KERR WOOD LEIDAL
consulting engineers

Vancouver Island
201 - 3045 Douglas Street
Victoria, BC V8T 4N2
T 250 595 4223
F 250 595 4224

2024 Water Master Plan Update

Final Report – Revision 2
June 3, 2024
KWL Project No. 0452.133

Prepared for:
City of White Rock

WHITE ROCK
City by the Sea!

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1. Introduction

1.1 Scope of Master Plan

Kerr Wood Leidal Associates Ltd. (KWL) was retained by the City of White Rock (the City) to prepare an update to the Water System Master Plan. The water master plan for White Rock was last updated in 2017.

The scope of the 2024 update includes:

- existing system demand development;
- future system demand development;
- hydraulic water model update;
- system evaluation including water main break history analysis; and
- recommended upgrades.

1.2 References

The following references have been used in the preparation of this report.

1. Brybil, *Process Narrative Oxford Water Treatment Plant,* September 2020.
2. City of White Rock, *Official Community Plan*, July 2021.
3. City of White Rock, Open Data Portal, < http://data.whiterockcity.ca/ >.
4. Coriolis Consulting Corp., *Residential and Commercial Development Forecasts as Input to White Rock's Official Community Plan Review*, November 18, 2016.
5. Insurer's Advisory Organization Inc., *Fire Underwriter's Survey Water Supply for Public Fire Protection*, 2020.
6. Kerr Wood Leidal Associates Ltd., *2017 Water System Master Plan Update*, October 2017.
7. Kerr Wood Leidal Associates Ltd., *Water Conservation Plan,* April 21, 2016.
8. Kerr Wood Leidal Associates Ltd., *Water System Master Plan Update, Final Report*, December 2010.
9. Kerr Wood Leidal Associates Ltd., *Fraser Health Requirements for Disinfection Implementation, Deferral of Secondary Disinfection Implementation*, June 2016.
10. Master Municipal Construction Documents Association, *MMCD Design Guidelines*, 2022.
11. Metro Vancouver Regional District, *Metro 2050*, February 2022.
12. Prairie Climate Centre, *Climate Atlas of Canada*, available from https://climateatlas.ca/, accessed on August 25, 2023.
13. SCM Risk Management Services Inc. (Opta Information Intelligence), *City of White Rock Fire Underwriters Survey*, 2018.
14. Utah State University, *Water Main Break Rates in the USA and Canada: A Comprehensive Study*, March 2018.
15. Water Research Foundation, *Residential End Uses of Water, Version 2*, April 2016.
16. Water Research Foundation, *Developing Water Use Metrics for the Commercial and Institutional Sectors,* October 2019.

1.3 Abbreviations

The following abbreviations have been used throughout the report.

AC	Asbestos Cement
BD	Base Demand
ca	Capita (person)
CI	Cast Iron
DI	Ductile Iron
DWM	Distribution Water Main
EPS	Extended Period Simulation
FUS	Fire Underwriters Survey
GCDWQ	Guidelines for Canadian Drinking Water Quality
ha	Hectare
HGL	Hydraulic Grade Line
HZE	High Zone East
HZW	High Zone West
ICI	Industrial Commercial and Institutional
KWL	Kerr Wood Leidal Associates Ltd.
MDD	Maximum Day Demand
MF	Multifamily
ML	Mega Litre (10^6 L)
MMCD	Master Municipal Construction Documents
MV	Metro Vancouver
NWWBI	National Water and Wastewater Benchmarking Initiative
OCP	Official Community Plan
PHD	Peak Hour Demand
PRV	Pressure Reducing Valve
PS	Pump Station
PVC	Polyvinyl Chloride
RES	Residential
RFP	Request for Proposals
RWM	Raw Water Main
SCADA	Supervisory Control and Data Acquisition
SD	Seasonal Demand
SF	Single Family
TWL	Top Water Level
TWM	Treated Water Main
WM	Water Main
WTP	Water Treatment Plant

2. Existing Water Demands

Water system demands have been broken down into the following components for the purpose of this study:

- Base demand (BD): Typical water usage on an average winter day. BD includes indoor use for single family residential (SF-RES), multifamily residential (MF-RES), and industrial commercial and institutional (ICI). BD also includes losses due to leakage.
- Seasonal demand (SD): Irrigation use and other seasonally dependant uses (typically relatively small compared to irrigation) on the peak summer day. SD includes irrigation use for SF-RES, MF-RES, and ICI.

The Maximum Day Demand (MDD) is the total peak day demand and is the sum of the base and seasonal demand components.

Note that the City executes a water main flushing program annually, but these flows are not a component of BD or SD.

The existing water demands and the breakdown between the demand components discussed above have been estimated using source flow data and customer water meter data. The following table is a summary of the existing demands used for this study. The sections below summarize the development of the existing water demands.

Table 2-1: Existing Demand Summary

Max Day Demand MDD = 135.9 L/s	**Base Demand** BD = 67.5 L/s	**ICI** BD-ICI = 11.8 L/s
		Single-Family Residential BD-SF-RES = 26.9 L/s
		Multi-Family Residential BD-MF-RES = 21.3 L/s
		Losses LOSS =7.5 L/s
	Seasonal Demand SD = 68.4 L/s	**ICI** SD-ICI =12.5 L/s
		Single-Family Residential SD-SF-RES = 40.3 L/s
		Multi-Family Residential SD-MF-RES = 15.6 L/s

2.1 Service Area Population

In addition to the City of White Rock, the water system also supplies 73 parcels in the City of Surrey. Data available from the 2021 census was used to estimate the water system service area population. The average population for a single-family home in White Rock is 2.5 ca/unit. The average population for multi-family homes is 1.5 ca/unit.

The total residential service population for the current White Rock water system is estimated at 22,142 (21,939 in the City of White Rock, 203 in the City of Surrey). The existing land use in White Rock is shown on Figure 2-3.

2.2 Source Flow Records

Source flow information for 2018 - 2022 was extracted from the City's Supervisory Control and Data Acquisition (SCADA) system.

Total system base demands for each year were estimated using the average flow for January, February, and March.

The base day and maximum day demands for 2018 - 2022 were added to the historical record for the White Rock water system and are shown on Table 2-1. It is noted that data for 2017 was not available.

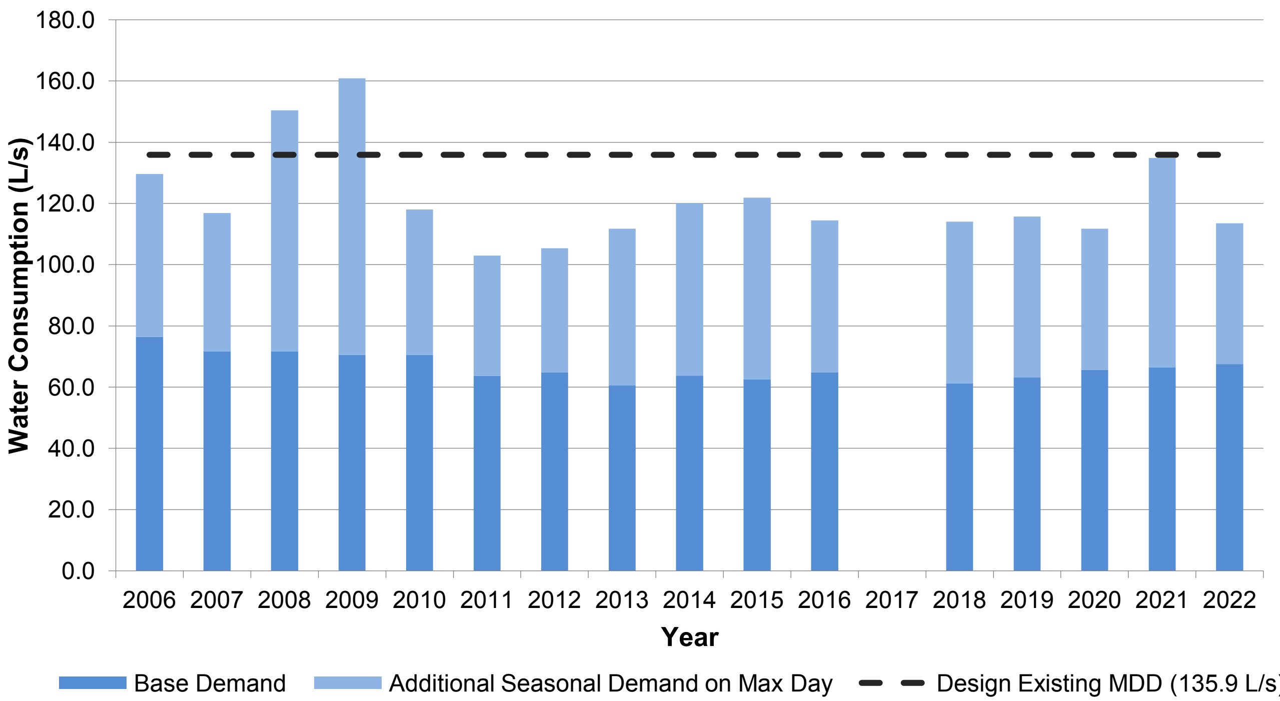

Figure 2-1: 2006 to 2022 Maximum Day and Base Day Demand Comparison

As shown in Table 2-1, the base demand observed in 2022 (67.5 L/s) was one of the highest in recent years. However, the seasonal demand component, which is influenced by weather, was lower in 2022 than in previous years. For the purpose of evaluating the water system, using seasonal demands from a representative hot/dry year will provide a conservative yet realistic basis for analysis. The year 2021 had the highest seasonal demand component in recent years.

A review of the highest 7-day average evapotranspiration (ET) rate for each year was conducted to confirm that 2021 is considered a hot/dry year. Average ET values[1] for each year in the historical water use record is shown on Table 2-2. It can be seen that the ET value observed in 2021 (5.9 mm/day) was the highest in the 17-year record.

Table 2-2: 2006 to 2022 Average Evapotranspiration Rates

Year	Additional Seasonal Demand on Max Day (L/s)	Max 7-day Average ET (mm/day)	Notes
2006	53.2	4.80	
2007	45.1	4.96	
2008	78.7	4.43	
2009	90.3	5.02	
2010	47.5	4.55	
2011	39.4	4.01	
2012	40.5	4.14	
2013	51.2	4.59	
2014	56.3	4.49	
2015	59.3	5.41	Seasonal demand used in 2017 Water Master Plan Analysis
2016	49.7	4.30	
2017	N/A	4.26	
2018	52.8	5.21	
2019	52.4	4.58	
2020	46	4.66	
2021	68.4	5.85	June 2021 'Heat Dome' Event
2022	46	4.48	

For the purposes of this study, the BD value observed in 2022 (67.5 L/s) was combined with the SD value observed in 2021 (i.e. 'the Heat Dome', 68.4 L/s) to obtain a total design existing MDD of 135.9 L/s.

2.3 Base Demand Unit Rates

The City's water meter data collected in winter months was used to calculate average base demand unit rates for existing land use types.

All of the City's water services are metered. Meter data provided by the City for 2022 indicates that there is a total of 4,539 water service meters. The water meters in the City's database are classified as single-family, multi-family, or ICI (includes City, Commercial, and Institutional meter types), and are read four

[1] Average ET values for White Rock obtained from Environment Canada's Farmwest website <http://farmwest.com/climate/et>

times per year. The City's meter database also includes the number of multi-family units associated with each multi-family water meter.

Average base demand unit rates for single-family residential parcels and multi-family residential units were calculated using water meter data with 2021 census populations. The calculated rates were 193 L/ca/day and 186 L/ca/day for single-family and multi-family, respectively.

A selection of ICI meters was assigned to parcels to develop an ICI base demand unit rate. An average rate of 1.40 L/m^2 parcel area/day was calculated for existing ICI parcels.

Water meter records for the Semiahmoo First Nation and Peace Arch Hospital were reviewed individually. The 2022 water meter records indicate that the base demands were 0.1 L/s and 3.0 L/s for Semiahmoo First Nation and Peace Arch Hospital, respectively.

2.4 Water System Losses

The water system loss estimate was based on the observed night flow and theoretical legitimate night usage estimate completed as part of the 2017 Water System Master Plan Update.

The loss component calculated previously (7.5 L/s) was verified by comparing the increase in base demands observed in 2022 (67.5 L/s) to the observed rate in 2016 (64.8 L/s). There has been significant growth in White Rock since 2016 (estimated 1,961 additional service population). The 2.7 L/s increase can be justified by the increase in population and therefore losses are not expected to have increased substantially since 2016.

2.5 Seasonal Demands

The distribution of the seasonal demand for the system was determined by examining the July, August and September meter readings from the 2022 meter data. Single-family meters accounted for 59% of the metered seasonal demand, multi-family meters accounted for 23%, and ICI meters (includes City, Commercial, and Institutional meter types) accounted for 18%.

2.6 Diurnal Demand Patterns

Diurnal patterns are assigned to each demand component to estimate peak hour demands. A separate demand pattern is assigned to each demand type (BD-RES, BD-ICI, and SD). The losses demand pattern (LOSSES) is assumed to be consistent throughout a 24-hour period.

The diurnal patterns developed for 2017 Water System Master Study were applied to the demands and are illustrated in Figure 2-2. below.

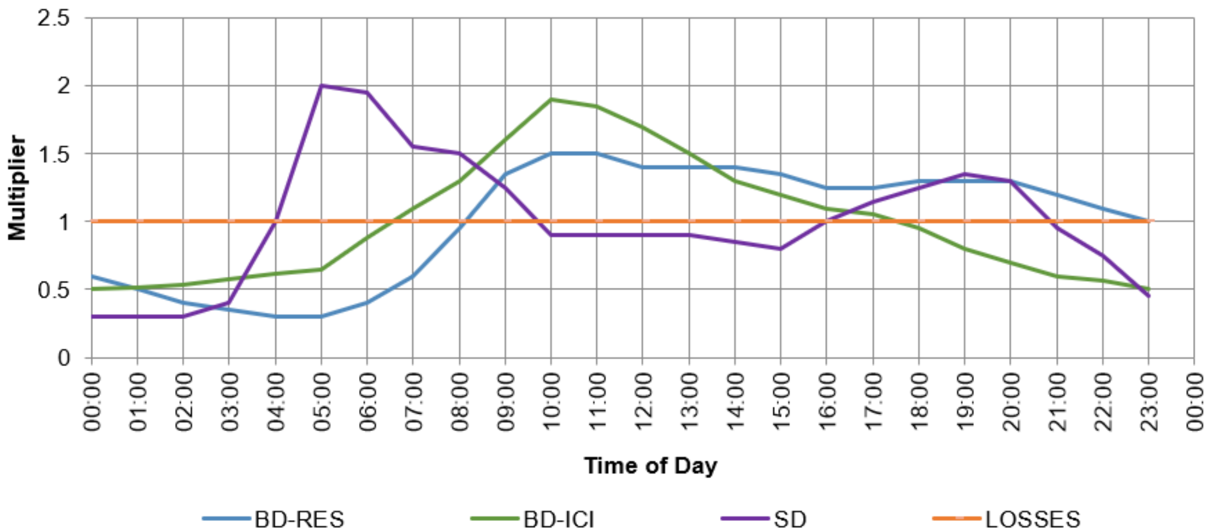

Figure 2-2: Modelled Diurnal Demand Patterns

2.7 Base Demand Unit Rate Comparison

The residential base demand rate calculated for this study (193 L/ca/day for single-family and 186 L/ca/day for multi-family) was compared against other observed rates. Residential base demand rates calculated by KWL for other local jurisdictions are:

- City of Richmond – 185 L/ca/day (2022);
- City of Surrey – 200 L/ca/day (2019);
- District of Oak Bay – 180 L/ca/day (2018);
- District of Sparwood – 190 L/ca/day (2018);
- District of Saanich – 200 L/ca/day (2017);
- Town of Sidney – 172 L/ca/day (2014); and
- French Creek – 170 L/ca/day (2013).

Also note that the rates calculated in previous White Rock master plans were 233 L/ca/day, 202 L/ca/day, and 195 L/ca/day for 2010, 2013, and 2017 respectively.

As shown above the residential base demand rates for other local jurisdictions range from 170 - 200 L/s and the existing average residential base demand per capita rate of 190 L/ca/day calculated for White Rock is also within this range. The base demand rate for White Rock has declined by 18% since 2010. Reduction in the base demand rate is attributed to increasing use of low flow fixtures and improved efficiency in new construction and growing awareness of water conservation benefits.

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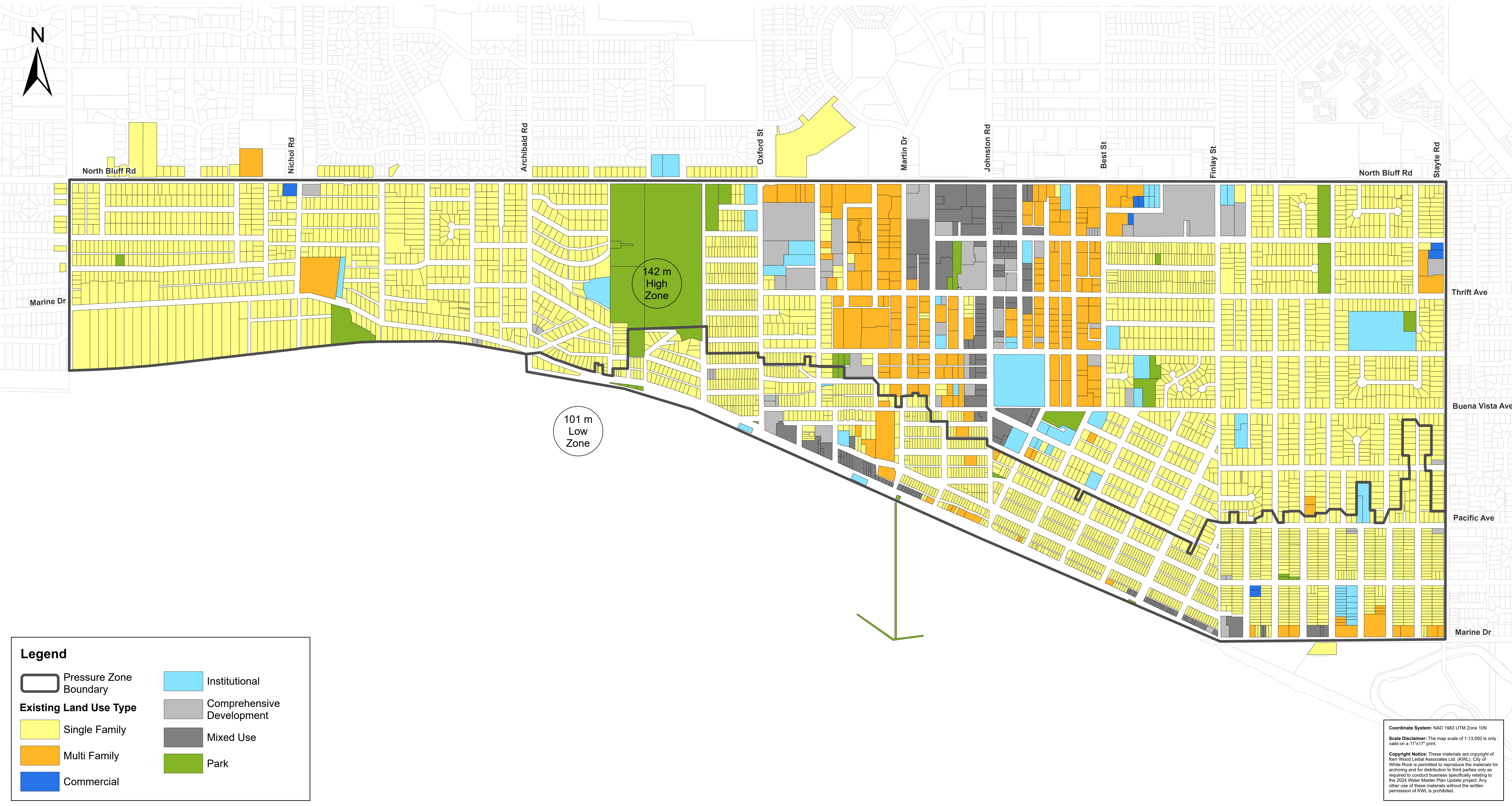

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Date April 2024

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Existing Land Use

Figure 2-3

3. Future Water Demands

A future 2050 demand scenario was developed using population growth and employment projections from Metro Vancouver. The growth was distributed according to the Land Use Plan and Development Permit Areas developed for the White Rock 2021 Official Community Plan (OCP).

The following table is a summary of the future demands used for this study. The sections below summarize the development of the future water demands.

Table 3-1: Future Demand Summary

Max Day Demand MDD = 152.5 L/s	**Base Demand** BD = 78.6 L/s	**ICI** BD-ICI = 13.3 L/s
		Single-Family Residential BD-SF-RES = 29.5 L/s
		Multi-Family Residential BD-MF-RES = 28.3 L/s
		Losses LOSS =7.5 L/s
	Seasonal Demand SD = 73.9 L/s	**ICI** SD-ICI =13.5 L/s
		Single-Family Residential SD-SF-RES = 43.6 L/s
		Multi-Family Residential SD-MF-RES = 16.8 L/s

3.1 Growth Projections and Future Land Use

The projected year 2050 population and ICI growth has been estimated using the information provided in the Metro 2050 regional planning document. It is noted that the Metro 2050 projections are in line with the projections from the City of White Rock 2021 OCP, but the information from Metro extends to the year 2050, while the design horizon considered in the OCP is 2045.

The year 2050 population estimate for White Rock is 27,870. This is the Mid-Range growth (+/- 15% range). This is a 570 or 2.1% increase beyond the 2045 growth projection used for the 2017 Master Plan.

The OCP includes projected increases to ICI floor area of up to 320,000 ft^2 to the year 2045. To account for the increase to the year 2050 (i.e. the horizon for this study), the ICI demand was increased by 2.1%, mirroring the projected increase in population growth.

The population and ICI increases have been distributed throughout the system using the City's Future Land Use Map. This map is shown in Figure 3-1. Each future land use area is described in the OCP document, including information about allowable densities. A summary of the distribution of additional population and ICI floor area to each future land use area is included in Table 3-2.

The OCP does not discuss an increase in population in the Mature Neighbourhood area (i.e. single family residential). A report completed by Coriolis in 2016 indicated that there are an average of 58 new single-family housing starts in White Rock, and two thirds of the new houses have secondary suites. This single-family home redevelopment frequency has continued in White Rock though 2024; assuming this trend continues, a portion of the projected growth (approx. 1,601) has been allocated to the Mature Neighbourhood area to account for construction of secondary suits and coach houses.

No growth has been attributed to the Semiahmoo First Nation or City of Surrey lots included in the White Rock service area.

Table 3-2: Summary of Population and ICI Growth Allocated to Future Land Use Areas

Future Land Use Area	Total Area (ha)	Allowable Development Density (FAR)	Additional Population Added	% of Total Population Growth	Additional ICI Floor Area Added (m^2)	% of Total ICI Growth
Town Centre	11	3.75	1,186	20.0%	8,498	28.0%
Town Centre Transition	22	2	1,186	20.0%	8,498	28.0%
Lower Town Centre	6	2.4	415	7.0%	3,035	10.0%
Waterfront Village	7	1.75	356	6.0%	3,338	11.0%
Urban Neighbourhood	24	1.5	949	16.0%	5,766	19.0%
East Side Large Lot	3	2.5	178	3.0%	910	3.0%
North Bluff East	1	1	59	1.0%	-	-
Neighbourhood Commercial	1	1	-	0.0%	303	1.0%
Mature Neighbourhood Infill	235		1,601	27.0%	-	-
Institutional	18		-	-	-	-
Open Space & Recreation	26		-	-	-	-
City of Surrey Lots	12					
Total	**368**		**5,931**		**30,350**	

3.2 Future Base Demand Unit Rates

A residential base demand unit rate of 193 L/ca/day for single family residential, 186 L/ca/day for multi family residential, and an ICI rate of 1.40 L/m^2 parcel area/day was calculated for the existing system as discussed in Section 2. Using existing ICI floor area data available in the OCP (about 72,500 m^2), the ICI base demand rate roughly equates to 2.9 m^3/m^2 floor area/year.

While these base demand rates are considered reasonable for existing construction and compare well with rates observed in other municipalities, lower rates have been selected for future growth to reflect new construction standards that include water efficient fixtures and appliances.

A residential base demand rate of 140 L/ca/day has been applied to additional population growth based on information available from the Water Research Foundation's Residential End Uses of Water 2016 study for newly constructed homes.

An ICI base demand rate of 1.6 m^3/m^2 floor area/year has been applied to additional ICI floor area growth based on information available from the Water Research Foundation's study on Development of Water Use Metrics for the Commercial and Institutional Sectors in 2019.

Applying these unit rates to the growth projections yields a total base demand of 78.6 L/s for the future demand scenario.

3.3 Future Water System Losses

The water system loss estimate for the existing system is 7.5 L/s as discussed in Section 2.

The magnitude of water losses in a system is a function of the size and age of the system and the rate of infrastructure renewal. The water service area in White Rock is not expected to increase. Furthermore, although the water mains are ageing, water main replacement and ongoing leak management activities can be expected to limit increases in losses. Therefore, the existing water loss estimate (7.5 L/s) has been used as an estimate of future losses.

3.4 Future Seasonal Demand

The seasonal demand estimate for the existing system is 68.4 L/s as discussed in Section 2.

The water service area in White Rock is not expected to increase therefore it has been assumed that irrigated area will not increase. It has also been assumed that White Rock will continue to issue watering restrictions when necessary – the seasonal demand is considered to be consistent with what can be expected under Stage 2 watering restrictions.

To account for potential climate change impacts (potential for higher temperatures and extended drought periods which require greater irrigation) a hot summer demand extrapolation was used. Current climate change models indicate that by 2050, the number of days above 30°C could increase to 7.5 consecutive days. For reference, the June 2021 “heat dome” event resulted in four consecutive days with daily highs greater than 30 °C. Using 2018 - 2022 data available for White Rock, the maximum summer demands were plotted versus observed temperatures; extrapolating for temperature predictions from the Climate Atlas of Canada climate model for the Vancouver Region, the estimated increase related to climate change is 1.08 times the current observed values; this translates to a total seasonal demand estimate of 73.9 L/s for the 2050 scenario.

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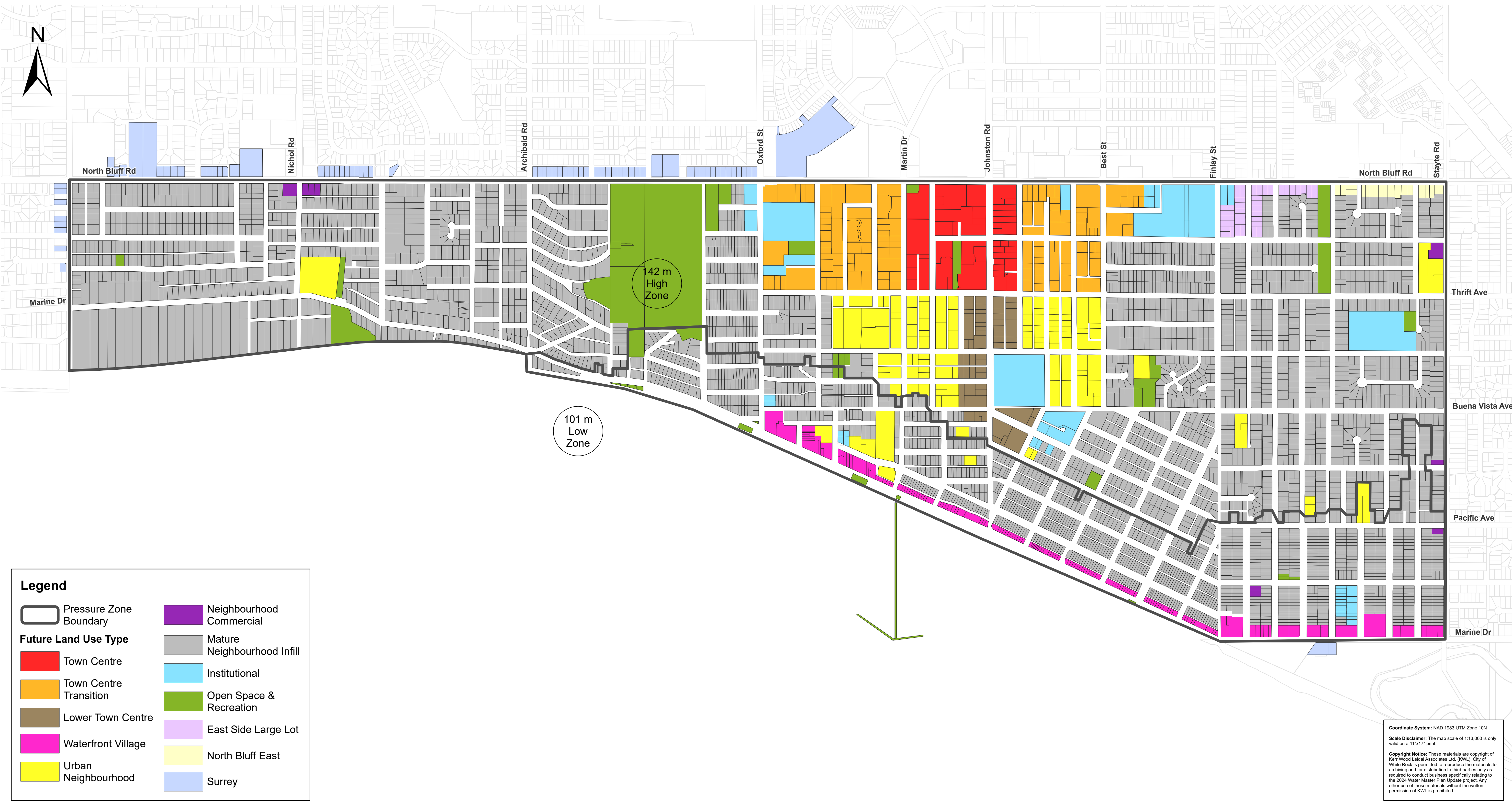

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Future Land Use

Figure 3-1

4. Water Model Update

4.1 Water System Overview

The White Rock water system supplies a population of approximately 22,000 residents as well as a small portion of Surrey (located on North Bluff Avenue and Bergstrom Road) and the Semiahmoo First Nation. The major facilities in the water distribution system include:

- Seven groundwater wells;
- Oxford Water Treatment Plant (WTP);
- Oxford Reservoirs and Booster Pump Station;
- Merklin Reservoirs and Booster Pump Station;
- Roper Reservoir and PRV Station;
- Stevens Street PRV Station; and
- Johnston Road PRV Station.

The water service area is divided into the High-Pressure Zone (nominally 142 m HGL) and the Low-Pressure Zone (nominally 101 m HGL).

The existing water system network is shown on Figure 4-1.

4.2 Water Model Update

A hydraulic water model of the White Rock water system has been created using Bentley's WaterCAD software (CONNECT Edition). The file version used in the analysis for this report is WR_v70.wtg.

Prior to this study, the last significant update was completed in October 2017. Water model updates completed for this report are summarized in Table 4-1.

Table 4-1: Model Update Summary

Update Description	Project Completion Date
Oxford WTP, including: • Raw water mains from Wells 4, 6 and 7 to Oxford WTP. • Treated water main from Oxford WTP to Oxford and Merklin reservoirs.	2018
Saturna Dr. Water Main Update, Archibald Rd. to High St., 200 mm dia. PVC.	2018
Archibald Rd. Water Main Upgrade, North Bluff Rd. to Mann Park Cres., 200 mm dia. PVC.	2018
Marine Dr. Water Main Upgrade, Bergstrom Rd. to Nichol Rd., 200 mm dia. PVC.	2018
Magdalen Cres. Water Main Upgrade, Marine Dr. to Sunset Dr., 150 mm dia. PVC.	2018
Johnston Rd. Water Main Upgrade, North Bluff Rd. to Russell Ave., 250 mm dia. PVC.	2018
Johnston Rd. Water Main Extension to Royal Ave, 150 mm dia. DI.	2019
Victoria Ave. Watermain Upgrade at Vidal Ave., 150 mm dia. DI.	2019
Marine Dr. Water Main Upgrade, Vidal Ave. to Martin St., 250 mm dia. PVC.	2019
15100 Block Marine Dr., between hydrants 35 and 201, 200 mm dia. HDPE.	2019

Update Description	Project Completion Date
Nichol Rd. Water Main Upgrade, Connection to North Bluff Rd., 200 mm dia. PVC.	2019
Roper Reservoir Supply Upgrade.	2019
Buena Vista Ave. Water Main Upgrades, Centre St. to Best St., 200 mm dia. PVC.	2019
Brearley St. Loop to North Bluff Rd. to Hydrant #157, 150 mm dia. PVC.	2020
Chestnut St. Water Main Upgrade, North Bluff Rd. to Blackburn Ln., 150 mm dia. DI.	2021
Stevens St. Water Main Upgrade, North Bluff Rd. to Russell Ave., 150 mm dia. DI.	2021
Prospect Ave. & Oxford St. Connection Upgrade, 200 mm dia. DI.	2021
Pacific Ave. & Dolphin St. Connection Upgrade, 150 mm dia. DI.	2021
George St. Water Main Upgrade, 250 mm dia. PRV, North Bluff Rd. to 1554 George St.	2022
North Bluff Rd. Water Main Upgrade, Johnston Rd. to George St., 300 mm. dia. PVC.	2022
Phoenix St. & Malabar Ave. Connection Upgrade, 150 mm dia. DI.	2022
Finlay St. Water Main Upgrade, 1526 Finlay St. to Russell Ave., 250 mm dia. PVC.	2022
Russell Ave. Water Main Upgrade, Finlay St. to Maple St., 250 mm dia. PVC,	2023
Johnston Rd. Water Main Upgrade, Russell Ave. to Thrift Ave., 250 mm dia. DI.	2024
Well #5 - adjacent to Anderson Street in Centennial Park.	2024 (anticipated)

4.3 Control Settings

The existing hydraulic controls are used in the water model are summarized in Table 4-2.

Table 4-2: System Controls and Modelling

Facility	Description	System Controls/Setpoints
Oxford WTP	Removal of naturally occurring manganese and arsenic and primary disinfection	174 L/s maximum capacity. Operates to keep the Oxford and Merklin Reservoirs at 60-98% full. Currently, SCADA is set such that a maximum of 75 L/s can be directed to the Merklin Reservoir; however, this has not been incorporated into the modelling analysis as per direction of the City [1]
Merklin Booster PS	2 duty pumps and 2 fire pumps	Set at 141.5 m HGL (320 kPa) [2]
Oxford Booster PS	4 duty pumps on VFDs	Set at 141.7 m HGL (525 kPa) [2]
Groundwater Wells (Wells 1, 2, 3, 4, 5, 6, 7, 8)	Individual groundwater wells, pump to Oxford WTP via. Raw Water Supply System	Highest capacity well (Well #5) set to off. All other wells turn on as required to maintain 60-98% level in Oxford and Merklin reservoirs.
Roper PRV (63 mm)	63 mm PRV	Normally closed.

Facility	Description	System Controls/Setpoints
Roper PRV (150 mm)	150 mm PRV	102 m HGL, fills Roper Reservoir between 11 PM and 5 AM (to 95%). Between 5 AM and 11 PM, opens to keep Roper 70-75% full.
Johnston PRV Station	150 mm PRV	Set at 98.5 m HGL (183 kPa).
Stevens St. PRV Station	150 mm PRV	Set at 97.2 m HGL (376 kPa)

Notes:
1. Information provided by Ahmed Hasan, March 21, 2024. As per direction provided by the City, modelling work has assumed this set point can be adjusted/increased.
2. Operational set points provided by Ahmed Hasan, October 12, 2023.

4.4 Water Main Inventory

The size and material type of the existing water mains in the distribution system in the water model are summarized in Table 4-3.

Table 4-3: Inventory of Distribution System Water Mains (Lengths in m)

Nominal Diameter (mm)	Cast Iron	Ductile Iron	HDPE	PVC	Unknown	Total	Percent of Total
25, 50	27	518		184	81	**810**	1%
100	7,999	2,231		45	10	**10,285**	13%
150	6,745	27,197		514	254	**34,710**	45%
200	6,485	15,075	91	1,376	91	**23,118**	30%
250	1,104	3,817		878		**5,799**	8%
300	27	1,930		116	81	**2,046**	3%
Total	**22,360**	**50,768**	**91**	**3,113**	**436**	**76,768**	
Percent of Total	**29%**	**66%**	**0.1%**	**4%**	**1%**		

City of White Rock

2024 Water Master Plan Update

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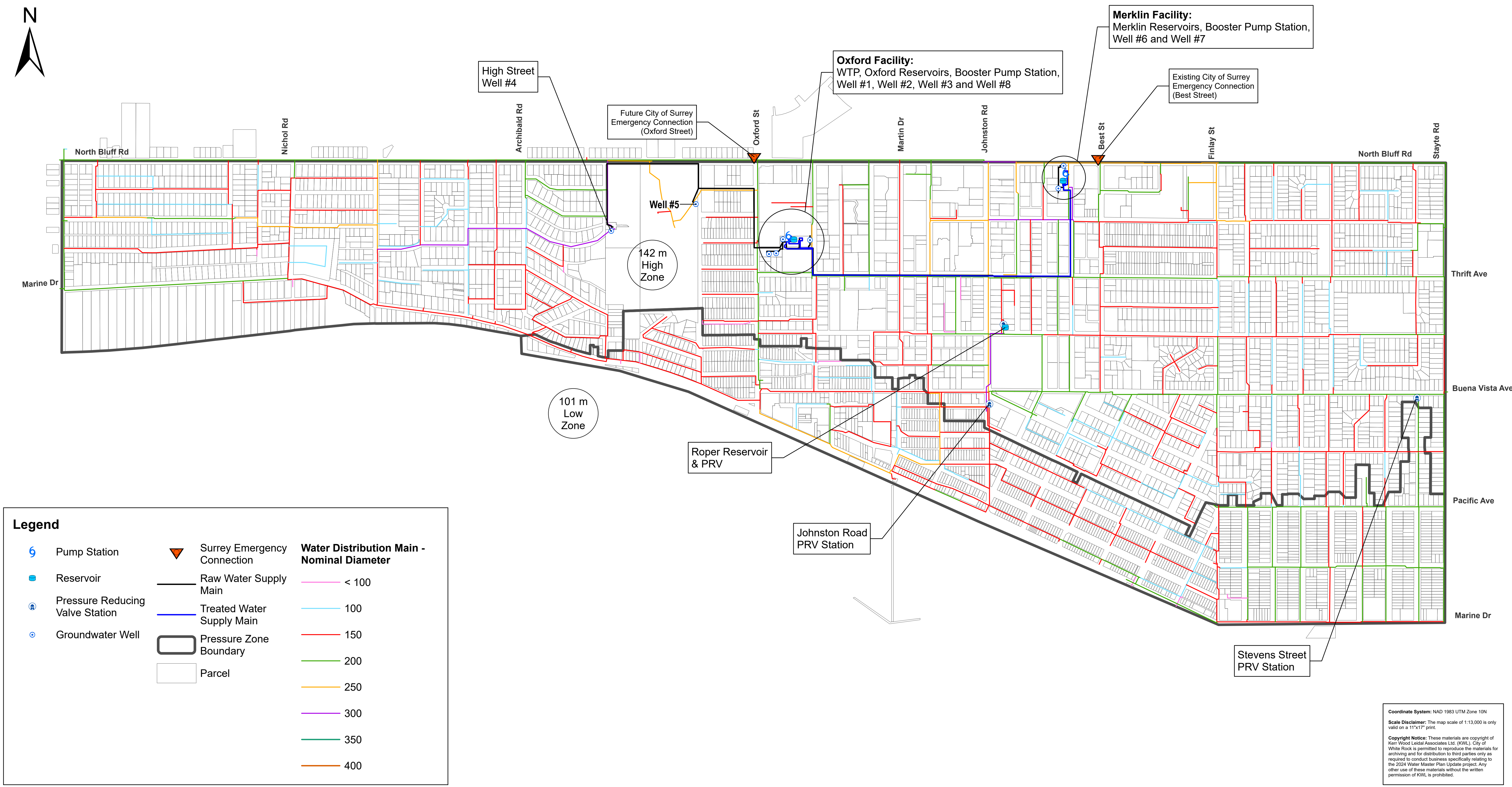

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

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Existing Water System

Figure 4-1

5. Water Model Validation

5.1 Source Data

The City provided SCADA data at eight pressure monitoring locations in the water system for June, July, and August 2021. The data for one second intervals was provided and was then averaged over one-hour intervals.

Plots showing the June, July, August 2021 pressure monitoring data is included in Appendix A.

5.2 Model Setup

The maximum day demand observed in recent record occurred on June 28, 2021. The following dates were chosen for model validation:

- Maximum observed pressure on June 28, 2021 to compare to modelled max day static conditions (i.e. low flow conditions).
- Minimum observed pressure on June 28, 2021 to compare to modelled max day peak hour conditions (i.e. lowest pressure observed on max day).

All model updates described in Section 2 are included in the model validation scenarios.

5.3 Validation Results and Discussion

The model validation results for each of the eight pressure monitoring sites is presented in the table below. There is generally good agreement when results are compared (i.e., less than 3.5 m or 5 psi difference). Locations where the difference between modelled and measured HGL is greater than 3.5 m are highlighted and discussed more below.

Table 5-1: Model Validation Summary

Logger ID/ Hydrant ID	Location	Pressure Zone	Max Day Maximum HGL (m)			Max Day Minimum HGL (m)		
			Field	Model	Difference	Field	Model	Difference
1/346	Johnston PRV	High	143.6	142.1	1.5	140.9	140.4	0.4
2/303	Beachview/Foster	Low	101.7	100.4	1.4	100.3	98.5	1.8
3/131	Blackburn/Bergstrom	High	143.5	142.3	1.2	138.9	139.1	-0.2
4/20	Archibald/Mann Park	High	142.3	142.3	0.0	138.4	139.4	-1.0
5/311	Buena Vista/Oxford	Low	107.4	100.3	7.1	105.7	98.4	7.4
6/330	Oxenham/Finlay	High	144.5	142.1	2.5	141.9	140.4	1.5
7/310	North Bluff/Stayte	High	138.5	142.0	-3.6	135.8	140.3	-4.5
8/100	Columbia/Stayte	Low	99.4	100.2	-0.8	97.0	97.2	-0.2

Notes:
1. June 28, 2021 data for Logger 3/Hydrant 131 was not available. Used data for June 27, 2021.

Logger 5 is located on Hydrant 311 on Buena Vista Avenue and Oxford Street in the Low-Pressure Zone. The comparison indicates the field measurements for both maximum and minimum demands are higher than the model results by upwards of 7 m or 10 psi. Further to this, the calculated HGL for the field results is 106 - 107 m, which is higher than theoretically possible for the Low-Pressure Zone (Roper Reservoir top water level is 100 m HGL). Possible reasons for the discrepancy include:

- Zone valve cracked open slightly in the vicinity, allowing high pressure supply to come into the area. Noted that the other loggers in the Low-Pressure Zone (IDs 2 and 8) are in line with model results and in line with the expected HGLs for the Low Zone.
- Logger error resulting in erroneous values. Noted that the values for this logger are consistently in the same range for the data provided (144 - 147 psi / 106 - 107 m HGL).

It is recommended that the City confirm all zone valves in the vicinity of Logger 5 are completely closed.

Logger 7 is located on Hydrant 310 on Stayte Road between North Bluff Road and Russell Avenue. The comparison indicates that field measurements for both maximum and minimum demands are 3.5 m to 4.5 m (5 - 7 psi) lower than the model results. It is noted that the discrepancy is consistent between the min and max values and is close to the targeted agreement threshold range (within 5 psi).

Given that the offset is consistent between both the maximum and minimum pressure values, the comparison for Logger 7 is considered acceptable and provides confidence that the model is accurately predicting head loss during maximum day demand conditions.

6. Design Criteria

Design criteria used for system evaluation are primarily from the MMCD Design Guidelines (2022).

6.1 Minimum Pipe Diameter

The minimum recommended pipe diameter is 200 mm. For looped distribution systems with lengths less than 500 m in residential subdivisions, the dimeter can be reduced to 150 mm diameter provided fire flows are met.

6.2 Pressure

The required system water pressures are summarized in the following table.

Table 6-1: Pressure Design Criteria

Description	Required Pressure (kPa (psi))
Maximum pressure	1,035 (150) (1)
Minimum pressure at peak hour demand	300 (43.5)
Minimum pressure coinciding with fire flow and MDD	150 (21.8)
1. MMCD allows for either a max. allowable of 850 kPa (125 psi) or 1,035 kPa (150 psi). The current White Rock system pressure zoning results in static pressures up to 1,100 kPa. Reducing pressures to 850 kPa would require extensive capital works for minor benefit accordingly the higher criteria was selected.	

6.3 Required Fire Flows and Storage

Table 6-2 shows the minimum required fire flows from the 2018 Fire Underwriters Survey (FUS) report for White Rock, 2022 MMCD Design Guidelines, 2020 FUS Water Supply for Public Fire Protection Guidelines, and the required fire flows used for this report which have been developed based on these three documents.

Table 6-2: Fire Flow Design Criteria

Type of Construction/Dwelling	Area(s)	Required Fire Flow (L/s)	Fire Storage (ML)
2018 FUS Report for White Rock			
Commercial and Multi-Family Residential	*Town Centre Area*	*212 L/s (2,800 Igpm)*	*1.98 ML (2.6 hr)*
Single-Family Residential	*West of Oxford Street and East of Town Centre*	*60 L/s (800 Igpm)*	*0.32 ML (1.5 hr)*
2022 MMCD Design Guidelines/FUS Storage			
Institutional/Commercial	*N/A*	*150 L/s*	*1.08 ML (2.0 hr)*
Apartments/Townhouses	*N/A*	*90 L/s*	*0.60 ML (1.85 hr)*
Single-Family Residential	*N/A*	*60 L/s*	*0.32 ML (1.5 hr)*
FUS Water Supply for Public Fire Protection Guidelines			
Single-Family Residential	*N/A*	*67 L/s (4,000 L/min)*	*0.36 ML (1.5 hr)*
Used for Evaluation in this Study			
High Density Commercial and Multi-Family Residential	Town Centre, Town Centre Transition, Lower Town Centre, North Bluff East	212 L/s	1.98 ML (2.6 hr)
Institutional, Commercial, and Multi-Family	Institutional, Waterfront Village, Lower Town Centre, and East Side Large Lot Areas	150 L/s	1.08 ML (2.0 hr)
Lower Density Commercial and Multi-Family	Urban Neighbourhood, Neighbourhood Commercial, and Open Space & Recreation Areas	120 L/s	0.86 ML (2.0 hr)
Single-Family Residential	Mature Neighbourhood Area	67 L/s	0.36 ML (1.5 hr)

It is noted that the selection of fire flow requirements is the responsibility of the City. Different jurisdictions set their own criteria or select standards of protection according to their specific circumstances. In British Columbia, it is common for municipalities to use MMCD Design Guidelines or allow for an alternate fire flow requirement (such as FUS) if detailed information is available or an area specific study has been conducted.

The 2018 FUS report breaks the City into broad fire service areas. The Town Centre area is rated at 212 L/s whereas the remainder of the City is rated at 60 L/s (single-family residential requirement). The FUS report does not consider specific higher fire flow requirements outside the town centre (such as for institutional, commercial, or multi-family developments).

For this study, for the areas outside of the Town Centre Area, values consistent with MMCD guidelines were assigned to the future land use areas shown on Figure 3-1. The required fire flow used for system evaluation is shown on Figure 7-3.

Fire flow requirements for new developments should still be verified with the City of White Rock during the development water servicing review process.

It is noted that both the High-Pressure Zone and Low-Pressure Zone have areas within the Town Centre area so a maximum required fire flow of 212 L/s and fire storage requirement of 1.98 ML applies to both zones.

A fire event occurred on May 15, 2016 in the Town Center area. The fire started at a building under construction at 15219 Royal Avenue and subsequently spread to a neighboring mixed commercial/multi-family residential building at 15210 Pacific Avenue. Fire flows used by the fire department during the event were in excess of the design criteria. This event illustrated the usefulness of having fire flow capabilities in excess of the minimums noted above. It is noted that fire flows during the 2016 event were further supplemented by use of the City's emergency connections to Surrey's water system.

Since the 2016 fire event, the following improvements have been included in the water system:

- 1.2 ML of additional storage was constructed at the Merklin Site. At a flow rate of 153 L/s (average fire flow rate observed in 2016 fire event), this equates to an additional 2.1 hours of firefighting capacity in the White Rock System.
- Improvements made to pressure monitoring and system operations capabilities, providing more information and allowing the crews to respond more efficiently.
- Improvements made to one of the City of Surrey emergency connections located at Best St and North Bluff Road, including flush ports and gate valves.
- Improvements made to the Roper Reservoir inlet/outlet piping to allow storage to be utilized from hydrants in the Low Pressure Zone.

7. Analysis

7.1 Groundwater Well Supply Capacity

The supply capacity of the groundwater wells in the system is summarized in Table 7-1 below.

Table 7-1: Supply Capacity of Groundwater Wells

Well Number	Location	Capacity (1) (L/s)
Well 1	Oxford Site	22.0
Well 2	Oxford Site	15.0
Well 3	Oxford Site	22.0
Well 4	High Street	17.1
Well 5	Centennial Park Anderson Site (2)	34.2
Well 6	Merklin Site	21.2
Well 7	Merklin Site	24.6
Well 8	Oxford Site	17.5
Total:		173.6
Total with Largest Well Out of Service:		139.4
Sufficient Capacity for Existing Conditions (MDD = 135.9 L/s)		Yes
Sufficient Capacity for Future Conditions (2050 MDD = 152.5 L/s)		No

Notes:
1. Capacity from WTP FULL TEST RUN.xlsx provided by the City of White Rock on February 22, 2024.
2. Well 5 is currently under construction. It is expected to be completed in fall 2024 with a capacity of 34.2 L/s.

The City is currently developing an additional well source (Well 5, adjacent to Anderson Street in Centennial Park). The capacity of this well source is expected to be 34.2 L/s. Completion of Anderson Street Well 5 is included in the recommended project list (See Project ID 01 on Table 8-4).

As shown in the table, with Well 5 the current groundwater wells have sufficient capacity (i.e. with the largest well out of service) to supply existing MDD conditions (135.9 L/s). Under future MDD conditions (152.5 L/s), the capacity is not sufficient. An additional 13.1 L/s is required for future conditions.

Recent redevelopment work with Well 3 shows that, due to its condition, it needs replacement rather than continued redevelopment. Initial hydrogeological studies show that the location for the replacement Well (Well 9) could be in the vicinity of Centennial Park. The capacity of this new well should be at least equal to 35.1 L/s: the capacity of Well 3 (22 L/s) plus the estimated shortfall (13.1 L/s) to provide sufficient supply for future conditions. See Project ID 05 on Table 8-4.

While White Rock's system does have emergency connections to the City of Surrey's water system the use of these connections has not been included in source capacity calculations. Using these connections cannot be considered as the current agreement with the City of Surrey is for emergency use only. Regular use of these connections to meet peak demands is not part of the use agreement established with the City of Surrey.

The base demand in White Rock is steadily increasing due to growth, as expected. The seasonal demand was significantly higher in 2021 (i.e. 'the Heat Dome); a 15% increase relative to 2015, the previous high seasonal demand year was observed in 2021. As discussed in Section 3.4, an 8%

increase to the future seasonal demand scenario has been included to account for climate change and future 'Heat Dome' events.

Demand side management practices encourage customers to modify their level and pattern of use; this is another method utilized by water purveyors to manage increasing water use trends. The City's water conservation plan was completed in 2016 and it is recommended that the plan be updated approximately every 5 years. A water conservation plan update study focusing on decreasing peak usage to alleviate stress on the system during hot/dry summers is recommended.

7.2 Storage Capacity

There are three reservoir sites in the White Rock system, described in the following table.

Table 7-2: Reservoir Summary

Site	Pressure Zone	Description	Total Volume (ML)	Operation
Oxford	High	1. Two cell, rectangular, concrete reservoir, constructed in 2015.	1.95	• Filled by WTP. • Water pumped from reservoir to distribution via. Oxford Pump Station.
Merklin	High	1. Two cell, rectangular concrete reservoir, constructed in 2016. 2. Circular, concrete reservoir, constructed in 1989.	2.80	• Filled by WTP. • Water pumped from reservoirs to distribution via. Merklin Pump Station.
Roper	Low	1. Circular, concrete reservoir, constructed in 1989.	1.14	• Filled via. Roper PRV. • Discharges directly to Low Pressure Zone.
Total			**5.89**	

The total storage capacity requirement for the system is calculated as the sum of the balancing, fire and emergency storage components, and is shown in Table 7-3. The High-Pressure Zone cannot access storage located in Roper Reservoir, while the Low Zone can access water stored at all three reservoir sites. Therefore, the analysis considers the high and low zones separately.

MMCD Design Guidelines indicate that balancing storage is calculated based on 25% of maximum day demands. However, where the reservoir is servicing an existing area (with known water demands) the balancing storage volume can alternately be calculated based on measured demand patterns during maximum day demand periods. MMCD also indicates that the value should not be less than 12.5% of maximum day demand.

The requirement for balancing storage for this study (16% of MDD) is based on analysis of peak hour usage completed as part of previous master plans. This value was confirmed by reviewing 5 min interval peak summer demand data for 2020-2023. The observed peak day balancing volume in the past four years is 8-12% of the maximum day demand (see Appendix B). 16% of MDD for balancing storage volume was maintained in this analysis to allow for volume needed for system operation.

Table 7-3: Balancing Storage Required Versus Available

Available Storage	High Zone	Low Zone
Merklin Reservoirs	2.80 ML	2.80 ML
Oxford Reservoir	1.95 ML	1.95 ML
Roper Reservoir (Low Zone Only)	0 ML	1.14 ML
Total Available	**4.75 ML**	**5.89 ML**
Existing System Storage Requirement	High Zone	Low Zone
Required Balancing Storage (16% of MDD):	1.49 ML	0.39 ML
Required Fire Storage (212 L/s for 2.6 hours):	1.98 ML	1.98 ML
Required Emergency Storage (25% of Balancing + Fire):	0.87 ML	0.19 ML
Total Required	**4.34 ML**	**2.56 ML**
Sufficient Capacity for Existing Conditions	**Yes**	**Yes**
Future System Storage Requirement	High Zone	Low Zone
Required Balancing Storage (16% of MDD):	1.68 ML	0.43 ML
Required Fire Storage (212 L/s for 2.6 hours):	1.98 ML	1.98 ML
Required Emergency Storage (25% of Balancing + Fire):	0.92 ML	0.60 ML
Total Required	**4.58 ML**	**3.02 ML**
Sufficient Capacity for Future Conditions	**Yes**	**Yes**

Based on the assessment, adequate balancing storage is provided by the current system for the forecast future demands.

Further review of 5 min interval reservoir levels during peak summer periods for 2020-2023 indicates actual reservoir volumes in the High Zone were below the volume reserved for fire plus emergency storage (2.85 ML) in 2021 (June 27 and 28) and 2023 (July 8 and 9). These events are illustrated in the plots included in Appendix B. The volume level decreased as low as 2.58 ML on June 27, 2021.

Given the balancing storage volume observed only amounted to 1.2 ML, the available storage volume should be sufficient without using volume reserved for emergency and fire conditions according to our calculations. Therefore, the following operational adjustments are recommended for the City to review and implement:

- Calibrate / verify pressure transducer readings (% full) are accurate based on actual levels.
- Adjust operation so that the full capacity of the reservoirs is utilized. Review of the available reservoir data in Appendix B suggests that approximately 0.5 ML of storage is not utilized (tanks are not completely filled).
- Review and adjust the fill setting for the Merklin reservoirs. As discussed in Section 4.3, the maximum fill rate for the Merklin reservoirs (combined) is 75 L/s as per the SCADA programming at the WTP. While this should not impact the current operation (where Oxford and Merklin combine to supply the High Zone), this will have an impact on the ability to provide adequate service when the Everall PRV (Project ID 04) is implemented and the Oxford supply HGL is lowered. The City has indicated that this setting will be reviewed/adjusted. If the 75 L/s setting cannot be adjusted, or only marginally increased, it is recommended that the Everall PRV project be re-examined.
- Ensure well supply capacity is adjusted daily to meet the average day demand requirement. It is noted that on June 27, 2021, the available well capacity was less than then average day demand

(128 L/s available vs. 133 L/s). Completion of Well #5 and development of a new well are recommended as high priority projects to ensure the available well supply can meet existing and future maximum day demands, as discussed in Section 7.1. A demand side management study is also recommended to promote water conservation (See project ID 06 on Table 8-4).

7.3 System Pressure

Figure 7-1 and Figure 7-2 show peak hour pressure under existing and future demand conditions, respectively.

Modelling indicates that there are low pressure deficiencies (< 300 kPa/44 psi) at the following locations:

- Top of the High-Pressure Zone in the vicinity of North Bluff Road between George Street and Merklin Street, near the Merklin Booster Station: Minimum pressures in this area are 41 psi. The pressures are governed by the discharge pressure setpoint at the Merklin Booster Pump Station (currently 320 kPa or 141.5 m HGL). To provide adequate pressures a slightly higher discharge setpoint is required (350 kPa or 145 m HGL).
- Top of the Low-Pressure Zone in the vicinity of Beachview Avenue and Johnston Road: Minimum pressures in this area are 27 psi. This area is serviced by a parallel watermain located in the High-pressure zone.
- On Royal Lane between Johnston Road and Dolphin Street in the Low-Pressure Zone. The elevation in this area is 69 m GD. The low pressures in this area are due to the normal operating levels in the Roper Reservoir (kept at approx. 70% full during the day, or 99 m HGL). As a result, the minimum pressure in this area is marginally below the criteria (41 psi vs. 43.5 psi).

Pressures in excess of the maximum pressure limit (1,035 kPa/150 psi) are located at the bottom of the High-Pressure Zone (West) near Marine Drive and Magdalen Crescent. Maximum pressures are experienced at the zone boundary on Marine Drive and Magdalen Crescent (160 psi) and Marine Drive and High Street (184 psi). Reduction in the High Zone West pressures by 10 m HGL or 14 psi is expected to address this deficiency except for a very short section of main on High Street north of Marine Drive (at the bottom of a steep hill at the zone boundary).

Splitting the existing High-Pressure Zone into a 145 m High Zone East (supplied by Merklin Pump Station) and a 135 m High Zone East (supplied by Oxford Pump Station) is recommended to address the observed high and low pressures.

The proposed pressure zone split would require:

- A new zone boundary on Thrift Avenue (no cost assuming existing valve is in adequate condition).
- A new Everall Street PRV and check valve station. A 200 mm diameter PRV and check valve are recommended to provide supply resiliency in emergency supply conditions. See Project ID 04.

7.4 Available Fire Flow

Figure 7-3 and Figure 7-4 show available fire flow results under existing and future demand conditions, respectively. Modelling indicates that the available fire flow does not meet the requirements at the following locations.

Table 7-4: Fire Flow Analysis Summary

Zone	Location	Fire Flow (L/s)			Discussion
		Required	Available		
			Existing	Future	
High West	North Bluff Rd. & Oxford St.	212	196	193	Constrained by 200 mm dia. CI pipes supplying the location. See Project IDs 07 and 10.
High East	Martin St., North Bluff Rd. to Thrift Ave.	212	169	168	Constrained by 150 mm dia. CI pipe on Martin St. See Project ID 08.
High East	Russell Ave., Best St. to Finlay St.	212	136	135	Constrained by 150 mm dia. CI pipe on Russell Ave. See Project ID 11.
High East	Vidal St., Thrift Ave. to Vine Ave.	212	194	193	Constrained by 150 mm dia. CI pipe on Vidal St. See Project ID 13.
High East	Merklin St., Roper Ave. to Thrift Ave.	212	181	180	Constrained by 100 mm dia. CI pipe on Merklin St. See Project ID 17.
Low	Oxford St., Buena Vista Ave to McDonald St.	212	175	174	Constrained by 150 mm dia. CI and DI pipes supplying the area. See Project IDs 14, 15, and 16.
Low	Everall St. & Blackwood Lane	212	132	131	Constrained by 150 mm dia. and 100 mm dia. pipes supplying the area. See Project IDs 15 and 16.
Low	Buena Vista Ave, Foster St. to Oxford St.	212	145	144	Constrained by 150 mm dia. CI pipe. See Project ID 16.
Low	Johnston Rd. & Royal Ave.	212	168	167	Constrained by 150 mm dia. CI pipe. See Project ID 12.
Low	Columbia Ln. & Balsam St.	67	58	57	Constrained by 100 mm dia. CI pipe. See Project ID 09.

The East Side Large Lot Infill Area (North Bluff Road between Finlay Street and Kent Street) is currently single-family residential but is zoned for future multi family. Should this area develop into multi-family, additional upgrades including 200 mm diameter mains and additional hydrants would be required on Maple Street (Project ID 42) and Lee Street (Project ID 43), and the 250 mm diameter water main recommended on Russell Avenue should be extended to Kent Street (Project ID 41). Similarly, water main upgrades on Foster Street (Project ID 44), George Street (Project ID 45) and Fir Street (Project ID 46) are recommended to service new development in these areas.

Multiple Hydrant Demonstration

On January 19, 2024, KWL provided a demonstration using the water model to review system pressures when multiple hydrants are opened in a single area (i.e. to simulate conditions in an actual fire event when multiple hydrants are utilized). The demonstration was attended by representatives from the City and the White Rock Fire Department. Three locations were demonstrated, as follows:

1. North Bluff Road and Finlay Street (High Pressure Zone).
2. Intersection of Johnston Road and Pacific Avenue (High- and Low-pressure zones).
3. Marine Drive and Finlay Street (Low Pressure Zone).

The analysis was performed as follows:

1. Run the model at a single model junction to calculate the maximum available flow with minimum 21.8 psi residual zone pressure.
2. Split the flow (max 100 L/s each) amongst several hydrants with the sum adding up to the maximum available fire flow calculated in step 1 and review impact on pressure.

The analysis was completed using the existing demand scenario. The results are included in Appendix C and demonstrate that, at these locations, the pressure in the system is not adversely impacted (i.e. does not drop below 21.8 psi) when available flows are split amongst several hydrants. In fact, in some areas, using multiple hydrants can improve the available pressure because the flow is not concentrated on a single section of water main.

7.5 Supply Resiliency

Two scenarios were analyzed to determine how the system performs under atypical, emergency supply conditions. These scenarios were modelled with the proposed Everall PRV station (Project ID 04) and are summarized as follows:

1. Supply from Oxford Pump Station only (e.g. Merklin Reservoir/Pump Station is offline).
2. Supply only available from the City of Surrey emergency connections located at Best Street and Oxford Street (e.g. WTP is offline).

Supply from Oxford Pump Station Only

Supply from the Oxford station only at a pressure of 135 m HGL (lowered High Zone West pressure with proposed Everall PRV) is not adequate to supply the entire system under the future base day demand scenario (i.e. minimal demand). The pressure at the high point on North Bluff Road at George Street (112 m elevation) is 11 psi. There are considerable losses in the distribution system under these conditions (15 m or 21 psi head losses) which can be addressed by water main upgrades; however, it is noted that a 135 m HGL supply pressure is not adequate to supply the highest area of the High Zone East. The supply pressure must be at least 143 m HGL to supply the highest point in the system.

The available pressure in the system is improved if the supply pressure from the Oxford Pump Station is adjusted to 143 m and the closed zone boundary valve at Thrift Avenue is opened; the pressure at the high point on North Bluff Road at George Street (112 m elevation) is 20 psi under the peak hour demand scenario. Figure 7-5 illustrates the water model results under this scenario.

The analysis indicates that peak hour demands on max day can be accommodated but pressures are lower than typical peak hour criteria (target minimum is 43.5 psi). Fire flows would need to be supplemented from an alternate source (i.e. City of Surrey emergency supply points, discussed below) under this scenario.

Supply from City of Surrey Emergency Connections Only

The White Rock water system has historically had four normally closed emergency connections to the City of Surrey. Since the experience of utilizing these connections in May 2016 for the large fire event, White Rock and Surrey have worked cooperatively towards improving the operability and quality of these connections. In 2022 the connection at North Bluff Road and Best Street was upgraded to include an additional isolation valve as well as blow offs. The City plans to upgrade the connection at North Bluff Road and Oxford Street as well in the near term.

Both the North Bluff Road/Oxford Street and North Bluff Road/Best Street connection are to Surrey's Sunnyside (149 m HGL) Pressure Zone. Based on modelling completed for the City of Surrey in 2018[2], the available supply pressure under maximum day demand emergency flow conditions (future demands maximum day demands plus fire flow = 370 L/s for White Rock) are as follows:

- 141 m HGL available at the North Bluff Road/Best Street connection; and
- 133 m HGL available at the North Bluff Road/Oxford Street connection.

Modelling was performed to analyze the impact to the system with only the City of Surrey emergency supply connections (i.e. all White Rock supply is offline).

Analysis results for peak hour pressure and available fire flow are included in Figure 7-6 and Figure 7-7, respectively. As shown, the minimum pressures are lower than typical peak hour criteria (target minimum is 43.5 psi) but are considered adequate for these emergency conditions. Likewise, the available fire flow is lower than the target criteria for White Rock.

The pressure and available fire flow results can be improved with additional upgrades to the White Rock distribution system, described as follows:

- Replace the existing 200 mm diameter cast iron main along North Bluff Road between Oxford Street and Finlay Street with 300 mm diameter main. This main is aging and located on the Surrey side of North Bluff Road. Upgrading this main with a 300 mm diameter main when replaced will improve the resiliency of the system during atypical supply conditions. See Project IDs 30 and 31.
- Replace the existing 200 mm diameter cast iron main on Oxford Stret between North Bluff Road and Thrift Avenue with 250 mm diameter main. This section forms key conveyance between the Oxford WTP and the rest of the system and upgrading this main to 250 mm diameter when replaced will improve system supply resiliency. See Project ID 32.

It is noted that the available pressure and fire flow in White Rock under these conditions is dependent on the available HGL in the City of Surrey system. The results presented herein are based on available modelling results for the Surrey distribution system. The available HGL should be periodically confirmed as additional planning and modelling work is completed by Surrey.

7.6 Distribution System Resiliency

Water Main Break History Update

The City provided an update of their water main break history from 2017 to 2022[3]; this was added to the previous break history for a record going back to 2000. A map showing the past pipe break locations are shown on Figure 7-10.

In the last three years of data the City has averaged 11 breaks/year. The break rate has remained essentially constant (with some year-to-year statistical variation) over the entire period of record.

The following observations are noted:

1. **The break rate is within the typical range.** The City's average break rate is 0.15 breaks/km/year. This compares to average rate of 0.22 break/km/year published in the 2018 Comprehensive Study

[2] Future 2045 demand scenario including the 10-year upgrade infrastructure plan.

[3] Location of 2019 breaks were not available. The City (email from Simon Pither September 1, 2023) indicated the number of breaks in 2019 were in the 6-10 range.

of Water Main Breaks in the USA and Canada by the University of Utah. The break rate observed in White Rock is within the normal average for utilities.

2. **Cast Iron pipe is more susceptible to breaks**. The break rate is much higher on the older cast iron pipe (182 total breaks on CI pipe vs. 19 breaks on DI pipe) although the number of breaks on DI piping has increased in recent years (see below).
3. **The break rate on Ductile Iron pipe is increasing**. In the years 2000 to 2018, the average break rate on DI pipe is 0-1 per year. Since 2018, the average rate of DI breaks has increased to an average of 3 per year. The City has indicated that corrosive soils are known within White Rock and have include cathodic protection on all new ductile iron water main installations.
4. **Most breaks occur on small diameter pipe**: 186 of 204 breaks (91%) of the breaks recorded in the historical record have occurred on pipe that is 150 mm dia. and smaller. As reference, this size of pipe makes up 60% of the White Rock distribution system.

Certain geographic clusters of breaks are noted in the break history. Areas with notable recurring break history (i.e. three or greater) are summarized below.

- Coldicutt Avenue, between Chestnut Street and Lancaster Street: 150 mm dia. CI;
- Kerfoot Road, between Vine Avenue and Sunset Drive: 100 mm dia. CI;
- Brearley Street, between North Bluff Road and Blackburn Avenue: 150 mm dia. DI;
- Martin Street, between Thrift Avenue and Roper Avenue: 150 mm dia. CI;
- Johnston Road, between Thrift Avenue and Prospect Avenue: 250 mm dia. CI;
- Columbia Lane, between Cypress Street and Ash Street: 100 mm dia. CI;
- Balsam Street, between Royal Lane and Pacific Avenue: 100 mm dia. CI;
- Parker Street, between Cliff Avenue and Pacific Avenue: 100 mm dia. CI;
- Kent Street, between Thrift Avenue and Buena Vista Avenue: 100 mm dia. CI;
- Prospect Crescent, west section connecting to Roper Avenue: 100 mm dia. CI; and
- Habgood Street, between Vine Avenue and Russell Avenue: 100 mm dia. CI.

Distribution System Resiliency Assessment

The White Rock distribution system is relatively dense and well looped. Small diameter mains (150 mm dia. and smaller) make up the majority (60%) of the distribution system. As shown in the break history review, smaller diameter mains are more susceptible to breaks and leaks.

A model scenario was completed in which the small diameter system looped connections (150 mm dia. and smaller) were closed to assess the performance of the system using only the larger more reliable mains. Model results for peak hour pressure and available fire flow under future maximum day demand conditions are included in Figure 7-8 and Figure 7-9, respectively.

As shown on Figure 7-8, the current large diameter network is able to meet peak hour pressure requirements.

Figure 7-9 illustrates that available fire flows are diminished under these conditions. For some single-family areas with 100 - 150 mm diameter piping only, it is expected that the available fire flow would be greatly diminished. Areas servicing commercial, multi family, and mixed-use development with available fire flow below the design criteria under these conditions that are not already captured in the available fire flow assessment under typical supply conditions (Section 7.4) are summarized as follows:

- North Bluff Road, between Best Street and Kent Street, See Project IDs 11, 31 and 33;
- Marine Drive between Martin Street and Dolphin Street, See Project IDs 34, 35, and 36; and
- Marine Drive between Finlay Street and Stayte Road, See Project IDs 37 and 38.

In addition, there is an area of the water system on Royal and Pacific avenues, between Johnston Road and Finlay Street that does not have full connectivity (i.e. sections of the loops have not been installed). To improve system resiliency in this area, additional water mains/ water main extensions are recommended (See Project IDs 39, 40, and 26).

Water Main Asset Management Study

An asset management study will allow the City to better understand the condition of the water mains in the system and allow for development of a proactive approach to water main replacement. The study would review asset classes, maintenance history (breaks, etc.), and condition information to determine a sustainable asset management program for the utility's water mains. See Project ID 18.

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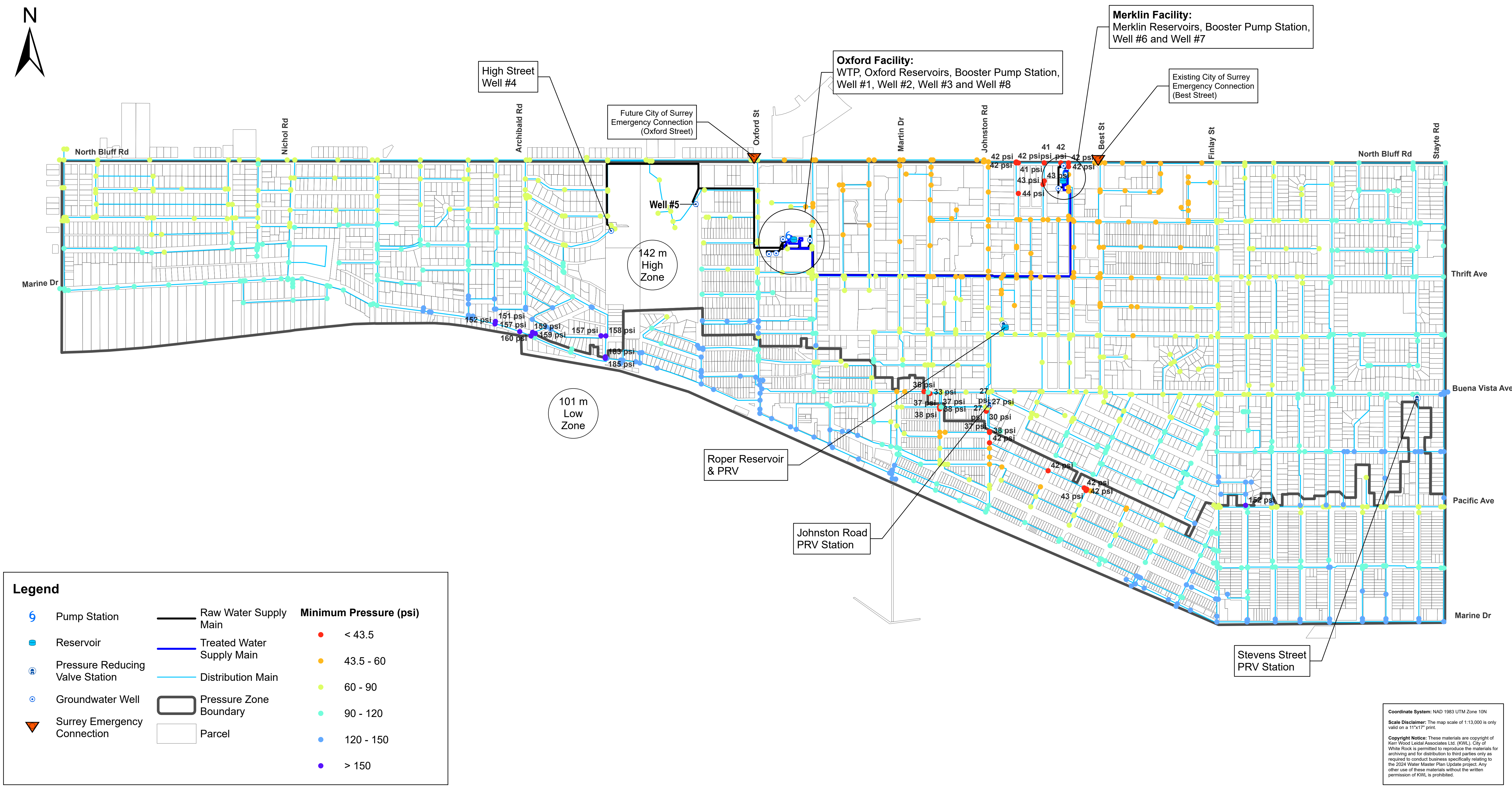


Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

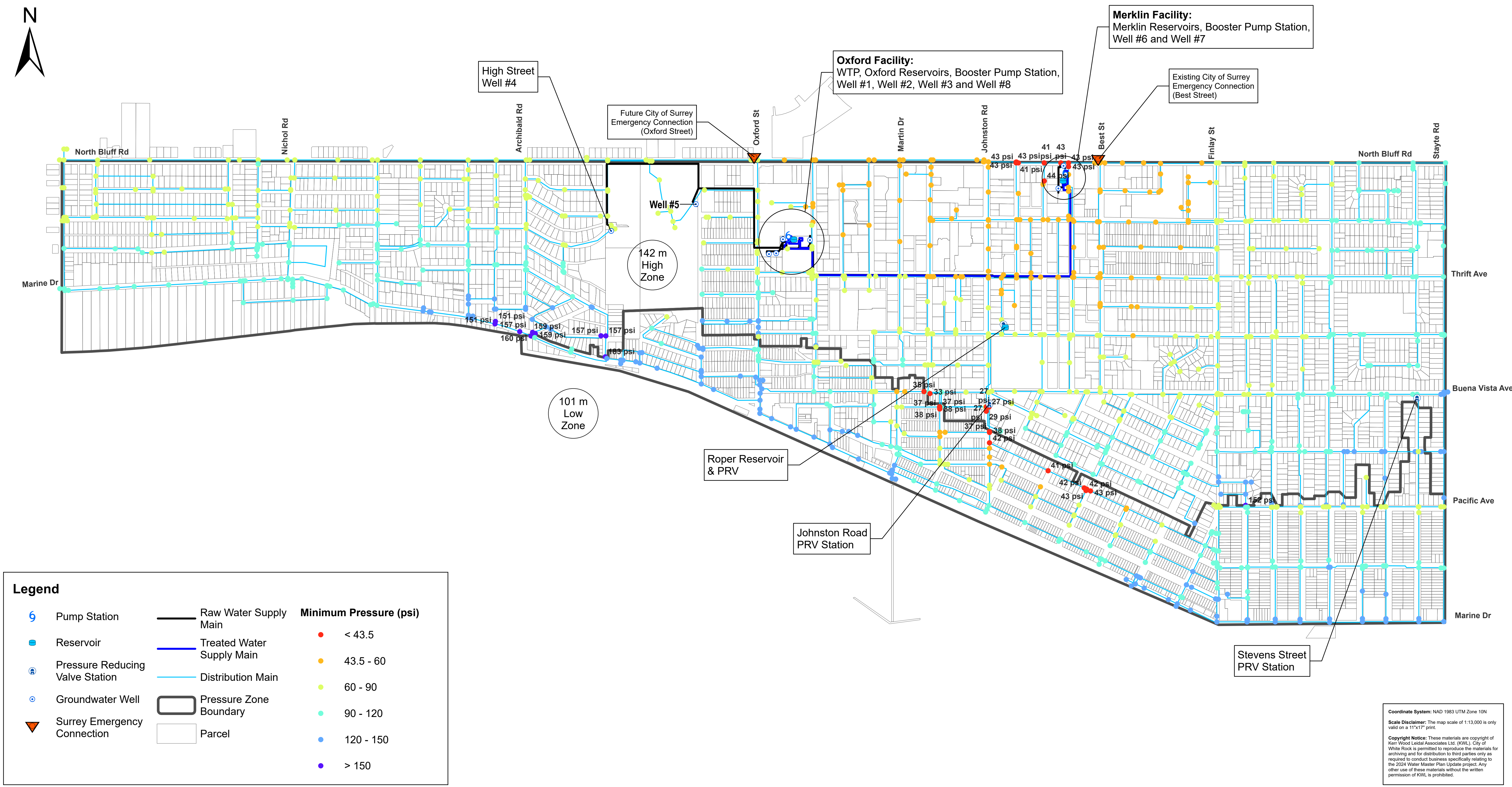
Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

Existing System with Existing MDD - Peak Hour Pressure

Figure 7-1

City of White Rock
2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

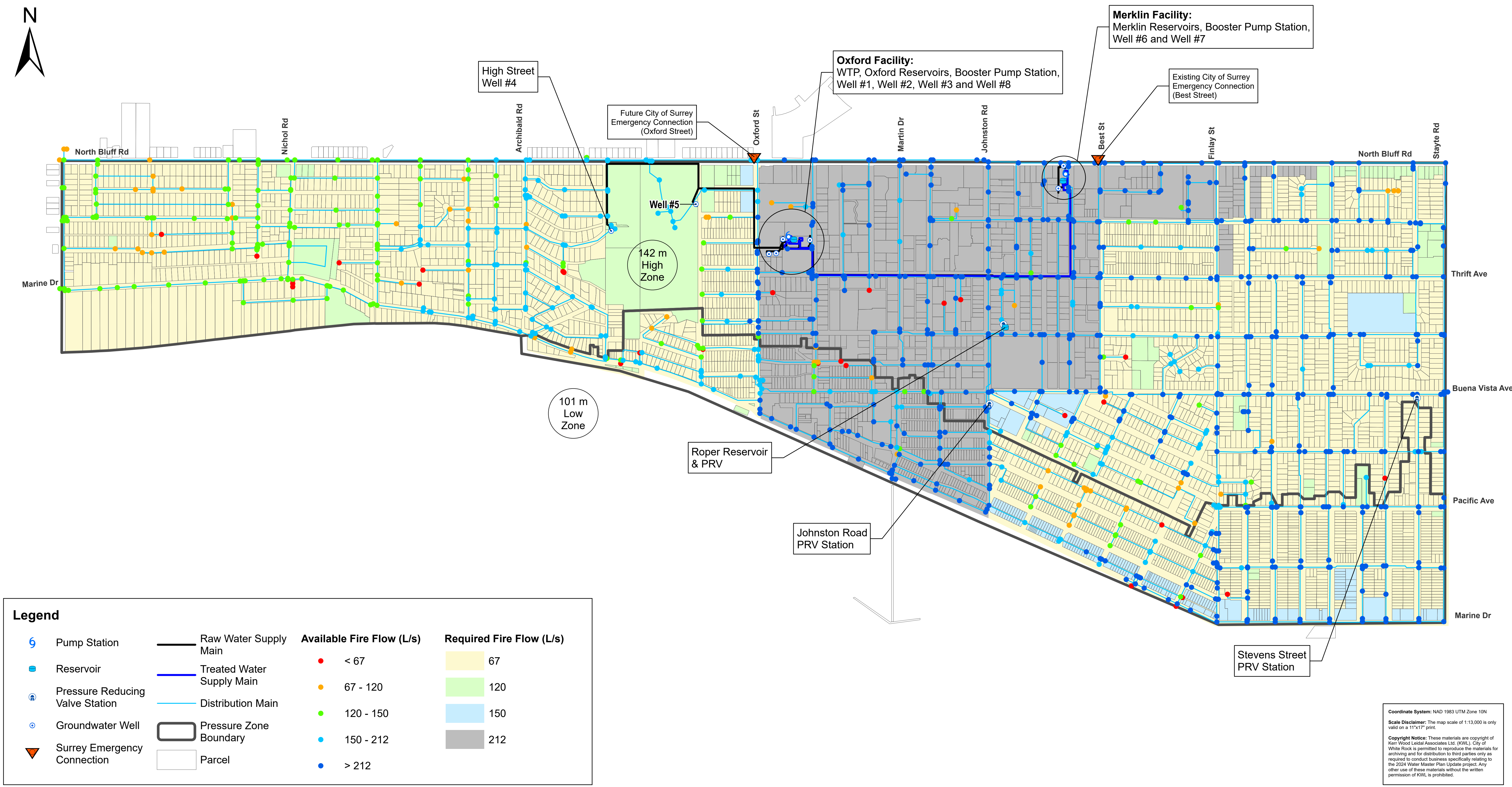
Existing System with Future MDD - Peak Hour Pressure

Figure 7-2

City of White Rock

2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



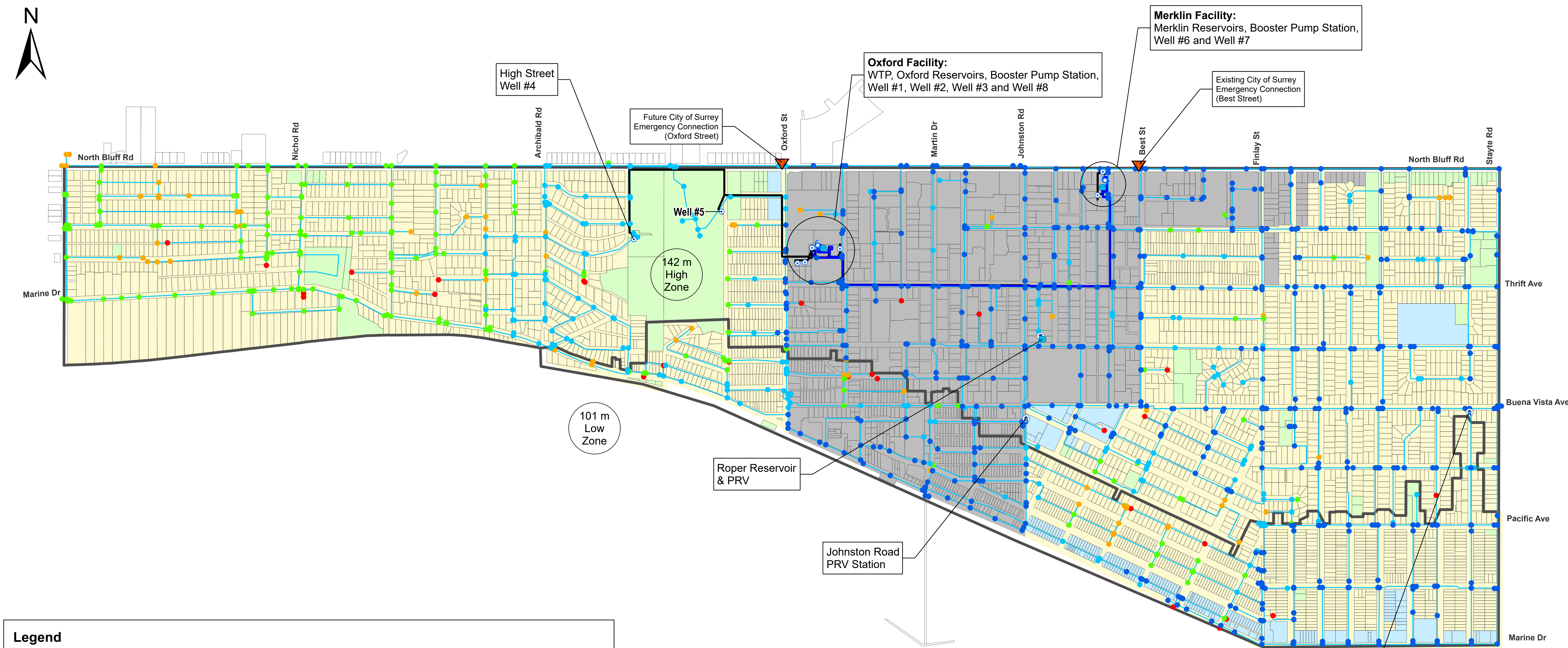
Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

Existing System with Existing MDD - Available Fire Flow

Figure 7-3



Legend

- Pump Station
- Reservoir
- Pressure Reducing Valve Station
- Groundwater Well
- Surrey Emergency Connection
- Raw Water Supply Main
- Treated Water Supply Main
- Distribution Main
- Pressure Zone Boundary
- Parcel

Available Fire Flow (L/s)

- < 67
- 67 - 120
- 120 - 150
- 150 - 212
- > 212

Required Fire Flow (L/s)

- 67
- 120
- 150
- 212

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

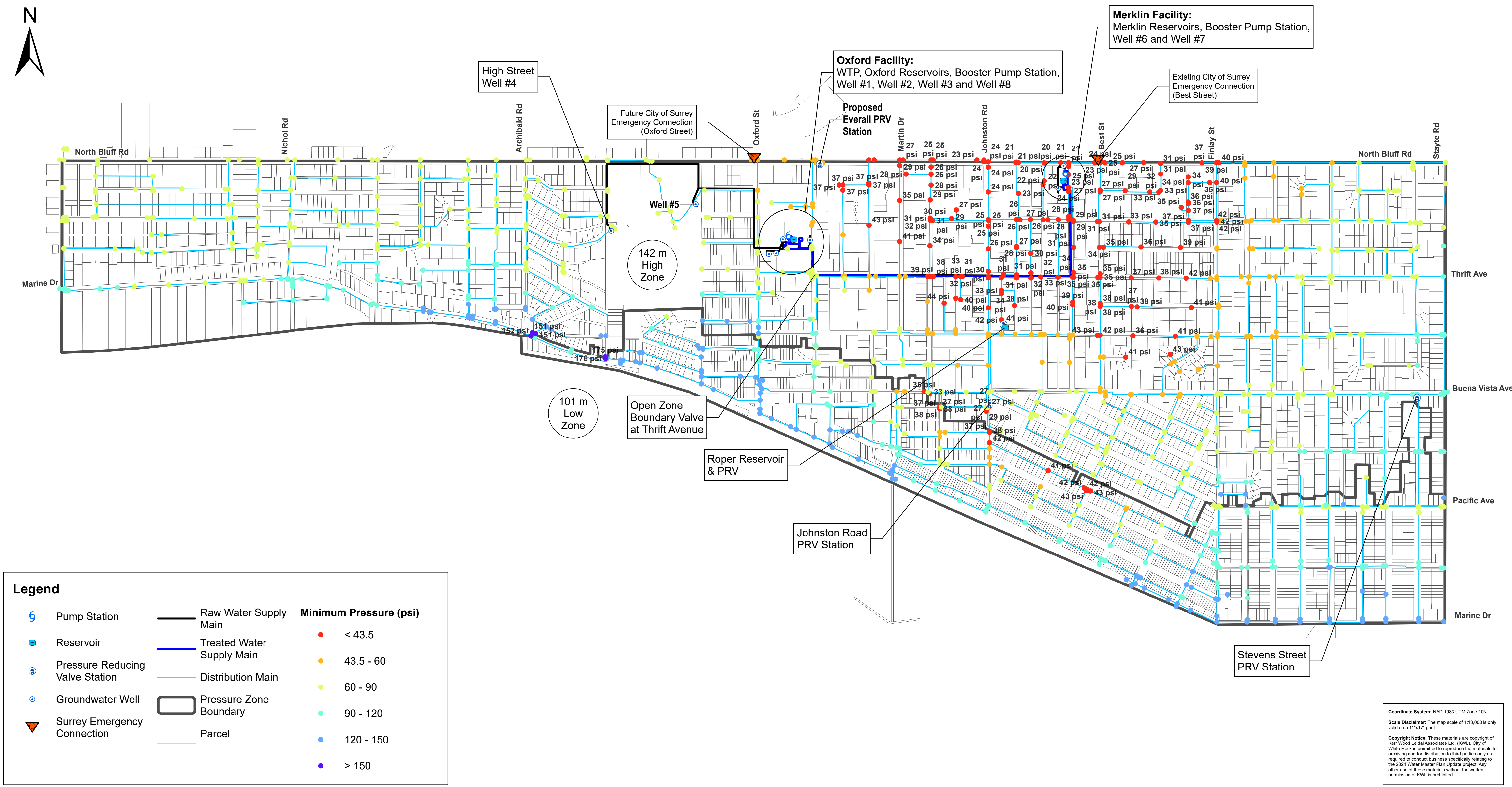
0 50 100 200 Metres

Existing System with Future MDD - Available Fire Flow

Figure 7-4

City of White Rock
2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



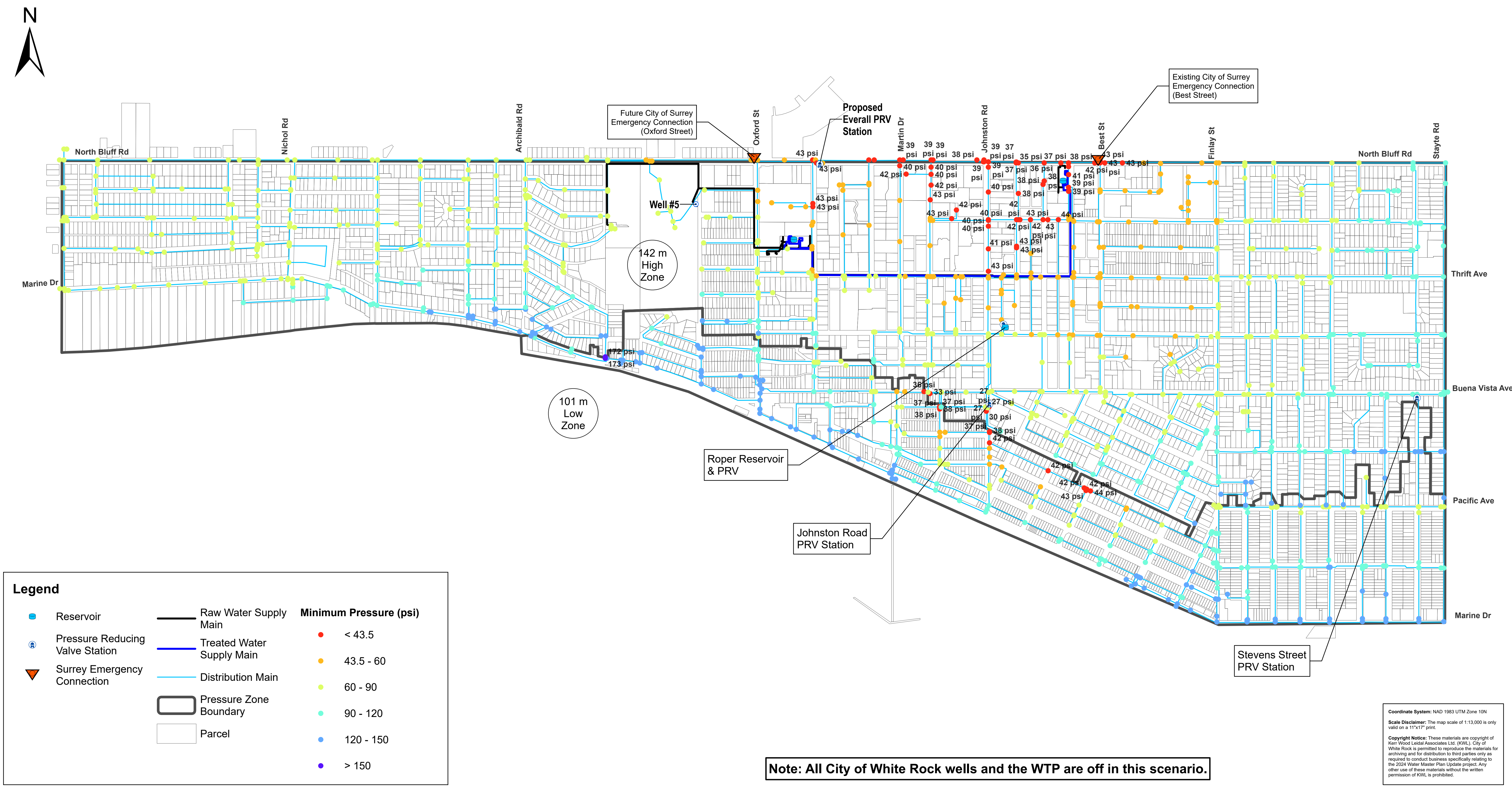
Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

Oxford Supply Only with Future MDD - Peak Hour Pressure

Figure 7-5

City of White Rock
2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Note: All City of White Rock wells and the WTP are off in this scenario.

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

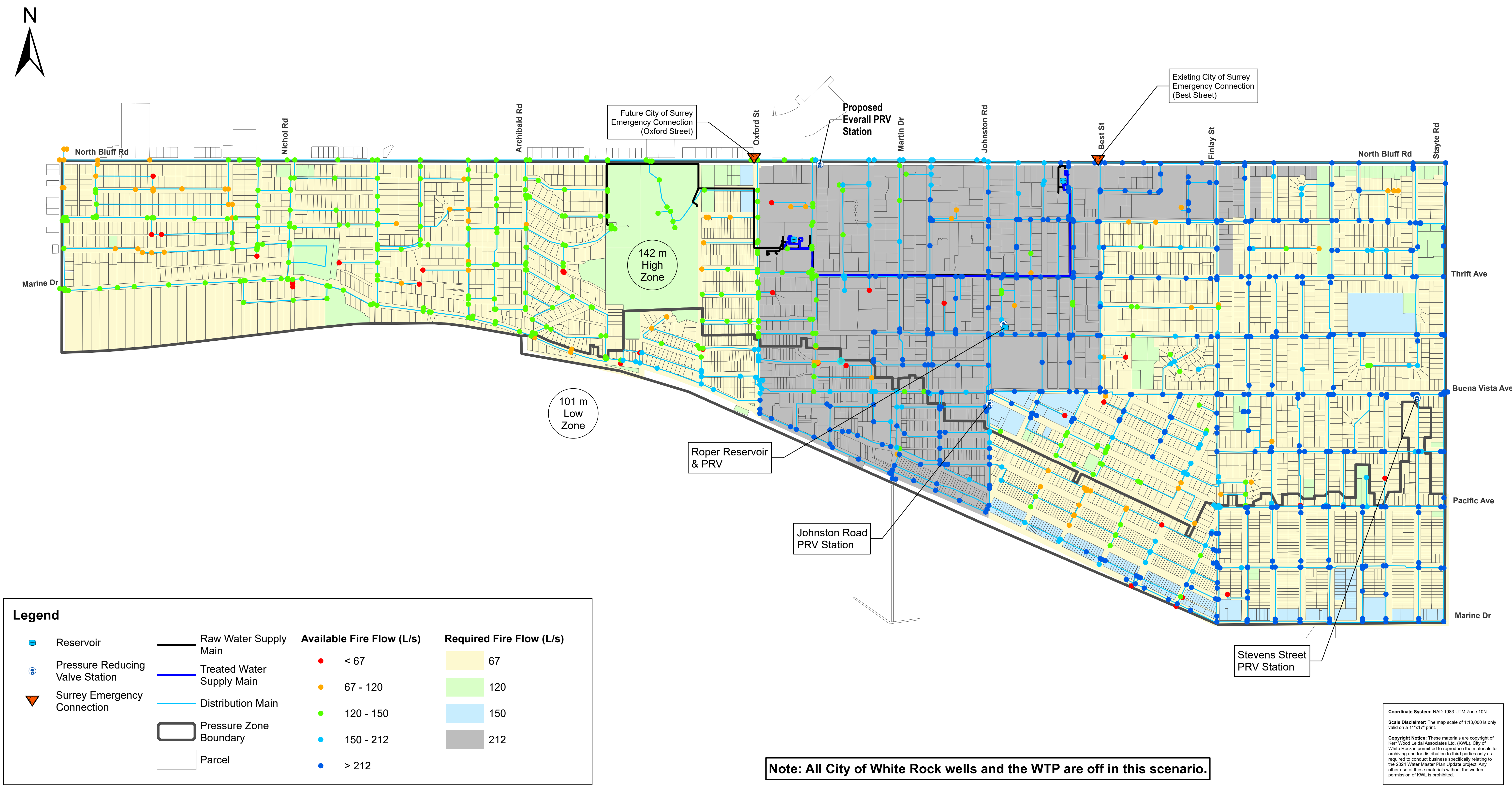
Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

City of Surrey Emergency Connection Supply with Future MDD - Peak Hour Pressure

Figure 7-6

City of White Rock
2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Note: All City of White Rock wells and the WTP are off in this scenario.

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

0 50 100 200 Metres

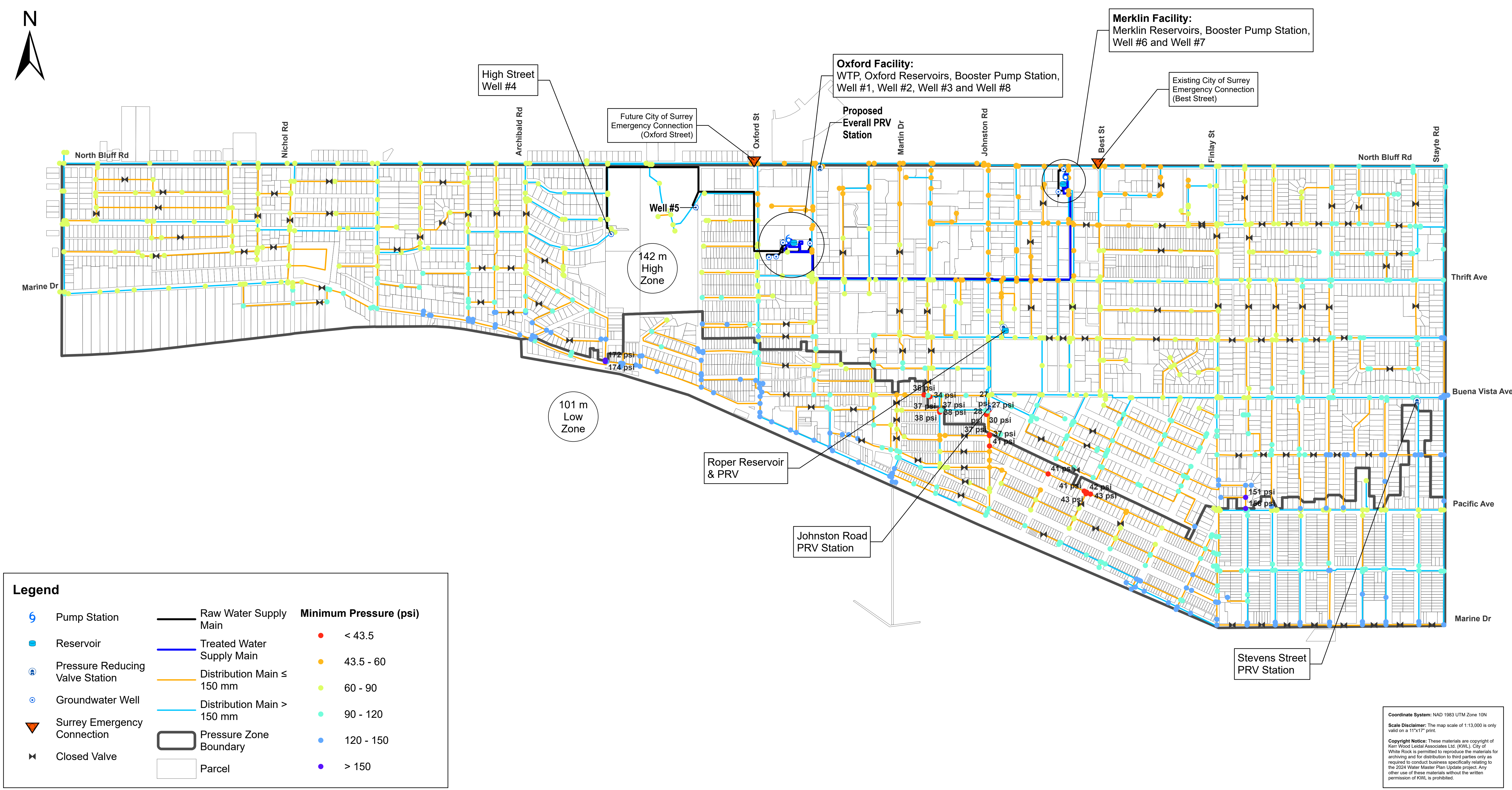
City of Surrey Emergency Connection Supply with Future MDD - Available Fire Flow

Figure 7-7

City of White Rock

2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

0 50 100 200 Metres

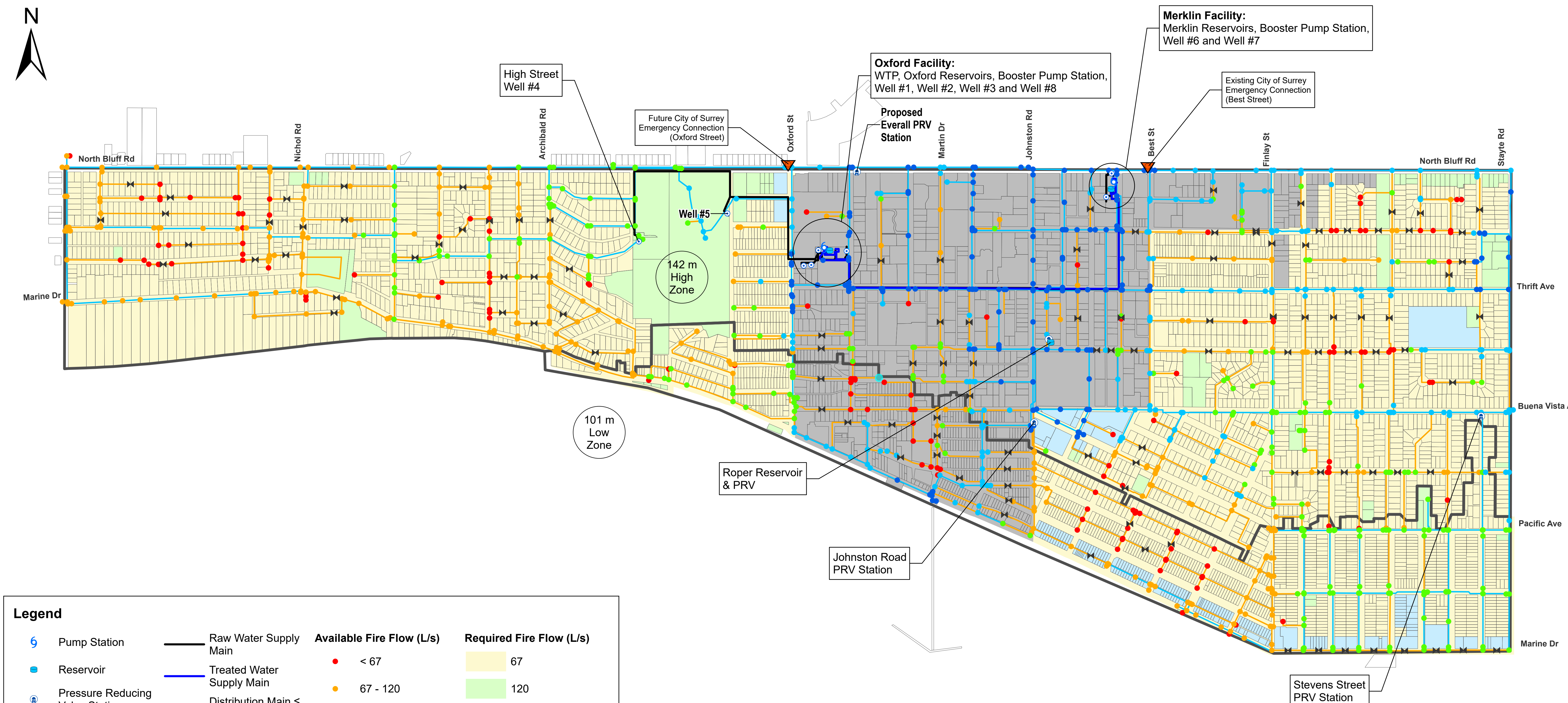
Distribution System Resiliency Assessment with Future MDD - Peak Hour Pressure

Figure 7-8

City of White Rock

2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Legend

Pump Station	Raw Water Supply Main
Reservoir	Treated Water Supply Main
Pressure Reducing Valve Station	Distribution Main ≤ 150 mm
Groundwater Well	Distribution Main > 150 mm
Surrey Emergency Connection	Pressure Zone Boundary
Closed Valve	Parcel

Available Fire Flow (L/s)	Required Fire Flow (L/s)
< 67	67
67 - 120	120
120 - 150	150
150 - 212	212
> 212	

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

0 50 100 200 Metres

Distribution System Resiliency Assessment with Future MDD - Available Fire Flow

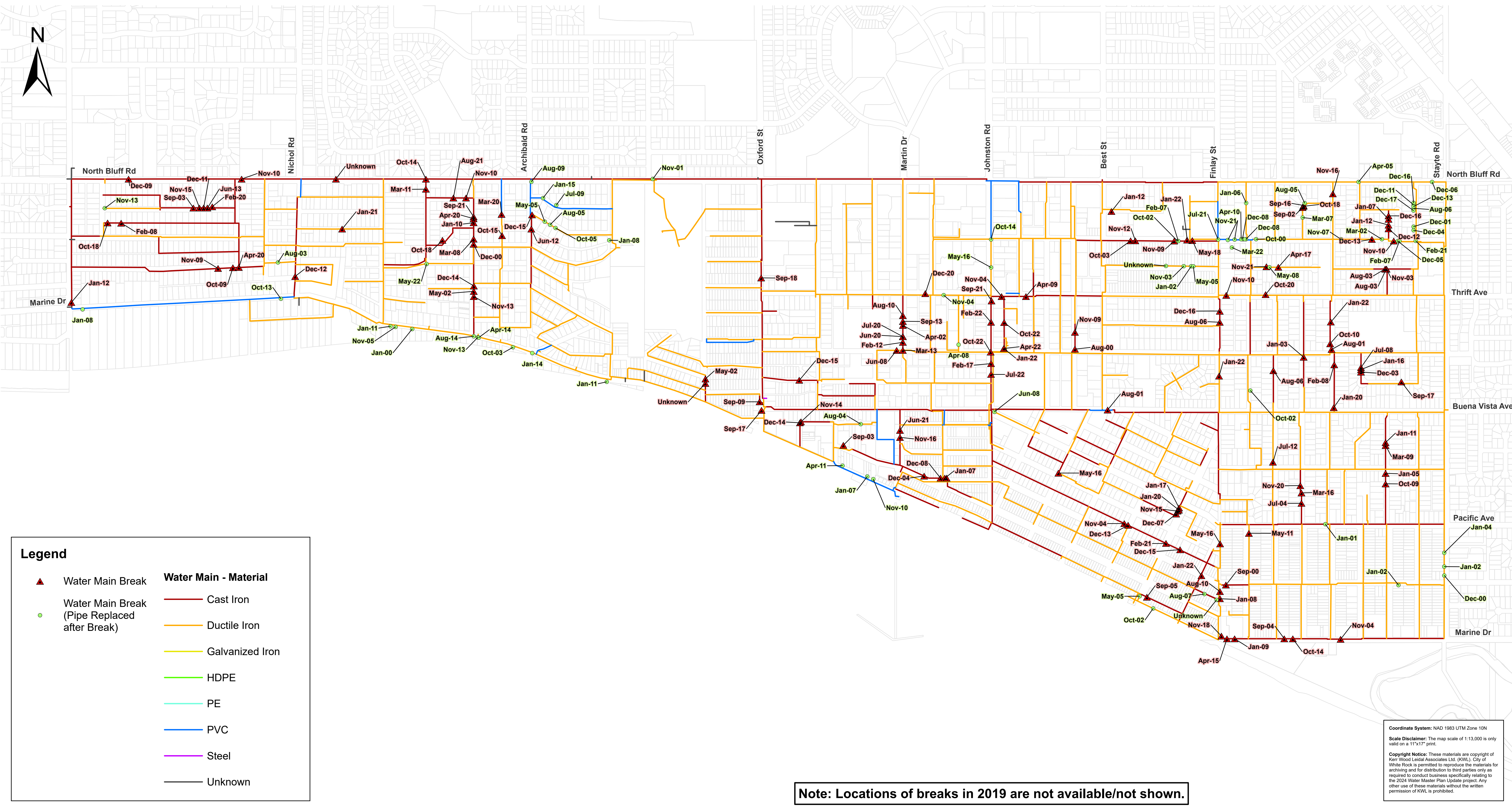
Figure 7-9

Path: P:\0400-0499\452-133\430-GIS\Pro Projects\0452133_Figures\0452133_Figures.aprx\0452133_Figure_WatermainBreaks_7-10 | Date Saved: 2024-03-28 3:50 PM | Author: tromans

City of White Rock

2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

0 50 100 200 Metres

Water Main Breaks: 2000 - 2022

Figure 7-10

8. Recommended Upgrades and Prioritization

8.1 Recommended Upgrades

All recommended improvements to address supply, pressure, and fire flow deficiencies are summarized on Table 8-4 and on Figure 8-1. Upgrades to improve supply and address condition and distribution system resiliency are also included in the recommended project list.

Model results with the recommended upgrades are shown on Figure 8-2 and Figure 8-3 for peak hour pressure and available fire flow, respectively.

To improve system resiliency and as per MMCD design criteria, the minimum recommended water main size is 200 mm diameter. In some cases, 150 mm diameter main is recommended to minimize water quality concerns in locations where the main services a small residential area or if the main is a dead end (i.e. zone boundary).

8.2 Cost Basis

Class 'D' indicative cost estimates have been developed for each recommended upgrade and are included in Table 8-4. These estimates have been developed with no site information and are considered to be suitable for long term capital planning.

Parameters used in cost estimating are summarized as follows:

- 20% allowance for engineering;
- 30% allowance for contingencies;
- Land acquisition costs (if required) are not included; and
- All costs are in 2023 dollars with no allowance for inflation.

Unit prices developed for water main project costing are summarized in Table 8-1.

Table 8-1: Water Main Unit Costs

Size	Unit Cost
150 mm dia.	$1,770
200 mm dia.	$1,860
250 mm dia.	$2,330
300 mm dia.	$2,640

8.3 Prioritization

The recommended upgrades have been prioritized as either of low, medium, or high priority. The methodology for ranking the projects considers the severity of the deficiency being addressed, the relative cost compared to the service area being impacted by the deficiency, and local area land use. The following general guidelines for project completion timelines is as shown below:

- High: Schedule for completion within 2 to 5-year timeframe;
- Medium: Schedule for completion in 5 to 10-year timeframe; and
- Low: Schedule for completion in 10 to 20-year timeframe or as local development takes place.

While the above guidelines are provided for budgeting, the need for the individual projects should be assessed year-to-year. For instance, the well development projects may be increased in priority if water demands increase quicker than forecast. Similarly, break history may indicate the need to re-prioritize certain projects. As well, the City should consider coordination of work with other utilities (sewer, road rehabilitation) when scheduling the projects.

A summary of the projects by priority is shown in the following table.

Table 8-2: Project Cost Summary by Priority Ranking

Priority	Number of Projects	Cost Estimate
High	5	$6,490,400
Medium	10	$5,084,600
Low	31	$18,544,600
Total	**46**	**$30,119,600**

A summary of the projects by main project driver is provided in the following table.

Table 8-3: Project Cost Summary by Main Project Driver

Main Project Driver	Number of Projects	Cost Estimate
Supply System	6	$6,990,000
Fire Flow	11	$6,189,800
Asset Management	12	$5,386,000
Resiliency	11	$9,156,300
Development Servicing	6	$2,397,500
Total	**46**	**$30,119,600**

Table 8-4: Recommended Upgrades

2023 ID	Description	Justification Category	Justification [2]	Priority	Location	Length (m)	Size	Cost Rate	Cost Estimate	Notes on Cost	Included in CoWR Current 5-Year Capital Plan [1] (Y/N)	Comparison to 2017 Water Master Plan Recommendations
01	New Supply Source - Well 5	Supply System	Increase supply capacity.	1 - High	Centennial Park at Anderson St.	N/A	N/A	N/A	$ 2,600,000	Cost provided by the City.	Y - 2023	Included in 2017 Master Plan, Project ID 1.
02	Surrey Emergency Connection Upgrading	Supply System	Through consultation with the City of Surrey, install emergency connections at four locations.	1 - High	Various	N/A	N/A	N/A	$ 300,000	Cost provided by the City.	Y - 2023	Included in 2017 Master Plan, Project ID 27.
03	Aquifer Capacity Study	Supply System	Review current well interference zones and inform location for new well with sufficient capacity (Project 05)	1 - High	System Wide	N/A	N/A	N/A	$ 300,000	Cost provided by the City.	N	Not included in 2017 Master Plan.
04	Everall Street PRV Station - 200 mm dia.	Supply System/ Pressure Management	Split High Zone to Merklin High Zone East and Oxford High Zone West and provide subsequent fire protection to proposed zones.	2 - Medium	North Bluff Rd., east of Everall St.	N/A	N/A	N/A	$ 750,000	Allowance	Y - 2028	Included in 2017 Master Plan, Project ID 5. Recommended diameter increased form 150 to 200 mm dia. to improve supply capacity under emergency supply conditions.
05	New Supply Source - Well 9	System Supply, Asset Management	Existing Well 3 requires frequent redevelopment and the capacity is degrading. Well 9 is intended to replace Well 3, and therefore the recommended capacity is 35.1 L/s, at minimum.	1 - High	Centennial Park	N/A	N/A	N/A	$ 3,000,000	Cost provided by the City.	N	Included in 2017 Master Plan, Project ID 19. Location has been revised from Oxford Site to Centennial Park based on recent hydrogeological studies and recommendations.
06	Water Conservation Plan Update	Supply System	Hot/dry weather is expected to increase due to Climate Change. The previous Water Conservation Plan was completed in 2016 and is recommended to be updated approximately every 5 years. The plan is recommended to focus on reducing and modifying patterns of use as to alleviate the peak day water demand during hot/dry periods.	2 - Medium	Customer Usage System Wide	N/A	N/A	N/A	$ 40,000	Allowance	N	Not included in 2017 Master Plan.
07	New Goggs St. WM - Oxford to Water Treatment Plant	Redundancy, Fire Flows	Improve supply capacity and redundancy of the distribution system around the Oxford booster PS. Also improves fire flow (193 L/s available vs 212 L/s criteria). The local area land use includes Town Centre Transition and Institutional.	1 - High	Goggs St. WM - Oxford to Water Treatment Plant	110	300	$2,640	$ 290,400	See Table 8-1	Y - 2026	Included in 2017 Master Plan, Project ID 7.
08	Martin St. WM Upgrade - North Bluff to Thrift	Fire Flows	Existing 150 CI main is undersized for high-density multifamily fire flows (168 L/s available vs 212 L/s criteria). The local area land use includes Town Centre and Town Centre Transition.	2 - Medium	Martin St., North Bluff to Thrift	410	200	$1,860	$ 762,600	See Table 8-1	Y - 2028	Included in 2017 Master Plan, Project ID 18.
09	Columbia Lane WM Upgrade - Cypress St. to Ash St.	Fire Flows, Asset Management	Replace existing 100 CI main to improve fire flows (currently marginal for SF; 57 L/s available vs 67 L/s criteria), project improves fire flow to 140 L/s. The local area land use is Mature Neighbourhood. Existing main also has break history (2 breaks in last 4 years).	2 - Medium	Columbia Lane - Cypress St. to Ash St.	310	200	$1,860	$ 576,600	See Table 8-1	Y - 2025	Included in 2017 Master Plan, Project ID 12. Recommended size increased from 150 mm dia. to 200 mm dia. to improve system resiliency.
10	North Bluff Rd. WM Upgrade - Oxford St. to Everall St.	Redundancy, Fire Flows	Existing 200 CI main is undersized for high-density MF fire flows (193 L/s available vs 212 L/s criteria). The local area land use includes Institutional and Town Centre Transition. Also replaces critical CI pipe on high traffic location.	2 - Medium	North Bluff Rd. from Oxford St. to Everall St.	200	300	$2,640	$ 528,000	See Table 8-1	Y - 2028	Included in 2017 Master Plan, Project ID 20. Recommended size increased from 250 mm dia. to 300 mm dia. to improve system resiliency.
11	Russell Ave. WM Upgrade - Merklin St. to Finlay St.	Asset Management, Fire Flows	Replaces existing CI pipe undersized for fire flows (135 L/s available vs 212 L/s requirement). The local area land use is Institutional.	2 - Medium	Russell Ave. from Merklin St. to Finlay St.	520	250	$2,330	$ 1,211,600	See Table 8-1	N	Included in 2017 Master Plan, Project ID 29. Recommended size increased from 200 mm dia. to 250 mm dia. and length increased from Weatherby St. to Finlay St. to improve system resiliency to supply the East Side Large Lot Area.
12	Johnston Rd. WM Upgrade - Beachview Ave. to Columbia Ln.	Fire Flows	Existing modelled fire flows in area are deficient (167 L/s vs 212 L/s criteria). The local area land use includes Urban Neighbourhood and Mature Neighbourhood. This project also replaces aging CI pipe in steep area.	3 - Low	Johnston Rd. - Beachview Ave. to Columbia Ln.	120	250	$2,330	$ 279,600	See Table 8-1	N	Included in 2017 Master Plan, Project ID 33. Recommended size increased from 200 mm dia. to 250 mm dia. to improve system resiliency.

2023 ID	Description	Justification Category	Justification [2]	Priority	Location	Length (m)	Size	Cost Rate	Cost Estimate	Notes on Cost	Included in CoWR Current 5-Year Capital Plan [1] (Y/N)	Comparison to 2017 Water Master Plan Recommendations
13	Vidal St. WM Upgrade - Thrift to Vine	Fire Flows	Existing modelled fire flows in area are deficient (193 L/s vs 212 L/s criteria). The local area land use is Town Centre Transition. This project also replaces aging CI pipe.	3 - Low	Vidal St. - Thrift Ave. to Vine Ave.	330	200	$1,860	$ 613,800	See Table 8-1	N	Included in 2017 Master Plan, Project ID 32.
14	Prospect Ave. WM Upgrade- Oxford St. to Everall St.	Fire Flows, Asset Management	Replaces existing 100 mm CI undersized for fire flows (174 L/s available vs 212 L/s criteria). The local area land use is Mature Neighbourhood.	3 - Low	Prospect Ave. from Oxford St. to Everall St.	200	200	$1,860	$ 372,000	See Table 8-1	N	Included in 2017 Master Plan, Project ID 21.
15	Everall St. WM Upgrade- Prospect Ave. to Buena Vista Ave.	Fire Flows, Redundancy	Replaces 150 mm dia DI piping undersized for fire flows (131 L/s available vs 212 L/s criteria. The local area land use is Mature Neighbourhood.	3 - Low	Prospect Ave. and Blackwood St. from Everall St. to Buena Vista Ave.	110	200	$1,860	$ 204,600	See Table 8-1	N	Included in 2017 Master Plan, Project ID 22. Alignment has been adjusted to avoid the ravine on Prospect Ave. between Everall St. and Blackwood St.
16	Buena Vista Ave. WM Upgrade - Foster St. to Everall St.	Fire Flows, Asset Management	Replaces existing 150 mm CI undersized for fire flows (144 L/s available vs 212 L/s criteria). The local area land use includes Urban Neighbourhood and Mature Neighbourhood.	3 - Low	Buena Vista Ave. from Foster to Everall St.	420	250	$2,330	$ 978,600	See Table 8-1	N	Included in 2017 Master Plan, Project ID 23. Alignment has been adjusted to avoid the ravine on Prospect Ave. between Everall St. and Blackwood St.
17	Merklin St. WM Upgrade - Thrift Ave. to Roper Ave	Fire Flow, Asset Management	Replaces existing 100 mm dia CI and 150 mm dia. DI for fire flows (180 L/s available vs. 212 L/s required). The local area land use includes Urban Neighbourhood.	3 - Low	Merklin St. between Thrift Ave. and Roper Ave.	200	200	$1,860	$ 372,000	See Table 8-1	N	Not included in 2017 Master Plan.
18	Water Main Asset Management Study	Asset Management	Existing CI mains are potentially nearing the end of their service life. Existing DI piping are showing signs of failure due to corrosion. This program will gather more information on pipe condition which will provide insight to an asset management strategy.	2 - Medium	System Wide	N/A	N/A	N/A	$ 200,000	Allowance	N	Included in 2017 Master Plan, Project ID 14.
19	Coldicutt Ave. WM Upgrade - 13755 Coldicutt to Lancaster	Asset Management	Existing CI main has extensive break history. Also will allow for future elimination of main on lane south of Coldicutt.	2 - Medium	Coldicutt Ave., 13755 Coldicutt to Lancaster	270	200	$1,860	$ 502,200	See Table 8-1	Y - 2023	Included in 2017 Master Plan, Project ID 17. Recommended size increased from 150 mm dia. to 200 mm dia. to improve system resiliency.
20	Martin St. WM Upgrade - Thrift to Roper	Asset Management	Existing CI main has extensive break history.	2 - Medium	Martin St., Thrift to Roper	200	200	$1,860	$ 372,000	See Table 8-1	N	Included in 2017 Master Plan, Project ID 16. Recommended size increased from 150 mm dia. to 200 mm dia. to improve system resiliency.
21	Habgood St. WM Upgrade	Asset Management	Break history. CI pipe. High pressure (100 psi).	3 - Low	Habgood St. between Vine and Russell	110	150	$1,770	$ 194,700	See Table 8-1	Y - 2023	Included in 2017 Master Plan, Project ID 25.
22	Kerfoot Rd. WM Upgrade - Vine Ave. to Marine Dr.	Asset Management	Existing 100 mm dia. CI main has extensive break history. Also will allow for connection to Marine Drive which is currently a closed valve.	3 - Low	Kerfoot Rd. from Vine Ave. to Marine Dr.	430	200	$1,860	$ 799,800	See Table 8-1	N	Not included in 2017 Master Plan.
23	Abandon Pipe in Rear Yard of 1500 Phoenix St. and Upgrade Park Ave. WM	Asset Management	Existing 100 mm dia. CI pipe is located in the rear and side yards of 1500 Phoenix St. and 14258 Park Ave. City has indicated the access to this main is limited and is a operation / maintenance concern. The existing main on Park Ave. servicing Hydrant #331 requires upsizing from 100 mm dia. to 150 mm dia. to provide adequate fire flow when the section in the rear yard is abandoned.	3 - Low	Park Ave. from Kerfoot Rd. to Hydrant #331	70	150	$1,770	$ 133,900	See Table 8-1 - ab additional allowance of $10,000 has been added to the water main cost to allow for abandoning the 100 mm dia. main.		Not included in 2017 Master Plan.
24	Brearley St. WM Replacement - North Bluff Rd. to Blackburn Ave.	Asset Management	Existing 150 mm dia. DI main has extensive break history. Section between North Bluff Rd. and Hydrant #157 has already been replaced.	2 - Medium	Brearley St. from Hydrant #157 (140 m S of North Bluff Rd.) to Blackburn Ave.	80	150	$1,770	$ 141,600	See Table 8-1	N	Not included in 2017 Master Plan.
25	Johnston Rd. WM Upgrade - Thrift Ave. to Prospect Ave.	Asset Management	Existing 250 mm dia. CI main has extensive break history.	3 - Low	Johnston Rd. from Thrift Ave. to Prospect Ave.	320	250	$2,330	$ 745,600	See Table 8-1	N	Not included in 2017 Master Plan.

2023 ID	Description	Justification Category	Justification [2]	Priority	Location	Length (m)	Size	Cost Rate	Cost Estimate	Notes on Cost	Included in CoWR Current 5-Year Capital Plan [1] (Y/N)	Comparison to 2017 Water Master Plan Recommendations
26	Balsam St., Royal Ave., Cypress St. and Pacific Ave. Loop	Asset Management, Resiliency	Existing 100 mm dia. CI main has extensive break history and is located rear yards which makes accessing the main for repairs challenging.	3 - Low	Balsam St. from Pacific Ln. to Royal Ave. Royal Ave. from Balsam St. to Cypress St. Cypress St. from Royal Ave. to Pacific Ln. Pacific Ave. from Cypress St. to Balsam St.	560	200	$1,860	$ 1,041,600	See Table 8-1	N	Not included in 2017 Master Plan.
27	Parker St. WM Upgrade - Cliff Ave. to Pacific Ave.	Asset Management	Existing 100 mm. dia. CI main has extensive break history. This section is closed at the south end to form the zone boundary (i.e. functionally a dead end main).	3 - Low	Parker St. from Cliff Ave. to Pacific Ave.	190	150	$1,770	$ 336,300	See Table 8-1	N	Not included in 2017 Master Plan.
28	Kent St. Water Main Upgrade - Thrift Ave. to Buena Vista Ave.	Asset Management	Existing 100 mm dia. CI main has extensive break history.	3 - Low	Kent St. from Thrift Ave. to Buena Vista Ave.	370	200	$1,860	$ 688,200	See Table 8-1	N	Not included in 2017 Master Plan.
29	Prospect Cres. WM Upgrade - West connection to Roper Ave.	Asset Management	Existing 100 mm dia. CI main has extensive break history. Forms a local loop around Prospect Crescent.	3 - Low	Prospect Cres. West connection to Roper Ave.	130	150	$1,770	$ 230,100	See Table 8-1	N	Not included in 2017 Master Plan.
30	North Bluff Rd. WM Upgrade - Everall St. to Johnston Rd.	Resiliency, Asset Management	Replaces existing 200 mm dia. CI main on the Surrey side of North Bluff Road. Provides improved resiliency along major supply corridor between Merklin Pump Station and Oxford WTP and services the Town Centre and Town Centre Transition areas.	3 - Low	North Bluff Rd. from Everall St. to Johnston Rd.	600	300	$2,640	$ 1,584,000	See Table 8-1	N	Not included in 2017 Master Plan.
31	North Bluff Rd. WM Upgrade - George St. to Finlay St.	Resiliency, Asset Management	Replaces existing 250 mm dia. CI on North Bluff Road. Provides improved resiliency along major supply corridor from Merklin Pump Station to the Hospital and services the Town Centre and Town Centre Transition areas.	3 - Low	North Bluff Rd. from George St. to Finlay St.	720	300	$2,640	$ 1,900,800	See Table 8-1	N	Not included in 2017 Master Plan.
32	Oxford St. WM Upgrade- North Bluff Rd. to Thrift Ave.	Resiliency, Asset Management	Replaces existing 200 mm dia. CI main on Oxford St. Provides improved resiliency along major supply corridor from Oxford WTP and services the Town Centre Transition area.	3 - Low		400	250	$2,330	$ 932,000	See Table 8-1	N	Not included in 2017 Master Plan.
33	Finlay St. WM Upgrade - Roper Ave. to Russell Ave.	Resiliency, Asset Management	Replaces existing 100 mm CI and 150 mm DI on Finlay St. Provides improved system resiliency on the periphery of the East Side Large Lot area.	3 - Low	Finlay St. from Russell Ave. to Roper Ave.	420	200	$1,860	$ 781,200	See Table 8-1	N	Not included in 2017 Master Plan.
34	Marine Dr. WM Upgrade - Martin St. to Foster St.	Resiliency, Asset Management	Replaces 150 mm dia. CI main on Marine Drive and improves resiliency of supply to Waterfront Commercial area.	3 - Low	Marine Dr. from Foster St. to Martin St.	170	200	$1,860	$ 316,200	See Table 8-1	N	Included in 2017 Master Plan, Project ID 31. One section of upgrade has already been completed (between Foster St. and Hydrant #201).
35	Marine Dr. WM Upgrade - Foster St. to Johnston Rd.	Resiliency, Asset Management	Replaces 150 mm dia. CI main on Marine Drive and improves resiliency of supply to Waterfront Commercial area.	3 - Low	Marine Dr. from Hydrant #201 (mid block) to Johnston Rd.	130	200	$1,860	$ 241,800	See Table 8-1	N	Included in 2017 Master Plan, Project ID 31. One section of upgrade has already been completed (between Foster St. and Hydrant #201).
36	Marine Ln. WM Upgrade - Johnston Rd. to Dolphin St.	Resiliency, Asset Management	Replaces 150 mm dia. CI main on Marine Ln. and improves resiliency of supply to Waterfront Commercial area.	3 - Low		280	200	$1,860	$ 520,800	See Table 8-1	N	Not included in 2017 Master Plan.
37	Johnston Rd. - Columbia Ln. to Marine Ln.	Resiliency, Asset Management	Replaces 150 mm dia. CI main on Johnston Rd. and improves resiliency of supply to Waterfront Commercial area.	3 - Low	Johnston Rd. from Columbia Ln. to Marine Ln.	230	250	$2,330	$ 535,900	See Table 8-1	N	Not included in 2017 Master Plan.
38	Marine Dr. WM Upgrade - Finlay St. to Stayte.	Resiliency, Asset Management	Replaces 150 mm dia. CI main on Marine Dr. and improves resiliency of supply to Waterfront commercial and multi family area.	3 - Low		820	200	$1,860	$ 1,525,200	See Table 8-1	N	Not included in 2017 Master Plan.
39	Royal Ave. to Fir St. Water Main Loop	Resiliency, Asset Management	Loops high zone piping and improves resiliency. Replaces 40 m of existing 100 mm dia. CI pipe.	3 - Low	Royal Ave. from Johnston Rd. to Fir St. Fir St. from Royal Ave to Pacific Ave.	160	200	$1,860	$ 297,600	See Table 8-1	N	Not included in 2017 Master Plan.
40	Pacific Ave. WM Extension - Fir St. to Dolphin St.	Resiliency, Asset Management	Loops high zone piping and improves resiliency. Replaces 120 m of existing 100 mm dia. CI pipe.	3 - Low	Pacific Ave. from Fir St. to Dolphin St.	280	200	$1,860	$ 520,800	See Table 8-1		Not included in 2017 Master Plan.
41	Russell Ave. WM Upgrade - Maple St. to Kent St.	To service development	Replaces existing 150 mm dia. DI on Russell Ave. to service the East Side Large Lot Area. Area is currently single family and is being developed into multi family.	3 - Low	Russell Ave. from Maple St. to Kent St.	300	250	$2,330	$ 699,000	See Table 8-1	N	Not included in 2017 Master Plan.

2023 ID	Description	Justification Category	Justification [2]	Priority	Location	Length (m)	Size	Cost Rate	Cost Estimate	Notes on Cost	Included in CoWR Current 5-Year Capital Plan [1] (Y/N)	Comparison to 2017 Water Master Plan Recommendations
42	Maple St. WM Upgrade - North Bluff Rd. to Russell Ave.	To service development	Replaces 150 mm dia DI piping on Maple St. to service East Side Large Lot Area. Currently there are no hydrants mid block and this area is single family residential and being developed into multi family.	3 - Low	Maple St from North Bluff Rd. to Russell Ave.	200	200	$1,860	$ 372,000	See Table 8-1	N	Not included in 2017 Master Plan.
43	Lee St. WM Upgrade - North Bluff Rd. to Russell Ave.	To service development	Replaces 100/150 mm dia DI piping on Lee St. to service East Side Large Lot Area. Currently there are no hydrants mid block and this area is single family residential and being developed into multi family.	3 - Low	Lee St. from North Bluff Rd. to Russell Ave.	200	200	$1,860	$ 372,000	See Table 8-1	N	Not included in 2017 Master Plan.
44	Foster St. WM Upgrade - North Bluff Rd. to Russell Ave.	To service development	Replaces 200 mm dia. DI piping on Foster St. to complete 250 mm dia. loop.	3 - Low	Foster St. from North Bluff Rd. to Russell Ave.	150	250	$2,330	$ 349,500	See Table 8-1		Not included in 2017 Master Plan.
45	George St. WM Upgrade - North Bluff Rd. to Russell Ave.	To service development	Replaces 200 mm dia. DI piping on George St. to complete 250 mm dia. loop.	3 - Low	George St. from North Bluff Rd. to Russell Ave.	100	250	$2,330	$ 233,000	See Table 8-1	N	Not included in 2017 Master Plan.
46	Fir St. New WM - Russell Ave to Thrift Ave.	To service development	New water main section required to service development and provide a hydrant midblock.	3 - Low	Fir St. from Russell Ave. to Thrift Ave.	200	200	$1,860	$ 372,000	See Table 8-1	N	Not included in 2017 Master Plan.

Notes:
1. City of White Rock 2023 to 2028 Draft Water Utility 5 Year Plan (provided November 17, 2023 but Corrine Haer).
2. For projects recommended to improve fore flow, confirmation of fire flow requirements and availability (via. Field testing) is recommended prior to construction.

City of White Rock
2024 Water Master Plan Update

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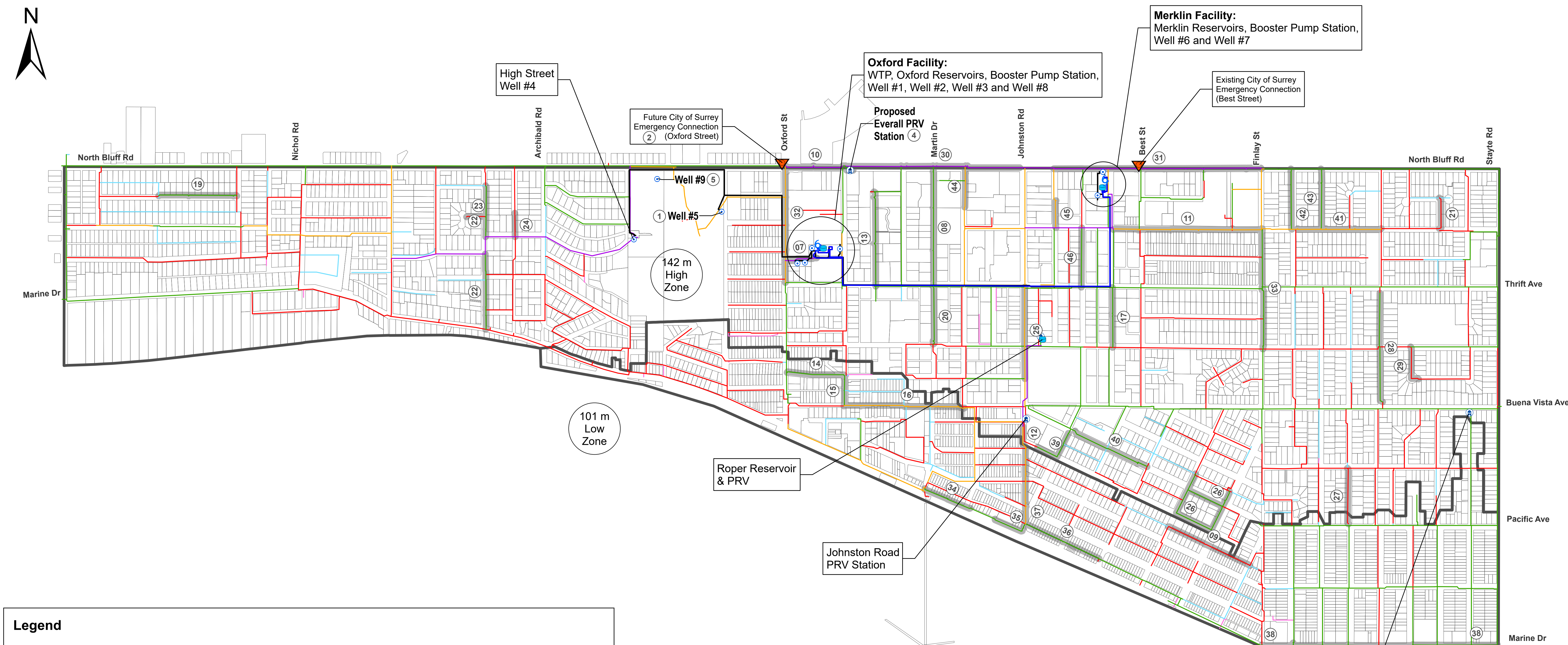


Legend

- Pump Station
- Reservoir
- Pressure Reducing Valve Station
- Groundwater Well
- Surrey Emergency Connection
- Raw Water Supply Main
- Treated Water Supply Main
- Pressure Zone Boundary
- Parcel

Water Distribution Main - Nominal Diameter

- < 100
- 100
- 150
- 200
- 250
- 300
- 350
- 400
- (ID) Proposed Water Main Upgrade

System Wide Projects:

(3) (6) (18)

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

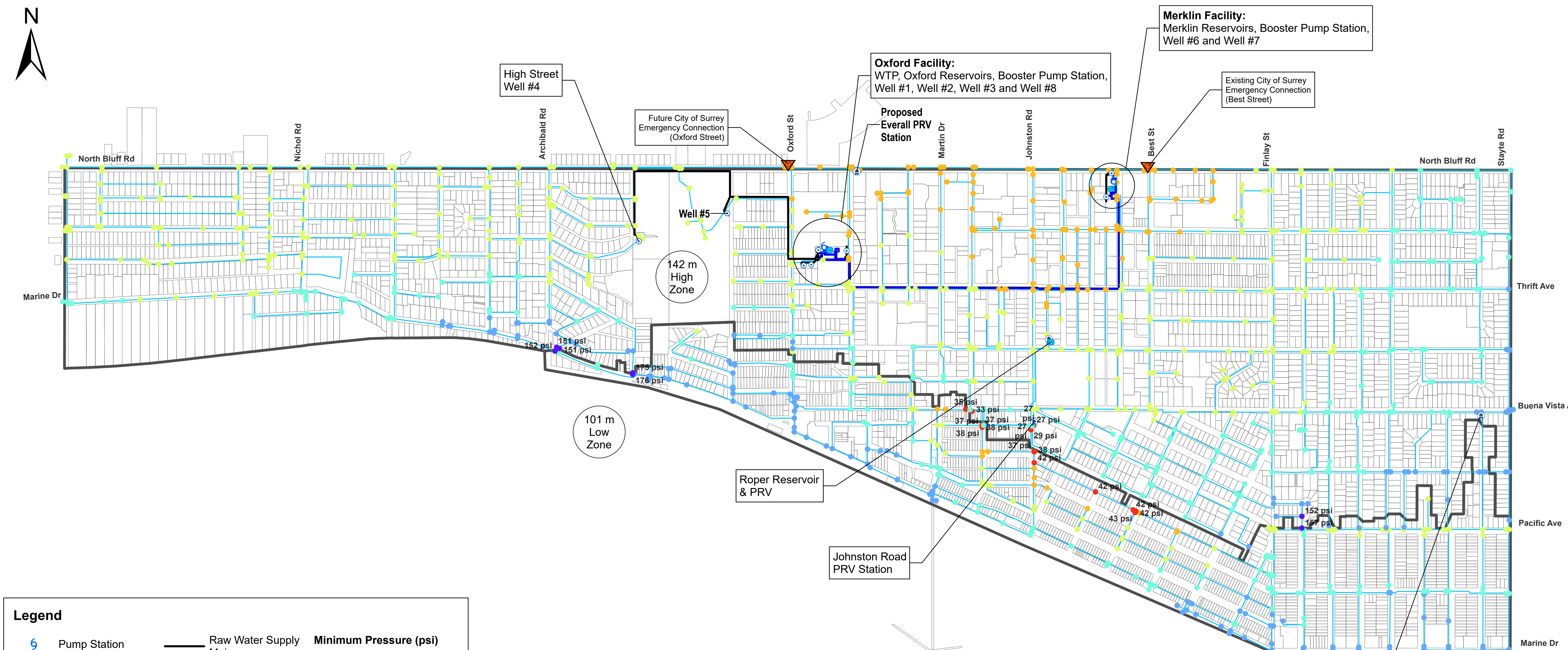
0 50 100 200 Metres

Recommended Water System Upgrades

Figure 8-1

City of White Rock
2024 Water Master Plan Update

KERR WOOD LEIDAL consulting engineers



Legend

Pump Station	Raw Water Supply Main	**Minimum Pressure (psi)**
Reservoir	Treated Water Supply Main	< 43.5
Pressure Reducing Valve Station	Distribution Main	43.5 - 60
Groundwater Well	Pressure Zone Boundary	60 - 90
Surrey Emergency Connection	Parcel	90 - 120
		120 - 150
		> 150

Coordinate System: NAD 1983 UTM Zone 10N

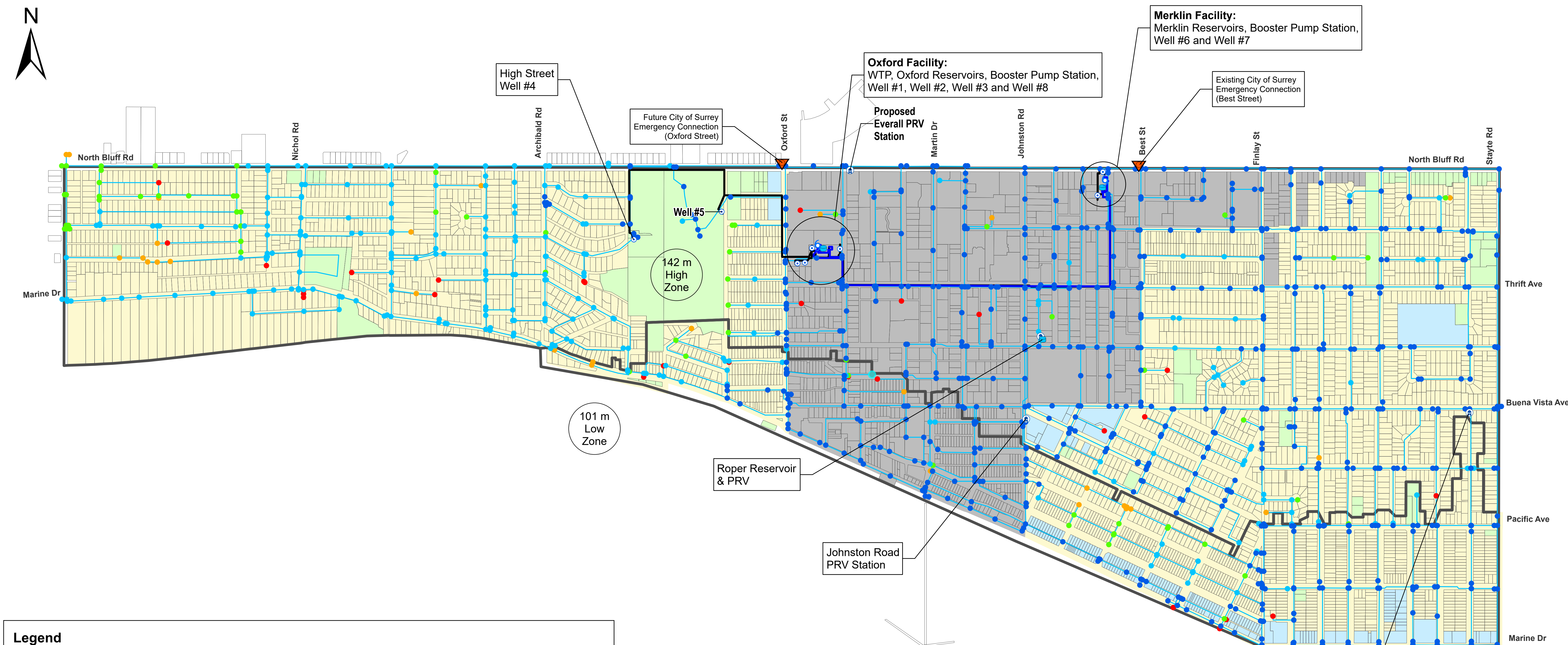
Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No. 452.133
Date April 2024
Scale 1:13,000
0 50 100 200 Metres

Recommended Water System with Future MDD - Peak Hour Pressure

Figure 8-2

Path: P:\0400-0499\452-133\430-GIS\Pro Projects\0452133_Figures\0452133_Figures.aprx\0452133_Figure_FF | Date Saved: 2024-04-22 2:14 PM | Author: tromans



Legend

- Pump Station
- Reservoir
- Pressure Reducing Valve Station
- Groundwater Well
- Surrey Emergency Connection
- Raw Water Supply Main
- Treated Water Supply Main
- Distribution Main
- Pressure Zone Boundary
- Parcel

Available Fire Flow (L/s)

- < 67
- 67 - 120
- 120 - 150
- 150 - 212
- > 212

Required Fire Flow (L/s)

- 67
- 120
- 150
- 212

Coordinate System: NAD 1983 UTM Zone 10N

Scale Disclaimer: The map scale of 1:13,000 is only valid on a 11"x17" print.

Project No.	452.133
Date	April 2024
Scale	1:13,000

0 50 100 200 Metres

Recommended Water System with Future MDD - Available Fire Flow

Figure 8-3

9. Conclusions

9.1 Summary and Recommendations

KWL was retained to prepare and update the White Rock Water System Master Plan. The key findings and recommendations are summarized below.

Census data and land use information was reviewed and the total service population for the existing White Rock Water System was estimated at 22,142 (21,939 in the City of White Rock, 203 in the City of Surrey). Average population rates were calculated as 2.5 ca/SF parcel and 1.5 ca/MF unit.

Source flow and customer water meter data was analyzed and compared to the historical record for White Rock to determine a design existing maximum day demand of 135.9 L/s. The calculated residential base demand rates were 193 L/ca/day and 186 L/ca/day for single-family and multi-family, respectively.

A significant increase in seasonal water use in 2021 was observed relative to previous high seasonal demand values (15% increase relative to 2015). An update to the 2016 Water Conservation Plan focused on decreasing peak usage is recommended.

Based on the Mid Range 2050 Metro Vancouver growth forecast, a 5,931 population increase and 30,350 m^2 of additional ICI floor area is expected by 2050. Lower base demand unit rates for residential and ICI usage were developed, and 140 L/ca/day and 1.6 m^3/m^2 floor area/year were used to estimate the increase in future base demand. The irrigated area is not expected to increase in the future, but an 8% increase was added to seasonal demand to account for potential impacts of climate change based on a hot summer demand analysis. The design future maximum demand for year 2050 was estimated at 152.5 L/s.

There are seven, soon to be eight, wells that supply the White Rock water system. The total rated supply capacity (including Well 5, with the largest well out of service) is 139.4 L/s. Additional source capacity is required to meet the future 2050 MDD estimate. Recent redevelopment work with Well 3 shows it needs replacement. A new well (Well 9) is recommended to replace Well 3 and provide capacity needed for future conditions. It is recommended that the City continue to upgrade the connections to the City of Surrey system for emergency / back up supply conditions.

The available reservoir storage capacity is 4.75 ML and 5.89 ML in the High and Low pressure zones, respectively. The required storage for the estimated future 2050 demands is 4.58 ML for the High and 3.02 for the Low pressure zones. Adequate storage capacity is provided by the current system for the estimated future demands.

A review of actual peak hour flow data for 2020-2023 indicates the observed balancing volume on peak day is 8-12% of the maximum day demand; this is below the calculated estimate of required balancing storage. However, review of the data indicates the actual reservoir volumes in the High Zone were below the volume reserved for fire plus emergency storage for 2 days in the summers of 2021 and 2023. According to our calculations, the available storage volume should be sufficient without using volume reserved for emergency and fire conditions. Therefore, the following operational adjustments are recommended for the City to review and implement:

- Calibrate/verify pressure transducer readings (% full) are accurate based on actual levels.
- Adjust operation so that the full capacity of the reservoirs is utilized. Review of the available reservoir data suggests that approximately 0.5 ML of storage is not utilized (tanks are not completely filled).

- Review and adjust the fill setting for the Merklin reservoirs (currently set at max. 75 L/s in the SCADA programming). While this should not impact the current operation (where Oxford and Merklin combine to supply the High Zone), this will have an impact on the system's ability to provide adequate service when the Everall PRV (Project ID 04) is implemented and the Oxford supply HGL is lowered. If the 75 L/s setting cannot be adjusted, or only marginally increased, it is recommended that the Everall PRV project be re-examined.
- Ensure well supply capacity is adjusted daily to meet the average day demand requirement. Completion of Well #5 and development of a new well are recommended as high priority projects to ensure the available well supply can meet existing and future maximum day demands. Demand side management can also be an effective tool to promote water conservation.

Modelling indicates that there are low pressure deficiencies (< 44 psi) in the vicinity of North Bluff Road and Merklin Street and high pressures >150 psi near Marine Drive and Magdalen Crescent. The High Zone separation project (Everall PRV) is recommended to allow the pressure in the High Zone East (145 m HGL) to be raised, and the pressure in the High Zone West to be lowered (135 m HGL).

Modelling indicates that there are fire flow deficiencies relative to the required fire flow assessment criteria. 11 water main upgrades are recommended to address these fire flow deficiencies. 6 additional upgrades which address fire flow deficiencies in the East Side Large Lot Infill area (currently single family residential) are recommended when development in this area proceeds.

Two scenarios were analyzed in conjunction with the Everall PRV project to determine how the system performs under emergency supply conditions.

1. With Oxford supply only (i.e. Merklin Reservoir/Pump Station offline) the existing system cannot supply adequate base day demands.
2. With supply from two of the City of Surrey Emergency Connections, the existing system can supply maximum day demands and fire flows, but at lower than typical design pressure and fire flow criteria.

With water main upgrades on Oxford Street and along North Bluff Road, the ability to provide adequate pressure and fire flow under emergency conditions is improved.

The City's break history data was analyzed, and it was determined that the break rate is within the typical range. It was also determined that cast iron pipes and small diameter piping is more susceptible to breaks, and the break rate on ductile iron pipe is increasing. A water main asset management study is recommended to develop a proactive water main replacement strategy. It is also recommended to complete water main replacement projects in 12 specific areas that have extensive break history.

The resiliency of the distribution system was assessed by modelling the larger diameter mains only (i.e. 200 mm dia. and larger); 100 mm dia. and 150 mm dia. looped sections were closed. Modelling indicated that the existing large diameter network can provide adequate peak hour pressure under future maximum day demand conditions but the available fire flows for some ICI and multi family areas were diminished. Water main upgrades on Finlay Street, Marine Drive, and Johnston Road are recommended to improve distribution system resiliency.

In total, there are 46 recommended upgrades, with a Class 'D' cost estimate of $30.1 M.

It is recommended that the water master plan be updated approximately every five years or as required as projects are completed, observed demands or daily use patterns are altered, growth projections are adjusted, or if major developments are proposed.

10. Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

2024-06-04
PROFESSIONAL
PROVINCE OF
R. A. C. SINNOTT
41806
BRITISH COLUMBIA
ENGINEER
Permit to Practice #1000696

Rose Sinnott, P.Eng.
Project Manager/Project Engineer

Reviewed by:

Andrew Boyland, P.Eng.
Technical Reviewer

Statement of Limitations

This document has been prepared by Kerr Wood Leidal Associates Ltd. (KWL) for the exclusive use and benefit of City of White Rock for the 2024 Water Master Plan Update. No other party is entitled to rely on any of the conclusions, data, opinions, or any other information contained in this document.

This document represents KWL's best professional judgement based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practising under similar conditions. No warranty, express or implied, is made.

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Revision History

Revision #	Date	Status	Revision	Author
0	May 13, 2024	Final		RS
1	May 27, 2024	Final – Revision 1	Incorporate comments provided by the City.	RS
2	June 3, 2024	Final – Revision 2	Revise to clarify water servicing is provided by the City to Semiahmoo First Nation.	RS

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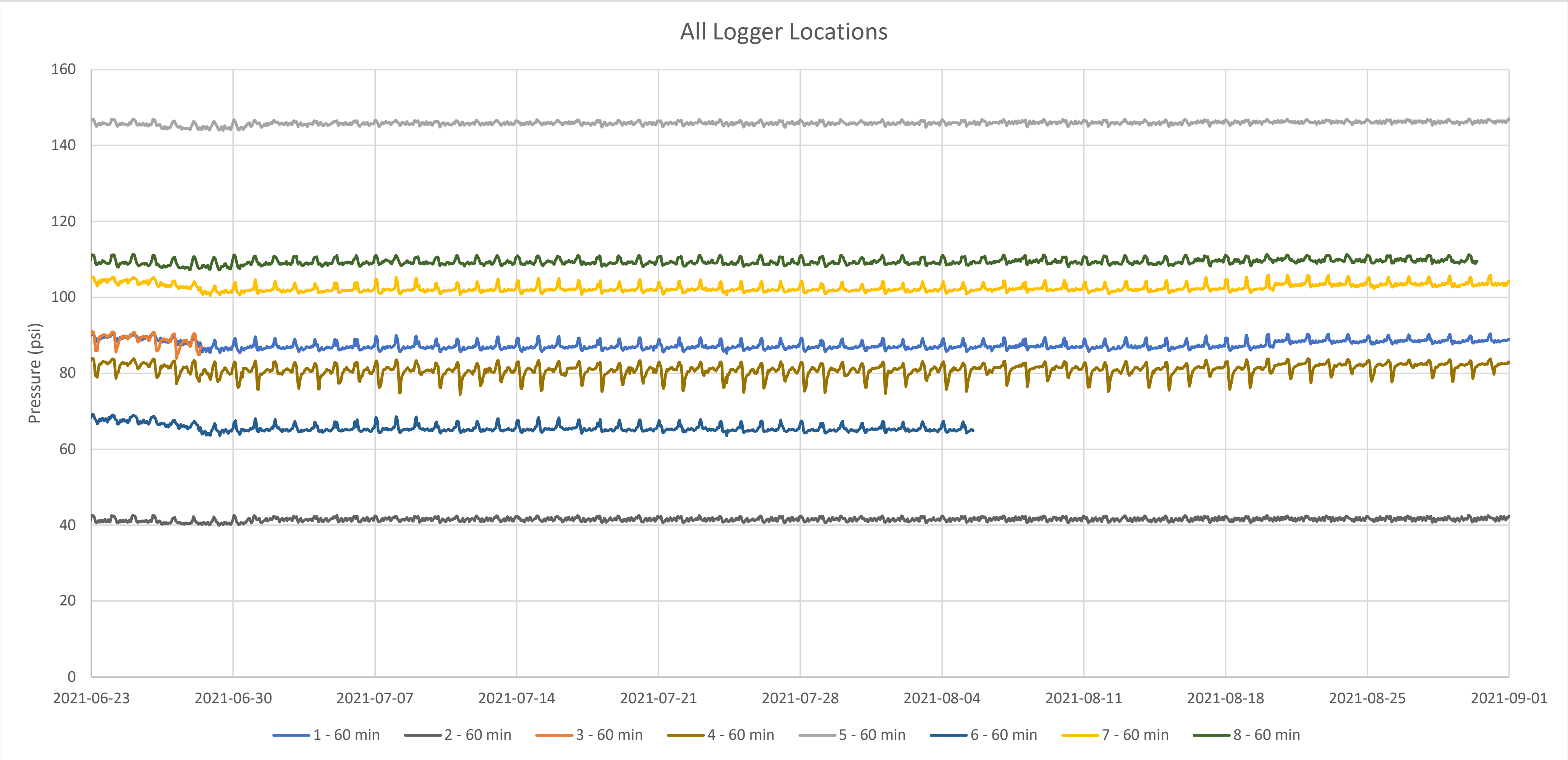
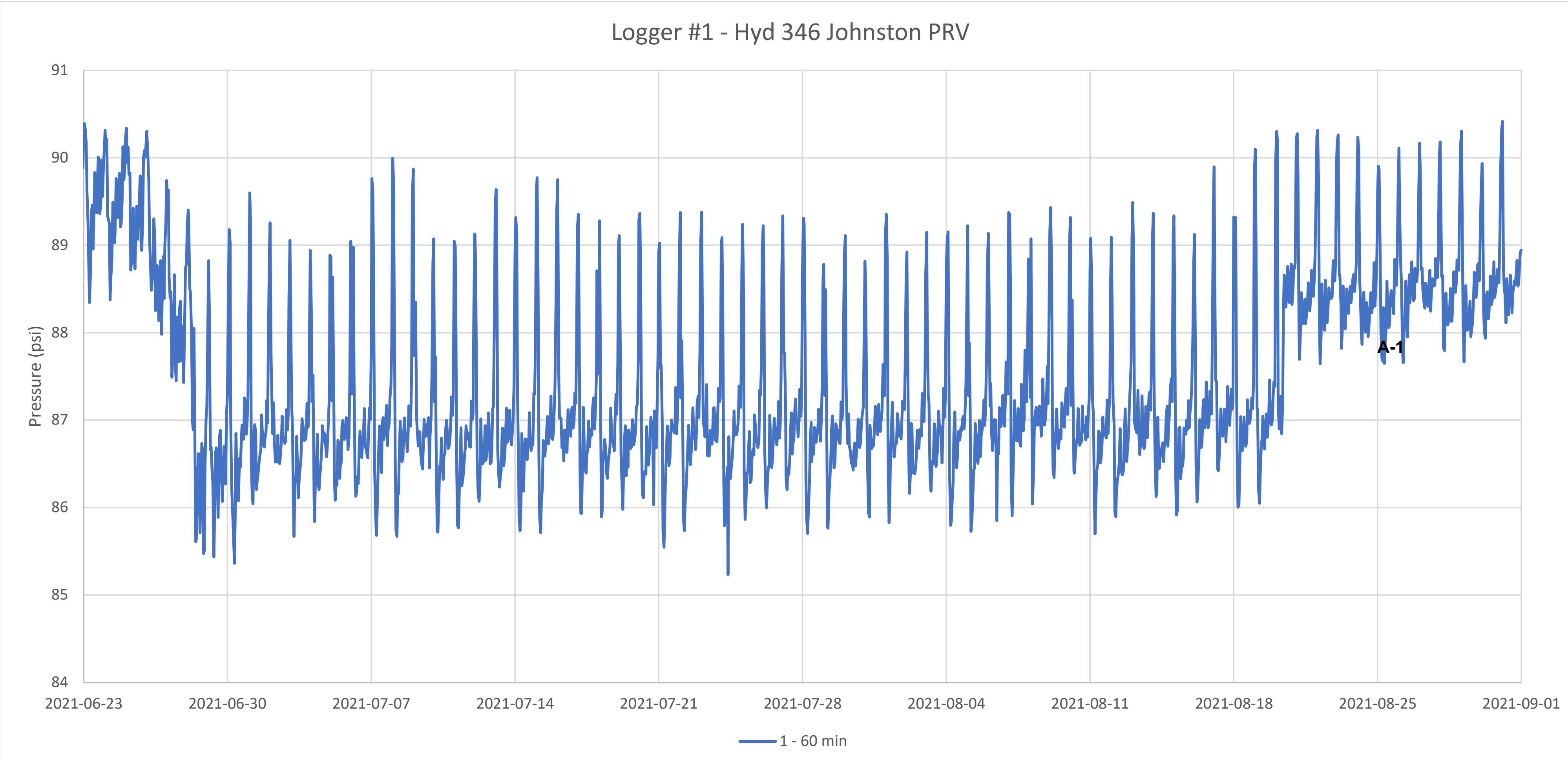
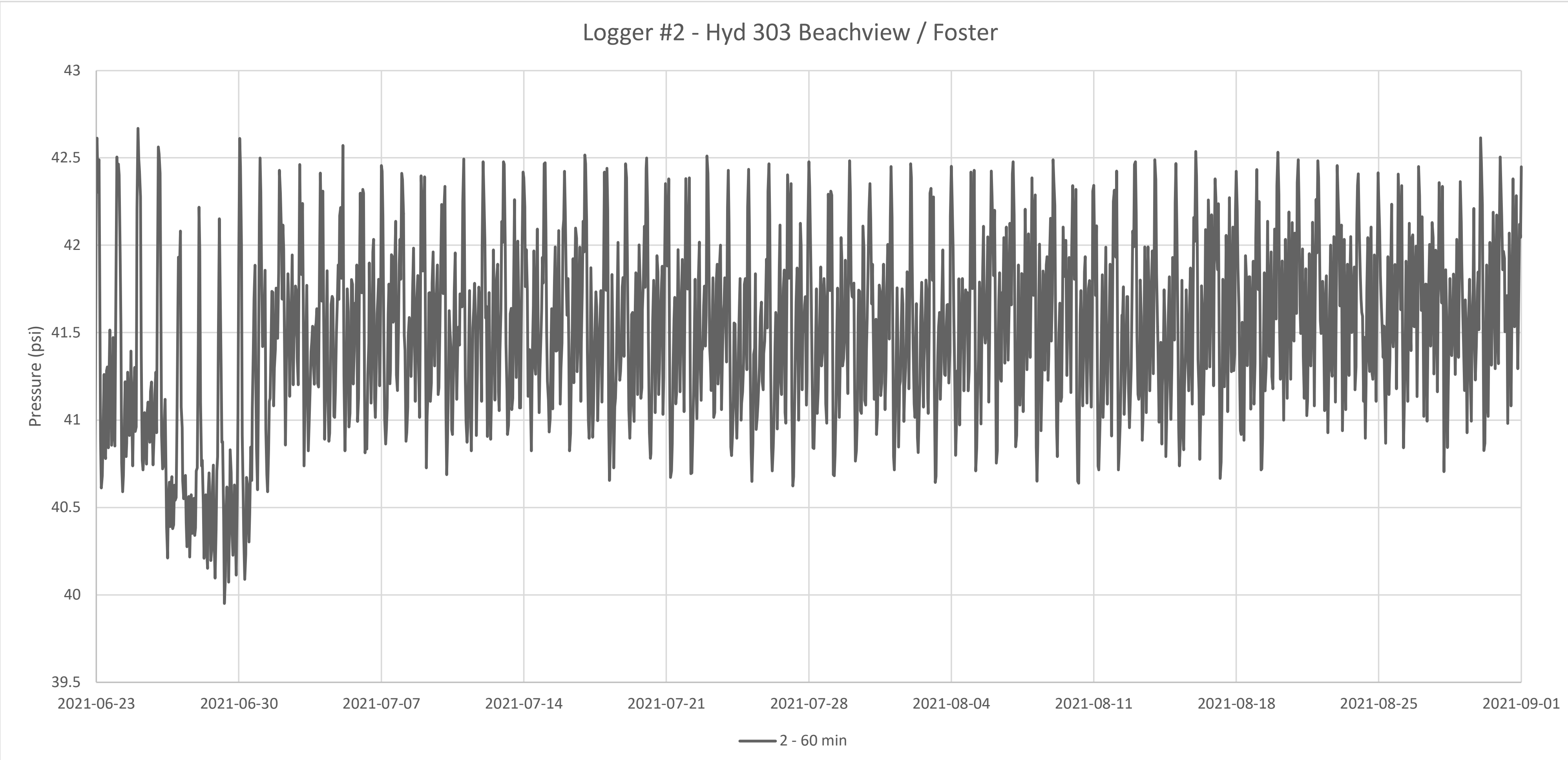
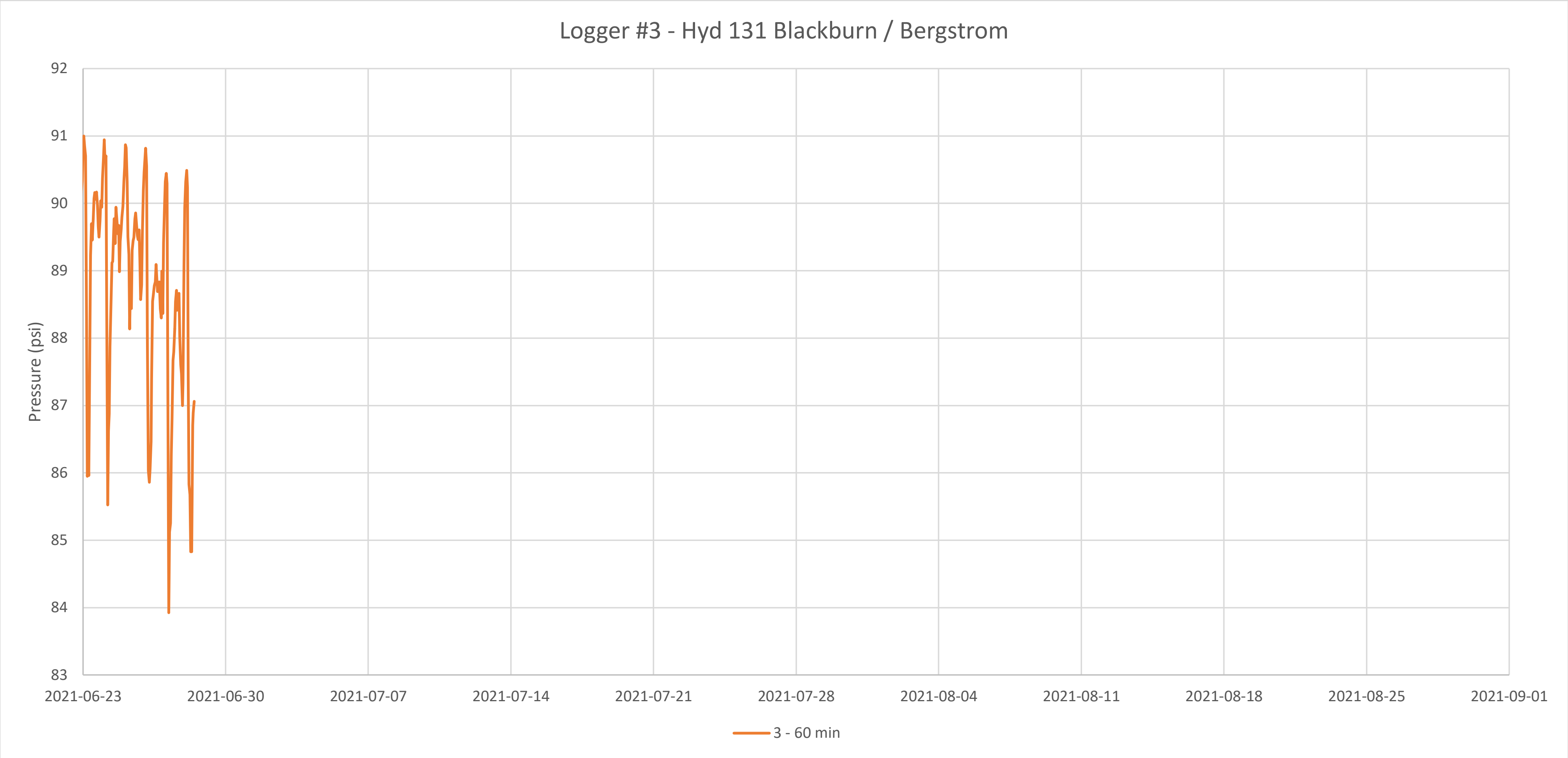
Appendix A

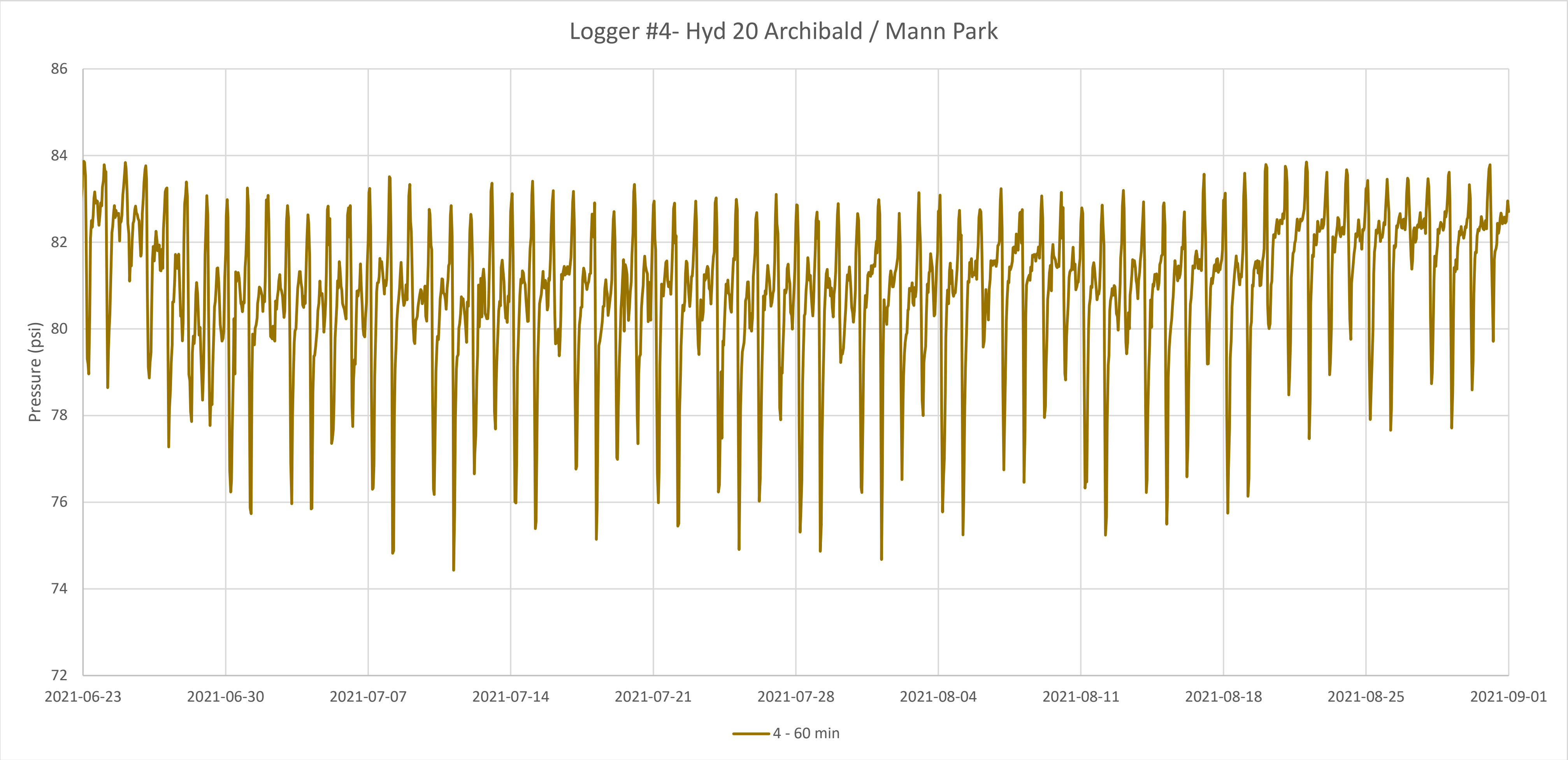
Summer 2021 Pressure Monitoring Data

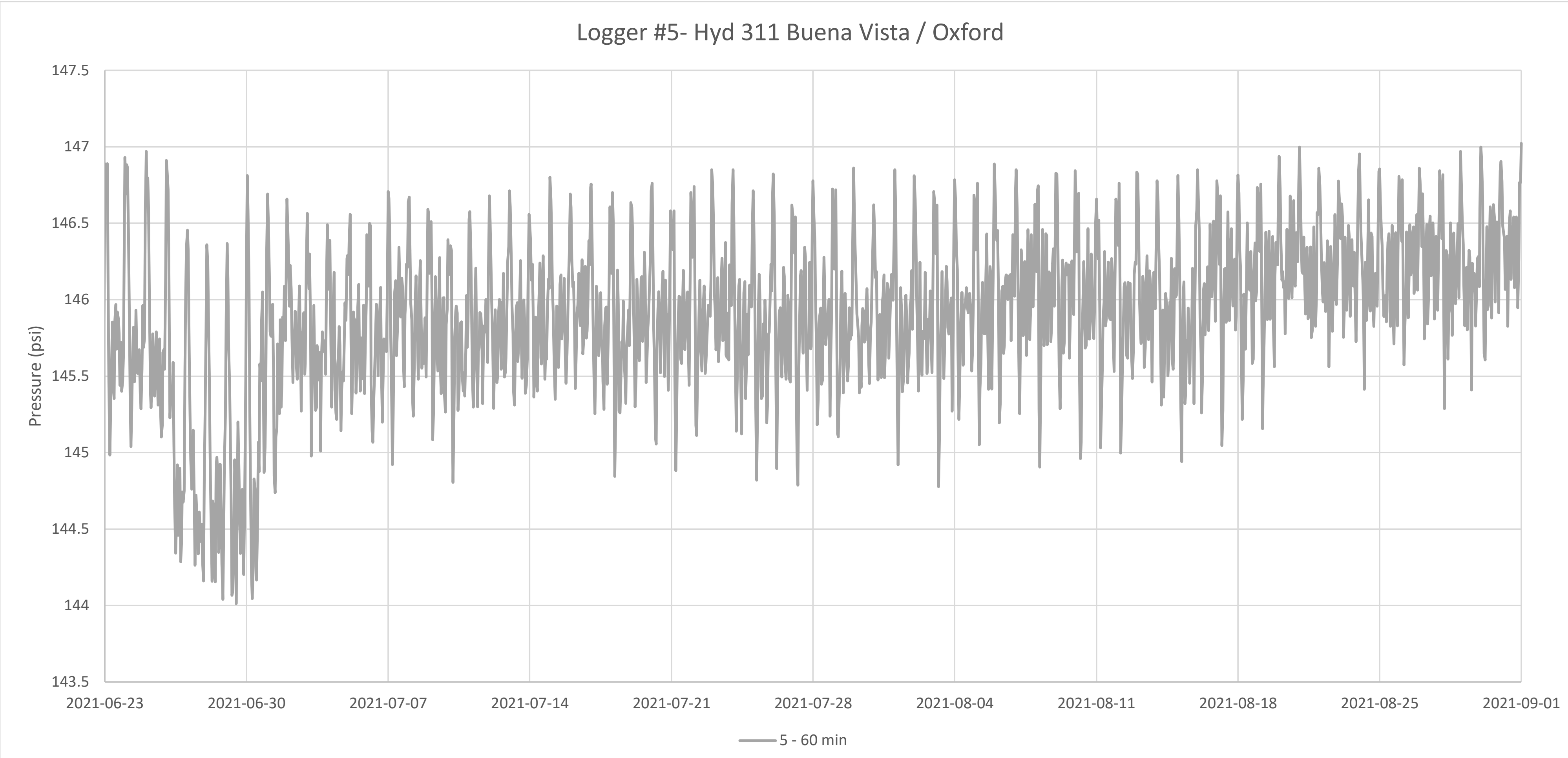

All Logger Locations
Pressure (psi)
160
140
120
100
80
60
40
20
0
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
1 - 60 min
2 - 60 min
3 - 60 min
4 - 60 min
5 - 60 min
6 - 60 min
7 - 60 min
8 - 60 min

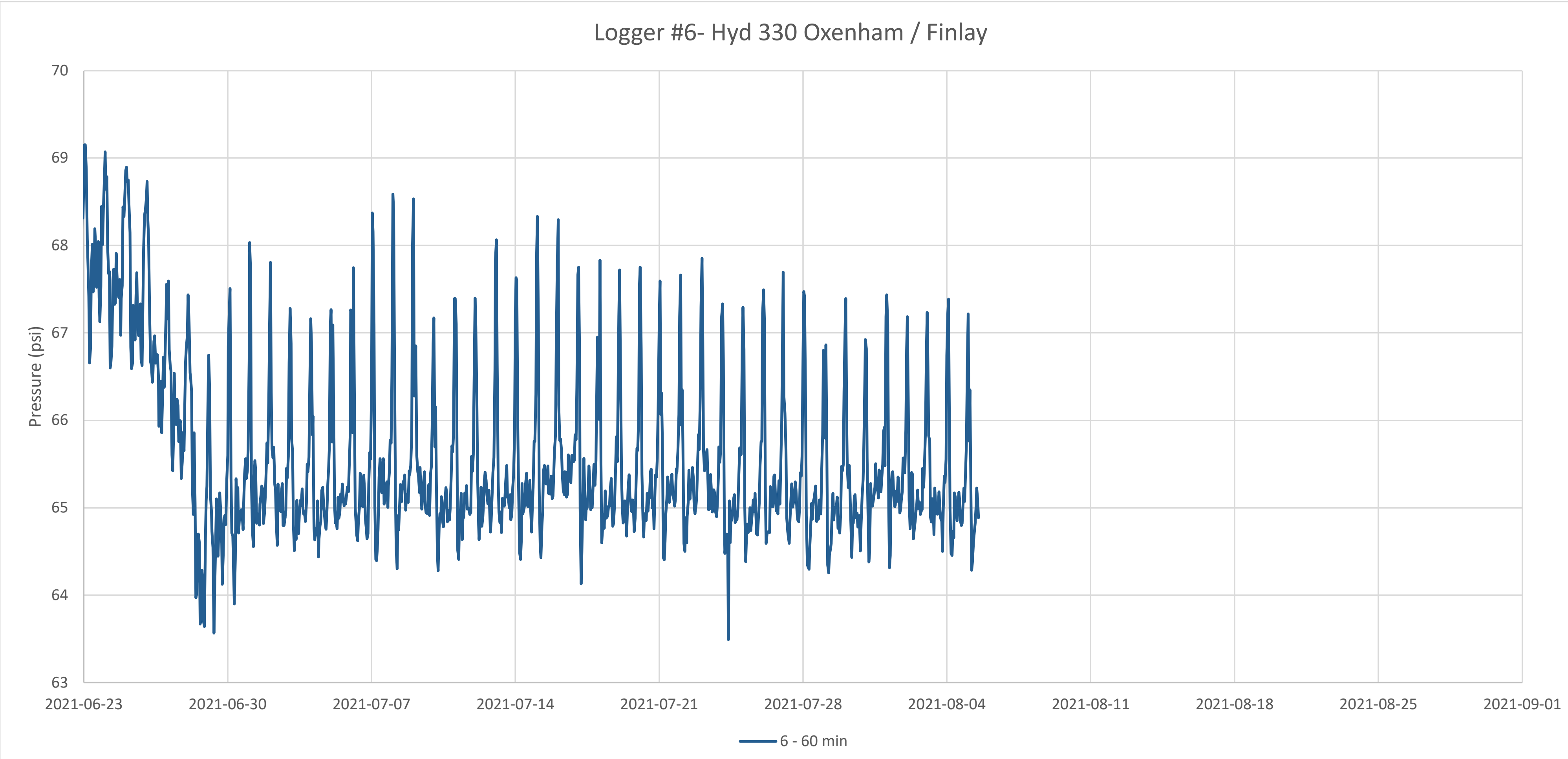

Logger #1 - Hyd 346 Johnston PRV
Pressure (psi)
91
90
89
88
87
86
85
84
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
1 - 60 min
A-1

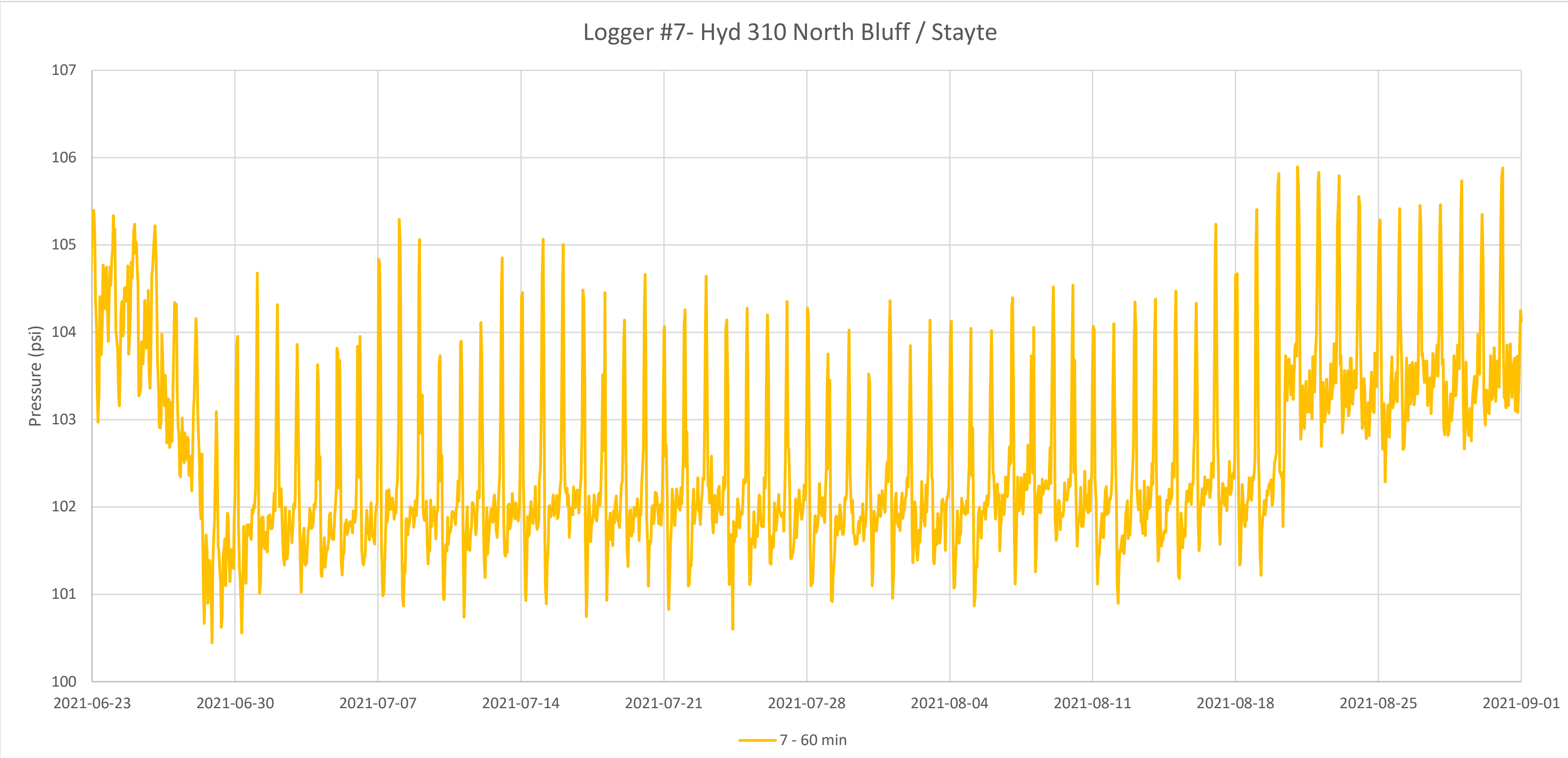

Logger #2 - Hyd 303 Beachview / Foster
Pressure (psi)
43
42.5
42
41.5
41
40.5
40
39.5
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
2 - 60 min

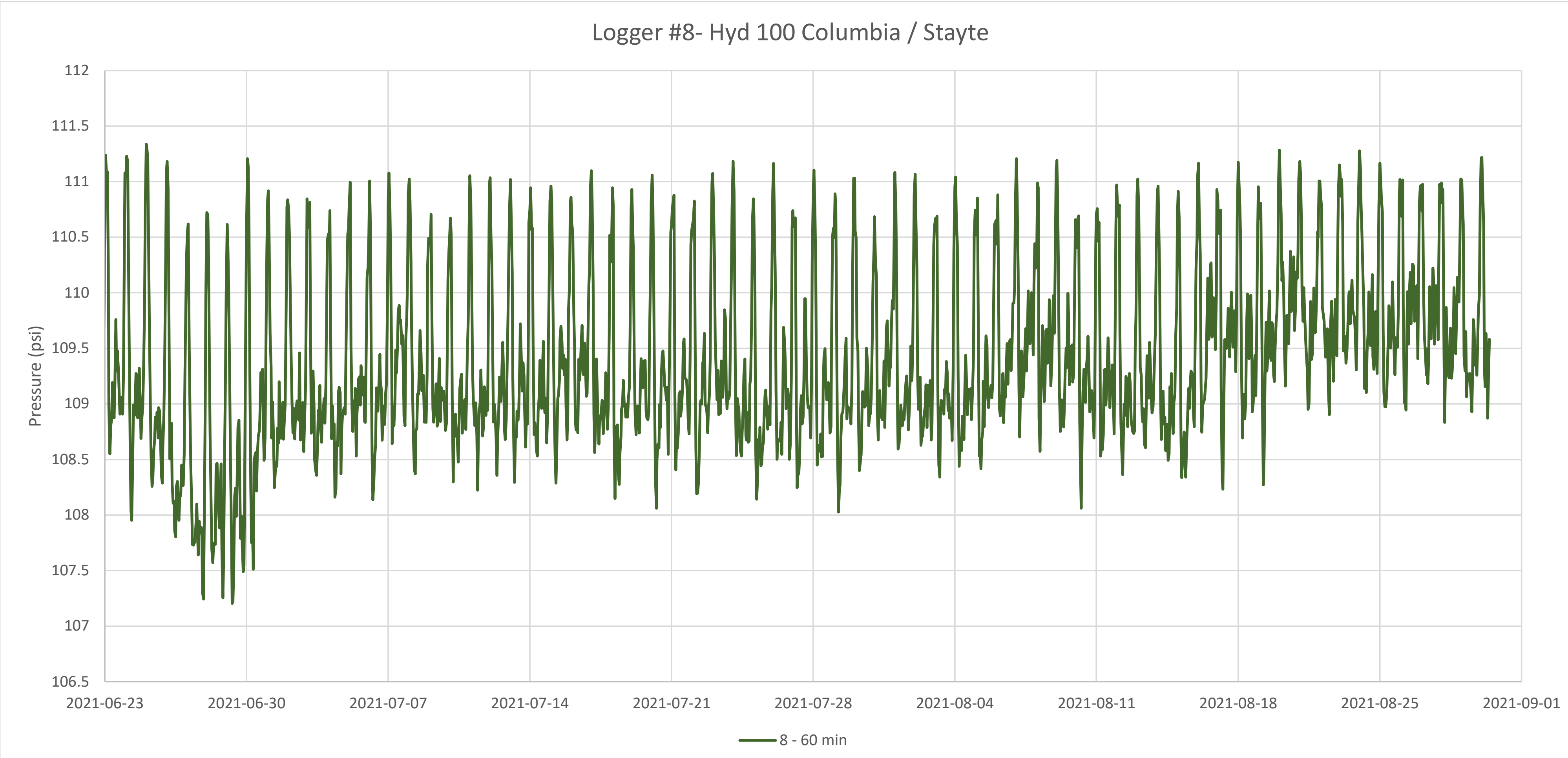

Logger #3 - Hyd 131 Blackburn / Bergstrom
Pressure (psi)
92
91
90
89
88
87
86
85
84
83
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
3 - 60 min


Logger #4- Hyd 20 Archibald / Mann Park
86
84
82
80
78
76
74
72
Pressure (psi)
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
4 - 60 min


Logger #5- Hyd 311 Buena Vista / Oxford
147.5
147
146.5
146
145.5
145
144.5
144
143.5
Pressure (psi)
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
5 - 60 min


Logger #6- Hyd 330 Oxenham / Finlay
Pressure (psi)
70
69
68
67
66
65
64
63
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
6 - 60 min


Logger #7- Hyd 310 North Bluff / Stayte
Pressure (psi)
107
106
105
104
103
102
101
100
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
7 - 60 min


Logger #8- Hyd 100 Columbia / Stayte
Pressure (psi)
112
111.5
111
110.5
110
109.5
109
108.5
108
107.5
107
106.5
2021-06-23
2021-06-30
2021-07-07
2021-07-14
2021-07-21
2021-07-28
2021-08-04
2021-08-11
2021-08-18
2021-08-25
2021-09-01
8 - 60 min

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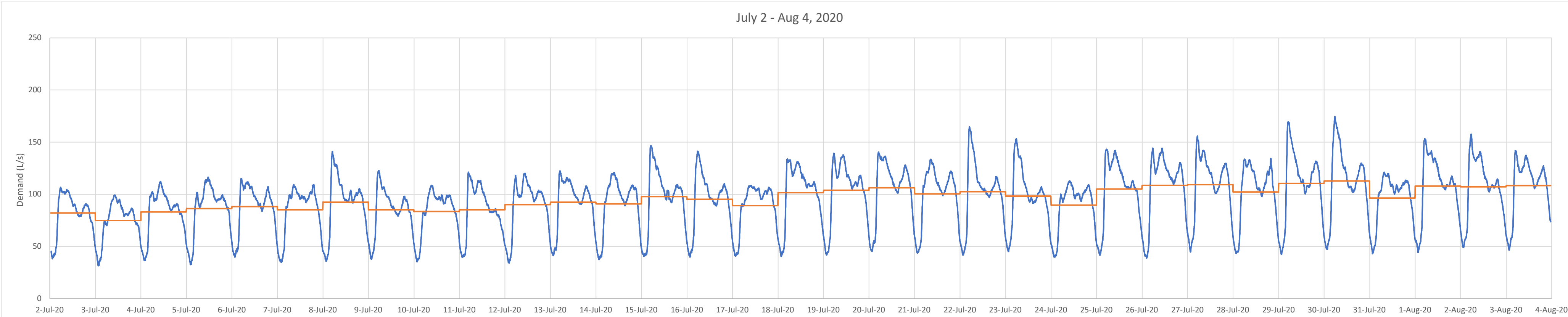
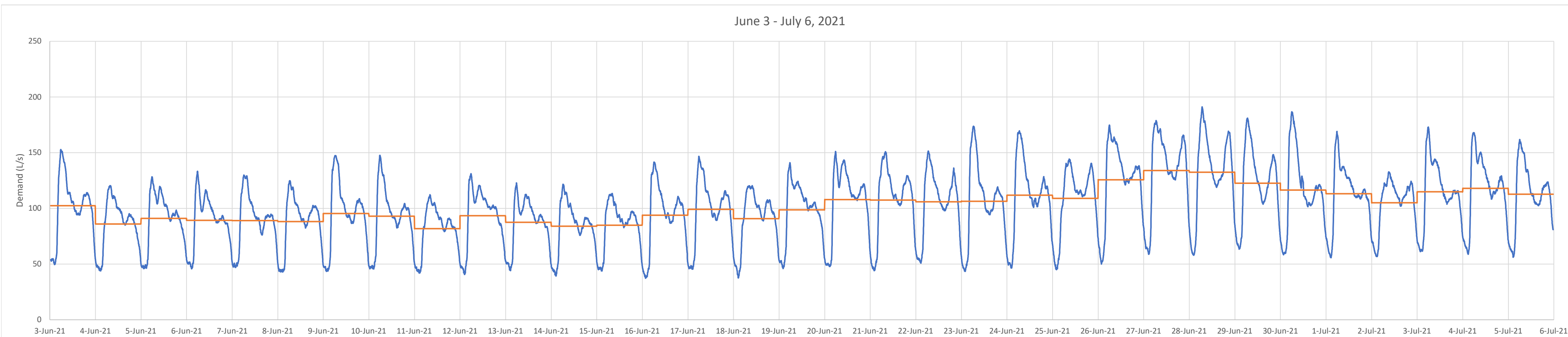
Appendix B

Balancing Storage Analysis



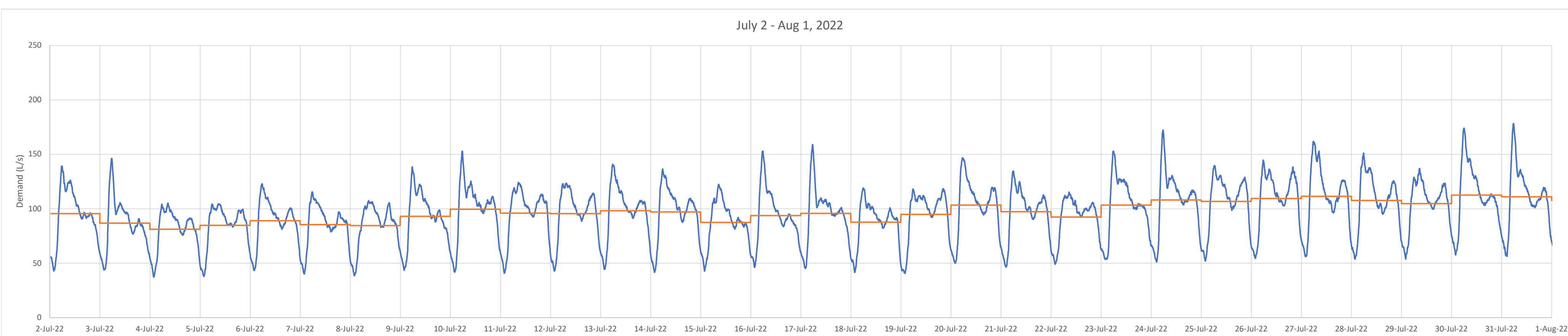
Maximum Day Demand:
112.8 L/s

Peak Daily Volume Required:
1.10 ML
9-11% of Average Daily Volume



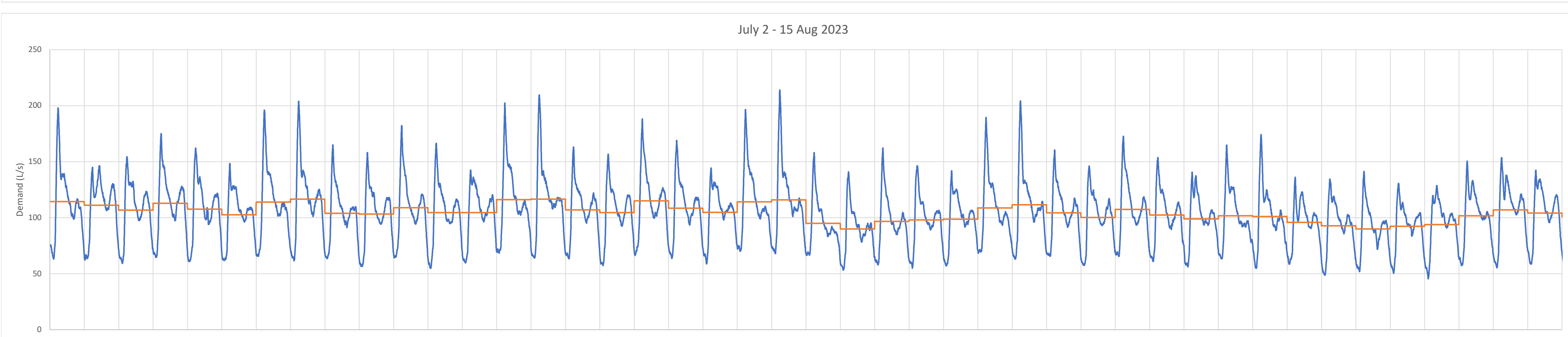
Maximum Day Demand:
134.0 L/s

Peak Daily Volume Required:
1.23 ML
8-12% of Average Daily Volume



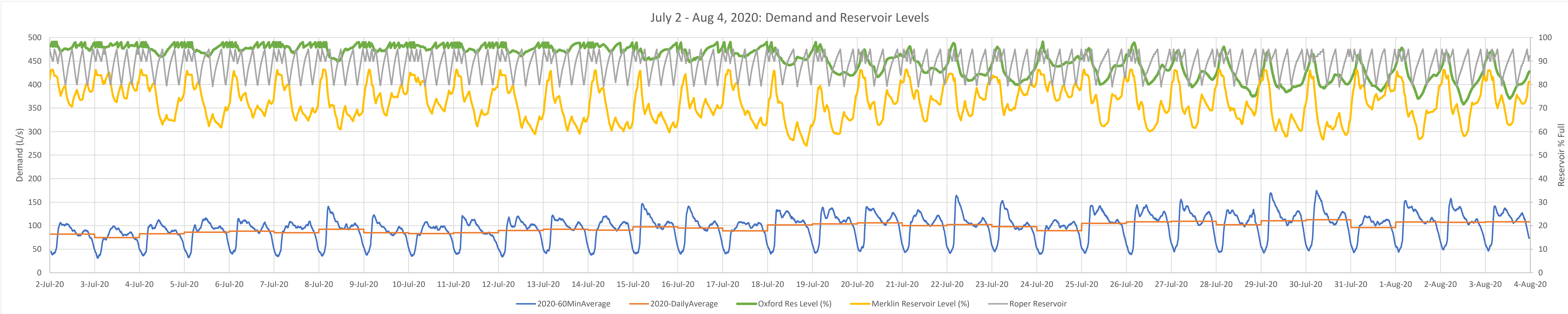
Maximum Day Demand:
112.5 L/s

Peak Daily Volume Required:
0.94 ML
8-10% of Average Daily Volume

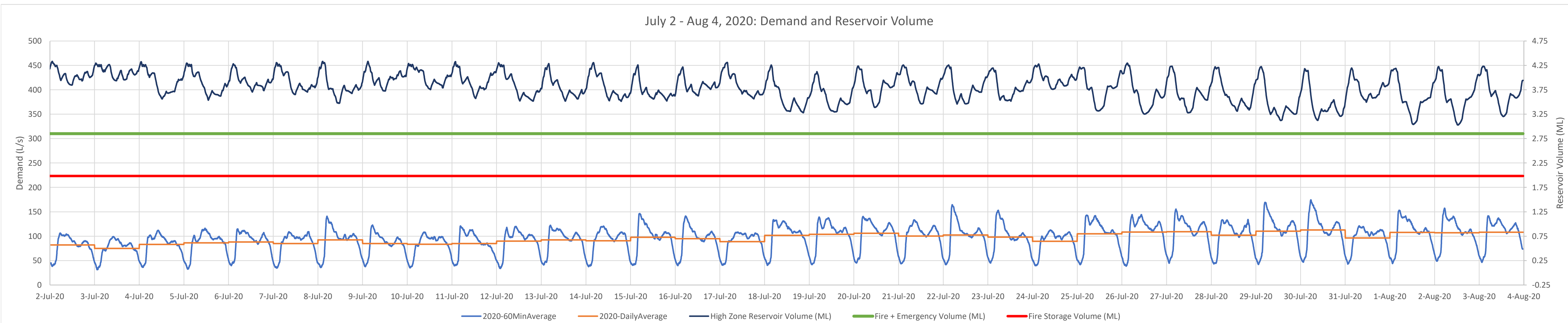


Maximum Day Demand:
116.7 L/s

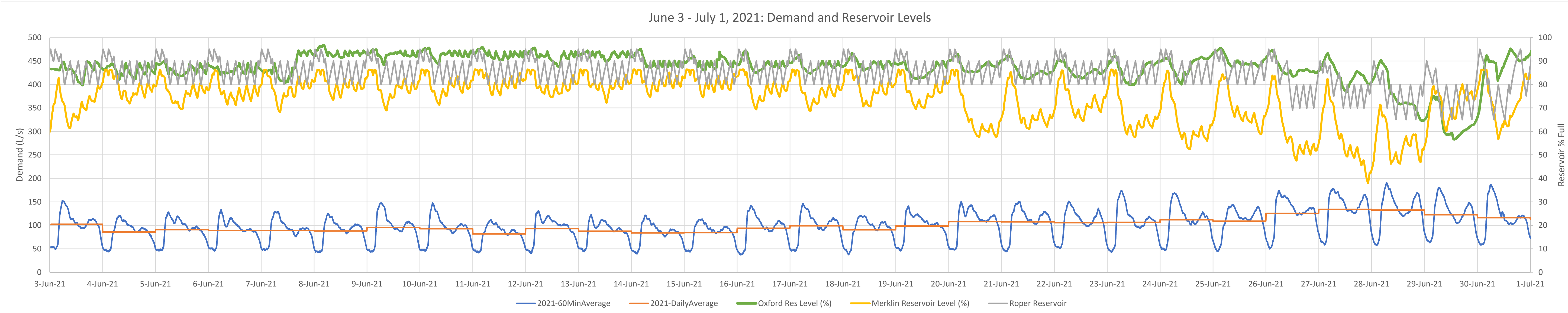
Peak Daily Volume Required:
1.07 ML
8-11% of Average Daily Volume

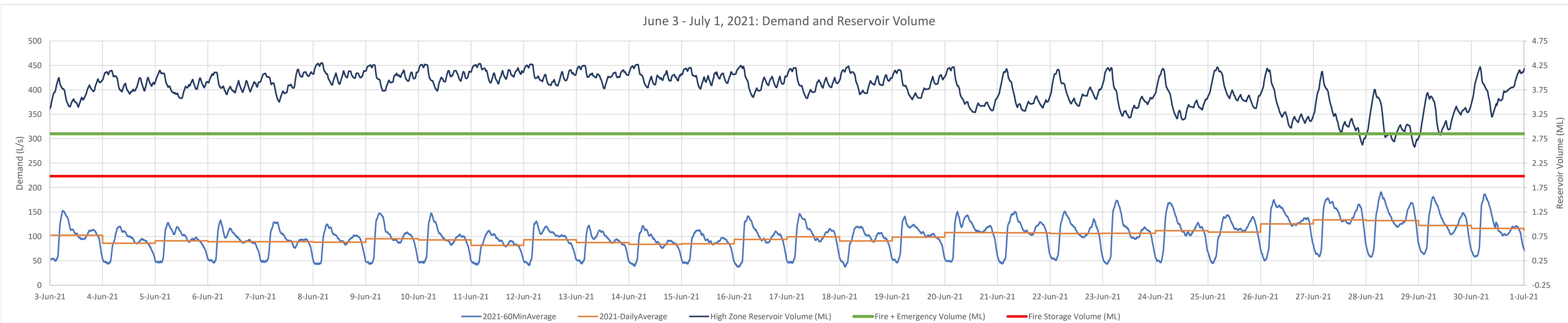


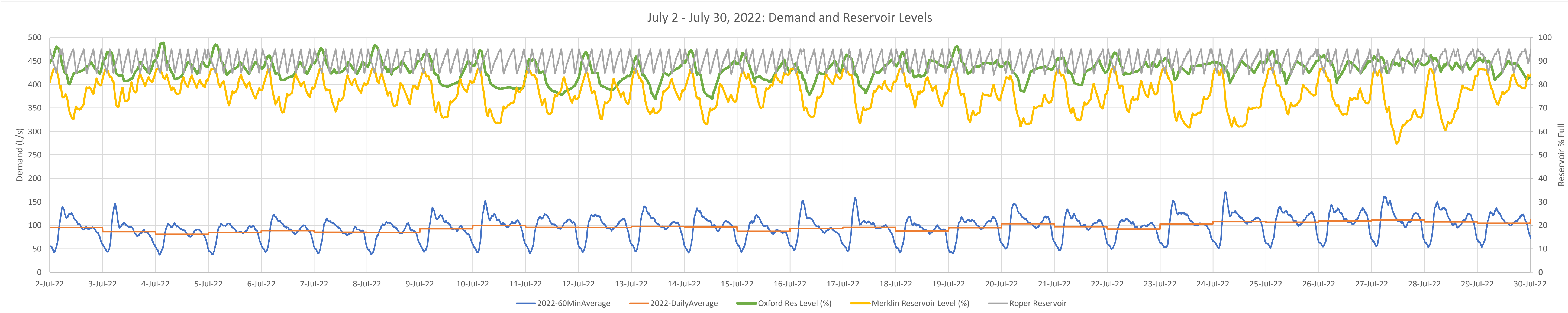
July 2 - Aug 4, 2020: Demand and Reservoir Levels
Demand (L/s)
Reservoir % Full
2020-60MinAverage
2020-DailyAverage
Oxford Res Level (%)
Merklin Reservoir Level (%)
Roper Reservoir

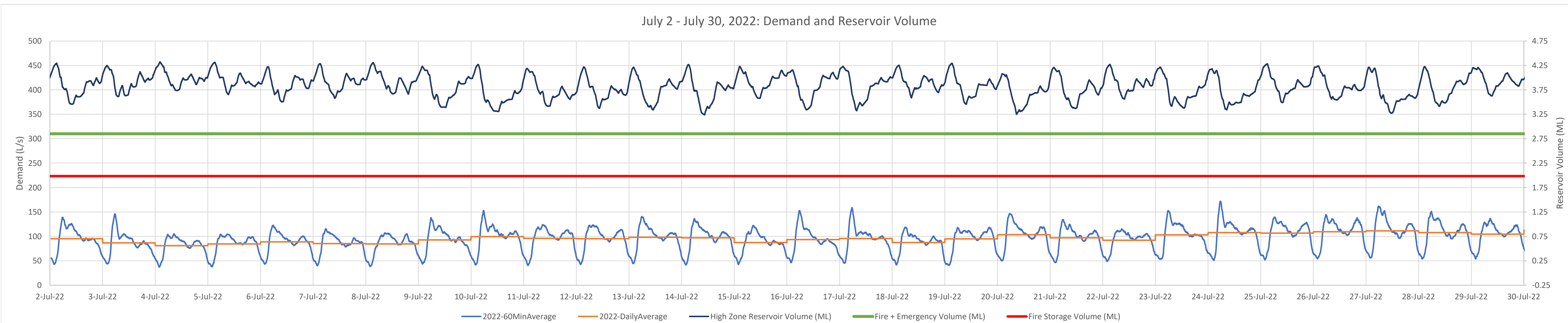


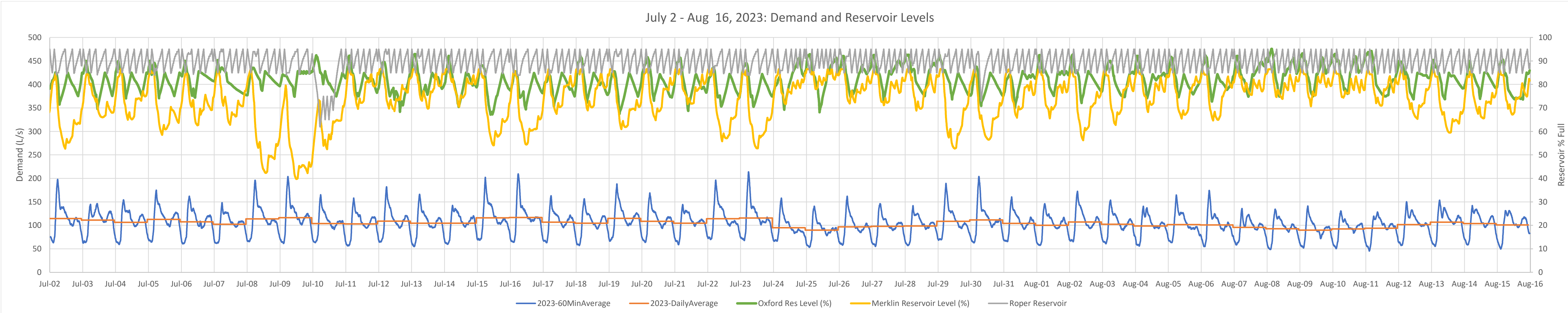
July 2 - Aug 4, 2020: Demand and Reservoir Volume
Demand (L/s)
Reservoir Volume (ML)
2020-60MinAverage
2020-DailyAverage
High Zone Reservoir Volume (ML)
Fire + Emergency Volume (ML)
Fire Storage Volume (ML)


June 3 - July 1, 2021: Demand and Reservoir Levels
Demand (L/s)
Reservoir % Full
0
50
100
150
200
250
300
350
400
450
500
0
10
20
30
40
50
60
70
80
90
100
3-Jun-21
4-Jun-21
5-Jun-21
6-Jun-21
7-Jun-21
8-Jun-21
9-Jun-21
10-Jun-21
11-Jun-21
12-Jun-21
13-Jun-21
14-Jun-21
15-Jun-21
16-Jun-21
17-Jun-21
18-Jun-21
19-Jun-21
20-Jun-21
21-Jun-21
22-Jun-21
23-Jun-21
24-Jun-21
25-Jun-21
26-Jun-21
27-Jun-21
28-Jun-21
29-Jun-21
30-Jun-21
1-Jul-21
2021-60MinAverage
2021-DailyAverage
Oxford Res Level (%)
Merklin Reservoir Level (%)
Roper Reservoir

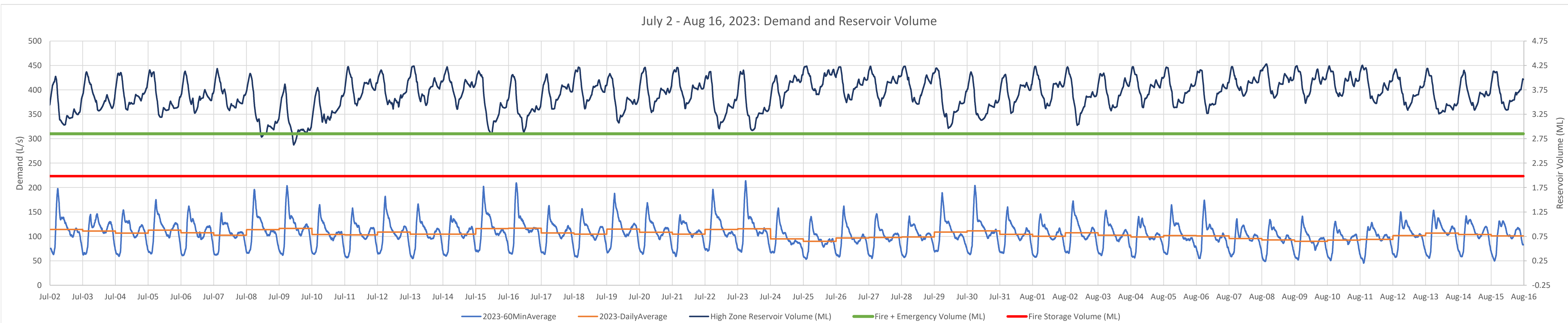

June 3 - July 1, 2021: Demand and Reservoir Volume
Demand (L/s)
Reservoir Volume (ML)
0
50
100
150
200
250
300
350
400
450
500
-0.25
0.25
0.75
1.25
1.75
2.25
2.75
3.25
3.75
4.25
4.75
3-Jun-21
4-Jun-21
5-Jun-21
6-Jun-21
7-Jun-21
8-Jun-21
9-Jun-21
10-Jun-21
11-Jun-21
12-Jun-21
13-Jun-21
14-Jun-21
15-Jun-21
16-Jun-21
17-Jun-21
18-Jun-21
19-Jun-21
20-Jun-21
21-Jun-21
22-Jun-21
23-Jun-21
24-Jun-21
25-Jun-21
26-Jun-21
27-Jun-21
28-Jun-21
29-Jun-21
30-Jun-21
1-Jul-21
2021-60MinAverage
2021-DailyAverage
High Zone Reservoir Volume (ML)
Fire + Emergency Volume (ML)
Fire Storage Volume (ML)


July 2 - July 30, 2022: Demand and Reservoir Levels
Demand (L/s)
Reservoir % Full
2022-60MinAverage
2022-DailyAverage
Oxford Res Level (%)
Merklin Reservoir Level (%)
Roper Reservoir


July 2 - July 30, 2022: Demand and Reservoir Volume
Demand (L/s)
Reservoir Volume (ML)
2022-60MinAverage
2022-DailyAverage
High Zone Reservoir Volume (ML)
Fire + Emergency Volume (ML)
Fire Storage Volume (ML)



July 2 - Aug 16, 2023: Demand and Reservoir Levels
Demand (L/s)
Reservoir % Full
2023-60MinAverage
2023-DailyAverage
Oxford Res Level (%)
Merklin Reservoir Level (%)
Roper Reservoir



July 2 - Aug 16, 2023: Demand and Reservoir Volume
Demand (L/s)
Reservoir Volume (ML)
2023-60MinAverage
2023-DailyAverage
High Zone Reservoir Volume (ML)
Fire + Emergency Volume (ML)
Fire Storage Volume (ML)

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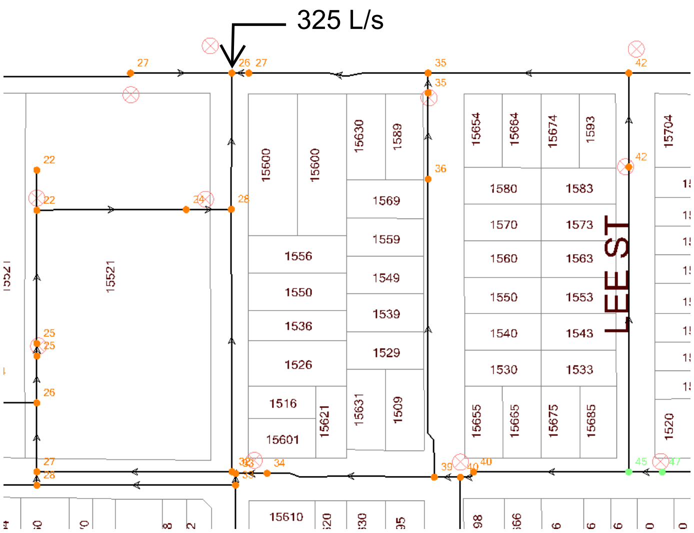
Appendix C

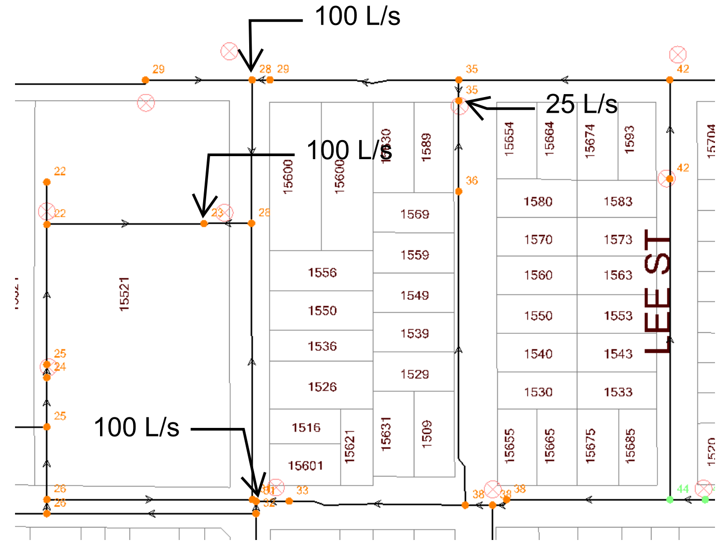
Multiple Hydrant Scenario Demonstration

Appendix C: Multiple Hydrant Scenario Demonstration

Location 1: North Bluff Road and Finlay Street

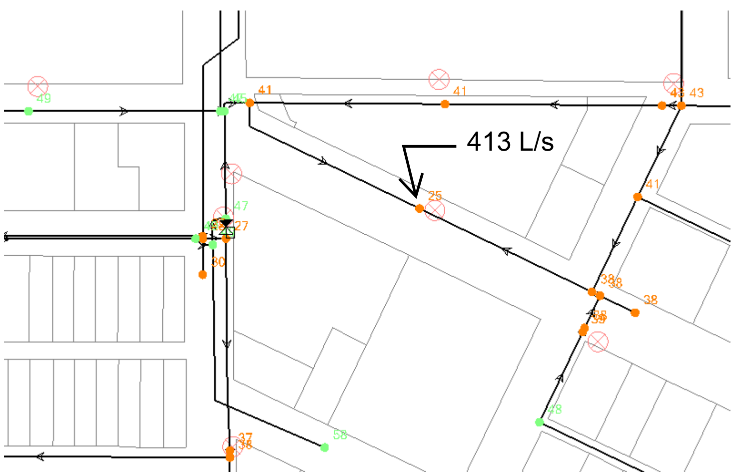


Simulating 1 hydrant flowing at 325 L/s - available pressure results displayed (psi)

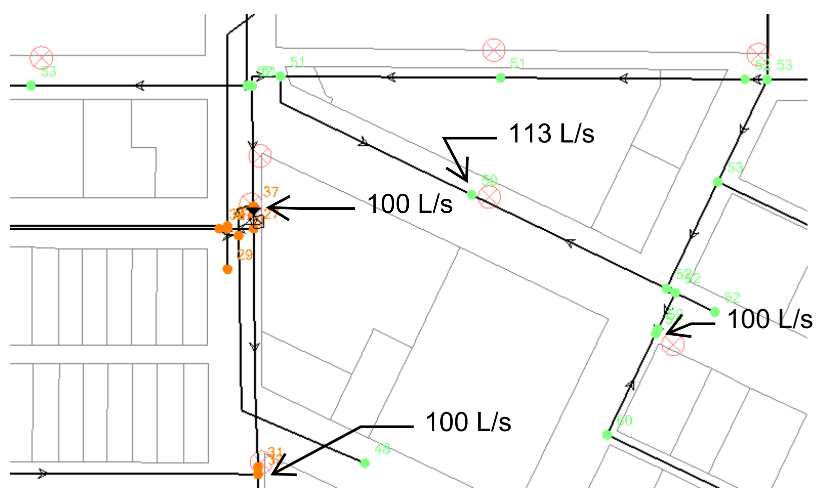


Simulating 4 hydrants flowing at 325 L/s combined - available pressure results displayed (psi)

Location 2: Johnston Road and Pacific Avenue

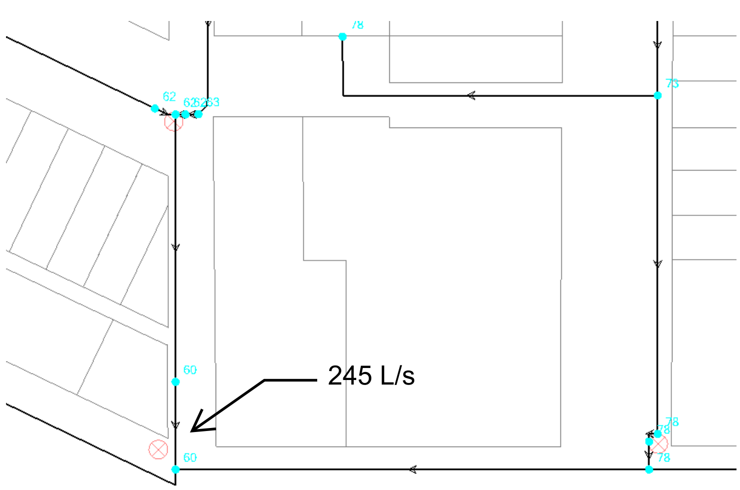


Simulating 1 hydrant flowing at 413 L/s - available pressure results displayed (psi)

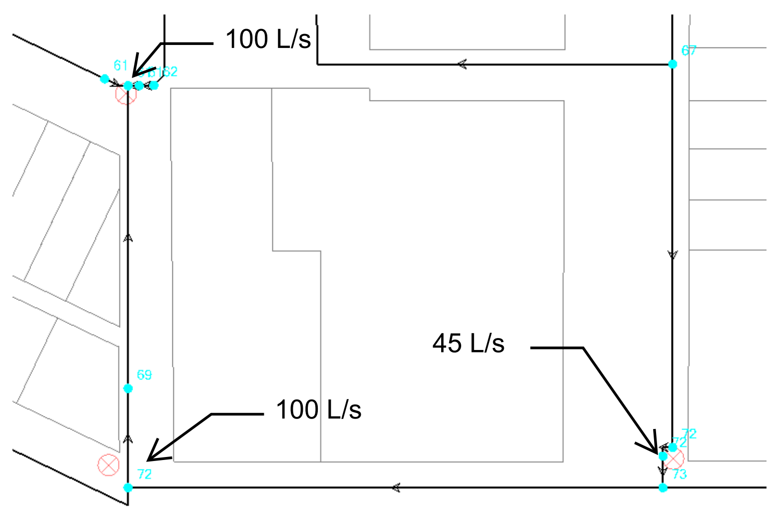


Simulating 4 hydrants flowing at 413 L/s combined - available pressure results displayed (psi)

Location 3: Marine Drive and Finlay Street



Simulating 1 hydrant flowing at 245 L/s - available pressure results displayed (psi)



Simulating 3 hydrants flowing at 245 L/s combined - available pressure results displayed (psi)