8.0 WATER REGION # 6 - NANAIMO RIVER

8.1 Regional Overview

The Nanaimo River water region (WR6-NR) is defined as the area extending from the coast at the Nanaimo River Estuary and Cedar, west to the top of the Nanaimo River catchment (Figure 79). It should be noted that the actual water region boundary in the southernmost part of WR6 (NR) was extended beyond the RDN boundary to coincide with the drainage basin. Although the RDN has no jurisdiction over this area, the water budget assessment needed to be completed at the basin scale and water resource management of this area will need to be a joint effort with the Cowichan Valley Regional District.

WR6 (NR) is largest water region within the RDN covering an area of approximately 939 km^2 (Table 51). The region is densely populated as it encompasses the communities of Cedar, South Wellington, Extension, and Cassidy. There are a total of 10 watersheds and subwatersheds in WR6 (NR), the largest of which is associated with the Nanaimo River (Figure 79). Five hydrometric stations, four climate stations, and approximately 359 surface water diversion licenses exist within the region (Figure 79, and Table 51).

The two largest water users in this area include the City of Nanaimo and Harmac Forest Products. It should be noted that the City of Nanaimo also pumps water outside of the Nanaimo River watershed for use in WR5 (SW-N).

Table 51: WR6 (NR) - Watersheds, Wells and Surface Water Licenses

Total Water Region Area	***939 km^2**
Major Watersheds	**Drainage Area[1] (km^2)**
Nanaimo River (including all tributaries)	829.5
Haslam Creek (tributary to Nanaimo River)	128.7
Hokken Creek (tributary to Haslam Creek)	14.6
South Nanaimo River (tributary to Nanaimo River)	213.3
Jump Creek (tributary to South Nanaimo River)	61.7
Sadie Creek (tributary to Nanaimo River)	29.3
Beck Creek	13.9
Berkley Creek (tributary to Nanaimo River)	9.2
Boulder Creek (tributary to Nanaimo River	12.1
Stark Creek (Tributary to Nanaimo River)	13.7
Wells and Surface Water Diversion Points	**No.**
# Water Wells listed in MOE DB	2686
Surface water diversion licenses	359

Note: Drainage Areas are based on 1:50,000 BC Watershed Atlas. *Total water region area includes areas which drain directly to the ocean and do not lie within a major watershed. The Nanaimo River drainage area includes all tributaries.

According to the MOE Wells Database (BCGOV ENV Water Protection and Sustainability Branch, 2012) WR6 (NR) has the highest number of water wells (2686 wells) of the six water regions in the RDN. The MOE database likely only represents a fraction of the actual wells currently in use. Many well records may not have been entered into the database and some wells may simply not be in use or have been abandoned. As there is no mandatory requirement for submitting well logs or well abandonment records, it is not possible to determine the groundwater demand from private wells with any degree of certainty, nor is it possible to assess the vulnerability that may exist with improperly abandoned or standing water wells.

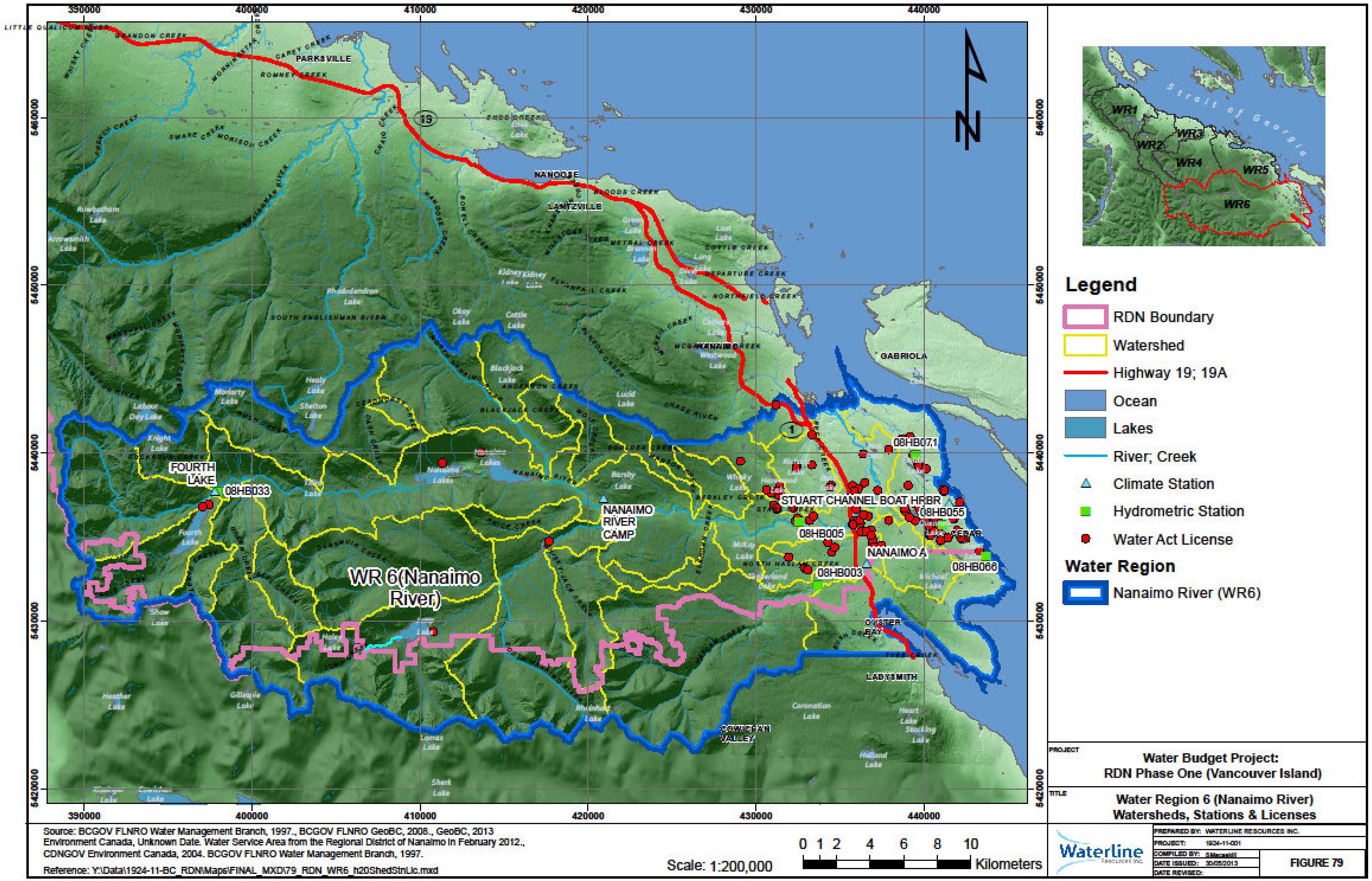


Figure 79: WR6 (NR) – Watersheds, Stations & Licenses

8.2 Surface Water Assessment

8.2.1 Terrain and Topography

The Nanaimo River Water Region (WR6) includes the Nanaimo River Watershed and its major tributaries as well as that part of southern NRD (Cedar and North Oyster) which drain directly to the ocean. The southern edge of the watershed crosses into the Cowichan Valley Regional District including a large part of Haslam Creek. The majority of the upper watershed is private forest lands managed by Timberwest. The lower part of the watershed consists primarily of rural development with agriculture land, low density residential development and some light industrial development.

The region rises from sea level at the Nanaimo River estuary and Stuart Channel up to Mount El Capitain (1,537 m) near Jump Lake. There are four main lakes within the watershed including Fourth Lake, Second and First Nanaimo Lakes and Jump Lake. Dams located at Fourth Lake and Jump Lake is used as surface water storage for the Harmac Pulpmill and City of Nanaimo Municipal Water Supply, respectively.

Some of the major tributaries to the Nanaimo River which have surface water licences include Haslam Creek, South Nanaimo River, Jump Creek and Sadie Creek. The major watersheds in the WR6 (NR) are shown in Figure 79.

8.2.2 Climate

The climate for the Nanaimo River Water Region is similar to the rest of the RDN with cool wet winters and mild dry summers. A single Environment Canada weather station is located at the Nanaimo Airport at lower elevation in the water region. The average total annual precipitation for the 1971 to 2000 period is 1,162.7 mm. Figure 80 shows the monthly distribution of temperature and precipitation recorded at the Nanaimo Airport. Climate station locations are shown on Figure 79.

Significant snowpack accumulations are generally found in the higher elevation sections of the watershed through the winter and spring. The Jump Creek Snow Pillow (03B23P), operated by the BC River Forecast Centre, is located above Jump Lake at Elevation 1,134 m near the watershed divide with Cowichan River to the south. The station has been operational since 1995 and indicates a normal April 1st snowpack SWE of about 1,300 mm and has a maximum recorded SWE of 3,000 mm on April 1st 1999 (see Figure 81). A snow course was also operated in the watershed at Green Mountain (Elevation 1,400 m) from 1954 to 1985 with an average April 1st snowpack SWE of 1,480 mm.

Maps showing the distribution of annual total precipitation and average annual temperature over the water region are shown in Figure 82 and Figure 83, respectively. These maps show the influence of the Vancouver Island Mountains on precipitation and temperature with annual precipitation estimated to be greater than 5,000 mm at the head waters of Saddie Creek.

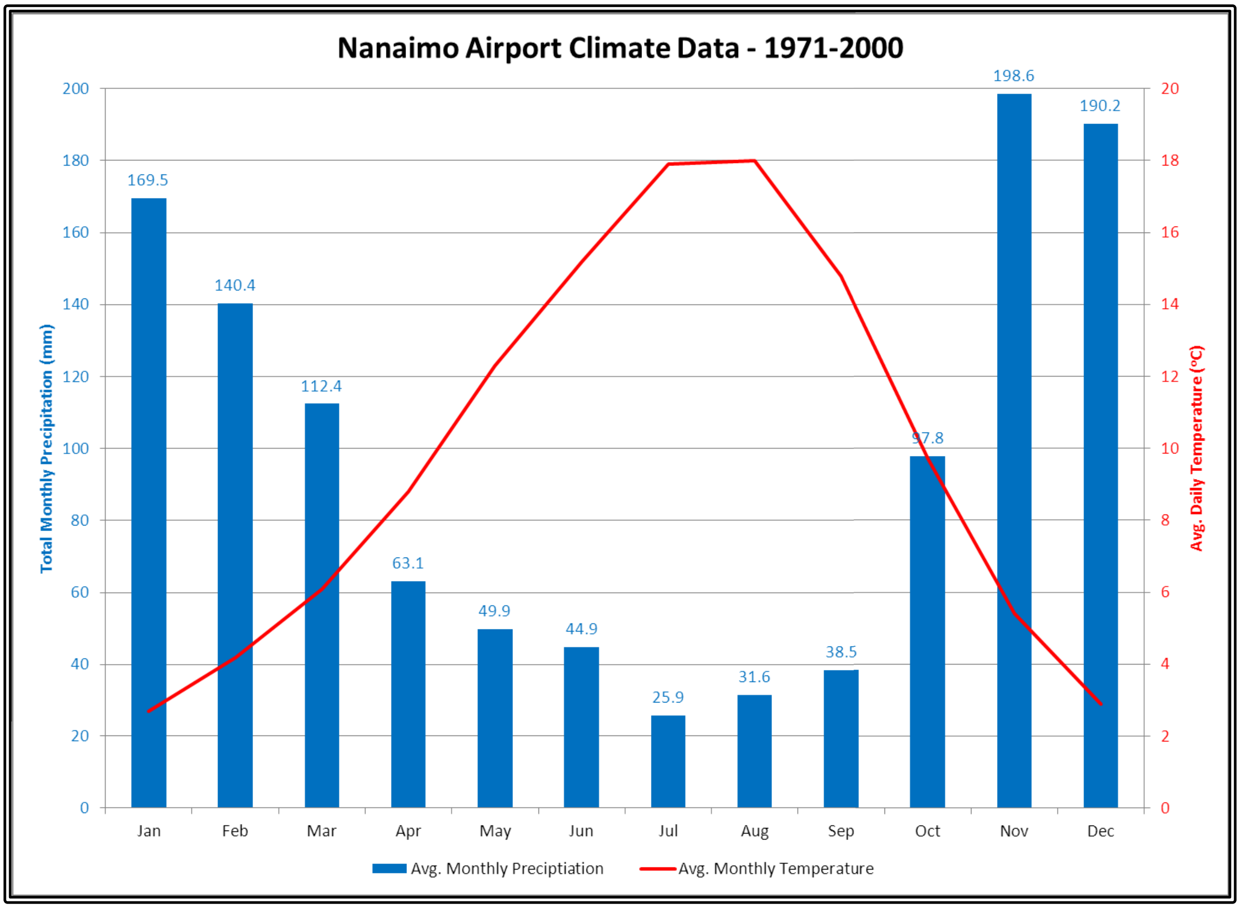
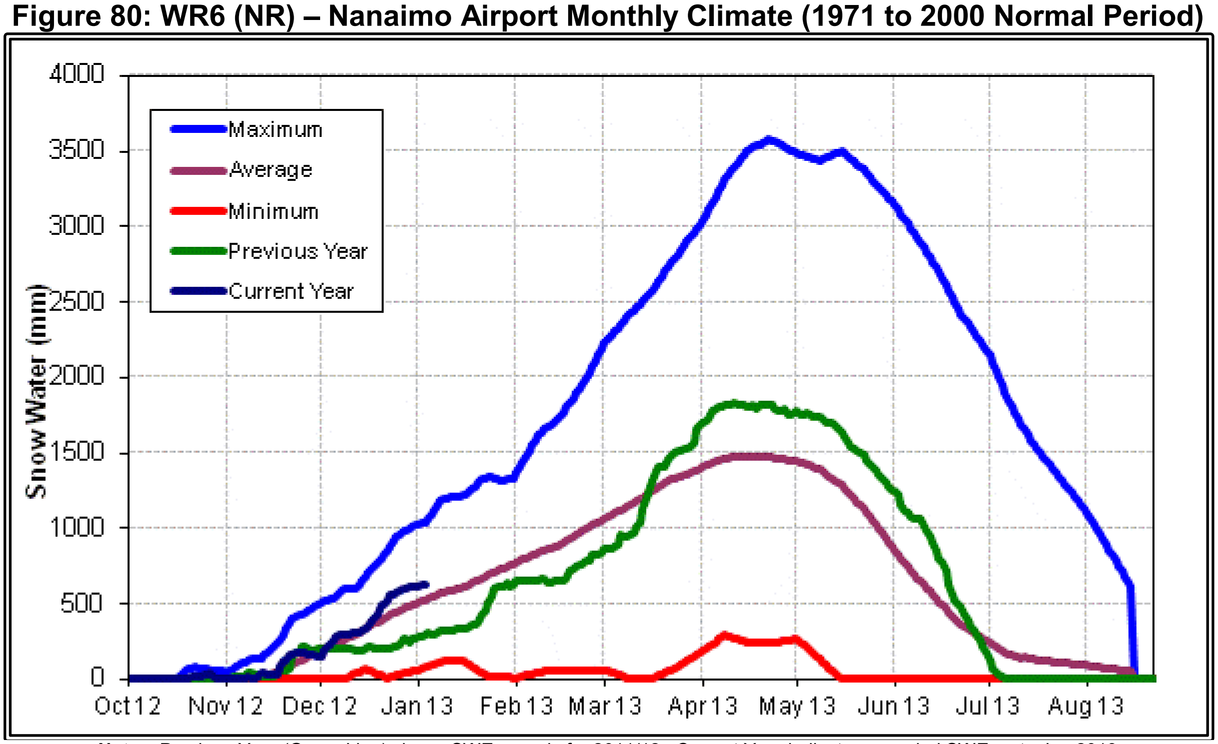


Figure 80: WR6 (NR) – Nanaimo Airport Monthly Climate (1971 to 2000 Normal Period)



Notes: Previous Year (Green Line) shows SWE records for 2011/12. Current Year indicates recorded SWE up to Jan 2013

Figure 81: WR6 (NR) – Jump Creek Snow Pillow

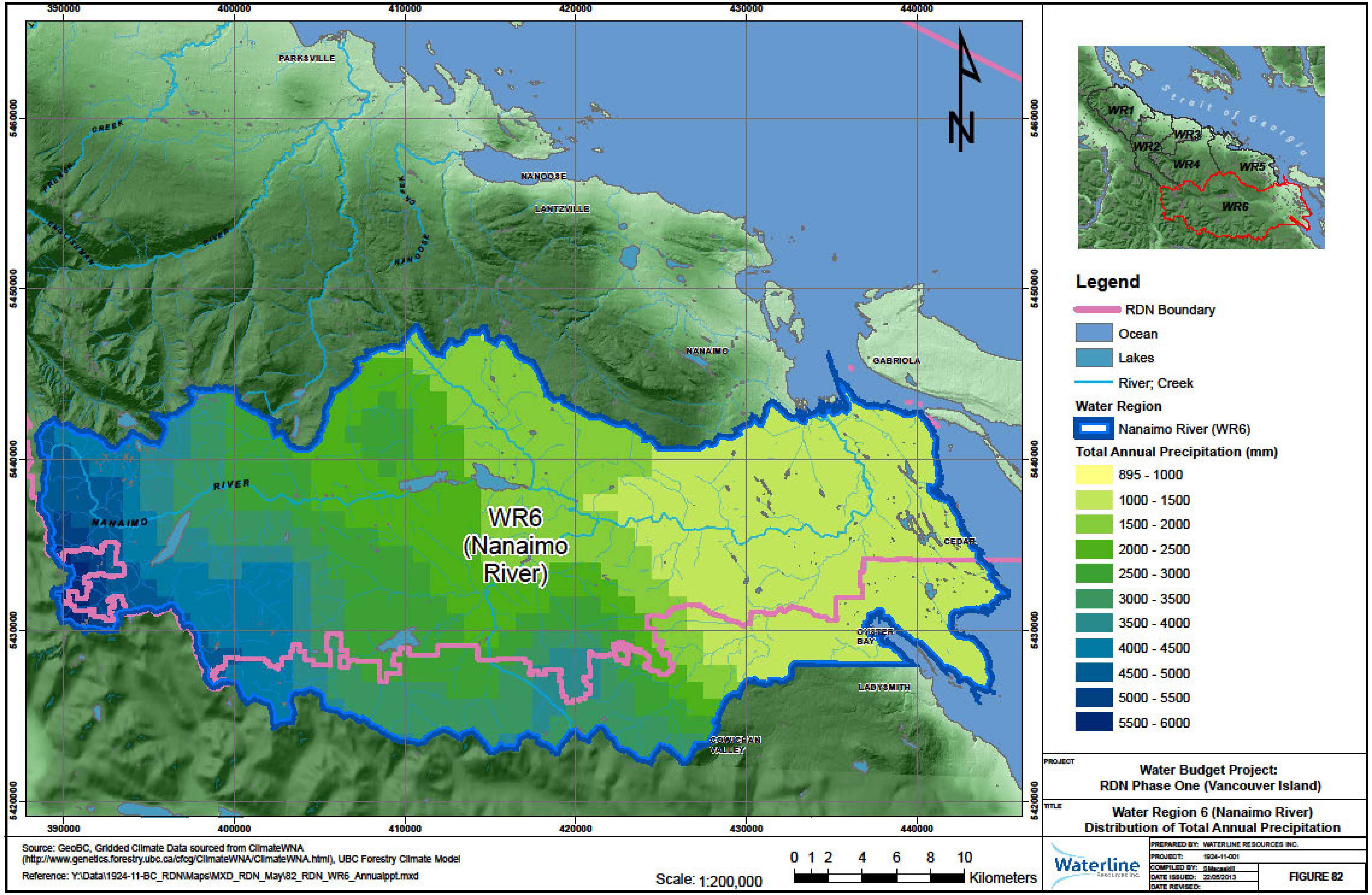


Figure 82: WR6 (NR) - Distribution of Total Annual Precipitation

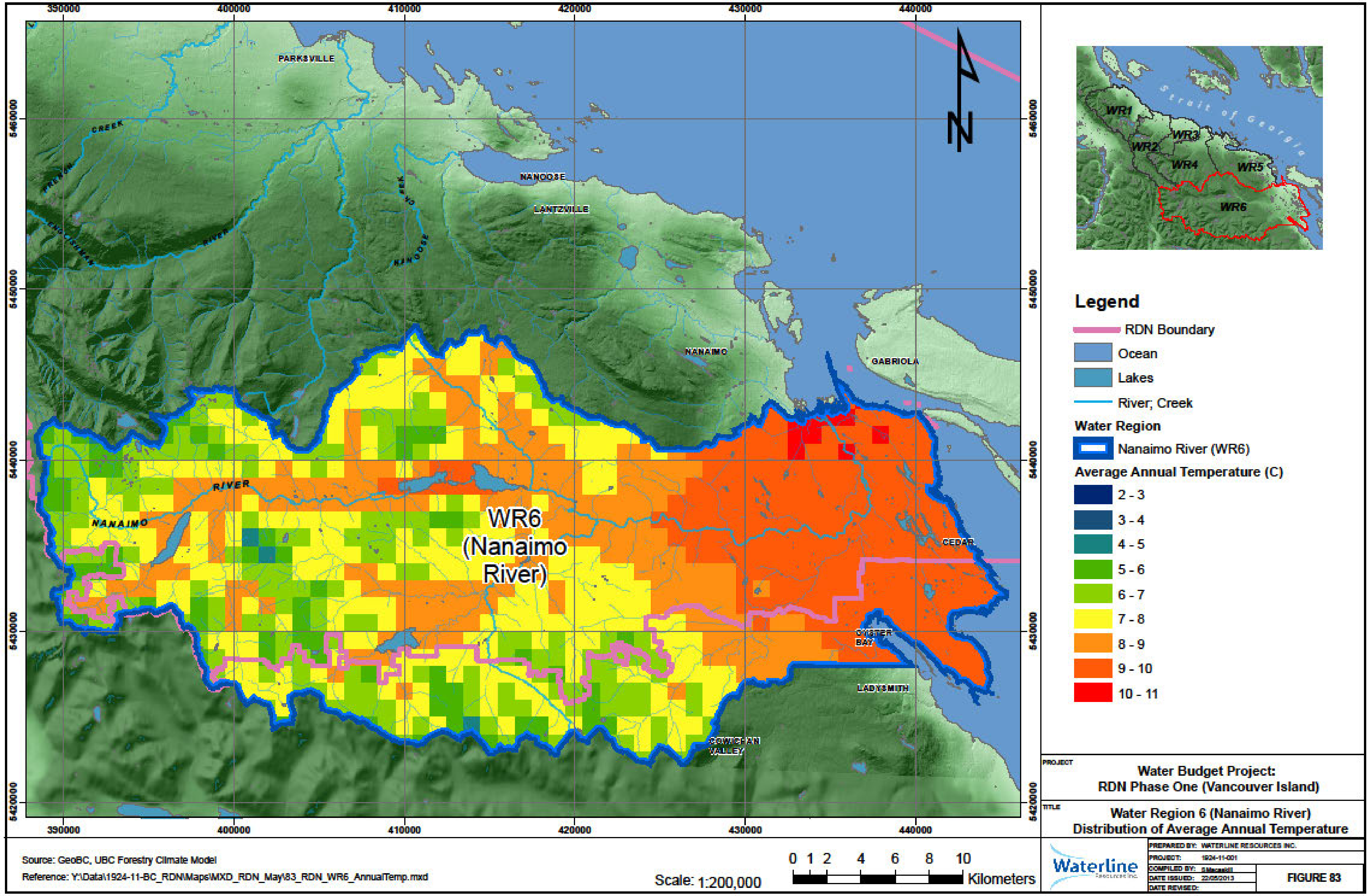


Figure 83: WR6 (NR) - Distribution of Average Annual Temperature

8.2.3 Stream Gauging and Monitoring

Three active and three discontinued water survey of Canada hydrometric stations are located within the Nanaimo River Watershed. The details for each of the stations are included in Table 52.

Table 52: WR6 (NR) – Water Survey of Canada Records

Station	Period	Natural or Regulated	Drainage Area to Gauge (km^2)	Mean Annual Discharge (m^3/s) and Volume (million m^3)	Mean Summer Discharge (m^3/s) and Volume (million m^3)
Nanaimo River near Cassidy (08HB034)	1965 to Present	Regulated since 1963	676	39.8 m^3/s 1,255 million m^3	7.51 m^3/s 59.7 million m^3
Nanaimo River near Extension (08HB005)	1913 to 1927 1948 to	Natural	645	40.5 m^3/s 1,277 million m^3	7.74 m^3/s 61.5 million m^3
Haslam Creek near Cassidy (08HB003)	1914 to1915 1948 to 1962 1992 to	Natural	95.6	4.38 m^3/s 138 million m^3	0.307 m^3/s 2.44 million m^3
South Nanaimo River near Junction	1997 to Present	Regulated	211	14.1 m^3/s 444.7 million m^3	1.98 m^3/s 15.8 million m^3
Jump Creek at the Mouth	1970 to Present	Regulated since 1974	62.2	4.82 m^3/s 0.416 million m^3	1.75 m^3/s 13.9 million m^3
Nanaimo River above Rockyrun Creek (08HB033)	1963 to 1964	Regulated	75.6	N/A	N/A

Monthly average hydrographs for Nanaimo River near Extension and Nanaimo River near Cassidy are shown in Figure 84. The figure provides an indication of the impact that regulation in the system has had on river flows.

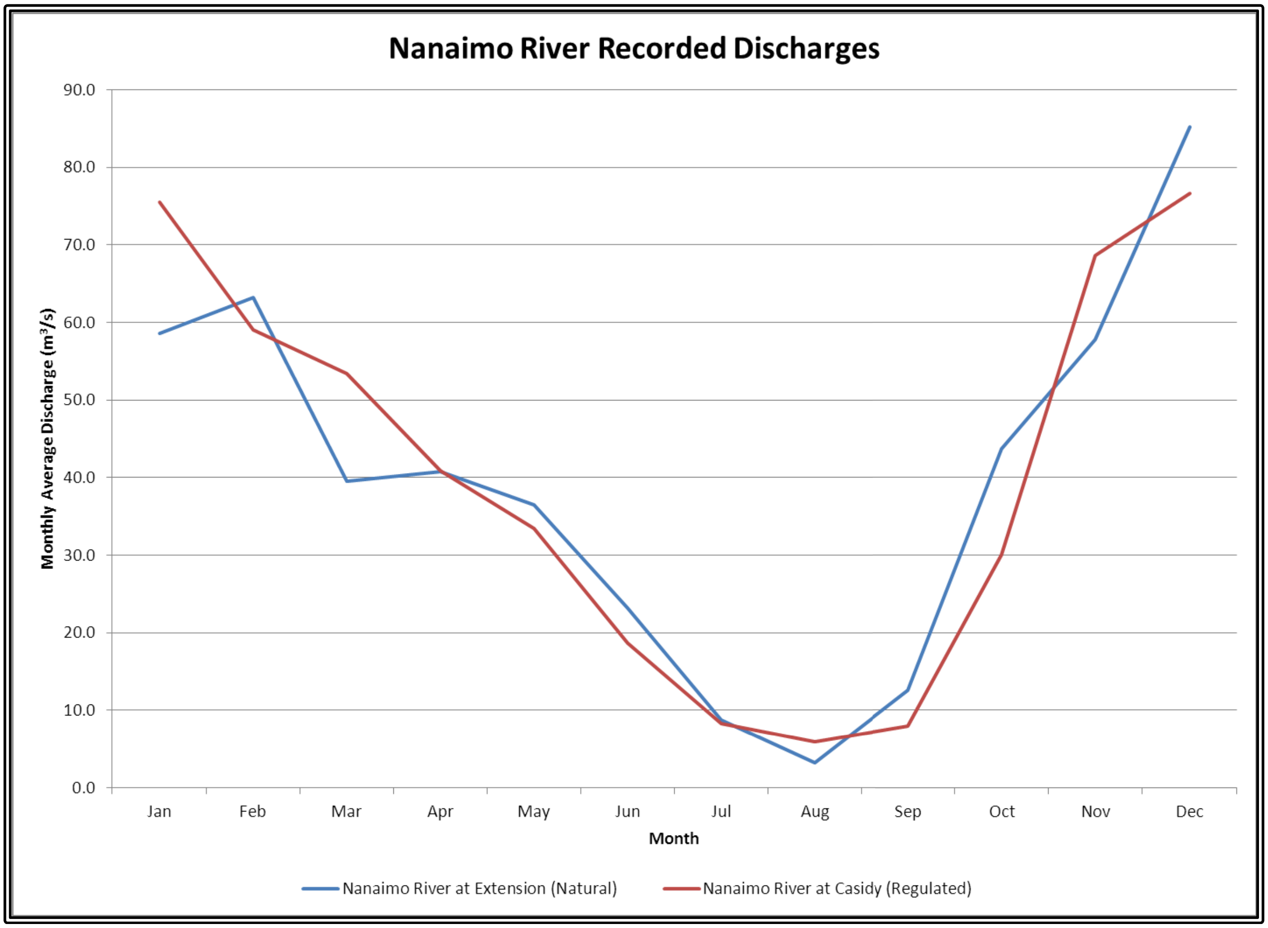


Figure 84: Nanaimo River Recorded Discharges

8.2.4 Hydrology and Surface Water Resources

The Regional Hydrological Model has been used to estimate mean annual discharge and volume as well as summer average discharge and volume for the Nanaimo River and the major tributaries. The results are shown in Table 53.

Table 53: WR6 (NR) – Natural (Unregulated) Surface Water Resources (1971 to 2000)

Watershed	Drainage Area (km^2)	Mean Annual Discharge (m^3/s) and Volume (million m^3)	Mean Summer Discharge (m^3/s) and Volume (million m^3)
Nanaimo River to the mouth (including all tributaries)	830	58.3 m^3/s 1,839 million m^3	7.83 m^3/s 62.2 million m^3
Haslam Creek to the Mouth	129	6.26 m^3/s 197 million m^3	0.378 m3/s 3.0 million m^3
South Nanaimo River	213	16.8 m^3/s 530 million m^3	1.2 m^3/s 9.54 million m^3
Jump Creek	61.7	5.25 m^3/s 165 million m^3	0.36 m^3/s 2.86 million m^3
Sadie Creek	29.3	4.09 m^3/s 128 million m^3	0.506 m^3/s 4.02 million m^3

Flows in the Nanaimo River are regulated at Fourth Lake Dam and Jump Creek Reservoir to support demands at the Harmac Pulpmill and the City of Nanaimo, respectively. Through and agreement with the Department of Fisheries and Oceans and BC Ministry of Forests, Lands and Natural Resource Operations a summer flow of 3.9 m^3/s at the Nanaimo River at Cassidy gauge should be maintained, with roughly 1.0 m^3/s from the Jump Creek dam and 2.9 m^3/s from the Forth Lake dam. During extreme low flow years, a minimum flow of 1.4 m^3/s is required to be maintained below the water intakes for the mill and 0.28 m^3/s in Jump Creek. Currently, the City of Nanaimo is in the planning and design process for construction of a new surface water reservoir on the South Nanaimo River. However, the details of the dam are preliminary and have not been included in the assessment.

8.2.5 Surface Water Demand

Table 54 summarizes the surface water licences in WR6 from the BC Surface Water Licence Database. Table 55 outlines the licenced surface water storage. The locations of the surface water licences for WR6 are shown on Figure 79.

Table 54: WR6 (NR) - Surface Water Demand

Type of Demand	Monthly (m^3/month)	Annual (million m^3)	Summer (Jul-Sept) (million m^3)
Consumptive Demand			
Agriculture	28,300	0.340	0.254
Domestic	2,400	0.0288	0.095
Industrial	9,910,000	118	29.7
Institutional	68	0.0008	0.00027
Water Works	5,390,000	64.7	21.4
Total Consumptive	15,330,000	184	51.3
Non- Consumptive Demand			
Power	699,840	8,398,080	
Conservation	-	-	
Total Non-Consumptive	699,840	8,398,080	

Table 55: WR6 (NR) - Licensed Surface Water Storage

Type of Demand	Total Storage (Million m^3)
Storage	64.3
Conservation Storage	0
Other Storage	0.87
Total Storage	65.1

The two largest water users in the Nanaimo River Water Region are the Harmac Pulpmill and the City of Nanaimo for Municipal Water Supply. The mill has a licence to withdraw up to 3.82 m^3/s (118 million m^3) while the City of Nanaimo has a licence to withdraw up to 64.7 million m^3 annually. However, both use less than their allocated amount. Actual recorded withdrawals for 2010 are included in Table 56.

Table 56: WR6 (NR) - Recorded Surface Water Withdrawal in 2010

Water User	Total Annual Volume (Million m^3)	Total Summer Volume (Million m^3)
City of Nanaimo	15.7	5.30
Harmac Pulp Mill	39.8	9.95
Total Recorded Withdrawal	55.5	15.5

Notes: Recorded withdrawal values were from Nanaimo River Baseline Report (Nanaimo Area Land Trust, 2011)

8.2.6 Surface Water Stress Analysis

As outlined in Section 2.4.2, a surface water stress analysis for each of the major watersheds has been completed. Water budget analysis for other smaller ungauged subwatersheds within WR6 (NR) should be completed when data is available and as part of a more detailed Tier 1 or Tier 2 water budget assessment (OMNR 2011). The results of the allocation and actual demand stress analysis for the watersheds in WR6 (NR) are shown in Table 57. A map showing the relative stress for each watershed is shown in Figure 85.

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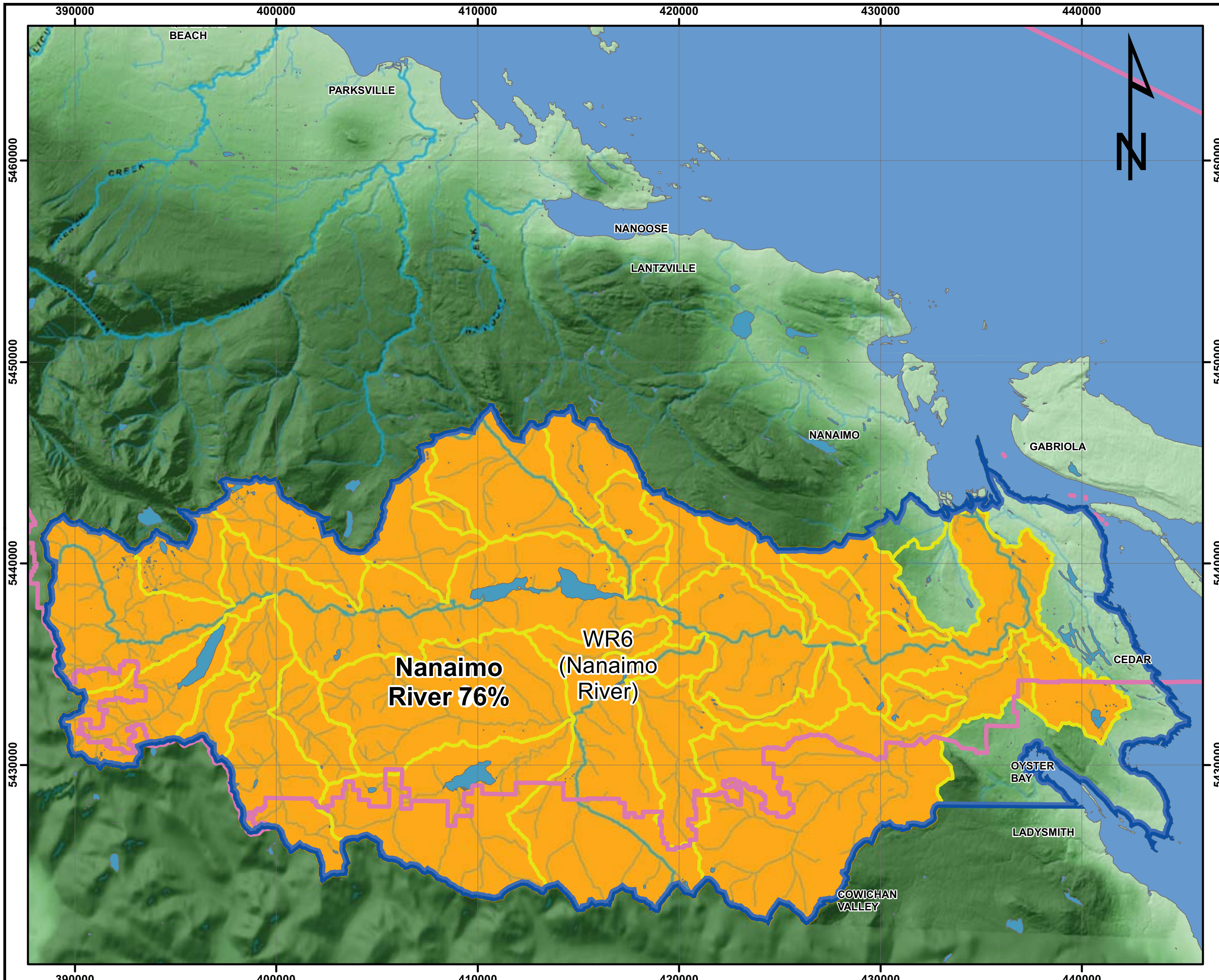

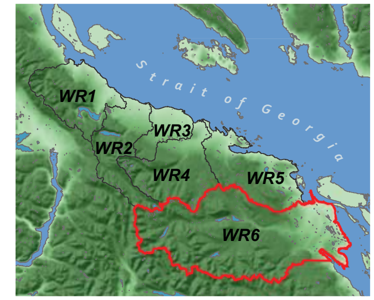

Legend

- RDN Boundary
- Watershed
- Ocean
- Lakes
- River; Creek

Water Region

- Nanaimo River (WR6)

Allocated Surface Water Stress Level (%)

- Low (0 - 25)
- Low - Moderate (25 - 50)
- Moderate (50 - 75)
- Moderate - High (75 - 100)
- High - Very High (> 100)

PROJECT

Water Budget Project: RDN Phase One (Vancouver Island)

TITLE

Water Region 6 (Nanaimo River) Relative Surface Water Stress

Source: UBC Forestry Climate Model, BC FLNRO Water Management Branch, RDN Soil and Land Cover, GeoBC

Reference: Y:\Data\1924-11-BC_RDN\Maps\MXD_RDN_May\85_RDN_WR6_WaterStress.mxd

Scale: 1:200,000

0 1 2 4 6 8 10 Kilometers

Waterline Resources Inc.

PREPARED BY:	WATERLINE RESOURCES INC.
PROJECT:	1924-11-001
COMPILED BY:	SMacaskill
DATE ISSUED:	21/05/2013
DATE REVISED:	

FIGURE 85

Table 57: WR6 (NR) - Surface Water Stress Analysis

Watershed	Average Natural River Flow Supply (million m^3)	Storage (million m^3)	Conservation Flow (10% of MAD) (million m^3)	Licensed Demand (million m^3)	Allocation Stress	Stress Level	Actual Demand (million m^3)	Actual Stress
Nanaimo River	62.2	64.2	45.8	51.5	**76%**	Moderate to High	15.5	**48%**

Notes: Volumes indicated in the table are average volumes for summer period (Jul to Sep). Average natural river flow is the estimated or recorded unregulated flow in the watershed. Total storage is based on licensed storage volume and assumes all storage is available to support conservation flow and licenced demand for the Jul to Sep period. The 10% of Mean Annual Discharge (MAD) conservation flow is based on current Ministry of Forest, Lands and Natural Resource Operations (MELP, 1996) minimum conservation flow policies for the east coast of Vancouver Island. Licenced demand is the total licenced volume for summer based on consumptive water licences. Allocation stress = (Average Natural supply + storage) / (Conservation Flow + Licenced Demand). Actual Stress = (Average Natural supply + storage) / (Conservation Flow + Average Recorded Surface Water Demand). Surface water stress color codes: blue=low, green =low to moderate, yellow =moderate, brown =moderate to high, red=high to very high. Values reflect average flow conditions and do not consider drought years.

8.3 Groundwater Assessment

8.3.1 Existing Groundwater Studies and Data – WR6 (NR)

Given the regional scale of the Phase One Water Budget Assessment, the most important data compiled and geo-referenced by Waterline was the water well information, elevation data, soil and geology maps, land cover, aggregate resource map, mapped aquifers, and water service areas. Other maps were generated using the input data as part of Waterline's work and some samples are provided in Appendix C for illustration purposes (Eg: overburden thickness (Map C7), piezometric contour maps (Maps C8 and C9), air temperature (Map C14), precipitation (Map C15), runoff (Map C16 and C17), evapotranspiration (Map C18), infiltration (Map C19), Water Service Areas (Map C20), and Water Demand Assessment in Non-service areas (Map C21). All of these maps are provided in Appendix C for the entire RDN study area with an explanation of how the map was geo-reference or created by Waterline. These data and layers are now available in the ARC GIS Geodatabase at the RDN Scale, water region scale, watershed scale, on other local scale needed for site specific assessments. These data will be provided to the RDN in electronic format as part of the ARC GIS Geodatabase system which was constructed by Waterline for use by the RDN. These regional datasets form the framework for construction of the conceptual hydrogeologyical model.

Although only some of the data in certain reports may have been incorporated into Waterline's Geodatabase, the primary studies in the region were used in Waterline's water budget assessment to provide the local hydrogeological are provided in Table 58.

Table 58: WR6 (NR) – Hydrogeology Reference Reports

Author	Year	Study Title
Associated Engineering	2007	South Nanaimo River-Watershed Yield Assessment (2007)
Associated Engineering	2009	Nanaimo River Fourth Lake Yield Assessment
GW Solutions, Vancouver Island University	2010	Area A Groundwater Assessment and Water Budget
Levelton	2011	RDN Observation Well Holden Corso and Lofthouse Roads, Cedar
Pacific Hydrology Consultants	1990	OCI Boat Harbour Development - Water Supply Completion Report
Piteau Associates	1992	Water Well Testing for Pylades Development
Piteau Associates	1995	Pylades Well – Pumping Test – 2380 Bissel Road Cedar
Piteau Associates	2001	North Cedar Improvement District Hydrogeologic Assessment to Identify New Well Source

Author	Year	Study Title
SRK Consulting	2007	TEL_17-123-432f_rpt_Cassidy Aquifer - Completion Report
Thurber Engineering Ltd.	2006	Water 2006S Nanaimo Lakes Groundwater Study

8.3.2 Description of Aquifers and Water Wells

A total of three unconsolidated aquifers and three bedrock aquifers have been mapped within WR6 (NR) (Table 59). The Capilano aquifer 161 (Cassidy Aquifer) was mapped as having high productivity, is highly developed, and is also high vulnerable due to its unconfined nature. The underlying Vashon sand and gravel aquifer (#160, Lower Cassidy Aquifer) exhibits moderate productivity, low vulnerability, and is not well developed. Bedrock aquifers in Extension (164) and South Wellington (165) exhibit low yield, moderate demand, and moderate vulnerability. The Cedar/Yellow Point aquifer (Aquifer 162) exhibits low productivity/yield, high demand, and high vulnerability. It should be noted that aquifers 963 and 964 are newly mapped aquifers in this region and water budgets were not included in the current water budget assessment.

Table 59: WR6 (NR) – Summary of Mapped Aquifers

Aquifer Tag No.	Aquifer Lithology	Location Within Water Region	Potential Groundwater-Surface water or Aquifer to Aquifer Interaction	Developed Aquifer surface Area	Confined, Semi, or unconfined, Aquifer Vulnerability Code	Yield
				(m2)		(L/M/H)
160	Vashon	Lr. Cassidy	NR	6.0E+06	Semi-Confined, IIC	M
161	Capilano	Cassidy	NR	3.0E+07	Unconfined, IIA	H
162	NG	Cedar, Yellowpoint	NR, Ocean	7.9E+07	Unconfined, IA	L
163	Quadra	North Holden Lk., Cedar	Ocean	1.6E+06	Unconfined, IIB	M
164	NG	Extension	NR	6.2E+06	Confined, IIB	L
165	NG	South Wellington	NR	1.7E+07	Confined, IIB	L

Notes: A/B/C is high/moderate/low vulnerability, I/II/III is heavy/moderate/light use, H/M/L means high/medium/low productivity/yield. All aquifer classification parameters, codes and yield are defined at the following MOE web address http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/Aq_Classification/Aq_Class.html#class. NG means Nanaimo Group.

Figure 86 shows the three sand and gravel aquifers mapped in WR6 (NR) with associated supply wells listed in the MOE Wells Database. Figure 87 shows the three bedrock aquifers with associated supply wells listed in the MOE Wells Database. There are a total of 2686 overburden and bedrock wells listed in the MOE data base in WR6 (NR) (Table 51). As there are no regulatory requirements in BC to submit wells logs to MOE for capture in the Wells Database, the water wells shown on Figure 86 and Figure 87 likely represents only a fraction of wells actually drilled.

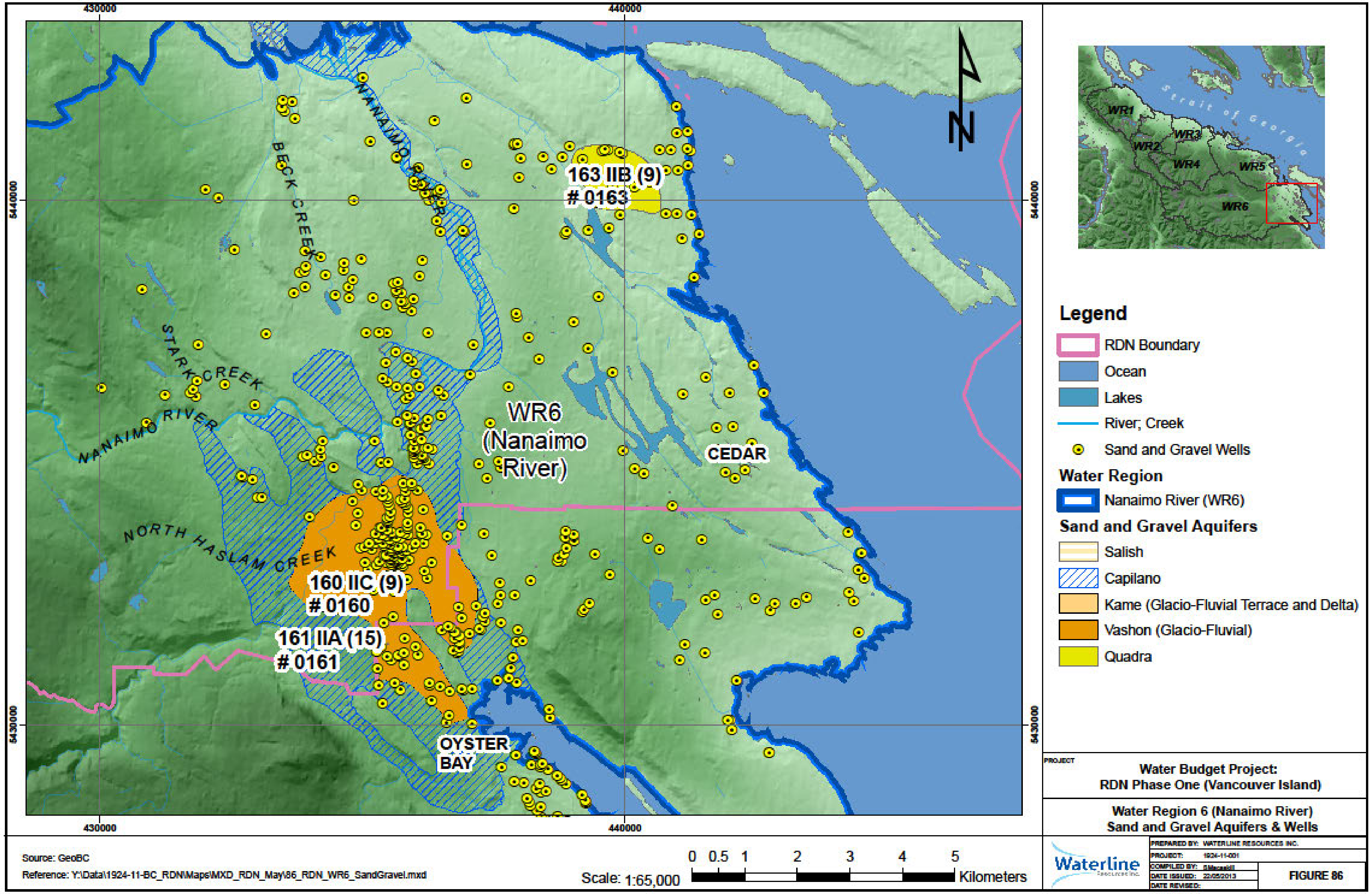

Figure 86: WR6 (NR) – Mapped Sand and Gravel Aquifers & Wells

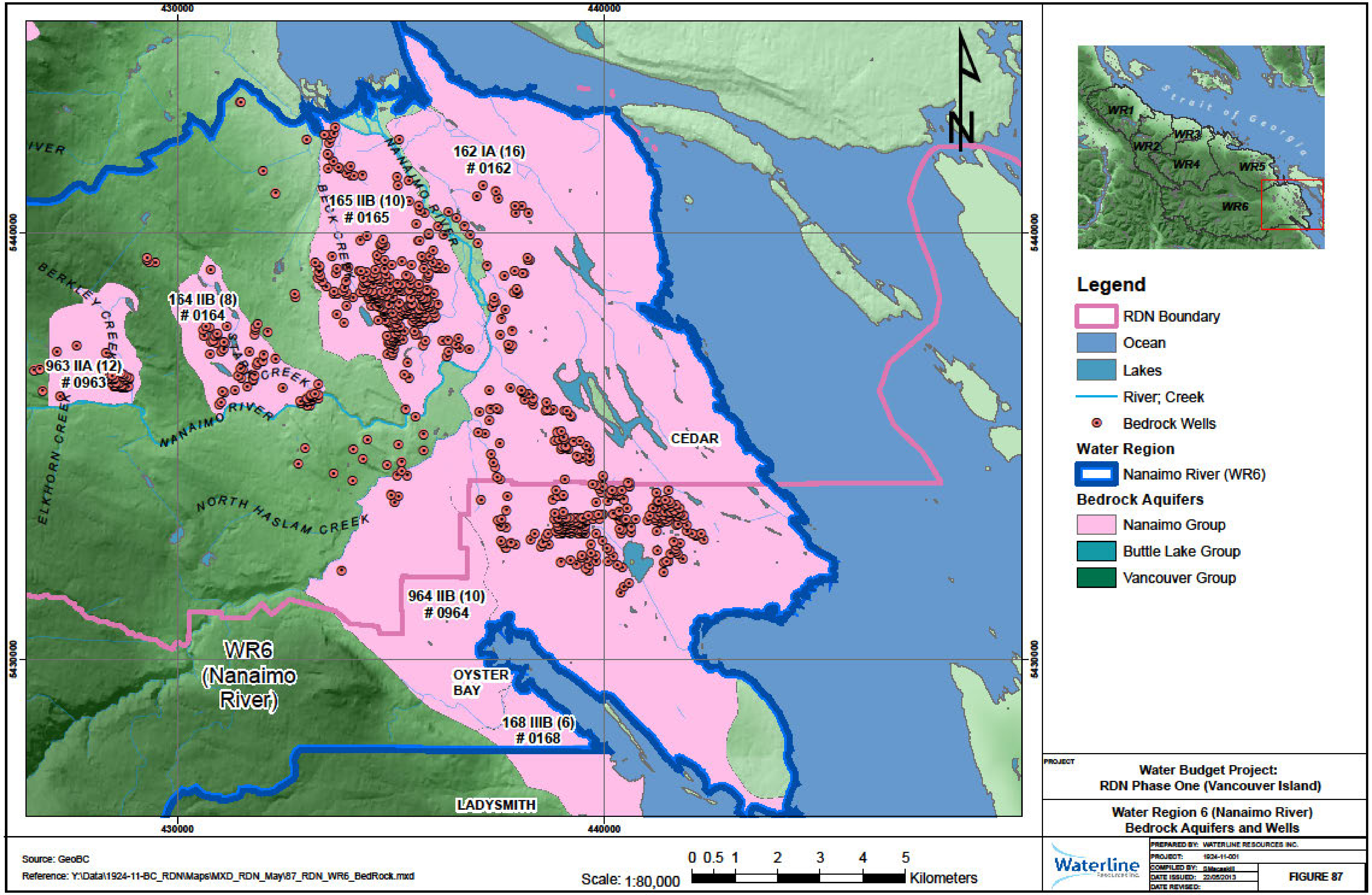

Figure 87: WR6 (NR) – Mapped Bedrock Aquifers & Wells

8.3.3 Groundwater-Surface Water Interaction - Conceptual Hydrogeological Model

A conceptual hydrogeological model of each aquifer with WR6 (NR) was developed in order to understand the key elements and linkages between surface water and groundwater systems required to complete the aquifer water budget assessment. Although conceptual hydrogeological model developed by Waterline includes numerous cross-sectional views developed within the Waterline Geodatabase, only one 3D view into the subsurface will be presented here.

Figure 88 shows a 3D block diagram illustrating the relationship between surface and subsurface geology in the Cassidy area of WR6 (NR) where two major water supply aquifers have been mapped. The schematic shows how the Capilano Aquifer (161) is exposed in Haslam Creek and the Nanaimo River and likely contributes important base flow to the creek during the summer and fall season. View 1 shows the upper Cassidy aquifer (161) with a high water table. The lower Cassidy aquifer (160) is considerably less developed but water levels appear to be high suggesting that it may be connected to overlying upper Cassidy aquifer (161).

8.3.4 Significant Recharge Areas

Significant recharge areas within WR6 (NR) were determined as part of the assessment of infiltration across the region base on topography, mapped textural soil characteristics, land cover (bare land, vegetation, impermeable surfaces), and leaf area index. These areas are important for maintaining recharge to aquifers and base flow to creeks and rivers. Figure 89 shows significant recharge areas mapped in WR6 (NR) as part of the water budget project.

Significant recharge areas are shown in red/orange and extend to the upper reaches of WR6 (NR) into upper Sadie Creek and Rockyrun Creek at the western most part of WR6 (NR), and to Whisky Jack and Boulder Creek in the east of the water region.

Some of the areas indicated are moderately developed (Boulder Creek), but most areas are largely undeveloped. Future development planning needs to consider these areas to ensure that aquifer recharge continues to be maintained. There is a need to develop protection zones around critical areas contributing recharge to underlying aquifers to ensure the future sustainability of groundwater resources in this region. Better definition of these areas should be completed as the current modelling completed by Waterline and KWL was done on a 1 km square grid.

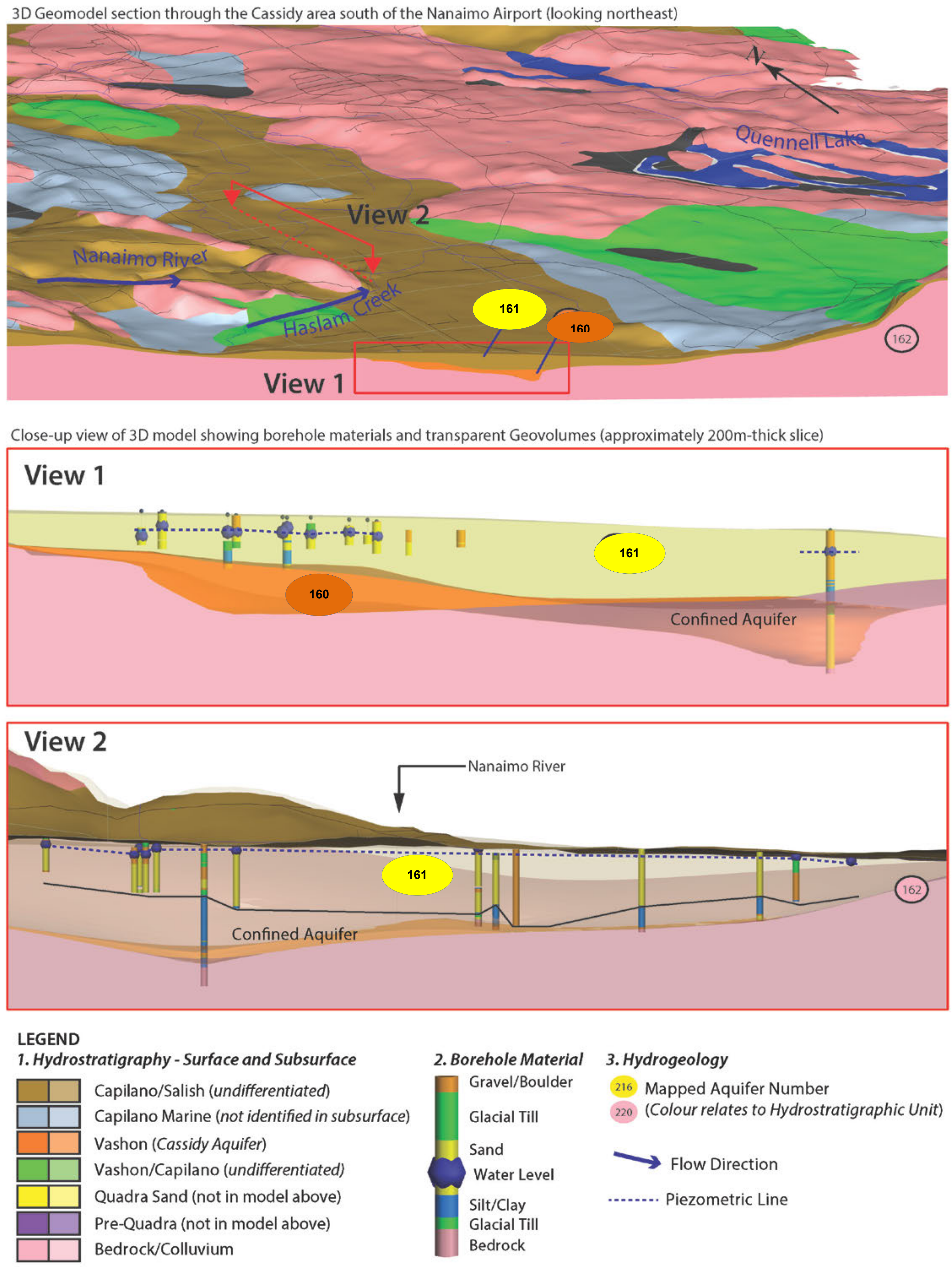

Figure 88: WR6 (NR) – Hydrogeological Conceptual Model – Cassidy Area

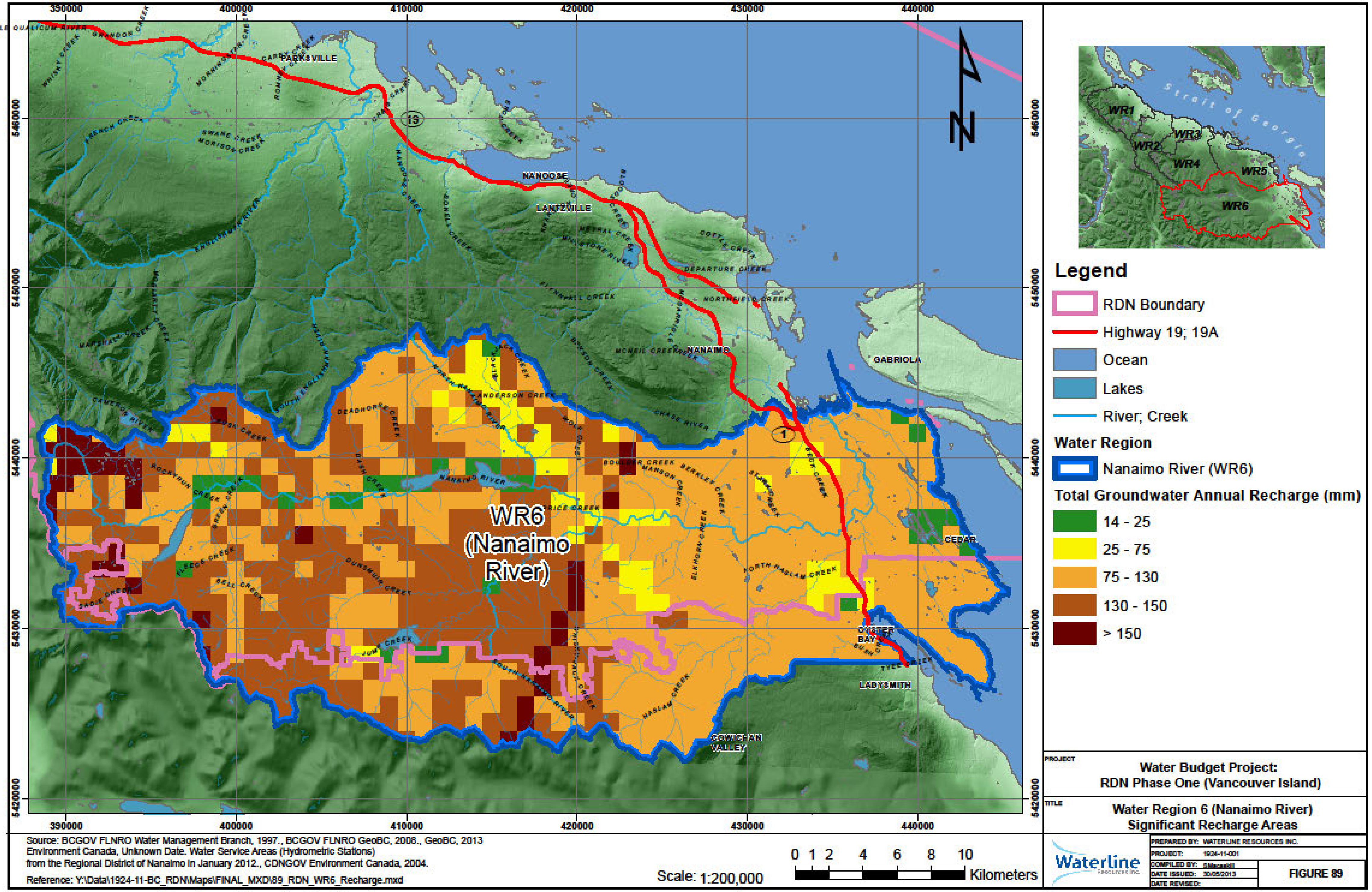

Figure 89: WR6 (NR) – Significant Recharge Areas

8.3.5 Groundwater Level Monitoring – BC MOE Observation Well Network

Long-term water level monitoring data provides an indication of an aquifer's response to global, regional, and local environmental changes in climate, groundwater pumping, and the impacts (if any) of other activities related land development. Long-term records also allow for establishing hydraulic linkages between the groundwater and surface water systems.

Figure 90 shows the locations of MOE observation wells and long-term water level monitoring records in relation to community water supply wells identified from the MOE Wells Database (E.g.: Large municipal users, the RDN, private utilities wells). Although numerous community wells are listed in the database, Waterline understands that not all of the wells shown on Figure 90 are currently active.

One of the problems encountered by Waterline during the water budget project was that community well owners generally do not cross reference active production wells to respective well logs in the MOE database. Often wells are referred to by local names (E.g.: RDN well # 1, #2, etc…). As water budget calculations require that production wells be assigned to specific aquifers, it is important that cross-referencing with the MOE well logs be completed. Well owners are encouraged to report the MOE well plate number so that accurate water level and groundwater extraction volumes can be allocated to the corresponding MOE well log and mapped aquifer.

Water level monitoring records are available for five MOE observation wells in WR6 (NR) (Figure 91 to Figure 96, inclusive). Two MOE wells (330 & 312) are completed in the Cassidy (upper) Aquifer 161 (Figure 91 and Figure 92), MOE well 228 in the Vashon (Lower Cassidy) Aquifer 160 (Figure 93), and three MOE wells in Nanaimo Group Bedrock (Cedar and Yellow Point) Aquifer 162 (Well # 337, 315, and 331 (Figure 94 to Figure 96). Water levels in MOE Wells were plotted along with the Nanaimo Airport precipitation record and the Jump Creek River Stage (level) in the case of MOE well 330 located at the confluence of Jump Creek and the Nanaimo River.

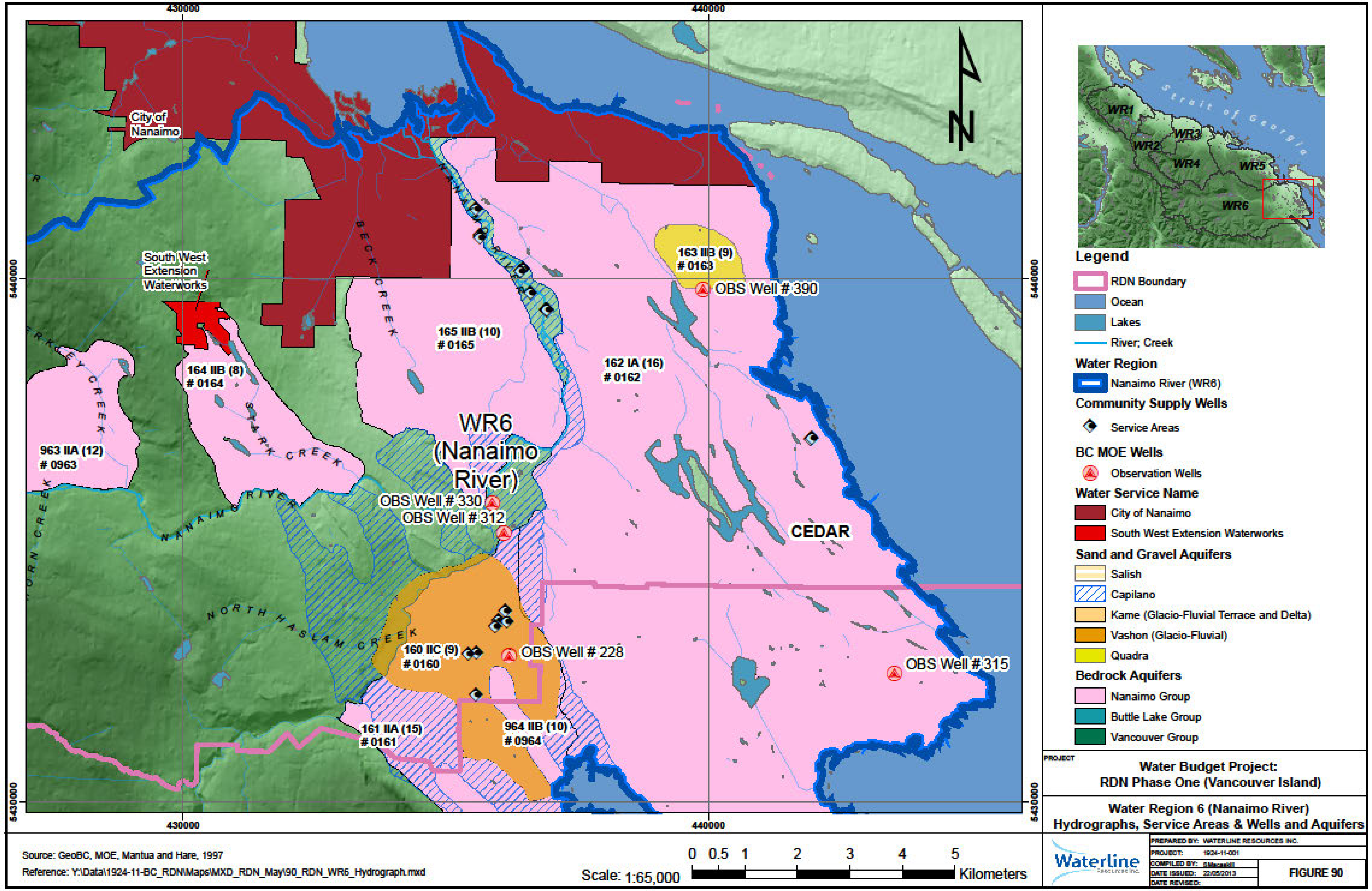

Figure 90: WR6 (NR) – MOE Well Hydrographs, Service Areas & Wells, and Aquifers.

MOE observation wells 330 and 312 completed in Capilano aquifer 161 (Upper Cassidy Aquifer) shows a 2-6 m water level decline since monitoring began until the year 2000. This was followed by a level trend to present day. Both wells also follow the Jump Creek level, Nanaimo Airport precipitation data, and PDO trend suggesting a direct connection to the surface. The data suggests that groundwater pumping significantly affects water levels in the Capilano aquifer 161 (Upper Cassidy Aquifer). High volume wells located near the Nanaimo River, and/or the fact that the flow in the Nanaimo River is regulated, could account for the water level drop in the aquifer observed between 1996 and 2000 (MOE Well 330) and 2003 (MOE Well 312). More information is needed to verify the cause and effect relationship.

Water level data collected in the underlying Lower Cassidy Aquifer (Well 228, Figure 93) shows a much more stable trend as only a few water supply wells extract groundwater from this aquifer. The water level record exhibits close correlation to the local precipitation data and the PDO trend suggesting a direct connection to the surface. This also means that the Lower Cassidy aquifer may be semi-confined and hydraulically connected to the overlying Cassidy aquifer.

The water level hydrograph for MOE well 337, completed in bedrock Aquifer 162 near Henry Roethel Road shows seasonal variations and an overall water level decline of 15m between 2002 and 2010. This decline can likely be attributed to a number of factors including local over-pumping of the aquifer and its location at the top of the watershed where there is a limited catchment area for aquifer recharge. MOE well 315 is also completed in bedrock Aquifer 162 near the coast but shows a relatively stable long-term water level, although Waterline understands that the logger in this well may not be functioning properly. Both MOE wells completed in Aquifer 162 show a one to two month offset from the precipitation record suggesting a semi-confined system. The record for MOE Well 390 is too short to assess the long-term trend.

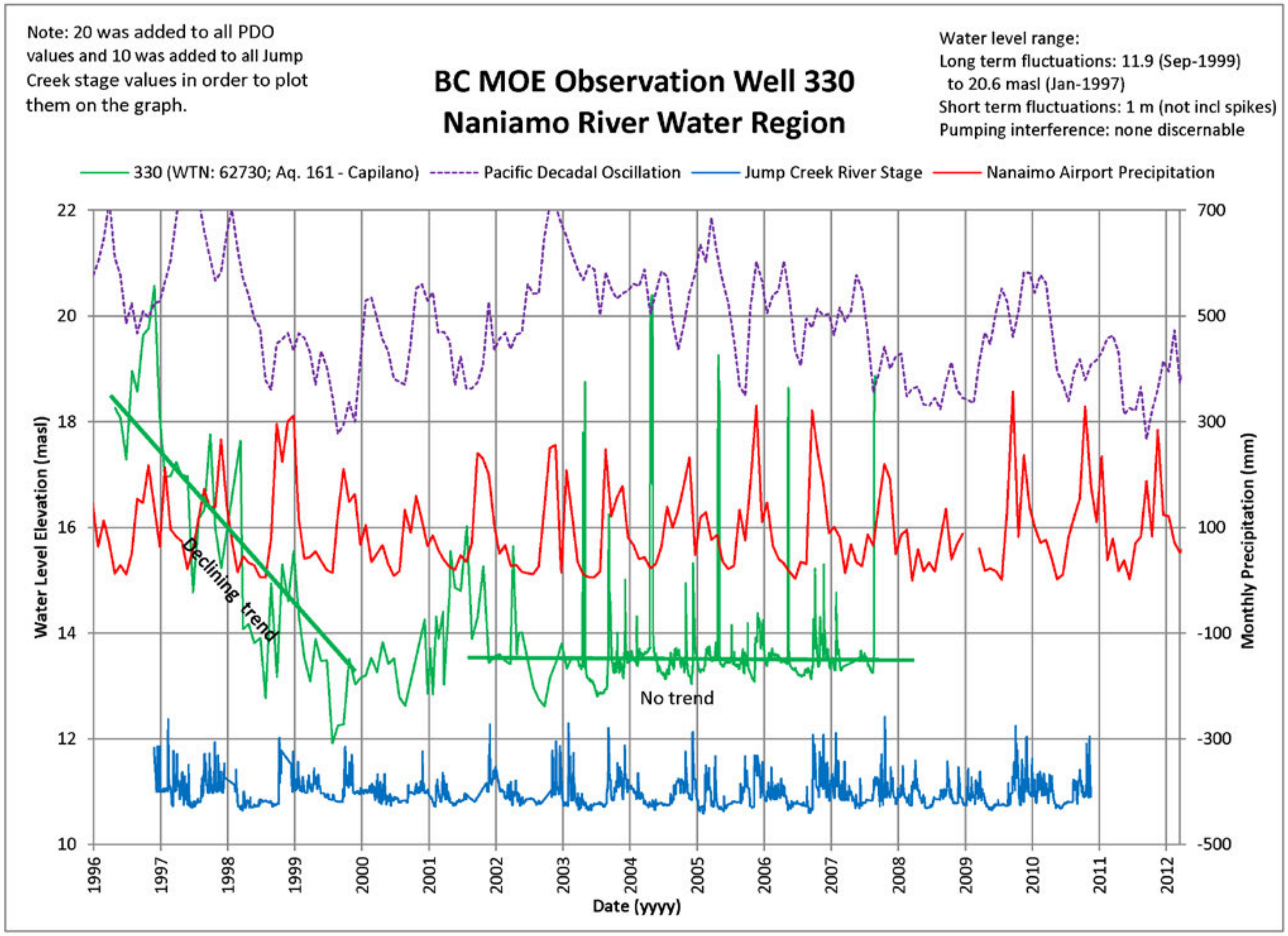

Figure 91: WR6 (NR) – Water Level Hydrograph BCMOE 330.

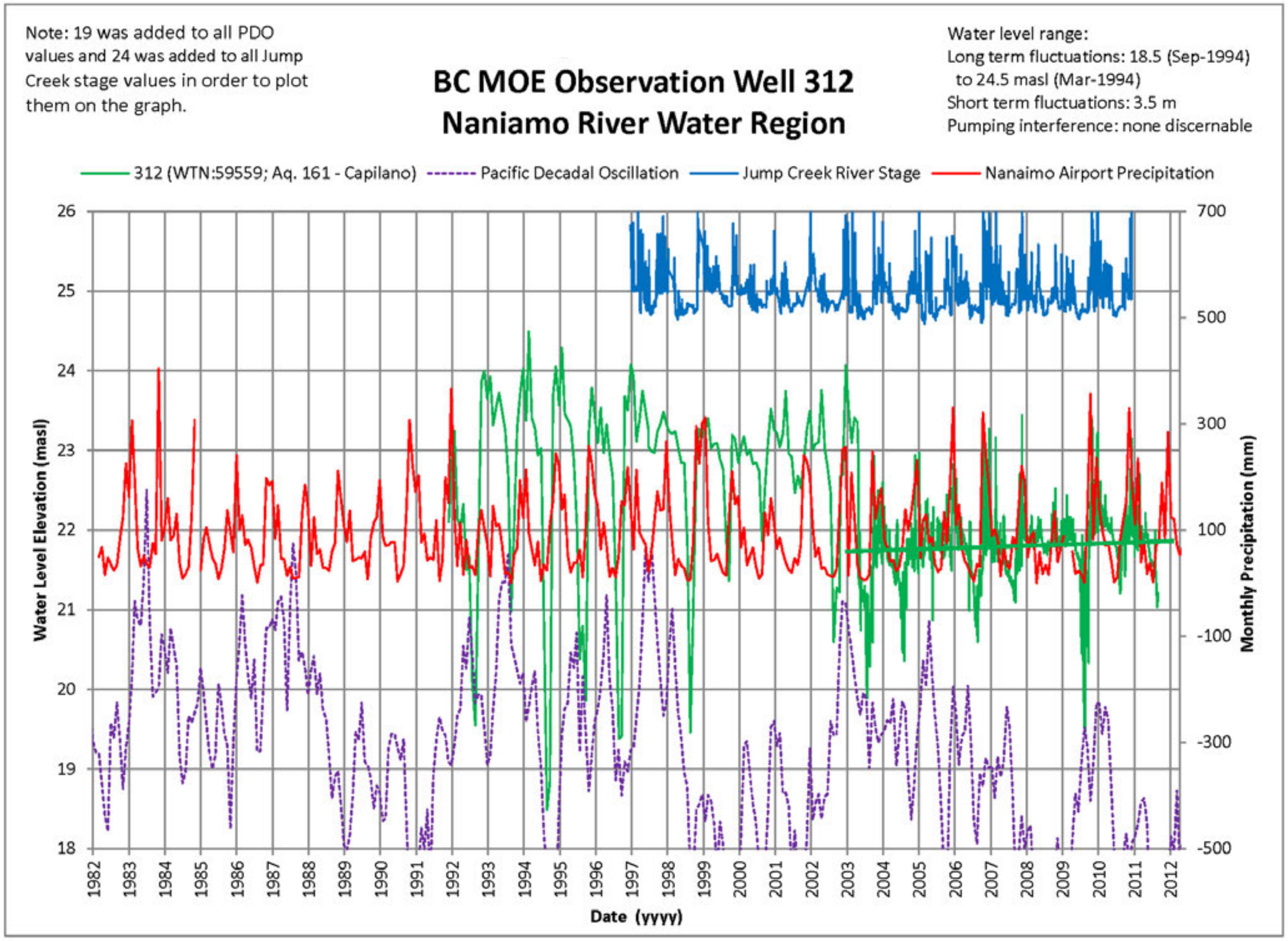

Figure 92: WR6 (NR) – Water Level Hydrograph BCMOE 312.

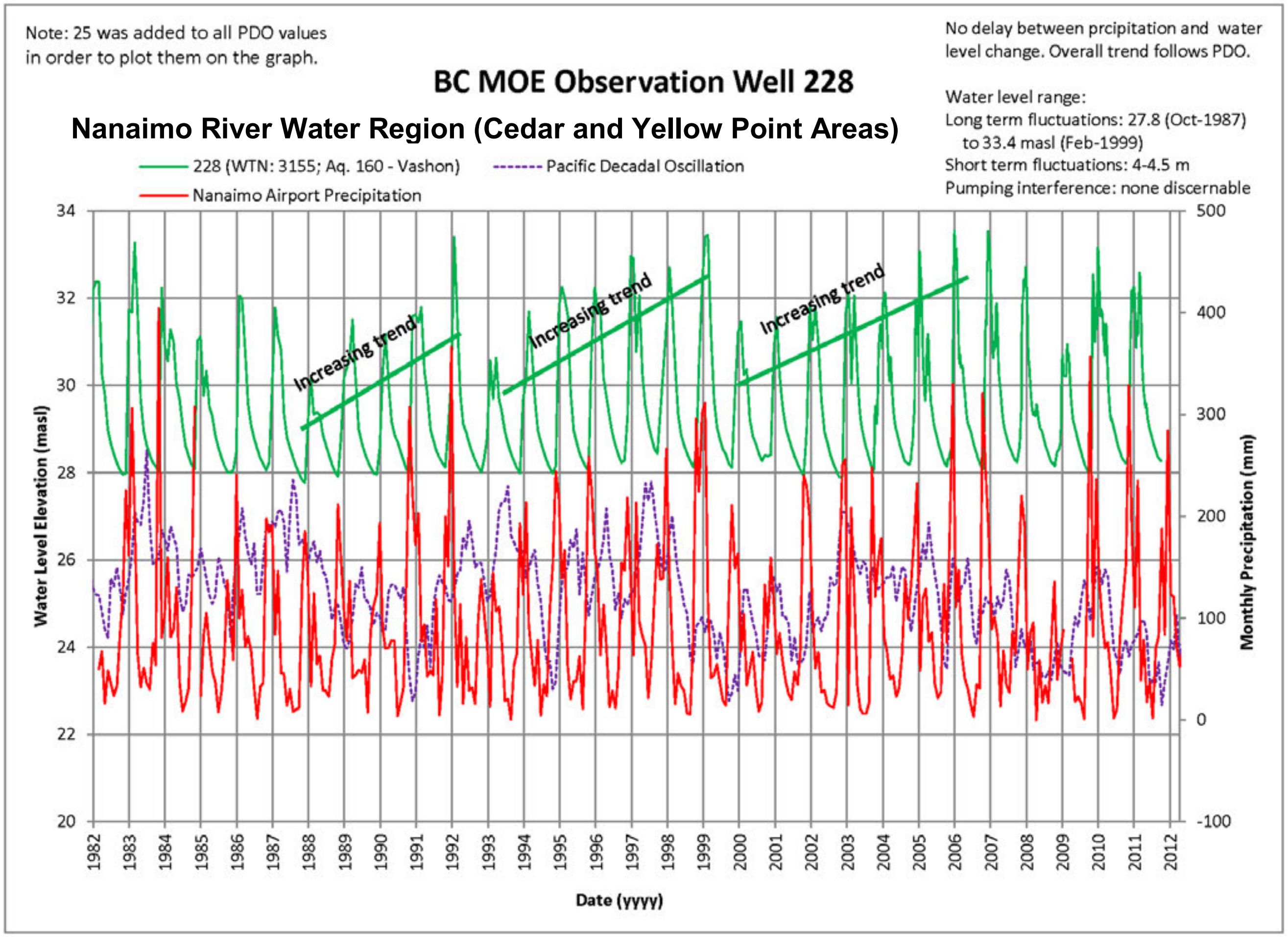

Figure 93: WR6 (NR) – Water Level Hydrograph BCMOE 228.

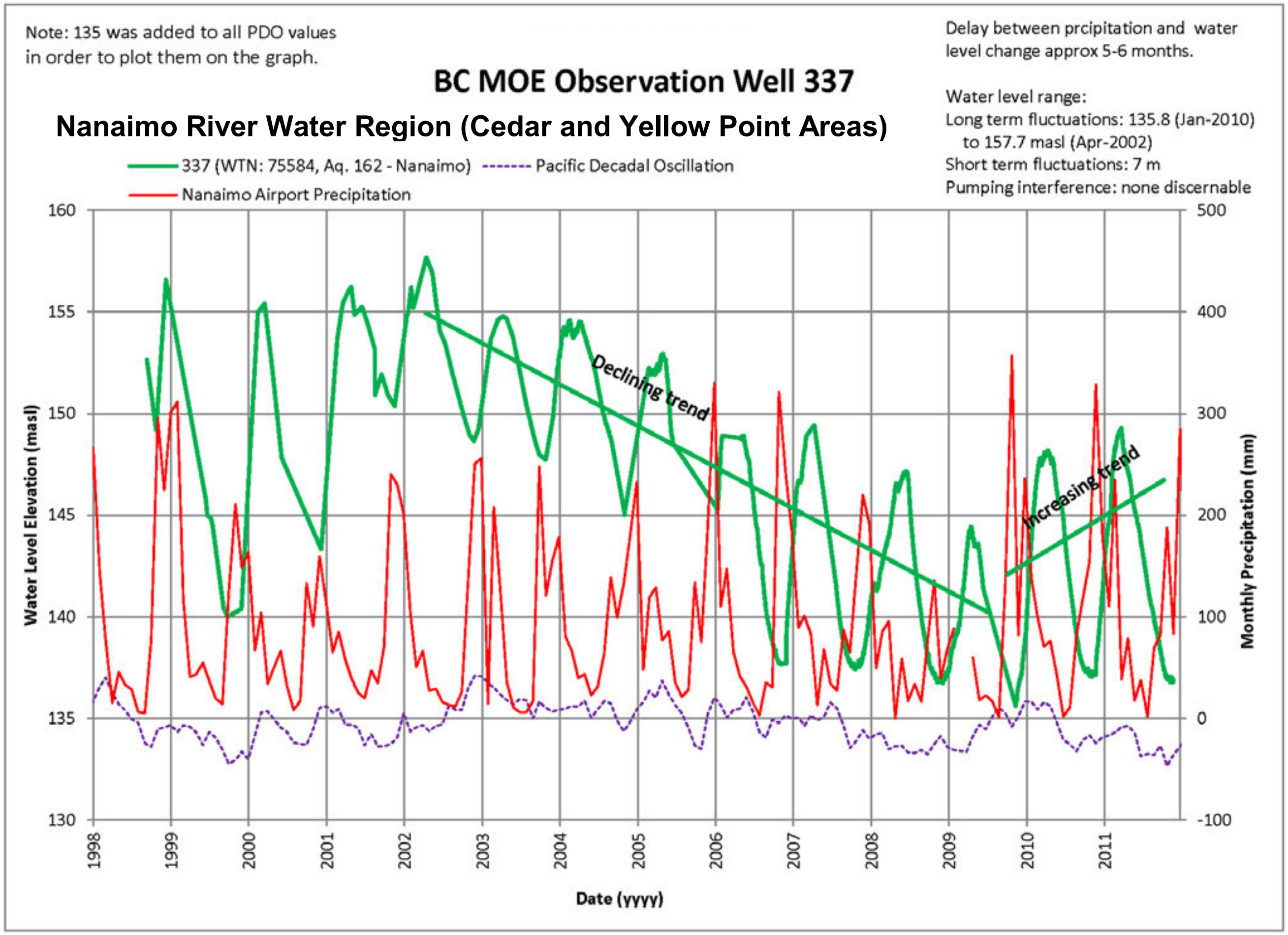

Figure 94: WR6 (NR) – Water Level Hydrograph BCMOE 337.

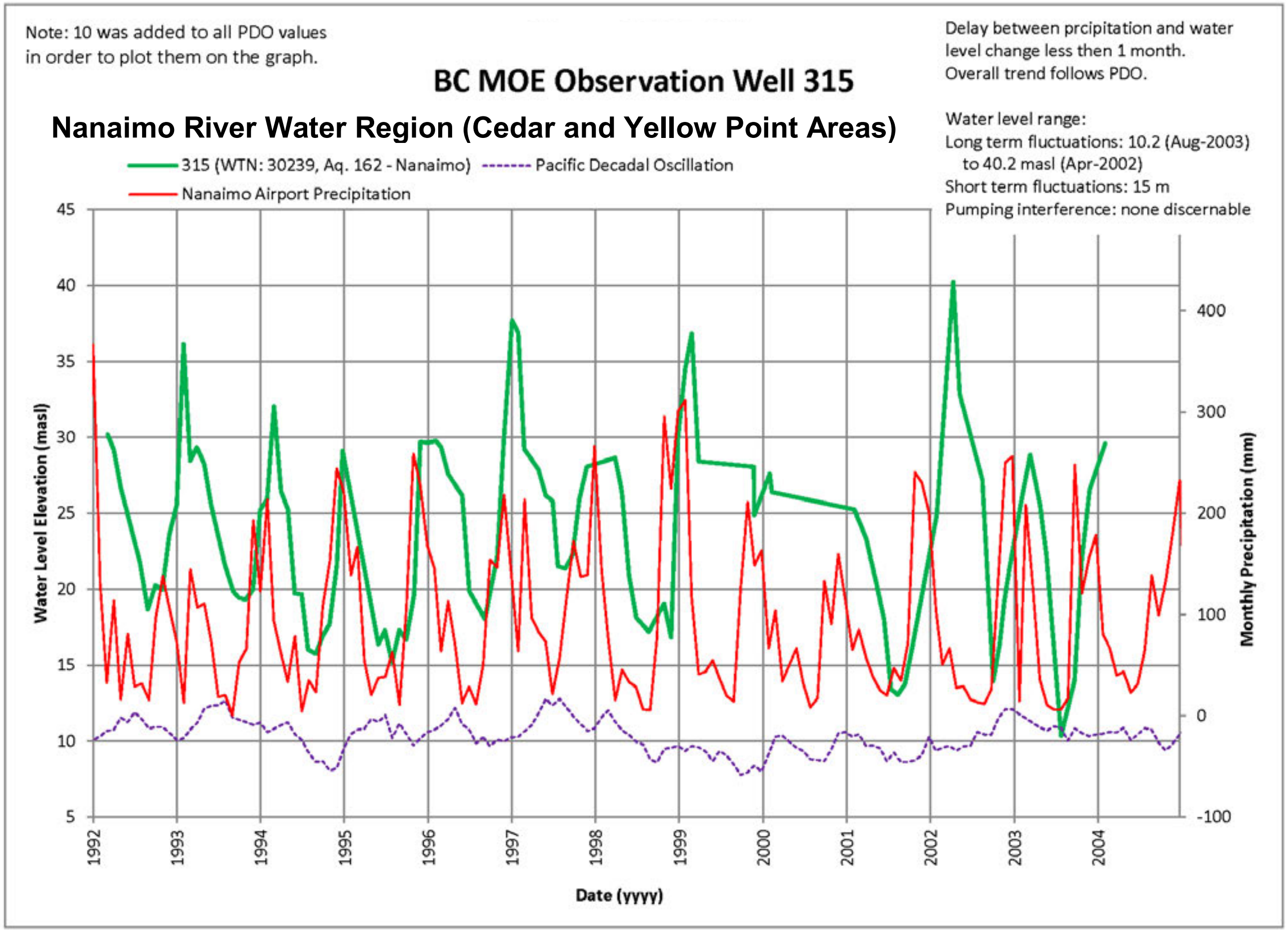

Figure 95: WR6 (NR) – Water Level Hydrograph BCMOE 315.

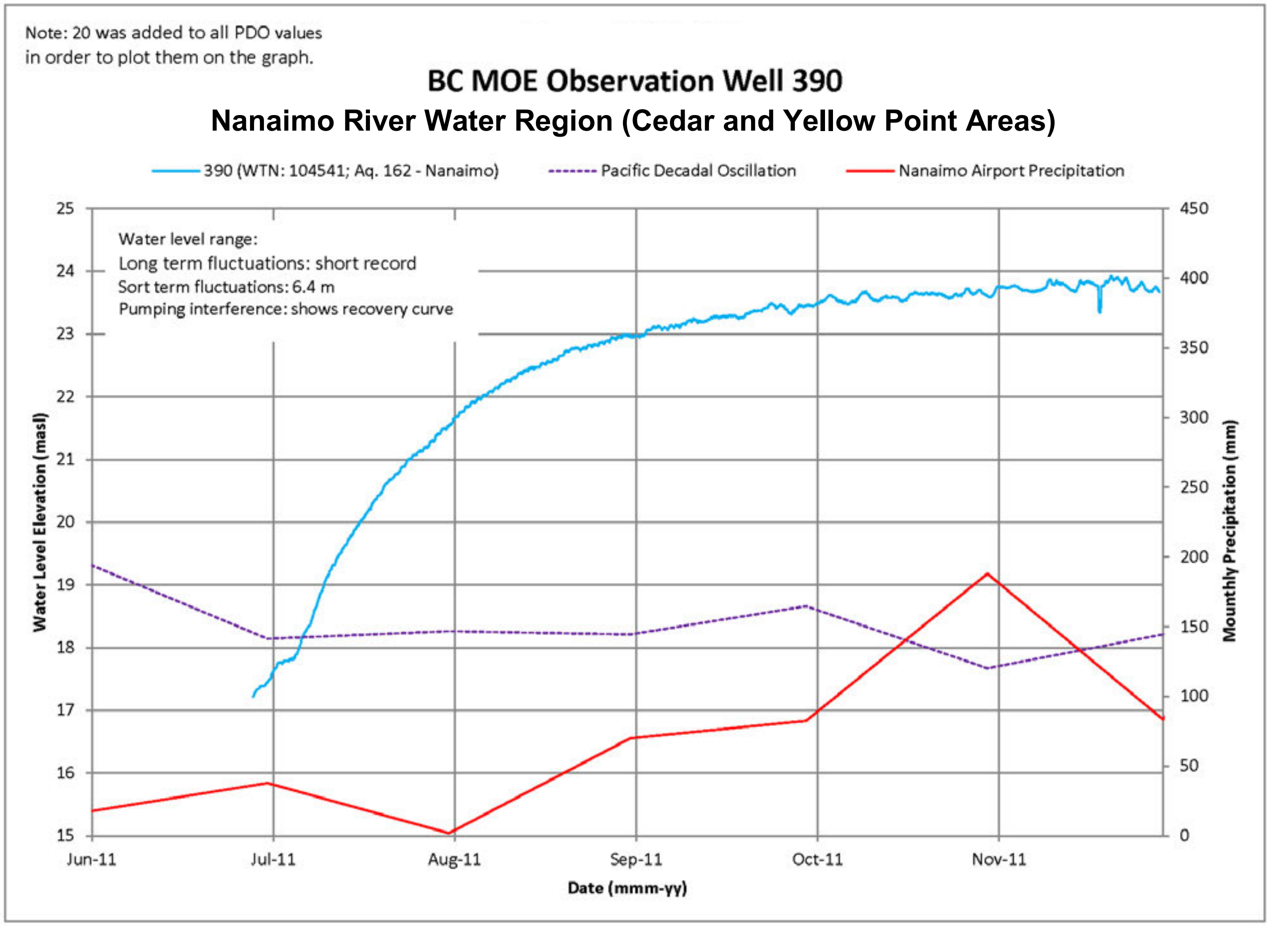

Figure 96: WR6 (NR) – Water Level Hydrograph BC MOE 331.

8.3.6 Anthropogenic Groundwater Demand

Table 60 summarizes the available groundwater demand data available for WR6 (NR).

Table 60: WR6 (NR) – Summary of Anthropogenic Groundwater Demand Analysis

Aquifer Tag No.	North Cedar Water Works	RDN DeCourcy	RDN Pylades	Snuneymuxw First Nation	Nanaimo Airport	Harmac	Other Private Wells (From RDN Water Use Est. based on Zoning compiled on GIS)	Total Ground Water Use Estimate (ANTHout)
	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)	(m^3/yr)
160	NA	NA	NA	NA	2.7E+03	NA	0.0E+00	2.7E+03
161	4.5E+05	NA	NA	?	2.7E+03	3.0E+07	2.0E+06	3.2E+07
162	NA	1.0E+03		NA	NA	NA	1.1E+07	1.1E+07
163	NA	NA	NA	NA	NA	NA	3.1E+05	3.1E+05
164	NA	NA	NA	NA	NA	NA	8.5E+05	8.5E+05
165	NA	NA	NA	NA	NA	NA	1.8E+06	1.8E+06

Notes: NA means not applicable, ? Means not known or unavailable, ANTHout means anthropogenic water extraction from aquifer.

The annual water use for serviced areas within the RDN (large municipal users, RDN wells, and private utilities) is typically measured and was provided by the RDN or taken from annual reports for 2010. The groundwater demand estimate for non-service areas was calculated from water use data provided by the RDN for serviced areas, and then applied to non-serviced areas based on civic addresses and zoning classification. Harmac appears to be the largest single user of groundwater in the region. The method of assessment is further described in Appendix C (Map C21) and Appendix D.

There may also be groundwater discharging from aquifers that is required for conservation of flow in creeks and rivers based on the physical model developed by Waterline. The total groundwater demand for each aquifer, including conservation flow requirements, was compared against the estimated aquifer recharge to assess the stress on each aquifer. The results are presented in the following section.

8.3.7 Aquifer Water Budgets and Stress Analysis

Table 61 provides a summary of the final water budget calculations for each aquifer mapped within WR6 (NR). Detailed water budget calculations are provided in Appendix D (Tables D7 and D8). Water budgets for aquifers that extend from one water region to an adjacent water region (E.g.: Aquifer 161 and 162, Figure 90) were completed as a single aquifer, respectively, regardless of the RDN boundary. The rationale for this was that despite the jurisdictional issues, the RDN will need to consider the water demand and balance for the entire aquifer, not just that portion that lies within its boundary.

Based on the water budget estimates for mapped aquifers within WR6 (NR), moderately high to highly stressed aquifers appear to dominate this region. Only aquifer 165 located in South Wellington exhibits a moderate stress level. The most stressed aquifers include the Upper Cassidy Aquifer (161), the Cedar Yellow Point aquifer (162), and the small Quadra Aquifer 163 mapped near the Holden Cross Road and Haro Road. Many of the aquifers have moderate to higher density wells that likely contribute to well to well interference, particularly in the lower productivity bedrock aquifers with limited recharge.

As indicated above, there are a total of 2686 overburden and bedrock wells listed in the MOE data base in WR6 (NR) which represents the largest number of wells in all of the 6 water regions across the RDN on Vancouver Island. It is also recognized that this number may only represent as little as 50% of water wells actually in operation in this region. This clearly shows that the demand for groundwater in WR6 (NR) is very high and that there is an urgent need to better manage groundwater extraction in this region.

Aquifer stress in this region is primarily due to anthropogenic water use and the lack of monitoring which would otherwise allow proper management of aquifer levels. The main reason for the high indicated stress on Aquifer 163 is due to the small areal extent of the mapped aquifer which limits recharge, and the agricultural water demand values assigned base on the method described in Appendix C (Map C21).

More accurate water budget and aquifer stress estimates could only be accomplished using a computer modelling approach, but again the lack of aquifer data would likely render this exercise inconclusive as well. Rigorous testing requirements and complete aquifer test analysis by groundwater practitioners to determine aquifer transmissivity and storativity properties, in addition to long-term groundwater monitoring data in each aquifer would be required to fully assess the actual stress on each aquifer in this region.

Table 61: Summary of Aquifer Stress Analysis – WR6 (NR)

Aquifer Tag No.	Aquifer Lithology	Potential Groundwater-Surface water or Aquifer to Aquifer Interaction	MOE Obs Well	Seas. Fluc.	Long Term Fluc.	WL Trend (up or down)	Total Est. AQ. Rec. (TRin) (Rp/l + Rmb)	Est. Ann. Disch to Cr. & Down Grad Aquifer (Tc out)	Ground Water Use Estimate (ANTHout)	Total Out [TcOut + $ANTH_{out}$]	Stress Anal. % GW Use of the avail. AQ. Rec.	Relative Stress Assess.
			ID	(m)	(m)	U/D	(m^3/yr)		(m3/yr)	(m^3/yr)	(%)	Lo, Mod, Hi
160	Vashon	NR	228	4, 4.5	0	L	1.26E+07	7.84E+06	2.7E+03	7.8E+06	62	Mod-Hi
161	Capilano	NR	330, 312	0, 3.5	9, 6	Aban., D/L	1.26E+08	1.05E+08	2.0E+07	1.2E+08	99	Mod-Hi
162	NG	NR, Ocean	337, 315, 390	7, 15	5, 10	D/L	1.30E+07	3.31E+06	1.1E+07	1.4E+07	110	Hi
163	Quadra	Ocean	?	?	?	?	2.87E+05	1.14E+06	3.1E+05	1.4E+06	502	V.Hi
164	NG	NR	?	?	?	?	1.11E+06	5.05E+03	8.5E+05	8.6E+05	77	Mod-Hi
165	NG	NR	?	?	?	?	3.20E+06	4.13E+05	1.8E+06	2.2E+06	68	Mod

Notes: NR means Nanaimo River, NA means not applicable, AQ means aquifer, Seas. Fluc. means seasonal fluctuation, PDO means Pacific Decadal Oscillation, WL means water level, Est means estimated, Disch. means discharge, Rec. means recharge ,Cr. Means creek, TRin means total recharge into aquifer, Rp/l means total recharge from precipitation and/or leakage from overlying aquifer, Rmb means total lateral recharge from upgradient aquifer or mountain block, Tc out means total aquifer groundwater discharge to creek, assess. means assessment , Total out means total discharge from aquifer (not including discharge to ocean), ANTH out mean total groundwater Anthropogenic groundwater extraction from aquifer, aquifer stress color codes: blue=low, green =low to moderate, yellow =moderate, brown=moderate to high, red=high to very high .

8.4 Water Management Planning Within WR6 (NR)

General guidance on water management planning for all water regions is provide in later sections of this document. Specific to WR6 (NR), the following recommendations are presented for consideration by RDN to improve the state of knowledge in the water region:

- At least one observation well should be installed in each mapped aquifer. Mapped aquifers that currently do not have MOE observation wells include Aquifer 164 and 165;
- Well owners should identify the MOE well plate and tag numbers for each of their active water wells. In this manner, water use and monitoring data can be easily cross-referenced with the BC MOE well records. These included North Cedar Water Works wells, RDN DeCourcy well(s), Nanaimo Airport wells, and Harmac supply wells;
- The significant recharge area map needs to be further updated by further processing of the NRCAN remote sensing data and by field verification;
- Further mapping of the groundwater surface water interactions is also required in Haslam Creek and the Nanaimo River to confirm the interactions between mapped aquifers 161 and 160. Waterline recommends specialized analysis (E.g.: isotopes[29], noble gases) of groundwater samples in this region to assist in determining groundwater age and origin. Thermal imaging of the river during high and low flows may help to quickly pinpoint areas where more detailed studies may be required;
- Reactivation of WSC surface water gauging station for Haslam Creek (08HB003) is recommended;
- Summer base flows (June to Sept) in Hokkenen Creek and Holden Creek should be collected as part of the Community Watershed Monitoring Network to gain a better understanding of summer base flows in smaller watersheds in the region; and
- Reservoir level and discharge data for Jump Creek and Forth Lake should be collected from the City of Nanaimo and Harmac at regular intervals and uploaded to the regional water database.

9.0 KNOWLEDGE AND DATA GAPS

9.1 Early Warning Monitoring and Cumulative Effects Analysis

Although an abundance of water-related information is being collected each year within the RDN, insufficient regulatory guidance and the inability of MOE/RDN to electronically track this information creates large data/knowledge gaps. This severely impedes the RDN's ability to properly manage watersheds and aquifers in a sustainable manner. In the absence of regulatory guidance, water users and groundwater practitioners are left to develop studies that may not be consistent with other studies or may not sufficiently advance the state of knowledge in a watershed or water region. Studies are often focussed on local scale issues, whereas a more regional approach may be necessary to understand the project impact and cumulative effects of numerous water users in a water region. There is a need for developing a consistent approach and consistent data requirements for all water-related studies.

Monitoring of surface water and groundwater use and its corresponding effects on creek/river flows and aquifer performance will provide an early warning system to help prevent over use. It is

[29] Chemical elements of the same family but with different atomic weights. Technique is used to assess origin, recharge elevation, and age of water.