160 ; 0.028]	[470 ; 0.031]
Transmissivity, T [m²/d]	**N/A**	**186.4**	**168.4**
Specific Storage, S [-]	**N/A**	**0.25**	**0.52**
Hydraulic Conductivity, K [m/d]	**N/A**	**84.7**	**26.3**
Leakage Factor, L	**N/A**	**230.0**	**260.0**

Note: Well #9 could not be analysed by this method as it is too distant from the observation wells.

5.2 Application of the De Glee Method

The De Glee Method can be applied from the observation wells when the drawdown has reached a stationary state under a constant pumping rate. Under this mode, the drawdown as a function of time during the pumping remains constant. The stabilized drawdowns at the observation wells as a function of the distance from the pumped well can be fitted to the De Glee curve in order to determine the aquifer parameters.

Table 5 - Aquifer Parameters from the De Glee Method

	PW: Well #4	
Pumping rate, Q [m³/d]	776	
Aquifer thickness, b [m]	6.4	
[x_{exp} ; y_{exp}] [x_{th} = 0.0001; y_{th} = 0.01]	[0.045 ; 0.0046]	
	Distance from pumped well [m]	**Stabilized drawdown** [m]
Well #12	78	0.88
Well #6	147	0.62
	Aquifer Parameters from the DE GLEE Method	
Transmissivity, T [m²/d]	**268.5**	
Leakage Factor, L	**450.0**	

Note: The De Glee Method only gave reasonable results for the Well #4 dataset likely due to fact that the aquifer does not meet all the assumptions in the De Glee methodology.

5.3 Parameters Analysis

The pumping test analysis and well responses display two distinct types of behaviours: leakage through the aquitard(s) and lateral recharge. Table 6 summarizes these data.

The leakage factors calculated in the range of 111 to 450 m. are in reasonable agreement and indicates significant recharge to the Harby Road Aquifer which is a positive aspect with regard to the sustainable capacity of Lantzville wells.

The aquifer transmissivities calculated from the Walton and De Glee analyses are provided in Table 7.

The field observations noted that no major precipitation events had occurred prior and during the tests. Hypothesis regarding the origins of the recharge may include the presence of a channel with preferential flow direction towards the wells, the underlying bedrock feeding the sand and gravel aquifer, further connexion to a stream flowing over a non-confined portion of the aquifer, etc.

Table 6 - Leakage Factors and Lateral Recharge

		Walton Method Leakage (L)				De Glee Method Leakage (L)	Recovery Method Recharge	Field observations
		OBSERVATION WELL						
		Well #4	Well #6	Well #9	Well #12		x-axis cross	
PUMPING WELL	Well #4	-	294.0	N/A	111.4	450.0	3.4	Clear, no rain in the past 72h
	Well #6	210.0	-	N/A	230.0	N/A	5.2	Clear, no rain in the past 24h
	Well #9	N/A	N/A	-	N/A	N/A	2.0	Clear, <1mm of rain in the past 24h
	Well #12	260.0	230.0	N/A	-	N/A	N/A	Clear, no rain in the past 24h

Table 7 - Summary of Calculated Transmissivities

		Walton Method (m^2/d)				De Glee Method (m^2/d)
		OBSERVATION WELL				
		Well #4	Well #6	Well #9	Well #12	
PUMPING WELL	Well #4	N/A	162.5	N/A	88.2	268.5
	Well #6	162.7	N/A	N/A	251.0	N/A
	Well #9	N/A	N/A	**195**	N/A	N/A
	Well #12	168.4	186.4	N/A	N/A	N/A

5.4 Discussion on Well Efficiencies

The standard method to determine a well efficiency is to project a theoretical drawdown at the pumped well from the observation well drawdown data on a logarithmic scale. This theoretical value is compared to the actual drawdown, usually greater. A highly efficient well will display a small difference between the theoretical and actual drawdown.

In the case of lateral recharge occurring, inaccuracies are introduced into the drawdown values. These inaccuracies are acute with the distance from the pumped well; therefore, the drawdown recorded at the observation wells may be under-estimated, resulting in an under-estimated theoretical drawdown. This leads to results displaying very low well efficiencies, while it may not actually be the case.

Using this standard method, the efficiencies for Well #4 and Well #6 are respectively 38% and 12%. These results appear to be too low.

6.0 STUDY OF THE SPECIFIC CAPACITY

6.1 Evolution of Specific Capacity

The evolution of the specific capacity from the several tests performed on the wells may provide an idea of the evolution of the well efficiencies. A significant decrease of the specific capacity would reflect a decrease of the well efficiency.

Well #6 and Well #9 showed such a decrease as shown in Table 8 below. This may be an indication that these wells need to be re-development.

Table 8 - Evolution of the Specific Capacities at Wells #4, 6, 9 and 12

WELL ID.	DATE DRILLED	ORIGINAL SPECIFIC CAPACITY*	SPECIFIC CAPACITY (2015)
No.	m / y	L/s/m	L/s/m
LID #4	09/79	0.80	0.815
LID #6	04/83	1.30	0.52
LID #9	10/86	0.50	0.42
LID #12	10/90	0.80	0.80

* *Specific Capacity is defined as the well flow rate divided by the well water level drawdown.*
Units used here are Liters per second per meter of drawdown.
Drawdown is the extrapolated to 100 days drawdown which is used for the long-term yield calculation

6.2 Comparison of Actual and Theoretical Specific Capacity and Well Efficiency

A table of theoretical specific capacities for a 100% efficient well is provided by F. G. Driscoll (1986) - Groundwater and Wells [Appendix 22.A]. An estimate of the well efficiency can be made by comparing the theoretical specific capacity from this table with the actual specific capacity, for given values of time, well diameter and transmissivity. Results are summarized in Table 9.

Table 9 - Well Efficiencies from Specific Capacity Method

	Well #4	Well #6	Well #9	Well #12
Pumping rate, Q [L/s]	8.98	6.39	2.22	7.59
Transmissivity*, T [m^2/d]	125.4	206.9	195	177.4
Time, t [day]	1	1	1	1
Drawdown at t, s(t) [m]	9.15	11.15	4.74	7.24
Well diameter [mm]	203.2	203.2	203.2	203.2
Aquifer type	Semi-confined	Semi-confined	Semi-confined	Semi-confined
Theoretical specific capacity [L/s/m]	1.35	1.76	1.6	1.86
Actual specific capacity [L/s/m]	0.98	0.57	0.44	1.05
Well efficiency	**73%**	**33%**	**28%**	**56%**

** The transmissivity is the average of the transmissivities reported in Table 7 from the observation wells. Well #9 T is estimated from the observed specific capacity*

7.0 CONCLUSIONS

7.1 Optimizing well efficiency will benefit the District of Lantzville in two ways:

1) Reduce electrical energy usage and operating cost for pumping water.
2) Maximize the yield potential from the existing wells.

7.2 Wells can be inefficient because of design flaws and due to deposition of fine grained material (usually silt) around the well screens. Other less common causes do occur such as bio-fouling.

7.3 Transmissivity values in the Harby Road Aquifer generally range between 50 and 250 m^2/d. Globally or world-wide aquifer transmissivities range between 12.4 to 12,400 m^2/d. For wells to be suitable for municipal water supply transmissivity values greater than 124 m^2/d are generally required.

7.4 Well efficiencies for the four production wells range from 28% to 73%. At these efficiency levels all the wells are due for re-development work. Well efficiencies close to 90% are achievable and desirable. Re-development may significantly increase well capacities, up to doubling capacities in the least efficient wells.

7.5 Wells #6 and #9 show a significant decrease in specific capacity since they were drilled and also have the lower efficiency estimates; 33% and 28% respectively.

7.6 Well LID #6 geology log indicates an aquifer thickness of only 2.2 m. but pumping analysis indicates a higher transmissivity at LID #6 compared with the other wells. All other wells indicate aquifer thickness of 6 to 10 m. We conclude that the well LID #6 may not penetrate the full aquifer thickness. If this is correct a deeper well with longer screen length could be installed to increase water supply capacity at this site. Also the pumping rate at this well was reduced because it produced sand at the higher rate. Considering this and the poor efficiency Well #6 should be replaced.

8.0 RECOMMENDATIONS

8.1 Re-development work is recommended for three of the district's active wells; LID's #4, 9 and LID #12. A program of surging and pumping using a cable tool drilling machine is recommended for re-development. Also a new well should be drilled at the site of well #6.

8.2 The order of priority for the recommended work is as follows:

1) Re-drill LID #6
2) Re-developing LID #9
3) Re-developing LID #12
4) Re-developing LID #4

The estimated cost for re-developing is #15,000.00 to $20,000.00 per well plus $3,500.00 per well for engineering and supervision.

8.3 Re-drilling at well LID #6 is also recommended. Drilling a new well will cost an estimated $30,000.00 for the drilling contractor and $8,500.00 for design and engineering. Drilling programs such as this should also have a 20% budget allowance for contingencies.

CLOSURE / DISCLAIMER

This report has been prepared in accordance with generally accepted groundwater engineering practices. The opinions expressed herein are considered valid at the time of writing. Changes in site conditions can occur, however, whether due to natural events or to human activities on these, or adjacent properties. In addition, changes in regulations and standards may occur, whether they result from legislation or the broadening of knowledge. This report is therefore subject to review and revision as changed conditions are identified.

Well yields and water quality can vary over time due to climate change, recharge area modification, or earth movements (earthquakes and blasting). Water quality standards also evolve over time and future revisions of the standards may necessitate changes to the recommendations for water treatment or testing.

In formulating our analyses, conclusions and recommendations we have relied on information supplied by others; well drilling contractors, pumping test contractors and a certified water testing laboratory. The information provided by others is believed to be accurate but cannot be guaranteed. If the recommendations in this report are not implemented, we assume no responsibility for any adverse consequences that may result.

If you have any questions or require any further information, please contact the undersigned.

Respectfully Submitted,

LOWEN HYDROGEOLOGY CONSULTING LTD.

PROFESSIONAL GEOSCIENTIST PROVINCE OF BRITISH COLUMBIA D. A. LOWEN

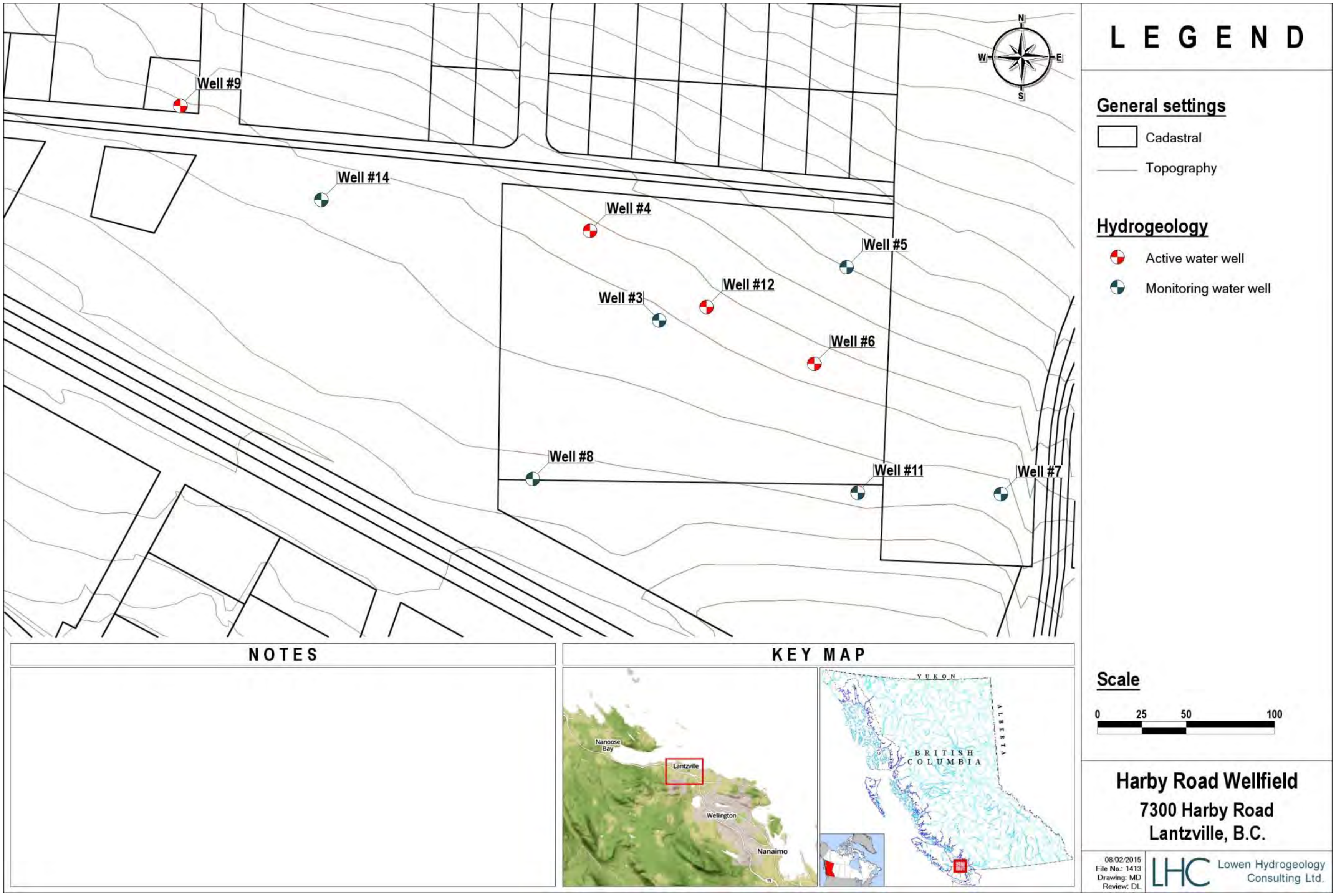
PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA D. A. LOWEN

Dennis Lowen

Dennis A. Lowen, P. Eng., P. Geo.
DL/MD/hr

Appendix A

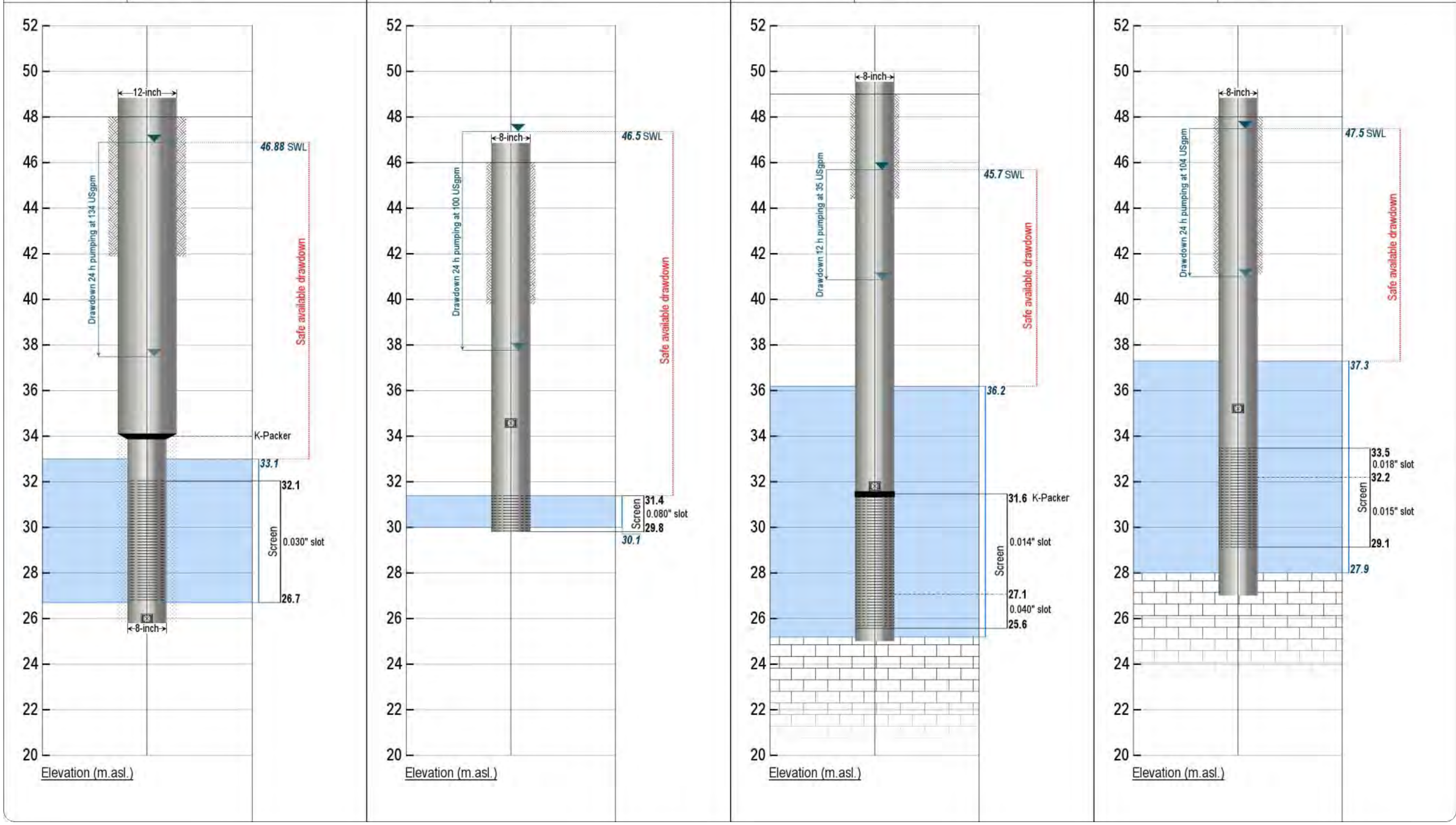
Well Field Plan and Well Locations


Well #9
Well #14
Well #4
Well #5
Well #12
Well #3
Well #6
Well #8
Well #11
Well #7
N
S
W
E
LEGEND
General settings
Cadastral
Topography
Hydrogeology
Active water well
Monitoring water well
Scale
0 25 50 100
NOTES
KEY MAP
Nanoose Bay
Lantzville
Wellington
Nanaimo
YUKON
ALBERTA
BRITISH COLUMBIA
Harby Road Wellfield
7300 Harby Road
Lantzville, B.C.
08/02/2015
File No.: 1413
Drawing: MD
Review: DL
LHC Lowen Hydrogeology Consulting Ltd.

Appendix B

Well Log Record

Well LID Name:	WELL #4	Well LID Name:	WELL #6	Well LID Name:	WELL #9	Well LID Name:	WELL #12
Well ID. Plate No.:	13311	Well ID. Plate No.:	13309	Well ID. Plate No.:	13312	Well ID. Plate No.:	13310
Static Water Level:	1.12 m	Static Water Level:	-0.49 m	Static Water Level:	3.31 m	Static Water Level:	0.52 m
Yield:	197 USgpm	Yield:	83 USgpm	Yield:	65 USgpm	Yield:	109 USgpm

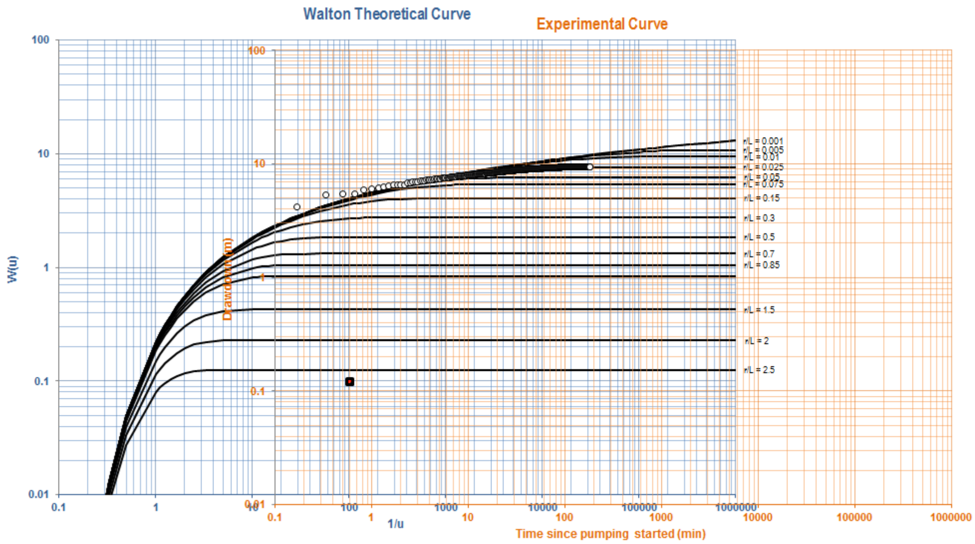


Appendix C

Estimation of the Aquifer Parameters

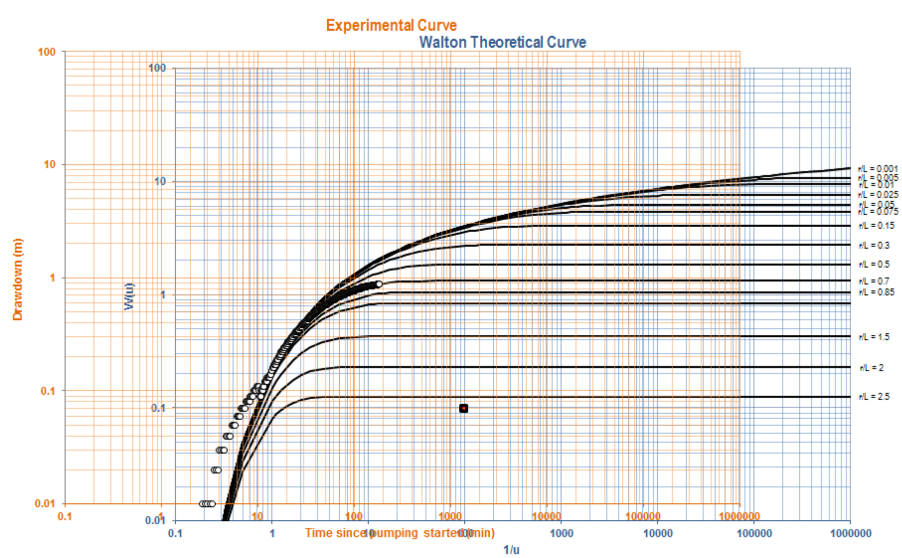
PUMPING WELL #4

Pumping Test Data at Pumped Well #4



Pumping rate, Q [m³/d]	776	**r/L**	0.025
Aquifer thickness, b [m]	6.4	**Transmissivity, T** [m²/d]	51.5
Distance from pumped well, r [m]	0	**Specific storage, S** [-]	-
[x_{exp} ; y_{exp}]	[0.59 ; 0.12]	**Hydraulic conductivity, K** [m/d]	8.0
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	-

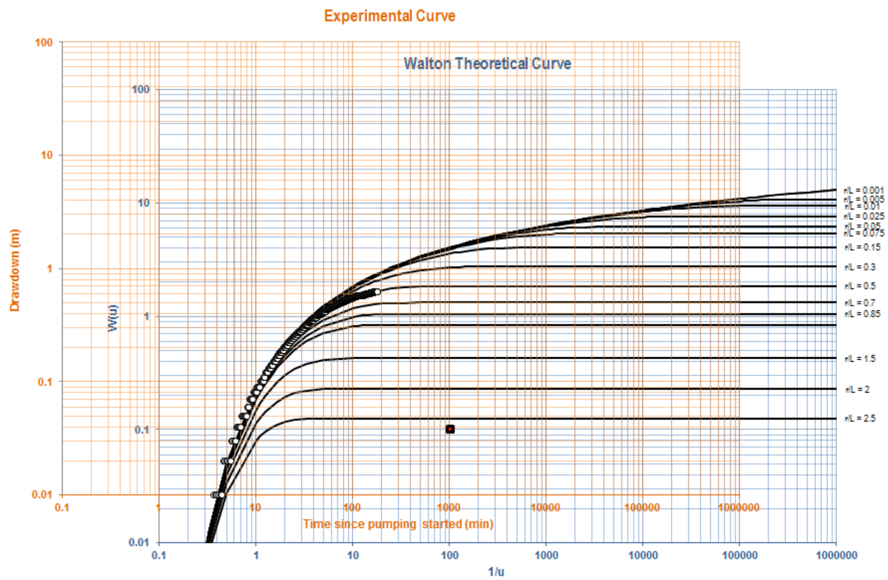
Pumping Test Data at Observation Well #12



Pumping rate, Q [m³/d]	776	**r/L**	0.7
Aquifer thickness, b [m]	9.4	**Transmissivity, T** [m²/d]	88.2
Distance from pumped well, r [m]	78	**Specific storage, S** [-]	0.783
[x_{exp} ; y_{exp}]	[1350 ; 0.07]	**Hydraulic conductivity, K** [m/d]	9.7
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	111.4

PUMPING WELL #4 - *Continued*

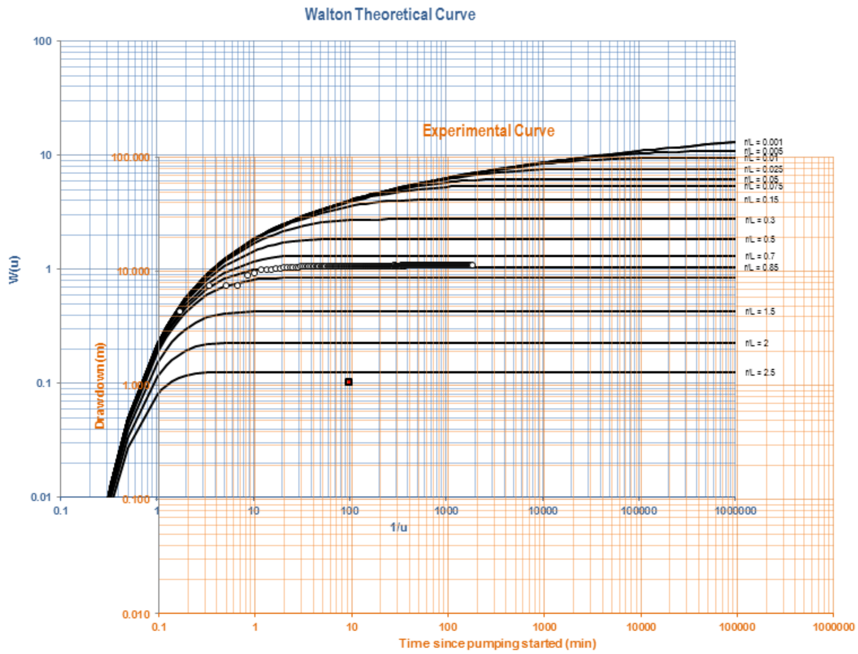
Pumping Test Data at Observation Well #6



Pumping rate, Q [m^3/d]	776	**r/L**	0.5
Aquifer thickness, b [m]	2.2	**Transmissivity, T** [m^2/d]	162.5
Distance from pumped well, r [m]	147	**Specific storage, S** [-]	0.307
[x_{exp} ; y_{exp}]	[1020 ; 0.038]	**Hydraulic conductivity, K** [m/d]	73.9
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	294.0

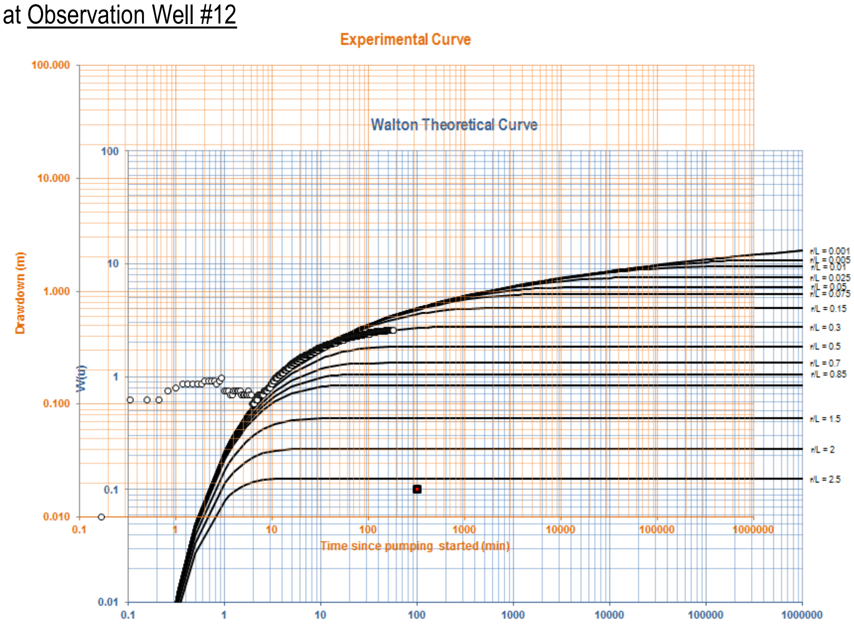
PUMPING WELL #6			

Pumping Test Data at Pumped Well #6



Pumping rate, Q [m³/d]	552	**r/L**	0.85
Aquifer thickness, b [m]	2.2	**Transmissivity, T** [m²/d]	4.2
Distance from pumped well, r [m]	0	**Specific storage, S** [-]	-
[x_{exp} ; y_{exp}]	[9.6 ; 1.05]	**Hydraulic conductivity, K** [m/d]	1.9
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	-

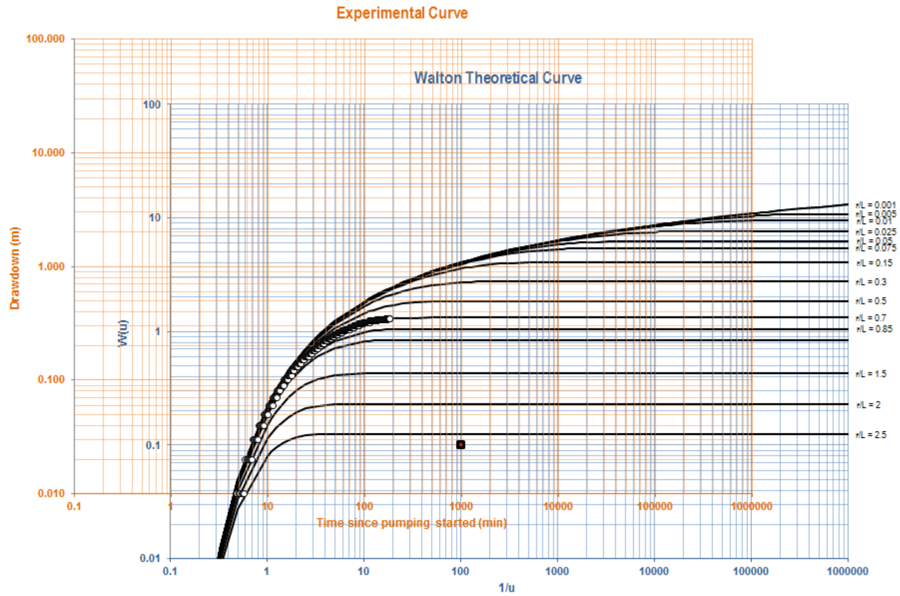
Pumping Test Data at Observation Well #12



Pumping rate, Q [m³/d]	552	**r/L**	0.3
Aquifer thickness, b [m]	9.4	**Transmissivity, T** [m²/d]	251
Distance from pumped well, r [m]	69	**Specific storage, S** [-]	0.675
[x_{exp} ; y_{exp}]	[320 ; 0.0175]	**Hydraulic conductivity, K** [m/d]	26.7
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	230.0

PUMPING WELL #6 - *Continued*

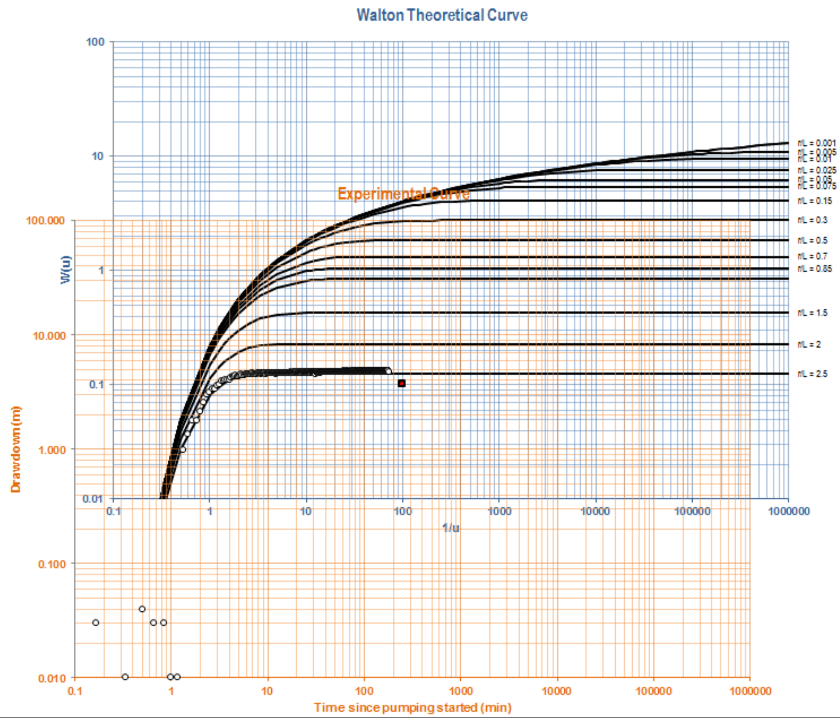
Pumping Test Data at Observation Well #4



Pumping rate, Q [m^3/d]	552	**r/L**	0.7
Aquifer thickness, b [m]	6.4	**Transmissivity, T** [m^2/d]	162.7
Distance from pumped well, r [m]	147	**Specific storage, S** [-]	0.295
[x_{exp} ; y_{exp}]	[980 ; 0.027]	**Hydraulic conductivity, K** [m/d]	25.4
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	210.0

PUMPING WELL #9

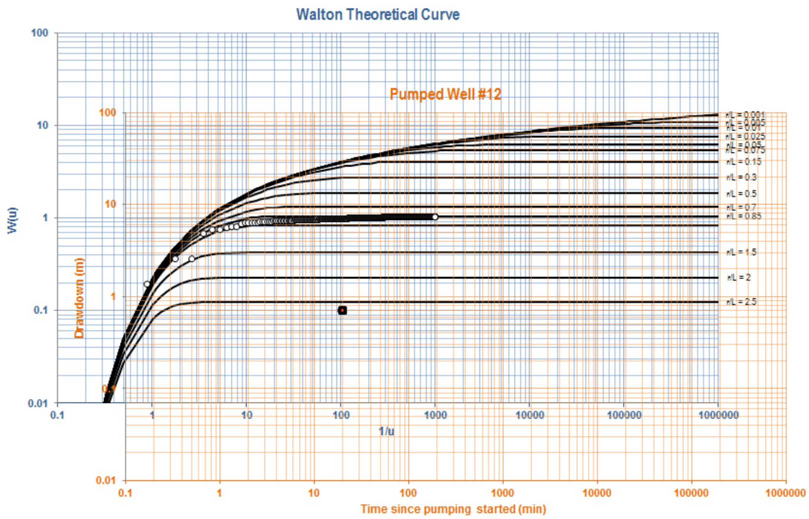
Pumping Test Data at Pumped Well #9



Pumping rate, Q [m³/d]	192	**r/L**	2.5
Aquifer thickness, b [m]	18.0	**Transmissivity, T** [m²/d]	0.4
Distance from pumped well, r [m]	0	**Specific storage, S** [-]	-
[x_{exp} ; y_{exp}]	[250 ; 3.7]	**Hydraulic conductivity, K** [m/d]	0.023
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	-

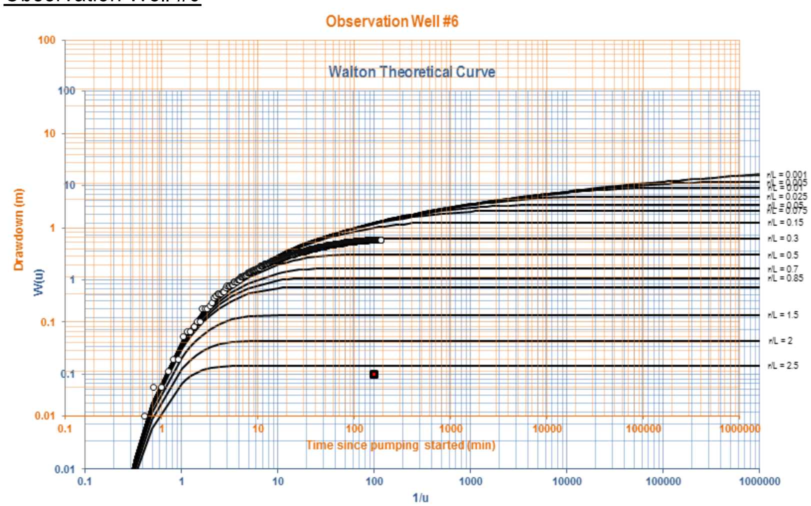
PUMPING WELL # 12

Pumping Test Data at Pumped Well #12



Pumping rate, Q [m^3/d]	656	**r/L**	0.85
Aquifer thickness, b [m]	9.4	**Transmissivity, T** [m^2/d]	7.5
Distance from pumped well, r [m]	-	**Specific storage, S** [-]	-
[x_{exp} ; y_{exp}]	[20 ; 0.7]	**Hydraulic conductivity, K** [m/d]	0.8
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	-

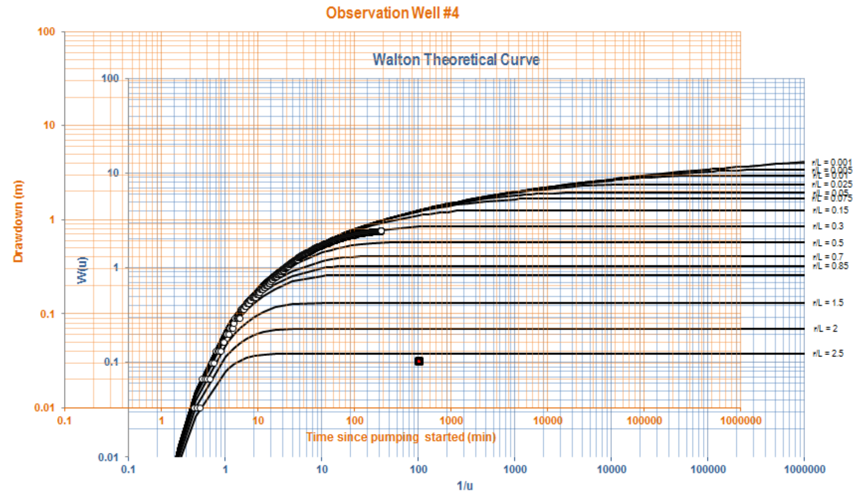
Pumping Test Data at Observation Well #6



Pumping rate, Q [m^3/d]	656	**r/L**	0.3
Aquifer thickness, b [m]	2.2	**Transmissivity, T** [m^2/d]	186.4
Distance from pumped well, r [m]	69	**Specific storage, S** [-]	0.25
[x_{exp} ; y_{exp}]	[160 ; 0.028]	**Hydraulic conductivity, K** [m/d]	84.7
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	230.0

P U M P I N G   W E L L   # 1 2 - *Continued*

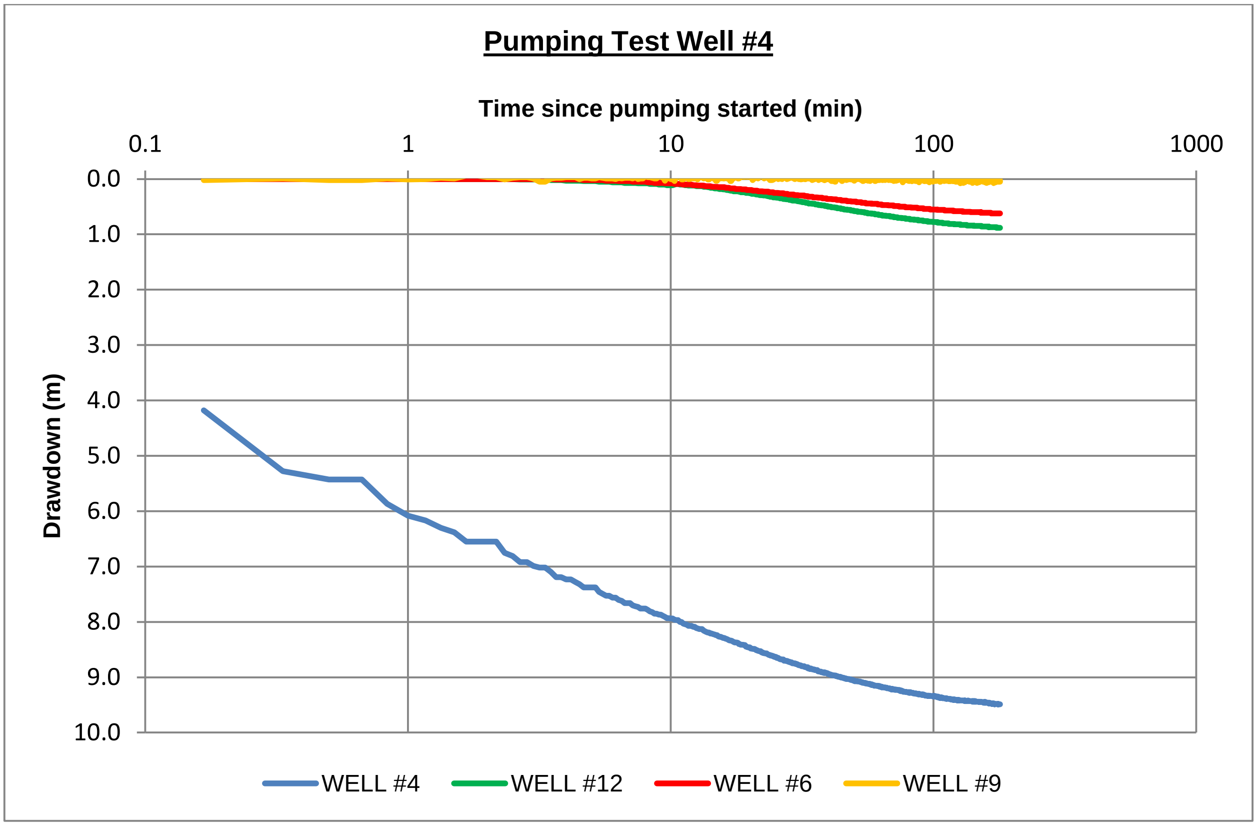
Pumping Test Data at Observation Well #4

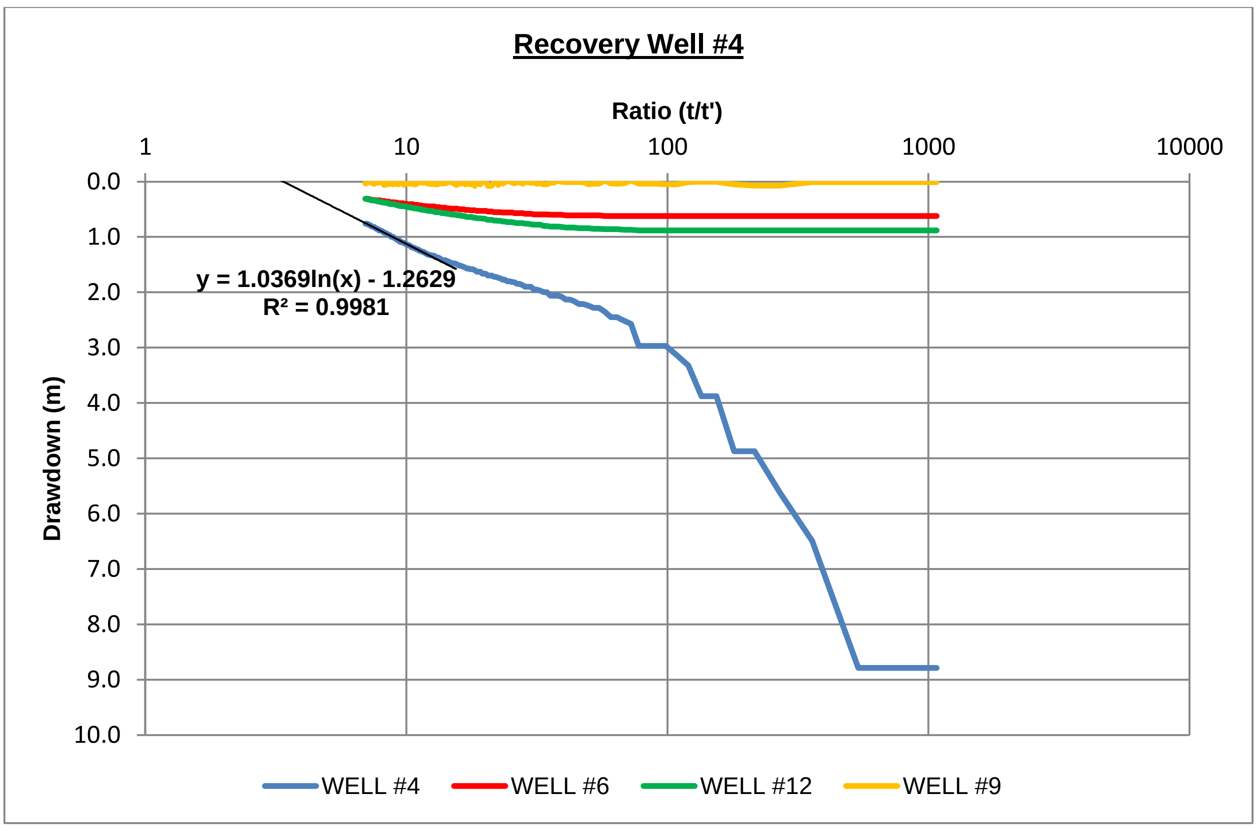


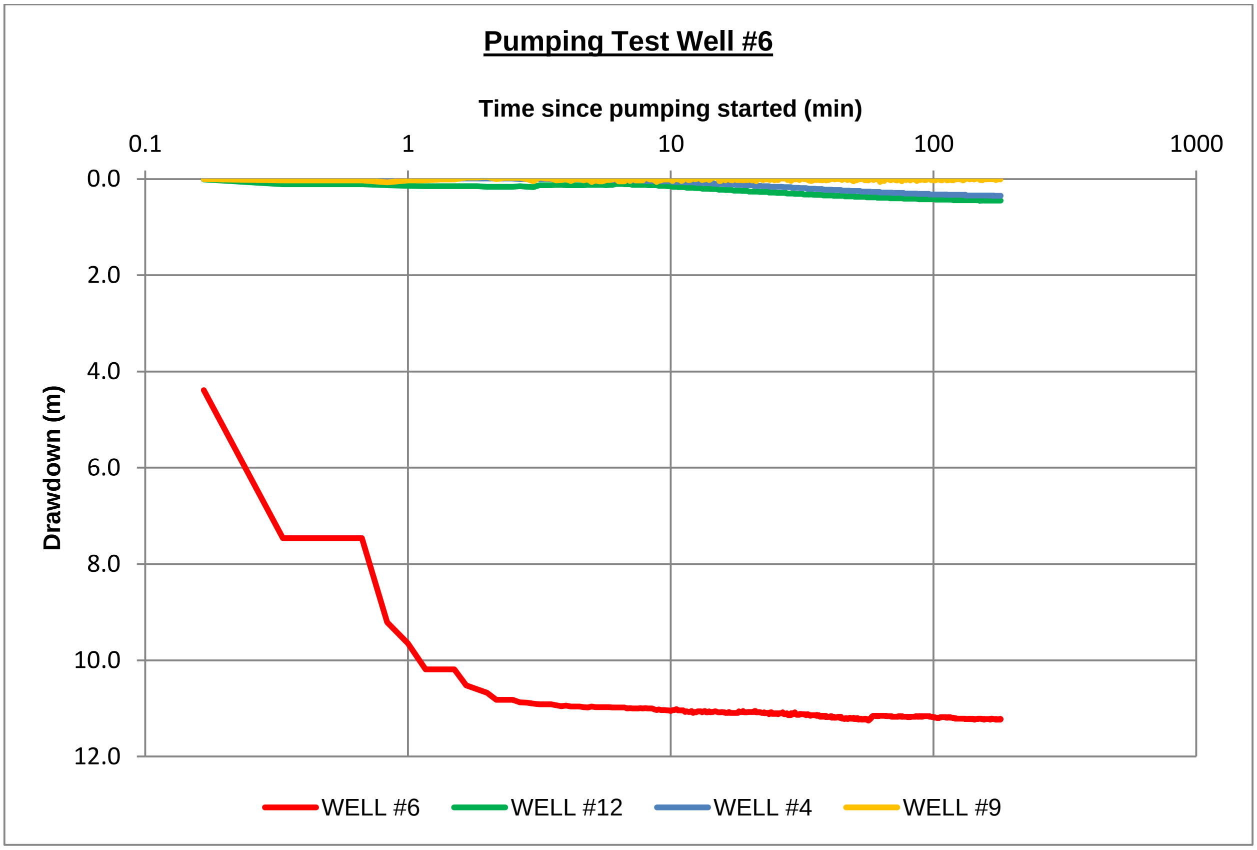
Pumping rate, Q [m^3/d]	656	**r/L**	0.3
Aquifer thickness, b [m]	6.4	**Transmissivity, T** [m^2/d]	168.4
Distance from pumped well, r [m]	78	**Specific storage, S** [-]	0.52
[x_{exp} ; y_{exp}]	[470 ; 0.031]	**Hydraulic conductivity, K** [m/d]	26.3
[x_{th} ; y_{th}]	[100 ; 0.1]	**Leakage factor, L** [m]	260.0

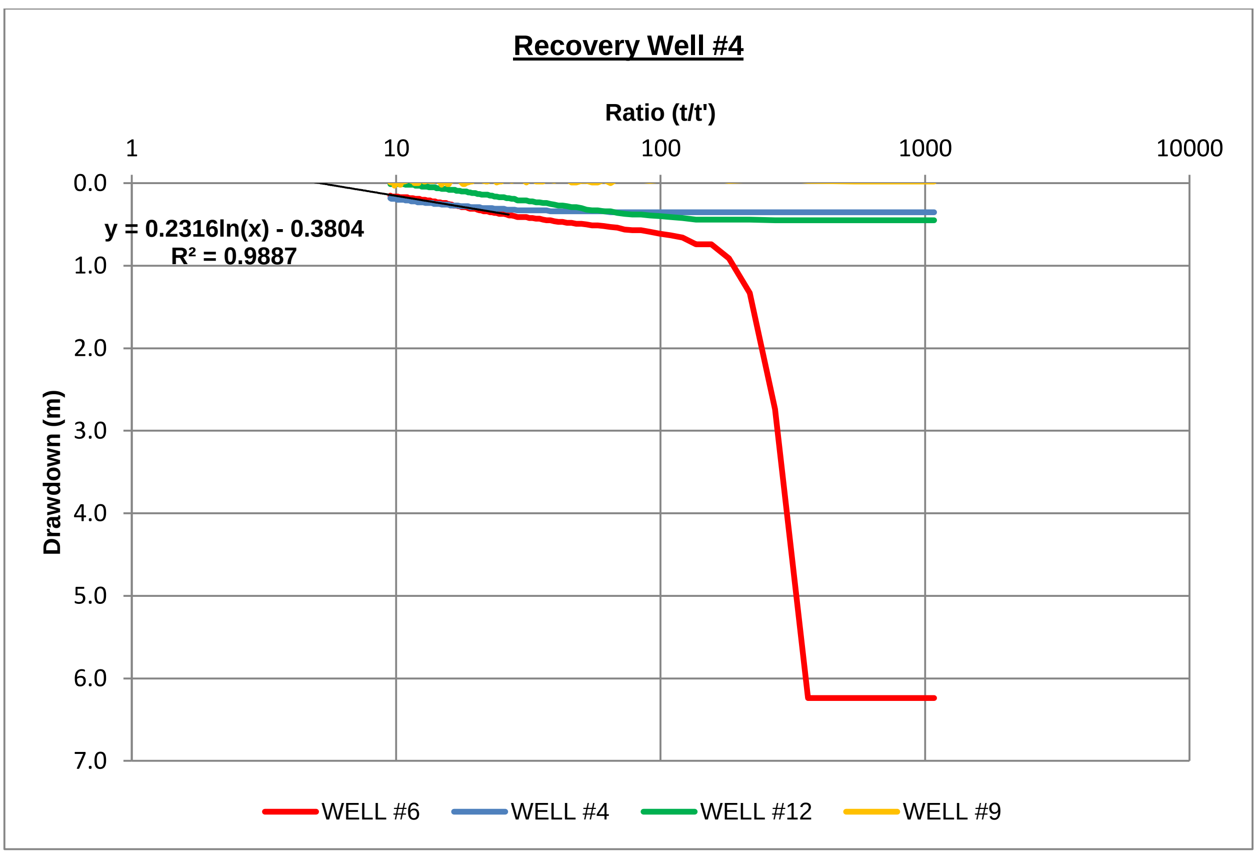
Appendix D

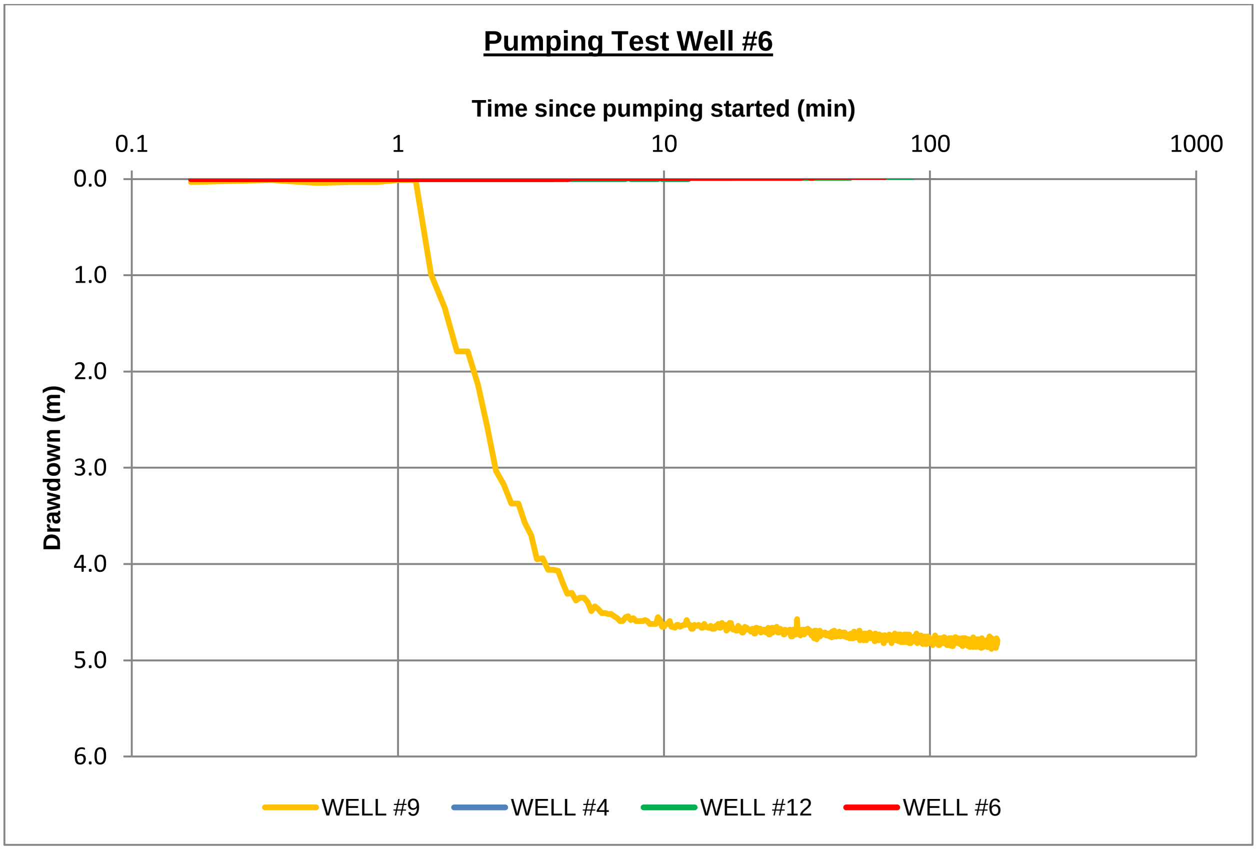
Drawdown and Recovery Graphs

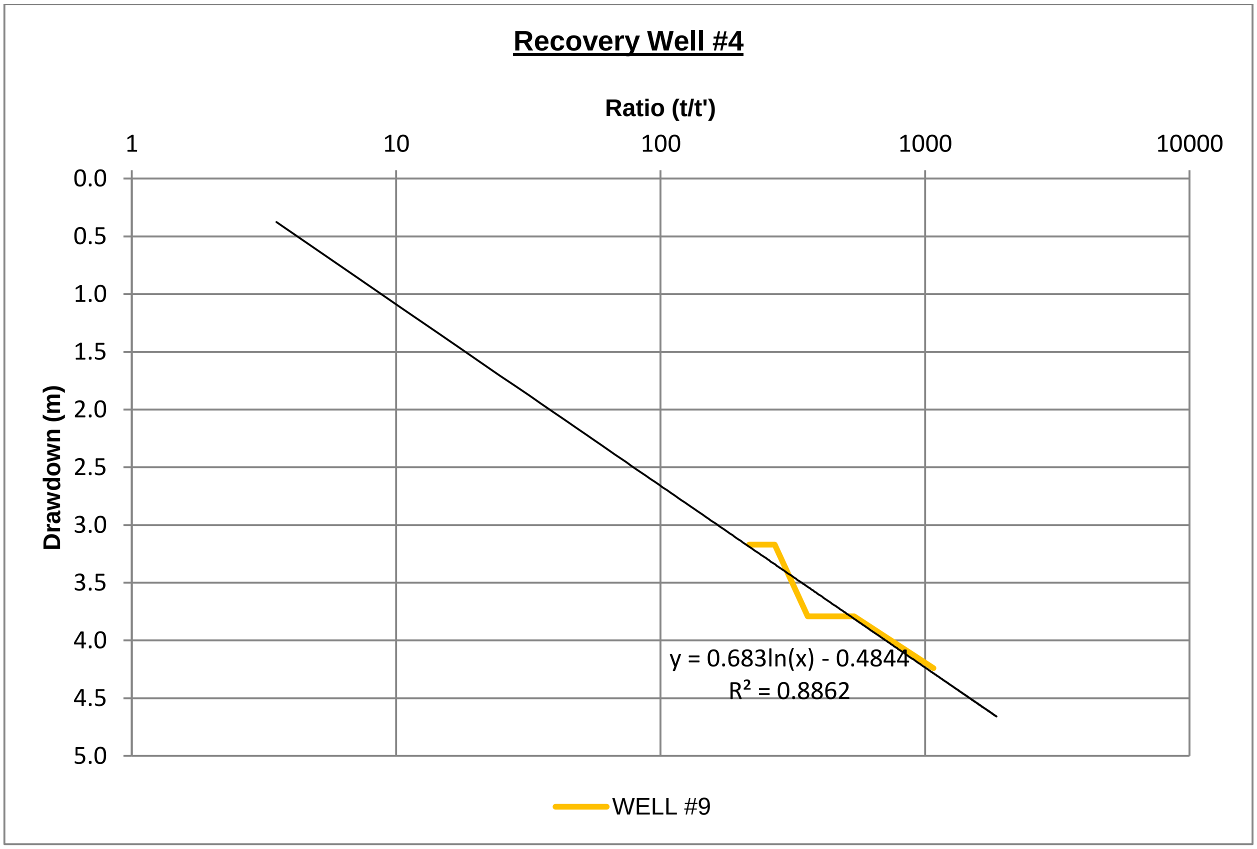

Pumping Test Well #4
Time since pumping started (min)
0.1
1
10
100
1000
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Drawdown (m)
WELL #4
WELL #12
WELL #6
WELL #9

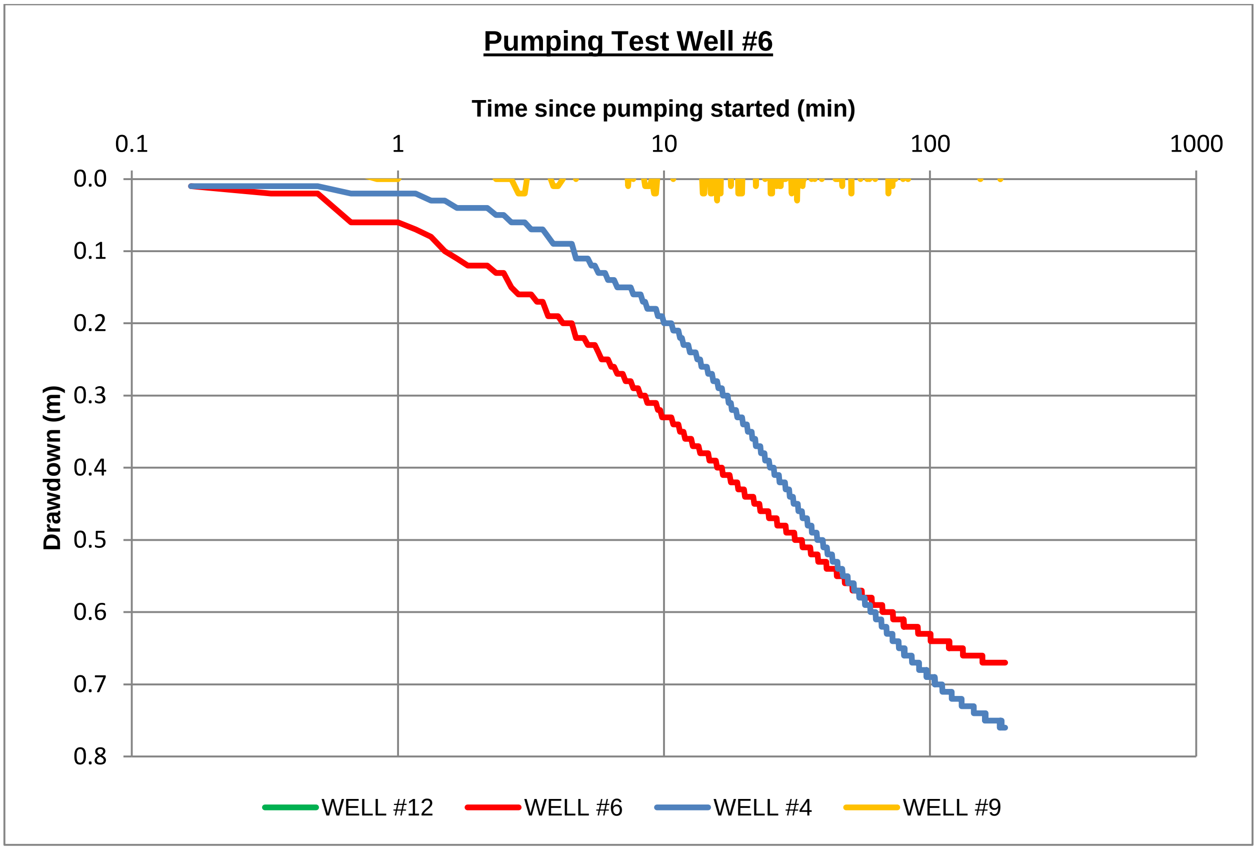

Recovery Well #4
Ratio (t/t')
1
10
100
1000
10000
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
Drawdown (m)
y = 1.0369ln(x) - 1.2629
R² = 0.9981
WELL #4
WELL #6
WELL #12
WELL #9

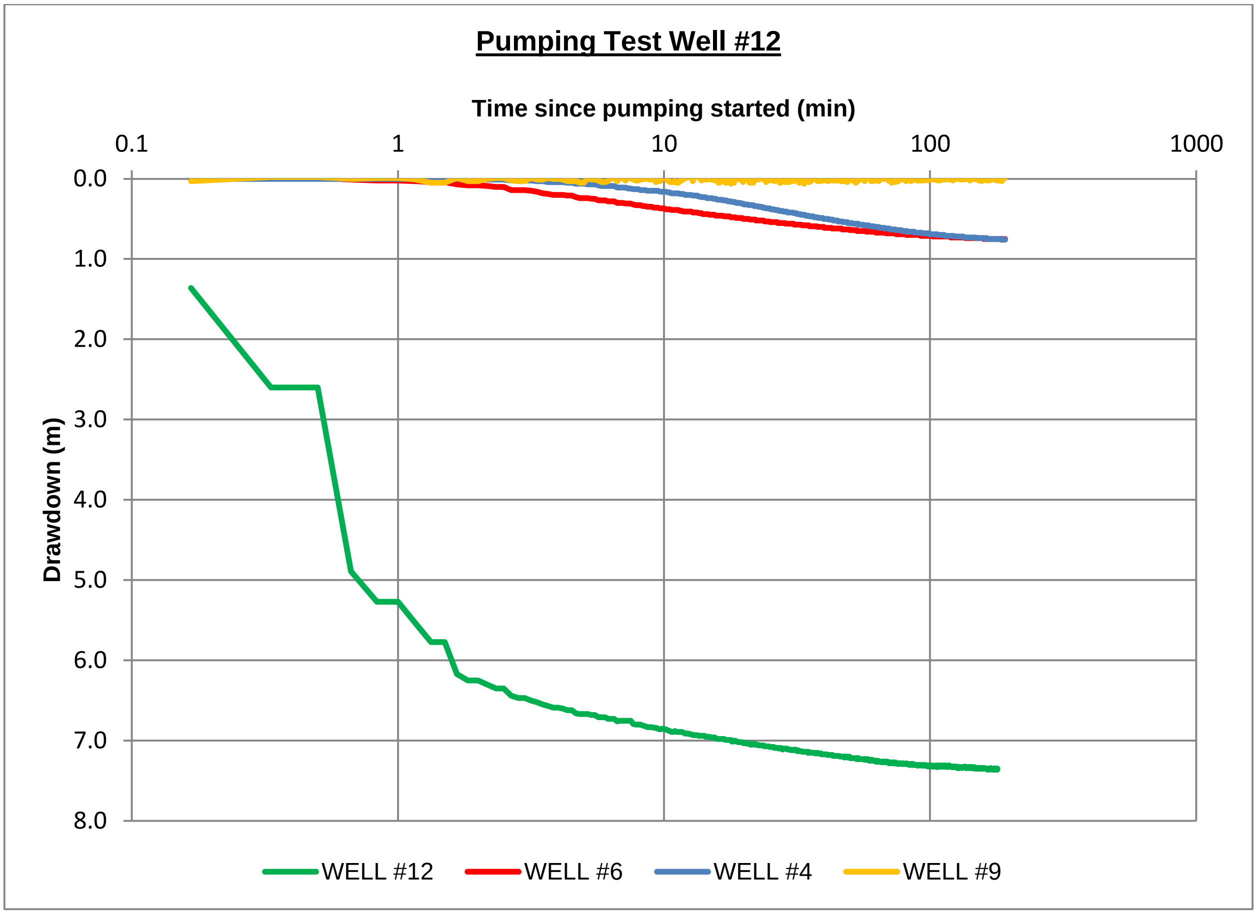

Pumping Test Well #6
Time since pumping started (min)
0.1
1
10
100
1000
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Drawdown (m)
WELL #6
WELL #12
WELL #4
WELL #9


Recovery Well #4
Ratio (t/t')
1
10
100
1000
10000
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Drawdown (m)
y = 0.2316ln(x) - 0.3804
R² = 0.9887
WELL #6
WELL #4
WELL #12
WELL #9


Pumping Test Well #6
Time since pumping started (min)
0.1
1
10
100
1000
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Drawdown (m)
WELL #9
WELL #4
WELL #12
WELL #6

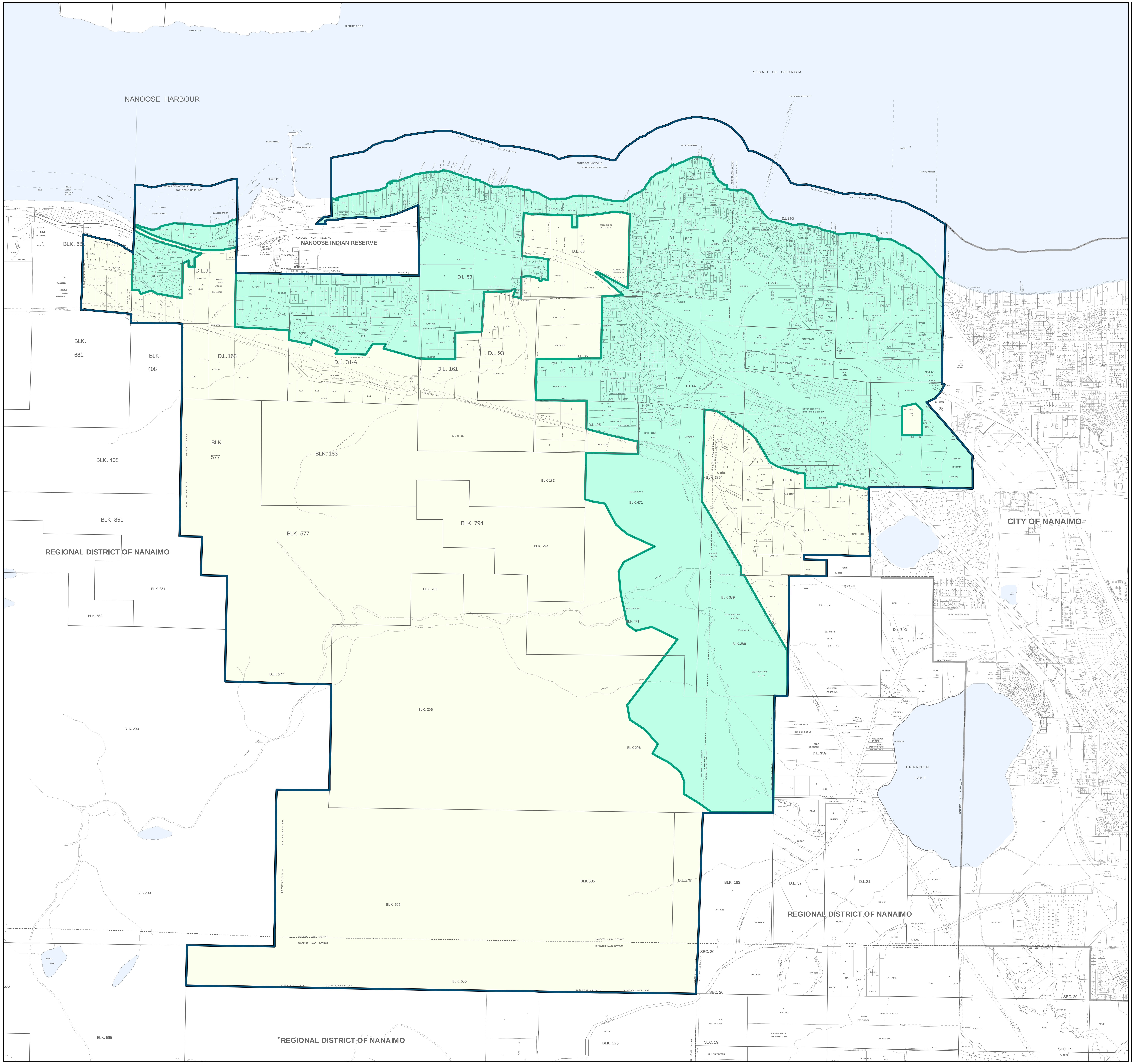

Recovery Well #4
Ratio (t/t')
1
10
100
1000
10000
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Drawdown (m)
y = 0.683ln(x) - 0.4844
R² = 0.8862
WELL #9


Pumping Test Well #6
Time since pumping started (min)
0.1
1
10
100
1000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Drawdown (m)
WELL #12
WELL #6
WELL #4
WELL #9


Pumping Test Well #12
Time since pumping started (min)
0.1
1
10
100
1000
Drawdown (m)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
WELL #12
WELL #6
WELL #4
WELL #9

Appendix D

OCP Map 7 – Water Service Area



DISTRICT OF LANTZVILLE OFFICIAL COMMUNITY PLAN

MAP NO. 7 WATER SERVICE AREA

Legend

- District of Lantzville Boundary
- Water Service Area

Mayor

Director of Corporate Administration

BYLAW NO. 50.2, 2007

N

0 100 200 400 600 800 1,000 1,200 Meters