2020 Source Water Protection Plan

Edmonton's Drinking Water System

PROVIDING MORE

EPCOR

TABLE OF CONTENTS

SECTION 1 – INTRODUCTION 1

SECTION 2 - SOURCE WATER PROTECTION PLAN VISION AND STAKEHOLDER ENGAGEMENT 4

SECTION 3 – SOURCE WATER CHARACTERIZATION 5

3.1 Delineation of the Source Water Protection Area 5
3.2 Land Use/Cover and Contaminant Sources 8
3.3 Water Quality and Quantity 62
3.4 Potential Hazards 115
3.5 Rank Hazards/Risk Statements and Identify Vulnerable Areas 126
3.6 Watershed Management and Compliance and Regulatory Requirements 128

SECTION 4 – EPCOR'S EDMONTON SWPP GOALS 141

SECTION 5 – EPCOR'S EDMONTON SWPP ACTION PLAN AND PROGRAM RESULTS 142

SECTION 6 - PERIODIC EVALUATION AND REVISION 146

SECTION 7 - VERIFICATION 147

SECTION 8 – REFERENCES 148

LIST OF FIGURES

FIGURE 1. COMPONENTS OF THE MULTI-BARRIER APPROACH (ADAPTED FROM CCME 2004). 1
FIGURE 2. COMPONENTS OF SOURCE WATER PROTECTION (ADAPTED FROM CCME 2004). 2
FIGURE 3. NSR WATERSHED UPSTREAM OF EDMONTON. 5
FIGURE 4. LOCATION OF EDMONTON'S DRINKING WATER TREATMENT PLANTS. 6
FIGURE 5. NSR WATERSHED IN ALBERTA (DATA SOURCE: ABMI 2010 AND GOA 2020). 9
FIGURE 6. SURFICIAL GEOLOGY OF THE NSR WATERSHED. 10
FIGURE 7. HUMAN FOOTPRINT IN NSR WATERSHED. 12
FIGURE 8. SUB-BASINS (AS DEFINED BY WATER SURVEY OF CANADA) AND MUNICIPAL BOUNDARIES IN THE NSR WATERSHED. 14
FIGURE 9. POPULATION DENSITY IN THE NSR WATERSHED. 15
FIGURE 10. PARKS AND PROTECTED AREAS IN THE NSR WATERSHED. 16
FIGURE 11. ENVIRONMENTAL SIGNIFICANT AREAS AND NATURAL SUB-REGIONS IN THE NSR WATERSHED. 17
FIGURE 12. PUBLIC LAND USE ZONES (PLUZS) IN THE NSR WATERSHED. 18
FIGURE 13. PREVIOUSLY RECOMMENDED PARK AREAS IN THE NSR WATERSHED. 19
FIGURE 14. STORM SEWER OUTFALLS LOCATED UPSTREAM OF THE E.L. SMITH AND ROSSDALE WTPS (FROM CITY OF EDMONTON 2020). 20
FIGURE 15. MUNICIPAL WASTEWATER FACILITIES IN THE NSR WATERSHED. 22
FIGURE 16. LAND COVER IN THE NSR WATERSHED 25
FIGURE 17. PERCENT OF THE WATERSHED IN EACH LAND COVER TYPE. 25
FIGURE 18. AGRICULTURAL LAND COVER (2016) IN THE WATERSHED. 26
FIGURE 19. PERCENT OF AGRICULTURAL LAND COVER IN EACH USE CATEGORY. 27
FIGURE 20. AGRICULTURAL LAND USE REPORTED BY CENSUS OF AGRICULTURE IN THE NSR WATERSHED FROM 1996 TO 2016. 28
FIGURE 21. TOTAL NUMBER OF HORSES, PIGS, SHEEP AND CATTLE REPORTED IN THE NSR WATERSHED BY CENSUS YEAR. 29
FIGURE 22. TOTAL CATTLE REPORTED BY SUB-BASIN IN THE NSR WATERSHED IN 2016. 30
FIGURE 23. MANURE PRODUCTION BY SUB-BASIN FROM ALL LIVESTOCK IN THE NSR WATERSHED IN 2016. 31
FIGURE 24. ESTIMATED ANNUAL MANURE PRODUCTION FROM ALL LIVESTOCK IN THE NSR WATERSHED BY CENSUS YEAR. 32
FIGURE 25. ESTIMATED ANNUAL PHOSPHORUS AND NITROGEN MANURE PRODUCTION FROM ALL LIVESTOCK IN THE NSR WATERSHED BY CENSUS YEAR. 32
FIGURE 26. SUMMARY OF RIPARIAN INTACTNESS FROM THE MODESTE AND STRAWBERRY WATERSHEDS (FROM FIERA 2018A AND 2018B) 35
FIGURE 27. RIPARIAN INTACTNESS MEASUREMENTS FROM STRAWBERRY CREEK WATERSHED (SOURCE: FIERA 2018A) 36
FIGURE 28. DANGEROUS GOODS TRUCK ROUTES AND RIVER CROSSINGS WITH EDMONTON BOUNDARIES UPSTREAM OF WTPS (SOURCE: CITY OF EDMONTON 2015). 38
FIGURE 29. TYPES OF DANGEROUS GOODS CARRIED IN ROADSIDE TRUCK SURVEY. 39
FIGURE 30. LINEAR DISTURBANCE IN THE NSR WATERSHED. 40
FIGURE 31. ROADS IN THE NSR WATERSHED IN 2018. 42
FIGURE 32. SEISMIC LINES IN THE NSR WATERSHED IN 2018. 43
FIGURE 33. PIPELINES IN THE NSR WATERSHED IN 2015 BY STATUS. 44
FIGURE 34. OPERATIONAL PIPELINES IN THE NSR WATERSHED BY SUBSTANCE CARRIED. 45

FIGURE 35. PERCENT OF TOTAL LENGTH OF OPERATIONAL PIPELINES IN THE NSR WATERSHED BY SUBSTANCE CARRIED. 45
FIGURE 36. MATERIALS TRANSPORTED BY PIPELINES WITHIN 250 METERS OF THE NSR MAINSTEM AND ITS MAJOR TRIBUTARIES IN 2015. 47
FIGURE 37. OPERATIONAL CRUDE OIL PIPELINES IN THE NSR WATERSHED. 47
FIGURE 38. OWNERSHIP OF OPERATIONAL PIPELINES IN THE NSR WATERSHED. 48
FIGURE 39. MAP OF WELL SITES IN THE NSR WATERSHED IN 2018. 50
FIGURE 40. MAP OF MINES AND RAILWAY LINES IN THE NSR WATERSHED. 51
FIGURE 41. MAP OF COAL MINES, AGREEMENTS, AND ACTIVE MINES IN THE NSR WATERSHED. 52
FIGURE 42. MAP OF GRAVEL PITS ALONG THE MAINSTEM NSR SOUTH OF WABAMUN LAKE. 56
FIGURE 43. FOREST MANAGEMENT AREAS IN THE NSR WATERSHED. 57
FIGURE 44. MAP OF HARVESTED AREAS IN THE NSR WATERSHED BY DECADE (LAST DECADE: 2010-2018). 60
FIGURE 45. TOTAL HARVESTED AREA IN THE NSR WATERSHED BY DECADE. 61
FIGURE 46. TREND IN TOTAL DISSOLVED PHOSPHORUS IN THE NSR AT THE ALBERTA/SASKATCHEWAN BORDER BETWEEN 1988 AND 2008 (FROM PPWB 2016). 65
FIGURE 47. TREND IN TOTAL NITROGEN IN THE NSR AT THE ALBERTA/SASKATCHEWAN BORDER BETWEEN 1993 AND 2008 (FROM PPWB 2016). 65
FIGURE 48. TURBIDITY AT ROSSDALE WTP INTAKE 1997 TO 2020 SHOWING MINIMUM, FIRST QUARTILE, MEDIAN, THIRD QUARTILE, AND MAXIMUM VALUES, AND TOTAL ANNUAL FLOW IN THE NSR. 68
FIGURE 49. DAILY MEAN TURBIDITY AT ROSSDALE WTP INTAKE AVERAGE FROM 1997 TO 2020 AND SELECT YEARS (2005, 2007, 2017, 2018 AND 2019). 69
FIGURE 50. TURBIDITY AT ROSSDALE WTP INTAKE FOR 1997 TO 2020 COMPILED BY WEEK OF THE YEAR. 69
FIGURE 51. COLOUR AT ROSSDALE WTP INTAKE 1997 TO 2020 SHOWING MINIMUM, FIRST QUARTILE, MEDIAN, THIRD QUARTILE, AND MAXIMUM VALUES, AND TOTAL ANNUAL FLOW IN THE NSR. 72
FIGURE 52. DAILY MEAN COLOUR AT ROSSDALE WTP INTAKE AVERAGE FROM 1997 TO 2020 AND SELECT YEARS (2005, 2007, 2016, 2017, 2018 AND 2019). 72
FIGURE 53. COLOUR AT ROSSDALE WTP INTAKE FOR 1997 TO 2016 COMPILED BY WEEK OF THE YEAR. 73
FIGURE 54. *E. COLI* CONCENTRATIONS IN ROSSDALE AND E. L. SMITH RAW WATER (2005-2020). 75
FIGURE 55. *CRYPTOSPORIDIUM* CONCENTRATIONS IN ROSSDALE RAW WATER (2006-2020). 77
FIGURE 56. *GIARDIA* CONCENTRATIONS IN ROSSDALE AND E. L. SMITH RAW WATER (2006-2020). 77
FIGURE 57. MONTHLY AVERAGE CONCENTRATIONS OF *CRYPTOSPORIDIUM* AND *GIARDIA* AT THE ROSSDALE WTP OF SAMPLES ABOVE THE DETECTION LIMIT (2006-2020). 78
FIGURE 58. SOURCES OF TSS LOADING IN THE NSR UNDER VARYING FLOW CATEGORIES, 2010 – 2019. 87
FIGURE 59. ESTIMATED UPSTREAM AND DOWNSTREAM TSS IN THE NSR, 2010 – 2019. 87
FIGURE 60. MAJOR TRIBUTARIES IN THE NSR WATERSHED ABOVE EPCOR'S WTPS. 89
FIGURE 61. WATERSHED MONITORING PROGRAM LOCATIONS AND TRIBUTARY WATERSHED AREAS. 94

FIGURE 62. COLOUR, TURBIDITY AND *E. COLI* IN THE MAJOR TRIBUTARIES IN THE NSR WATERSHED (1975 – 2020). 97
FIGURE 63. TOTAL PHOSPHORUS, AMMONIA AND NITRATE IN THE MAJOR TRIBUTARIES IN THE NSR WATERSHED (1975 – 2020). 98
FIGURE 64. WATER YIELD DATA FOR SUB-BASINS IN THE NSR WATERSHED (DATA SOURCE: GOLDER 2008A) 99
FIGURE 65. DAILY MEAN HYDROGRAPH OF THE NSR FLOW BASED ON 1970 TO 2019 WATER SURVEY OF CANADA DATA AT EDMONTON (05DF001, EDMONTON LOW LEVEL BRIDGE). 100
FIGURE 66. OPEN WATER FLOW CONTRIBUTIONS (MAY TO AUG) TO THE NSR AT EDMONTON (2005 TO 2020). 101
FIGURE 67. CONTIRUBTION OF FLOW DURING YEARS OF HIGH SPRING (2005 AND 2011) AND LOW SPRING RUNOFF (2008 AND 2010) TO THE NSR UPSTREAM OF EDMONTON. 102
FIGURE 68. MEAN MONTHLY NSR FLOWS AT EDMONTON BEFORE AND AFTER DAM OPERATION 103
FIGURE 69. MEAN ANNUAL NSR FLOWS AND FIVE YEAR RUNNING AVERAGES, 1912 TO 2019. 104
FIGURE 70. SUSTAINED WET AND DRY INTERVALS FOR STREAMFLOW RECONSTRUCTION FOR THE NSR, 1063 - 2006 (FROM SAUCHYN ET AL. 2011). 105
FIGURE 71. MEAN WEEKLY PERCENT OF THE NSR FLOW WITHDRAWN BY THE WTPS DURING A HISTORICAL LOW FLOW PERIOD (1714-1718). 106
FIGURE 72. HIGHEST WEEKLY WTP WITHDRAWAL FROM 2012 – 2016 AS A PERCENT OF THE LOWEST WEEKLY FLOWS EACH WEEK FOR THE 900 YEAR NSR FLOW RECONSTRUCTION. 106
FIGURE 73. DAILY MEAN FLOW AND ANNUAL PEAK FLOWS IN EDMONTON FROM 1911 TO 2019 108
FIGURE 74. E. L. SMITH AND ROSSDALE WTP DAILY INTAKES AS A % OF NSR FLOW FROM 2000 – 2019 110
FIGURE 75. MEAN DAILY % OF NSR FLOW WITHDRAWN BY E. L. SMITH AND ROSSDALE WTPS BY MONTH FROM 2000 TO 2019. 111
FIGURE 76. MEAN ANNUAL RUNOFF IN THE NSR AT EDMONTON FROM 1951 – 2100 (FROM SAUCHYN 2020). 113
FIGURE 77. NATURALIZED DAILY NSR FLOW IN THE NSR AT EDMONTON UNDER BASELINE AND FUTURE CLIMATE (FROM SAUCHYN 2020). 113
FIGURE 78. 2019 MOUNTAIN PINE BEETLE AERIAL SURVEYS NEAR ROCKY MOUNTAIN HOUSE (FROM ALBERTA AGRICULTURE AND FORESTRY 2019A). 121
FIGURE 79. WILDFIRES IN THE NSR WATERSHED BETWEEN 1931 AND 2019. 122
FIGURE 80. AREA BURNED BY WILDFIRES IN THE NSR WATERSHED BETWEEN 1931 AND 2019. 123
FIGURE 81. RELATIVE LIKELIHOOD OF FIRE BASED ON ALBERTA AGRICULTURE AND FORESTRY'S BURNP3 MODEL 124
FIGURE 82. WATER FOR LIFE ROLES AND RESPONSIBILITIES (MODIFIED FROM AWC 2008). 131
FIGURE 83. PLANNING INITIATIVES IN THE NSR WATERSHED (DATA SOURCE: GOA 2020) 135
FIGURE 84. INDUSTRIAL HEARTLAND AND CAPITAL REGION WATER MANAGEMENT AREA (FROM NSWA 2012A). 136

LIST OF TABLES

TABLE 1. POPULATION AND GROWTH OF MUNICIPALITIES IN NSR WATERSHED 13
TABLE 2. TYPES AND AREA OF PARKS AND PROTECTED AREAS IN THE NSR WATERSHED. 16
TABLE 3. WASTEWATER TREATMENT FACILITIES IN THE NSR WATERSHED (AECOM, 2009) 22
TABLE 4. WASTEWATER MONITORING REQUIREMENTS IN THE NSR WATERSHED 23
TABLE 5. LIVESTOCK NUMBERS IN THE WATERSHED BY LIVESTOCK TYPE AND CENSUS YEAR. 29
TABLE 6. AREA OF LAND (KM^2) THAT PESTICIDES, MANURE, AND/OR FERTILIZER WERE ADDED BY CENSUS YEAR. 33
TABLE 7. PIPELINES IN THE NSR WATERSHED AS A FUNCTION OF LOCATION TO THE NSR MAINSTEM AND MAJOR TRIBUTARIES. 46
TABLE 8. SUMMARY OF TRACE ORGANICS DETECTED IN QUARTERLY SAMPLING AT E.L. SMITH AND ROSSDALE RAW WATER INTAKES FROM 2004 TO 2020. 80
TABLE 9. SUMMARY OF TRACE ORGANICS DETECTED IN ADDITIONAL SAMPLING AT E.L. SMITH AND ROSSDALE RAW WATER INTAKES FROM 2011 TO 2012. 82
TABLE 10. SUMMARY OF FIRE FIGHTING FOAMS USED BY UPSTREAM COMMUNITIES. 83
TABLE 11. MAJOR TRIBUTARIES TO THE NSR. 90
TABLE 12. NUMBER OF WATER QUALITY SAMPLES COLLECTED NEAR MOUTHS OF TRIBUTARIES TO NSR (1975 - 2020). 96
TABLE 13. HISTORICAL HIGH FLOW EVENTS IN EDMONTON 107
TABLE 14. POTENTIAL HAZARDS FOR EDMONTON'S DRINKING WATER SYSTEM. 116
TABLE 15. VARIOUS CONTAMINANTS ASSOCIATED WITH THE IDENTIFIED HAZARDS (LAND-USE AND POLLUTANT ANALYSIS MATRIX) (WATER RESEARCH FOUNDATION 1991). 117
TABLE 16. CONCERNS RELATED TO POTENTIAL CONTAMINANTS. 118
TABLE 17. EDMONTON DRINKING WATER SYSTEM RISK / RISK ANALYSIS CHART. 127

SECTION 1 – INTRODUCTION

Source Water Protection (SWP) is part of a multi-barrier approach (Figure 1) for water utilities to protect both quality and quantity of water sources. SWPP works to understand and mitigate potential risks to source water supplies through a watershed and aquifer approach. The quality of a surface or groundwater source is a direct result of the natural processes and human activities that occur within a watershed or within or above an aquifer. A healthy, functional watershed with fewer human disturbances is more likely to generate high source water quality.

Although there are costs associated with protecting water sources due to monitoring, treatment and/or best management practices, there are also many benefits that generate economic vitality and growth. Communities with clean water are desirable places to live, improve quality of life, and reduce the threat of waterborne illnesses (Pollution Probe 2004).

This plan was prepared for Edmonton's Rossdale and E.L. Smith water treatment plants (WTPs) which are operated by EPCOR Water Services Inc. (EPCOR), as part of EPCOR's due diligence to protect the communities it serves. EPCOR recognizes that it does not own a significant portion of land within the watersheds in which it operates, and is therefore committed to working with stakeholders to implement improvements and support science-based management in the watershed to protect its source water. EPCOR has a vested responsibility to ensure the drinking water provided to our customers does not pose a threat to public health and is satisfactory in its physical, chemical and aesthetic characteristics.

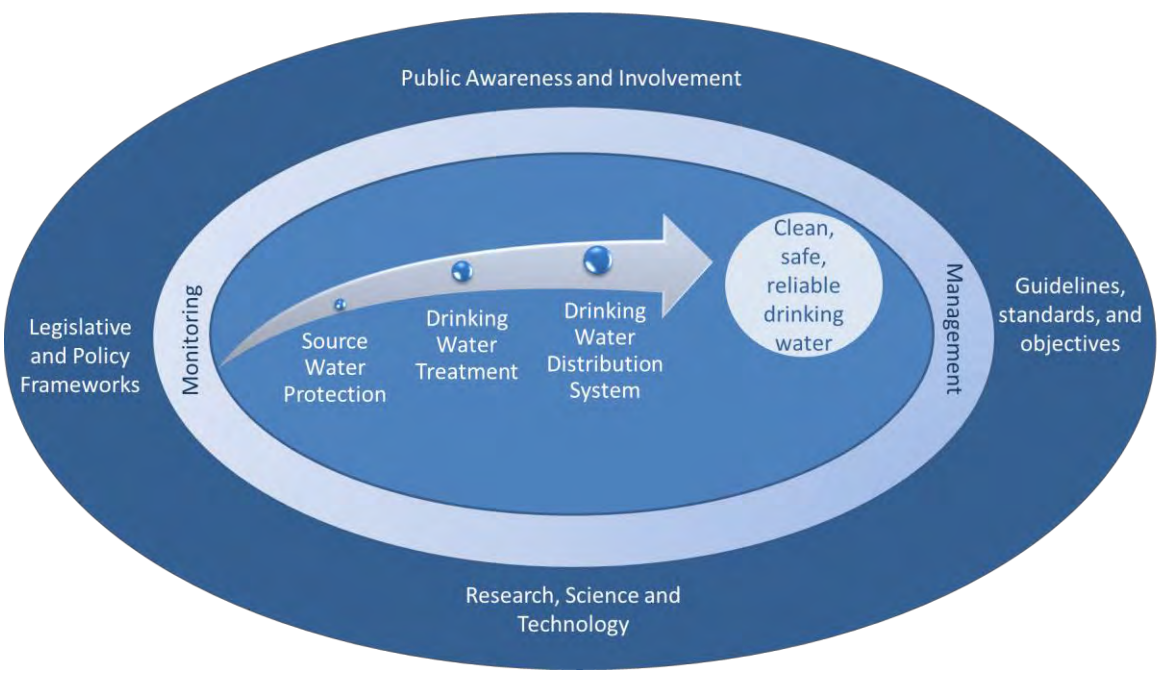


Figure 1. Components of the Multi-barrier Approach (Adapted from CCME 2004).

This plan compiles existing information on the North Saskatchewan River (NSR) and its watershed, the drinking water source for Edmonton, and uses this information to identify hazards, assess risks to source waters, and make recommendations on how to manage these risks.

Source Water Protection Planning is a strategy for water utilities designed to minimize the impacts that human activities and natural events have on water sources. It is critical to understand and characterize the watershed, as the water quality in receiving waterbodies is affected by what is occurring on the land. The key components of a conceptual Source Water Protection Plan (SWPP) as defined by the Canadian Council of Ministers of the Environment (CCME) are outlined below (Figure 2).

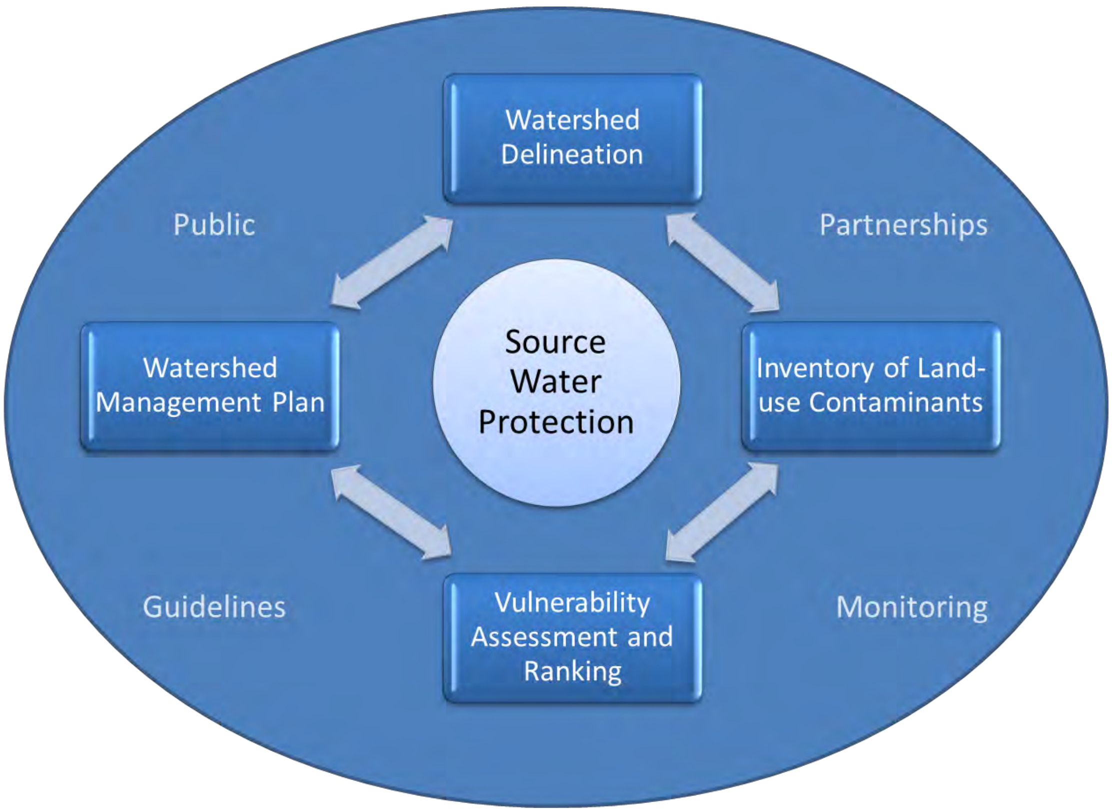


Figure 2. Components of Source Water Protection (Adapted from CCME 2004).

Similarly, the American Water and Wastewater Association (AWWA) developed a standard and a guide for Source Water Protection Plan development (AWWA 2014, 2016). Successful source water protection programs may vary widely in their details, but successful programs share six fundamental elements:

1. source water protection plan vision and stakeholder involvement;
2. source water characterization;
3. source water protection goals;

4. source water protection action plan;
5. implementation of the action plan; and
6. periodic evaluation and revision of the entire program.

The Alberta Water Council's guide for Source Water Protection is also based on these same six elements (AWC 2020). Within this generalized framework, individual utilities may establish and maintain source water protection programs that account for their unique local conditions, incorporate the interests of local stakeholders and reflect sustainable long-term commitments to the process by all parties.

The above elements were considered when developing the SWPP for EPCOR's Edmonton operations. As well, this SWPP addresses each of the components outlined by the CCME and provides recommendations on how to manage and mitigate risks to source waters.

SECTION 2 - SOURCE WATER PROTECTION PLAN VISION AND STAKEHOLDER ENGAGEMENT

The following is EPCOR's vision statement for the North Saskatchewan River SWPP:

- EPCOR is committed to ensuring clean and abundant water supplies for E.L. Smith and Rossdale WTPs through application of a source water protection program.

- EPCOR recognizes that SWP is but one of the multiple barriers for ensuring the safety and quality of drinking water and that a successful plan requires input from stakeholders with whom it shares the watershed.

- EPCOR recognizes that it does not own a significant portion the watersheds in which it operates; therefore it is committed to working with stakeholders in a collaborative watershed approach to implement management decisions that ensure a safe, secure drinking water supply for its customers.

- EPCOR recognizes that sufficient resources are required to implement the SWPP in order to meet its responsibility to ensure the drinking water provided to its customers does not pose a threat to public health and is satisfactory in its physical, chemical and aesthetic characteristics.

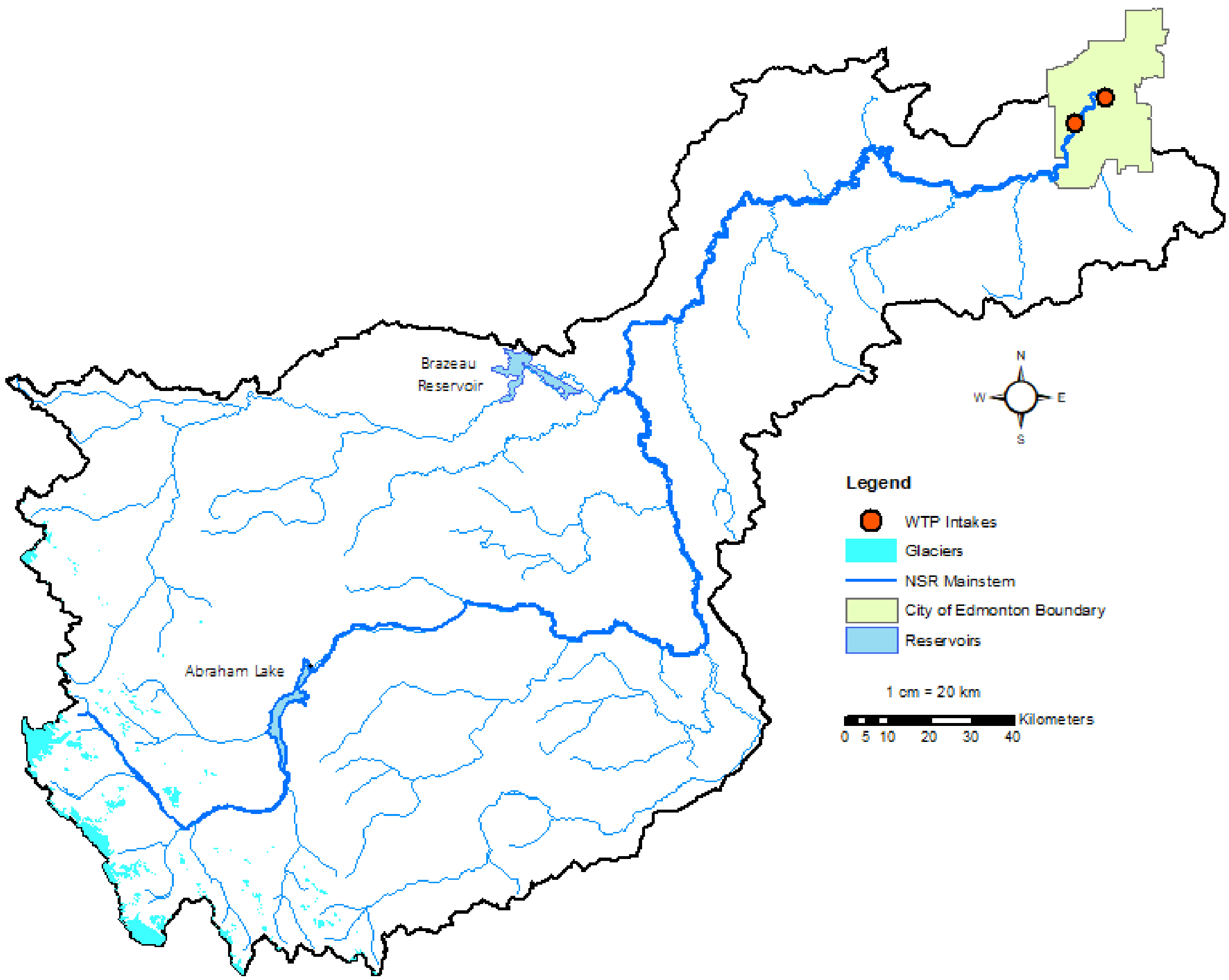
- EPCOR recognizes that the SWPP is an "evergreen" plan and a focus on applying continual improvement principles to the 'Plan' through three year review is essential.

EPCOR also recognizes that there are multiple stakeholders involved in SWP in the NSR watershed. Stakeholders include regulators, other municipalities, and water users upstream and downstream of Edmonton, Watershed Planning and Advisory Councils (WPACs), watershed stewardship groups, the Alberta Water Council, environmental non-governmental organizations and economic sectors such as agriculture, forestry, industry, oil and gas. Each of these stakeholders has an important role to play in SWP. EPCOR is engaged primarily with other stakeholders through participation on the North Saskatchewan Watershed Alliance (NSWA), which is the WPAC for the NSR, and the Headwaters Alliance which is comprised of upstream municipal council members and run by the NSWA. However, EPCOR also regularly engages other stakeholders directly.

SECTION 3 – SOURCE WATER CHARACTERIZATION

3.1 Delineation of the Source Water Protection Area

Edmonton's source water protection area has been identified as the entire watershed upstream of the Rossdale Water Treatment Plant (WTP) in Edmonton, Alberta to the headwaters in the Rocky Mountains (Figure 3). For the purposes of this plan, the 'North Saskatchewan River watershed' refers to the 28,000 km^2 portion of the NSR's watershed that is upstream of Edmonton's Rossdale WTP.



Data Source: Government of Alberta [GoA] 2020

Figure 3. NSR Watershed Upstream of Edmonton.

Water Treatment Plants

The North Saskatchewan River supplies raw water to both of Edmonton's WTPs, E.L. Smith and Rossdale. Raw river water is withdrawn through concrete intake structures located in the middle of the river and below the water surface at both locations. The E.L. Smith plant is located upstream of much of the city, while the Rossdale plant is located near the city centre (Figure 4). Consequently, the impact of urban activity on raw water quality is higher at the Rossdale location. The Rossdale WTP has been in operation since 1903. The current plant was built in 1947 and expanded in 1955. The E.L. Smith WTP was built in 1976 and underwent a significant upgrade in 2008. E.L. Smith produces approximately 85,000 million liters per year (ML/y) of treated water, whereas Rossdale produces approximately 40,000 ML/y.

Figure 4. Location of Edmonton's Drinking Water Treatment Plants.

The process of producing drinking water at EPCOR's two WTPs include coagulation, flocculation, filtration, and use free chlorine, chloramine and UV light for disinfection. Both plants achieve at least a minimum of 5.5-log reduction *Cryptosporidium* and *Giardia* and 4-log reduction for viruses. It was identified that reducing solids discharge from WTP processes during winter months would be beneficial for the NSR. In 2009, the Edmonton WTP's began to convert to Direct Filtration (DF) operation during the winter months. Since 2012, the WTPs have attempted to extend DF mode of operation for up to seven months in the year (i.e. September through March); however, high colour (> 6 TCU) in the NSR in the fall in some years have resulted in shorter periods of DF. The intake points at both WTPs are located in the deepest part of the NSR, below the water surface so that oil, floating debris and ice will pass over them. Both WTPs are equipped with a turbidity, colour, temperature, pH, and an ammonia on-line monitoring units. On-site water quality laboratory analysis is also completed to inform WTP processes and includes a suite of nutrients, suspended solids, colour, conductivity, hardness, chloride, bromide, bromate, fluoride, chlorine, total coliforms, total organic carbon, *E. coli*, *Cryptosporidium*, *Giardia,* pesticides, pharmaceutical and personal care products, microcystin, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs) and perfluoroalkylated substances (PFAS). The frequency varies depending on the parameter.

Both WTPs are designed to cope with the highly turbid water that occurs occasionally in the NSR. Turbidity of the NSR is usually less than 5 Nephelometric Turbidity Units (NTU) during the winter and between 10 and 60 NTU during the summer. However the turbidity of the NSR can be as high as 7,300 NTU during large rainfall events. All turbidity values over 4000 NTU have occurred during May and June rainfall events. As the turbidity of the NSR increases, it becomes more difficult and costly for the WTP to remove all of the particles in the water and treat it properly for distribution. Another treatment challenge occurs when the NSR has high colour (a measure of dissolved organic matter) events. This often occurs during spring freshet and during periods of extended rainfall in the upper water. High colour during spring and summer storms is typically short-lived but create taste and odour challenges. High colour in the NSR can also be a challenge in the fall when the WTP are waiting to convert to direct filtration and colour remains above 10 TCU for extended periods of time.

EPCOR's drinking water system does not have an upstream warning station to warn the plants of a possible contaminant moving down the NSR. EPCOR has investigated the feasibility of installing an upstream monitoring station; however, found several barriers including: a lack of adequate upstream infrastructure, inability to effectively monitor a large river such as the NSR, and that the necessity of the station being located upstream precludes the ability to monitor for contaminants entering the NSR downstream of the monitoring station, but upstream of the WTP intakes. In the event of a possible spill/release that may affect the WTPs, EPCOR does rely on communication from those responsible for the spill/release, Alberta Environment and Parks (AEP), the Alberta Energy Regulator (AER), the City of Edmonton's Fire Department, and EPCOR Drainage Services. EPCOR utilizes upstream meteorological and flow stations as well as cameras installed along major tributaries to inform when water quality in the NSR may change rapidly due to spring runoff and/or heavy rainfall events. EPCOR also receives notifications from AEP regarding high water levels and floods that could damage the WTPs. There is work underway to develop a predictive model that uses meteorological data to predict high turbidity and colour events through machine learning. As well the WaterSHED program is installing sondes (instruments that measure parameters in the water continuously) throughout the watershed that can provide real-time water quality data that will inform treatment.

3.2 Land Use/Cover and Contaminant Sources

3.2.1 General North Saskatchewan River Watershed

The headwaters of the North Saskatchewan River originate from the Saskatchewan Glacier located in the Columbia Icefield in Banff National Park. The NSR watershed drains an area of 28,018 km^2 upstream of Edmonton. The whole NSR watershed in Alberta drains an area of approximately 57,000 km^2 and flows over 885 km through five natural regions from its headwaters to the Alberta/Saskatchewan border (Figure 5). A network of approximately 3,600 km of streams feed into the NSR along this journey through Alberta. The NSR begins in the Rocky Mountain Natural Region and more specifically the Montane and Alpine subregions. These subregions are typified by cooler, mountainous landscapes with exposed rock and vegetation ranging from coniferous forests in higher elevations to mixed forests and grasslands in the valley areas. From there, the NSR flows through the Foothills subregion, where steep topography is covered by coniferous forests in the upper foothills and the rolling hills of Lower Foothills are covered with a greater mix of deciduous and coniferous forests. The watershed upstream of the Upper Foothills subregion is considered to be an environmentally significant area. Just upstream of Edmonton, the NSR winds its way through the Parkland Region, which has largely been converted to agricultural or urban areas.

On a larger scale, the NSR joins the South Saskatchewan River in Saskatchewan and eventually empties into Hudson Bay as part of the Nelson River Basin. Additional information about the larger NSR basin in Alberta can be found in the North Saskatchewan River Watershed Alliance's (NSWA) watershed atlas (NSWA 2012a).

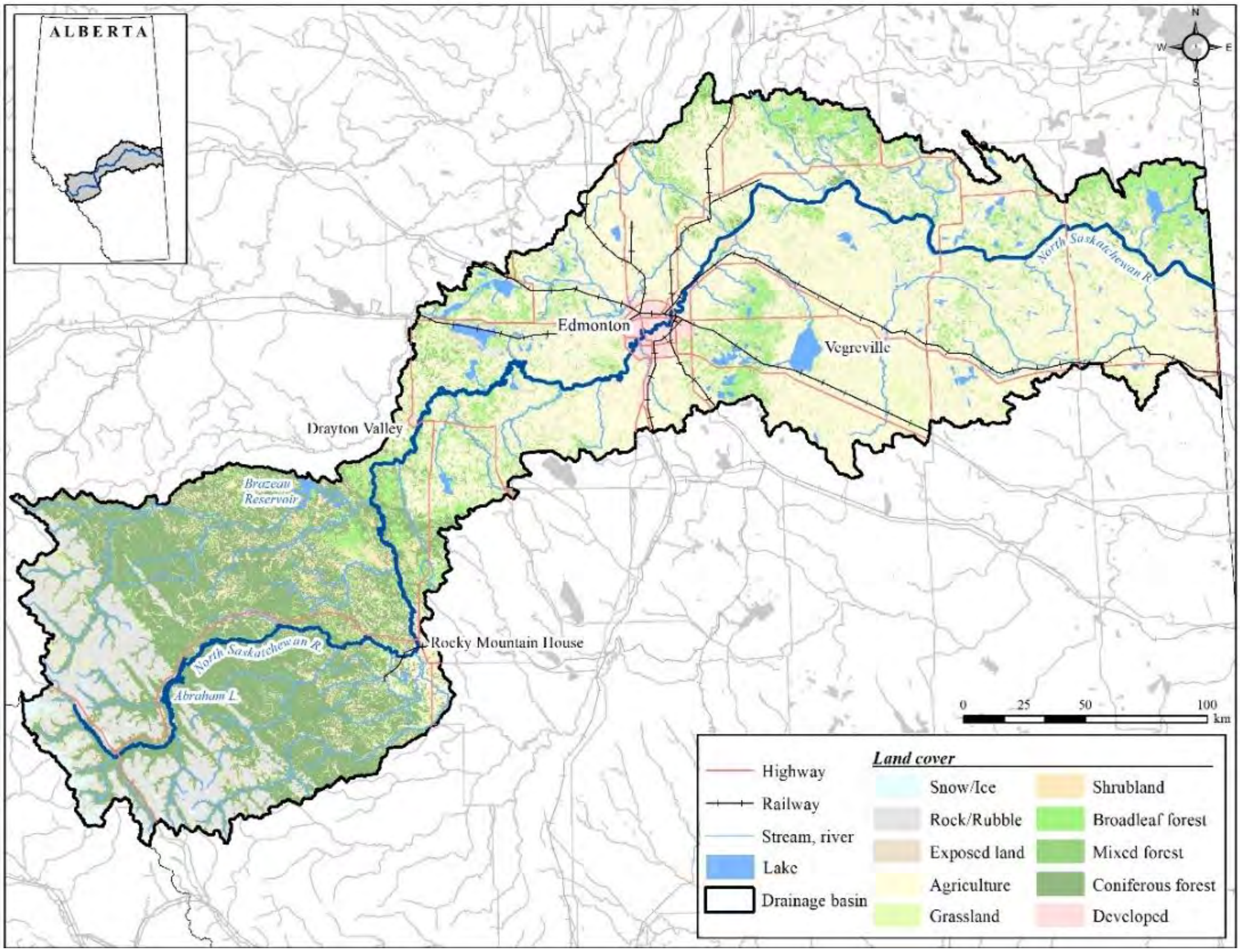


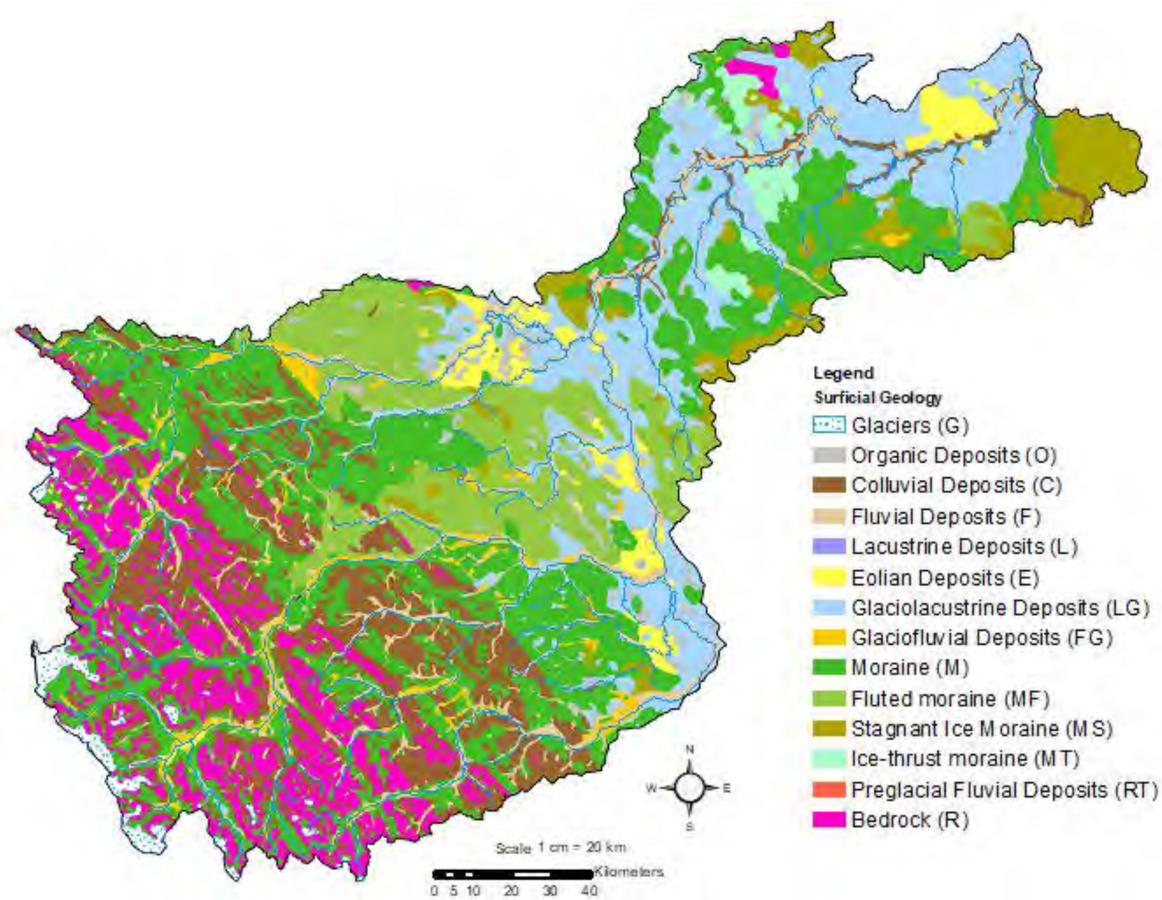
Figure 5. NSR Watershed in Alberta (Data Source: ABMI 2010 and GoA 2020).

3.2.2 Geology

The ancestral North Saskatchewan River flowed across the prairies for millions of years in a shallow-sloped valley called the Beverly Valley (Godfrey 1993). About 27,000 years ago a major glacier from the Canadian Shield advanced over the Edmonton region. When the glaciers retreated 12,000 years ago, the eastern and western mountain drainage was blocked and formed large glacial lakes including Lake Edmonton. The sediments of glacial Lake Edmonton cover most of the Edmonton area. The receding glaciers, along with Glacial Lake Edmonton drainage, deposited thick sediment, burying the Beverly Valley.

The river valley that we see in Edmonton is about 12,000 years old and it was formed when regional drainage occurred as the glaciers retreated. Since that time, the river has carved through these soft sediments. In some places the bed of the river is largely Cretaceous sedimentary rocks and there are formations that are 100 million years old, such as the Horseshoe Canyon Formation. Erosion of sediments continues today, but the rate is much less than during the initial glacial retreat. Effects of continued erosion are evident along the banks of the NSR which form landslides into the river during higher flow periods.

The surficial geology of the NSR basin reflects the glacial history and subsequent land drainage of Lake Edmonton. The geology changes extensively between the headwaters and Edmonton (Data Source: GoA 2020
Figure 6). In the Rocky Mountains, the surficial geology is, not surprisingly, largely bedrock. In the upper foothills the surficial geology turns largely to colluvial deposits and moraine, which are a mixture of materials such as clay, sand, pebbles, cobbles and boulders that have been moved by gravity and glacial ice, respectively. In the lower foothills, the surficial geology is largely fluted moraine, which is composed largely of glacial till that has been shaped by erosion and glaciation. Much of the surficial material in the headwaters is resistant to erosion, resulting in high water quality of the NSR mainstem and tributaries. Along much of the NSR mainstem from Rocky Mountain House to Edmonton, and along many of the major tributaries in this reach, the surficial geology is composed largely of glaciolaucustrine deposits. These deposits are largely silts and clays that are deposited in glacial lakes, such as Glacial Lake Edmonton. These silts and clays are highly susceptible to erosion, and are responsible for the silty and turbid nature of the NSR during periods of high flow.



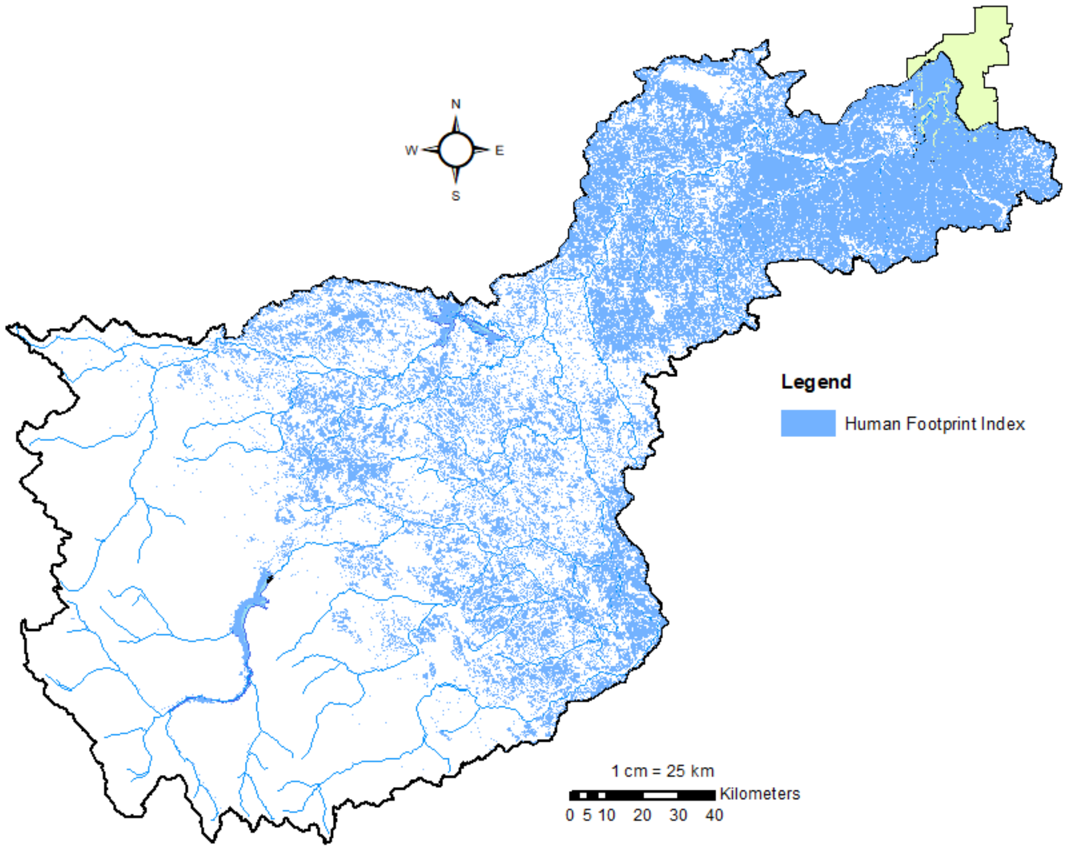
Data Source: GoA 2020

Figure 6. Surficial Geology of the NSR Watershed.

3.2.3 Human Footprint

The human footprint is a metric for disturbance and or human influence in an area. It can be used as a general gauge of watershed health but is not directly linked to changes in water quality or quantity. This is because each footprint is different in its impact. For example, a 40 year old cutblock (an area of land that has had the trees removed) has a different effect than a parking lot. That said, there is often disturbance threshold above which natural processes and function are compromised such that watershed health and subsequently water quality and quantity are significantly affected. For example, in research conducted on lake watersheds suggests that a human footprint greater than 50% will significantly alter lake water quality; however, it will depend on the watershed.

The human footprint the NSR Watershed was 7,790 km^2 or 27% of watershed area in 2012 and 8,600 km^2 in 2018 or 30.7% of the watershed area (Data Source: ABMI 2018
Figure 7). The human footprint was calculated using Alberta Biodiversity Monitoring Institute's 2012 and 2018 Wall-to-Wall Human Footprint data, which provides a comprehensive representation of human footprint in Alberta. The human footprint includes attributes and features related to the energy, forestry, and agriculture industries, as well as urban development. This metric includes roads, dwellings, cutblocks, seismic lines, transmission lines, urban areas, reservoirs, well sites, etc. At the watershed perspective, given that just one third of the NSR Watershed has a human footprint suggests that the watershed has a relatively low impact. The implication is that if hydrological function, forest succession, and natural disturbance regimes, for example, are maintained on at least 70% of landscape then water quality and quantity would be maintained within natural variability. This assumes that water quality and quantity are driven by non-point sources rather than point sources, which for the NSR basin upstream of Edmonton is largely true. However, the human footprint is extremely low in the upper reaches of the watershed, and extremely high in the areas near Edmonton; suggesting that most of the disturbance of the NSR occurs between Drayton Valley and Edmonton.



Data Source: ABMI 2018

Figure 7. Human Footprint in NSR Watershed.

3.2.4 Population and Municipal Boundaries

The NSR Watershed is divided by six rural county boundaries: Clearwater, Yellowhead, Brazeau, Wetaskiwin, Parkland and Leduc, as well as Jasper and Banff National Parks (Data Source: GoA 2020
Figure 8). The majority of the population is located in the small urban municipal towns of Rocky Mountain House, Drayton Valley and Devon who have similar populations of approximately 7,000 people each (Table 1).

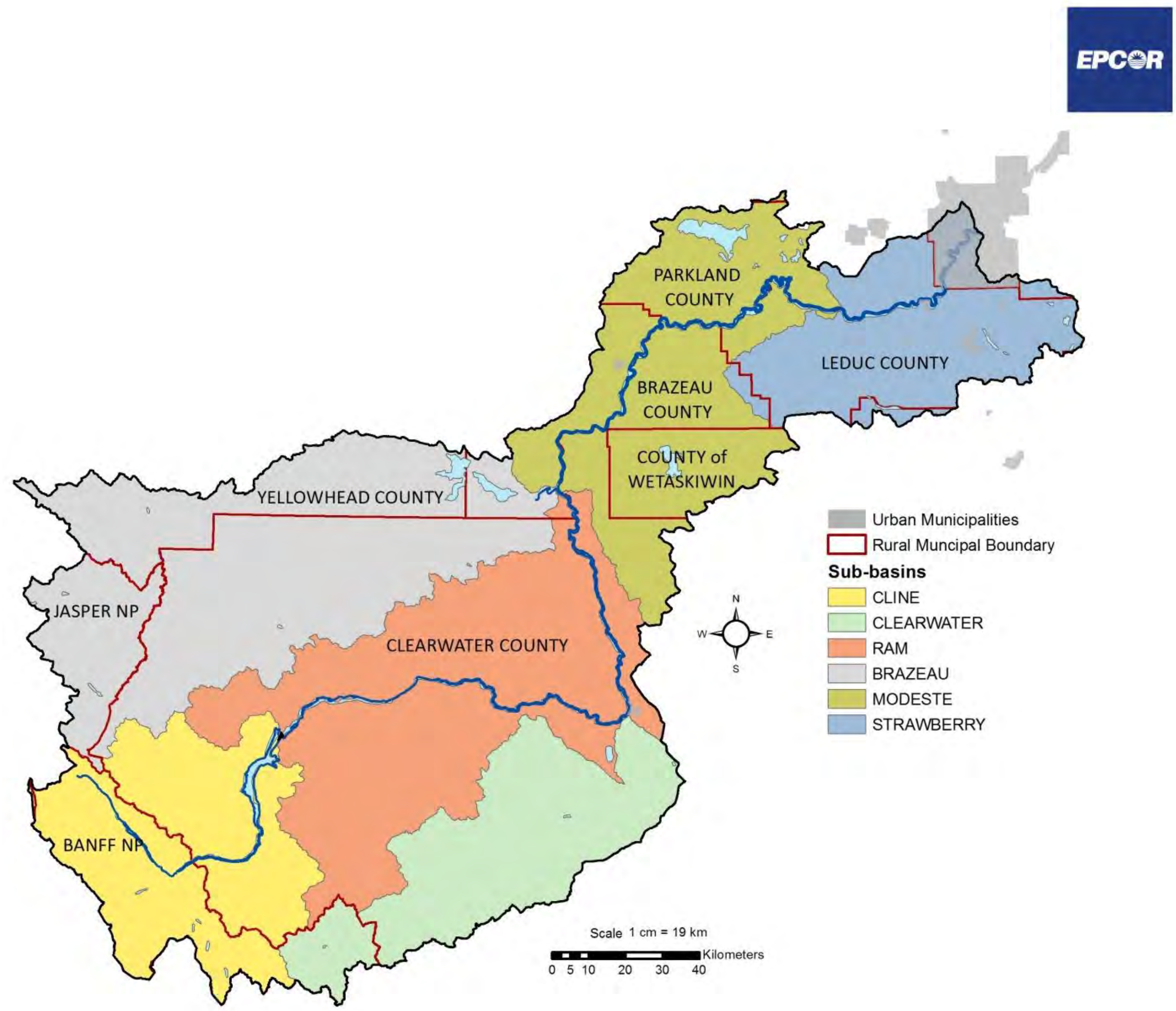
Table 1. Population and Growth of Municipalities in NSR Watershed

Community	2011	2016	2019	% Change
Rocky Mountain House	7,161	6,792	6,668	-5% in last 5 years
Drayton Valley	7,389	7,426	7,373	-5% in last 5 years
Devon	6,751	6,734	6,779	-2% in last 5 years

Source: Statistics Canada (2016), GoA (2021)

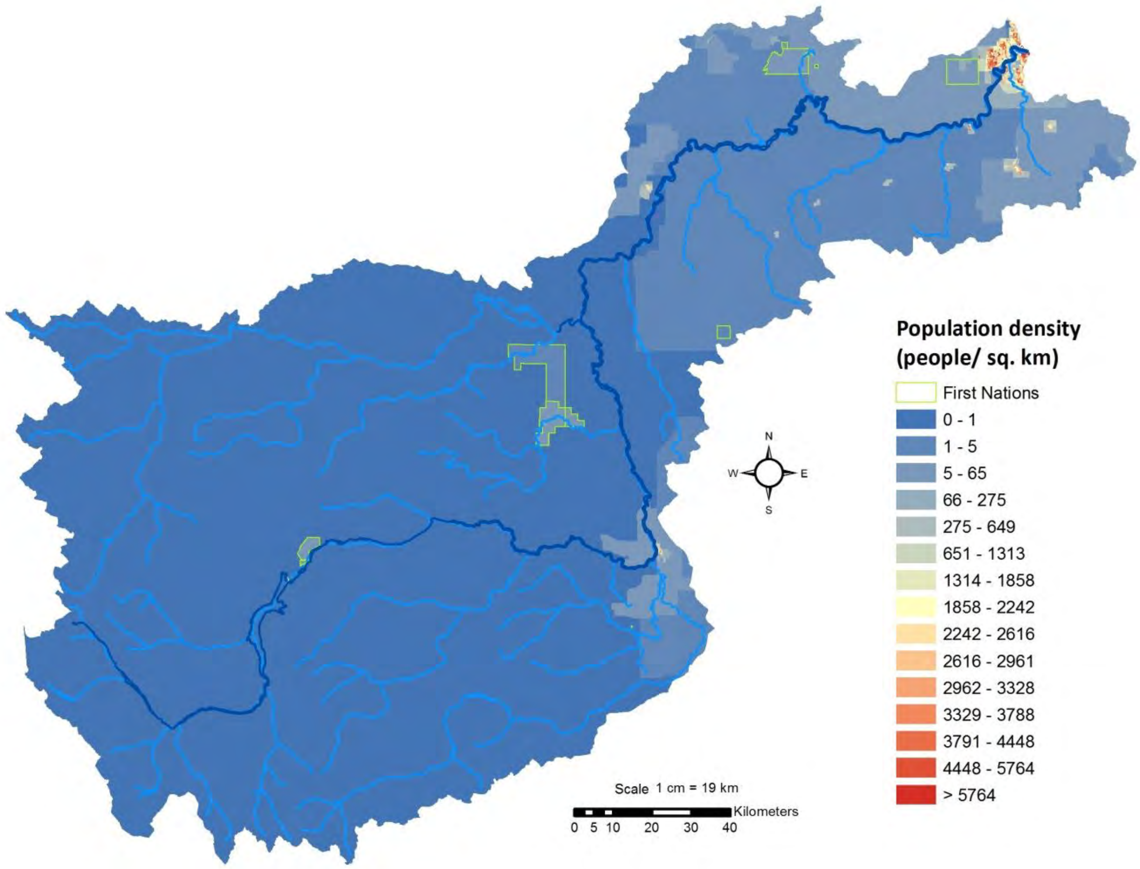
The surrounding rural counties of Clearwater (12,175: -2% 5-year growth), Brazeau (8,439: 8% 5-year growth), Parkland (33,005: 1% 5-year growth) and Leduc County (13,561: -5% 5-year growth) combine for total population of just under 66,000, although not all of this population is with the NSR watershed boundaries. Large portions of Yellowhead and Wetaskiwin counties are outside the NSR watershed and would contribute little to the overall population. In total, there are eighteen hamlets, eight summer villages, four villages and five towns (which include Devon, Drayton Valley and Rocky Mountain House) scattered throughout the watershed. Population density in the headwater region is low and most of the population is located within the Drayton Valley to Edmonton corridor (Data Source: Statistics Canada 2011, GoA 2020
Figure 9). It is estimated that approximately 90,000 people live in the NSR basin upstream of the City of Edmonton boundary (based on City of Edmonton Neighbourhood Census Data).

A significantly larger population lives upstream of the Rossdale WTP due to the inclusion of the drainage areas in south and west Edmonton, as well as the towns of Leduc and Beaumont. It is estimated that an additional 510,000 people live in this area, and population is rapidly growing. The populations of Leduc and Beaumont increased 15% and 28%, respectively over the last 5 years (2015-2019). Edmonton's population grew 11% during this period, and much of this growth occurred in the southern edges of Edmonton. In terms of source water protection above the Rossdale WTP, it is important to note that wastewater generated by this population is treated at the Gold Bar WWTP, located downstream of the WTPs. Stormwater impacts from this urbanized area are significant and considered further in Sections 3.2.4 and 3.3; however, stormwater impacts are related to land use and impervious surfaces, which to some degree is independent of population size.



Data Source: GoA 2020

Figure 8. Sub-basins (as defined by Water Survey of Canada) and Municipal Boundaries in the NSR Watershed.



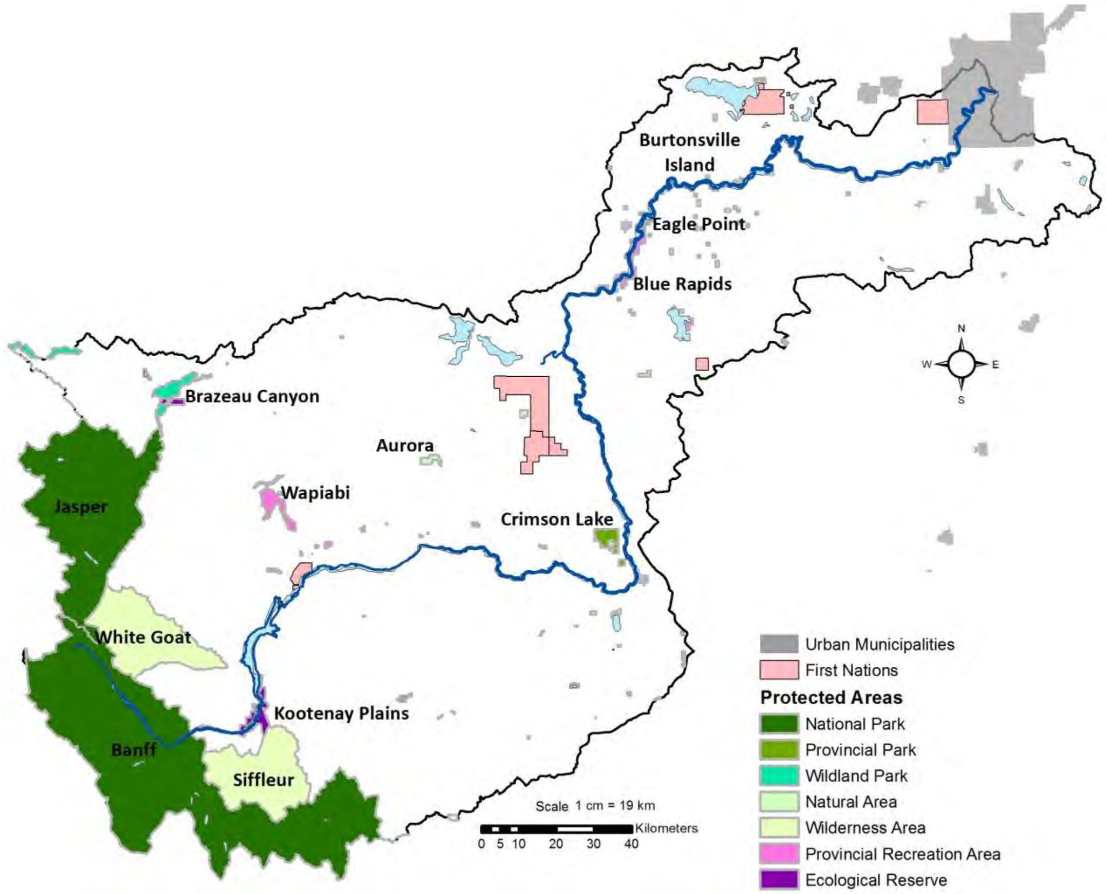
Data Source: Statistics Canada 2011, GoA 2020

Figure 9. Population Density in the NSR Watershed.

3.2.5 Parks and Protected Areas

Parks and protected areas are important for maintaining ecological and watershed integrity through limiting disturbance and human footprint. Although parks and other areas differ in their level of protection, in general within their management mandates, environmental protection is forefront. The area of the NSR watershed that is comprised of parks and protected areas is just under 17%. Banff and Jasper National Parks comprise 3,376 km^2 or 12% of the NSR watershed and provide protection for the critical headwater areas (Data Source: GoA 2020
Figure 10,Table 2).

White Goat and Siffleur Wilderness Areas provide an additional 870 km^2 of protection, equating to 3% of the watershed area upstream of Edmonton. Outside of the National Parks, all parks and protected areas combine to just under 5% of the total watershed area.



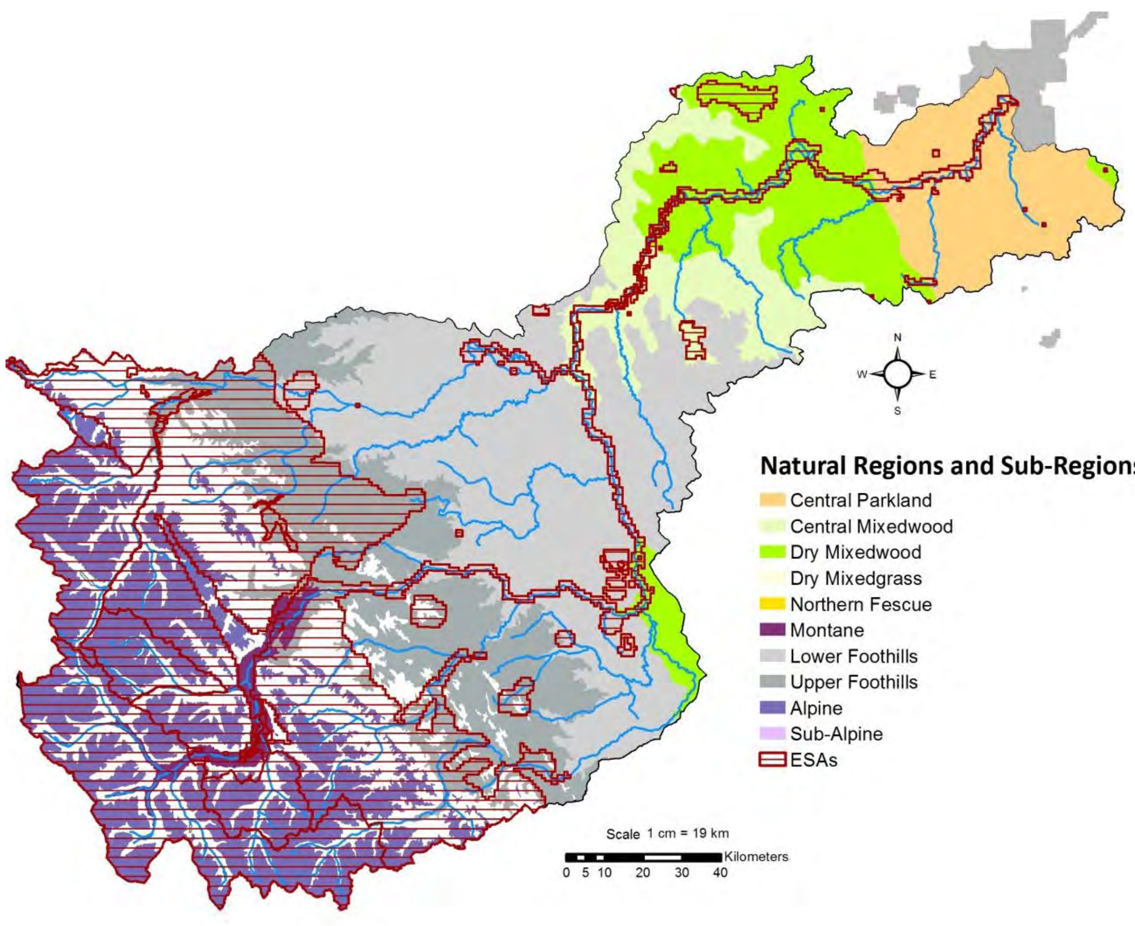
Data Source: GoA 2020

Figure 10. Parks and Protected Areas in the NSR Watershed.

Table 2. Types and area of Parks and Protected Areas in the NSR Watershed.

Type	Number	Area (km^2)
Environmental Reserve	2	46
Natural Area	29	72
National Park	2	3,376
Provincial Park	4	58
Public Recreation Area	38	102
Wilderness Area	2	870
Wildland Park	2	222
Grand Total	**79**	**4,746**

Almost half (46%; 12,487 km^2) of the upstream of Edmonton is considered to be environmentally significant area (ESA) (Figure 11). ESAs are generally defined as areas that are important to maintain biological diversity, physical landscape features and/ or other natural processes on the landscape (Fiera 2014). They provide a good start for prioritizing areas of conservation and help inform land use planning for multiple uses. Most of the distribution of the ESA is in the headwater areas and includes the Rocky Mountain (80%) and Boreal (14%) natural regions. The riparian areas along the banks of the NSR, as it travels to Edmonton, are also considered environmentally significant areas. ESAs in Alberta are not specifically defined, but are considered to be important and/or unique and/or sensitive part of the landscape. ESAs represent areas that are important for the long-term care and viability of biodiversity, soils, water and other natural attributes. Although ESAs do not have legislated protection, again, they are a valuable tool to inform land use decisions.

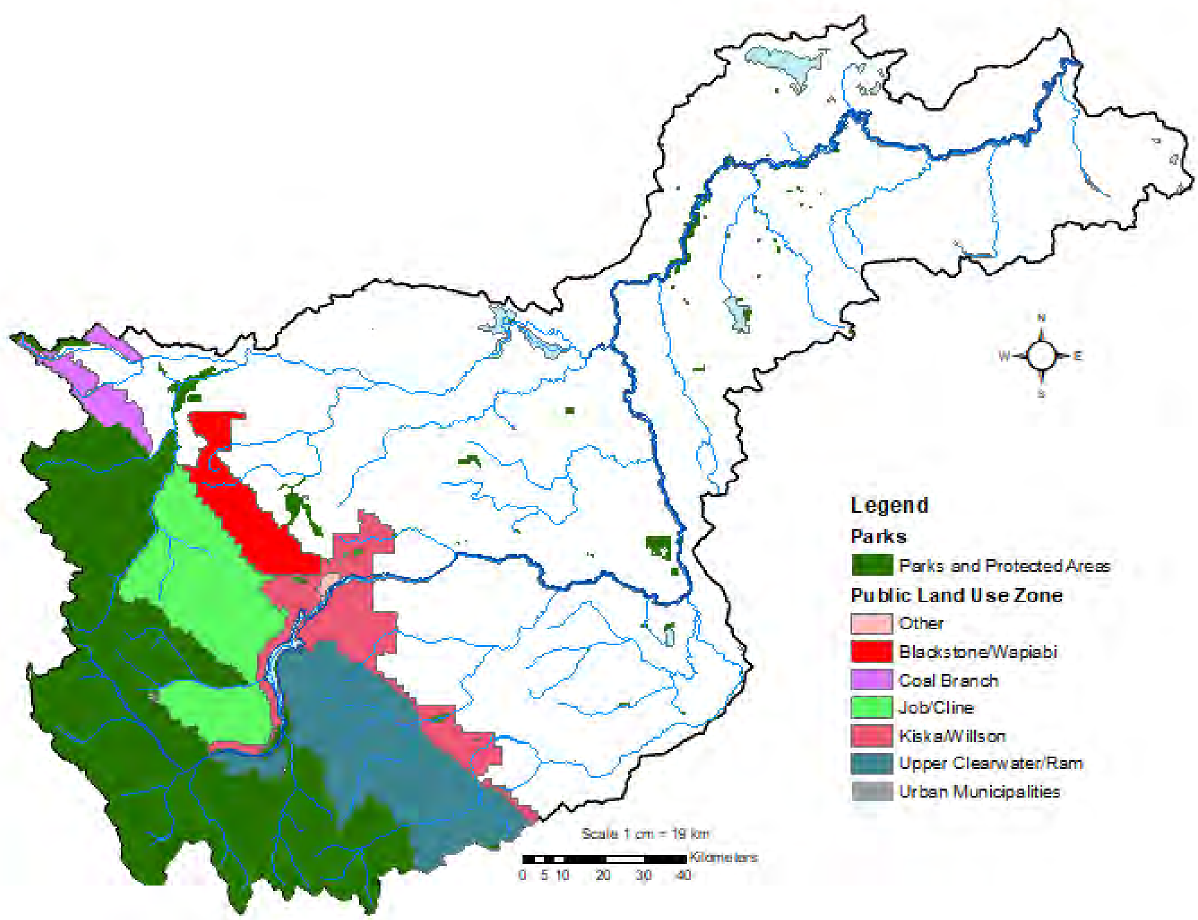


Data Source: GoA 2020

Figure 11. Environmental Significant Areas and Natural Sub-Regions in the NSR Watershed.

Although not considered parks or protected areas, there are 4,810 km^2 of the NSR Watershed adjacent to the National Parks that are designated Public Land Use Zones (PLUZ; Figure 12).

A PLUZ is an area of public land to which legislative controls apply under authority of the *Public Land Administration Regulation* to manage multiple uses on the landscape including industrial, commercial, and recreational. For example the government can designate if activities such as off-highway vehicle use, motorboat use, random camping, or hunting, for example, are permitted. Forestry and oil and gas activity may also be permitted in PLUZ. The land use conditions are designed primarily to protect areas containing sensitive resources and manage conflicting land-use activities. Within PLUZ, off-highway vehicles must remain on designated trails in order to ensure that sensitive habitats, including stream beds, are protected. In the PLUZ in the NSR watershed, there are no significant industrial activities. Logging is permitted within PLUZ.

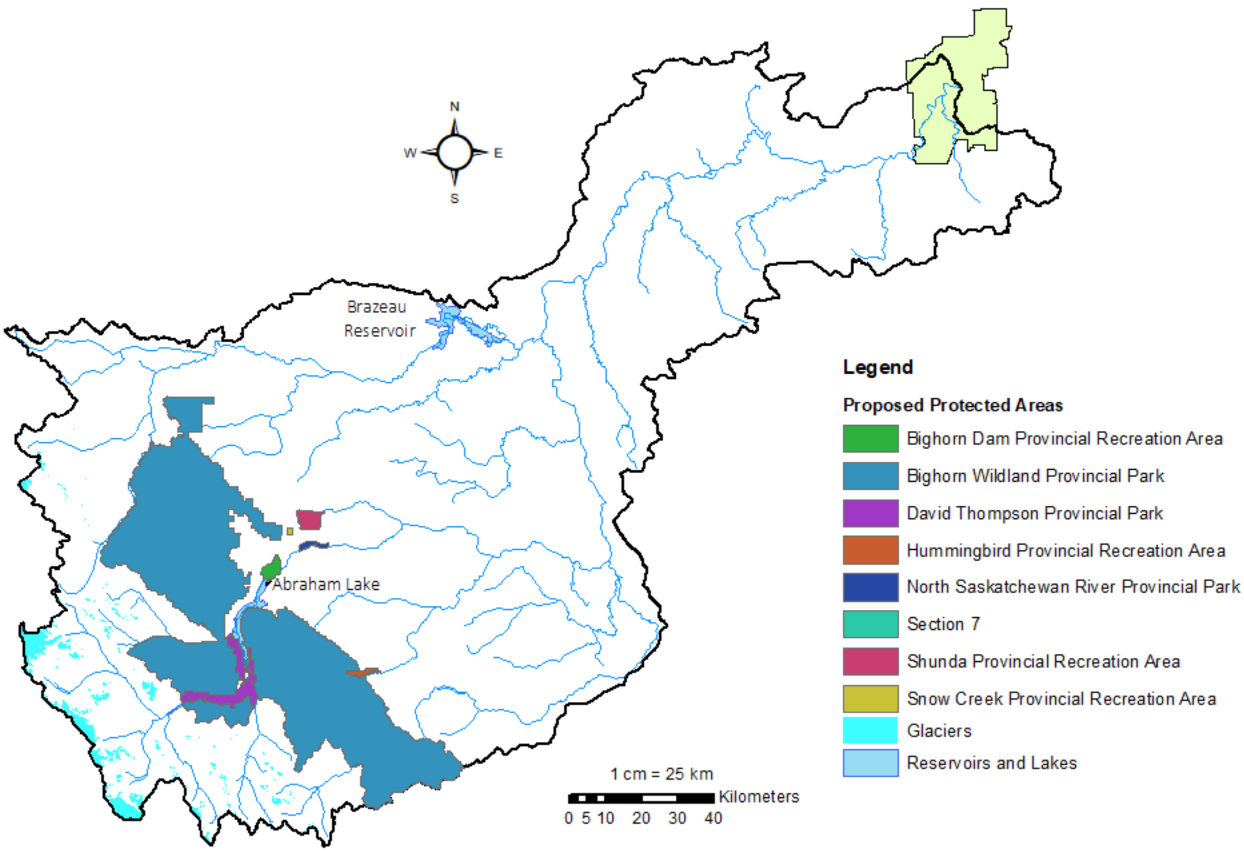


Data Source: GoA 2020

Figure 12. Public Land Use Zones (PLUZs) in the NSR Watershed.

The Bighorn backcountry is an area of public lands to the east of Banff and Jasper National Park in the headwaters of the NSR that has received calls for increased protection due to unregulated recreation and resource development. The size and boundary of the Bighorn backcountry are not clearly defined, and differs among various organizations. Generally, the area of the Bighorn backcountry is 5,000 to 6,700 km^2 covered by the existing PLUZ (Figure

13). In November 2018, the Government of Alberta announced eight new parks covering over 4,000 km^2 in the Bighorn Backcountry. This plan was reversed in 2019 in favour of using the ongoing regional planning process to evaluate land use in the area. Depending on the outcomes of this process, parks and protected areas could total ~8,700 km^2 and 31% of the NSR Watershed upstream of Edmonton.



Data Source: GoA 2020

Figure 13. Previously Recommended Park Areas in the NSR Watershed.

3.2.6 Municipal Wastewater Treatment Facilities and Stormwater

Edmonton

Storm sewer outfalls drain runoff from roads and urban areas into the NSR. Stormwater typically has elevated concentrations of sediments, nutrients, pathogens, metals and pesticides from urban runoff. EPCOR monitors the largest storm sewer outfalls and estimates the total loading from all of the storm sewer outfalls as part of its Environmental Monitoring Program which is described in greater detail in Section 3.3.

There are currently only two storm sewer outfalls located upstream of the E.L. Smith WTP; however, further growth of the City of Edmonton may result in additional storm sewer outfalls being built upstream (Figure 14). There are 55 storm sewer outfalls that drain directly to the NSR that are located upstream of the Rossdale WTP; however, the location of the outfalls along the shore line and location of the WTP intake mid-channel means that a number of the outfalls will not affect water quality at the intake. There are an additional 22 storm sewer outfalls located in ravines that drain into the NSR upstream of the Rossdale WTP. A majority of these are located in the Ramsay Ravine, which is located a short distance upstream of the Groat Road Bridge. There are also an additional 26 storm sewer outfalls that are located on Whitemud or Blackmud Creek.

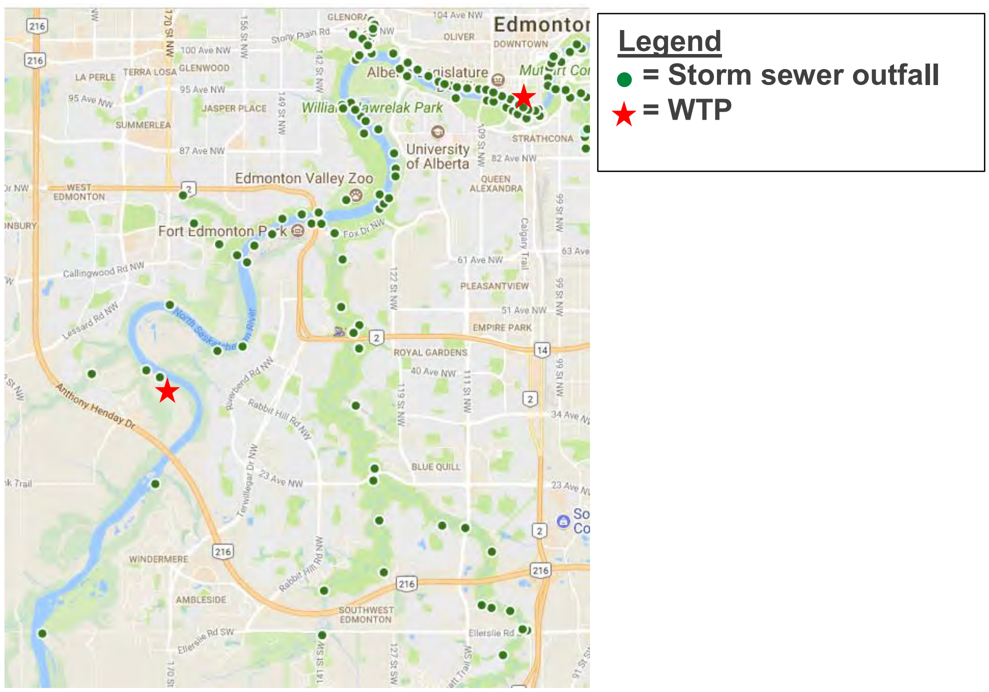


Figure 14. Storm Sewer Outfalls Located Upstream of the E.L. Smith and Rossdale WTPs (from City of Edmonton 2020).

Although storm sewer outfalls are designed to convey stormwater, under some conditions, sewage can enter to storm sewer system and be released to the NSR through:

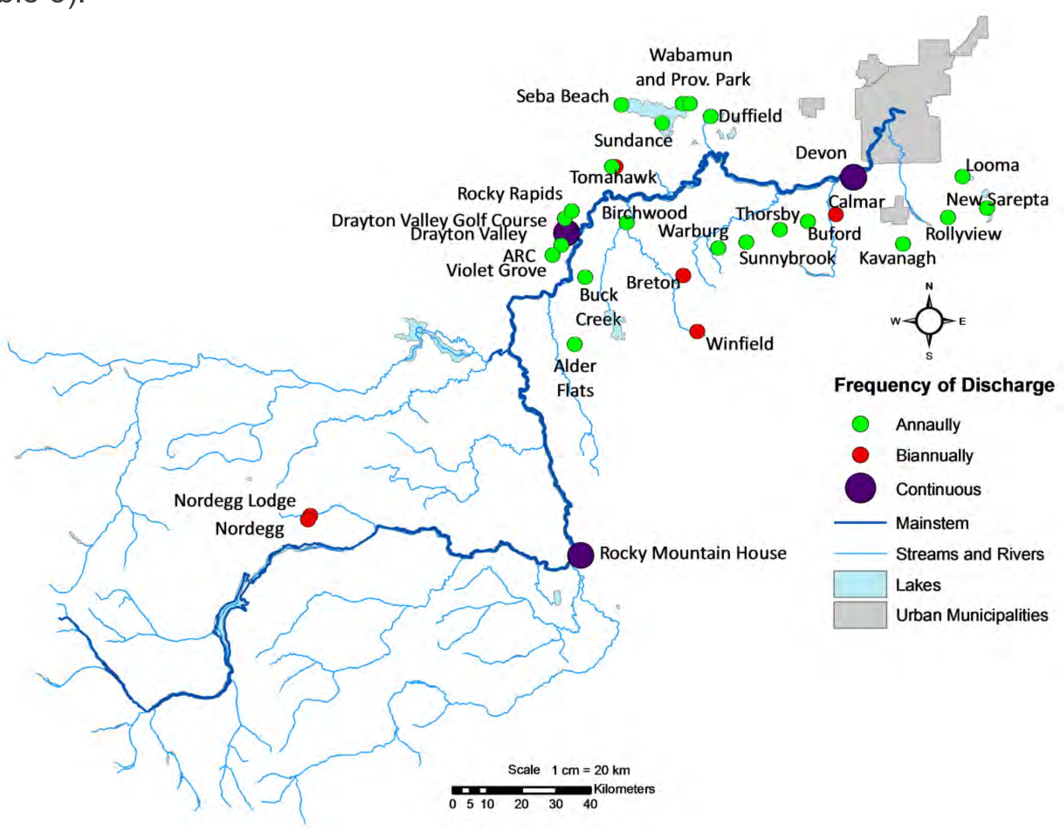
- Improper interconnections;
- Leakage of double barrel pipes;
- Sewage lift stations; and
- Blocked and/or backed up sewers.

EPCOR Drainage has been active in identifying and sealing-off interconnections, replacing double barrel pipes, and maintaining and repairing lift stations to eliminate any sanitary inputs into the river. For double barrel pipes storm flow and sanitary flow are combined in one pipe with vertical separation down the centre of the pipe. Over time, the separation can fail and this allows mixing of sanitary with storm water.

EPCOR Drainage will be investing approximately $1.6 billion over the next 20 years as part of its Stormwater Integrated Resource Plan (SIRP), which consists of a mixture of grey and green infrastructure to reduce flooding risks within Edmonton. Although flooding risk is the main driver, it is expected that water quality improvements will be made through the implementation of green infrastructure. The SIRP approach is to capture the stormwater volumes in dry ponds prior to reaching the storm trunk network to provide additional capacity in the pipes in the immediate path of the storm. The addition of Low Impact Development throughout the catchment area will further retain these volumes and reduce the impact on the entire pipe network as storms travel across the community. The plan does include tunnels, trunks and sewer separation in locations where due to configuration of the community there is limited space to install additional ponds or LID components to fully capture the expected water volumes during a major storm event. In the Blackmud/Whitemud Creek area storm runoff volumes are managed through the Blackmud /Whitemud Creek Surface Water Manage Group and established runoff rates.

Upstream of Edmonton

Upstream of Edmonton, there are three mechanical wastewater treatment plants that discharge effluent continuously to the NSR (Rocky Mountain House, Drayton Valley and Devon) and 27 municipal sewage lagoons that discharge periodically to the NSR or tributaries of the NSR (Data Sources: GoA 2020, AECOM 2009
Figure 15,Table 3).



Data Sources: GoA 2020, AECOM 2009

Figure 15. Municipal Wastewater Facilities in the NSR Watershed.

Table 3. Wastewater Treatment Facilities in the NSR Watershed (AECOM, 2009)

Name	Size	Treatment	Freq.	Discharge Point
Alder Flats	Hamlet	Lagoon	1/yr	Rose Creek
ARC Resources	Field Stn.	Lagoon	1/yr	Unnamed drainage to NSR
Birchwood VG	Devel.	Lagoon	1/yr	Modeste Creek
Breton	Village	Lagoon	2/yr	Modeste Creek
Buck Creek	Hamlet	Lagoon	1/yr	Buck Lake
Buford	Hamlet	Lagoon	1/yr	Unnamed drainage to NSR
Calmar	Town	MAL	2/yr	Conjuring Creek
Devon	Town	MAS	Cont.	NSR
Drayton Valley	Town	MAL	Cont.	NSR
Drayton Valley	Golf Crs.	Lagoon	1/yr	Unnamed tributary to NSR
Duffield	Hamlet	Lagoon	Evap.	n/a
Kavanagh	Hamlet	Lagoon	1/yr	Discharge to slough
Looma	Hamlet	Lagoon	1/yr	Unknown
New Sarepta	Village	Lagoon	1/yr	Unknown
Nordegg	Hamlet	MAL	2/yr	Long Lake
Nordegg Resort Lodge	Resort	Lagoon	2/yr	Shunda Creek
Rocky Mountain House	Town	MAL	Cont.	NSR
Rocky Rapids	Hamlet	Lagoon	1/yr	Unnamed Tributary to NSR
Rollyview	Hamlet	Lagoon	1/yr	Unknown
Seba Beach	Sum. Village	Lagoon	Evap.	n/a
Sundance	Plant	Lagoon	1/yr	Lake Wabamun
Sunnybrook	Hamlet	Lagoon	1/yr	Strawberry Creek
Thorsby	Village	Lagoon	1/yr	Weed Creek
Tomahawk	Hamlet	Lagoon	2/yr	Tomahawk Creek
Tomahawk School	School	Lagoon	1/yr	Tomahawk Creek
Violet Grove	Hamlet	Lagoon	1/yr	Unnamed Creek to NSR
Wabamun	Village	Lagoon	1/yr	Unnamed Creek NSR
Wabamun	Prov. Park	Lagoon	1/yr	Unnamed Creek to NSR
Warburg	Village	Lagoon	1/yr	Strawberry Creek
Winfield	Hamlet	Lagoon	2/yr	Poplar Creek

Note: MAL = mechanically aerated lagoon, MAS = mechanically activated sludge, Evap. = Evaporative Lagoon

Water quality data from most wastewater facilities is limited. As set out in the *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems* (GoA 2013a) wastewater lagoons are not required to conduct any water quality monitoring, and aerated lagoons for smaller communities are only required to collect weekly CBOD samples during periods of discharge. However, a small amount of data, typically only BOD and TSS, is available for the majority of sites listed in Table 3. Monitoring at the wastewater treatment plants in Rocky Mountain House, Drayton Valley and Devon is limited to a small number of parameters (Table 4). Devon recently commissioned a new WWTP, which is now fully operational.

Table 4. Wastewater Monitoring Requirements in the NSR Watershed

Community	Parameters	Frequency	Effluent Limits	Average Daily Effluent (m^3/d)
Rocky Mountain House	CBOD	Weekly grab	< 25 mg/L	2,379
	TSS		n/a	
Drayton Valley	BOD	Weekly grab	< 25 mg/L	4,999
	TSS		n/a	
	Total coliforms		< 1,000/100 mL	
	Faecal coliforms		< 200/100 mL	
	Chlorine residual	Daily Grab	< 2.0 mg/L	
	Volume	Daily Total	n/a	
Devon	CBOD	Daily Composite	< 20 mg/L	2,200
	TSS	Daily Composite	< 20 mg/L	
	Ammonia	Daily Composite	< 5 mg/L June - Nov < 10 mg/L Dec - May	
	Total Phosphorus	Daily Composite	< 1 mg/L	
	Volume	Daily Total	n/a	
	pH	Daily Composite	6.5 - 8.5	
	Total coliforms	5 samples/week	< 1,000/100 mL	
	Fecal coliforms	5 samples/week	< 200/100 mL	
	Acute lethality	quarterly grab	n/a	

Only an estimated 30,000 rural residents in the watershed are serviced by wastewater treatment facilities (lagoons or continuous-discharge mechanical treatment). The remaining 60,000 individuals are likely serviced by private septic systems. Municipal effluents contribute a consistent but low concentration of parasites (*Cryptosporidium* spp. and *Giardia* spp.) to the NSR and its tributaries (CABIDF 2002). Most discharges from lagoons occur over a three week period in October and, if two discharges per year are permitted, they most often occur in April or early May.

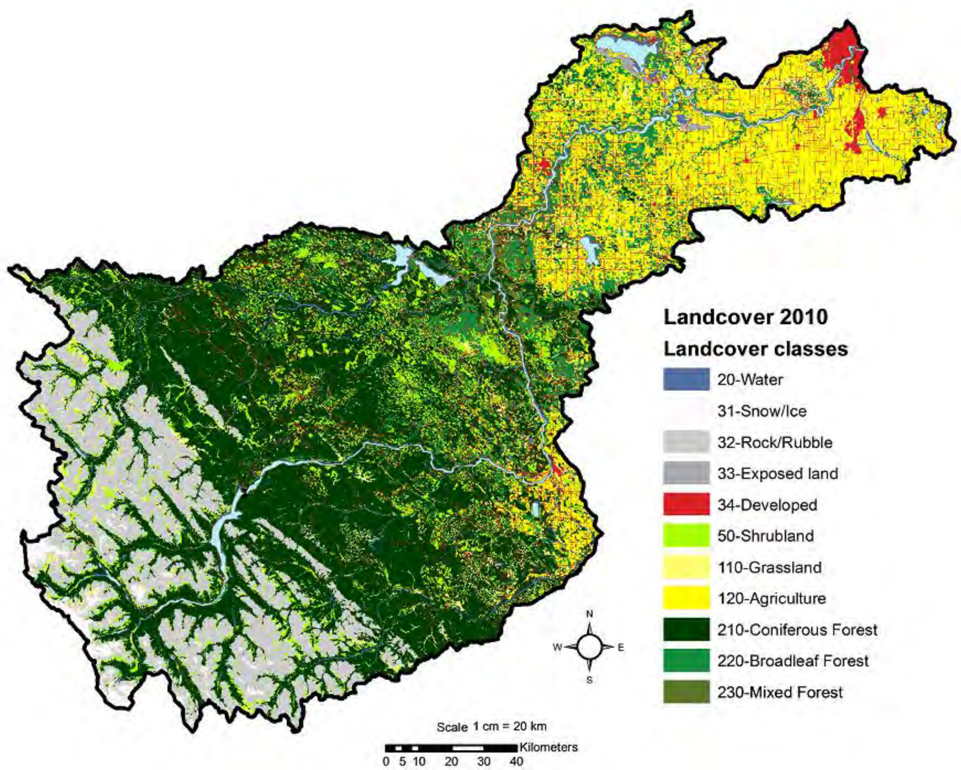
> Innovative methods for wastewater lagoon management are being implemented in the North Saskatchewan Watershed. For instance, in Parkland County lagoon operators use evaporators to reduce lagoon volumes. Also, a portable membrane filtration system is being piloted in the county with hopes of effectively refining lagoon effluent.

The three upstream WWTPs (Rocky Mountain House, Drayton Valley and Devon) are relatively small, and would not significantly affect water quality at EPCOR's intakes for measured parameters such TSS, BOD, nutrients and pathogens, assuming effluent limits are maintained. Similarly, the reported discharge volumes of lagoons are small, and the loads of TSS and BOD would likely have little effect of the water quality in the NSR at EPCOR's intakes. Nutrient and pathogen data is generally not available from lagoon discharges, but the small discharge volumes suggest that the resulting impact to water quality at EPCOR's intakes would be relatively low. Water quality data on pharmaceuticals, pesticides and other contaminants of emerging concern are not available for these WWTP and lagoons, but it is assumed that they are a source of these parameters in the NSR.

3.2.7 Land Cover

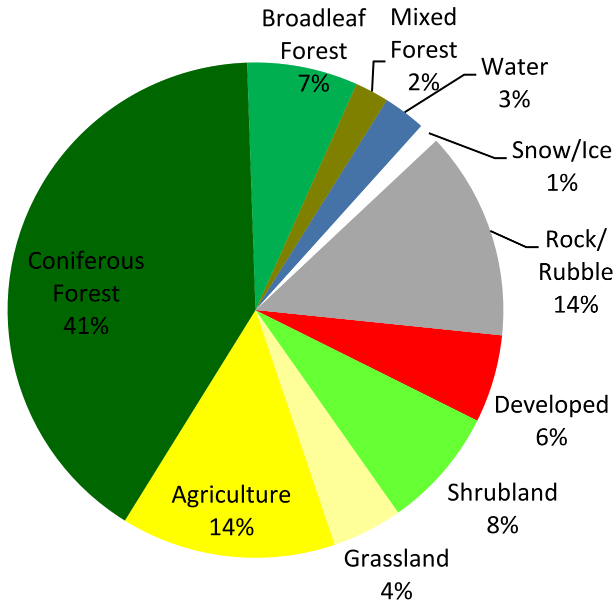
Land cover is an indicator of watershed disturbance and can indicate the risk of contaminants reaching downstream waterbodies. For example, there is evidence that with increased percent agricultural land in a watershed there are increased nutrient levels in downstream waterbodies. It is important to note land cover is based on a satellite image taken at a single point of time. Also, it provides a general indication of disturbance, but does not determine land use (what activities are occurring on the land). For example, there are many different types of cropping practices (row crop versus broadcast) that could occur on the land base and they would all be classified as 'cropland'.

The majority of the NSR watershed is in forest cover (58%;Figure 16). Of that, 41% is conifer forest, 7% is deciduous, 2% is mixed and 8% is shrub (Figure 17). Grassland comprises 4% of the watershed. Grassland is either native or as a result of fields that have been left to grow naturally. Agricultural land cover is the greatest anthropogenic footprint in the watershed with 14%. The agricultural land cover is concentrated in the lower part of the watershed, where soils are favourable for agriculture, whereas the headwater areas remain largely forested or rock (i.e., mountains).



Data Source: ABMI 2010

Figure 16. Land Cover in the NSR Watershed



Data Source: ABMI 2010

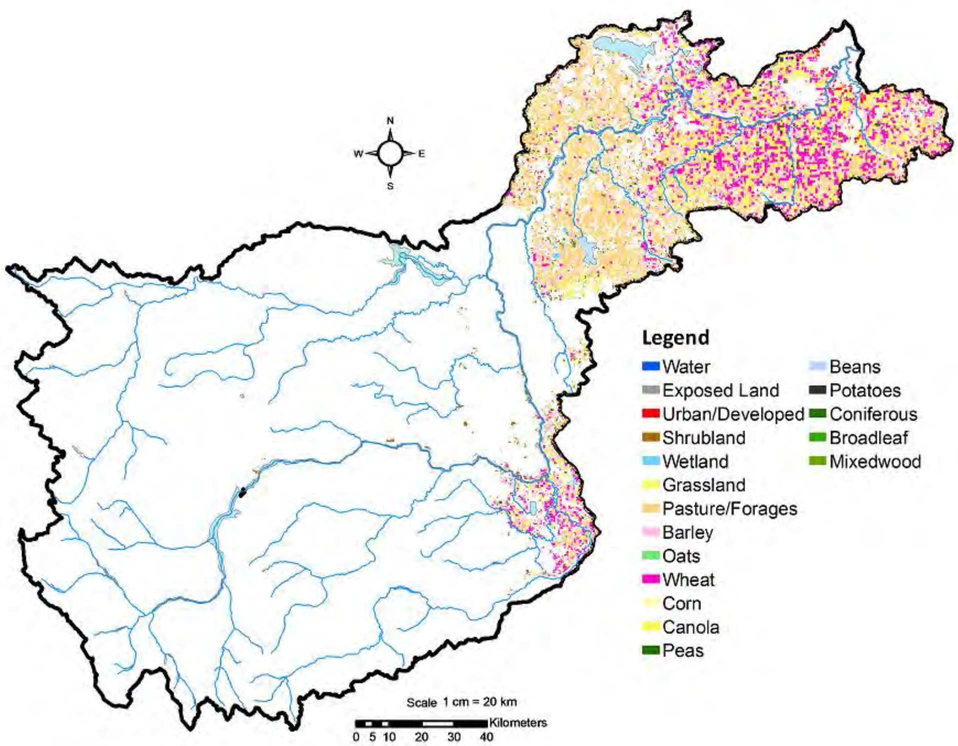
Figure 17. Percent of the Watershed in each Land Cover Type.

3.2.8 Agriculture

As mentioned in Section 3.2.5, land used for agriculture makes up just under one sixth of the NSR watershed. However, in the lower part of the watershed from the Edmonton Metropolitan Region and east, about 85% of the land area is used for agriculture and food production. Specifically, land used for agriculture in Leduc and Wetaskiwin Counties is over 81% of the land base, whereas in Parkland County, it is over 66% of the County's land base.

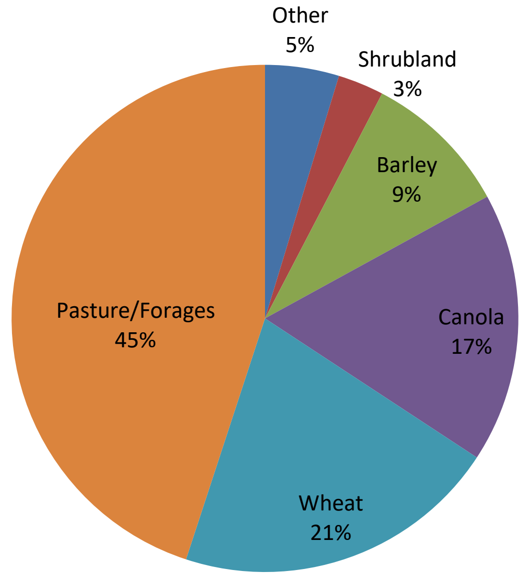
In the areas around Drayton Valley, perennial crops such as forages [hay and pasture] are the predominant agricultural land cover type, whereas, closer to Edmonton and near Rocky Mountain House, cropped land is more common (Figure 18). Livestock typically graze on pasture but may also utilize some hay lands and wooded or treed areas at certain times of the year, if they are fenced. Cattle on pasture often use remote watering systems because agricultural producers limit livestock access to waterbodies as a common practice in order to protect water quality and to protect herd health.

Of the 4,100 km^2 of land that is classified as annual and perennial crops by satellite imagery, the majority is in forages [hay or pasture] (45%), followed by wheat (21%), canola (17%), and barley (9%) (Figure 19). Other crops such as oats, potatoes, beans, corn, and peas are grown, but comprise a small percentage of cropped area (less than 1% combined). The vast majority of agricultural producers conserve their soil and limit risk to surface water quality by common practices such as direct seeding, reduced tillage, sustainable crop rotations, employing 4R technologies (Right product, Right place, Right rate & Right time), integrated pest management and farm implements/equipment that utilize GPS. Since 1996, the incidence of summerfallow [bare ground subject to wind and water erosion] has been nearly eliminated in the NSR watershed. For the past two decades, agricultural producers have adapted to these advanced land conservation and management, productivity and accountability practices since instatement of Maximum Residue Levels (MRL's) on major crop commodities. The agricultural communities in the NSR appreciate that their enterprises and livelihoods depend on healthy soils and quality water supplies.



Data Source: Agriculture and Agri-Food Canada 2016

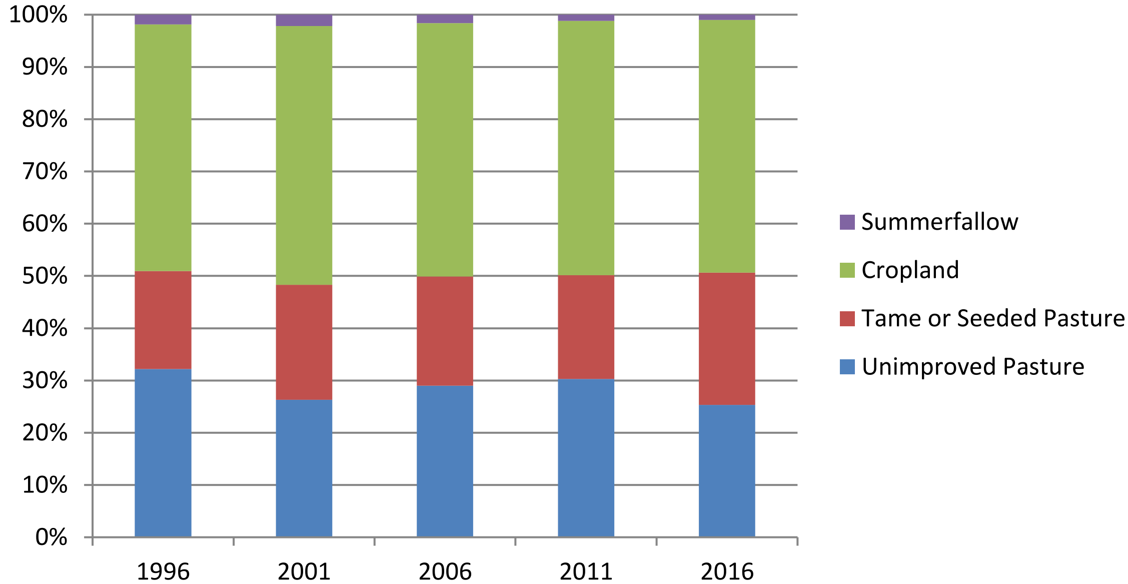
Figure 18. Agricultural Land Cover (2016) in the Watershed.



Data Source: Agriculture and Agri-Food Canada 2016

Figure 19. Percent of Agricultural Land Cover in Each Use Category.

The Federal Government collects census data every five years which provides a snapshot of agricultural practices. These statistics are indicative of numbers at a single point in time (the day of the survey), are based on the number of farms reporting, and may not reflect current numbers. As well reporting is based on farm headquarters and the reported data may not necessarily be located in the watershed. Data for manure production and livestock numbers were aggregated at the watershed scale for 1996, 2001, 2006, 2011, and 2016 census. Data were also available at a smaller sub-watershed scale: 174 farms reported for the Clearwater sub-watershed; 139 farms for the Ram sub-watershed; 1,262 farms for the Strawberry sub-watershed; zero farms for the Brazeau sub-watershed; and 907 farms for the Wabamun sub-watershed. Total agricultural area reported in the 2016 census was similar to satellite imagery, and therefore it is likely that a high number of farms completed the census. Census data show that the agricultural land in the NSR watershed is divided approximately evenly between pasture and crops, and that this ratio does not change substantially year to year (Figure 20).



Data Source: Agriculture and Agri-food Canada 2016

Figure 20. Agricultural Land Use Reported by Census of Agriculture in the NSR Watershed from 1996 to 2016.

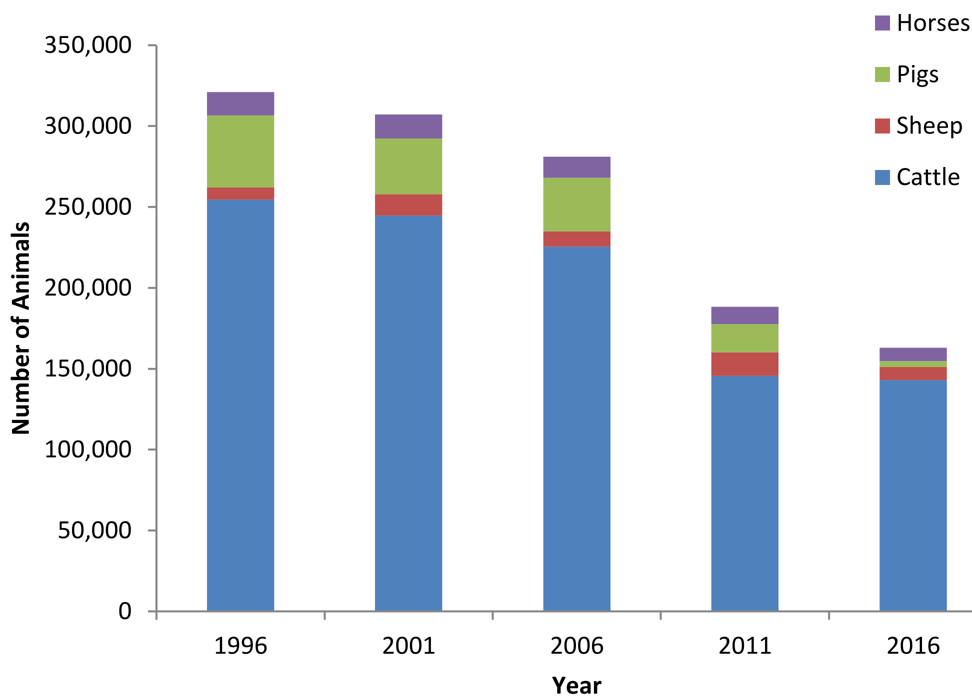
It is well documented that areas of higher livestock density within a sub-watershed can lead to impacts on downstream aquatic systems, often because of waste production and physical access of livestock to waterbodies. Within the NSR watershed, there were approximately 143,000 cattle; just under 3,500 pigs; 8,000 sheep; and 8,000 horses in 2016. The numbers of livestock have been declining between each census period, but the largest declines were observed between 2006 and 2011 (Table 5, Figure 21).

The decline in number of farms and overall livestock numbers reflected in the NSR watershed is part of a national trend well (Statistics Canada 2017). There were also over 1,300 fewer farms in the NSR reporting cattle from 1996 to 2016. Statistics Canada has reported that nationally there are fewer farms, and fewer cattle in Canada, and this trend appears to hold true for the NSR watershed as well (Statistics Canada 2017). This is a result of the BSE crisis in 2003, more farmers retiring, fewer intergenerational farm transfers, farm consolidations or relocations and other external market factors.

Table 5. Livestock Numbers in the Watershed by Livestock Type and Census Year.

Type/Year	1996	2001	2006	2011	2016
Total Farm Reporting	3,786	3,366	3,106	3,022	2,484
Total Farms Reporting Cattle	2,505	2,001	1,824	1,305	1,166
Cattle (#)	254,463	244,591	225,515	145,596	142,928
Sheep (#)	7,686	13,366	9,468	14,564	8,197
Pigs (#)	44,527	34,466	33,107	17,356	3,481
Horses (#)	14,267	14,779	12,945	10,775	8,332
Poultry (#)	633,169	628,055	502,116	321,264	356,215
Total Large	**320,943**	**307,202**	**281,035**	**188,291**	**162,938**
Total	**954,112**	**935,257**	**783,151**	**509,555**	**519,152**

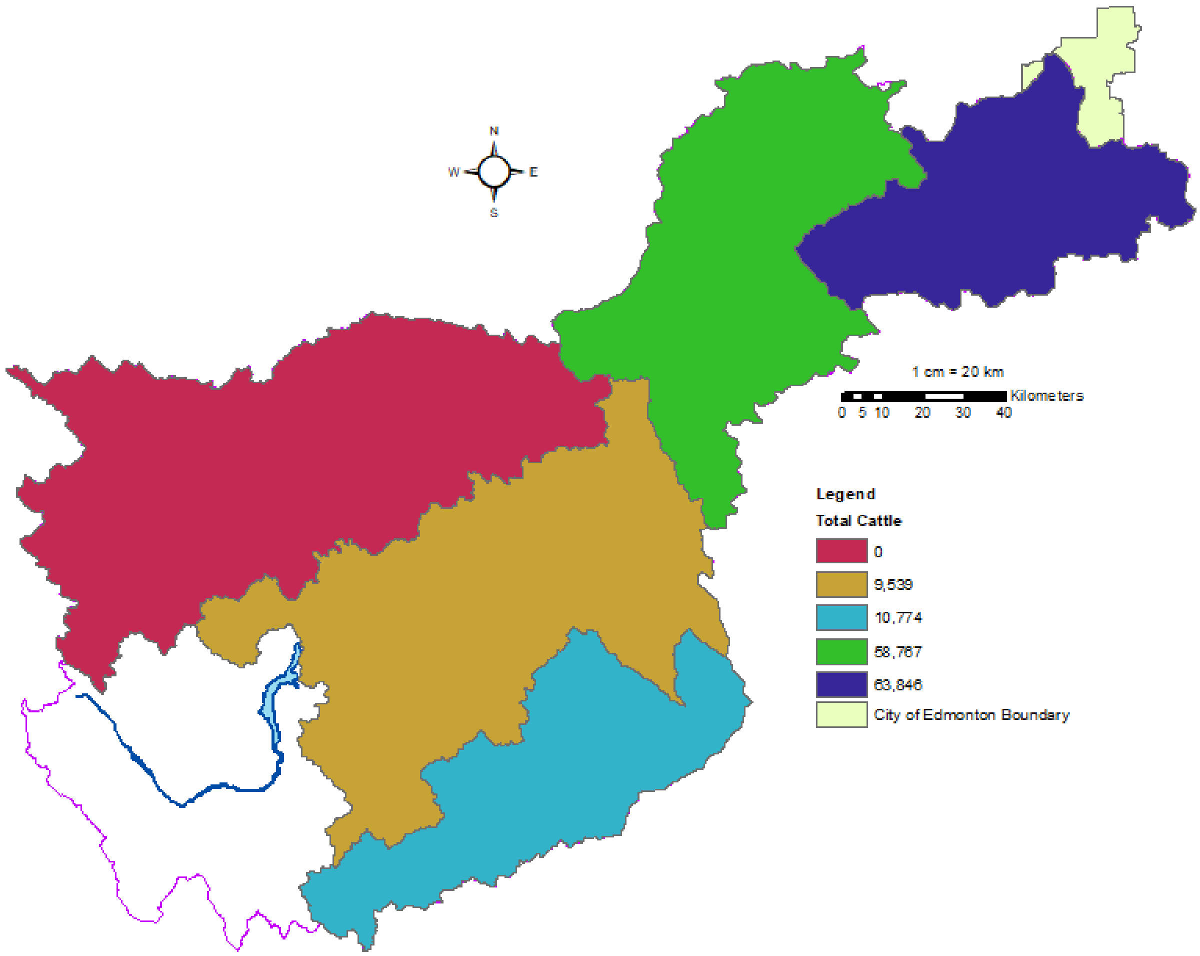
Data Source: Agriculture and Agri-food Canada 2016



Data Source: Agriculture and Agri-food Canada 2016

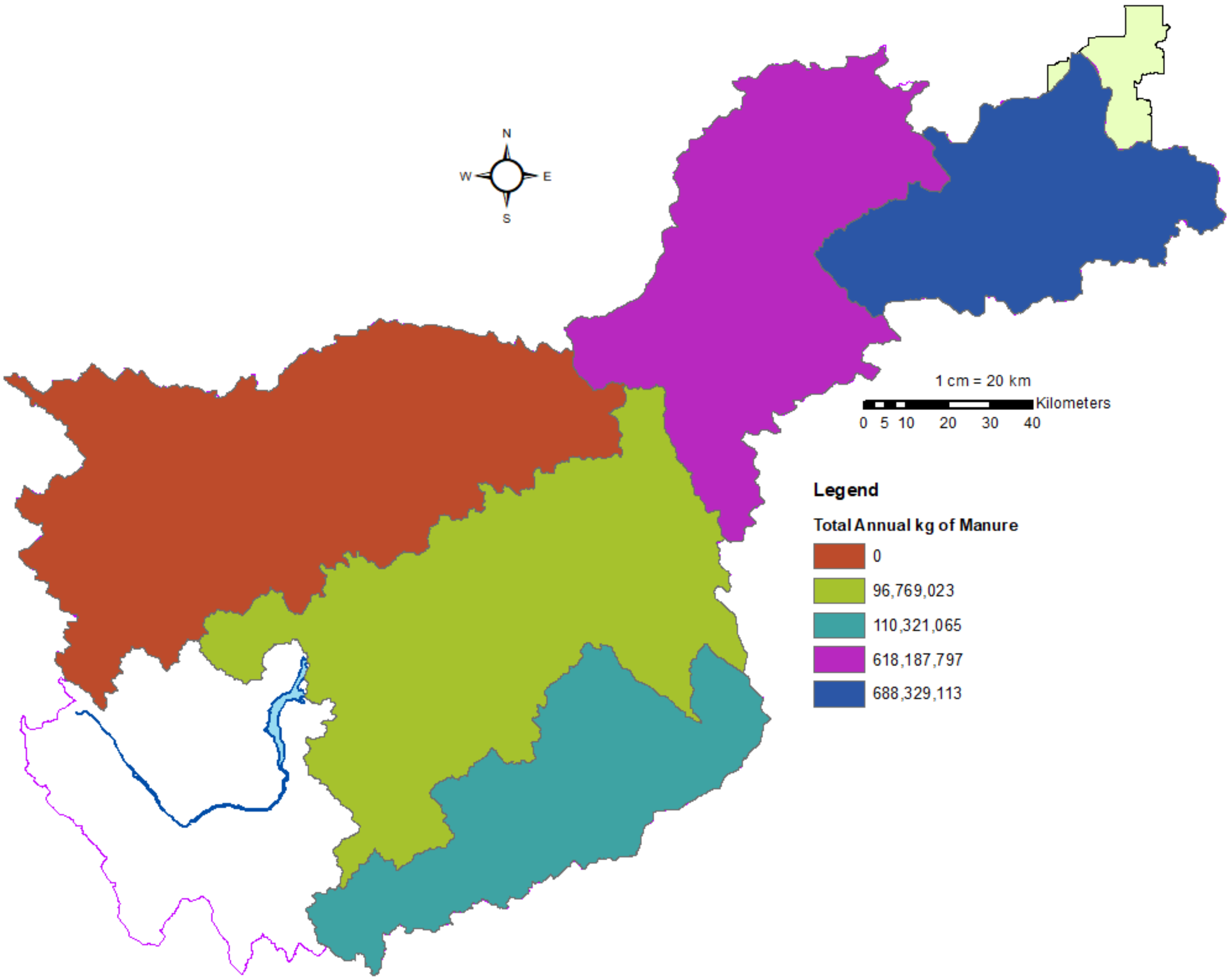
Figure 21. Total number of Horses, Pigs, Sheep and Cattle Reported in the NSR Watershed by Census Year.

Both the total number of cattle and manure production show that most of the livestock in the NSR watershed are concentrated in the lower part of the watershed (Figures 22 and 23). There are also 31 confined feeding operations in the watershed. As expected, with the decrease in the number of livestock between 1996 and 2011, there is a corresponding decline in the amount of manure produced, and the amount of nitrogen and phosphorus produced from manure (Figures 24 and 25).



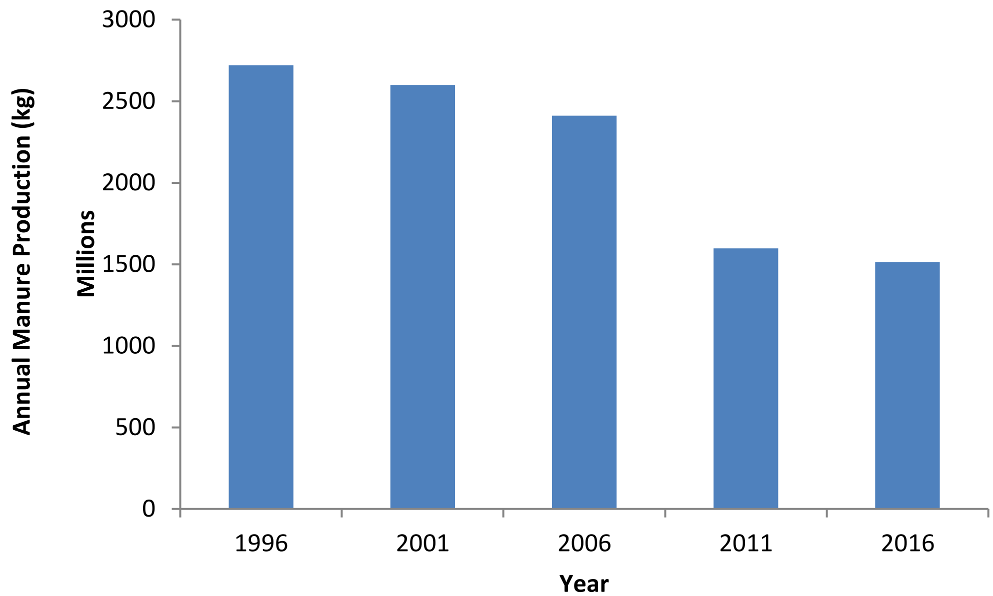
Data Source: Agriculture and Agri-food Canada 2016

Figure 22. Total Cattle Reported by Sub-basin in the NSR Watershed in 2016.



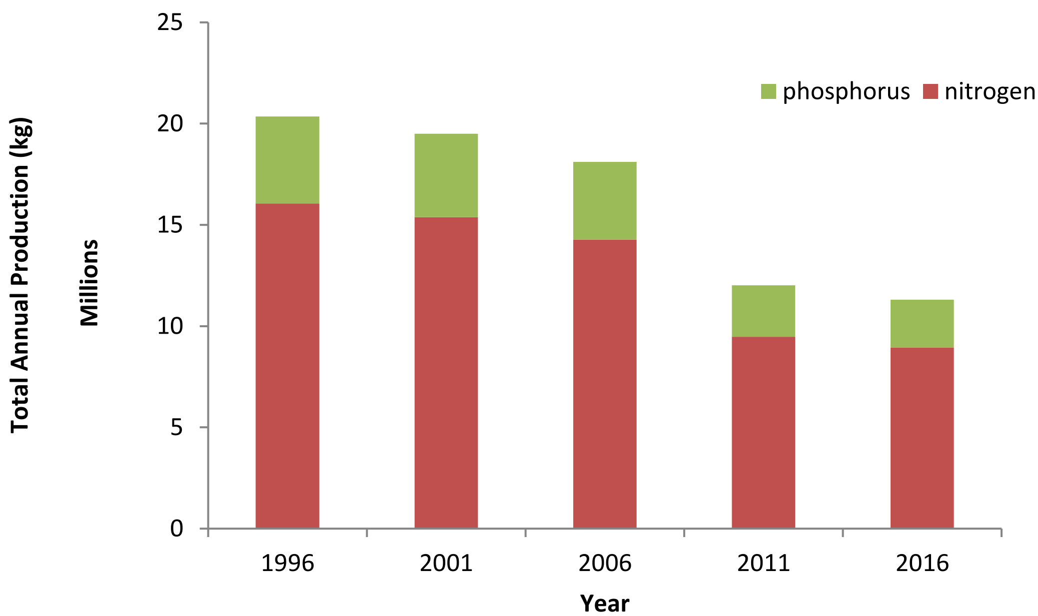
Data Source: Agriculture and Agri-food Canada 2016

Figure 23. Manure Production by Sub-basin from All Livestock in the NSR Watershed in 2016.



Data Source: Agriculture and Agri-food Canada 2016

Figure 24. Estimated Annual Manure Production from All Livestock in the NSR Watershed by Census Year.



Data Source: Agriculture and Agri-food Canada 2016

Figure 25. Estimated Annual Phosphorus and Nitrogen Manure Production from All Livestock in the NSR Watershed by Census Year.

The area of land in the NSR watershed that uses pesticides [pesticides include herbicides, insecticides & fungicides] has steadily increased between 1996 and 2016 (Table 6). Since 1996, many of the most toxic & persistent pesticides have been de-registered and are no longer available for use. All commercial applicators must be certified and agricultural producers are encouraged to do the same and employ the 4R technologies. The Alberta 'Blue Book' produced annually by Alberta Agriculture provides a thorough list of available crop protection chemicals, safety & application guidelines, and cultural alternatives. The Census of Agriculture does not provide information regarding the total amount of pesticides used, only the area over which it was spread. The area of land that fungicides and insecticides were added has quadruped between 1996 and 2016; however, it remains a small percentage of overall agricultural land (< 3%). For herbicides, the increase between 1996 and 2016 was 48% on an area representing approximately 4% of the source watershed. The area of manure application more than quadrupled between 2006 and 2011 but went down to the lowest area to date in 2016. Manure is estimated to be applied to less than 1% of the source watershed. Fertilizer use has remained relatively consistent in the last 20 years and is applied to approximately 5% of the area of the source watershed.

Table 6. Area of Land (km^2) that Pesticides, Manure, and/or Fertilizer were added by Census year.

Addition	1996	2001	2006	2011	2016
Fungicide	70	56	116	152	304
Insecticide	20	32	70	41	116
Herbicide	934	981	1,074	1,177	1,378
Manure	246	285	315	1,379	172
Fertilizer	1,559	1,475	1,474	1,263	1,453

Data Source: Agriculture and Agri-food Canada 2016

Best Practices in Agriculture

Recognizing the impact that agricultural activities can have on receiving water bodies, land owners, often in partnership with stewardship groups, have worked hard to implement beneficial/best management practices (BMPs). BMPs are specific to each type of land use and are intended to prevent bare ground, control runoff, and optimize inputs and resources. These practices include nutrient, crop and manure management, better storage of fuel, riparian management and reduction of the use of pesticides.

A BMP success story for the Province was the promotion of conservation tillage which significantly reduced the amount of summer fallow to previous levels; this resulted in significant reductions in soil erosion. In the NSR watershed summer fallow was 105 km^2 in 1996 and only 48 km^2 in 2016. The area of conservation tillage increased from 331 km^2 in 1996 to 469 km^2 in 2016. In 2011, over 551 farms of 3,022 reported using buffers around waterbodies.

EPCOR recognizes the importance of agricultural BMPs to improve water quality and quantity from agricultural areas. Agricultural streams are elevated in ammonia and organic material (colour), particularly during spring runoff. Improved water quality in the NSR could result in reduced operating costs for EPCOR’s WTPs, and reduce taste-and-odour events that can affect the aesthetic quality of our customer’s drinking water. BMPs also function to keep water on the land, instead of rapidly entering the river. Improved hydrology within our watershed has the potential to help offset significant impacts of flooding and drought to our WTPs. EPCOR has supported a number of initiatives relating to the implementation and researching the effectiveness of implementing BMPs in the watershed.

EPCOR is financially supporting two research projects are currently underway in the Modeste and Strawberry Creek subwatershed that will evaluate ecosystem services, such as improvements in water quality and quantity, by implementing BMPs. These projects are utilizing the Integrated Modelling for Watershed Evaluation of BMPs (IMWEBs) model that has been developed by Wanhong Yang from the University of Guelph. IMWEBs is a watershed model that evaluates water quality and quantity improvements of over 30 BMPs, including crop and nutrient management, grazing and manure management, irrigation, conservation tillage, marginal land conservation, riparian buffer management and wetland restoration. Output from IMWEBs is based on the implementation of BMPs on individual fields and can scale up these field-level benefits into overall watershed scale improvements. This project is integrated in with the NSWA’s riparian mapping project which will help target areas for improvement in riparian intactness.

ALUS Canada is an NGO that partners with municipalities and farmers to help to implement BMP projects on the ground. ALUS has partnered with Brazeau, Parkland, Wetaskiwin, and Leduc counties in order to implement BMPs. ALUS is also involved in the IMWEBs projects described above, as the output from these models will help ALUS prioritize their efforts to achieve the highest benefits. EPCOR has financially supported ALUS in their work to implement BMPs upstream of Edmonton in the past.

The North Saskatchewan Watershed Alliance has led extensive work assessing the health of riparian habitat in the Modeste and Strawberry Creek watersheds utilizing satellite imagery. Riparian habitats are the transition between terrestrial and aquatic habitats and provide key ecosystem services such as improving water quality, reducing erosion and slowing the release of water. Changes in land use have frequently resulted in the loss of riparian intactness, which can have negative impacts to water quality, and ultimately require increased treatment at EPCOR's WTPs. Based on the NSWA's analysis, the Strawberry watershed has considerably more riparian habitat that is considered to have "very low intactness" and "low intactness" compared to the Modeste watershed (Figure 26). The higher intactness of riparian areas in the Modeste subwatershed is due to a number of streams in this watershed that are located outside agricultural areas, and creeks within agricultural areas were similarly impacted in the Modeste and Strawberry watersheds. A map of the Strawberry watershed shows that the lowest riparian intactness typically occurs along unnamed tributaries and the upper reaches of named tributaries (Figure 27). At these locations, creeks are likely small, intermittent and poorly defined and may be more susceptible to damage by agricultural activities. In contrast, creeks typically had high intactness closer to their confluence with the NSR, likely because at these locations the creek is larger and more defined and agricultural activities are more likely to be set back further in these areas.

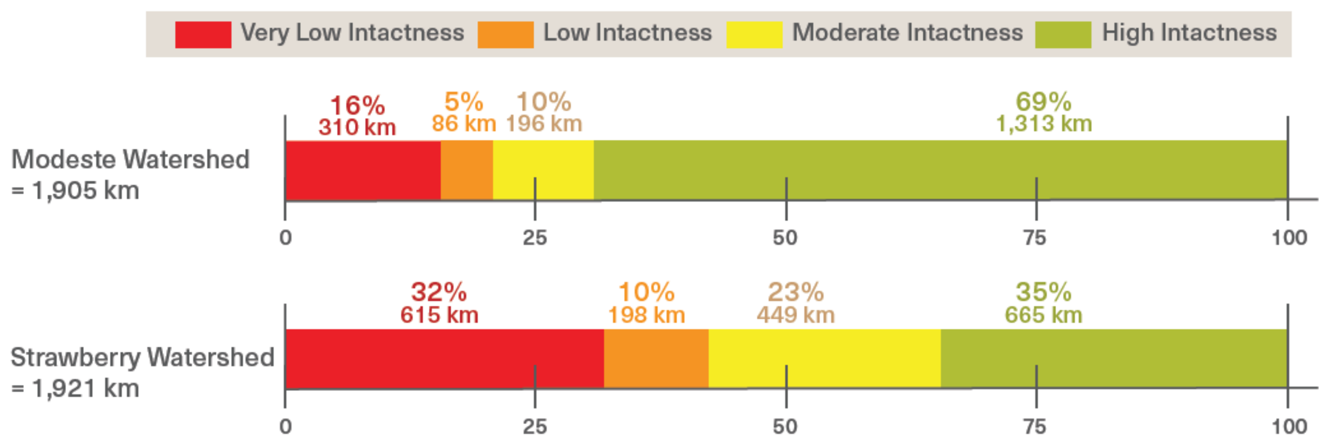


Figure 26. Summary of Riparian Intactness from the Modeste and Strawberry Watersheds (from Fiera 2018a and 2018b)

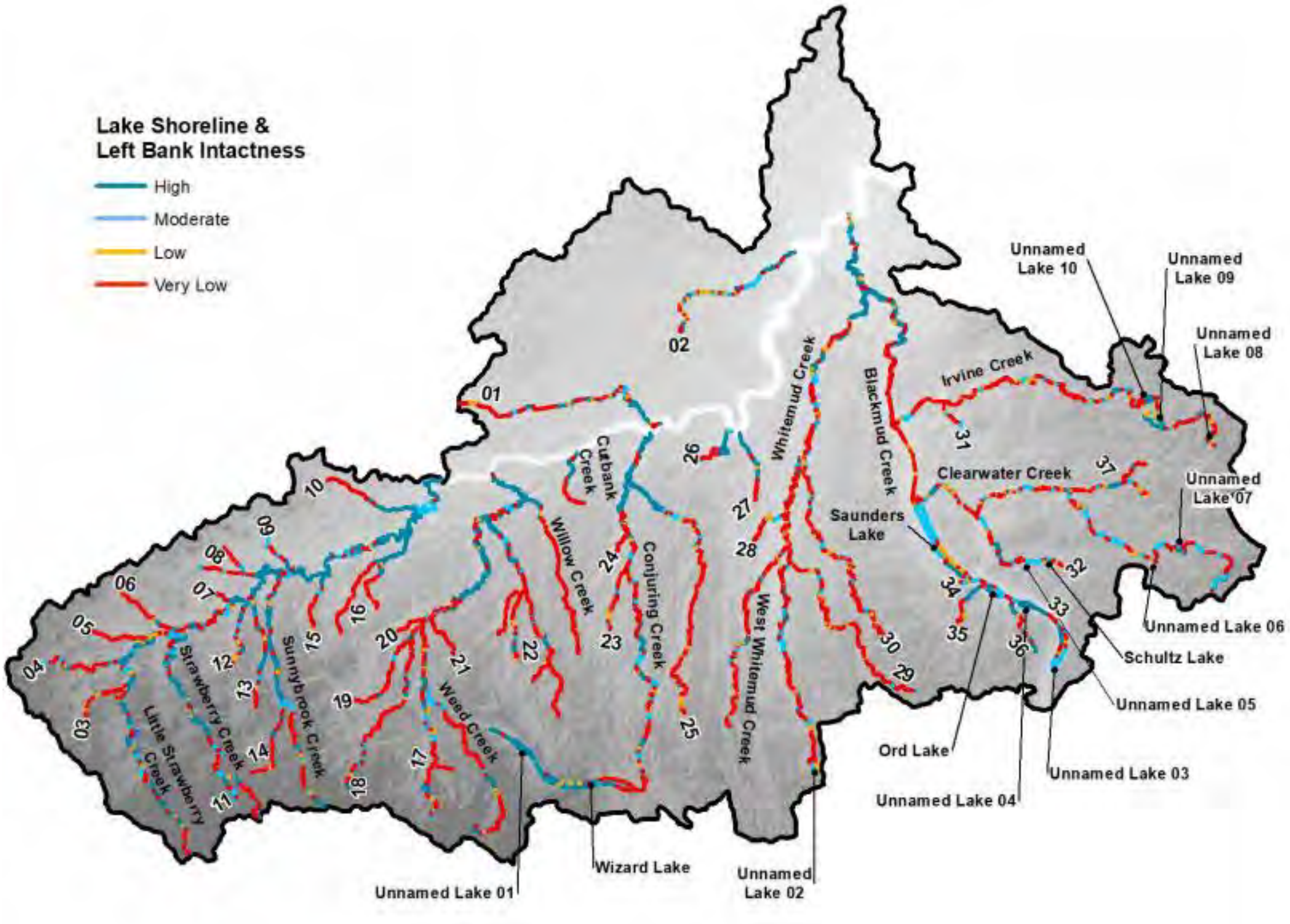


Figure 27. Riparian Intactness Measurements from Strawberry Creek Watershed (Source: Fiera 2018a)

The NSWA's work on riparian habitat extends beyond assessing intactness, and includes the assessment of the resulting "pressure" of the land that would impact the riparian area. Utilizing this information, NSWA has highlighted areas that have a high value for conservation or restoration so that efforts and resources can be focused on areas that would generate the greatest benefit. The NSWA is also developing the Riparian Web-portal which will display all the information in an easy to use interface. The portal will be used to share riparian data, showcase riparian projects on the ground, and connect landowners with restoration and conservation programs.

3.2.9 Industrial Activities

Chemicals are transported throughout the watershed, through pipelines, roads, or train routes, and therefore, there is a risk of contamination to the NSR from spills. Routes that pose the highest risk are ones that allow movement of chemicals across the NSR or its tributaries. In terms of transportation corridors, there are many public roads and highways located in the basin upstream of Edmonton. Each transportation corridor is not a potential hazard in itself; however, the traffic which uses the corridors could be a potential hazard depending on the type of material being carried, the probability of a spill/release to the environment and watershed and/or the location in relation to a surface water source. Industrial activities that discharge to receiving waterbodies are also of concern for water quality.

Dangerous Goods Routes

Within Edmonton, there are several dangerous goods routes that cross the NSR upstream the WTPs. Specifically, just upstream of E.L. Smith, the Anthony Henday Bridge crosses the NSR and is designated as a dangerous goods route (Figure 28). The Quesnell bridge is also a designated as a dangerous goods route, and is located upstream of the Rossdale WTP. Other river crossings upstream of the Rossdale WTP include the Groat Road Bridge, High Level Bridge and Walterdale Bridge. The High Level and Walterdale Bridges are designated 24 hour truck routes (green line). While these bridges are not considered dangerous goods routes, traffic crossing these bridges could still be carrying dangerous goods. Additionally, The Anthony Henday also crosses the Blackmud, Whitemud and Horsehills creeks which drain to the NSR upstream of the Rossdale WTP, and Whitemud Drive also crosses Whitemud Creek.

Upstream of Edmonton, there are six highway crossings along the NSR. These include Highway 60 near Devon, Highway 770 near Genesee, Highway 759, Highway 22 near Drayton Valley, and Highways 11 and 11A near Rocky Mountain House.

A roadside truck survey conducted by the City of Edmonton in 2012 found that 4.3% of trucks over 4,500 kg were transporting dangerous goods (City of Edmonton 2013). A majority of the dangerous goods were various types of petroleum products (Figure 29).

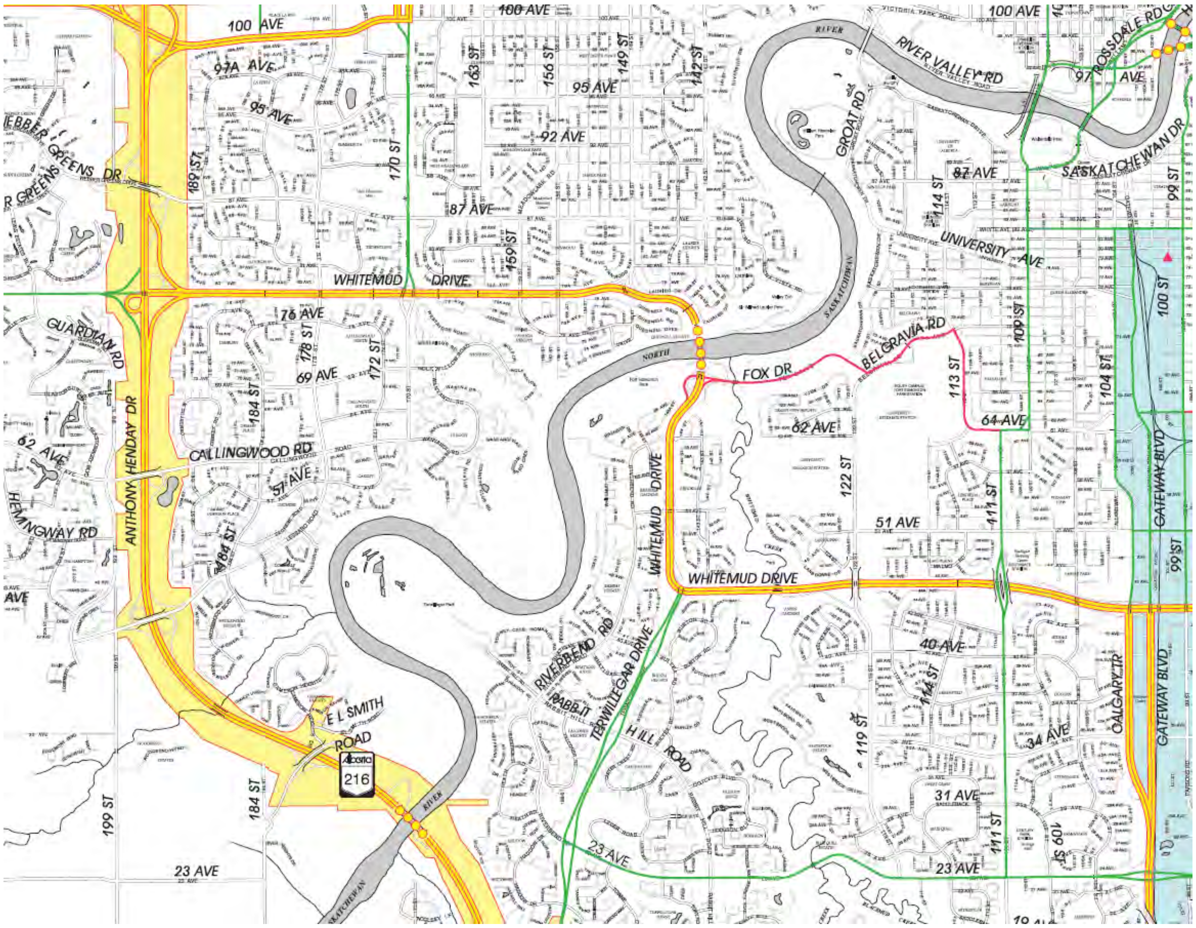
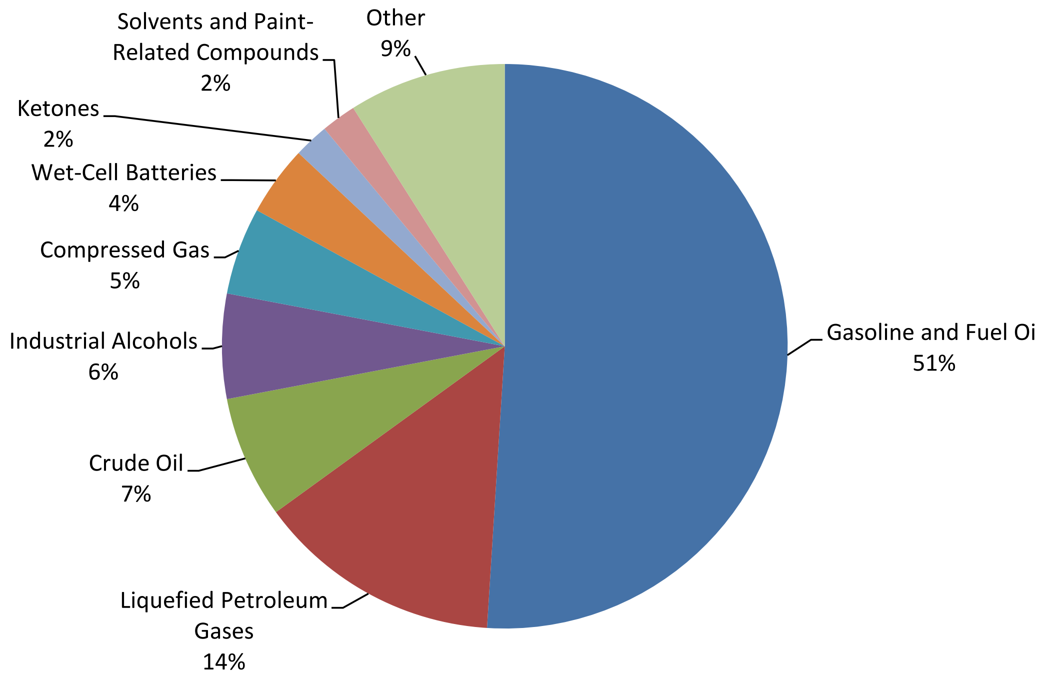


Figure 28. Dangerous Goods Truck Routes and River Crossings with Edmonton Boundaries Upstream of WTPs (Source: City of Edmonton 2015).



Data Source: City of Edmonton 2013

Figure 29. Types of Dangerous Goods Carried in Roadside Truck Survey.

Industrial Discharges

There are few heavy industrial operations upstream of Edmonton. Some of them include:

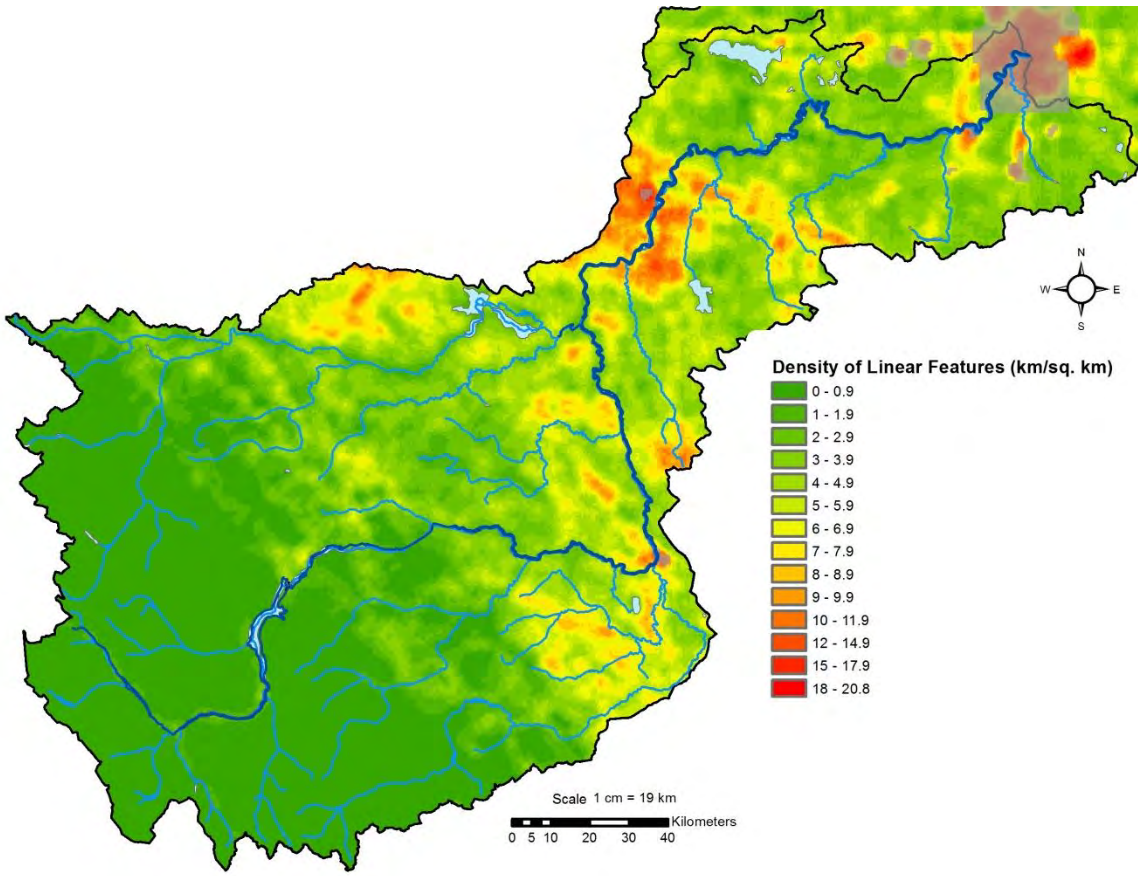
- Capital Power's Genesee Generating Station – coal-fired power plant located south of the NSR within the Strawberry subwatershed
- TransAlta's Keephills and Keephills 3 Generating Stations - coal-fired power plants located north of the NSR within the Modeste subwatershed
- TransAlta's Sundance Generating Station - coal-fired power plant located north of the NSR within the Modeste subwatershed

Cooling water used for thermoelectric power generation at the Genesee, Keephills and Sundance plants represent the largest water diversion use in the upstream basin. However, since the majority of the water is used for once-through cooling water purposes, there are no significant impacts from a drinking water source perspective associated with discharges back to the river from these thermoelectric facilities.

Linear disturbance

Linear disturbance can be used to indicate the cumulative anthropogenic footprint on a landscape, and in green zone areas (public land) it is often associated with industrial development (roads, pipelines, transmission lines, cutlines, etc.). Impacts of linear disturbance include habitat fragmentation, erosion, changes to hydrology and water quality. If linear disturbance is extensive enough, the ecological integrity of watersheds can be disrupted

(AESRD 2012a). The total linear disturbance density in the NSR watershed ranges from almost zero in the uppermost headwaters, to upwards of 21 km/km^2 near the oil and gas fields of Drayton Valley (Figure 30). Linear disturbance values in the more pristine areas of the watershed such as the Ram, Clearwater, Baptiste, and Brazeau sub-basin are high (near 7 km/km^2), considering that these areas are often perceived to be undeveloped. For comparison purposes, densities in the Alberta portion of Yukon to Yellowstone Conservation Initiative (Y2Y) found mean disturbance densities of 2.7 km/km^2 and maximum densities in excess of 8.0 km/km^2 (Sawyer and Mayhood 1998).



Data Source: ABMI 2018

Figure 30. Linear Disturbance in the NSR Watershed.

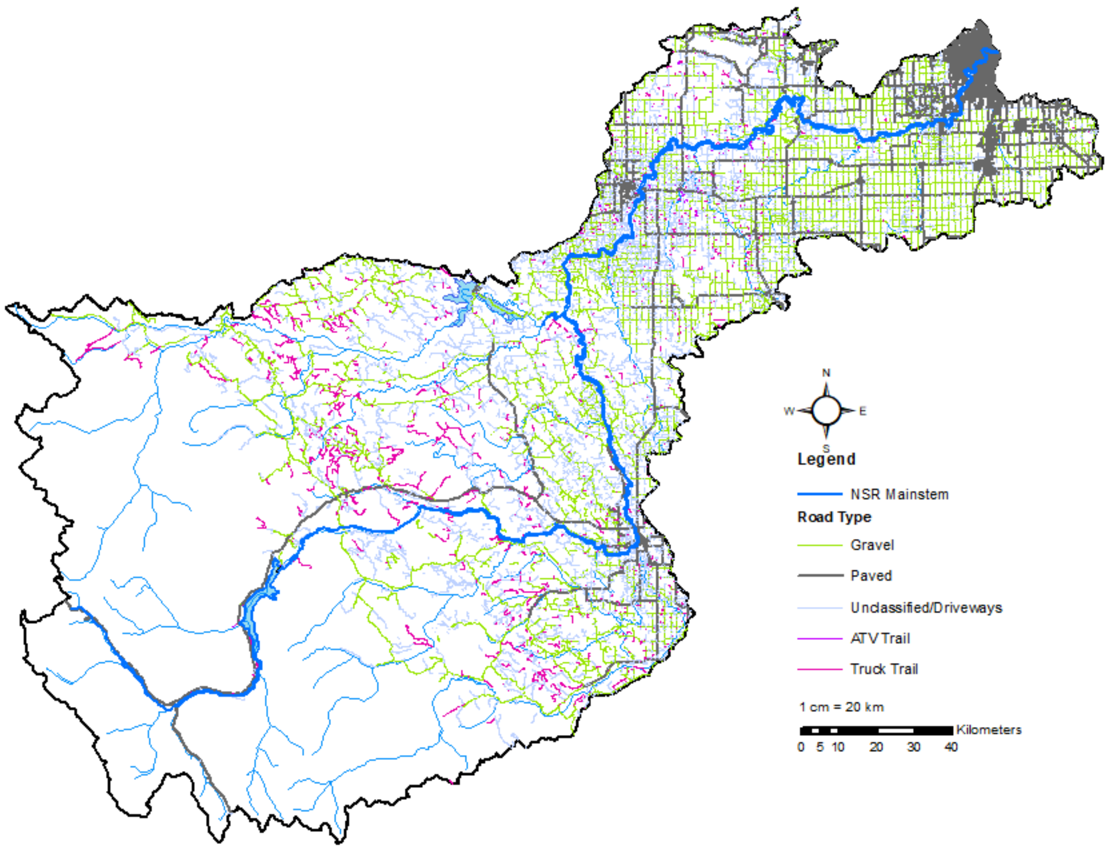
Roads and Seismic Lines

Roads and seismic lines are specific examples of linear disturbances that can have a negative impact watersheds. Roads, and trails, particularly those used for off-highway vehicles, have been shown to alter the flow and water quality in headwater streams and negatively impact the soils, vegetation and animals in these watersheds (Farr et al. 2017).

Roads and seismic line abundance was calculated using data from ABMI's (2018) linear disturbance layer. There are a total of 23,460 km of roads and truck trails in the NSR watershed equating to a density of 0.83 km/km^2, an area of 282 km^2, and 1% of the watershed area (Figure

31). There has been an increased of road area of 9% from 2014 to 2018. Paved roads comprise 4,974 km and cover 91 km^2 of the watershed. However, in rural areas paved roads extend only approximately 2,000 km and cover less than 50 km^2. Gravel roads, consisting of mainly county maintained roads, comprise 6,793 km in length and 76 km^2 in area. Most of the paved and gravel roads are concentrated in the lower portion of the watershed between Edmonton and Drayton Valley. Driveways/unclassified roads are largely found in rural areas and are 9686 km long and cover and area of 105 km^2. Truck trails are largely limited to Crown land in the upper portion of the watershed and make up 1,464 km and cover 9 km^2. There is 56 km of designated ATV trails.

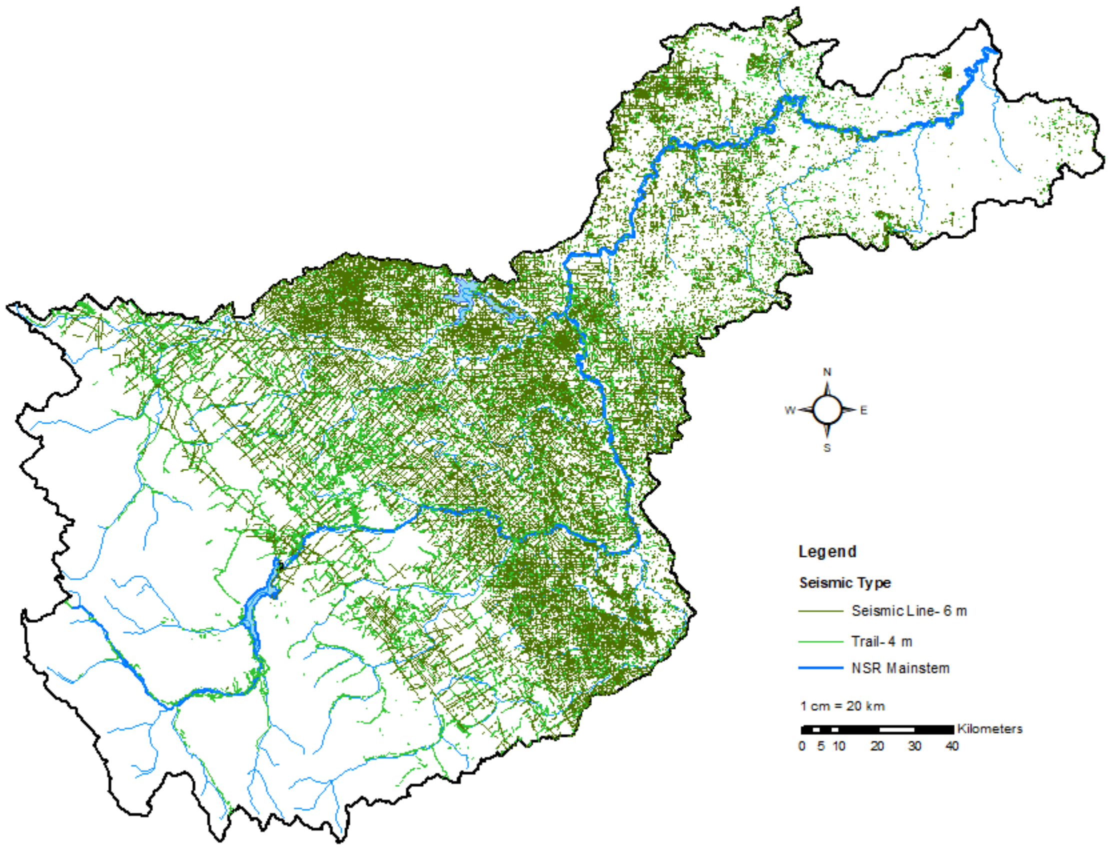
Alberta Environment and Sustainable Resources Development (AESRD 2012a) summarized the thresholds at which various animals are impacted by road densities: 0.4 km/km^2 for grizzly bear, 1.25 km/km^2 for black bear and 0.62 km/km^2 for elk. AESRD (2012a) also summarized the relationship between road density and bull trout populations and found that moderate risk to bull trout populations occurred at densities of 0.1 – 0.2 km/km^2, high risk occurred at 0.2 – 0.6 km/km^2, very high risk occurred at densities of 0.6 – 1.0 km/km^2 and bull trout were extirpated at densities 1.0 km/km^2. Work conducted by the U.S. Forest Service shows that habitat effectiveness for grizzly bears, an indicator species, decreases as road densities increase. At road densities of 0.8 km $road/km^2$, habitat effectiveness is reduced to 50%; at road densities of 1.6 km $road/km^2$, habitat effectiveness is further reduced to 25%. To meet the U.S. Forest Service established management goal of maintaining habitat effectiveness in occupied grizzly bear habitat at 80%, road densities should be maintained below 0.3 km/km^2. Based on the literature values, road densities in the NSR watershed are high enough to have a notable an effect on each of the species described above. Road densities are low in the headwaters and increase with proximity to Edmonton. It is recognized that while there is likely little direct relationship the abundance and health of these indicator species and source water quality; however, these species are functional components of the ecosystem, and if these components have been compromised, the integrity of the watershed and its ability to perform ecosystem services (i.e., maintain water quality) has also been compromised.



Data Source: ABMI 2018

Figure 31. Roads in the NSR Watershed in 2018.

Seismic lines typically range in width from three meters (low impact) to six meters (pre-low impact). Once a seismic line revegetates, it often becomes a trail-like feature and has been categorised as such in ABMI's data layer. Based on ABMI's 2018 data, there are 34,155 km of seismic lines in the watershed, which makes up 119 km^2 of area. Most of the seismic lines are located between Drayton Valley and Rocky Mountain House in the upper portion of the watershed; however little seismic activity has occurred in the upper-most portion of the watershed (Figure 32).



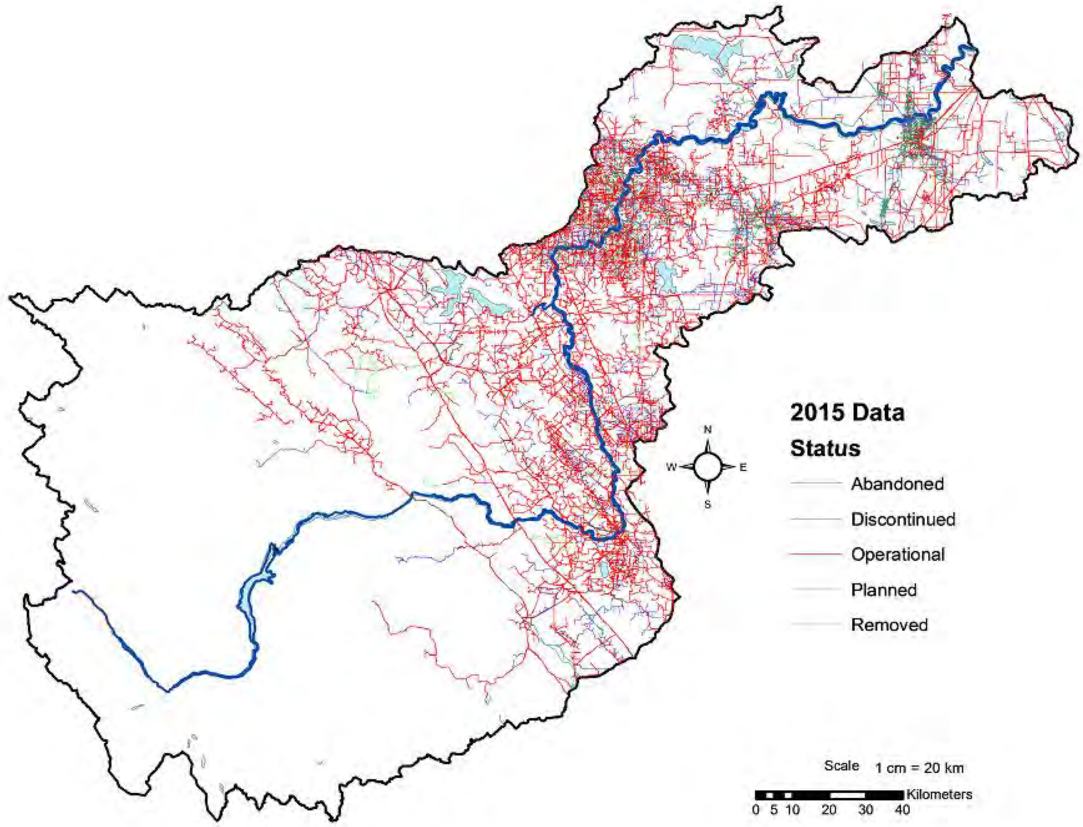
Data Source: ABMI 2018

Figure 32. Seismic Lines in the NSR Watershed in 2018.

Pipelines

Based on the Alberta Energy Regulator's 2015 data, there are 31,953 kilometres of pipeline in the NSR watershed. Of that, 21,847 km of pipeline is considered to be operational. The highest densities are near Drayton Valley, Devon and Rocky Mountain House (Figure 33). There is 4,773 km of abandoned pipeline, 5,008 km of discontinued pipeline, 10 km of pipeline that has been removed, and, as of 2015, 314 km of pipeline that was pending construction.

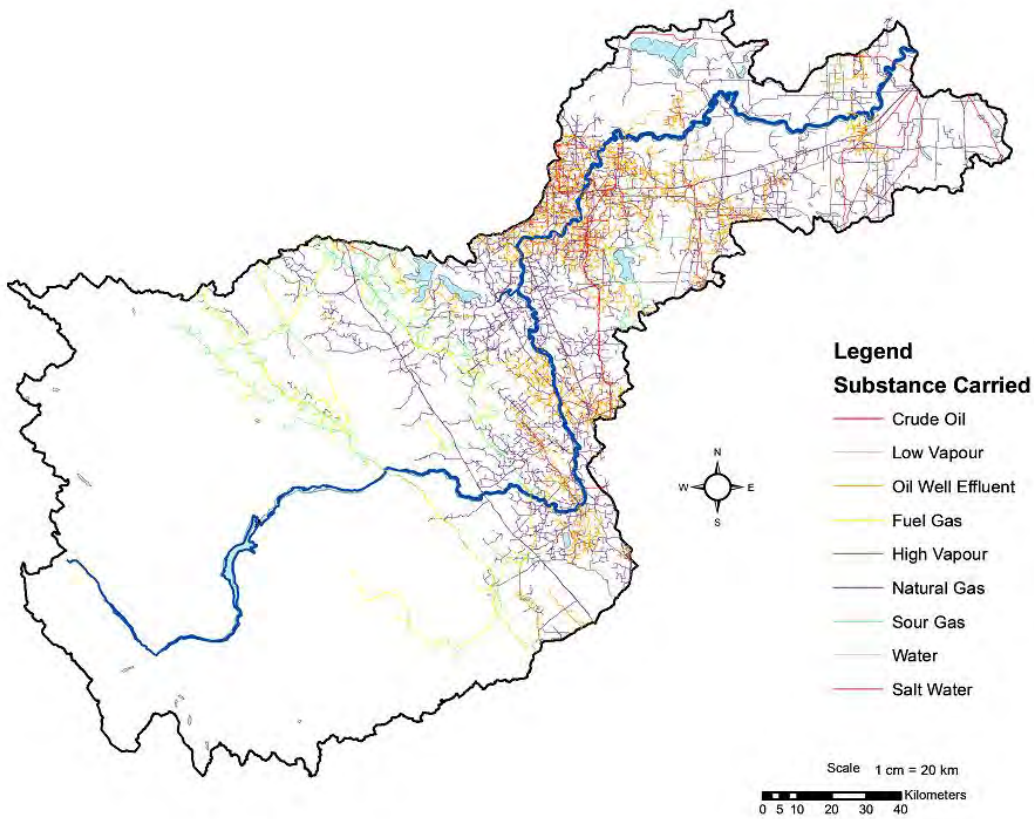
The average age of the operational pipelines is just over 20 years old, although many of the pipelines established in the early 1940s and 1950s have been converted or upgraded.



Data Source: Alberta Energy Regulator 2017a

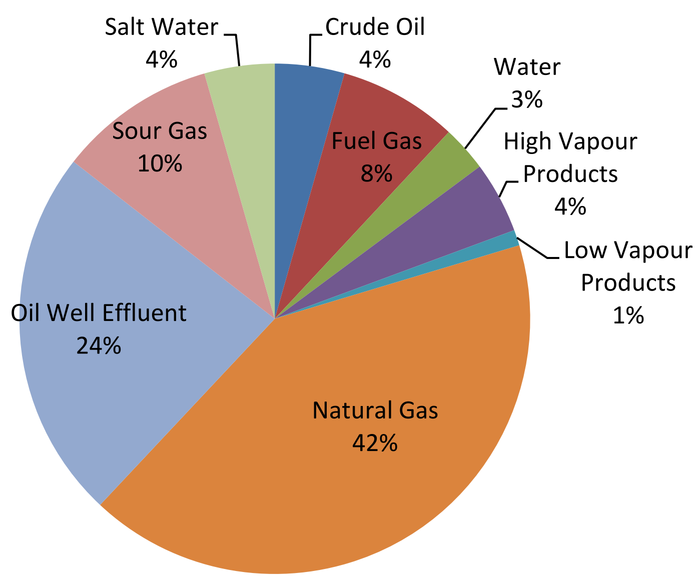
Figure 33. Pipelines in the NSR Watershed in 2015 by Status.

Of operational pipelines, over half of carry natural gas (42%) or sour natural gas (10%) (Figures 34 and 35). High vapour products (HVP) comprise 4%; salt water comprises 4%; and surface and potable water comprise 3% of the pipeline length. Substances that are potentially more challenging from a water treatment perspective comprise a total of 37% of the length of pipeline in the watershed and include oil well effluent (24%), fuel gas (8%), low vapour products (1%), and crude oil (4%).



Data Source: Alberta Energy Regulator 2017a

Figure 34. Operational Pipelines in the NSR Watershed by Substance Carried.



Data Source: Alberta Energy Regulator 2017a

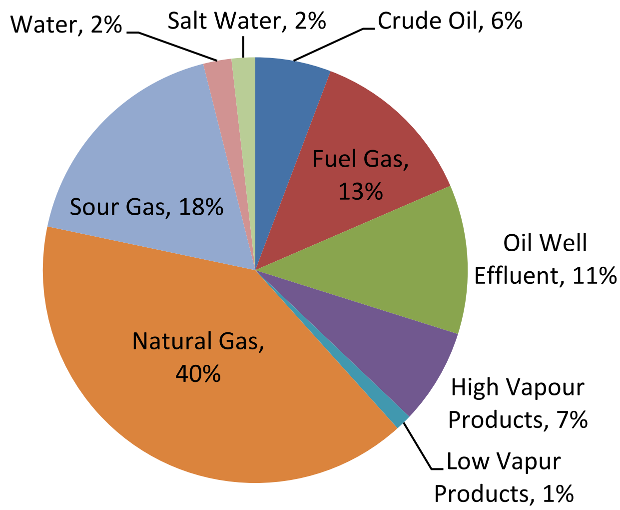
Figure 35. Percent of Total Length of Operational Pipelines in the NSR Watershed by Substance Carried.

From the perspective of source water protection, both pipeline density, and the substance carried by pipelines is important in terms of assessing the risk to source water. Additional important considerations are the location of the pipeline relative to the mainstem and major tributaries of the NSR, and the distance from the WTP intakes. There are nearly 4,000 km of pipeline located within 250 m of the NSR mainstem and its major tributaries (Table 7). There are an estimated 380 operational pipelines that cross or intersect the mainstem and major tributaries the NSR basin upstream of Edmonton, and of these, 119 pipelines cross the NSR mainstem. Of these pipelines, 58% carry natural or sour gas, 7% carry high vapour products, and 4% carry fresh or salt water. These products are of relatively low risk to source water protection in the event of a release into the NSR. However, 11% of pipelines crossing the NSR or a major tributary carry oil-well effluent, 6% carry crude oil and 1% carry low vapour products such as diesel, which are of high risk to source water protection should a spill occur (Figure 36). The pipelines which carry crude oil are shown in Figure 37.

Table 7. Pipelines in the NSR watershed as a function of location to the NSR mainstem and major tributaries.

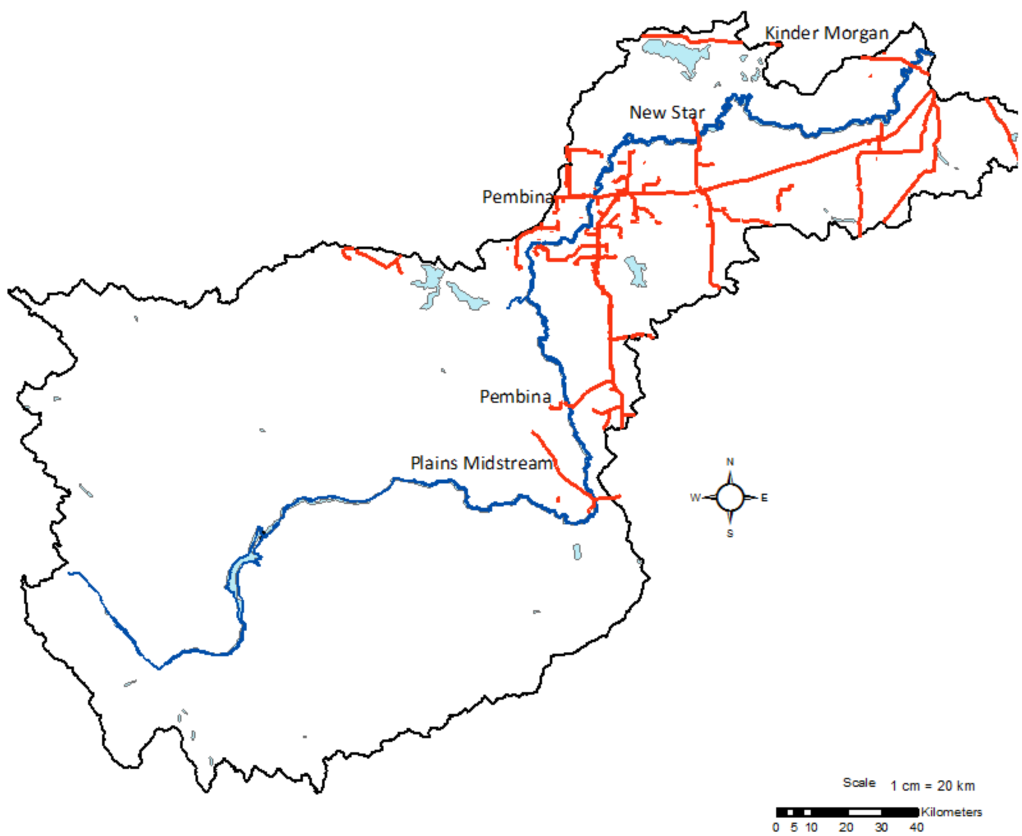
Substance	Description	Code	# Pipelines Crossing Major Tributary or Mainstem	# Pipelines Crossing Mainstem	Length of Pipeline within 250 m of NSR or Tributary (km)
Crude Oil	Blended Crude Bitumen, Crude Oil, Sour Crude Oil, Synthetic Crude Oil	CO	19	6	228
Fuel Gas	Fuel Gas	FG	35	5	504
Water	Potable Water, Surface Water	FW	17	14	85
High Vapour Products	Butane, Ethylene, Propane, Pentanes, Liquid Ethane	HV	22	8	286
Low Vapour Products	Condensate, Diesel Fuel, Gasoline, Heating Oil, Hydrocarbon Diluent, Kerosene, Solvents	LV	8	3	49
Natural Gas	Methane, Synthetic Natural Gas, Natural Gas With 10 Mol/kmol Or Less Of Hydrogen Sulfide Content	NG	146	39	1,580
Oil Well Effluent	Multiphase Fluids	OE	68	27	448
Sour Gas	Natural Gas With More Than 10 Mol/kmol Of Hydrogen Sulfide Content	SG	47	4	702
Salt Water	Salt Water	SW	18	13	71
Total			**380**	**119**	**3,953**

Data Source: Alberta Energy Regulator 2017a



Data Source: Alberta Energy Regulator 2017a

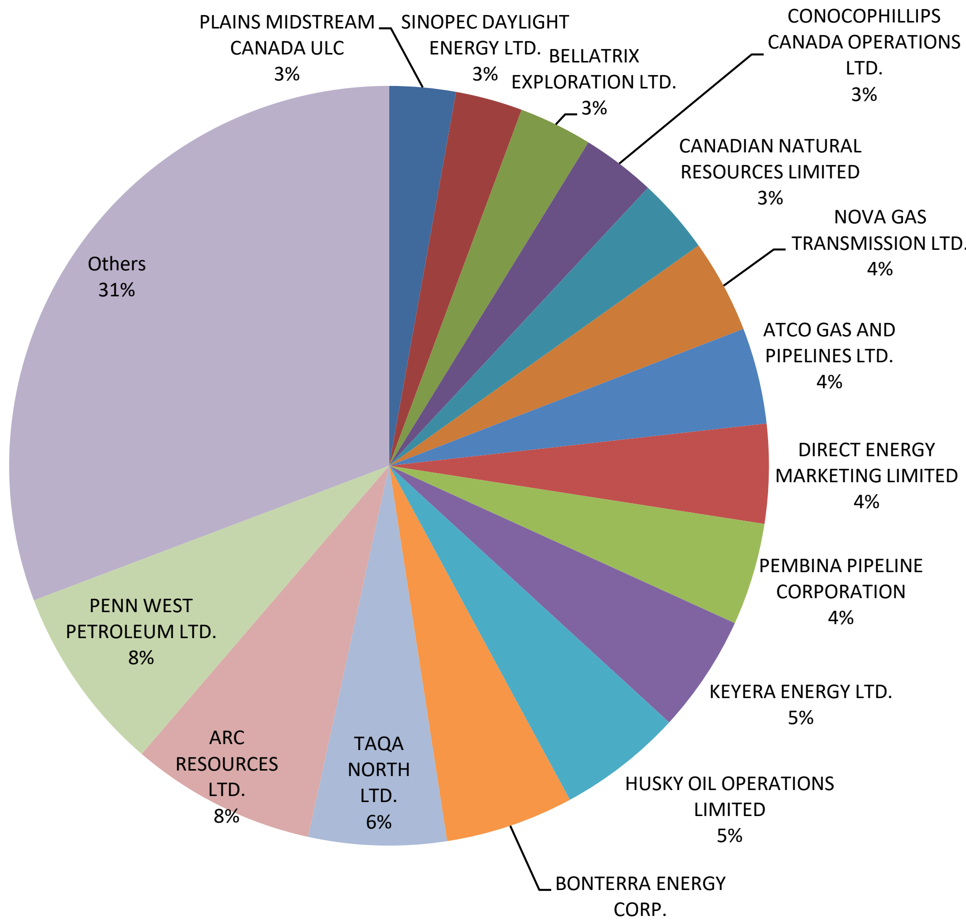
Figure 36. Materials Transported by Pipelines Within 250 Meters of the NSR Mainstem and its Major Tributaries in 2015.



Data Source: Alberta Energy Regulator 2017a

Figure 37. Operational Crude Oil Pipelines in the NSR Watershed.

There are 204 companies who share ownership of pipelines in the watershed. The highest percent ownership is at 8% and is shared by Penn West and ARC Resources (Figure 38). Of the companies operating in the watershed, 64 operate pipelines that cross the NSR mainstem and its major tributaries. Of those, crude is transported only by Kinder Morgan, New Star Energy Ltd., Pembina Pipeline Corporation, and Plains Midstream Canada UCL (Figure 37).



Data Source: Alberta Energy Regulator 2017a

Figure 38. Ownership of Operational Pipelines in the NSR Watershed.

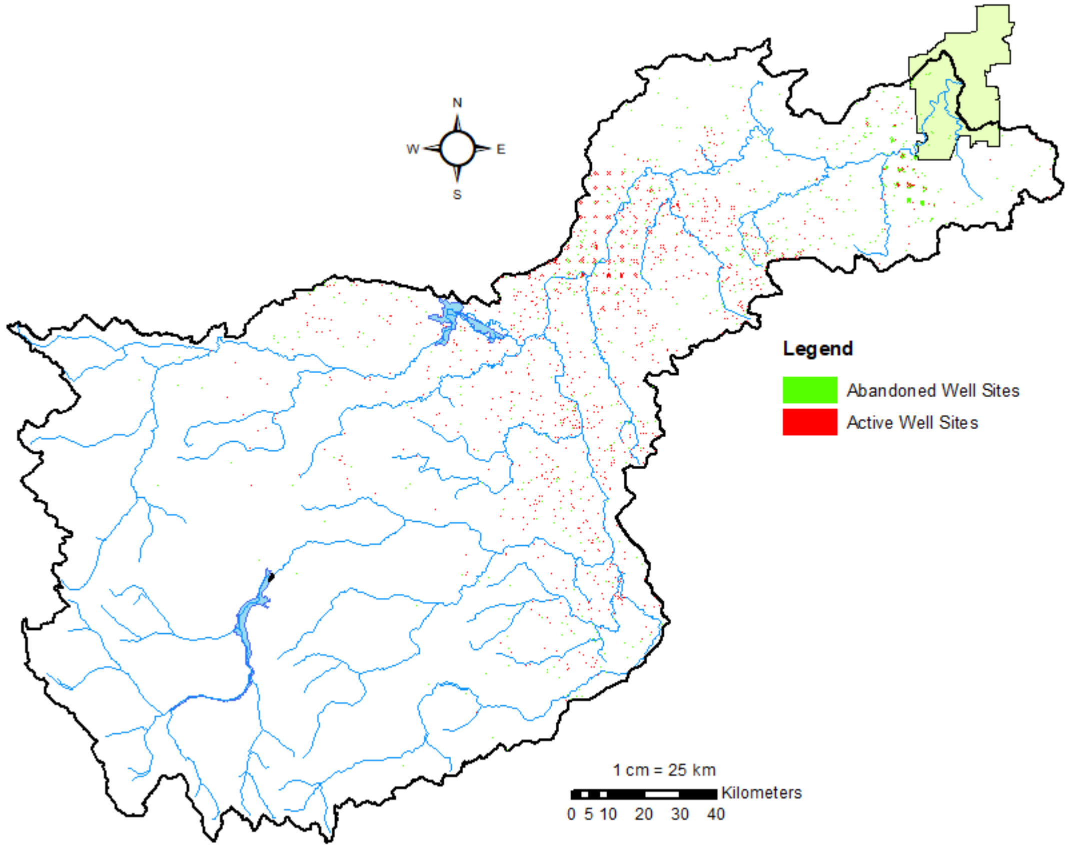
The Alberta Energy Regulator works to ensure that the design, construction, operation and maintenance of pipelines complies with Alberta's *Pipeline Act*, *Pipeline Regulation*, and applicable Canadian Standards Association standards. The Alberta Energy Regulator's pipeline inspection program considers the potential risks of individual pipelines such as the products, location, size, failure history and operator's compliance history. Pipelines that have greater potential risks, such as those that are near waterbodies, or have a poor compliance history, receive greater scrutiny (Alberta Energy Regulator, 2017b).

Due to the large number of oil and gas facilities and pipelines located in the NSR basin, the likelihood and consequence of a spill / release to the environment was determined to have an inherent medium-high risk to Edmonton's drinking water system (see Section 3.5). Given that many of the pipelines are located a considerable distance upstream, advanced warning is anticipated to occur before the spill reaches the WTP intakes. However, the Kinder Morgan / TransMountain Pipeline crosses the NSR approximately 9 km upstream of the Rossdale WTP, and a spill would reach the intake in under two hours. The responsibility to notify downstream users of a spill belongs to the responsible party; however, depending on the nature and timing of the event, EPCOR's WTPs could be notified by the Alberta Energy Regulator, Alberta Environment and Parks or the Alberta Emergency Management Agency. EPCOR is engaged in conversations with industry and regulators to ensure that EPCOR's WTPs are promptly notified in the event of a spill.

EPCOR can implement a number of control measures in the event of a spill including monitoring on the NSR and at the WTP intakes and shutting off raw water intakes until the spill has passed. Additionally, depending on the product spilled and how it mixes in the NSR, the product may not enter the submerged WTP intakes. Lastly, the two WTPs may be able to fully remove all contaminants and continue to produce safe drinking water. These control measures were determined to reduce the inherent risk and result in a medium-low residual risk (see Section 3.5). Although there is a low likelihood of a significant oil pipeline spill reaching EPCOR's WTP intakes, the consequence could be high, as it could result in the shut-down of the WTP intakes for several months. Communities on the NSR in Saskatchewan, downstream of Edmonton, were forced to shut off their intakes and find alternate sources of water after the Husky Energy pipeline spill into the NSR in Saskatchewan in July 2016.

Well Sites

As of 2018 there were 9,710 active wells whereas in 2014 there were 9,992 active wells sites comprising an area of 137 km^2. Of these approximately 50% were oil wells and 30% were gas wells and the remaining wells were cased or other types of wells. Additionally, there were 5,800 abandoned well sites comprising an area of approximately 74 km^2 in the watershed. Most of the active well sites were located near Drayton Valley; however, most of the abandoned well sites were located closer to Edmonton (Figure 39). The oldest oil and gas wells were drilled in the 1940s. The average age of oil wells was 1981 whereas the average age of gas wells was 1996.

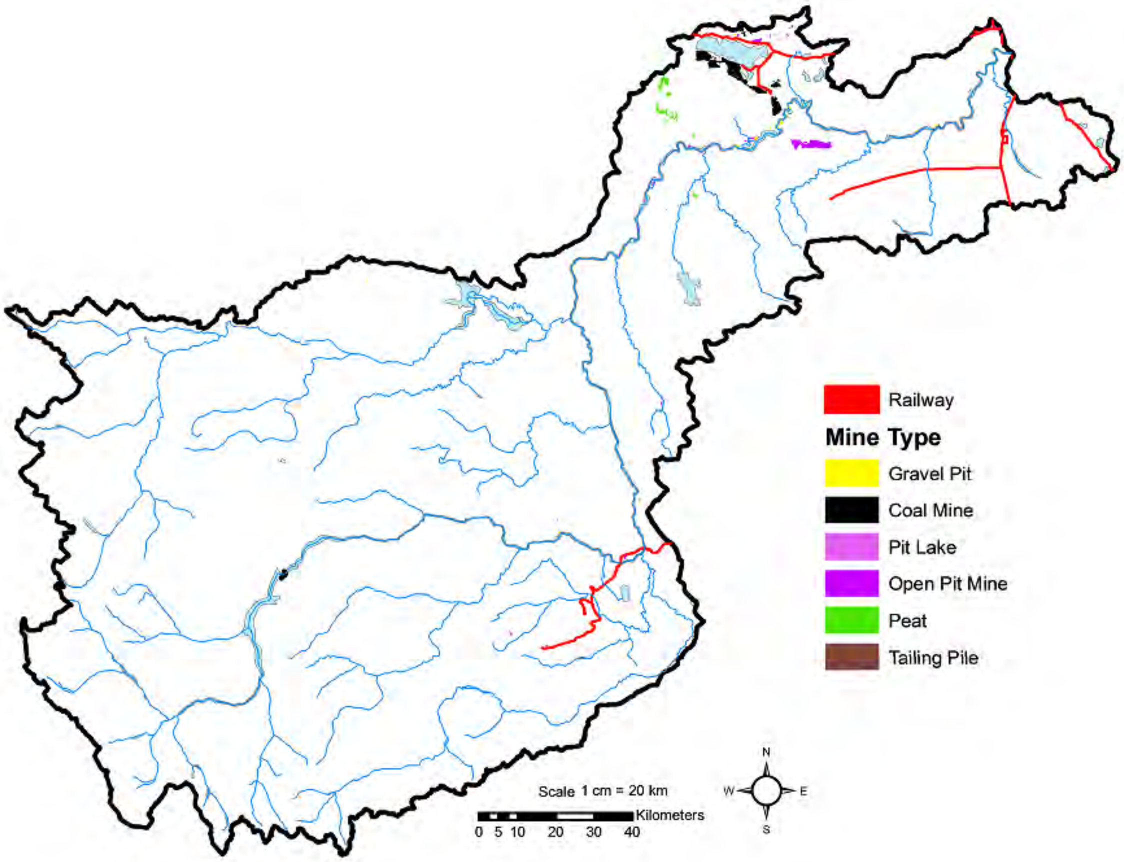


Data Source: AMBI 2018

Figure 39. Map of Well Sites in the NSR Watershed in 2018.

Railways

There are relatively few railways in the NSR watershed. There are only two rail crossings of the NSR, and both are located near Rocky Mountain House (Figure 40). There are also railways located near Lake Wabamun, and a railway crosses several tributaries of the NSR a short distance upstream of Edmonton.

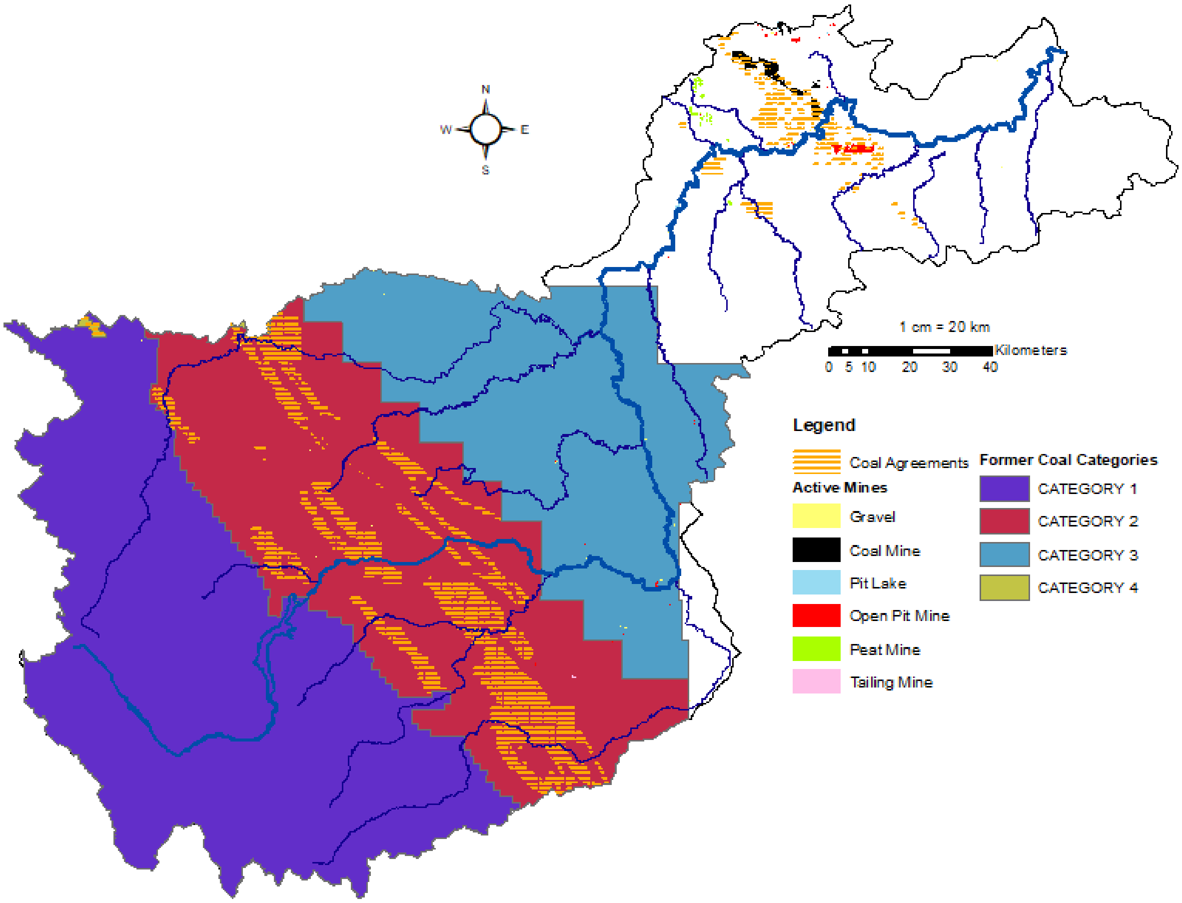


Data Source: ABMI 2018

Figure 40. Map of Mines and Railway Lines in the NSR Watershed.

Mines (Coal, Gravel)

There is currently relatively little coal mining activity in the NSR watershed; 54 km^2 of the watershed categorized as coal mine and 26.9 km^2 is categorized as open coal pit mine (0.3% of watershed). Coal mining is currently limited to the Wabamun Area and drains into Wabamun Lake or pit lakes (1.5 km^2) (Figure 41). Wabamun Lake connects to the NSR through Wabamun Creek; however, because of a weir at the outlet, water from Wabamun Lake does not overflow into the creek very often.



Data Source: GoA 2020

Figure 41. Map of Coal Mines, Agreements, and Active Mines in the NSR Watershed.

Coal mine development in Alberta is guided by the Coal Policy which was originally published in 1976. The scope of the policy was wide-ranging and included a land use classification system divided the Rocky Mountains and Foothills in Alberta into four main categories. The categories dictate where and how coal leasing, exploration and development can occur. There is no mining or exploration allowed in category 1 lands which generally includes National and Provincial Parks and other protected areas. Surface mining is generally not permitted on category 2 lands, which included parts of the Rocky Mountains and the Foothills, and exploration and underground development is limited. Exploration is allowed on lands listed as category 3 under the normal process, but development in these areas is still somewhat restricted. Category 4 lands consisted of the remaining areas, where coal mining is permitted. There are no category 4 lands within the NSR watershed. The Coal Policy was rescinded in July of 2020 and was cited by the Government of Alberta as being obsolete. In this period, restrictions on category 2 and 3 lands were removed whereas protection of category 1 lands remained. Due to public outcry, the Coal Policy was reinstated on Feb 8th, 2021 shortly before publication of this SWPP. It is expected the current Coal Policy will be reviewed in the coming years and replaced with a new policy. The City of Edmonton and EPCOR are working together to complete and publish a more detailed risk assessment on the potential effects of coal mining in 2021. EPCOR has also completed a detailed risk assessment and literature review that outlines potential effects to aquatic ecosystems, source water, and other water uses and that work informs this SWPP. The assessment here is limited only to drinking water source risks at Edmonton and does not include other risks or locations (i.e., aquatic health/headwaters areas).

Although the active mine area is currently small, there are coal deposits, coal fields, and associated coal agreements that have not yet been developed. Specifically, there are 1,510 km^2 (just over 5% of watershed) of coal agreements in place that are all located in Category 2 in areas categorized as high-volatile bituminous coal (Figure 41). Of the remaining agreements, 327 km^2 is under the normal Approval process and 15 km^2 is under category 3. Coal agreements are leases issued by the Government of Alberta that give the holder the exclusive right to recover coal within these areas and allows exploration to proceed with a permit. In 2019-2020 seven exploration permits were granted for approximately 320 km^2 total area. However, a coal agreement does not grant permission to develop a mine. In order to develop a mine, the holder of a coal agreement requires a mine permit and a mine licence from the Alberta Energy Regulator (AER). Under the *Environmental Protection and Enhancement Act* (*EPEA*), an environmental impact assessment (EIA) would be required, which allows the AER to examine the effects that the proposed project may have on the environment, and determine if the project is in the public interest. An approval issued by the AER under *EPEA* outlines the obligations and responsibilities for design, construction, operation and reclamation of the coal mine. Following the completion of mining activities, reclamation certificates issued under *EPEA* certify that all reclamation requirements have been met and that companies have done everything they can to return land to a state functionally equivalent to what was there before development took place. It is not clear if, under new regulations, if coal mining would be economically feasible for any areas in the NSR basin. However, there have been no new mining licence applications in the NSR basin since the 1976 Coal Policy was rescinded and now reinstated, and to EPCOR’s knowledge, there are no new project pending.

While open pit or surface coal mines have the potential to affect water quality and quantity in a number of ways, the impacts to drinking water quality in Edmonton are expected to be minimal due to the relatively small footprint (<5% of the watershed) and the dilution capacity of the NSR. This does not mean that coal mine impacts are not important for streams in the headwaters of the North Saskatchewan River in terms of water quality and aquatic ecosystem health, just that from an Edmonton drinking water perspective, source water quality is not expected to change in a significant way. That said, due to emerging science of selenium fate and transport and long-term mining effects that can be set in motion by the physical alteration of the headwater areas with low remediation potential, it is critical that modelling assessments be completed before any mining activity is permitted. This is particularly true at a watershed scale where the cumulative effects of mining need to be considered.

The removal of surface vegetation and construction of roads have the potential to increase erosion, and therefore increase suspended solids, turbidity and the volume of runoff. Mine waste can also result in acidification, elevated metals and total dissolved solids. However, coal mines would require Environmental Assessments and Aquatic Effects Monitoring programs required by the AER and AEP under *EPEA*, which are designed to limit downstream impacts to water quality. Mines would presumably install tailings dams/ponds in order to capture flows and reduce suspended solids and metals. With these control measures in place, it is assumed that impacts to water quality will be relatively small and localized. Given the anticipated government requirements, the distance downstream of EPCOR's WTPs, the assimilative capacity and existing water quality of the NSR, again it is anticipated that the impacts to water quality in Edmonton would be negligible from a drinking water perspective.

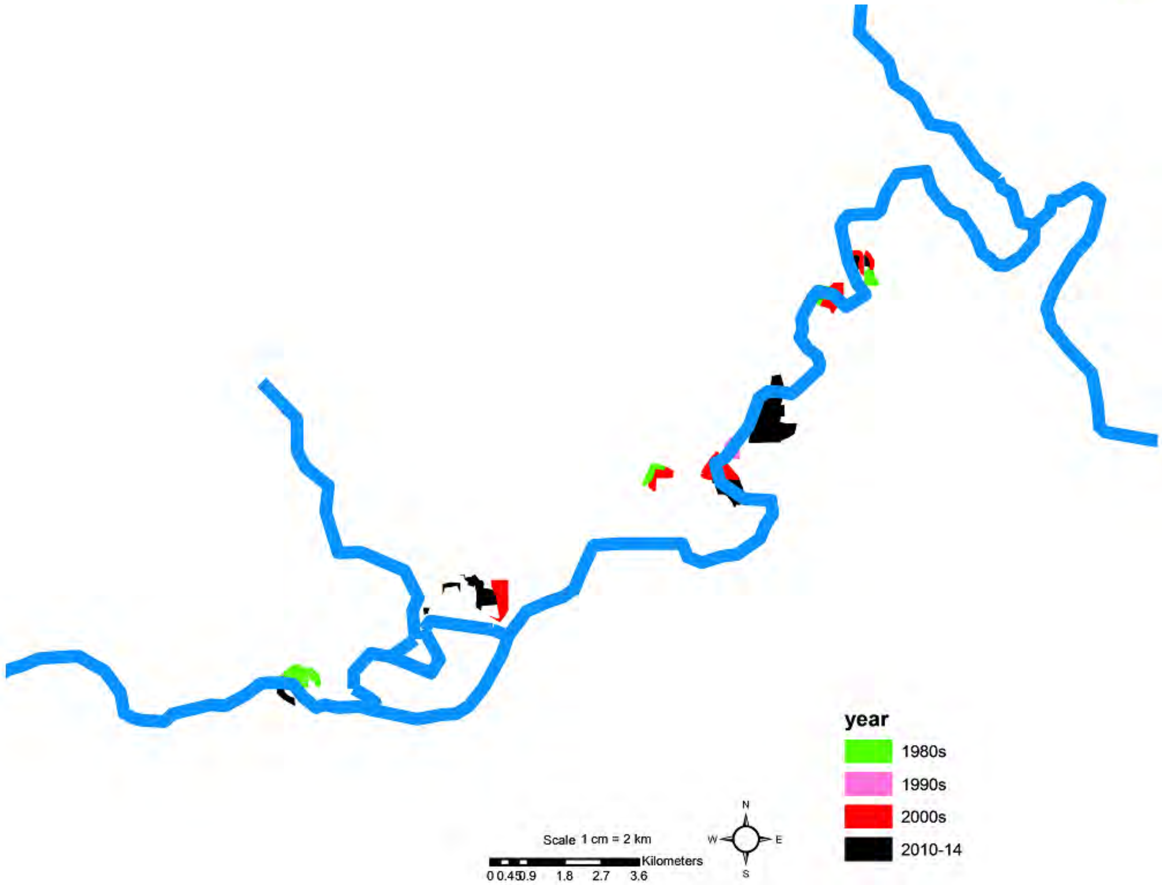
Selenium is a parameter of concern that has been associated with coal mining effects globally and in Alberta's mountain regions. From a drinking water treatment perspective it anticipated to have a negligible effect; background levels in the NSR are very low (<0.5 µg/L) and two orders of magnitude lower that current Health Canada Guidelines (50 µg/L). Selenium is an essential element for humans and other organisms, but can be toxic in elevated concentrations, and it can bio-accumulate within tissues and result in decreased fish reproduction and viability. Elevated selenium has been well documented downstream for open pit coal mines in the Rocky Mountains. For example Luscar Creek and Gregg River, which are directly downstream of mining activities, have average concentrations of 17 µg/L (<2 µg/L upstream) 7 µg/L (upstream <1 µg/L), respectively. When rocks that are high in selenium are brought the surface, runoff can enter downstream waterbodies leading to impacts in aquatic life. Alberta Environment and Parks' water quality guideline is 2 µg/L for selenium for the protection of aquatic life, and there is an additional 'alert concentration' of 1 µg/L. The alert concentration indicates the need for increased water quality and aquatic ecosystem monitoring to support early detection of potential bioaccumulation of selenium. It would be expected that new coal mines would be expected to meet these guidelines, particularly considering that once selenium rich rock is exposed, remediation is very costly and difficult.

EPCOR monitors selenium in the NSR at the WTP intakes monthly, and concentrations are very low and far below guidelines. At the E.L. Smith WTP, 60% of samples have been at or below the detection limit of 0.2 µg/L, and the highest recorded concentration was 0.5 µg/L, 100 times below the drinking water quality guideline. Similar results were found at AEP's sampling at Devon, where 82% of samples were at or below 0.2 µg/L; however, elevated selenium (i.e. 1.2 to 6 µg/L) was detected in three samples during the 1990s. The low concentrations of selenium in the NSR, the large assimilative capacity of the river in Edmonton, robust water treatment, and the high drinking water guideline compared to protection of aquatic life guidelines, means that increases in selenium and impacts to drinking water are not expected in Edmonton. However should any coal mining be approved it would be recommended that a cumulative modelling approach be taken where rates of selenium loading be quantified on a watershed scale (with all potential mines included). Specifically, a calibrated and validated water quality model that includes selenium geochemical processes and quantifies expected concentration changes in relation to protection of aquatic life guidelines should be developed. Again, this is because once disturbance occurs it is very difficult to mitigate and effects on water quality and subsequently fish and overall aquatic ecosystem health.

The largest risk from an open-pit coal mine to Edmonton's drinking water source water is the possibility of a mine disaster such as the failure of a tailings dam. Waste pits, end-pit lakes, and tailings dams are structures utilized to retain runoff and/or wastewater from mine operations. The volumes contained within these structures can be large, and typically are high in solids, metals and other parameters. In 2013, a tailings dam at the Obed Mountain coal mine near Hinton AB failed, releasing over 1 million cubic meters of waste water elevated in arsenic, metals and PAHs into the Athabasca River. In 2014, a tailings dam at the Mount Poly gold and copper mine (not a coal mine) in B.C. failed, releasing 24 million cubic meters of mine waste into Quesnel Lake. While the failure of tailings dams are rare occurrences, they can have an extreme impact to downstream water quality. Without a specific details of a proposed mine or tailings pond, it is not possible to make a definitive statement regarding the potential impacts of the failure of a tailings dam on the water quality in Edmonton; however, such a release would be likely a significant event and could require the WTPs to close their intakes. It is impossible to estimate how long water quality in the NSR would remain impacted following a mine disaster; however, water quality could remain significantly impaired for a number of days. Potential impacts of having to shut down the WTPs for an extended period could include implementing demand management, boil water advisories, or do-not-consume advisories.

Peat mining is the next largest mining activity, by area, in the watershed. Like active coal mines, peat mining is also limited to the upland areas away from direct drainage into the NSR, and comprises 13 km^2 of the watershed. Due to the small area of peat mining and the location in the watershed, water quality impacts from this activity are expected to be negligible.

Gravel mining consists of only 10 km^2 of the watershed but is largely located along the mainstem of the NSR. In fact, 60% of the gravel mining area is within 500 meters of the NSR mainstem (Figure 42). There are 194 gravel pit extraction areas along the NSR, mostly clustered near the town of Tomahawk (south of Wabamun Lake) and near Rocky Mountain House. Since 2000, 6 km^2 of new gravel pits were dug in 106 new pits. The new pits were typically dug next to existing pits. Parts of the NSR riverbed is gravel-bed with significant near-surface sand and gravel deposits. As these deposits are typically connected to surface water features, including key tributaries and the river's mainstem, gravel extraction can be of concern due to the potential impact to the aquifer and increase of sediment entering the river. In 2016, the Government of Alberta's started a review of the sand and gravel program to address growing public concern over impacts to waterbodies.

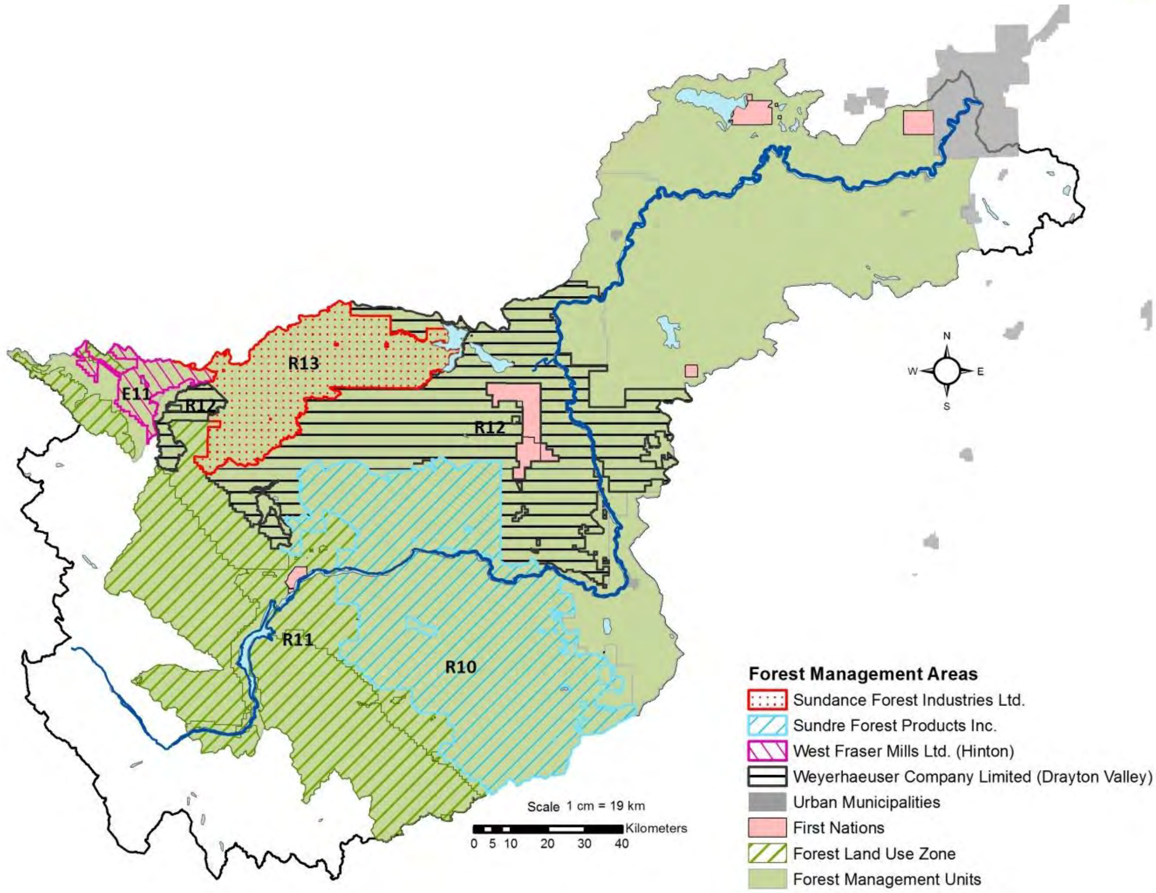


Data Source: GoA 2020

Figure 42. Map of Gravel Pits Along the Mainstem NSR South of Wabamun Lake.

3.2.10 Forestry

The majority of the forestry activity in the North Saskatchewan River watershed is located in the upper watershed (Figure 43). The forest is a mix of coniferous and some stands of mature deciduous forest. These forests are critical to source water quantity and quality in the watershed, and the loss of forest and perennial vegetation can affect watershed hydrology. Land disturbances due to loss of forests and uncontrolled access have the potential to cause significant land erosion, leading to increased amounts of sediment, organic material and nutrients entering the NSR and its tributaries. These events could cause challenges for EPCOR's WTPs, particularly during spring runoff and/or heavy rainfall events.



Data Source: GoA 2020

Figure 43. Forest Management Areas in the NSR Watershed.

The headwaters of the NSR are located in the Green Area, which is primarily publicly owned Crown land where resources are managed for forestry, watershed protection, biodiversity, tourism and recreation, fish and wildlife, oil and gas development, and conservation. Much of the Green Area is divided among various Forest Management Units (FMUs), which are administered by the Province. Within each FMU there are several Forest Management Areas (FMAs), which are managed using Forest Management Agreements and Plans that are written by forestry companies who operate within the FMA. The total area held by FMAs in the NSR watershed is 10,018 km^2 or 36% of the watershed. The largest FMA in the watershed is held by Sundre Forest Industries (16% of the watershed) followed by Weyerhaeuser (14%), Sundance (5%) and West Fraser Mills (1%). As part of each of the company's forest management plan, they must demonstrate that they consider the effect of harvesting on environmental aspects of the watershed including water quality and biodiversity.

Sundre Forest Products: FMA is 16% of the watershed. They harvest in the headwaters including the NSR mainstem, Ram and Clearwater watersheds. They have a comprehensive mountain pine beetle plan which includes targeting the most susceptible stands of pine for harvest.

Weyerhaeueser: FMA is 14% of the watershed. Their FMP has a detailed plan to address mountain pine beetle; an Eastern Slope Integrated Plan that outlines critical wildlife areas; and goals to maintain integrity of watersheds.

Sundance Forest Industries: FMA is 5% of the watershed. They harvest mostly in the Brazeau and Nordegg watersheds, was the first company in Alberta certified under the American Forest and Paper Association's Sustainable Forestry Initiative (SFI) Program.

West Fraser Mills Ltd.: FMA is 1% of the watershed.

Harvesting and the regeneration practices are important, as these activities ensure that the forest industry that Alberta and Canada's forested watersheds remain healthy and sustainable. The Government of Alberta regulates harvest levels by specifying an allowable annual cut (AAC), which is the annual level of harvest allowed in a forest area over five years to ensure long term sustainability. The Government of Alberta approves AACs which vary over time and reflect the area available for harvest and the forest management strategies applied to that area. AACs are updated due to changes in forest growth and yield data, the area available for timber harvest (may change to land use designations such as parks), FMA boundaries, statistical analysis methods, wildfire and pest/disease infestations, and provincial management strategies. AACs are approved separately for coniferous (*e.g.,* lodgepole pine or white spruce) and deciduous (*e.g.,* trembling aspen) groups. In Alberta, AACs are set for Forest Management Units (FMUs).

Provincially, actual harvest levels have generally fallen below the AAC level because of market conditions or business decisions. Specifically, from 2009 to 2013 only 77% of the AAC of coniferous and 50% of deciduous was harvested.

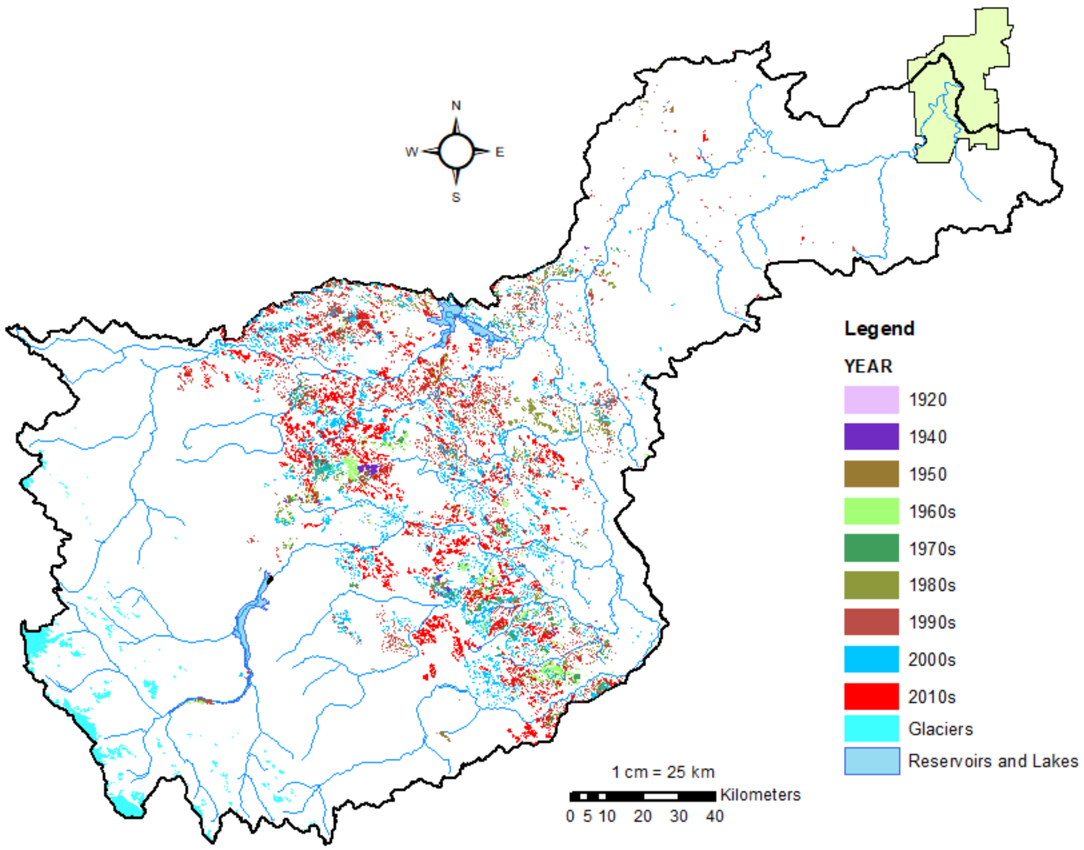
In the NSR watershed clearcutting is the primary method for harvesting timber. For example, in 2018 all timber harvesting consisted of clear cutting. All areas of provincial Crown land that are harvested for timber are required to be regenerated. Regeneration can occur naturally (i.e., natural seeding, root sprouting and fire) or by using artificial (direct seeding and seedling planting) means; in general, in Alberta has is an equal split between the two regeneration methods. Successful regeneration of harvested areas ensures that forest lands continue to produce timber, but also continue to provide key ecosystem services, such as storing carbon, regulating water quality and quantity, and providing wildlife habitat and recreation opportunities. Standards and regulations for achieving successful regeneration address the following: species composition, density and distribution; age and height of the regenerating trees; and the distribution of various forest types and age classes across the landscape.

The provincial government also monitors compliance of forest operations and timber production through audits, field inspections, as well as mandatory self-reporting by forest companies and individuals. In 2008 a new forestry inspection program called Forest Operations Monitoring Program (FOMP) was introduced to help complement existing initiatives. Compliance is considered very high for the province and forested enforcement actions have shown a steady decrease from 90 enforcement actions in 2008, to 20 in 2015 (Alberta Agriculture and Forestry 2017). This decrease is determined to be the result of greater awareness of legislative requirements as a result of FOMP. A total of 2,600 FOMP inspections were conducted in 2015.

Harvesting Rates

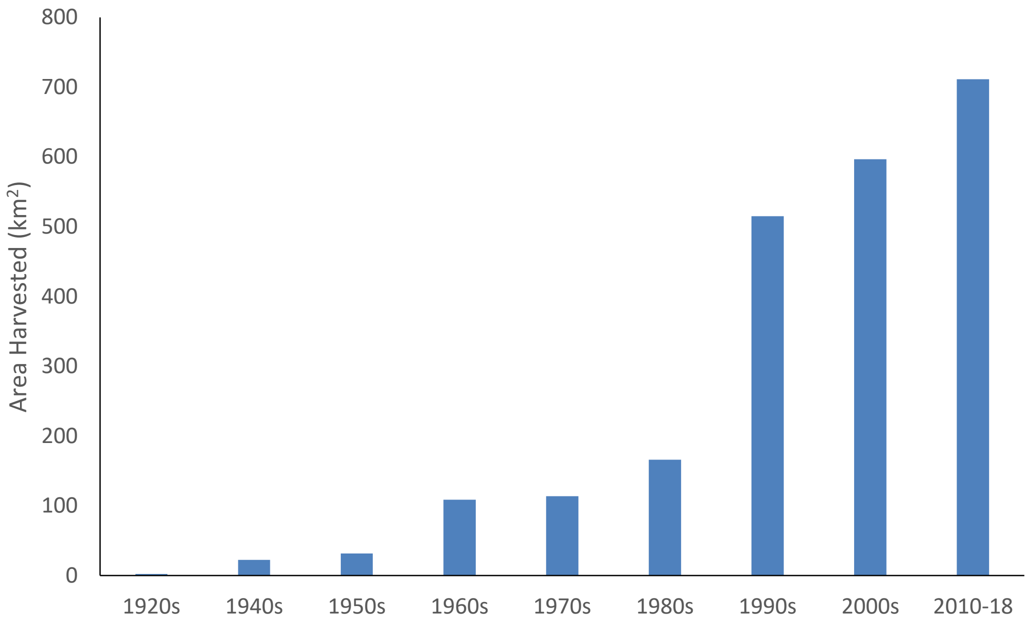
Forestry harvest rates in the NSR were assessed using ABMI's cutblock data. A cutblock is defined as areas where forestry operations have occurred (clearcut, selective harvest, salvage logging, etc.). Less than 1% of the total watershed and less than 2% of the FMA area was harvested each decade from 1920s through the 1980s (Figures 44 and 45). However, forest harvesting rates have increased since the 1980s. In the 1990s, a total of 1.8% of the watershed and 5.0% of the FMA area was harvested. In the 2000s, a total of 2.1% of the watershed and 6.0% of the FMA area was harvested. From 2010 to 2018 an additional 2.5% of the watershed and 7.1% of the FMA area was harvested.

From 1989 to 2018 (30 years) a total of 6.5% of the watershed and 18.2% of the FMA area has been harvested for timber. Annual rates of harvest vary from year to year but in the last 30 years an average of 61 km^2 or 0.22% of watershed and 0.6% of the FMA per year was harvested for timber. This results in about a 6% harvest rate per decade of the FMA area. While it is known that forest harvesting activities can have negative effects on downstream water quality; most of the research appears to be focused on the effects measured at small sub-watershed scales. Current research is suggesting that contemporary harvesting practices can result minimal increases of sediment, nutrients and organic material to downstream waterbodies compared to harvesting practices used 20 – 40 years ago (Silins et al. 2020). Further, the impacts from harvesting practices are small compared natural disturbances such as floods and wildfires. EPCOR is financially supporting the *for*Water Network which is conducting research on how forest management practices and events such climate change and forest fires will impact water quality and water treatability of source water at downstream WTPs.



Data Source: AMBI 2020

Figure 44. Map of Harvested Areas in the NSR Watershed by Decade (Last Decade: 2010-2018).



Data Source: ABMI 2020

Figure 45. Total Harvested Area in the NSR Watershed by Decade.

3.2.11 Wildlife

The vast forest and steep canyon walls of the NSR headwaters area provides important winter habitat for bighorn sheep and elk. A diversity of other mammalian wildlife is found within the watershed, including coyote, beaver, muskrat, cougar, moose, deer, bear and other small mammals. It should be noted that wildlife, such as beaver, muskrats and coyotes, have partially contributed to parasites in the watershed. Contamination of farm dugouts is a potential risk to human health, therefore removal of wildlife from domestic and animal water supplies such as dugouts would reduce the risk to human health (CABIDF 2002).

The mainstem of the NSR also has many species of fish and contains a higher diversity of fish species than any other waterbody in the province. Fish species in the NSR system from its headwaters to the Saskatchewan border include: Lake Sturgeon, Goldeye, Mooneye, Lake Chub, Pearl Dace, Emerald Shiner, River Shiner, Spottail Shiner, Northern Redbelly Dace, Finescale Dace, Fathead Minnow, Flathead Chub, Longnose Dace, Quillback, Longnose Sucker, White Sucker, Mountain Sucker, Silver Redhorse, Shorthead Redhorse, Northern Pike, Mountain Whitefish, Cutthroat Trout, Rainbow Trout, Brown Trout, Bull Trout, Eastern Brook Trout, Trout-Perch, Burbot, Brook Stickleback, Spoonhead Sculpin, Iowa Darter, Sauger and Walleye. Of particular note is Lake Sturgeon, which is often referred to as a 'living dinosaur' because of its bony plates and leather like tissue rather than the scales that cover most other fish. The population in the North Saskatchewan system is in a vulnerable state, consisting of possibly fewer than 1000 fish (Alberta Lake Sturgeon Recovery Team 2011). For that reason it is classified as Threatened under Alberta's Wildlife Act.

3.3 Water Quality and Quantity

An integral part of EPCOR's Watershed Protection Program includes gathering scientific data to assess source water quality and quantity, fostering collaborative long-term monitoring programs to evaluate source waters and effluent impacts, and participating in research partnerships to understand evolving contaminants of concern. This work also includes investigating linkages between water quality and quantity and environmental influences (land use, climate change, etc.), as well as evaluating water quality in both the mainstem NSR and its tributaries. EPCOR's involvement with monitoring is accomplished through partnerships with either provincial and/or federal agencies, Watershed Planning and Advisory Councils, stewardship groups, municipalities, as well as through independent EPCOR initiatives. The following sections describe historical and current water quality monitoring programs in the mainstem NSR and its tributaries.

North Saskatchewan River Upstream of Edmonton

3.3.1 North Saskatchewan River Mainstem Water Quality

Historical Water Quality

Water quality monitoring in the NSR was first initiated in the 1940s in response to pollution problems associated with the City of Edmonton. At that time, municipal wastewater, which included domestic sewage and industrial wastes, received only primary treatment. Untreated sewage was discharged directly into the river during rainfall events, garbage was disposed along the river bank, and accidental oil spills at industrial sites were not uncommon. Additionally, the population of Edmonton almost doubled in the 1950s, and many new industrial plants were constructed. With these pressures, it is not surprising that the first report on water quality in 1951 noted elevated bacterial levels, extremely low dissolved oxygen levels, odour problems, visible garbage, grease deposits and oil. Measurements of these basic water quality parameters resulted in pollution control orders to be issued to Edmonton by the Provincial Board of Health in the 1950's.

Water quality conditions persisted until about 1960 when Edmonton constructed a secondary sewage treatment plant, packing plant wastes were diverted to lagoons, and garbage disposal along the riverbank was discontinued. Additionally, the newly constructed Brazeau dam increased winter flows and assimilation capacity during this critical time. Despite improvements, water quality downstream of the City of Edmonton continued to reflect the impacts of Edmonton's municipal wastewater. Further improvements to water quality in the NSR accompanied upgrades in treating municipal wastewater, including biological nutrient removal and ultraviolet treatment between 1998 - 2005 at the Gold Bar Wastewater Treatment Plant, and in 2005 at the Alberta Capital Region Wastewater Treatment Plant. The Gold Bar WWTP utilizes Enhanced Primary Treatment reduces the amount of untreated overflow that enters the NSR during wet weather flows.

Alberta Environment and Parks (AEP)

Long-term sampling of the NSR by AEP is part of the Long-Term River Network Project (LTRN). Sites are located at Saunders Campground (near Nordegg), Rocky Mountain House, Devon, and Pakan. Monthly sampling was done independent of flow conditions, which limits the ability to calculate loads accurately. To address this limitation, the LTRN sites underwent enhanced sampling between 2008 and 2012, with a focus on higher flow events. LTRN data is from Devon and Pakan from 1987 to present. LTRN sites were established at Rocky Mountain House and Saunder's Compground in 2003 and 2015, respectively. In 2009, the LTRN at Rocky Mountain House moved a few kilometers upstream to be located upstream of the influence of the Clearwater River. LTRN data are used to evaluate long-term trends in water quality and AEP produces updated trend-analysis reports. The most recent report was completed in 2012 for data collected from 1987 to 2011. Anderson (2012) concludes that water quality downstream of Edmonton has shown marked improvement with respect to nutrient levels and bacteria, and these improvements coincide with enhanced wastewater treatment and reductions in loadings from point sources. Additionally, lower nutrient concentrations and smaller releases of oxygen-consuming material have resulted in improved dissolved oxygen concentrations in NSR downstream of Edmonton. Water quality also improved between 1987 and 2011 at Devon, but the improvements were smaller than those downstream of Edmonton, presumably due to the existing good water quality upstream of Edmonton, and smaller point sources of loading located upstream.

Beyond the LTRN program, AEP has collected water quality data at a number of locations in the NSR dating back to 1953. While this data is available electronically, much of it was collected prior to the establishment of the upstream dams, or was collected over a relatively short period of time. AEP also completed two synoptic water quality monitoring studies on the NSR mainstem and major tributaries. Synoptic sampling involves following a plug of water down the river over a time period to quantify changes due to tributary and point source inputs. These particular studies followed the plug of water as it moved from the NSR headwaters down to the border with Saskatchewan. A total of 17 mainstem sites were sampled. The first study occurred between 1985 and 1989, included 12 synoptic sampling events. The second study, which occurred in 2008 and 2012, included six synoptic sampling events.

The synoptic surveys included the following water quality parameters: routine water chemistry; coliforms; *Cryptosporidium*; *Giardia*; metals; organics; bacterial source tracking; biological aquatic ecosystem health indicators (planktonic and benthic algae); pesticides; and nutrients. EPCOR partnered with AEP on this initiative in 2008 and 2012 to complete *Cryptosporidium* and *Giardia* analysis, which otherwise would not have been done. A summary report of the

2008 and 2012 synoptic surveys was completed by Hutchinson (2014). Conclusions made in this report include:

- The NSR naturally increases in nutrients, turbidity and some metals as the river flows from the mountains to the prairies;
- Increased nutrients are found downstream of Edmonton, but the magnitude of this effect has declined considerably since the 1980s in response to upgrades at the waste water treatment plants;
- Periods of increased flow in the NSR correspond to increased concentrations of nutrients, turbidity, metals, bacteria and pathogens both upstream and downstream of Edmonton; and
- Runoff events result in discharges from Combined Sewer Overflows in Edmonton and bypasses at the Gold Bar Waste Water Treatment Plant, resulting in large increases in bacteria downstream of Edmonton.

Environment Canada

Environment Canada operates two water quality monitoring stations on the NSR: one at Whirlpool Point in the headwaters, and the other at the Alberta-Saskatchewan Border (Prairie Provinces Water Board [PPWB] site). Data are available from the early 1980s on, and sites are sampled monthly for a similar suite of parameters as at the LTRN sites. Data from these sites were used by the North Saskatchewan Watershed Alliance to propose site-specific water quality objectives for the NSR. In addition, the PPWB is required to monitor the quality of the aquatic environment, make comparisons with the PPWB water quality objectives and provide written reports on the quality of water in these interprovincial river reaches. The PPWB is comprised of representatives from the Governments of Alberta, Saskatchewan, Manitoba and Canada. The PPWB conducted a trend analysis on water quality data in the North Saskatchewan River collected at the Alberta/Saskatchewan border from 1988 to 2008 (PPWB 2016). Their analysis showed that nutrients in the NSR have declined since 1988, likely as a direct response to improvements made at the Gold Bar Wastewater Treatment Plant. The trends for total dissolved phosphorus and total nitrogen are shown in Figures 46 and 47. Dissolved oxygen and total suspended solids showed no significant trend over the monitored period. Concentrations of metals either showed decreasing trends or no significant difference. Overall, the trends suggest that water quality in the NSR at the Alberta/Saskatchewan border has improved since 1988.

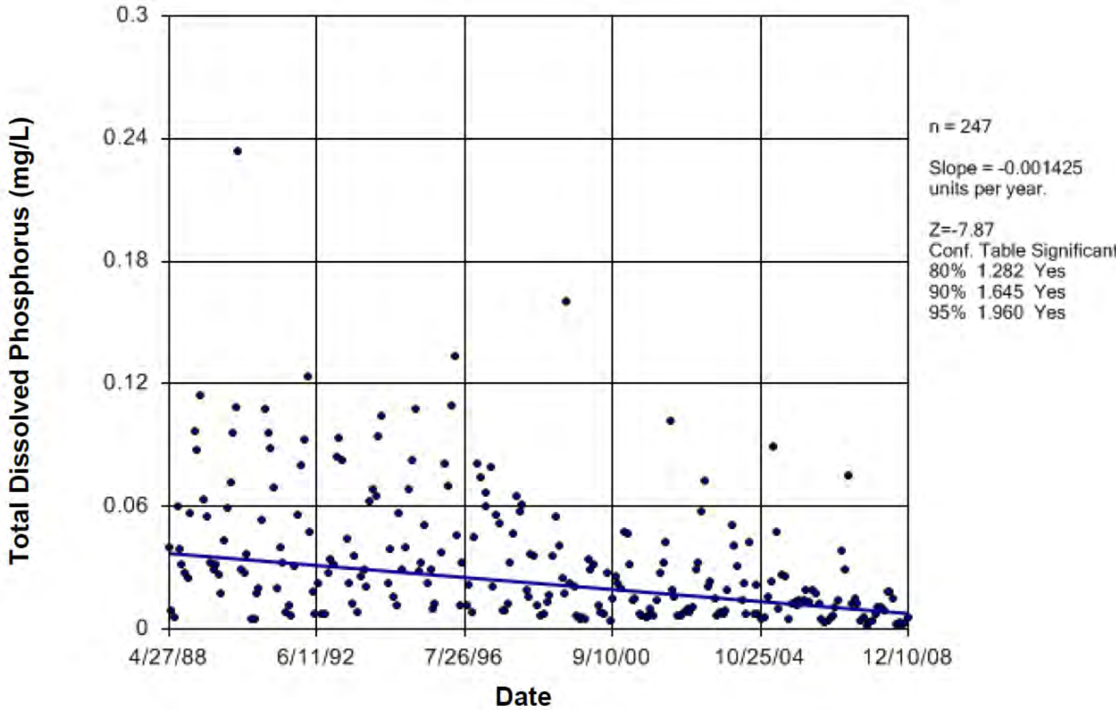


Figure 46. Trend in Total Dissolved Phosphorus in the NSR at the Alberta/Saskatchewan Border between 1988 and 2008 (From PPWB 2016).

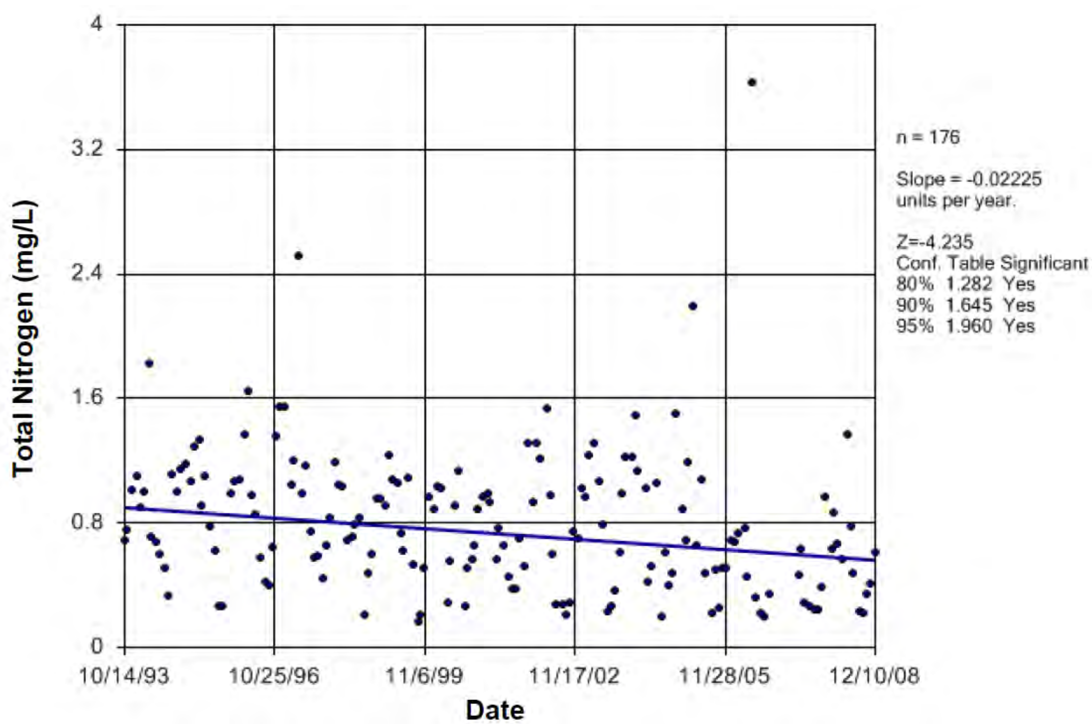


Figure 47. Trend in Total Nitrogen in the NSR at the Alberta/Saskatchewan Border between 1993 and 2008 (From PPWB 2016).

EPCOR WTPs

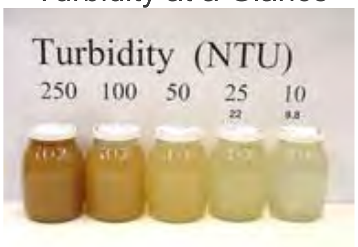
Since the early 1980s, EPCOR has routinely monitored water quality in the NSR at the Rossdale and E. L. Smith Water Treatment Plants (WTP) raw water intakes. Digitized data for major parameters are available from 1995 to present, with a smaller number of parameters being available back to 1981. The frequency of monitoring is dependent on the parameter. Turbidity, colour, conductivity, pH, and temperature, are measured continuously through online analyzers. Ammonia is also monitored using online analyzers during key periods such as spring-off. VOC analyzers are also being installed. Due to their operational importance, colour, turbidity and VOCs are measured daily, or more frequently, using on-site laboratories. Bacteria such as total coliforms and *E. coli* are measured daily at Rossdale and weekly at E.L. Smith. *Cryptosporidium* and *Giardia* are generally measured weekly to monthly, depending on the plant and time of the year. Microcystin, an algal toxin, is measured monthly. Nitrate and ammonia, chloride, bromide, bromate, sulphate, alkalinity, total organic carbon and fluoride are measured weekly, or more frequently during key periods. Total and dissolved phosphorus, total Kjeldahl nitrogen, select metals, total suspended solids, total dissolved solids (TDS), total and free chlorine, and sulfide are measured monthly. Pharmaceuticals, pesticides and contaminants of emerging concern such as polycyclic aromatic hydrocarbons (PAHs) and perfluoroalkylated substances (PFAS) are measured four times per year.

A summary of EPCOR's intake water quality for key parameters is found below. For simplicity, this report is limited to turbidity, colour, pathogens and select pharmaceuticals and pesticides and contaminants of emerging concern as they are key parameters of concern for drinking water treatment.

- Turbidity is a measure of cloudiness in water and is also can be used as a proxy for sediment levels. Increased turbidity can be caused by soil erosion, stormwater, runoff from disturbed landscapes, and algal growth, to name a few. High sediment can increase the costs of water treatment.
- Colour in water can be an indicator of the extent of plant matter decay, other organic matter, algae growth, and minerals (i.e., iron or manganese). The impact that colour has on surface water is usually one of aesthetics, however it may also be an indication of toxicity or the presence of pathogens. Colour is also associated with taste and odour concerns in drinking water. High colour can challenge a WTP's ability to produce drinking water and also increases the cost of water treatment.
- *Cryptosporidium* and *Giardia* species are protozoan parasites that cause gastrointestinal illness and infect mammals. In humans, the main causes of disease are *C. parvum*, *C. hominis* and *G. lamblia*. Along with indicating a direct risk of human infection, its presence indicates that the water is contaminated by fecal matter.

Mainstem Water Quality Intake Data Summary

Turbidity at a Glance



Turbidity

Median annual turbidity is slightly higher in the NSR at the Rossdale WTP intake compared to the E. L. Smith WTP intake. While this difference is statistically significant, turbidity is only 4% higher at Rossdale. This difference is likely attributable to increased inputs from tributaries and storm runoff within Edmonton. Due to the similarity of turbidity values and seasonal patterns between E. L. Smith and Rossdale WTP, data is only presented for the Rossdale WTP.

Although there is year to year variability, neither median nor peak sediment levels (as measured by turbidity) have changed significantly in the NSR in the last 20 years (Figure 48). Thus, there is no evidence that the river is experiencing increased loads or concentrations of sediment. Sediment concentrations in the river are closely associated with higher flows, both as a function of re-suspension of bed sediments and increased sediment inputs from the watershed during runoff periods. In years where average precipitation and river flow are higher, average sediment concentration in the river is also higher. On a smaller timescale, sediment concentrations in the river are also highest during peak flow/runoff events (Figure 49). Because the occurrence of high sediment concentrations in the NSR are dependent on hydro-climatic patterns, it is not predictable from year to year. For example, in 2016 sediment peaked in April due to spring runoff, and again in late July and late August corresponding to large amounts of precipitation and flow; however, values were atypically low during the late spring and summer due to a period of dry conditions and low flows. Typically, peaks in turbidity occur in mid-April, corresponding to spring runoff and again in June and July, corresponding with large precipitation events. In general, turbidity will rise above 100 NTU during spring runoff and during three to four storms throughout the year.

Sediment concentrations in the NSR are highest during spring runoff, often occurring in April and during summer storms because of increased runoff from the watershed and re-suspension or erosion of the river bed and shore.

Climate change is expected to both increase and decrease turbidity in the NSR. Climate models generally predict increases in precipitation, particularly through more frequent and intense storm events, which will increase both runoff and erosion, resulting in increased turbidity. Increased flows in the NSR will also result in increased resuspension of solids and increased bank erosion. In contrast, climate models also predict periods of drier conditions and decreased flows in the NSR, particularly in the late summer and fall, which will result in extended periods of lower turbidity.

Elevated turbidity typically does not cause operational challenges for EPCOR's WTPs, which are capable of treating highly turbid water; however, elevated turbidity does require additional alum and increased operation costs. Low turbidity in the NSR is required by the WTPs in order to convert to direct filtration, a mode of operation that the WTPs enter each fall/winter that requires less treatment and therefore lower operational costs. The conversion of the WTPs to direct filtration has typically not be hindered by turbidity, but rather colour, which is discussed below.

Daily mean turbidity values over 100 NTU occur around 7% of the time, whereas 77% of the time daily mean values are below 20 NTU. Turbidity values in the NSR over 1,000 NTU occur less than 0.5% of the time; however, these periods can present difficulties for water treatment plant operation. From a WTP operation perspective, understanding the probabilities around turbidity values on a week-by-week basis is of value. For example, before the beginning of March (week 10) daily mean turbidity is below 10 NTU 90% of the time based on historical data (Figure 50). By early April (week 14), turbidity is below 10 NTU less than 50% of the time and below 100 NTU 90% of the time. This information allows EPCOR to adapt its treatment processes to changing river quality in a timely manner.

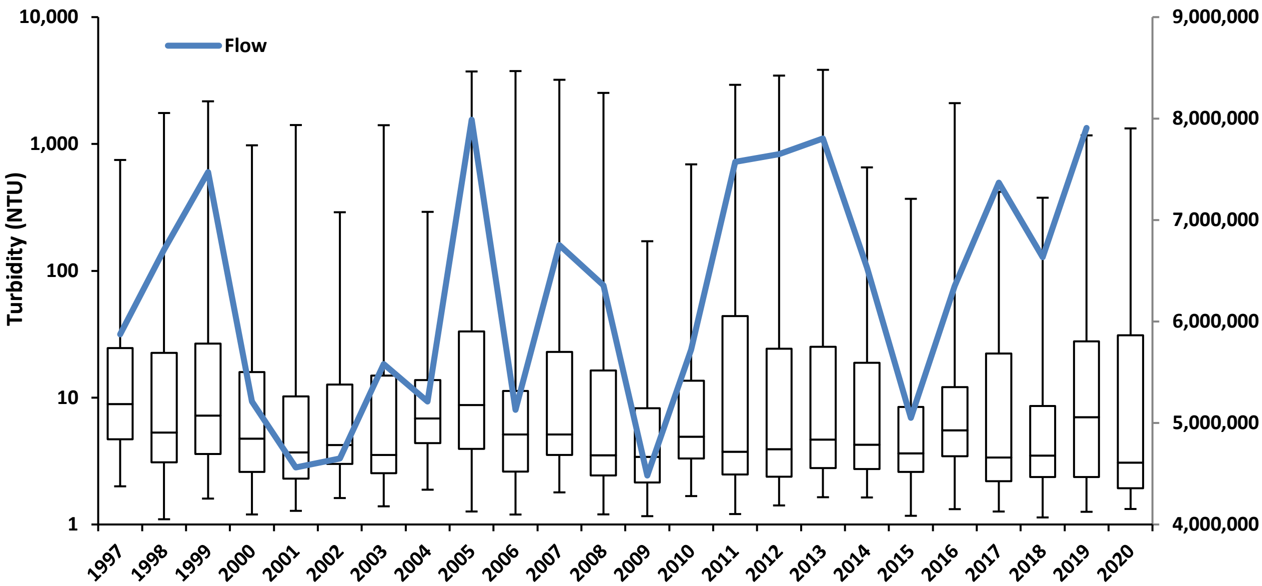


Figure 48. Turbidity at Rossdale WTP Intake 1997 to 2020 Showing Minimum, First Quartile, Median, Third Quartile, and Maximum Values, and Total Annual Flow in the NSR.

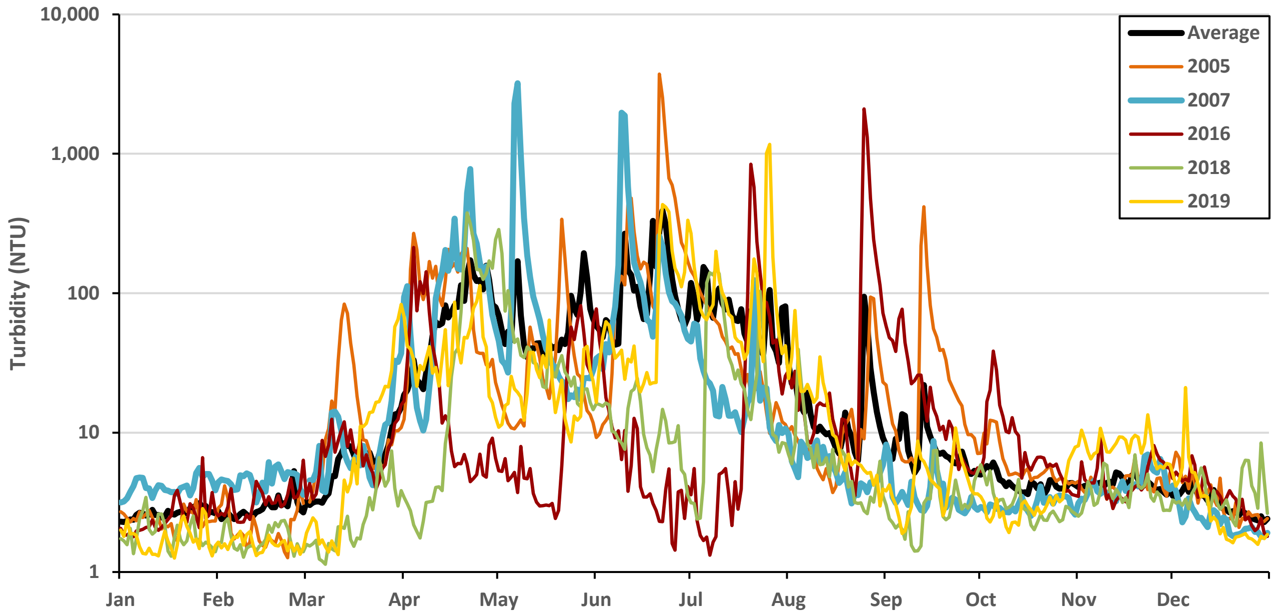


Figure 49. Daily Mean Turbidity at Rossdale WTP Intake Average from 1997 to 2020 and Select Years (2005, 2007, 2017, 2018 and 2019).

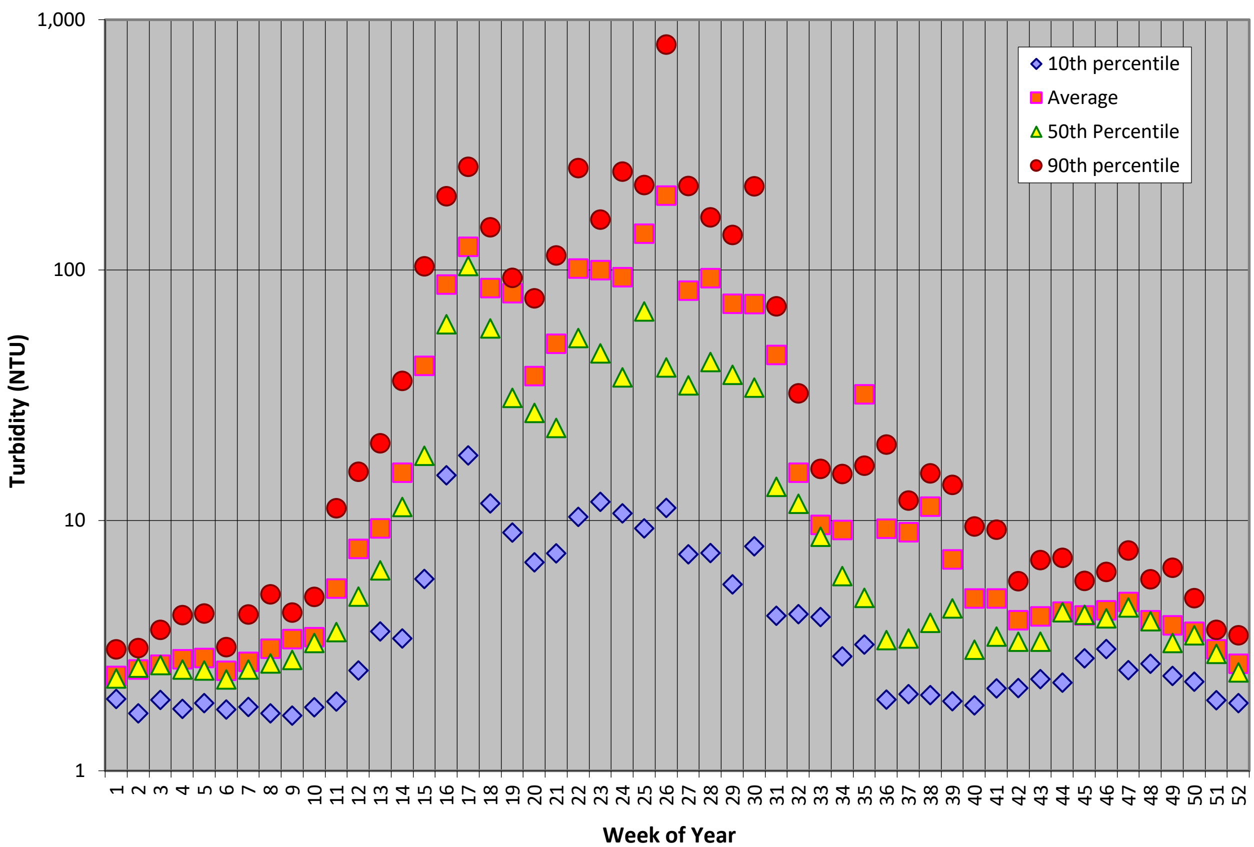


Figure 50. Turbidity at Rossdale WTP Intake for 1997 to 2020 Compiled by Week of the Year.

Colour

Similar to turbidity, median annual colour is slightly higher in the NSR at the Rossdale WTP intake compared to the E. L. Smith WTP intake. While this difference between the two WTPs is statistically significant, colour is only 3% higher at Rossdale. The higher colour values at Rossdale are likely attributable to increased inputs from tributaries and storm runoff within Edmonton.

Colour is a key parameter that can affect the ability and the costs of WTPs to produce drinking water. Each spring, elevated colour requires that the WTPs dose powdered activated carbon as part of the treatment process, resulting in increased operational costs. High colour events associated with summer precipitation events have also required the WTPs to dose powdered activated carbon. Colour is typically the key variable in determining when WTPs can convert to direct filtration, a mode of operation that the WTPs enter each fall/winter that requires less treatment and therefore lower operational costs. In some years, elevated colour in the fall has significantly delayed the conversion to direct filtration. Elevated colour during the winter months or early spring has also caused the WTPs to convert back to conventional operation prematurely.

Average annual colour is variable from year to year and there is no long-term trend (Figure 51). Colour values are highest during years of higher river flow and precipitation due to larger loads from the watershed. Similar to turbidity, mean colour is highest in months when flow is greater, but overall, is highest during the spring runoff period (April and May) rather than during summer storms (Figure 52). This is due, in part, to increased inputs of particulate and organic matter from spring melt which has accumulated over the winter months. This accumulation includes manure that has amassed in livestock winter feeding areas.

While there is no long-term trend for colour, there have been a number of instances in recent years where elevated colour has resulted in operational challenges at the WTPs. In 2016, a large precipitation event in late August resulted in a large spike in colour up to 200 TCU, which is the highest value measured at the WTPs. This large increase in colour affected the ability of the WTPs to produce drinking water of sufficient quality, and production could not keep up with the demand and voluntary water restrictions were put in to place. Colour in the NSR quickly dropped and the WTPs were able to resume drinking water production. Colour continued to remain elevated into the fall and winter of 2016, at levels not previously recorded. This elevated colour significantly delayed the WTPs from switching production to direct filtration, which typically occurs in late fall or early winter when colour and turbidity values in the NSR are typically low. An early melt in February 2017 resulted in elevated colour and required the WTPs to prematurely stop direct filtration. Large precipitation events in July 2019 resulted in the second largest colour peak recorded. Elevated colour has also been observed during the late fall and winter in the past several years, and has resulted in challenges for the WTPs to remain in direct filtration. The instances of elevated colour in recent years are likely due to the cyclical patterns of elevated precipitation, but could be indicative of a larger trend.

Climate change is expected to have a variety of effects on colour in the NSR. Longer growing seasons and increased decomposition of organic material in soils is anticipated to result in increased export of colour (Ritson et al. 2014). Increased precipitation, particularly through more frequent and intense storm events will increase runoff and loading of colour in the NSR. Periods of droughts or dry conditions will result in reduced runoff and colour; however, Ritson et al. 2014 observed that large flushes of colour occur following the first rainfall after a period of prolonged dry conditions, which may have occurred during the high colour event in 2016.

Mean daily colour values over 15 TCU (which is the Canadian Drinking Water Quality Guideline aesthetic objective for treated water) occurred around 20% of the time since 1997, at both plant intakes. The timing of high colour in the NSR is important from a treatment perspective as it is linked to taste and odour concerns, which require the addition of carbon to remove. Using historical data, the probabilities of colour by week has been compiled (Figure 53). This data shows that, for example, by the beginning of March (week 10), colour is below 10 TCU over 90% of the time, but by early April (week 14), there is 50% chance that colour will be above 10 TCU and a 10% chance it will be above 40 TCU. Again, predicting the timing of colour spikes in the NSR is difficult as it is driven by hydroclimatic and runoff patterns, which are difficult to model and predict on a watershed scale. However, historical data can provide some insight into the most likely periods in which colour will be high in the NSR.

EPCOR is highly interested in being able to predict the timing and magnitude of increases of colour due to the impact to WTP operation. It is known that colour increases shortly after creeks such as Modeste, Strawberry, Weed and Conjuring open in the spring and begin loading colour to the NSR. Historically, EPCOR relied upon in-person visual observations from these creeks to determine when spring runoff had begun. EPCOR also developed a spring runoff prediction tool to predict when colour would increase at the WTPs. This simplistic tool is based on a multiple regression model that included a number of different temperature metrics (i.e., the minimum temperature over the past five days, the average temperature over the past two days, etc.) and the day-of-year. This tool appears to predict the timing of colour increases fairly well; however, there are certainly limitations to this approach, including the inaccuracy of temperature forecasts and extreme swings in temperature (i.e., several days above 10 ^{o}C, followed by several days below -10 ^{o}C). The most significant limitation of the tool is that it is unable to predict the magnitude of the colour increase. EPCOR has also been somewhat able to predict the fluctuations of colour in late-fall and winter by understanding the changing patterns in flows from the Bighorn dam (which is low in colour) and the Brazeau dam (which is higher in colour). There is a need to better understand and predict colour in the NSR. EPCOR is working with other partners on developing a 5-year modelling strategy that will be used to develop models for predicting water quality in the NSR. EPCOR will look to improve existing watershed water quality/quantity models, and also how machine learning can be applied to predict the timing and magnitude of colour increases. Beginning in 2019, EPCOR, in conjunction with AEP as part of the WaterSHED Monitoring Program, began installing cameras on creeks upstream of Edmonton. These cameras provide real-time photos of the creeks that are highly useful for determining when spring runoff begins, or when large storm events may generate higher colour values in the NSR.

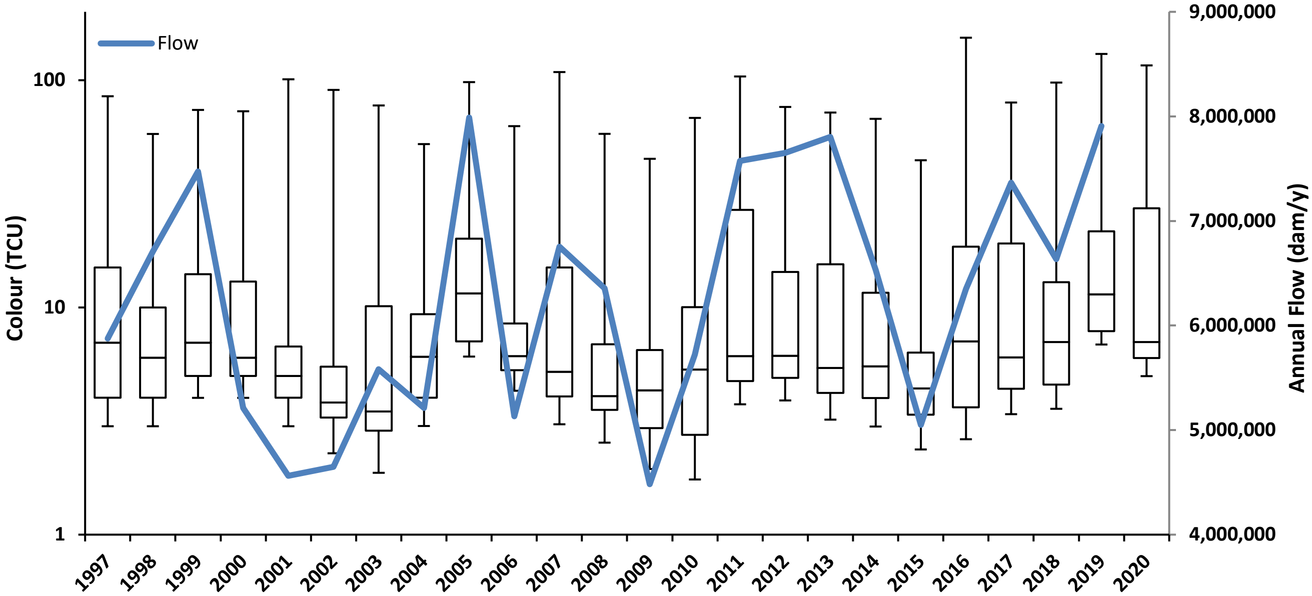


Figure 51. Colour at Rossdale WTP Intake 1997 to 2020 Showing Minimum, First Quartile, Median, Third Quartile, and Maximum Values, and Total Annual Flow in the NSR.

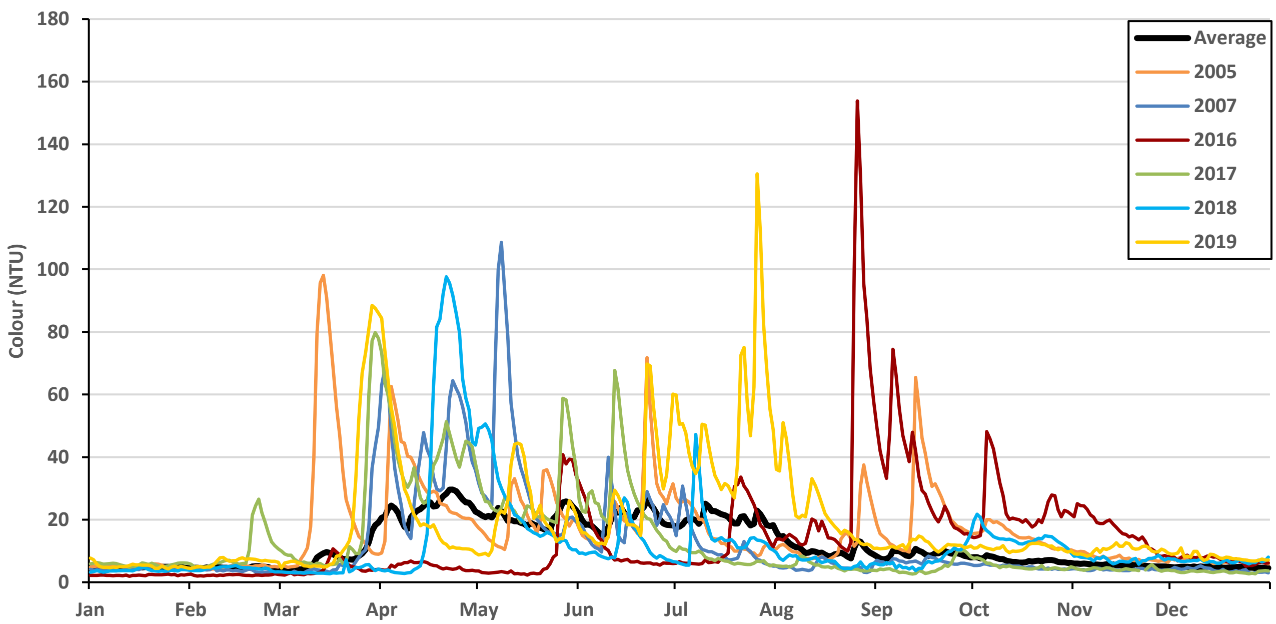


Figure 52. Daily Mean Colour at Rossdale WTP Intake Average from 1997 to 2020 and Select Years (2005, 2007, 2016, 2017, 2018 and 2019).

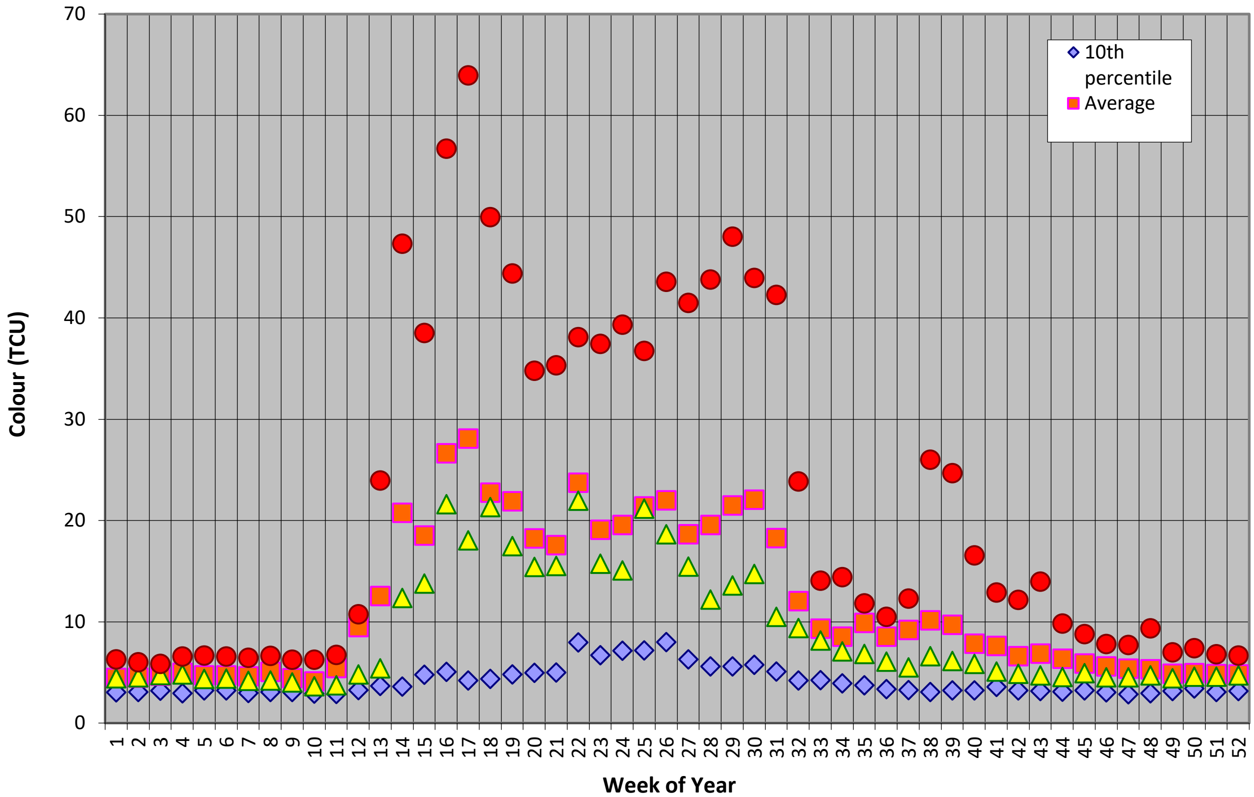


Figure 53. Colour at Rossdale WTP Intake for 1997 to 2016 Compiled by Week of the Year.

Indicator Bacteria

A variety of indicator bacteria have been monitored at the WTP intakes over the years. Fecal coliforms were measured by membrane filtration until 2008. With the introduction of Colilert™ testing (i.e., defined substrate technology), EPCOR slowly began to move away from membrane filtration, and in 2005 began enumerating *E. coli* and total coliforms*.*

Since 2005, concentrations of total coliforms and *E. coli* have been measured weekly at the E.L. Smith intake, but daily at the Rossdale intake. The increased frequency of testing at the Rossdale intake is related to the increased risk of source water contamination from storm sewers outfalls located upstream. Storm sewers can discharge high loads of *E. coli* into the NSR, particularly during storm events.

E. coli showed no discernable trend between 2005 and 2016, but a notable shift occurred in 2017, with increased concentrations measured at both WTPs (Figure 54). A plot of the individual samples (not shown) showed that mid-way through 2020, *E. coli* concentrations rapidly returned to pre-2017 values. Not only was there a notable increase in median values between 2017 and 2019, but there was an absence of samples during the winter months that were below the detection limit, which frequently occurred prior to 2017. It is believed that the Devon WWTP was the source of the elevated *E. coli*, as it was undergoing upgrades during this period. As *E. coli* concentrations were continually elevated throughout the year, it suggested that the *E. coli* was from a point source of loading such as a WWTP. Concentrations were elevated at both WTPs, this suggested that the source of the *E. coli* was upstream of Edmonton; however, concentrations were not elevated in samples collected by AEP at the Devon LTRN located a short distance above the Devon WWTP. The Devon WWTP was only required to measure TSS and BOD from its effluent during this period, thus it is unknown if it was the source of elevated *E. coli* loading. Conversations with WWTP staff indicated that their effluent had notably higher TSS and BOD loads until their WWTP completed upgrades in 2020, which seems to correspond to when *E. coli* concentrations dropped.

Prior to 2017, median *E. coli* concentrations were 8 MPN/100 mL at the E.L. Smith WTP and 28 MPN/100 mL at the Rossdale WTP (Figure 54). The higher *E. coli* concentrations between the two locations is statistically significant (Mann Whitney U Test; p-value > 0.001).

E. coli concentrations in the NSR are typically of low concern for drinking water, as both the E.L. Smith and Rossdale WTPs treat the raw water from the NSR using chlorination and UV disinfection. However, *E. coli* is regularly measured at the raw water intakes as an indication of possible contamination of the source water. To evaluate the water quality in the NSR, *E. coli* concentrations can be compared to the Alberta recreational water quality guidelines. It should be noted that the exceedances of the recreational water quality guidelines have no impact on the safety of the drinking water supply and this comparison is made only for illustrative purposes to show the relative health of the NSR.

The Alberta recreational water quality guideline for *E. coli* is that the geometric mean over a 30-day interval is below 100 MPN/100 mL. Additionally, no more than 10% of samples should exceed 320 MPN/100 mL over a 30-day interval. As this guideline is a recreational guideline for, it should largely only be applicable between the months of May to September. Between 2005 and 2016 recreational guidelines at E.L. Smith were exceeded the first and second guideline for 7% and 8% of the months, respectively. *E. coli* concentrations were higher at Rossdale, and exceeded the first and second guidelines for 8% and 17% of the months respectively. However, between 2017 and 2019 when *E. coli* concentrations were elevated, the number of months exceeding the two guidelines increase to 27% and 33% at E.L. Smith and to 100% and 87% at Rossdale.

In summary, recreational contact guidelines were occasionally exceeded at E.L. Smith, and were exceeded somewhat more frequently at Rossdale. During the period of 2017 – 2019, guidelines were exceeded more frequently, and almost continuously at Rossdale. While urban stormwater has typically been seen as a major source of *E. coli*, sources upstream of Edmonton are also capable of causing greater and nearly continuous exceedances. These trends also indicate that parameters that have otherwise been consistent for years can suddenly shift due to changing conditions upstream. Parameters may need to be reviewed more frequently.

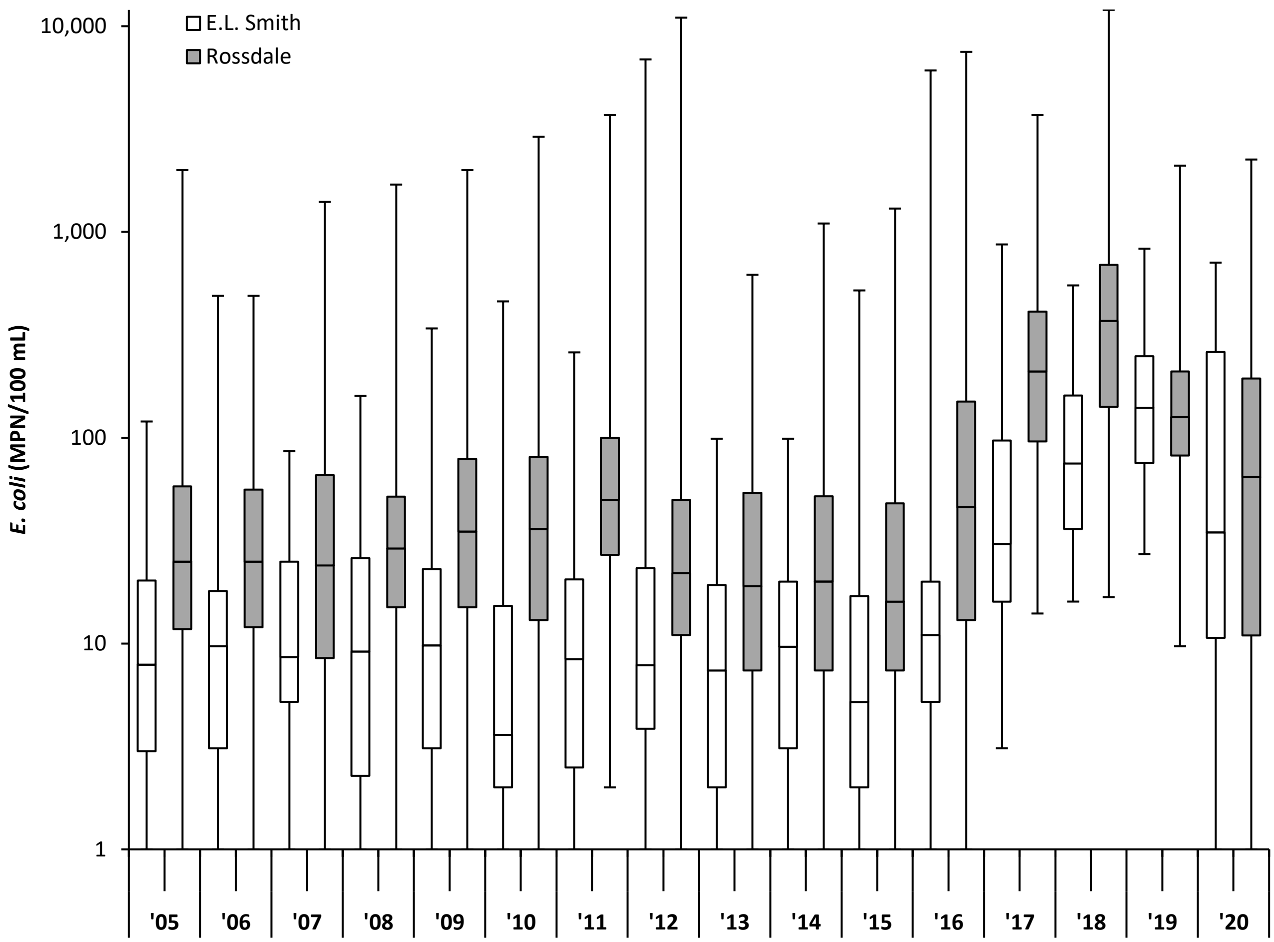


Figure 54. ***E. coli*** **concentrations in Rossdale and E. L. Smith Raw Water (2005-2020).**

Cryptosporidium and *Giardia*

Since the infective stages of *Cryptosporidium* and *Giardia*, oocysts and cysts respectively, are shed with feces, the presence of *Cryptosporidium* and *Giardia* in a water source indicates that the source has been exposed to fecal contamination. *Cryptosporidium* and *Giardia* have been associated with several waterborne disease outbreaks, such as the outbreak of *Cryptosporidium* in North Battleford in 2001. *Cryptosporidium* and *Giardia* in the NSR present a low risk to the drinking water due to the level of multi-barrier treatment provided by the WTPs (i.e., physical removal, chemical and UV treatment).

Human population densities, livestock densities, manure application to land, impervious land cover, and sanitation systems will impact the occurrence, distribution, and concentration of potential sources of fecal contamination, and therefore impact concentrations of *Cryptosporidium* and *Giardia* in the NSR. Elevated concentrations of *Cryptosporidium* and *Giardia* can impact drinking water safety and recreational water use. The infective stages of *Cryptosporidium* and *Giardia* are monitored monthly most of the year. In the fall/winter, when river water quality is high and the plant relies on direct filtration for drinking water treatment, samples are collected on a weekly or bi-monthly basis. While the concentrations of protozoan parasites might seem high, it is important to note that US EPA Method 1623 used for detection neither provides information on viability of organisms (i.e., counting dead and alive organisms) nor does it provide information on species detected, where only a few are relevant to human health. As a result, the counts produced are conservative in nature. It should also be noted that the detection limit of both *Cryptosporidium* and *Giardia* can vary by an order of magnitude or two, and can complicate how trends are assessed. For this report, samples that were below the detection limit are plotted separately at the value of the detection limit. While *Cryptosporidium* and *Giardia* samples have been collected since 1998, the current methodology has been in place since 2006. Concentrations of *Cryptosporidium* and *Giardia* were similar at the E.L. Smith and Rossdale intakes, but only data from the Rossdale WTP are presented below.

Concentrations of *Cryptosporidium* have been steadily declining, and samples that are below the detection limit occur more frequently (Figure 55). In 2020, only one *Cryptosporidium* sample was above the detection limit. Similar declining trends are observed for *Giardia* (Figure 56). Over 65% of the *Giardia* samples were below the detection limit in 2020, whereas *Giardia* below the detection limit infrequently occurred prior to 2013. The downward trends of *Cryptosporidium* and *Giardia* could be related to the decline in cattle in the watershed, and/or improvements in agricultural practices but could also be changes in analytical methods. EPCOR is investigating potential laboratory analysis issues. The species of *Cryptosporidium* is also important as some *Cryptosporidium* species/genotypes are not considered infectious to humans. The fraction of *C. hominis* and/or *C. parvum*, the dominant human infectious forms of the parasite, are important in assessing risk to drinking water. Some preliminary work has shown *C. andersoni* is the dominant form in many Alberta basins including the NSR however more research is needed to understand seasonal changes in pathogen loads.

A study by van Beers (2014) attempted to determine which environmental variables were predictive of *Cryptosporidium* and *Giardia* concentrations in the NSR. This study found that while a relationship with rainfall was expected, the trend was not found to be statistically significant. Instead, the relationship between ambient temperature and protozoa concentrations was found to be significant. This is logical since winter conditions result in a reduced contaminant loading to the NSR, while increases in temperature drive spring runoff and increased contaminant loading the NSR. There are strong seasonal trends of *Cryptosporidium* and *Giardia* with peak abundances of both species occurring during the spring freshet (Figure 57).

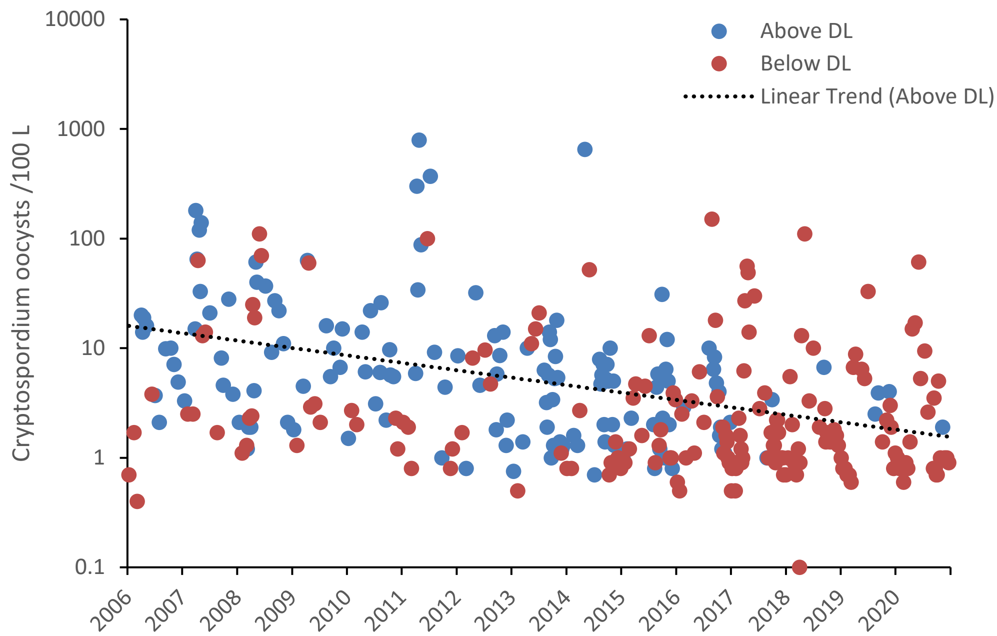


Figure 55. ***Cryptosporidium*** **concentrations in Rossdale Raw Water (2006-2020).**

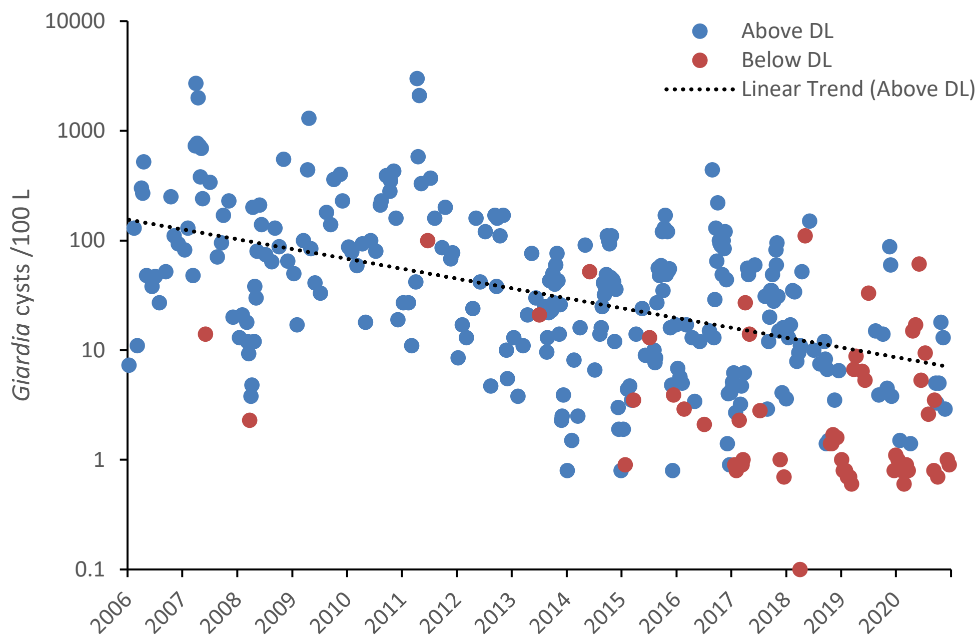


Figure 56. ***Giardia*** **concentrations in Rossdale and E. L. Smith Raw Water (2006-2020).**

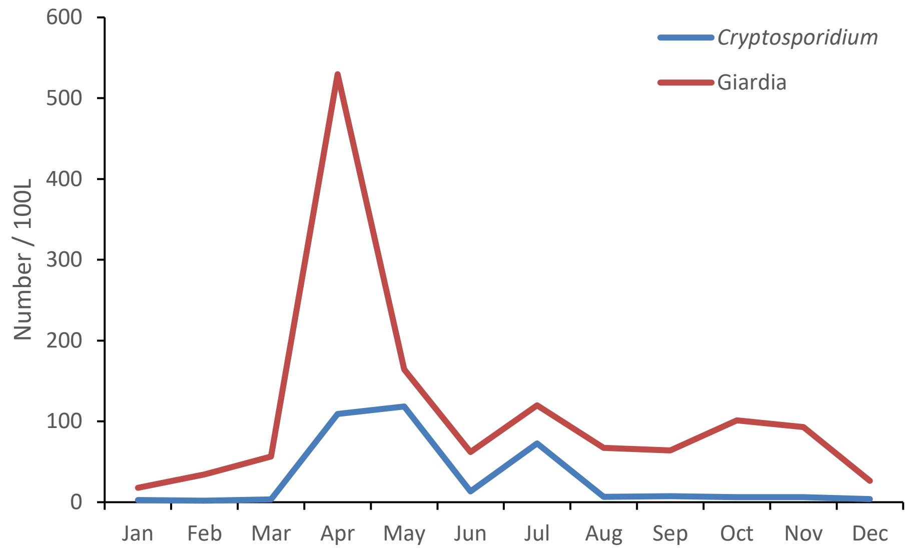


Figure 57. Monthly average concentrations of *Cryptosporidium* and *Giardia* at the Rossdale WTP of samples above the detection limit (2006-2020).

Microcystin

Several species of cyanobacteria (also known as blue-green algae) have the ability to produce cyanotoxins which have negative affects to human health. The concentrations of toxins can become elevated particularly during an algal bloom, and can persist in the environment after the bloom is over. These toxins can be ingested, inhaled or absorbed through the skin. The persistence of toxins in the environment can potentially affect downstream users, where the bloom may not be directly observed. Microcystins are typically considered to be most important class of cyanotoxins, and microcystin-LR has been the prevent and studied microcystin (Health Canada 2017). Health Canada drinking water quality guidelines are based on the toxicity of microcystin-LR; however, the maximum allowable concentration is 1.5 µg/L of total microcystins (Health Canada 2020a). Health Canada has also recommends a precautionary level of 0.4 µg/L of total microcystins in treated drinking water. Health Canada recently released a proposed recreational water quality guideline of 10 µg/L total microcystins (Health Canada 2020b). Alberta's recreational water quality guidelines for microcystin-LR are set at 20 µg/L (GoA 2018), and the US EPA guideline is 8 µg/L (US EPA 2019).

Microcystin concentrations in the NSR are well below drinking water quality guidelines. Total microcystins are have been measured monthly at the E.L. Smith and Rossdale WTPs since 2017. The highest concentration of microcystins detected is 0.27 µg/L with 75% of the samples being below the detection limit of 0.1 µg/L. Microcystins were detected at both the E.L. Smith and Rossdale WTPs at similar frequencies and concentrations.

Contaminants of Emerging Concern

Beginning in 2004, EPCOR began monitoring raw and treated water for contaminants such as pesticides, phthalates, pharmaceuticals, Polycyclic Aromatic Hydrocarbons (PAH), phenols, hormones, steroids, and other personal care products (PCP). Samples were generally collected quarterly at both WTPs. Since monitoring commenced in April of 2004, 142 raw water intake samples (E. L. Smith and Rossdale combined) have been analyzed for over 230 parameters, with some variation among the parameters analyzed each year.

The number of detections in that period was low (247 detections out of over 25,000 tests), particularly considering that analytical detection limits for measured parameters are very low (typically ng/L). Of the detections, 37%, of the detections were low level phthalates, 27% were pesticides, 23% were pharmaceuticals, and 13% were PAHs (Table 8). With the exception of four PAHs, concentrations of each parameter were below Alberta Surface Water Quality Guidelines and the Alberta Surface Water Quality Guidelines for the Protection of Aquatic Life. Concentrations were each parameter were always below the Canadian Drinking Water Quality Guidelines, with most concentrations being several orders of magnitude below the applicable guideline.

In 2011 and 2012, EPCOR also collected additional samples for pharmaceuticals, hormones/sterols and personal care products. Three samples were collected from each water intake for a total of six samples. These samples were tested for a wider range of parameters than the quarterly samples described above, and were tested for 150 parameters, only 36 of which were also tested for in the quarterly samples. These samples were also analyzed at lower detection limits than the quarterly samples. The number of detections in these samples was low (24 out of a possible 900 tests; Table 9). Several parameters (i.e., acetaminophen, cotinine and DEET) were found in concentrations that were below the method detection limits of the quarterly samples, suggesting that these parameters could be present, but not detected by the quarterly sampling. None of the detected parameters have corresponding drinking water quality guidelines; however, two parameters have guidelines for the protection of aquatic life. Alpha ethinyl estradiol was found to exceed the Alberta Surface Water Quality Guideline for the Protection of Aquatic Life (0.5 ng/L). Measured concentrations of nonylphenol were three and four orders of magnitude below the chronic and acute guidelines, respectively.

There are a number of possible sources of these compounds to the NSR. Phthalates are ubiquitous in our environment as they are used as softeners in plastics or resins, and sources include wastewater plants, leachate from landfills and industrial discharges. Pesticides are used in forestry, agricultural, and municipal land uses, and enter the NSR through runoff. Pharmaceuticals are typically the result of human use and are therefore found in wastewater treatment plant effluent; however, some parameters could be due to animal use and could be enter the river through runoff. PAHs are found in coal tar and fire smoke, and likely enter the river through runoff.

Table 8. Summary of Trace Organics Detected in Quarterly Sampling at E.L. Smith and Rossdale Raw Water Intakes from 2004 to 2020.

Parameter	Category	Number of Samples	Number of Detections	Maximum Concentration (µg/L)	Alberta Surface Water Quality Guideline (µg/L)	Canadian Drinking Water Quality Guideline (µg/L)
2,4-D	Pesticide	142	19	0.094	4	100
2,4-Dinitrophenol	Pesticide	142	2	0.1	-	-
Acetaminophen	Pharmaceuticals	136	2	0.1	-	-
Aldrin	Pesticide	142	1	0.007	-	-
Aminomethyl phosphonic acid	Pesticide	74	1	3.41	-	-
Amoxicillin	Pharmaceuticals	32	1	0.05	-	-
Benzo(a)anthracene	PAH	142	4	0.059	0.018	-
Benzo(a)pyrene	PAH	142	1	0.023	0.015	0.04
Benzo(b)fluoranthene	PAH	142	2	0.2	-	-
Benzo(b,j,k)fluoranthene	PAH	142	2	0.05	-	-
Benzo(e)pyrene	PAH	92	0	0.02	-	-
Benzo(k)fluoranthene	PAH	134	1	0.6	-	-
Bis(2-ethylhexyl) phthalate	Phthalates	142	28	2.1	16	6*
Bromoxynil	Pesticide	142	1	0.007	5	5
Butylbenzylphthalate	Phthalates	142	26	0.7	-	-
Caffeine	Pharmaceuticals	132	12	0.04	-	-
Carbamazepine	Pharmaceuticals	132	1	0.0034	10	-
Chrysene	PAH	142	3	0.0558	-	-
Ciprofloxacin	Pharmaceuticals	136	2	0.06	-	-
Clindamycin	Pharmaceuticals	136	2	0.01	-	-
Clodinafop-propargyl	Pesticide	142	1	0.08	-	-
Cotinine	Pharmaceuticals	142	1	0.015	-	-
Diazinon	Pesticide	142	2	0.004	0.17	20
Dicamba	Pesticide	142	1	0.015	10	120
Diethyl phthalate	Phthalates	142	14	0.3	-	-
Di-n-butylphthalate	Phthalates	142	21	0.7	19	-
Di-n-octyl phthalate	Phthalates	142	4	0.2	-	-
Enrofloxacin	Pharmaceuticals	136	1	0.02	-	-
Fluoranthene	PAH	142	2	0.203	0.04	-
Fluorene	PAH	142	2	0.009	3	-
Fluroxypyr	Pesticide	142	3	0.024	-	-

Table 88. Summary of Trace Organics Detected in Quarterly Sampling at E.L. Smith and Rossdale Raw Water Intakes from 2004 to 2020. Continued.

Parameter	Category	Number of Samples	Number of Detections	Maximum Concentration (µg/L)	Alberta Surface Water Quality Guideline (µg/L)	Canadian Drinking Water Quality Guideline (µg/L)
Fluoxetine	Pharmaceuticals	136	1	0.01	-	-
Gemfibrozil	Pharmaceuticals	132	1	0.003	-	-
Glyphosate	Pesticide	88	4	3.282	800	280
Ibuprofen	Pharmaceuticals	132	3	0.023	-	-
Imazamox	Pesticide	142	1	0.017	-	-
Imazethapyr	Pesticide	142	2	0.05	-	-
Indeno(1,2,3-cd)pyrene	PAH	142	1	0.01	-	-
MCPA	Pesticide	142	2	0.009	2.6	100
MCPP	Pesticide	142	4	0.038	13	-
Metconazol	Pesticide	22	1	0.006	-	-
Methylnaphthalene	PAH	43	1	0.007	-	-
N,N-diethyl-m-toluamide (DEET)	Pharmaceuticals	104	9	0.324	-	-
Naphthalene	PAH	142	2	0.012	1	-
Naproxen	Pharmaceuticals	132	8	0.02	-	-
Norfloxacin	Pharmaceuticals	142	2	0.07	-	-
Perylene	PAH	121	2	0.012	-	-
Phenanthrene	PAH	142	4	0.092	0.4	-
Picloram	Pesticide	142	6	0.054	29	190
Propiconazole	Pesticide	142	1	0.042	-	-
Pyrene	PAH	142	2	0.015	0.025	-
Quinclorac	Pesticide	142	1	0.018	-	-
Retene	PAH	121	3	0.038	-	-
Salicylic acid	Pharmaceuticals	132	10	0.24	-	-
Thiamethoxam	Pesticide	142	2	0.052		
Triclopyr	Pesticide	142	8	0.02	-	-
Trifluralin	Pesticide	128	3	0.009	0.2	45

Note: * = US EPA guideline as no Health Canada Guideline was available.

Table 9. Summary of Trace Organics Detected in Additional Sampling at E.L. Smith and Rossdale Raw Water Intakes from 2011 to 2012.

Parameter	Number of Detections [a]	Concentration range (ng/L)
Acetaminophen	2	19-21
Alpha-Ethinyl Estradiol	3	15-56
Amitriptyline	1	1.5
Amphetamine	1	1.5
Androstenedione	2	26-29
Benzoylecgonine	4	1-2
Benztropine	3	0.33-0.79
Beta-Sitosterol	1	533
Caffeine	4	37-46
Cholesterol	4	49-508
Ciprofloxacin	1	10.7
Cocaine	2	0.18-0.29
Cotinine	4	3.3-7.7
DEET	6	3.1-7.8
Diltiazem	1	0.33
Diphenhydramine	1	2.4
Enalapril	1	0.38
Erythromycin	1	0.29
Flumequine	1	1.5
Metformin	4	36-74
Naproxen	2	3.3-3.6
Nonylphenol	1	6.6
Sulfamethoxazole	1	1.1
Valsartan	2	4.1-9.5

[a] a total of six samples analyzed.

Beginning in 2018, EPCOR began collecting quarterly samples for per- and polyfluoroalkyl substances (PFAS), which are a large family of synthetic chemicals found in a wide range of consumer products such as non-stick products, food packaging, polishes, waxes, paints, cleaning products and fire fighting foams. The two most studied PFAS compounds, perfluorooctane acid (PFOA) and perfluorooctanesulfonic acid (PFOS) are highly persistent in the environment, probably carcinogens lead to adverse health outcomes and have maximum allowable concentrations in drinking water established by Health Canada. PFOS was phased out of fire fighting foams in the early 2000s; however, PFOA may be present in trace amounts in some foams. Other PFAS compounds are still used in foams, but are expected to be less toxic because of their chemical structure, but still have screening values established by Health Canada. Since monitoring began in 2018, PFOS, PFOA or any PFAS compounds have not been detected in the raw or treated water.

To determine the possible risk from PFAS compounds from fire fighting foams, EPCOR reached out to fire services in upstream communities and counties to determine which types and quantities of foams are being used (Table 10). The Edmonton International Airport and Parkland

County use a product that contains 6:2 flurotelomer sulfonate, which has a Health Canada screening value. Most of the upstream communities use a product (FireAde) that is reported to contain PFOA at concentrations of 80 µg/L, and may contain other PFAS compounds (City of Calgary, 2020). Alberta Wildfire uses retardants that do not contain PFAS compounds (personal communication, D. Thomas, 2020). For many products, it is difficult to determine if they contain PFAS compounds, and which specific compounds, as this information is considered proprietary on Safety Data Sheets and manufacturers have not responded to EPCOR's requests for information. However; given that upstream municipalities typically do not use large volumes of foam, the concentrations in the NSR are anticipated to be well below Health Canada Guidelines. However, if a single community were to discharge their entire stock in a single event, and if a majority of this product entered the river, there theoretically would be enough PFAS to exceed Health Canada guidelines and screening values for a short period of time in the NSR at Edmonton. This would not be caught by our quarterly testing and therefore the municipality should inform EPCOR of this event so that sampling can occur.

Table 10. Summary of Fire Fighting Foams Used by Upstream Communities.

Community / Location	Product being used	Estimated amount used per year	Contains PFAS?
Edmonton International Airport	Ansulite 3% AFFF (Formula DC-3)	1,000 L	Yes: 6:2 fluorotelomer sulfonate
City of Edmonton	Niagara 1-3 alchohol resistant film forming fluroprotein foam concenrate	1,000 L	Suspected PFAS
Leduc County	FireAde Mil 3% AFFF Fire Fighting Foam	2,000 L	Calgary suggests FireAde contains trace PFOA
City of Leduc	Angus Fire Hi-Combat A Foam concentrate	300 L	Unknown
Town of Devon	FireAde 3% FireAde 0.1% - 1.0%	FireAde 3%: 60 L FireAde 0.1-1%: 240 L	Calgary suggests FireAde contains trace PFOA
County of Wetaskiwin	FireAde Fire Fighting Agent	100 L	Calgary suggests FireAde contains trace PFOA
Parkland County	Niagra Foam Ansulite Fire Aid A/B Silvex Class A	Niagra Foam: 20 L Ansul light: 200 L Fire Aid A/B: 800 L Silvex Class A: 700 L	Ansulite contains 6:2 fluorotelomer sulfonate
Drayton Valley / Brazeau County	T-Storm SFFF ALCOSEAL 3/6% AR-FFFP FlameOut Fire Suppressor AFFF	T-Storm: 600 L ALCOSEAL: 120 L FlameOut : 400 L	Alcoseal contains fluorosurfactants, suspected PFAS. T-storm and FlameOut do not appear to contain PFAS
Clearwater County	FireAde - Class A&B	800 L	Calgary suggests FireAde contains trace PFOA
Alberta Wildfire	Phos-Check WD-881C Class A Foam Concentration	Unknown	No

Taken together, these results demonstrate that contaminants such as pesticides, pharmaceuticals, phthalates, and PAHs are present in the NSR; however, they are found in very low concentrations, and are typically not detected. Additionally, a majority of the trace organics that have been tested for, have never been detected. The concentration at which these parameters have been detected are typically several orders of magnitude below drinking water quality guidelines and surface water quality guidelines for the protection of aquatic life. Many of these parameters are also found in EPCOR's drinking water reservoirs, suggesting that they are not fully removed through conventional water treatment. Assessing the risk associated with these compounds is challenging as many parameters do not have water quality guidelines.

A study by the World Health Organization (2012) concluded that impacts of pharmaceuticals in drinking water is unlikely to impact human health, and that concentrations in drinking water are generally more than 1000-fold below the minimum therapeutic dose. A study conducted by the Water Research Foundation (2015) found that a person would need to drink 100,000,000 glasses of water to obtain a therapeutic dose and there is no definitive links between pharmaceuticals in drinking water and human health.

While some PAHs are known to be carcinogenic, a study by the World Health Organization (2003) concluded that it is not possible to directly asses the risk on PAHs on humans due to the lack of human data, and that risk is likely due to exposure to mixtures of PAHs, and not individual PAHs. It should be noted that PAHs were relatively infrequently detected in the NSR. Additionally, the most extensively studied PAH, benzo[a]pyrene, due to its potential effects on human heath, has only been detected once, with concentrations below drinking water quality guidelines.

Compared to many other waterbodies, the risk associated with many of these compounds are presumably lower in the NSR given the relatively low population and development upstream of Edmonton. However, this area is an area of ongoing research, and additional knowledge of the effects of combinations of low concentrations of contaminants of emerging concern is required before risk can properly be assessed.

Spills on the NSR

Chemical spills can enter the NSR through a variety of pathways including industrial discharges, storm sewer outfalls, overland flow, tributaries, and directly into the NSR itself. Many of the locations and methods of spills being introduced to the NSR are covered in Section 3.2. EPCOR's WTPs recognize the threat of spills to drinking water quality and have developed lines of communication with provincial regulators (AEP and AER), Drainage Services, and the City of Edmonton fire department to directly contact the control rooms of the WTPs in the event of a spill on the NSR. EPCOR is running exercises to test these lines of communication.

There have been several notable spills in the NSR in recent years, while none have directly impacted EPCOR's WTPs, but highlight the risk represented by spills in the NSR. In 2016, the Husky Energy Pipeline spilled 225,000 L of crude oil in the NSR near Maidstone Saskatchewan. This spill significantly impacted the downstream communities of North Battleford and Prince Albert, which were forced to shut down their water intakes for months and find alternative water supplies. In 2005, 800,000 L of fuel oil spilled into Lake Wabamun when a train derailed; however, the spill was contained within Lake Wabamun. In August 2019, 40,000 L of oil emulsion spilled into Washout Creek near Drayton Valley, and the spill was contained within the creek.

Several smaller spills have occurred within Edmonton and been reported to EPCOR's WTPs, as the material entered the drainage system and the NSR. These spills have typically been sewage or diesel, and have typically been small volumes and have not impacted the WTPs, but highlights the potential risk of spills entering the NSR in close proximity to the WTP intakes.

In 2017, EPCOR engaged Stantec to provide a summary of the risks of a hydrocarbon spill upstream of Edmonton. Stantec (2017) identified that the three primary modes of hydrocarbon transport are pipeline, rail and truck. Pipelines were considered to be the highest risk due to the large amount of pipelines located upstream (see Section 3.2.7) and that the average pipeline spill volume is 12,259 L. Pipelines were also reported to have 1.5 incidents per 1,000 km of pipeline. Of these incidents, 88% resulted in leaks, and 5% resulted in ruptures. While rail lines were identified as a possible source of hydrocarbon spills, there are relatively few rail lines upstream of Edmonton, and the only one which crosses the NSR is located in Rocky Mountain House far upstream of Edmonton. While truck transport is also a possible source of hydrocarbon spills on the NSR, there are relatively few crossings (see Section 3.2.7), and the maximum volume carried by a truck is relatively small compared to other potential spill sources. Stantec's report also explored preliminary options of the WTPs ability to be able to treat water to meeting drinking water quality guidelines, despite a hydrocarbon spill on the NSR. Lastly, Stantec's report also explored options of alternative water supplies, and this is discussed in greater detail in Section 3.3.3.

EPCOR has conducted studies with Natural Resources Canada exploring how hydrocarbon spills change over time, and how EPCOR's WTPs could treat a hydrocarbon spill with powdered activated carbon, which the WTPs regularly use to treat water with high colour/organic material in the spring. Preliminary studies show that the WTPs could treat raw water that has been contaminated with crude oil and gasoline.

EPCOR's Stormwater Environmental Monitoring Program

Since 1991, stormwater quality and quantity have been monitored within Edmonton as part of the Environmental Monitoring Program (EMP). Prior to 2017, the EMP was conducted by the City of Edmonton, but is now managed by EPCOR.

> The EMP monitors discharges from storm and combined sewer outfalls, as well the mainstem NSR, stormwater management facilities, and tributaries within the City of Edmonton boundaries.

Initially, the EMP focused on annual water quality surveys of the NSR, within and downstream of the City limits. Over time, the program has evolved and expanded in scope to include seasonal monitoring at key points in the NSR as it flows through Edmonton and past Fort Saskatchewan. Tributaries to the NSR and outflows from the Gold Bar and Capital Region Wastewater Treatment Plants (WWTPs) have also been sampled as part of the seasonal surveys, along with several stormwater management lakes and constructed wetlands. Tributary monitoring was typically only conducted twice per year as part of seasonal surveys, but sampling effort has increased in recent years. In addition, the EMP maintains a network of continuous monitoring stations that are located at the four largest storm sewer outfalls (i.e., 30th Avenue, Groat Road, Quesnell and Kennedale) and the two largest combined sewer outfalls (CSOs) (i.e., Rat Creek and Capilano). The stations include flow monitoring equipment and automated water samplers, which are configured to automatically collect water quality samples during runoff events and to send out emails once the sampling has started. Supplementary manual base flow samples are also collected twice per month from the four largest storm sewer outfalls. The parameters measured for the EMP vary among sites and events, but most frequently include biochemical oxygen demand, total suspended solids (TSS), chloride, total Kjeldahl nitrogen, ammonia, nitrate + nitrite, total phosphorus, and *E. coli*. Other less frequently monitored parameters include metals and hardness, pesticides, pathogens and volatile organic compounds.

The EMP currently has three main focus points: The quantification of loads to the NSR from the combined sanitary system and stormwater system; mainstem monitoring at four intake locations within/downstream of Edmonton; and monitoring water quality in tributaries.

The EMP has demonstrated that loading from the WWTPs, storm sewer outfalls and tributaries increase TSS, chloride, nitrogen, ammonia, total phosphorus, and *E. coli* concentrations in the NSR, particularly during precipitation and runoff events. Taking TSS as an example, the largest sources of loading of TSS are the storm sewer outfalls and storm water loading into creeks within Edmonton; however, upstream sources of TSS greatly exceed these urban loading sources, particularly during periods of elevated flow (Figure 58). Notable increases of TSS in the NSR typically only occur during the spring and fall when flows in the NSR and upstream loads of TSS are low, but when loads are high are elevated from urban sources during runoff events (Figure 59). Of the sources shown in Figure 58, only a small portion of the unmonitored storm sewer outfalls are located upstream of the E.L. Smith WTP; however, the Wedgewood and Whitemud creeks, as well as the 30th Avenue, Groat Road, Quesnell and a larger portion of the unmonitored storm sewer outfalls are located upstream of the Rossdale WTP. TSS concentrations were higher at the Rossdale WTP compared to the E.L. Smith WTPs, presumably due to additional loading of TSS from the creeks and storm sewers.

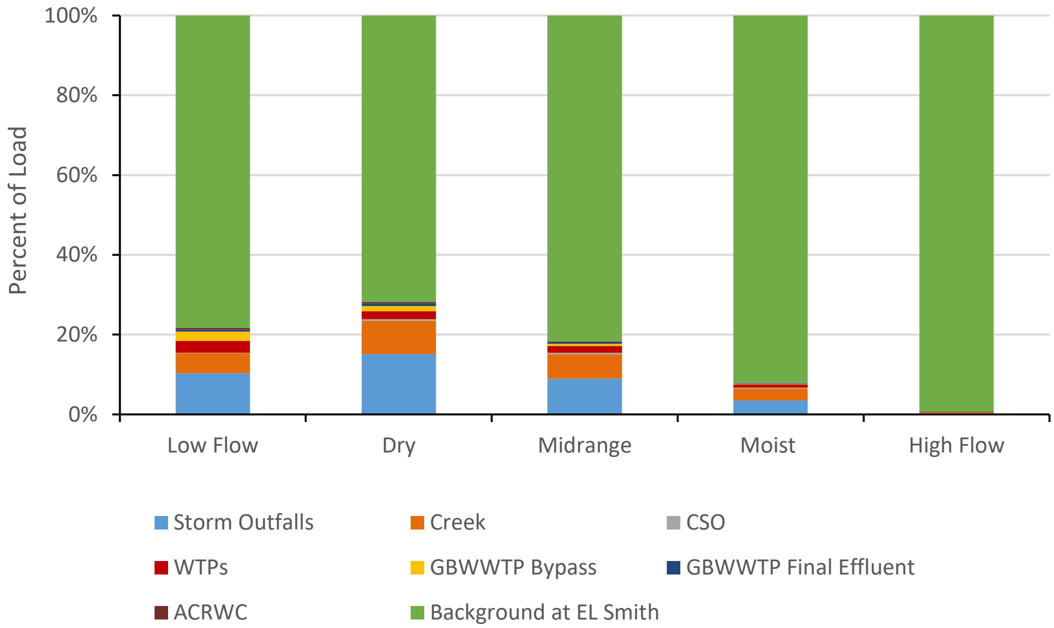


Figure 58. Sources of TSS Loading in the NSR Under Varying Flow Categories, 2010 – 2019.

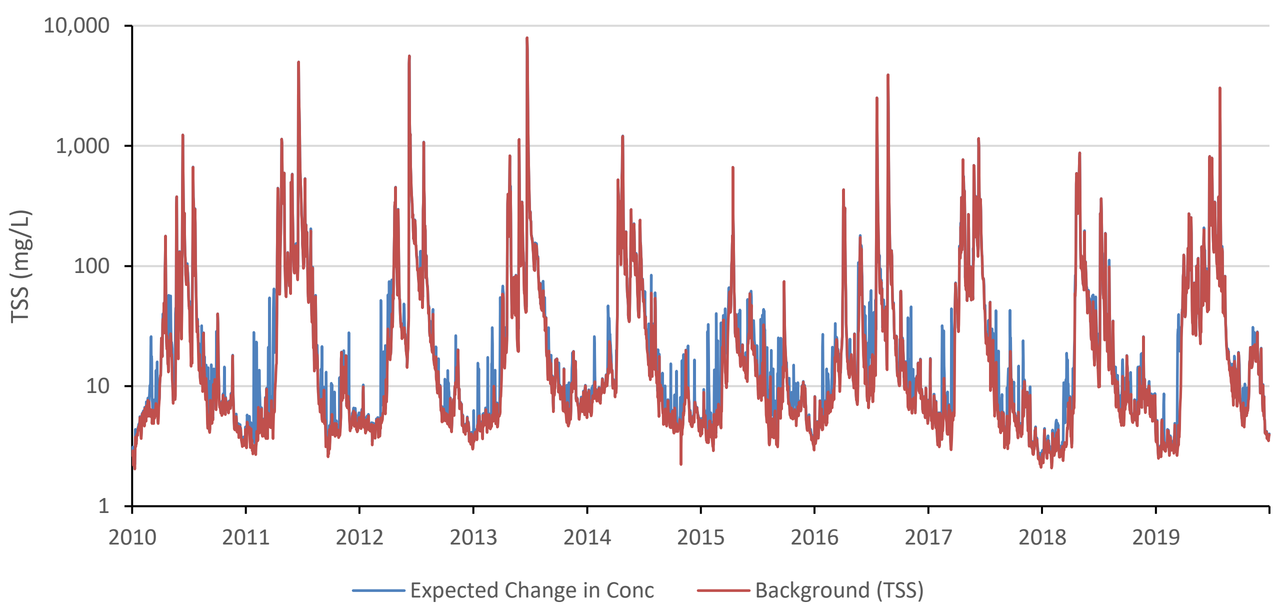


Figure 59. Estimated Upstream and Downstream TSS in the NSR, 2010 – 2019.

Pesticide concentrations are elevated in stormwater, but are still several orders of magnitude below drinking water quality guidelines and represent a low risk to source water. A total of 17 different pesticides have been detected at stormwater outfalls, most of which have also been detected in the NSR at the WTP intakes. Pesticides are also detected more frequently at

Rossdale compared to E.L. Smith, indicating that stormwater is source of pesticide loading to the NSR.

Metal concentrations are also elevated in stormwater, but represent a low risk to drinking water due to their concentrations, but also that they are frequently attached to particulate material and are removed from drinking water by the WTPs. Elevated metal concentrations from stormwater present a greater impact to aquatic life in the NSR and concentrations of arsenic, cadmium, chromium, cobalt, copper, lead, mercury, selenium, silver and zinc, have been found to exceed guidelines for the protection of aquatic life.

Volatile organic compounds (VOCs) are also detected in stormwater outfalls and in tributaries; however, a majority of VOCs that were tested were either not detected, or were in low concentrations that were consistently below water quality guidelines.

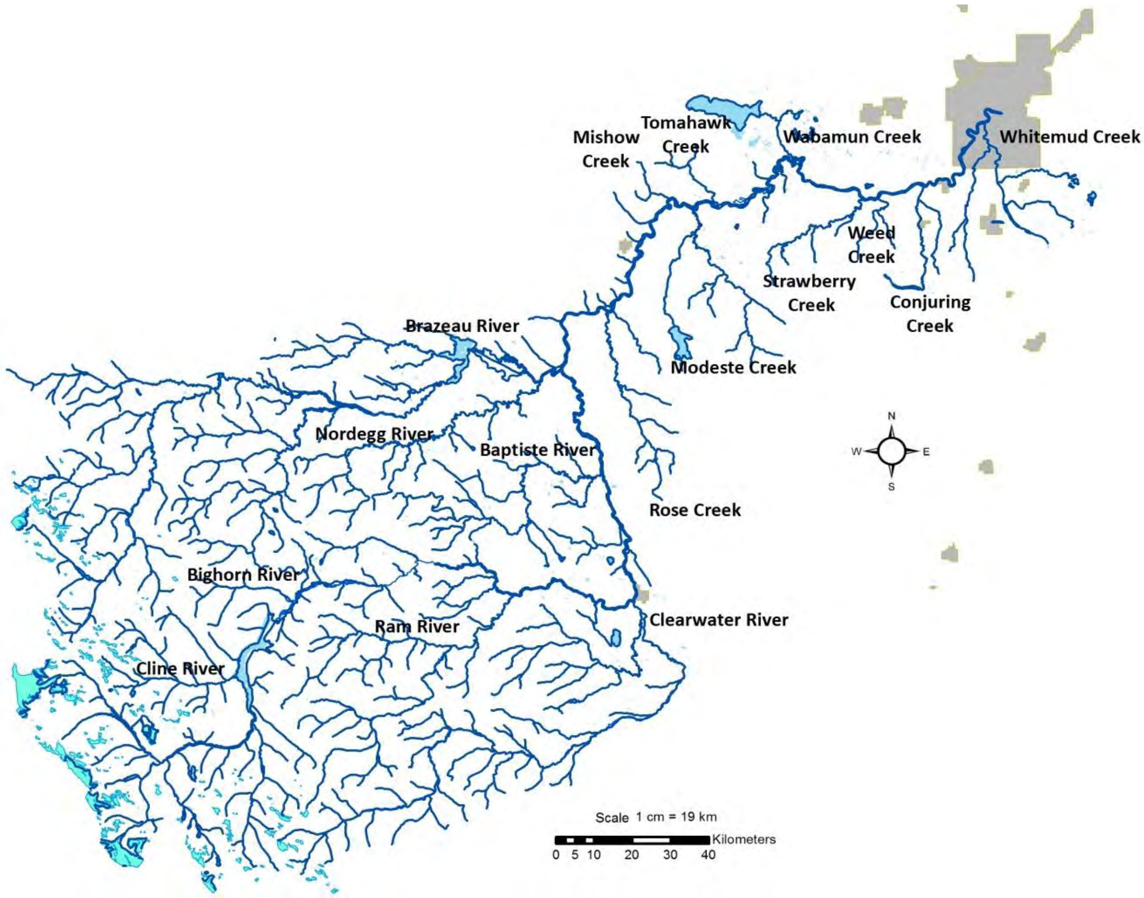
Monitoring of the tributaries within Edmonton revealed that tributaries with heavily urbanized basins that also received direct stormwater runoff had higher concentrations of all parameters compared to tributaries that received less stormwater runoff and were in basins that were less urbanized. Thus, while tributaries can be significant sources of loading, the addition of stormwater runoff can significantly increase loadings of parameters to the NSR.

Edmonton also has numerous stormwater management facilities and constructed wetlands. While the major function of these waterbodies is to retain stormwater flows and prevent flooding, they also provide an opportunity to improve stormwater quality. Monitoring of these waterbodies show that they effectively remove *E. coli* from stormwater, and that TSS, phosphorus and metals are also removed, but the trends are variable and inconsistent among the sampled waterbodies. Increasingly EPCOR is building stormwater management facilities and constructed wetlands for the purpose of preventing flooding, but also for improving stormwater quality.

3.3.2 Tributary Data

A total of 64 named tributaries flow directly into the NSR, upstream of Edmonton. Of these tributaries, 44 enter the NSR upstream of Rocky Mountain House, whereas the remaining twenty enter between Rocky Mountain House and the Rossdale WTP. The major contributing tributaries in terms of annual flow to the NSR are the Cline, Clearwater, Ram, Baptiste, and Brazeau rivers (Figure 60). Most of the flow from the headwaters is from snowpack accumulation and subsequent melt during the summer months. The NSR mainstem is dammed by the Bighorn Dam creating Abraham Lake. The Cline River joins the NSR at Abraham Lake, whereas the Bighorn, Clearwater and Ram rivers flow into the NSR downstream of the Bighorn Dam. Another dam occurs in the basin on the Brazeau River,

which is dammed just upstream of its confluence with the Nordegg River, creating the Brazeau Reservoir. Major tributaries that flow into the NSR are summarized in Table 11.
.



Data Source: GoA 2020

Figure 60. Major Tributaries in the NSR Watershed above EPCOR's WTPs.

Table 11. Major Tributaries to the NSR.

Location in basin	Name	Notes
Headwaters: Rocky terrain mixed with forested landscapes. Largely undisturbed. Cline River joins the NSR at Abraham Lake, which is dammed by the Bighorn Dam.	Cline River	• Enters Abraham Lake • 10 tributaries
	Howse River	• Enters NSR u/s of Abraham Lake
	Mistaya River	
	Siffleur River	
	Clearwater River	• 18 tributaries • Enters NSR at RMH
	Ram River	• 12 tributaries • Enters NSR at RMH
	Bighorn River	• Enters NSR d/s of Bighorn Dam
Upper-reach: Largely forested with major human use of forestry and oil and gas extraction.	Baptiste River	• Enters NSR just d/s of RMH
	Nordegg River	• Enters NSR via Brazeau River
	Brazeau River	• Enters NSR d/s of RMH • Flows into Brazeau Reservoir
	Rose Creek	• Watershed a largely forested/wetland
Mid-reach: Largely agriculture based landuse dominated by pasture and cow-calf operations.	Modeste Creek	• Small creeks that flow significantly only during runoff events in open water season
	Tomahawk Creek	
	Wabamun Creek	
	Strawberry Creek	
	Mishow Creek	
	Weed Creek	
	Conjuring Creek	
Within city: Urban environment.	Whitemud Creek	• Whitemud Creek is influenced heavily by stormwater inputs


Brazeau River Power Plant

Water quality data has been collected for many of NSR tributaries over the past 40 years. Historically mid-reach tributaries have received more attention because of specific projects investigating the influence of agricultural activities on water quality. Water quality data for headwater and upper-reach tributaries is less available due in part to the difficulty accessing these streams and the limited development in these areas. Overall, the lack of water quality data on the headwater tributaries has limited the ability to determine sources of contaminant loads.

Tributary Monitoring Programs

The following sections describe the historical and current water quality monitoring programs for tributaries in the NSR watershed.

Synoptic Studies

Select tributaries to the NSR were sampled as part of AEP's synoptic monitoring program. Samples were taken between 1985 and 1989 in a series of 12 synoptic sampling events and again in 2008 and 2012 when additional six synoptic sampling events were completed. Tributaries included in sampling were: the Bighorn, Ram, Clearwater, Baptiste, Nordegg and Brazeau rivers, and Rose, Modeste and Strawberry creeks and additional downstream tributaries.

Alberta Environmentally Sustainable Agriculture (AESA)

The AESA Program is a long term, provincially funded program that facilitates management practices that make agriculture more environmentally sustainable. One aspect of the program is the monitoring of water quality through its Water Quality Resource Monitoring Program, of which the AESA Stream Survey is a part. The AESA Stream Survey is a long-term monitoring program that tracked water quality in 23 streams in agricultural areas across Alberta from 1997 to 2006, three are in the NSR watershed upstream of Edmonton: Rose, Strawberry and Tomahawk creeks.

Initiated in 1997, the AESA Stream Survey was operated by Alberta Agriculture, Food and Rural Development, AESRD, Alberta Health and Wellness, and Agriculture and Agri-Food Canada (Lorenz et al. 2008)

EPCOR Upstream Tributaries

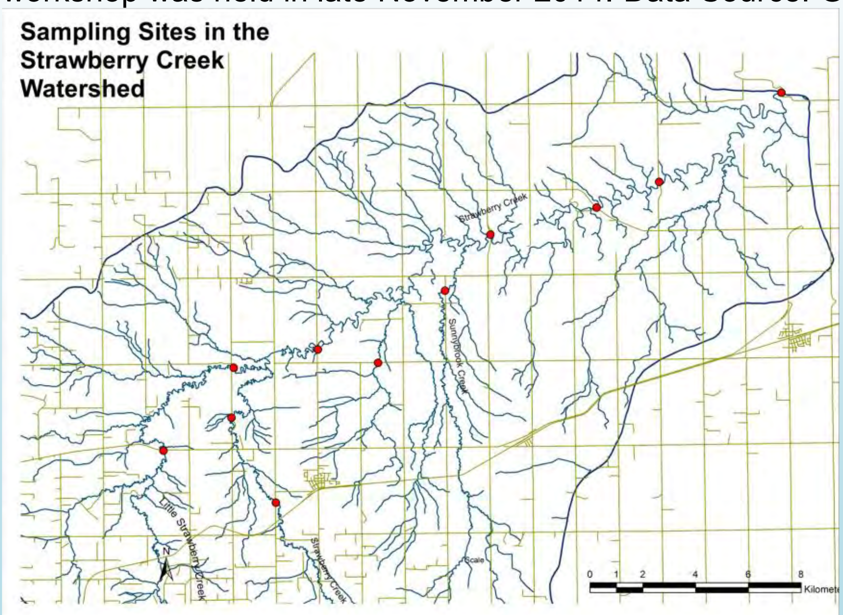
EPCOR has conducted regular upstream sampling in tributaries to the NSR since 1992. Monitoring has often been done in partnership with the province; EPCOR partnered with AEP to conduct upstream monitoring between 1998 and 2005. The samples were generally collected during spring runoff and summer storm runoff periods.

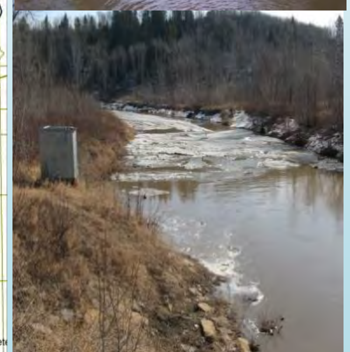
As part of this monitoring network, in late 1990s, EPCOR partnered with the Canada-Alberta Beef Industry Development Fund, Alberta Agricultural Research Institute, and AEP to undertake enhanced tributary water quality monitoring in the basin as part of a research project. Specifically, a research project was initiated to identify potential major sources of waterborne parasites in the NSR upstream of Edmonton and resulted in a 2002 report, "Relationship between Beef Production and Waterborne Parasites (*Cryptosporidium* spp. and *Giardia* spp.) in the NSR basin, Alberta, Canada". The report found that livestock contribute peak loads of parasites to the NSR and municipal wastewater effluent from upstream municipalities are a chronic source of *Giardia* spp upstream of Edmonton. The following tributaries, located between Rocky Mountain House and Edmonton were sampled as part of this research: 620 Creek, Baptiste River, Big Beaver Creek, Canyon Creek, Chicken Creek, Conjuring Creek, Graminia Creek, Mishow Creek, Modeste Creek, Nordegg River, Prentice Creek, Rose Creek, Sand Creek, Shoal Lake Creek, Strawberry Creek, Tomahawk Creek, Violet Creek, Wabamun Creek, Washout Creek and Weed Creek. This research project has enabled EPCOR to better understand potential sources of contamination and better direct funds for further research studies, stewardship projects and public awareness initiatives upstream within the NSR basin.

Clearwater River Photo Credit: Eddie Carle

In 2006, provincial agricultural program funding for upstream tributary monitoring was discontinued. However, EPCOR continued collecting raw water samples from select tributaries of the NSR during spring runoff. In 2008, EPCOR's program was enhanced to include storm events and baseflow water quality testing, as well as extend into the headwaters (Clearwater and Ram Rivers). To allow better access to the headwater streams, EPCOR has partnered with Clearwater Landcare to collect samples from headwater tributaries. The intention of the program is to better quantify loads of contaminants from all tributaries entering the NSR and better understand how land use practices alter these contaminant loads across seasons. Between 2013 and 2018, EPCOR's Water Monitoring Program focused on the Strawberry Creek Watershed as part of a pilot project on watershed management, stewardship and BMP implementation. That work is now complete and may be continued if suggested by the IWWEBs research work.

The Strawberry Creek Pilot Project- is a project that was initiated by EPCOR in 2013. It investigates water quality on 11 sites along Strawberry Creek and eventually aims to develop beneficial management strategies in the watershed to improve water quality in the creek. Since that time a working group has formed that includes Leduc County, Alberta Agriculture and Rural Development, Cows and Fish, Agriculture Canada and EPCOR that is looking to partner on initiatives in the watershed. A stakeholder "What's Happening in Strawberry Creek" workshop was held in late November 2014. Data Source: GoA 2020





EPCOR Urban Tributaries

Tributaries within Edmonton's boundaries are monitored by EPCOR as part of the EMP. From a source water perspective, the relevant only urban tributaries include Wedgewood Creek, which enters the NSR just downstream from the E.L. Smith WTP, and Whitemud Creek, which enters the NSR just downstream of the Quesnel Bridge, both of which are above the Rossdale WTP. There is an existing Blackmud/Whitemud Creek watershed management program and EPCOR also completes monitoring on urban tributaries. See section 3.3.1 for more details on the EMP.

WaterSHED (Saskatchewan Headwaters Edmonton Downstream) Monitoring Program

The monitoring programs described above have provided a significant amount of data; however, they have been disjointed, project specific, and not comprehensive enough to meet EPCOR's (and other stakeholder's) needs of balancing land use decisions with maintaining water quality and quantity. To address the gap of these monitoring programs, EPCOR spearheaded a Water Quality and Aquatic Ecosystem Working Group in Partnership with the North Saskatchewan Watershed Alliance to address monitoring challenges in the North Saskatchewan River basin. This group identified a need for a scientifically defensible, sustainably funded, long-term water quality and aquatic ecosystem health monitoring program for the North Saskatchewan River and its major tributaries. The goals of this program would be to 1) allow the assessment of drivers of water quality and quantity; 2) understand the effects of continued land use change and population growth pressures and; 3) to inform planning at the regional, source water, and municipal scale.

In 2016, EPCOR Water Canada put forward a request for up to one million dollars per year for four years from the Edmonton Rate Payers for an environmental monitoring program for the North Saskatchewan River and was supported by Edmonton City Council. This funding lead to the formation of the WaterSHED Monitoring Program, which is lead by a steering committee consisting of EPCOR, Alberta Environment and Parks, the North Saskatchewan Watershed Alliance and the City of Edmonton. The Program was designed in 2018, monitoring and flow station installation began in 2019, and funding is guaranteed until the end of 2021. EPCOR is seeking approval to continue monitoring through 2026.

The monitoring was program is based on a mass balance approach with paired water quality and quantity data and representative sub-watersheds were chosen based on hydrological response and watershed characteristics (Figure 61). In order to understand the link between watershed characteristics, climate, and water quality and quantity, the program is designed to be long-term. To be useful it must capture inter-annual variability (wet and dry years) and seasonal variability (ex. fast spring melt) across headwater watersheds to parkland/agriculture dominated watersheds.

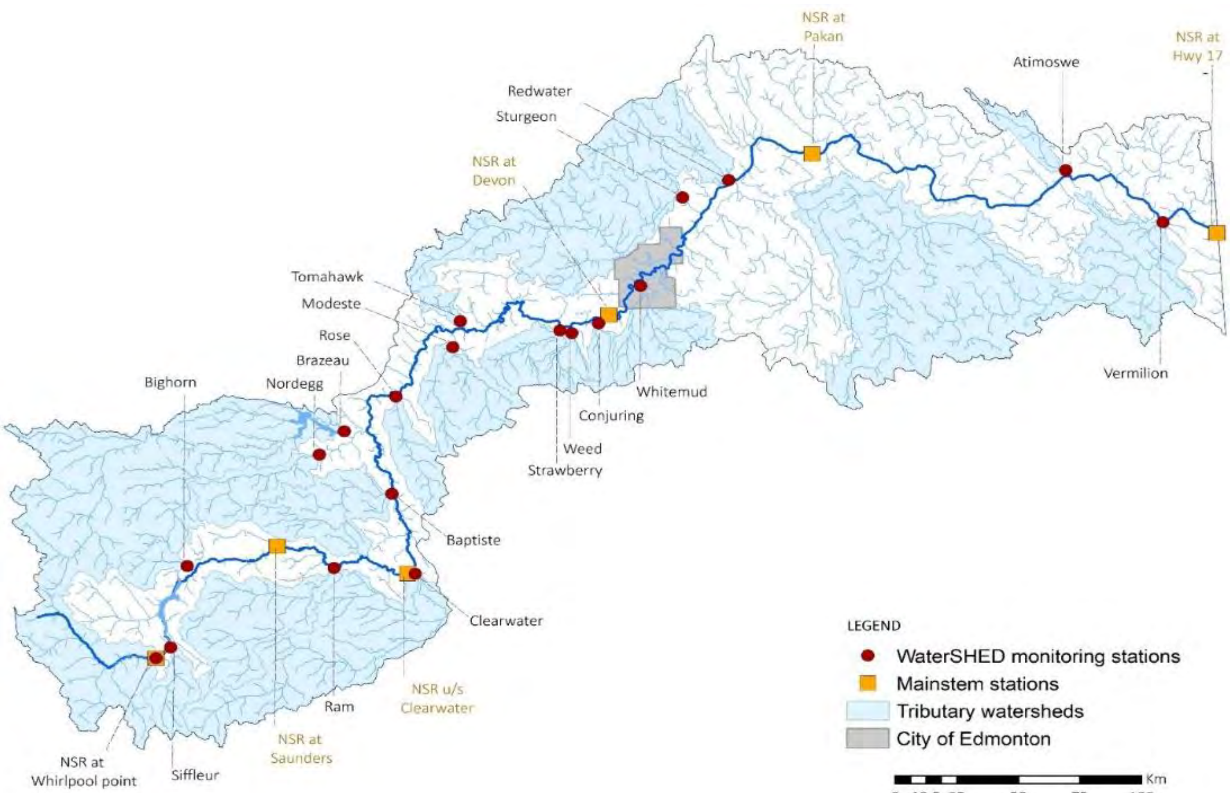


Figure 61. WaterSHED Monitoring Program Locations and Tributary Watershed Areas.

Tributary Water Quality

For this report, water quality was summarized for tributaries using stations nearest to the confluence with the NSR. In most cases, samples were collected in the early 1980s, late 1990s, and more consistently throughout the 2000s. For the headwater tributaries, only a small number of samples have been collected, whereas some of the mid-reach streams have been sampled over 200 times for some parameters (Table 12). Additionally, some programs did not sample during high-flow events, whereas other programs intentionally targeted these events. As a result, it is difficult to fully compare the water quality amongst the upstream tributaries. With these data limitations in mind, a general trends of increasing concentrations of most parameters from headwater reaches to mid-reach tributaries is evident (Figures 62 and 63). Some of these changes can be accounted for by natural phenomenon such as soil type, underlying geology, and ecoregion differences; however, human land use plays an important role as well (see section 3.2). Median and maximum concentrations of parasites, sediment, nutrients, and organics are notably higher in mid-reach tributaries than in more pristine headwater and upper reach tributaries.

Prairie Creek. Photo credit; Gary Lewis of Clearwater Landcare

Understanding and quantifying contributions from tributaries becomes important when trying to assess risks to the NSR river source water. Without understanding all aspects of contaminants, including load calculations, entering the NSR from tributaries it is difficult to target land management practices to maintain high water quality. It is clear that mid-reach tributaries have the poorest water quality, but they also comprise a small amount of the annual flow of the NSR on an annual basis. However, we also know that during spring runoff, these tributaries can combine to contribute almost half the flow to the NSR.

Knowing that water quality is dependent on runoff conditions, it is important that the relationship between flow and water quality is well understood to calculate loads accurately. For streams that are driven by spring melt runoff and storm events, such as the ones in the mid-reaches of the NSR, it is estimated that 90% of the load is added during less than 10% of the year, emphasizing the need to capture these events. As mentioned above, water quality data for the upper tributaries is limited and for the mid-reach tributaries only a few tributaries have been sampled extensively enough to allow accurate annual and seasonal load calculations.

Table 12. Number of Water Quality Samples Collected Near Mouths of Tributaries to NSR (1975 - 2020).

Tributary	Fecal Coliforms	*E. coli*	Turbidity	*Giardia.*	*Cryptosporidium*	TSS	Total Phosphorus	TKN	Nitrate	Ammonia	Colour	DOC
Cline	5	5	5	1	1	5	5	5	5	5	3	5
Siffleur	8	8	20	1	1	20	20	20	20	20	18	20
Bighorn	17	19	43	4	4	44	43	43	44	44	35	41
Ram	26	27	56	4	4	54	56	56	56	57	46	53
Clearwater	16	21	49	5	5	50	48	48	49	50	39	47
Baptiste	38	41	77	24	24	72	70	70	71	72	61	58
Nordegg	47	56	81	45	45	76	73	72	74	74	75	41
Brazeau	33	35	70	18	17	64	62	62	64	64	54	55
Rose	266	268	31	12	12	341	342	341	341	337	91	27
Mishow	38	40	45	46	46	40	39	38	40	37	37	7
Modeste	35	34	59	32	32	55	54	53	56	59	49	39
Tomahawk	84	85	68	51	51	153	152	150	152	153	126	18
Wabamun	5	9	8	7	7	9	7	7	8	9	9	5
Washout	6	6	5	6	3	6	6	6	5	6	6	3
Strawberry	227	229	70	46	46	295	294	293	294	287	130	31
Weed	39	43	68	54	49	60	60	59	60	63	63	23
Conjuring	21	27	43	22	22	39	38	36	40	40	39	24
Whitemud	35	91	115	4	4	170	163	164	161	163	23	32

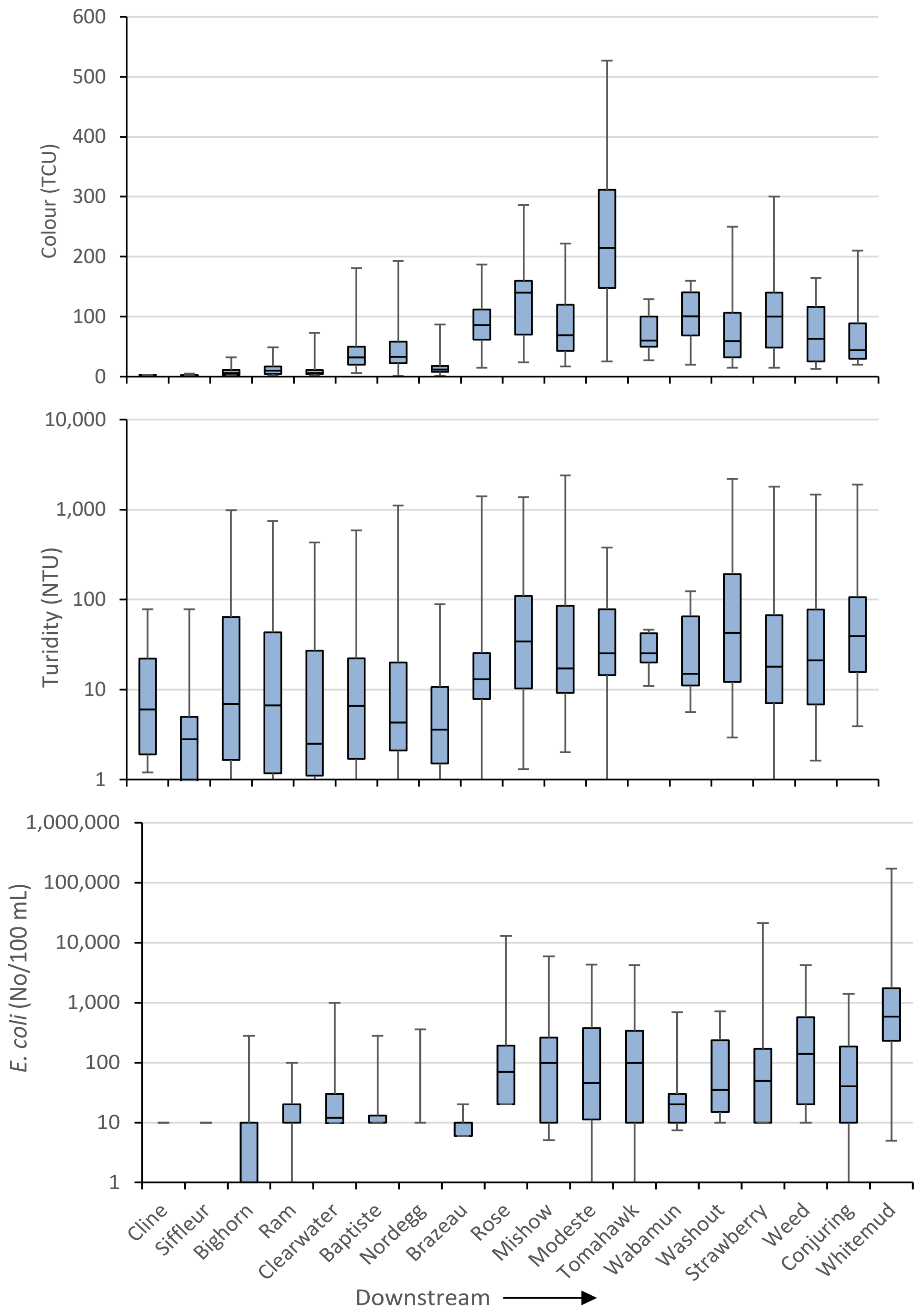


Figure 62. Colour, turbidity and *E. coli* in the major tributaries in the NSR watershed (1975 – 2020).

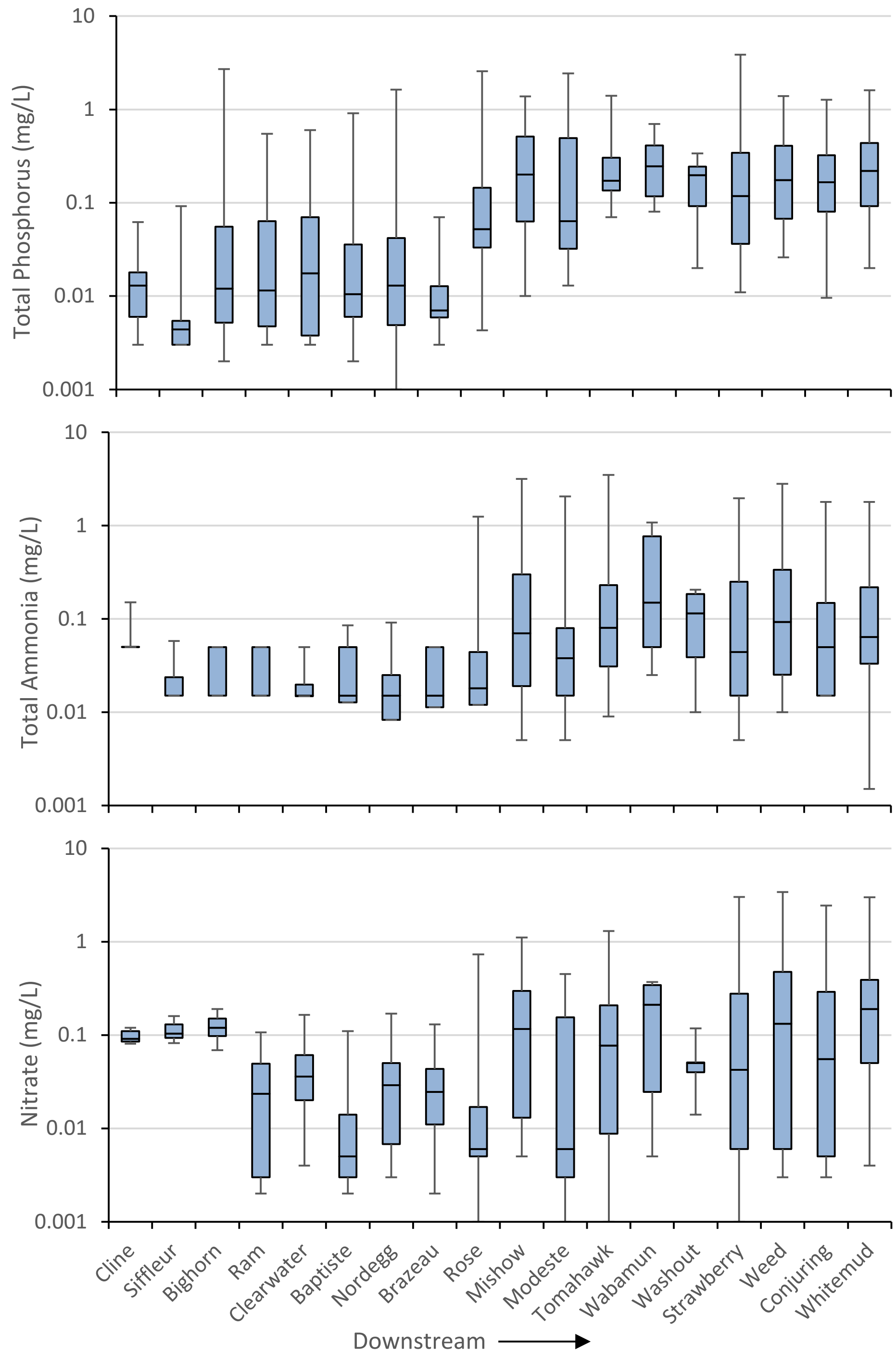


Figure 63. Total Phosphorus, ammonia and nitrate in the major tributaries in the NSR watershed (1975 – 2020).

3.3.3 Water Quantity

General Patterns

The majority of water in the NSR basin originates from the headwater areas with almost 90% of the water entering the river upstream of Drayton Valley.

On an annual basis, most of the water in the NSR originates in the headwater areas of the Rocky Mountains. Specifically, it has been estimated that of the mean annual natural discharge of the NSR at the Alberta/Saskatchewan boundary (7,510 Mm^3), the headwater hydrologic region contributes almost half (3,600 Mm^3) of the annual cumulative yield (Figure 64; Golder 2008a). Putting it another way, by the time the NSR reaches Drayton Valley, 87% of flow at the border is accounted for, on an annual basis. The headwater area yields a remarkable amount of water considering that it comprises only 4,110 km^2 compared to the NSRB's gross drainage area of 56,860 km^2. This highlights the importance of protecting this source water area to ensure a sustainable supply of water for downstream reaches.

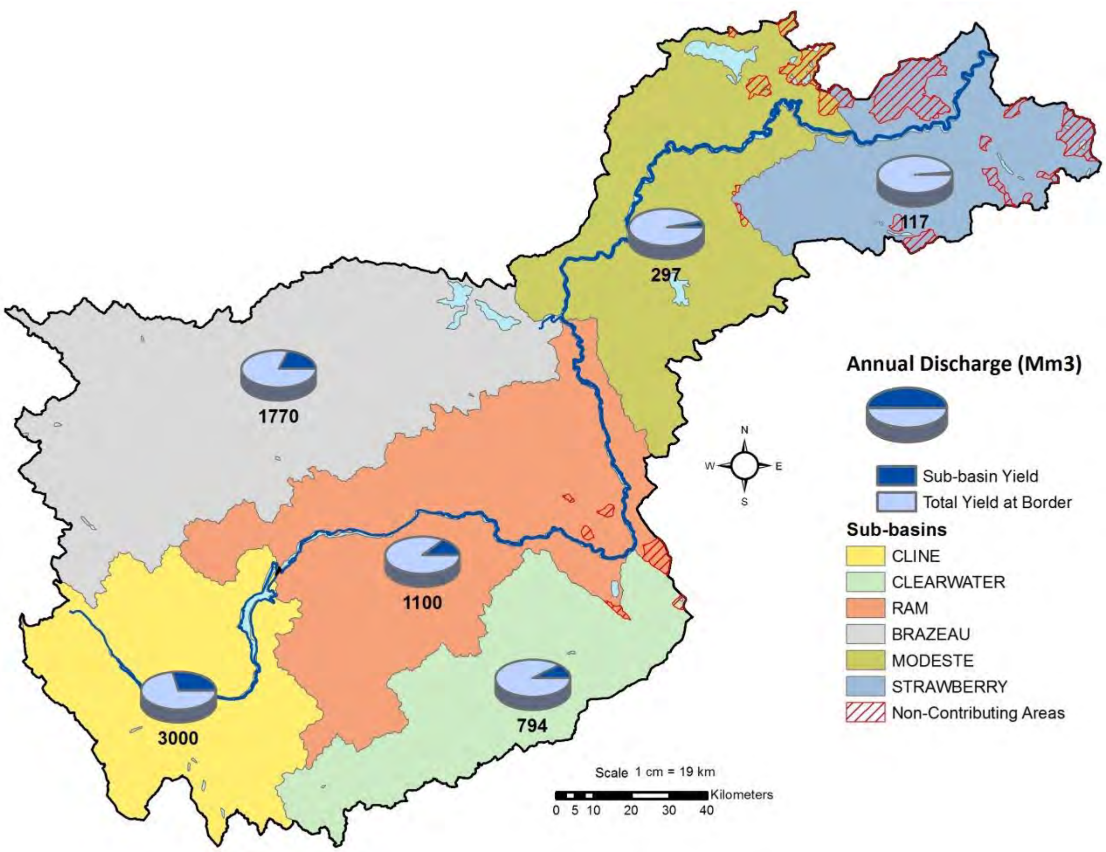
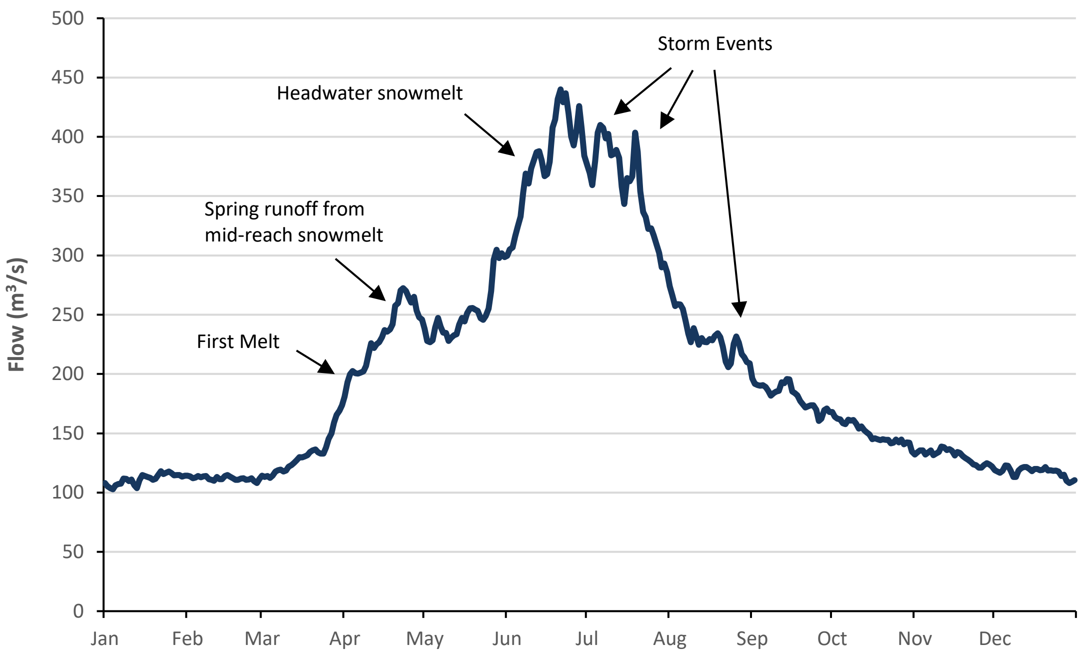


Figure 64. Water Yield Data for Sub-basins in the NSR watershed (Data Source: Golder 2008a)

Annual water yield paints only part of the picture when it comes to understanding water quantity in the NSR. Seasonal patterns are apparent in the NSR and reflect snow accumulation and melt, storm events, and early spring runoff patterns in mid-stream reaches (Figure 65). Spring runoff typically occurs in late March and mid-April for the areas around and upstream of Edmonton. In contrast, the peak monthly yield from the headwater regions along the eastern slopes of the Rocky Mountains occur in July because of the gradual rise in temperature during spring and early summer at these high elevations. Peaks in flow occur during storm events and the effect on flow depends on the severity, geographic extent and duration of the storm. Variability in annual flow from year to year is driven mainly by headwater snowpack volumes. Spring runoff peaks in the NSR are determined by local snowpack volume as well as by climate (for example, how rapidly temperatures rise) in the spring.



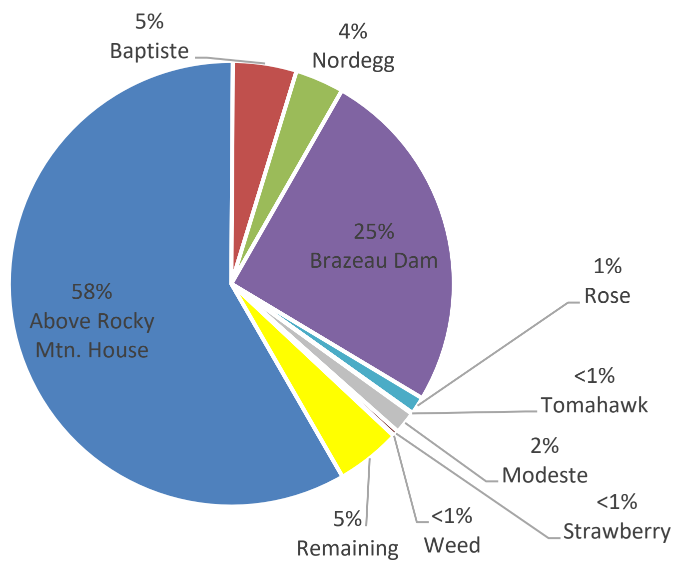
Data Source: Water Survey of Canada 2020

Figure 65. Daily Mean Hydrograph of the NSR Flow Based on 1970 to 2019 Water Survey of Canada Data at Edmonton (05DF001, Edmonton Low Level Bridge).

Flow gauge data from monitored tributaries were evaluated from 2005 to 2020, and similar trends were observed as per the Golder (2008a) report. In the open water season, contributions from headwater areas above Rocky Mountain House (RMH) comprise 60% of the flow at Edmonton and this is largely from snowmelt, though groundwater contributions occur as well (Figure 66). Contributions from the Brazeau River and reservoir continue to play on important role, comprising 26% of the flow. Mid-stream reaches, where land use is primarily agriculture, comprise a small amount of overall flow to the NSR. For example, Rose, Weed, Modeste, Tomahawk and Strawberry creeks comprise approximately 5% of the annual open water flow in the NSR. The Baptiste and Nordegg Rivers, whose watersheds remain largely forested, comprise 9% of the open water flow.

During the winter months, a continuous supply of groundwater augments flow to the NSR when runoff from the landscape does not occur. Groundwater, combined with contributions from upstream dams (Brazeau and Bighorn), comprises the majority of flow during the winter months; however, flows of the NSR at Rocky Mountain House are not typically monitored during the winter; therefore it is not possible to determine the relative contribution of the sources of the flow.

Although mid-reach streams contribute less than 5% to the NSR flow on an annual basis, during spring runoff period they can contribute almost 50% the flow of the river.



Data Source: Water Survey of Canada 2020

Figure 66. Open water flow contributions (May to Aug) to the NSR at Edmonton (2005 to 2020).

The relatively low contributions of these mid-reach tributaries mean that, from a water quantity perspective, they are less important than headwater areas. However during spring runoff periods, before snowmelt has occurred in the headwaters, they can combine to make up a large proportion of the flow of the NSR. For example, during the spring runoff periods in 2005 and 2011, the mid-reach streams contributed to over 20% of the flow the NSR at Edmonton (Figure 67). Because land use in these watersheds have been altered significantly in the last 100 years, during certain periods, these streams can have a significant impact on NSR water quality. However, during years with smaller or more gradual spring runoff, such as 2008 and 2010, the contribution of the mid-reach streams remained small. Colour in the NSR at EPCOR's WTPs is closely related to the intensity of the spring runoff, and how much these mid-reach streams contribute to flows in the NSR.

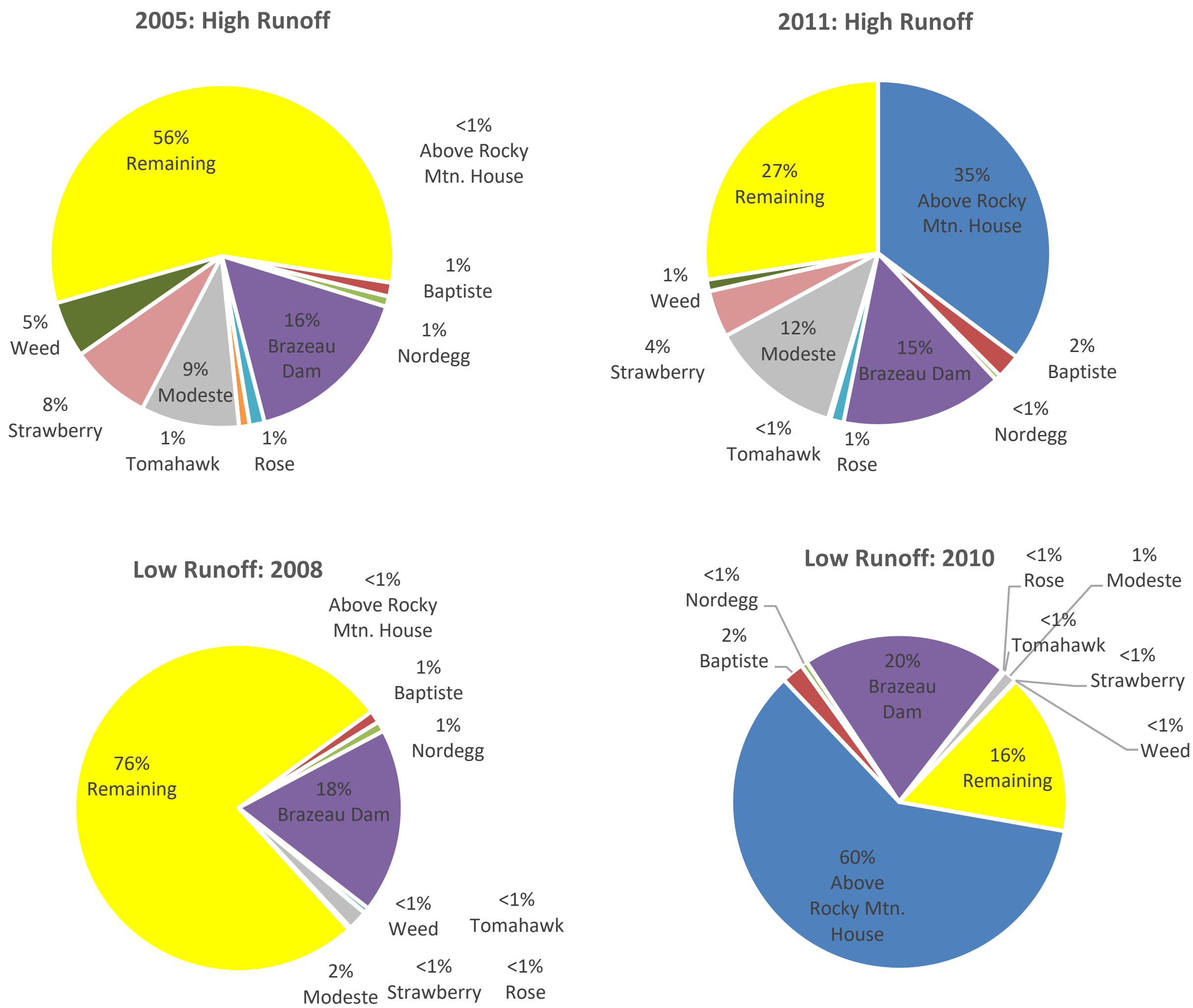
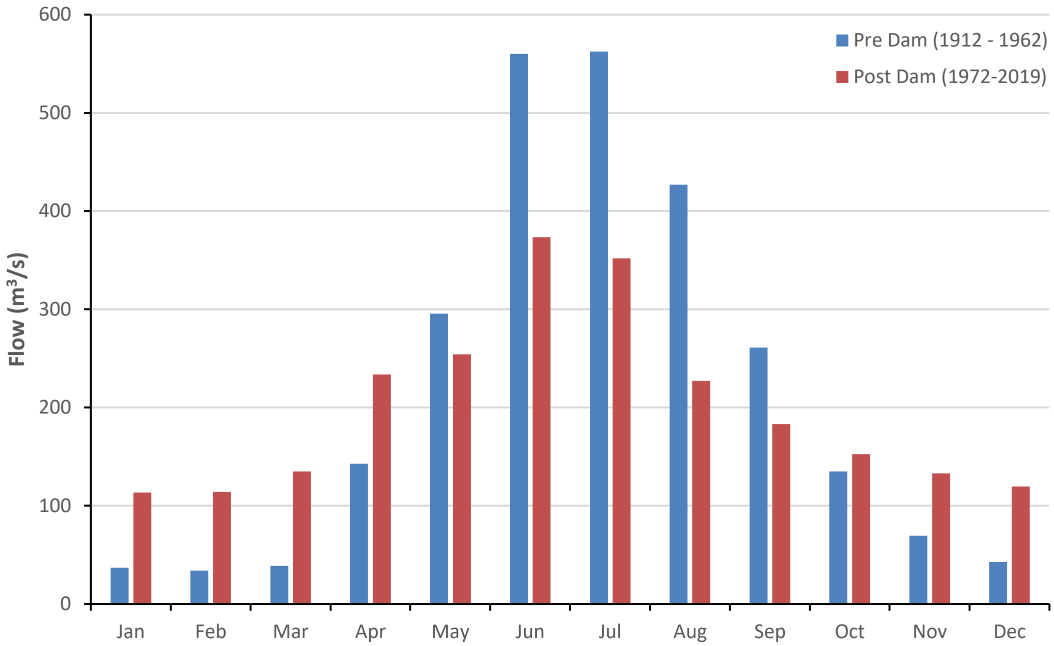


Figure 67. Contirubtion of flow during years of high spring (2005 and 2011) and low spring runoff (2008 and 2010) to the NSR upstream of Edmonton.

Water Supply Trends

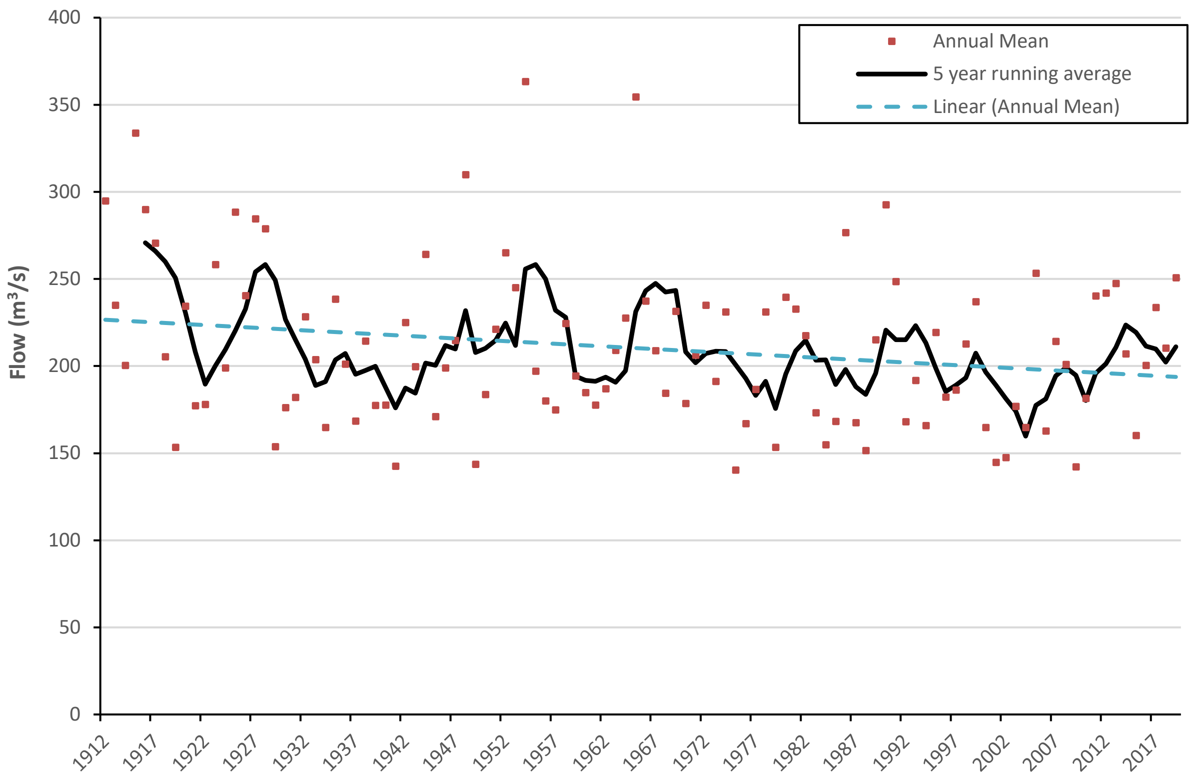
The normal operation of the Bighorn and Brazeau dams have altered the natural flow regime of the NSR, resulting in increased flows in the winter and decreased flows in the summer (Figure 68). This has resulted in a more consistent source of high water quality in the NSR during the winter months. The dams typically reach full capacity in late summer and early fall, and are nearly emptied by the start of spring runoff each year. As a result, the dams do not substantially alter the annual discharge of the NSR, but only the timing of the flows. The purpose of the two dams are for the generation of hydroelectric power, and they offer little protection against floods or droughts.



Data Source: Water Survey of Canada 2020

Figure 68. Mean Monthly NSR Flows at Edmonton Before and After Dam Operation

From a source water protection view point, it is important to understand how water availability has changed through time. Total annual flow in Edmonton shows a statistically significant decreasing trend through time, but also considerable interannual and decadal variability (Figure 69). These interannual and decadal trends in NSR flow are linked to ocean-atmospheric oscillations such as the El Niño Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) that alter the hydroclimate of western North America, and flow patterns in the NSR (Sauchyn et al. 2020). ENSO phases typically last less then a year, and reoccur every 3 to 7 years, whereas the PDO is a decadal cycle, which can remain in the same phase for 20 to 30 years. El Niño is associated with warmer temperatures and below average precipitation in western Canada, while La Niña is associated with cooler and wetter conditions. Likewise, the negative phase of PDO is linked to higher stream flows in western Canada, and the positive phase is linked with lower flows (St. Jacques et al. 2010). Floods in the NSR are more likely to occur during the positive phase of the PDO (Gurrapu et al. 2016), while droughts are more likely to occur during the negative phase (Sauchyn et al. 2020). In summary, given the high natural variability and decadal oscillations of flow, a simplistic linear trend over the past 100 years is insufficient to address the question of if flows in the NSR are declining over time. Over the past 50 years, there has been no decreasing trend in flow. If flows in the NSR are decreasing over time, the decline is small relative to the observed variability.

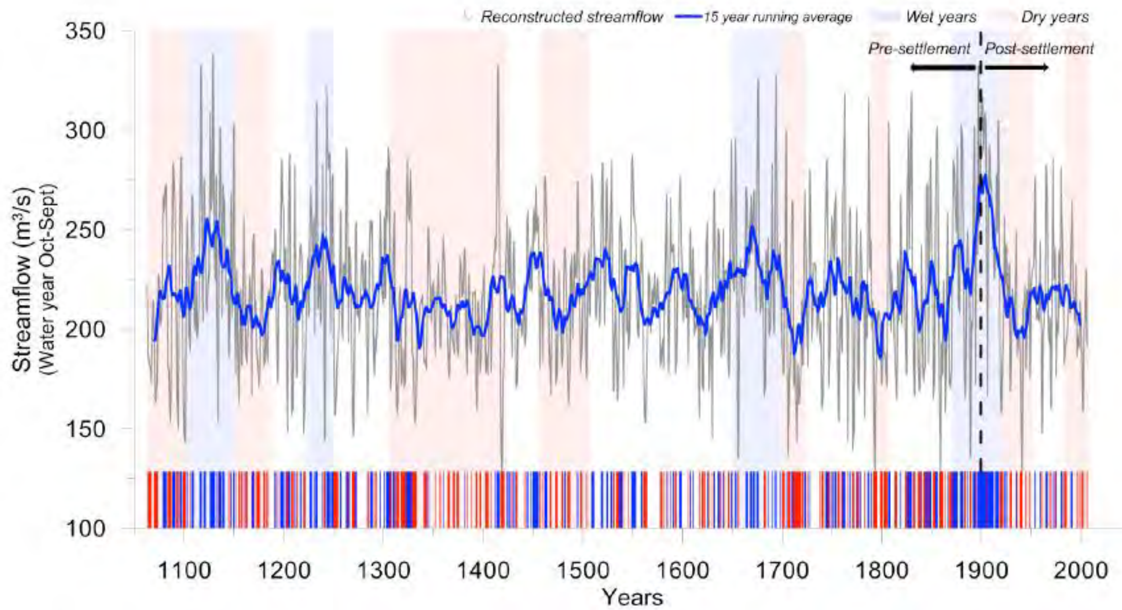


Data Source: Water Survey of Canada 2020

Figure 69. Mean Annual NSR Flows and Five Year Running Averages, 1912 to 2019.

The flow gauge record on the NSR provides a little over 100 years of data and does not provide a complete picture of natural variability of flow in the river. EPCOR partnered with Prairie Adaptation Research Collaborative (PARC) to determine the natural hydroclimatic variability of the NSR beyond the recorded gauge record. PARC's collaborative team used an innovative method of tree ring growth correlated with the precipitation record to extend the gauge record for the NSR from the mid-11th century (1063) to the end of the 21st century (Sauchyn et al. 2011; Figure 70). The main findings of the report were:

- The 100-year gauge record does not capture the full range of natural variability in the flow of the NSR;
- The NSR basin was settled during one of the wettest periods on record;
- Drought periods similar to the 1930s are not uncommon, and have historically been longer and more intense;
- Storage behind the Bighorn and Brazeau dams will help mitigate these impacts since low flows can be managed with the release of stored water. However, stored water will not be available to enhance summer flows if there is a dramatically reduced snowpack and/or drought in consecutive years. The worst-case scenario would be a prolonged drought, as shown in the reconstruction of the natural flows.



Note: Red bars and shading represent low flows in the 75th percentile, while blue bars and shading represent high flows in the 25th percentile. Reconstruction is smoothed with a 15-year running average (blue line).

Figure 70. Sustained Wet and Dry Intervals for Streamflow Reconstruction for the NSR, 1063 - 2006 (From Sauchyn et al. 2011).

The research conducted by PARC and Sauchyn et al. (2011) provides critical information about annual flows in the NSR over the past 900 years; however, annual flows are not necessarily helpful, as the risks to Edmonton's water supply are dependent on instantaneous flows in the NSR. Sauchyn and Ilich (2017) used the 900 years of tree-ring data to generate weekly flow estimates for this period. The flow data generated represent the naturalized flows at Edmonton, which assumes that there are no upstream dams on the NSR. EPCOR used the data provided by Sauchyn and Ilich (2017), and applied correction factors to the data to simulate the impacts of the upstream dams. To explore how drought may affect the water supply in the NSR, flows during a prolonged drought period from 1714-1718 (this drought is observable in Figure 70) were compared to EPCOR's current water withdrawals. These results show that during one of the largest droughts of the past 900 years, EPCOR's current withdrawals would take no more than 5% of the flow of the NSR assuming that flow is regulated by the upstream dams (Figure 71). However, if the flows in the NSR were naturalized (i.e., the upstream dams were removed), EPCOR's current withdrawals would take upwards of 18% of the NSR during the winter months.

To generate a worst-case scenario, the lowest flows of each week for the past 900 years were plotted against the EPCOR's highest weekly water use in the last five years. The results of this analysis show that there would be sufficient flow in the river to meet EPCOR's water withdrawals; however, upwards of 60% of the flow of the NSR would be withdrawn (Figure 72). Obviously this scenario is far from ideal, but it is important to note that even under an extreme scenario there is expected to be sufficient flow in the NSR for EPCOR to provide drinking water. It is also important to note that ~ 90% of the withdrawn water would be returned to the NSR via the wastewater treatment plants, as most use of water is not consumed, but is returned as treated wastewater.

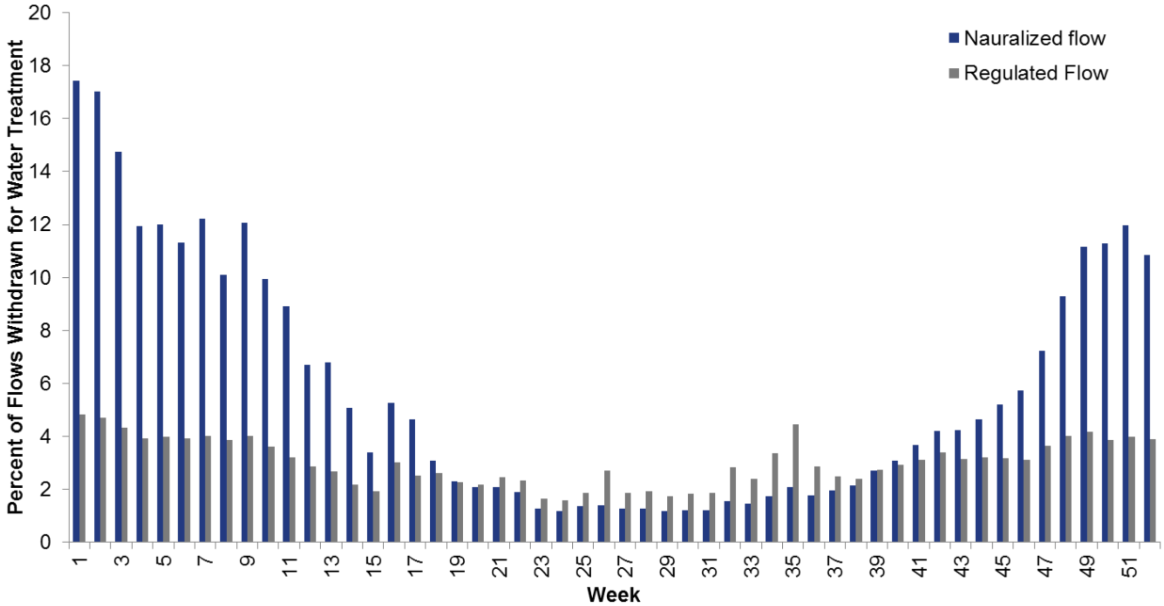


Figure 71. Mean Weekly Percent of the NSR Flow Withdrawn by the WTPs during a Historical Low Flow Period (1714-1718).

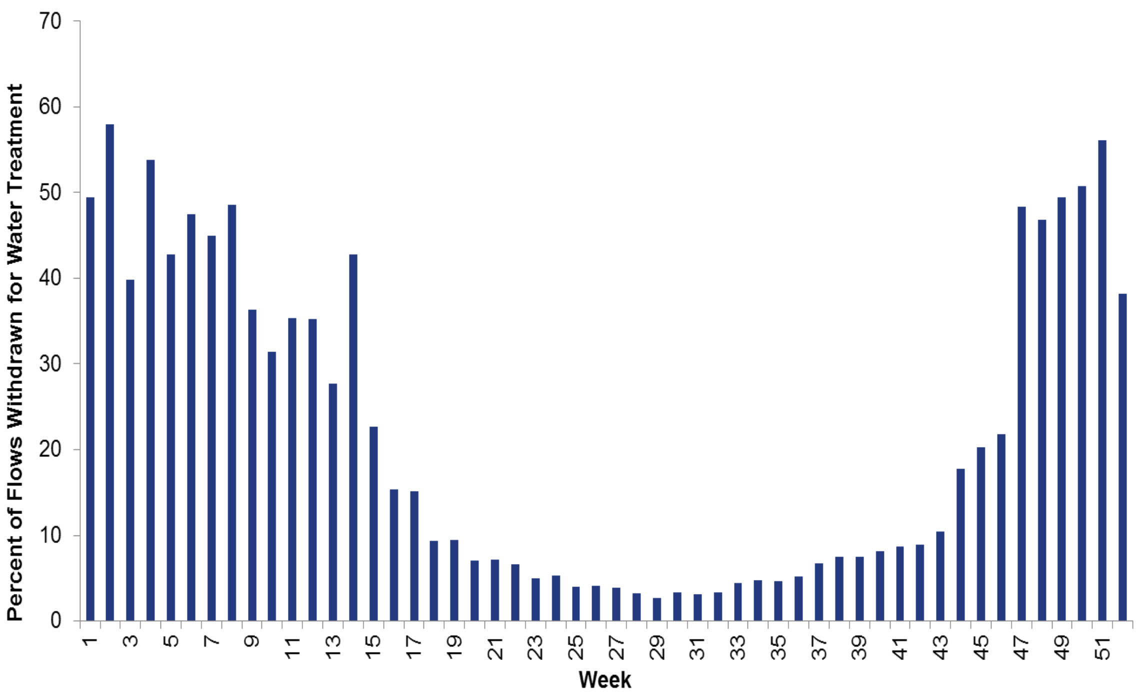


Figure 72. Highest Weekly WTP Withdrawal from 2012 – 2016 as a Percent of the Lowest Weekly Flows Each week for the 900 year NSR Flow Reconstruction.

Floods

As EPCOR's WTPs are both located in the NSR flood plain, flood events present a significant risk of damage to critical infrastructure. Even if direct damage does not occur, high water levels and high concentrations of organic material and suspended sediment can limit or completely prevent the ability of the WTPs to produce potable water for a period of time. Left unmitigated, 1:100 year return period floods or greater have the potential to cause significant damage to EPCOR's WTPs. Lower magnitude flood events, such as a 1:50 year return period flood, have the potential to cause shorter term disruptions to drinking water treatment due to an inability to drain the clarifiers at both WTPs. EPCOR is currently evaluating the susceptibility of the WTPs to floods events, and is implementing several projects improve their resiliency.

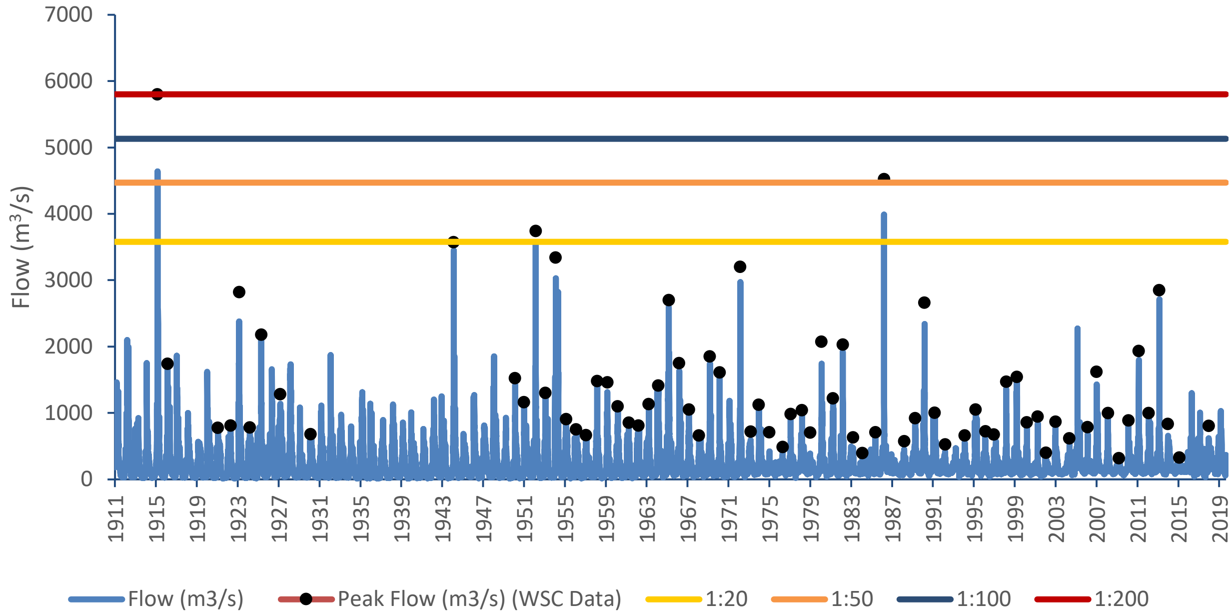
The five highest recorded flood events in gauge record are detailed in Table 13, along with the recent flood events of 2005 and 2013 (the 7th and 11th largest recorded flood events). Flows in the NSR along with the peak instantaneous flows and the flood return frequencies are presented in Figure 73.

Table 13. Historical High Flow Events in Edmonton

Year	Date	Average Daily Flow (m^3/s)	Maximum Daily Flow (m^3/s)	Return Frequency
1915	June 29	4,640	5,800*	1:200
1986	July 19	3,990	4,520	1:50
1952	June 25	3,540	3,740	1:20
1944	June 16	3,450	3,570	1:20
1954	June 8	3,030	3,340	1:10
2013	June 23	2,710	2,850	1:5
2005	June 21	2,270	2,611*	1:5

* Estimated

Data Source: Water Survey of Canada 2020, AEP 2020



Data Source: Water Survey of Canada 2020, AEP 2020

Figure 73. Daily mean flow and annual peak flows in Edmonton from 1911 to 2019

Current flood predictions and return frequencies do not consider the potential impacts of climate change, or future changes to the land use within the watershed. Climate change is anticipated to increase both the frequency and severity of precipitation events (Kuo et al. 2015), which may result in more frequent and severe flooding in the NSR. Increased development and growth of urban areas will increase the runoff from impervious surfaces. Forest fires can significantly increase the intensity of downstream flooding due to the loss of vegetation (Conedera et al. 2003) but risks of a fire of that magnitude in the watershed is very low.

The upstream Bighorn and Brazeau dams offer little protection against floods (AENV 1990). The area above the Bighorn dam typically does not experience major rainfall events that cause flooding in Edmonton, and the Brazeau dam typically has limited live storage during the summer months when flood events typically occur.

Ice Jam Flooding

High water levels on the NSR can also be caused by ice jams. On April 21, 2020 water levels at the Low Level Bridge rose 3.6 m over a period of four and a half hours due to an ice jam, causing minor flooding at the E.L. Smith WTP. It is not known how frequently ice jams occur on the NSR, and many presumably go relatively unnoticed or unreported. Ice jams that raise water levels enough to cause concern for EPCOR’s WTPs occur infrequently; however, the potential consequences are significant.

Ice jams can occur during both winter freeze up and spring breakup; however, ice jams associated with spring breakup are typically more significant due to increased flows that occur during spring runoff (Turcotte et al. 2019). While the mechanisms of ice jams are well understood, the ability to predict the frequency, severity, timing, likelihood and location of ice jams is complicated by the large number of interacting variables that are need to occur to generate an ice jam (Kovachis et al. 2017, Madaeni et al. 2020). Even in rivers that are highly monitored for ice jam flooding, such as the Athabasca River near Ft. McMurray, it is challenging to predict when and where ice jams will occur (Turcotte et al. 2019).

Climate change will have uncertain impacts on the frequency and severity of ice jams in the NSR and other rivers (Turcotte et al. 2019). Warmer winter temperatures may contribute to thinner ice cover and therefore fewer ice jams. Warmer spring temperatures and increased precipitation during the winter and spring may also contribute to increase thermal breakups of ice, again reducing the likelihood and severity of ice jams. However, warmer spring temperatures and increased precipitation during the winter and spring could also result in more frequent and severe ice jams. Turcotte et al. (2019) concluded that future ice-jam flood risk under a warming climate in Canadian rivers may increase, decrease, or remain unchanged. Rokaya et al. (2019) looked at the frequency of ice jams in the Athabasca River under climate change scenarios and concluded that the probability of ice jam flooding would decrease, but extreme ice jam floods would still occur.

In summary, ice jams on the NSR severe enough to impact EPCOR's operations occur infrequently, and there is no definitive research to suggest this will change in the future. EPCOR has had multiple discussions with Dr. Yuntong She at the University of Alberta, who is conducting research on ice dynamics in the NSR. Future research and collaboration may help inform future predictions on the frequency and severity of ice jams in Edmonton.

Effect of Current and Future Water Use on Supply

> Approximately 27% of the NSR flow is allocated for use. Of that, less than 3% is considered consumptive use where it is not returned directly to the river after use.

To better understand emerging water quantity issues for the NSR, the NSWA commissioned a report on the current and future water use in the NSR basin (AMEC 2007). The NSWA presented an unpublished update to this report, and in general found the trends unchanged (NSWA 2017). The 2007 report provided a comprehensive analysis of water allocations, licensing and use. The analysis was divided by sub-basin and sector (type of use) and summarized current annual and estimated future use (to the year 2025). It was determined that the current annual surface water allocations total about 2 billion m^3 – or approximately 27% of the river's average total annual discharge as measured at the Alberta-Saskatchewan border. Of all allocations, 98% are for surface water. Further, upstream sub-basins (Modeste and Strawberry) hold 65% of the total allocations. However, many licensees' actual water use volumes are much less than their allocations. In the Modeste sub-basin most of the allocation is for cooling purposes for power generation and it is estimated that 88% of this is returned to NSR. The report identified that, watershed wide, current actual use is about 0.19 billion m^3/per year, or 2.6% of the average annual NSR discharge. Both river flow and use will vary throughout the year and these percentages vary accordingly.

Based on findings of the 2007 report, future municipal water use in the basin is expected to increase by 16% in a medium growth scenario, with the majority of growth occurring in the Edmonton Capital Region sub-basins. However, the unpublished 2017 update to this report found that although population increased by 26% since 2006, the water allocations for municipal licenses have only increased by 1% and that EPCOR has only increased the volume of water treated by 2.2%. This has been achieved by increased water-use efficiency as the Edmonton per capita water use in 2019 was 271 L per person per day compared to 345 L per person per day in 2010.

Increased water use upstream of Edmonton is not expected over the next 15 years. Currently, less than 5% of the daily flow is withdrawn for drinking water purposes and most of that is returned to the NSR.

The Modeste sub-basin has seen a 24% decrease in water use due to the decreased need for cooling purposes associated with power generation. In summary, water use in the NSR in 2016 is similar, or slightly lower than use in 2006. Further, there are no foreseeable changes to water use upstream of Edmonton, and the availability of water due to increased consumption is not a primary concern for Edmonton.

Currently, the volume of water in the NSR is high compared to the amount of water withdrawn by the WTPs for drinking water purposes. The average daily percent withdrawal for the Rossdale and E.L. Smith WTP is less than 3% of the total daily flow (Figure 74). Seasonally, withdrawals make up a greater percentage during winter low flow periods (around 4%) compared to during open water periods (2% to 3%; Figure 75).

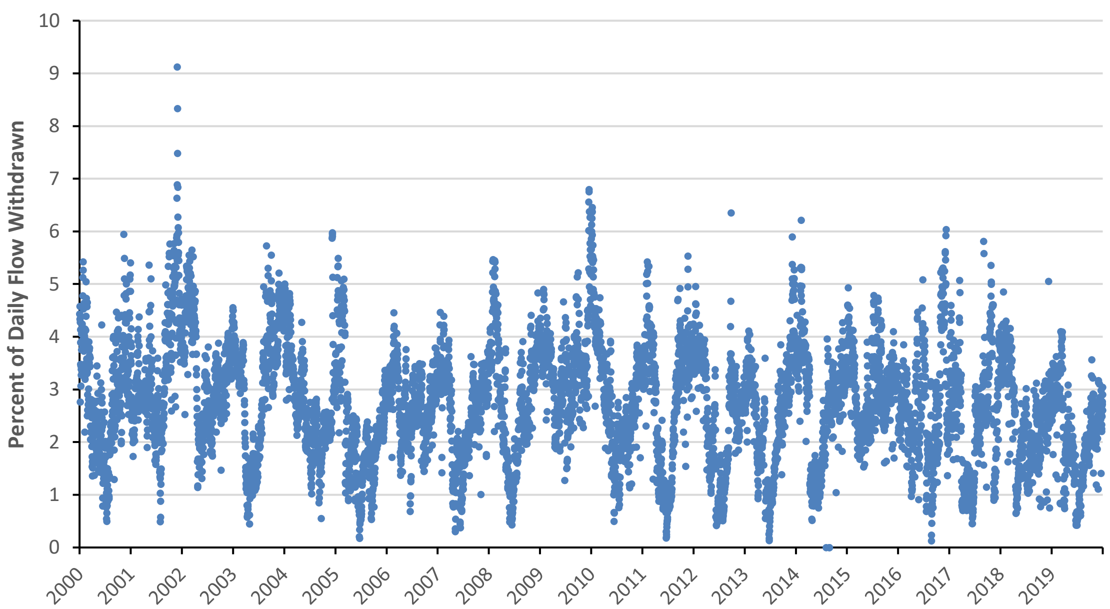


Figure 74. E. L. Smith and Rossdale WTP Daily Intakes as a % of NSR Flow from 2000 – 2019

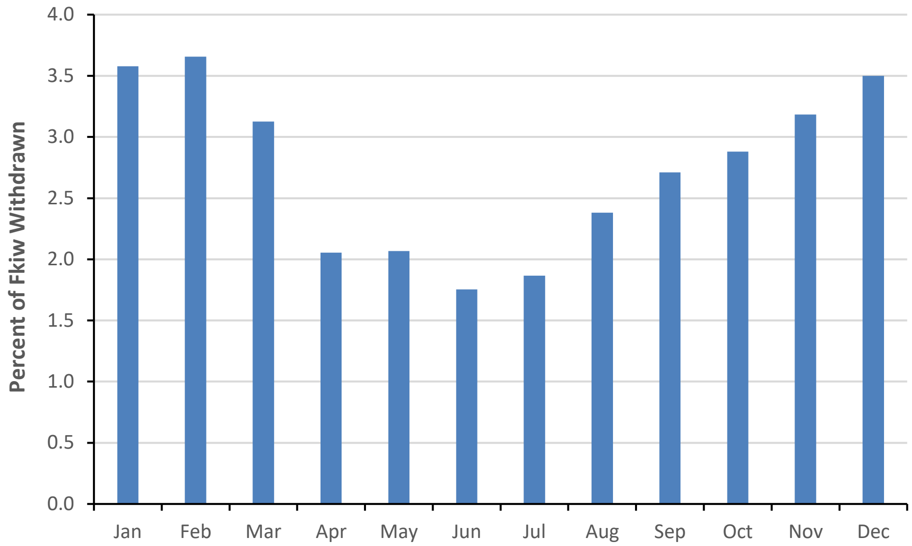


Figure 75. Mean daily % of NSR flow withdrawn by E. L. Smith and Rossdale WTPs by month from 2000 to 2019.

Effect of Climate Change on Supply

It is critical to consider the availability of water in the NSR in the future under a changing climate. EPCOR understands that water resources are not stationary and that historical trends and patterns may not be applicable under a changing climate. Water management must be adjusted to a hydrological cycle which is increasingly sensitive to the timing and frequency of rainfall events, and has less of a buffer from glacier ice and late snowmelt. EPCOR has engaged and supported Dr. David Sauchyn and the researchers at PARC to develop future predictions and evaluate the uncertainty of model projections on the streamflow in the NSR (Sauchyn et al. 2020).

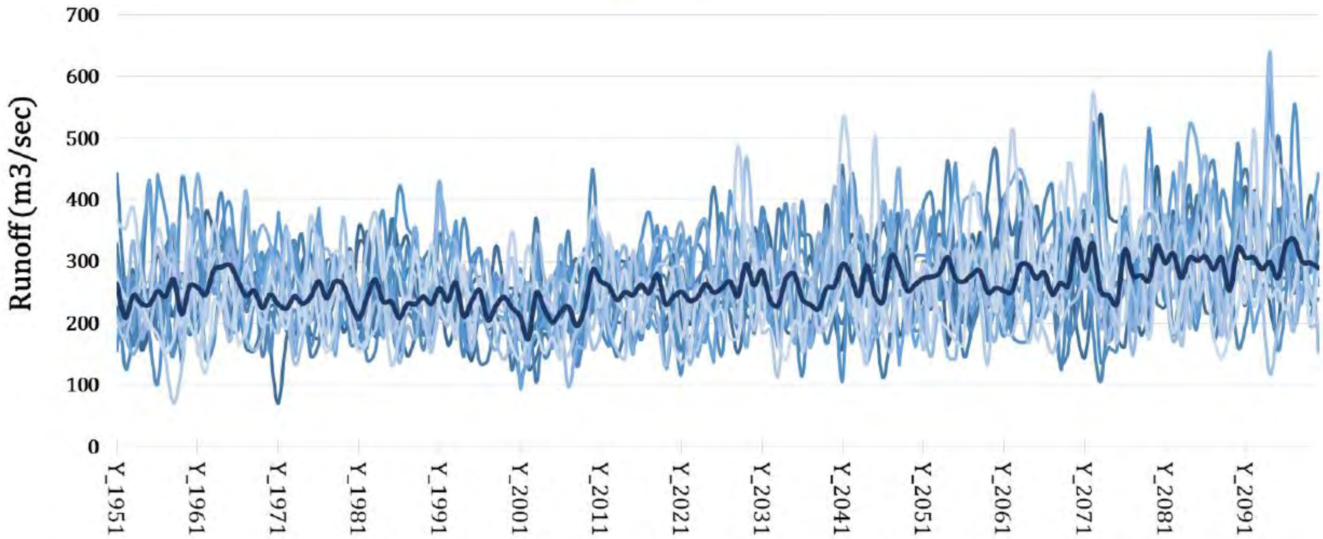
In Edmonton, mean annual temperatures have risen by more than 2 ^{o}C; however, summers? are not getting hotter, but rather, winters are much less cold, with temperatures rising 6.5 ^{o}C during winter months (Sauchyn et al. 2020). Mean annual precipitation has also increased in Edmonton; however, the increase is small relative to the large inter-annual and decadal variability (Sauchyn et al. 2020). In the headwaters of the NSR, mean annual temperature has already increased by 1.5 ^{o}C, and future increases will be over 3 ^{o}C in the next 25 – 50 years (Weaver 2017).

Climate models run within the NSR basin by Golder (2008b), Kienzle et al. (2012) and Sauchyn et al. (2020) consistently predict increased temperatures and precipitation, earlier spring melts and increases in annual flow. Model data provided by Sauchyn et al. (2020) predicts an 8% increase in total annual flow by the year 2080, and increased interannual variability (Figure 76). The increased variability between years may be the more significant impact compared to a modest increase in flow. The overall increase in flow is driven by increased flow in the winter and spring that is offset by decreased flow during the summer month. This is driven by warmer temperatures, increased evaporation, and an earlier decline in snow pack (Figure 77).

Climate change is expected to lead to early spring melt and lower summer flows, and an overall increase to the annual NSR flow. A greater threat is a prolonged drought, which is not uncommon in the NSR basin.

Natural and Externally Forced Hydroclimatic Variability in the North Saskatchewan River Basin- is a project that was initiated by EPCOR in 2018 and done in collaboration with the Prairie Adaptation Research Collaborative (PARC). The project sought to develop projections of future climate and flow in the NSR at Edmonton using the latest Regional Climate Models (RCMs). Projections of future climate and flows in the NSR in previous studies have been derived from Global Climate Models (GCMs). Flows for the NSR at Edmonton were derived using the MESH (Modélisation Environmentale-Surface et Hydrologie) land surface hydrology model, and 15 runs of the Canadian Regional Climlate Model (CanRCM4) under the RCP 8.5 emission scenario (i.e., business as usual). Projected flows are based on the naturalized flow in the NSR, which assume that the upstream dams are not in operation. Understanding how operation of the dams may change under future climate scenarios will be explored in further studies.

Modelled results show that the timing of spring runoff, peak summer flows and the decline in flows in the fall will each advance by a month for the period of 2041 – 2100. It is important to note that the flows depicted in Figure 77 are the naturalized flows of the NSR, which assume no operation of the Bighorn or Brazeau dams. However, as described above, the operation of the two upstream hydroelectric dams have a profound effect on the timing of flows in the NSR. Thus, the resulting flows in the NSR will be affected not only by changes in climate, but how the upstream dams alter their operations due to changes in the timing and magnitude of flows into their reservoirs. EPCOR has been engaging with TransAlta regarding how climate change may affect the operations of both organizations.



Note: Simulated mean annual runoff from 15 model runs. Dark blue line represents the mean.

Figure 76. Mean Annual Runoff in the NSR at Edmonton from 1951 – 2100 (From Sauchyn 2020).

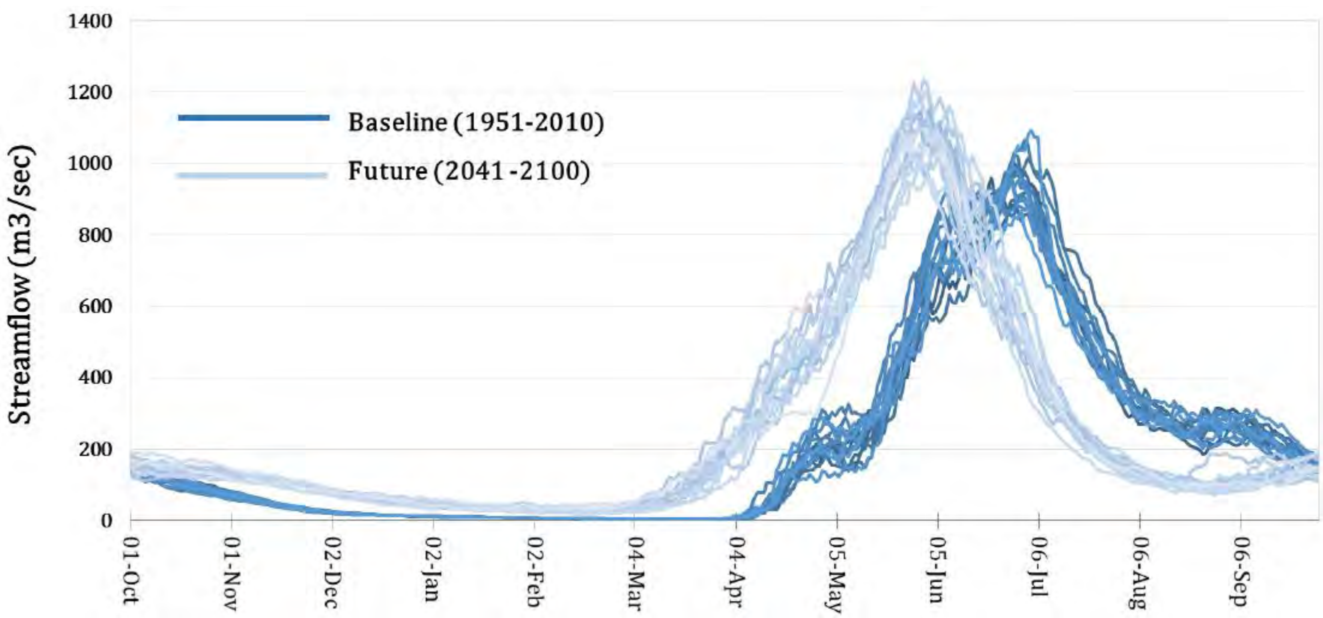


Figure 77. Naturalized Daily NSR Flow in the NSR at Edmonton under Baseline and Future Climate (From Sauchyn 2020).

Alternative Water Supplies and Groundwater

EPCOR engaged Stantec to evaluate various alternative water supplies to determine their feasibility in the event of a hydrocarbon spill. Stantec (2017) evaluated six lakes (Wabamun, Lac Ste. Anne, Cooking, Beaverhill, Pigeon and Big lakes), three river locations (Athabasca, Red Deer and Sturgeon Rivers) and groundwater as alternative water sources for temporary and permanent requirements. Based on their review, Wabamun Lake and Lac Ste. Anne were considered as the primary options for use as a temporary alternative source of water. Costs of setting up a temporary water supply system with hoses and pump stations for a 30-day period from either of these sources would exceed $80 million. Additionally, neither of these lakes has sufficient water volume to be considered a permanent water source. Both the Athabasca and Red Deer rivers were considered for a permanent water source in the 2017 study, with the Athabasca River being preferable due to higher water quality and quantity. Costs of setting up a permanent water supply from the Athabasca River could approach $520 million, not including land costs.

Groundwater was evaluated by Stantec (2017) as an alternative source of water and it was concluded that a single well could not supply Edmonton's water demand, and that a well field, consisting of multiple wells would be required. Additionally, Stantec concluded that more detailed studies would be required to fully evaluate the potential for groundwater. Groundwater as an alternative water source may be an added source of resiliency, not only in terms of hydrocarbon spills (which was the focus of Stantec's report), but also in terms climate change, which may reduce the quantity and quality of other surface water sources evaluated by Stantec (2017).

Godfrey (1993) provides an overview of groundwater resources in the Edmonton Area and states that freshwater aquifers are found in cretaceous bedrock and surficial deposits. Bedrock aquifers in Edmonton are found in the Horseshoe Canyon Formation which was deposited 65 to 100 million years ago in a largely swampy, deltaic environment which was occasionally flooded by the sea. The lowermost depths of this formation contains multiple coal seams, and where these coal seams are fractured, they constitute important aquifers. These wells are generally capable of producing groundwater at rates ranging from 0.4 to 7.5 L/s, but coal seams beneath the Cooking Lake Moraine (a short distance east of Edmonton) may be more productive. Wells 45 m deep in this area can produce up to 8 L/s, and wells between 45 and 60 m deep can produce up to 2 L/s. Water from coal aquifers generally has high TDS, between 1,000 and 1,500 mg/L, and high iron and would requires treatment for iron and TDS reduction.

Alternatively, aquifers in surficial deposits are the result of more recent glacial activity. As described in Section 3.2.2, the ancestral flows of the North Saskatchewan River were stopped by glaciers and these river valleys were buried by deposits from the resulting Glacial Lake Edmonton. These ancient river channels are now buried-valley aquifers, and are the most important and productive aquifers in the Edmonton region. These larger valleys can produce water in rates in excess of 8 L/s in many places. Godfrey (1993) states that as much as 30 L/s has been pumped continuously by the town of Stoney Plain to lower the water table for more than 15 years. The chemistry of groundwater in these surficial deposits differs significantly from water in the underlying bedrock and the water is generally hard because of high calcium and magnesium concentrations. TDS concentrations can vary over short distances and range from 500 to 3,000 mg/L, and can be as high as 6,000 mg/L in some locations. Additionally, these waters often have high iron content and require iron removal for drinking water.

A more recent assessment of groundwater in the Edmonton area by Barker et al. (2011) suggests in the Edmonton area, the recommended groundwater extraction rates are between 0.5 and 0.75 L/m, but note that they do not represent the actual groundwater yield possible for each geological formation. Barker et al. (2011) also report that the hardness of groundwater in much of the Edmonton region ranged between 250 and 500 mg/L and that some areas to the east are above 500 mg/L. Similarly, total dissolved solids (TDS) is typically less than 1,000 mg/L but range between 1,000 and 1,500 mg/L in some areas. In a series of reports, Barker et al. (2013a, b, c, d and e) provide more detailed maps of groundwater chemistry (including calcium, magnesium, sodium, potassium, chloride, sulphate, alkalinity, iron, TDS and hardness) of bedrock and surficial aquifers in the Edmonton region. This series of reports would be an important resource when undertaking a more detailed evaluation of the feasibility of utilizing groundwater resources.

Despite the previously mentioned studies, relatively little information is known about groundwater resources in the basin. It is not known what fraction of the river flow at Edmonton is comprised of groundwater, or where the sources of groundwater in watershed are located. As described above, buried pre-glacial channels exist in/near Edmonton, but the volume of groundwater in the channels their recharge rates, and their ability to interact with the NSR is unknown. There is also limited understanding of how drought, climate change and future land use changes may impact surface water-groundwater interactions. EPCOR is providing financial support to a research project led by the University of Alberta and the Alberta Geological Society to provide a greater understanding of groundwater resources in the NSR.

In order to fully determine if groundwater is a feasible source of water supply for Edmonton, additional studies would be required. It is unclear if there is sufficient volume, and water quality would also need to be explored in greater detail. Additionally, EPCOR would need to determine if groundwater would feasible as presumably a large well field, with a large number of wells would need to be built to meet water demands.

3.4 Potential Hazards

By using a risk management approach, EPCOR has identified hazards to the water supply which could impair the operation of the components of the water system and result in threats to public health. This was informed by the detailed characterization of the watershed found in the previous sections. The risk assessment was done as part of EPCOR's Drinking Water Safety Plan (DWSP) (see Section 3.6.5) using an EPCOR methodology authorized by AEP.

A hazard refers to a source of (potential) harm to the functioning of any aspect of the drinking water system or to human health. Hazards can be the result of natural and/or human (anthropogenic) activities. A risk refers to the chance or possibility of a hazard causing this harm to the functioning of any aspect of the drinking water system or to human health (CCME 2004).

Refer to Table 14 for a list of all potential hazards. See Table 15 for a list of various contaminants associated with the identified hazards and Table 16 for a list of concerns related to potential contaminants in the NSR raw water source.

Table 14. Potential Hazards for Edmonton's Drinking Water System.

Source	Land-uses / Potential Contaminant Source/Activity
POINT	Small urban waste water discharges
	Pipeline break
NON-POINT	Livestock waste excretion
	Livestock physical alteration of watershed
	Agricultural cropping activities
	Agricultural land cover and use
	Wildlife activity in watershed.
	Rural septic fields
	Small urban stormwater runoff
	Forest harvesting activities
	Pine beetle infestation
	Forest fires
	Waste disposal sites
	Alteration in climate (natural and anthropogenic)
	City of Edmonton stormwater runoff
	Contamination of pet fecal matter in urban areas
	Proximity to transportation corridor
	Spill on a bridge
	Recreational activities
	Ground water contamination from airport
	Gravel extraction
	Coal surface mining
	Disposal of animal remains within watershed
	Dam operation and management
	Contamination of shallow aquifers
	Industrial land spillage
OTHER	Intentional contamination at critical source intakes
	Insufficient raw water quantity
	Catastrophic failure of dams
	Contamination of raw water due to intentional dumping or release of chemicals from industries
	Construction activities on the River – Upstream Bridges
	Lack of integration among watershed and other land and water planning initiatives

Table 15. Various Contaminants Associated with the Identified Hazards (Land-Use and Pollutant Analysis Matrix) (Water Research Foundation 1991).

Land-use/ Potential Source	Contaminant											
	Turbidity	pH	Nutrients	Algae	Viruses/ Parasites	Bacteria	THM Precursors	Pesticides	Other SOCs	VOCs	Heavy Metals	Iron/ Manganese
Hazardous Materials								X	X	X	X	X
Urbanisation	X	X	X	X	X	X	X	X	X	X	X	X
Municipal WWTP and Lagoons	X	X	X	X	X	X	X	X	X	X	X	X
Agricultural Grazing	X		X	X	X	X	X					
Industrial Discharges	X	X	X	X		X	X	X	X	X	X	X
Recreational Activities					X	X						
Roads	X		X	X			X					X
Mining	X	X	X								X	X
Cropland Runoff	X		X	X	X	X	X	X			X	X
Dairies / Feedlots	X		X	X	X	X	X					
Septic Systems		X	X	X	X	X	X	X				
Acid Rain		X										
Forest Management	X		X	X		X	X	X				X

Hazardous Materials: oil and gas pipelines, waste disposal sites, chemical and fuel storage sites, spills, grease and toxic chemicals. THM: Trihalomethane. SOCs: synthetic organic chemicals. VOCs: volatile organic compounds.

EPCOR

Table 16. Concerns Related to Potential Contaminants.

CONTAMINANT CATEGORIES		CONCERNS
Microbial Pathogens*	bacteria, protozoa, viruses, parasites (Giardia, Crypto, *E. coli* 0157:H7)	Most significant effect to public drinking water because the effects are acute.
		If ingested, pathogens can give people gastrointestinal illness within hours or days.
		Some cases, ingesting pathogens can result in permanent damage to internal organs or lead to chronic health problems.
		In the most severe cases, ingesting pathogens can be fatal.
Chemical and Radiological Contaminants	pesticides, inorganic chemicals (metals, total dissolved solids)	Health effects tend to be chronic, only appearing after people are exposed to high levels of the substance consistently over a period of years.
		Generally, only a small percentage of the population would see any effects.
		Health effects vary depending on the specific contaminant.
Physical Water Quality Parameters	turbidity, sediment, colour, taste and odour, temperature, pH	Physical characteristics do not pose a direct threat to human health.
		Can indicate presence of other chemical or biological concerns.
		Particulate matter (turbidity) can interfere with drinking water treatment processes, thereby increasing the risk of microbiological threats.
		WTPs have difficulty operating under these types of conditions
Interactions between Contaminant Categories		It is important to note, different types of hazards could interact with one another.
		Interaction may result in synergistic or antagonistic effects.

3.4.1 Point Source Contamination

Point source contamination is a source of pollution that can be traced back to a specific location (point of discharge and/or origin).

The following is a list (in no particular order) of possible point source contamination hazards that could affect the NSR raw water:

- Small urban communities waste water from continuous waste water discharges (Rocky Mountain House, Drayton Valley and Devon) and other municipal sewage lagoons discharging pharmaceuticals, personal care products, contaminants of emerging concern, nutrients, pathogens and hazardous chemicals
- Industrial discharges or dam/tailing pond breaches releasing hazardous chemicals
- Pipeline breakage releasing hydrocarbons or other chemicals

3.4.2 Non-point Source Contamination

Physical, chemical, and biological characteristics and processes in a watershed affect the water quality of waterbodies that drain these areas. Changes to either the processes and/or physical characteristics of a watershed will ultimately lead to changes in water quality in downstream waterbodies. If these changes result in alteration of background water quality and/or quantity, it can be considered pollution. Without the ability to trace back to a single point of origin and/or discharge, it can be defined more specifically as non-point source pollution (NPSP). Examples of NPSP include: the addition of chemicals to the land base (e.g. nutrients, pesticides) which then run off into waterbodies and increase background levels and alteration of watershed functions and processes such as the removal of trees resulting in erosion and increased sediment concentrations in receiving waterbodies.

The following is a list (in no particular order) of possible non-point source contamination hazards that could affect NSR raw water:

- Agriculture – fertilizers and pesticides from cropping, bacteria, and nutrients from livestock waste excretion, increased erosion, and movement of contaminants from physical alteration of watershed
- Stormwater/urbanization – excess nutrients, metals, sediment, fertilizers, herbicides, insecticides and pet waste
- Mining – sediment, nutrients, dissolved solids, metals from leachate
- Forestry activities – sediment and nutrients from increases erosion, herbicides
- Roads – sediment and nutrients from increases erosion, metals, salt
- Construction sites – hydrocarbons, sediment
- Recreational activities – sediment and nutrients from increases erosion
- Septic systems – bacteria, nitrate, ammonia, pharmaceuticals, personal care products
- Atmospheric deposition – metals, contaminants of emerging concern
- Accidental spills / releases – hydrocarbons/petroleum products, heavy metals

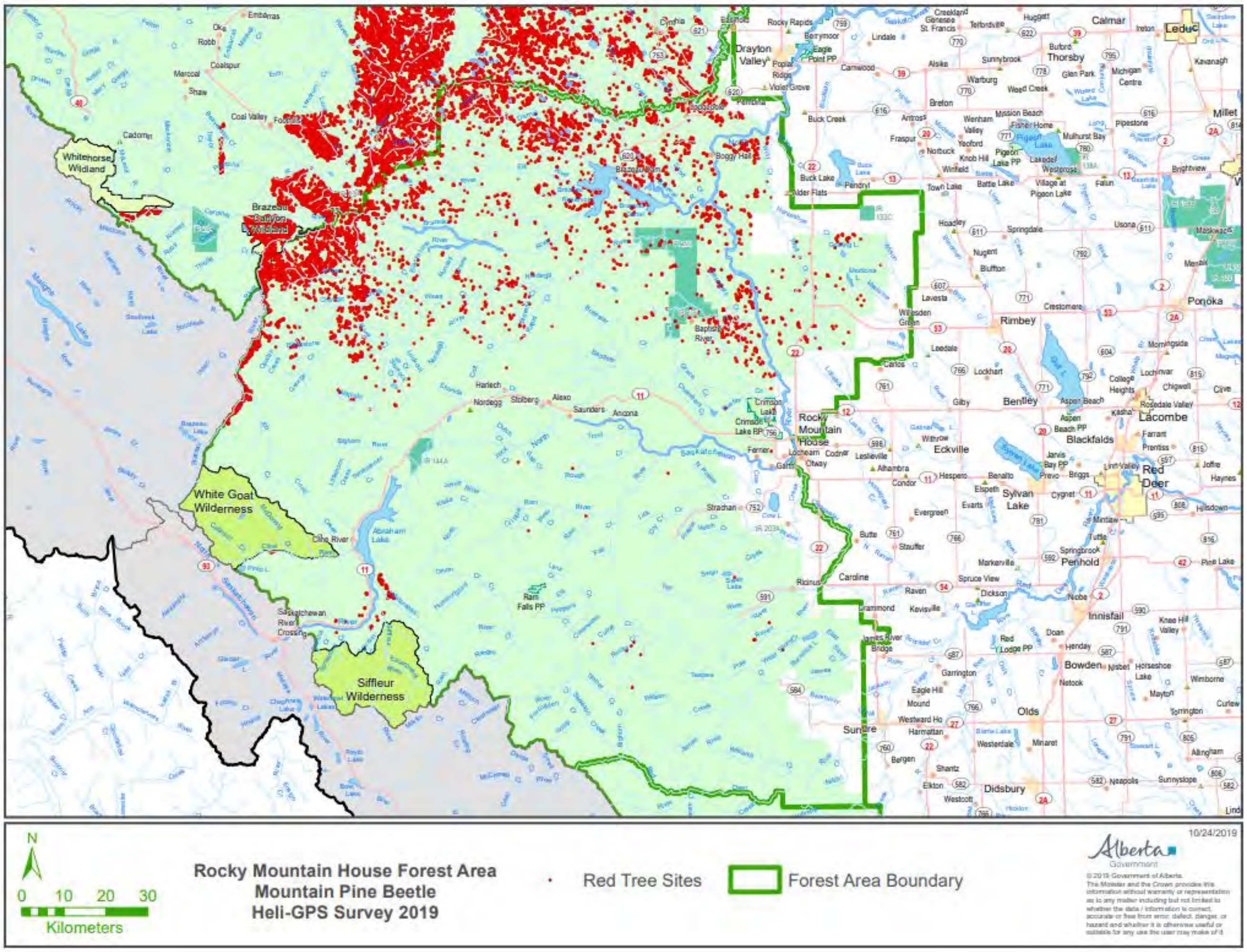
3.4.3 Other Potential Hazards

<u>Mountain Pine Beetle</u>

The mountain pine beetle (*Dendroctonus ponderosae*) is a small (< 1 cm) insect with a lifecycle that is spent mostly beneath the bark of pine trees and are native to temperate pine forests from Mexico to central British Columbia. They play an important role in pine forests because their preference for stressed and over-mature (80+ years) trees allows for the development of a younger forest. However, when populations of mountain pine beetle grow, they can attack young and healthy trees and cause significant and widespread mortality of pine forests. The loss of functional tree cover can negatively impact a watershed through rising water tables, increases in streamflow due to reduced evaporation, earlier run-off patterns, and increased soil erosion; all of which can cause increased turbidity and decreased water quality. Large abundances of dead trees could increase the risk and severity of forest fires; however, research in the US Pacific Northwest suggests that mountain pine beetle infestations are not correlated with the frequency of forest fires and may reduce the severity of forest fires (Meigs et al. 2015, Meigs et al. 2016)

Cold winter temperatures have historically prevented mountain pine beetles from establishing in Alberta, as winter temperatures below -40 ºC result in significant beetle mortality (AESRD 2010). Localized outbreaks of mountain pine beetle occurred in Alberta in the 1940s and again in the 1970s. Forest management practices and cold temperatures resulted in the extermination of beetle populations from Alberta. In 1997, a third wave of mountain pine beetle infestation was detected in a number of locations in Alberta. By 2005 mountain pine beetle had become firmly established in western Alberta and the outbreak was declared as an emergency. Large populations of beetles arrived from British Columbia in 2006 and 2009 resulting in large infestations into west-central Alberta. The upper reaches of the NSR have large abundances of lodgepole pine and therefore effects of a pine beetle infestation could be significant. As it stands water quality and hydrology have not shown impacts but the infestation, though widespread, hasn't impacted a significant number of trees to date.

Aerial surveys conducted by Alberta Agriculture and Forestry since 2005 indicate that mountain pine beetle was first detected in the NSR basin in 2011 in a small location upstream of Abraham Lake, and in isolated locations around the Brazeau Reservoir. Aerial surveys conducted as recently as 2017 showed very few infected trees in the NSR basin. However, by 2019 the number of infected trees dramatically increased, particularly in the Brazeau subwatershed, but in a number of other areas across the NSR headwaters (Figure 78). This data suggests that mountain pine beetle populations have significantly expanded within the basin, and it is reasonable to expected increased spread in future years.



Note: boundaries of the Rocky Mountain House Forest Area do not correspond to the NSR basin.

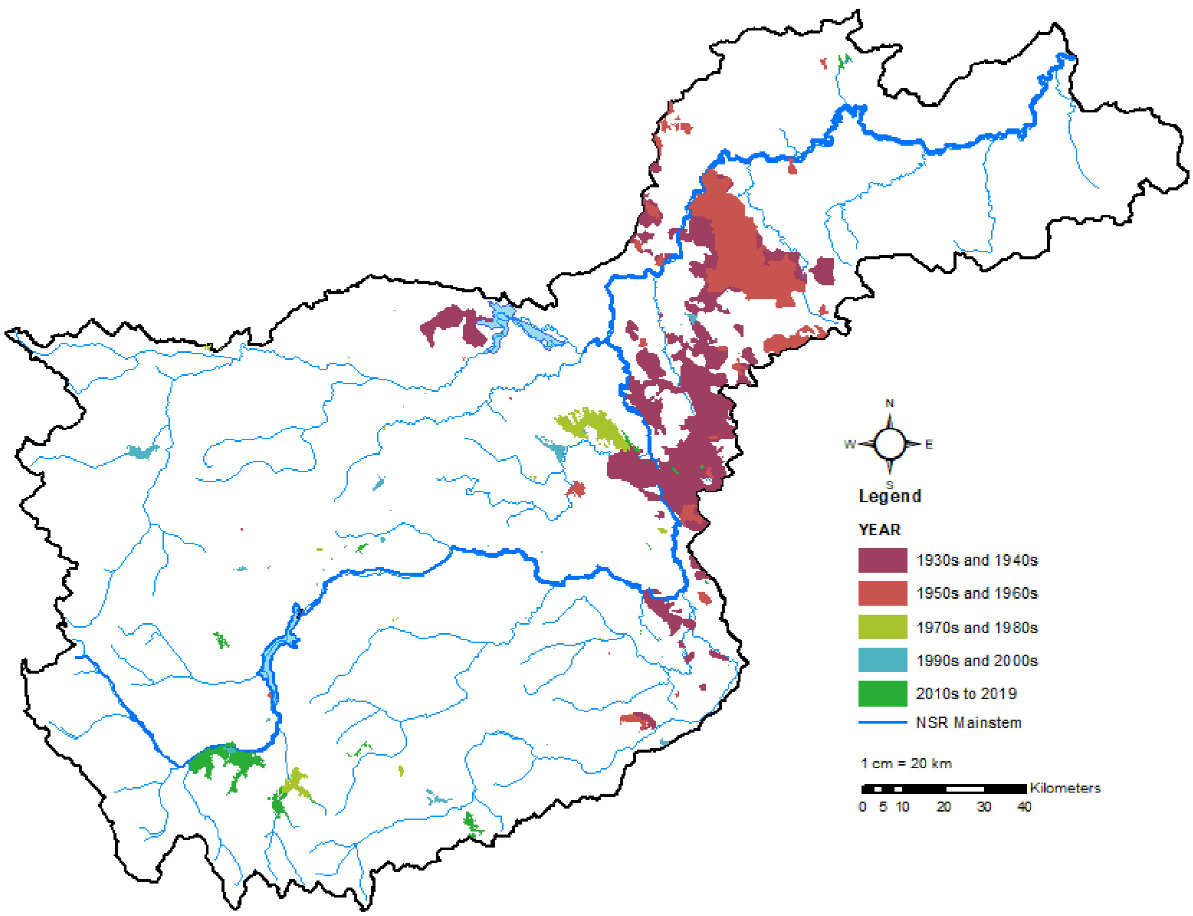
Figure 78. 2019 Mountain Pine Beetle Aerial Surveys Near Rocky Mountain House (from Alberta Agriculture and Forestry 2019a).

Climate Change

Representatives from water utilities, climate-change researchers and the Government of Alberta are currently working together to identify high-priority drinking water issues that may result from climate change. These are discussed in detail in Sections 3.3.1 and 3.3.3 of this report.

Forest Fires

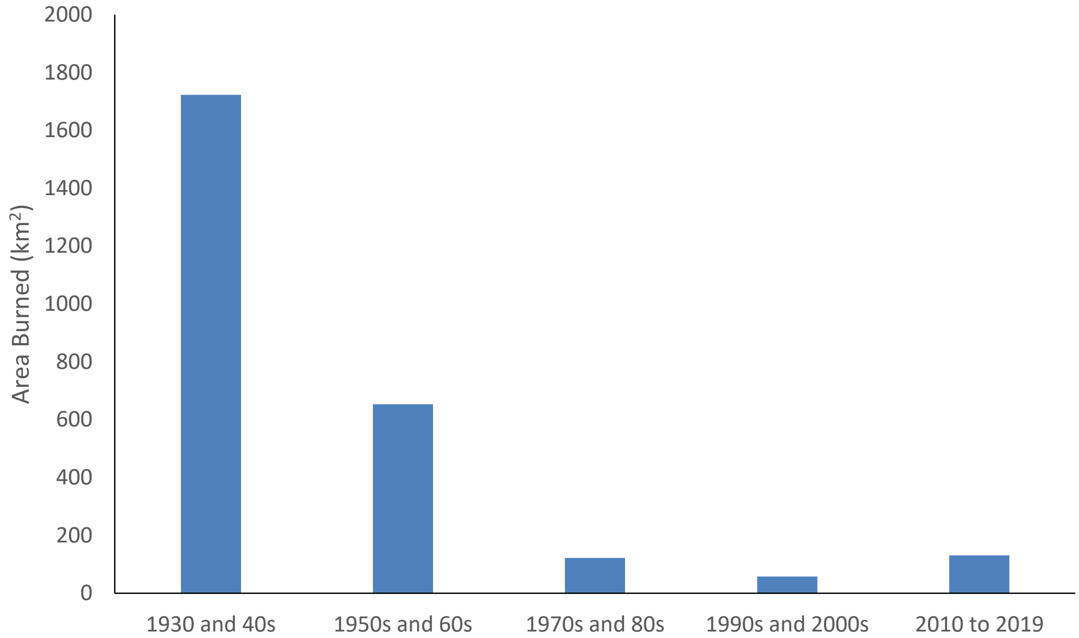
Since 1934, a total of 2,686 km^2 of the watershed has experienced a wildfire, with a majority of the wildfires occurring between Drayton Valley and Rocky Mountain House (Figure 79). Relatively little of the upper watershed has experienced a fire since 1930s. A majority of the forest fires that have occurred in the NSR watershed occurred during the 1940s and 1950s (Figure 80). Forestry management practices (see Section 3.2.9) in the headwaters may have resulted in fewer fires; however, there are still large sections of the headwaters of the NSR that have experienced neither forestry activities nor a wildfire since records began in the 1930s.



Data Source: GoA 2019

Figure 79. Wildfires in the NSR Watershed between 1931 and 2019.

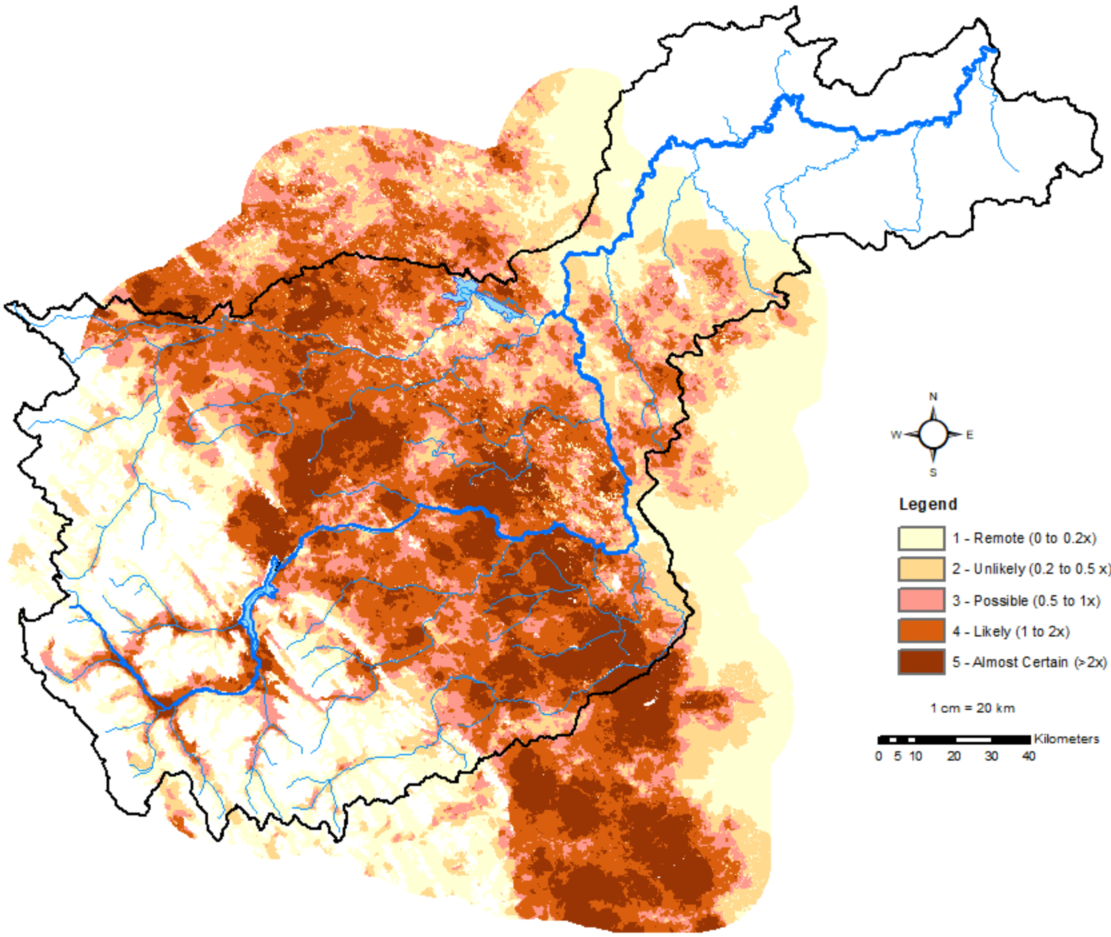
Prior to the 20th century, the fire regime in Alberta's montane region was dominated by frequent, small, low-severity fires as traditional burning in these areas by Indigenous people was common (Farr et al. 2018). More recently, the frequency of fires has decreased due to the end of traditional burning practices and increased fire suppression. This has resulted in the aging of Alberta's forests. AESRD (2012b) demonstrated that over 20% of Alberta's forests were categorized as "over-mature" in 2011. The frequency, severity and size of wildfires along Alberta's eastern slopes are anticipated to increase due to older forests and climate change that is anticipated to result in warmer and drier conditions and a longer fire season.



Data Source: GoA 2019

Figure 80. Area Burned by Wildfires in the NSR Watershed between 1931 and 2019.

Forest fires can have a wide range of effects on downstream water quality and quantity (Sham 2013). The loss of vegetation and ecosystem function can result in increased runoff, increased peak flows, flooding and increased erosion. Water quality can also decline after forest fires, including increases in colour (dissolved organic carbon), turbidity, nutrients and metals such a lead or arsenic. A study conducted in the headwaters of watersheds in the Rocky Mountains in southern Alberta found that large forest fires resulted in a doubling of DOC, a tripling of turbidity, and increased phosphorus for several years post-fire (Emelko et al. 2011, 2016). Following the 2016 wildfires in Ft McMurray, increased concentrations of suspended sediment, nutrients organic carbon, and metals were found in the Athabasca River following precipitation events (Emmerton et al. 2020). This study demonstrated that wildfires have the ability to impact water quality in large rivers that have low-relief and wetland-dominated landscapes, and can impact water treatment costs similar to other studies that have focused on smaller, steeper, and more hydrologically connected headwater streams. A recent study by Robinne et al. (2019) calculated an exposure risk of wildfires ability to impact drinking water sources in Alberta. The North Saskatchewan watershed above Edmonton had a ‘moderate’ risk compared to other regions in Alberta, largely due the cooler and wetter headwater regions of the NSR contributing to fewer and smaller wildfires.



Data Source: Alberta Agriculture and Forestry 2019b

Figure 81. Relative likelihood of fire based on Alberta Agriculture and Forestry's BurnP3 model

In summary, wildfires in the NSR watershed have the ability to impact water quality in the NSR in Edmonton; however, the likelihood and risk of significant impacts to EPCOR's WTPs is relatively low. Most wildfires in Edmonton's headwaters are anticipated to be relatively small and infrequent, as wildfires that are deemed to have been "significant" by Alberta Agriculture and Forestry (personal communication, McLoughlin, 2018) such as the 2014 Spreading Creek fire, burned a less than 0.6% of the watershed. Additionally, the Bighorn and Brazeau dams likely attenuate the impacts of wildfires in these subwatersheds, due to settling of suspended material, and the dilution of flushes from burned areas. Wildfires have the ability to increase turbidity and organic material in the NSR with can increase EPCOR's costs to treat water, and interfere with the WTPs ability to convert to and maintain direct filtration. However, the effects of smaller scale wildfires are unlikely to be noticed amongst the highly variable water quality of the NSR. More significant impacts would be expected if a significant portion (i.e. > 20%) of the watershed were burnt; however, a wildfire of this scale is unprecedented in the last century, and is unlikely to occur in the future (personal communication, McLoughlin, 2018).

Frazil Ice

Frazil ice (i.e. slushy ice) has not previously been a concern for EPCOR; however, in December 2018, high concentrations of frazil ice in the NSR caused minor damage to traveling screens at the WTPs which are designed to remove debris. Frazil ice has the potential to completely block intakes; however, this has never occurred at EPCOR's WTPs.

Frazil ice is formed during the late fall and early winter when the water is supercooled (i.e. drops below 0^{o}C) before stable ice cover is achieved. This typically occurs when air temperatures rapidly drop; however, the precise conditions that generate high concentrations of frazil ice are complex and not fully understood. EPCOR now monitors air and water temperature to help anticipate when frazil ice conditions are possible; however, EPCOR's WTP currently have few options to mitigate frazil ice; however, possible mitigation measures are being evaluated. EPCOR is currently exploring various engineering solutions to manage frazil ice. EPCOR is currently engaging with the University of Alberta to better understand this phenomenon. Frazil ice in concentrations that can affect EPCOR's WTPs is an infrequent event, and there is no indication that the likelihood of these events is increasing, or will increase under a warming climate.

3.5 Rank Hazards/Risk Statements and Identify Vulnerable Areas

Using the developed list of hazards/risk statements for Edmonton's water treatment operations, the level of risk associated with each has been identified through EPCOR's risk management approach (MS03-STD1-Risk Management Process- Risk Assessment, Risk Treatment and Risk Review Standard) and as part of EPCOR's Drinking Water Safety Plan (DWSP).

As part of this process, two types of risk were determined: inherent and residual risk. Inherent risk was defined as a risk without any controls applied, in this case the controls would be water treatment plants and watershed management. Assuming normal plant operations and continued watershed management, the remaining risk was defined as residual risk. The difference between the inherent and the residual risk is a measure of the effectiveness of the controls and both are important in assessing risks to source waters. In most cases robust treatment renders a parameter with high inherent risk (upstream WWTP effluent) to low residual risk, particularly if those parameters are effectively treated at the WTPs, such as sediment or bacteria.

Risk was derived as a function of consequence and likelihood. The risk was determined by rating the consequence (impact) and the likelihood (probability) and then applying them to the EPCOR Risk Matrix. Consequence and likelihood ratings were based on historical evidence (quantitative assessment) as well as the best available knowledge of subject matter experts (qualitative assessment).

The steps to analyze the risk included:

1. **Rating the Consequences (Impacts/Effects)**
   Using the consequence categories in the EPCOR Risk Matrix, each risk/hazard was rated for the greatest potential consequence that could plausibly happen. This was done by scanning across all the consequence categories and determining which impact/effect is the greatest. The five categories were:
   - Health and safety (public and employees)
   - Reputation (credibility as a utility service provider)
   - Environmental consequences (including public health)
   - Regulatory compliance
   - Financial consequences (business/operating loss – financial/asset damage/reliability/business interruption)
2. **Rating the Likelihood (Frequency/Probability)**
   - Using the likelihood categories in the EPCOR Risk Matrix, the likelihood that the risk event would occur was determined.
3. **Estimating Risk (Calculating the Risk Level, Rank and Score)**
   The risk level was determined to be either:
   a. Level I "Green" with rank "Low"
   b. Level II "Yellow" with rank "Medium-Low",
   c. Level III "Orange" with rank "Medium-High" or
   d. Level IV "Red" with rank "High".

It should be noted the predictive nature of hazard identification and risk management dictate that substantial uncertainty will always be associated with these activities (CCME 2004).

Table 17. Edmonton Drinking Water System Risk / Risk Analysis Chart.

Source	Land-Uses / Potential Contaminant Source/Activity	Inherent Risk	Residual Risk
POINT	Small urban waste water discharges	H	L
	Pipeline break	M-H	M-H
NON-POINT	Livestock waste excretion	H	L
	Livestock physical alteration of watershed	M-H	L
	Agricultural cropping activities	M-H	L
	Agricultural land cover and use	M-H	L
	Wildlife activity in watershed	M-H	L
	Rural septic fields	M-H	L
	Small urban stormwater runoff	M-H	L
	Forest harvesting activities	M-H	L
	Pine beetle infestation	M-H	L
	Forest fires	M-H	M-L
	Waste disposal sites	M-L	L
	Alteration in climate (natural and anthropogenic)	M-H	M-L
	City of Edmonton stormwater runoff	H	L
	Contamination of pet fecal matter in urban areas	M-H	L
	Proximity to transportation corridor	M-H	L
	Chemical spill on a bridge	M-H	M-L
	Recreational activities	M-L	L
	Ground water contamination from airport	M-L	L
	Gravel extraction activities	M-L	L
	Coal surface mining	L	L
	Disposal of animal remains within watershed	M-L	L
	Dam operation and management	M-L	L
	Contamination of shallow aquifers	M-H	M-L
	Industrial land spillage	M-H	M-L
OTHER	Intentional contamination at critical source intakes	M-H	M-L
	Insufficient raw water quantity	M-L	L
	Catastrophic failure of dams	M-H	L
	Contamination of raw water due to intentional dumping or release of chemicals from industries	M-H	M-L
	Construction activities on the River – Walterdale Bridge	M-H	M-L
	Lack of integration among watershed and other land and water planning initiatives	M-H	L

Low = L, Medium-Low= M-L, Medium-High= M-H, High - H

3.6 Watershed Management and Compliance and Regulatory Requirements

3.6.1 United States

The United States (U.S.) has been more advanced when it comes to protecting their drinking water sources. Many Canadian drinking water utilities will and should refer to existing U.S. policy, regulations and literature for assistance in developing SWPPs.

United States Environmental Protection Agency (US EPA)

The United States Environmental Protection Agency (US EPA) has released a number of documents, some of which include:

- "Consider the Source: A Pocket Guide to Protecting Your Drinking Water". June 2002. US EPA Office of Ground Water and Drinking Water.

As well, the US EPA maintains a comprehensive SWP website which addresses all aspects of drinking water source protection and has links to current state, NGOs, and other organisation initiatives as they involve SWP: https://www.epa.gov/sourcewaterprotection

3.6.2 Government of Canada

In Canada, there are no current policies or legislation regarding source water protection specifically. However, the Federal Government has emphasized the importance of source water protection as the first step in a 'multi-barrier approach' to protect drinking water sources. The Government of Canada and the Canadian Council of Ministers of the Environment (CCME) have released a number of documents on source water protection that include:

- "From Source to Tap: The multi-barrier approach to safe drinking water". May 12, 2002. Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group.
- "From Source to Tap: Guidance on the Multi-Barrier Approach to Safe Drinking Water". 2004. Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group.
- "Guidance for Providing Safe Drinking Water in Areas of Federal Jurisdiction. Version 2. 2013. Health Canada.

Environment Canada released Wastewater Systems Effluent Regulations (WSER) in 2012 which, do not refer to source water protection directly; however, go a long way in ensuring point source effluent from waste water treatment plants are managed effectively to protect water quality. The new regulations align with the CCME Canada-wide Strategy for the Management of Municipal Wastewater Effluent.

Indigenous and Northern Affairs Canada

Indigenous and Northern Affairs Canada (INAC) has developed a number of tools and documents regarding improving water and wastewaters services in First Nation communities. The following document is available on source water protection:

- "First Nations On-Reserve Source Water Protection Plan: Guide and Template". 2014. Aboriginal Affairs and Northern Development Canada

3.6.3 Other National Level Organizations

Governance for Source Water Protection in Canada is a collaborative research initiative supported by the Canadian Water Network. They have been since in existence since 2008 and are led by the Water Policy and Governance Group at the University of Waterloo. Researchers, academia, government, NGOs, First Nations, watershed groups work in collaboration to improve the knowledge around water governance will the ultimate goal of improved source water protection processes and outcomes throughout Canada. Two key reports are available:

- "Tools and Approaches for Source Water Protection in Canada". 2010. Simms, G., Lightman, D. and de Loë, R. Governance for Source Water Protection in Canada.
- "Governance for Source Water Protection in Canada Synthesis Report." 2012. de Loë, R.C. and D. Murray. Water Policy and Governance Group.

3.6.4 Province of Alberta

Although all levels of government in Canada have responsibility for drinking water, the legislative responsibility for providing safe drinking water to the public generally falls under provincial or territorial jurisdiction (CCME 2004).

Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems

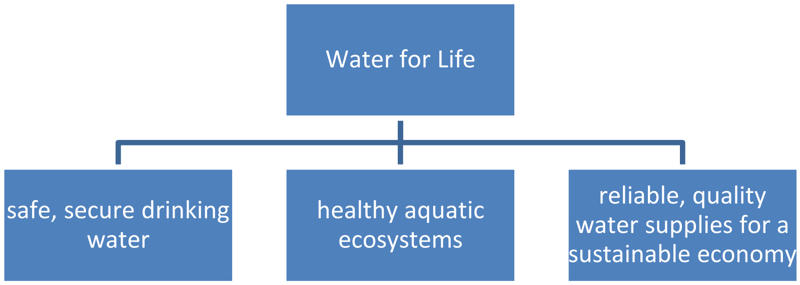
In 2012, Alberta Environment and Parks revised the "Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems". Part 2 of this revised document is titled "Guidelines for Municipal Waterworks" and includes a section on source water protection and highlighted the importance for municipalities to conduct source water protection planning.

Drinking Water Safety Plans

As part of the Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems, there is a requirement to complete Drinking Water Safety Plans (DWSP). These plants include a source to tap risk assessment. EPCOR completed its risk assessment in 2013, and the DWSP, including the action plan, was finalized in 2013. The risk assessment component for source waters has been incorporated the hazard and risk assessment in Section 3.5. EPCOR continues to re-evaluate and reassess its DWSP annually.

Water for Life Strategy

AEP's Water for Life (WFL) Strategy was introduced in 2003 and guides watershed and water management in Alberta under the guidance of three main goals (see below) and through knowledge and research, partnerships, and water conservation.



Three main partnerships exist under WFL and they have a shared accountability to achieve Water for Life goals (Figure 82). The first partnership is a provincial partnership with the Alberta Water Council (AWC). The AWC is a consensus-based partnership that provides timely and strategic advice to governments, industry, and non-government organizations towards achieving WFL goals and outcomes. The second partnership is regional partnerships with Watershed Planning and Advisory Councils (WPACs), who are designated leaders in watershed assessment and planning. EPCOR is engaged primarily at this level and, for Edmonton operations, engagement occurs through participation on the NSWA. Thirdly, there are local partnerships which occur with watershed stewardship groups. Watershed stewardship groups take community-level, on the ground action to safeguard our water sources. This section of the report will focus on the role of watershed planning and source water protection within the broader WFL strategy.

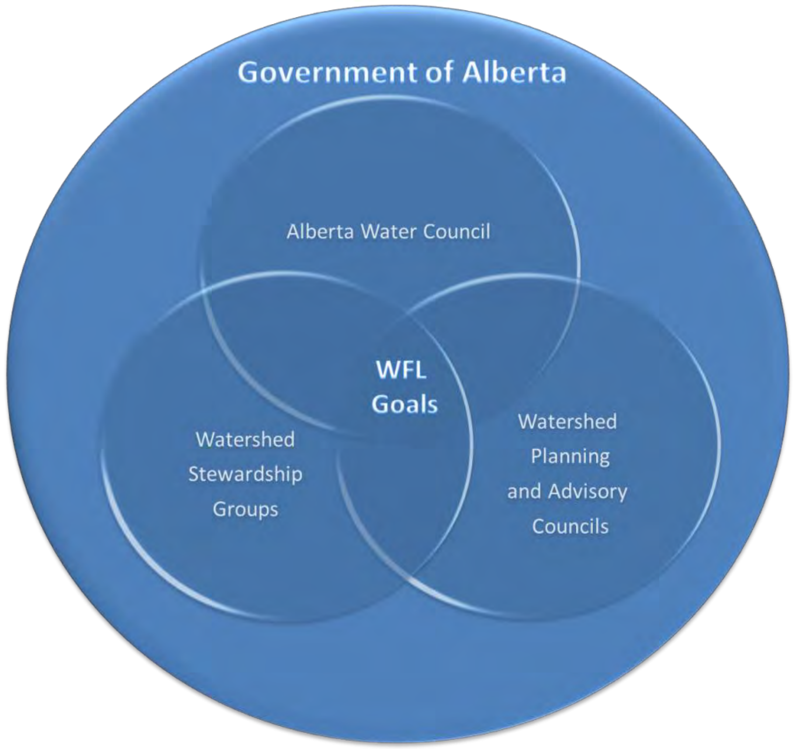


Figure 82. Water for Life Roles and Responsibilities (modified from AWC 2008).

In 2008, the Government of Alberta released a renewed Water for Life strategy and followed in 2009 with a *Water for Life Action Plan*, which supports the original goals and directions in the WFL strategy. The renewal emphasized partnerships and specifically highlighted working with the Alberta Water Council, Watershed Planning and Advisory Councils and watershed stewardship groups. The renewal was clear: Alberta's water resources must be managed within the capacity of individual watersheds and to ensure safe, secure drinking water we must recognize our dependence on aquatic ecosystems as source water.

The Action Plan outlines a comprehensive strategy to protect our drinking water as a specific outcome. The strategy involves ensuring Albertans have timely access to information about drinking water quality in their communities and that drinking water infrastructure strictly adheres to emerging standards. Key actions from the original strategy, as they pertain to source water protection, include:

- Development of a waterborne disease surveillance system and the undertaking of waterborne contaminant research. Progress to date is minimal.
- An update of water quality programs to support source protection information and planning. Progress to date includes enhanced tributary monitoring as part of the WaterSHED program.
- Working with WPACs to incorporate drinking water source protection into watershed planning. Progress to date: support of the Alberta Water Council Source Water Protection Projects.

Alberta Water Council

Incorporated as a not-for-profit society in 2007, the AWC is a multi-stakeholder partnership with twenty-four members from government, industry, and non-governmental organizations. Its primary task is to monitor and steward the implementation of Alberta's WFL strategy and to champion the achievement of its three goals. Recommendations on various aspects of water and watershed management are made to the provincial government, who then can choose to or not implement those recommendations into policy. Some key documents produced by the AWC which focus on watershed planning include: "Strengthening Partnerships: A Shared Governance Framework for Water for Life Collaborative Partnerships" and "Recommendations for a Watershed Management Planning Framework for Alberta". These documents were used to form current government policies in the WFL renewal and action plans and support sector-based approaches to watershed management.

In addition, projects teams have been developed in the areas of water conservation, efficiency and productivity, healthy aquatic ecosystems, Alberta's water allocation transfer system, non-point source pollution, and riparian management and conservation. EPCOR has been involved on project teams through participation with the NSWA or other stewardship groups. EPCOR was involved in the formation of the AWC's "Guide for Source Water Protection Planning" (AWC 2020) which provides an overview of how drinking water providers in Alberta can begin voluntarily undertake the creation of a SWPP. EPCOR is also working on an AWC project looking to scope how a web-based toolkit could be made available to assist communities in creating source water protection plans.

North Saskatchewan River Watershed Alliance (NSWA)

As the WPAC for the basin, the NSWA is mandated under WFL to complete State of Watershed reporting and to develop an Integrated Watershed Management Plan for the basin- which aligns with aforementioned WFL goals. Since its inception, an EPCOR staff member has been an active participant on the NSWA board and project teams.

The NSWA completed a "State of the North Saskatchewan River Watershed" in 2005, as well as a "Municipal Resource Guide" for communities in this watershed in 2006. In late 2005, the Alliance began work on developing an Integrated Watershed Management Plan (IWMP) for the basin, which was intended to set land use, water quantity, and water quality objectives for the basin. The plan was completed in 2012 (NSWA 2012b).

As a key part of the IWMP, a NSWA Technical Advisory Committee developed mainstem water quality objectives for the NSR. The final report: "Proposed Site-Specific Objectives for the Mainstem of the North Saskatchewan River" (NSWA 2010) set objectives for the NSR that helped guide watershed planning in the IWMP. The document promotes a "no further degradation in water quality" philosophy in the NSR. In areas, downstream of Edmonton, there is a call for improvement in water quality for some parameters.

Throughout the IWMP development, knowledge and data gaps were identified and a series of reports were completed to augment objective setting for the basin. The following key reports were completed:

Strawberry Watershed Riparian Area Assessment	2018
Modeste Watershed Riparian Area Assessments	2018
Preliminary Steps for the Assessment of Instream Flow Needs in the North Saskatchewan River Basin	2014
Vermilion River Watershed Management Plan	2012
Workbook Results: Integrated Watershed Management Plan for the North Saskatchewan River	2012
Discussion Paper for the Development of the IWMP for the North Saskatchewan River Watershed	2011
Economic Activity and Ecosystem Services in the North Saskatchewan River Basin	2010
North Saskatchewan River Basin Socio-Economic Profile	2010
Proposed Site-Specific Water Quality Objectives	2010
North Saskatchewan River Basin Overview of Groundwater Conditions, Issues, and Challenges	2009
Hydrodynamic and Water Quality Model of the North Saskatchewan River	2009
Cumulative Effects Assessment of the North Saskatchewan River Watershed using ALCES	2009
Cumulative Effects Assessment of the North Saskatchewan River Watershed Using ALCES	2009
Water Supply Assessment for the North Saskatchewan River Basin	2008
Climate Change Effects on Water Yield in the North Saskatchewan River Basin	2008
Current and Future Water Use in the North Saskatchewan River Basin	2007
Instream Needs Scoping Study	2007

Involvement with the NSWA will continue to provide an effective platform from which EPCOR can ensure effective and collaborative watershed management is achieved, with source water protection principles in mind.

Cumulative Effects Management and Land Use Framework

The Government of Alberta enabled cumulative effects management on a landscape level with the release of the Land-use Framework (LUF) in December 2008, followed by the *Alberta Land Stewardship Act* (ALSA) in early 2009. The Land Use Framework is the overarching planning mechanism for Alberta’s natural resources and is enforced through the ALSA, which supersedes all other provincial legislation. Regional plans, which are developed under LUF, present one of the first opportunities for a cumulative effects management approach. LUF has committed the province to taking a cumulative effects approach to environment management in seven designated regions. Regional Advisory Councils (RACs) will be established to help guide/set landscape level outcomes which will be included in Regional Plans. Consultation of Phase 1 of the regional plan for the NSR Watershed is complete.

Cumulative effects management requires integration amongst spatial scales – provincial, regional, sub-regional, local and site-specific. At present, AEP is developing Management Frameworks that support regional plans under the LUF, including Water Quality Management Frameworks. Water quality management frameworks are place-based and likely to be developed for the mainstem rivers and other priority areas. The Industrial Heartland and Capital Region Water Management Framework is an example of an existing place-based framework that takes a cumulative effects approach to land and water management. EPCOR is engaged in planning through the Water Management Framework for the Industrial Heartland and Captial region.

Water Management Framework for the Industrial Heartland and Capital Region

The Water Management Framework (WMF) of the Industrial Heartland and Capital Region (AENV 2007) outlines specific environmental outcomes for the region and sets targets for sustainability and regional strategies for the tracking and management of air, water, and land. The WMF for the Industrial Heartland and Capital Region Report is the result of consultation, collaboration, and planning for growth by AEP, industry, municipalities, municipal water and wastewater treatment facilities, and the NSWA. The key strategic objective is to develop a world-class integrated water management system from the plan are to make Alberta a world leader is water and wastewater reclamation technology and to minimize the impact of "footprint" on the NSR by improve the quality of the water and ensuring water conservation practices are in effect. The WMF will be used to manage water quantity to ensure that sufficient water remains in the river to maintain aquatic life, support current and proposed industrial development, attain water quantity and quality targets, and move toward a minimal-loading discharge policy for return flows to the NSR. Updates on the Water Management Framework for the Industrial Heartland and Capital Region were completed in 2013, 2016 (GoA 2013b, 2016).

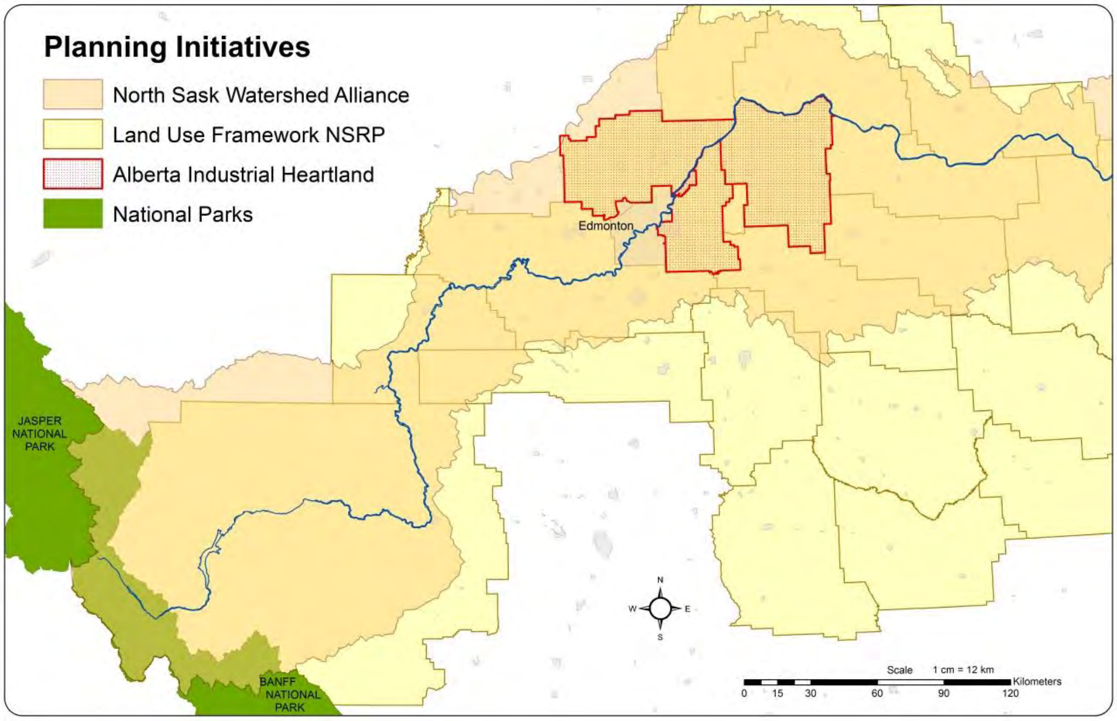


Figure 83. Planning Initiatives in the NSR Watershed (Data Source: GoA 2020)

As part of this work, AEP has completed a multitude of water quality modelling and assessment projects and reports as found below:

Effluent Characterization Program for the Industrial Heartland and Capital Region	2015
North Saskatchewan River: Water Quality and Related Studies (2007 – 2012)	2014
Pilot Water Quality Objectives and Allowable Contaminant Loads for the North Saskatchewan River.	2013
The Water Management Framework for the Industrial Heartland and Capital Region – Five Years of Implementation.	2013
Investigations of Trends in Select Water Quality Variables at Long-Term Monitoring Sites on the North Saskatchewan River	2012
Guidance For Deriving Site-Specific Water Quality Objectives for Alberta Rivers.	2012
Synthesis of Recent Knowledge on Water Quality, Sediment Quality, and Non-Fish Biota in the North Saskatchewan River with Special Emphasis on the Industrial Heartland – Capital Region Water Management Framework Reach.	2011
North Saskatchewan River Water Quality Model: Alberta Environment Technical Report - Version 1.1.	2009
Analysis of Water Quality Trends for the Long-term River Network: North Saskatchewan River, 1977-2002	2005

Central to WMF is the publication of pilot maximum allowable loads for the Devon to Pakan reach of the NSR (AESRD 2013). The goal of this was to ensure that water quality is maintained or improved in the NSR. As such pilot water quality objectives (WQOs) were established for the Industrial Heartland reach, inclusive of the river mainstem from Devon downstream to Pakan. The WQOs apply specifically to the long-term river network (LTRN) monitoring sites at Devon and Pakan sites, and are based on ambient in-stream concentrations, except where ambient concentrations exceed the most stringent federal/provincial water quality guidelines. Maximum allowable loads (MALs) were calculated from WQOs and provide a measure against which long-term changes can be assessed. It is expected that final WQO and MALs will be established over the next five years.

The WMF also completed an Effluent Characterization Program, which describes the monitoring and reporting requirements of point sources of industrial discharges entering the NSR in the Devon to Pakan reach. The goal is to have a better understanding of the relationship between effluent and surface water quality to better manage the cumulative effects to the NSR. This monitoring is continuing in 2020-2022. The next step of the WMF is to refine and use the results from the Effluent Characterization Program to manage effluents and the cumulative effects to water quality in the NSR through load apportionment.

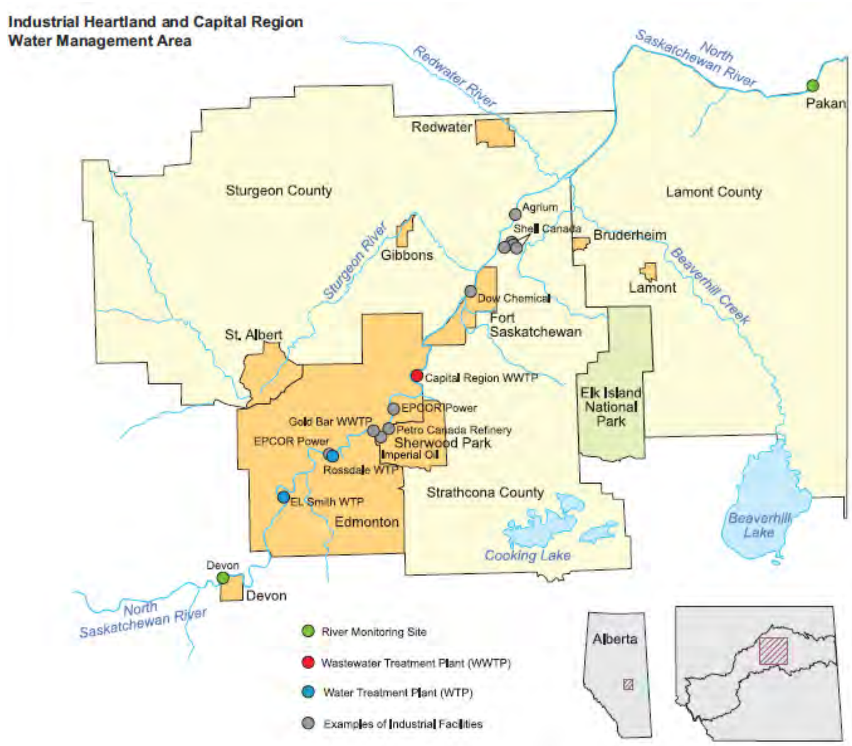


Figure 84. Industrial Heartland and Capital Region Water Management Area (from NSWA 2012a).

EPCOR's Watershed Protection Program

EPCOR's Watershed Protection Program (WPP) has two primary goals: to ensure a safe, secure drinking water supply through the application of source water protection principles and to ensure minimal effects from operations on water quality and aquatic ecosystem health in receiving water bodies. EPCOR recognizes that SWPP is a critical first step in a multi-barrier approach for water utilities to protect both quality and quantity of waters sources. Experience has shown the protection and proper management of the upstream watershed can improve or prevent deterioration of the quality of raw water entering treatment plants. Awareness of upstream activities also enables EPCOR to respond quickly to developing water quality issues within the watershed.

Watershed management is complex, particularly when multiple stakeholders affect land use and water quality in the upper reaches of the basin; as well when there are various landscape planning initiatives occurring at different levels of government. EPCOR's WPP works within the existing watershed management and source water frameworks, at both the federal and provincial level. The WPP has four main focus areas: watershed planning, implementation of watershed plans and programs, monitoring and research, and education and awareness. Although these focus areas are interrelated, in general, the core of EPCOR's WPP entails developing watershed planning documents, supporting the outcomes of those plans though implementation programs, developing and supporting monitoring and research programs to measure changes in selected metrics, and garnering support from watershed stakeholders.

EPCOR's Integrated Watershed Management Strategy

EPCOR is currently drafting an Integrated Watershed Management Strategy (IWMS) to manage total loading effects on the health of the NSR and to ensure source water protection for the Edmonton water supply in one unified watershed management program. The IWMS reviews the current state of planning, assessment, and implementation at multiple scales with the penultimate goal of a nested approach to watershed management. Integral to this approach is using established river outcomes to evaluate the impact of storm water, combined sewer, wastewater, and water treatment plant waste streams on the NSR and its tributaries. In this vein, once the relative influence of each source is understood the effectiveness of assessment programs and implementation and management decisions will also be evaluated. Where monitoring, modelling, or research is not adequate to determine relative contribution or effects on river or stream outcomes, recommendations will be made to fill those gaps. Although river outcomes provide the foundation from which to determine effects, we note that EPCOR is also grounded in a commitment to ensuring clean and abundant water supplies for EPCOR's WTPs and to also reduce the impact of discharges released to the NSR.

The IWMS will also guide and replace EPCOR Drainage's Total Loading Plan which was a 10 year old, continuous commitment to protect the regional watershed, comply with regulatory requirements and sustain the surface water quality by managing and limiting loadings from storm water and wastewaters collection systems. 2019 marked the end of original 10 year Total Loading Plan and there was a need to re-evaluate established benchmark and align the Total Loading Strategy with EPCOR corporate strategic goals of preserving and sustaining Edmonton's environment and above all maintain a healthy river.

EPCOR's Stormwater Integrated Resource Plan

To reduce flooding risks within the City of Edmonton, EPCOR developed the Stormwater Integrated Resource Plan (SIRP). SIRP is intended to reduce urban and riverine flooding events through capital and operational changes applying a risk ranking assessment based on hazards/risks related to: Health and Safety, Environment, Financial and Economic Impact and Social or Service Level impact. EPCOR developed the investment recommendations considering a mix of grey and green infrastructure components. On commercial or industrial land green infrastructure funding is targeting to highly impervious lots that are major contributors to storm collection system. The approximately $1.6 billion capital program proposed through the SIRP can be classified into five themes of investment: slow, move, secure, predict and respond. Although flooding risk is the main driver of SIRP, it is expected that water quality improvements will be made through the implementation of green infrastructure and managing surface runoff at the source. Peak flow reduction and overall stormwater volume reduction will reduce impact on urban creeks, specifically reducing bank erosion and destruction of natural drainage ways as result of land development.

The SIRP approach is to capture the stormwater volumes in dry ponds prior to reaching the storm trunk network to provide additional capacity in the pipes in the immediate path of the storm. The addition of Low Impact Development (LID) throughout the catchment area will reduce peak flow and further retain these volumes at the source and reduce the impact on the entire pipe network as storms travel across the community as well as impact on urban creeks and all natural drainage ways. The plan also includes tunnels, trunks and sewer separation in locations where, due to configuration of the community, there is limited space to install additional ponds or LID components to fully capture the expected water volumes during a major storm event. Need for additional trunks/tunnels will be re-evaluated as we progress with SIRP implementation but currently the focus is to control and reduce the inflow and utilize existing collection system to maximum through monitoring and control.

City of Edmonton

In 2012 the City of Edmonton published their River for Life Strategy (City of Edmonton 2012). The strategy committed to a number of policy objectives aimed at long-term protection of water quality of the North Saskatchewan River under its environmental strategic plan, The Way We Green (City of Edmonton 2011). At the time, the City of Edmonton's Drainage Services contributed to these objectives by developing a framework and 30 year strategic plan to reduce pollutant discharge within the watershed, with the ultimate goal of achieving net zero impact from human activities. The idea was that River for Life would take into account three discharge pathways: urban runoff from storm events, combined sewer overflows, and municipal wastewater and was intended to guide the City's efforts to reduce contaminants in each pathway in the short, medium and long term. The drivers to achieve net zero impact relied on watershed planning, municipal leadership, responding to regulations, ensuring infrastructure is resilient, investing in high value resources to reduce contaminant discharges, and being proactive and innovative. Since Drainage Services joined EPCOR in 2018, River for Life has come under EPCOR's umbrella and was reviewed as part of EPCOR's Integrated Management Strategy. EPCOR has incorporated the general intent of this strategy into its Integrated

Watershed Management Strategy, which is currently in development, and River for Life is now a legacy initiative.

The importance of the NSR is highlighted in the City of Edmonton's Climate Resilient Edmonton: Adaptation Strategy and Action Plan (City of Edmonton 2018), and ConnectEdmonton Strategic Plan (City of Edmonton 2019), in terms of water quality and quantity for drinking water, as well the risk of potential river flooding.

Blackmud/Whitemud Creek Surface Water Management Group

The pace of development in the Edmonton-Leduc corridor has been increasing recently and the 1200 km^2 area is expected to be developed over the next 50 years. This development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by previous development. In order to determine the cumulative effects of additional stormwater discharges to these creeks, the Blackmud/Whitemud Surface Water Management Group was formed. Stakeholders participating included the Leduc County, the City of Edmonton, the City of Leduc, the Town of Beaumont, Strathcona County, and the North Saskatchewan Watershed Alliance. More recently EPCOR has been involved in this group.

The group completed the Blackmud/Whitemud Creek Surface Water Management Study which involved hydrologic, hydraulic and environmental analyses of the Blackmud and Whitemud Creek basins to develop a stormwater management strategy to accommodate future development in the basin (Associated Engineering 2017). As development continues in the Blackmud and Whitemud basins, the runoff rates and volumes will increase and it is expected that flooding, erosion, and declining water quality will result unless stormwater releases are managed. Historical release rates vary across the municipalities and range from 2 to 9 L/s/ha. The key objective of this project was to prepare a Surface Water Management Plan (SWMP) in accordance with the Stormwater Management Guidelines for the Province of Alberta and the Alberta Wetland Policy, to ensure that cumulative effects on the watershed are understood and will be appropriately mitigated and managed. A final release rate of 3.0 L/s/ha was agreed upon by the group which will be achieved through a series of grey and green infrastructure projects through SIRP.

3.6.5 Industry Best Practice

Pollution Probe

Pollution Probe is a non-profit charitable organization that promotes clean air and clean water. Pollution Probe published the following document on SWP:

- "The Source Water Protection Primer". May 2004. Pollution Probe.

American Water Works Association

The American Water Works Association (AWWA) has developed numerous documents, but the most relevant and recent one for SWPP is:

- “Operational Guide to Source Water Protection”. 2016. American Water Works Association.

Water Research Foundation

The Water Research Foundation (WRF) is research organization that focuses on advancing research in water quality, water treatment, stormwater and wastewater. WRF has published over 200 studies on various aspects of source water protection, including climate change, contaminants of emerging concern, pathogens, cyanotoxins, stormwater, watershed management and risk assessment.

SECTION 4 – EPCOR'S EDMONTON SWPP GOALS

The goals of this Source Water Protection Plan are as follows:

1. Protect public health by ensuring the safety and reliability of the drinking water supply.
2. Establish a risk management based approach in setting priorities when creating action plans and determining the focus of watershed management plans.
3. Support and participate in aquatic health, water quality, and water quantity monitoring initiatives in the watershed and research opportunities.
4. Encourage stricter effluent discharge criteria of municipal sewage effluent through support of monitoring and load apportionment frameworks.
5. Support and encourage implementation of agricultural Best Management Practices focusing on industrial, agricultural, and urban land use.
6. Promote and participate in technical studies and influencing regulators with respect to best management practices and policy development (agriculture, forestry, and oil and gas development sites).
7. Ensure there is excellent communication between AEP, AER, the City of Edmonton Fire Departments, and EPCOR Drainage on notification of spills and releases that may have an effect on the operation of the WTPs.
8. Support and participate in understanding and mitigating risks from pipelines in the watershed and the possible purposeful contamination of intakes.
9. Participate in technical studies to determine the effects of climate change on the watershed and the water supply, terms of both quantity and quality.
10. Promote environmental stewardship through educational programs and collaborative initiatives.
11. Support watershed planning and policy through participation on Watershed Planning and Advisory Councils (NSWA), Alberta Water Council, Regional Planning, Water Management Frameworks, stewardship groups, and other water and watershed planning initiatives.

SECTION 5 – EPCOR'S EDMONTON SWPP ACTION PLAN AND PROGRAM RESULTS

EPCOR's Source Water Protection Plan has identified the following actions needed to mitigate existing and future threats to the quality of the NSR. As well, program results or initiatives are included along with some identified barriers and challenges. In general, the watershed planning component of Source Water Protection Planning leverages already established frameworks in Alberta. These frameworks and initiatives have their unique challenges but EPCOR understands that working within existing water and watershed planning frameworks is beneficial in the long-term and will likely result in better source water protection outcomes.

<table>
<tr><th></th><th>Actions</th><th>Program Results</th></tr>
<tr><td rowspan="8">Planning</td><td>Alberta Water Council: Work with the Alberta Water Council on the development of water policy that aligns with SWPP goals.</td><td>Co-chaired the Protecting Sources of Drinking Water in Alberta: Guide to Source Water Protection Planning project team.

Co-chairing the SWP Risk Assessment Tools and Data Working Group

Past: On Non-Point Source Pollution, Lake Management, Riparian Health Project Teams</td></tr>
<tr><td colspan="2">Challenges and Barriers: Recommendations from Project Team reports are often not implemented by GoA</td></tr>
<tr><td>Watershed Planning Groups: Continue leadership on watershed and water management through support of existing watershed planning initiatives.</td><td>NSWA Board member, Strategic Planning and Priority Committee member, and Headwater Alliance TAC member.

Co-chairing the Industrial Heartland and Capital Region Water Management Framework Advisory Committee and Member of theTechnical Committee

Blackmud/Whitemud Creek Watershed Management Plan Working Group Member</td></tr>
<tr><td colspan="2">Challenges and Barriers: NSWA lacks the authority to implement aspects of the plan and land and water planning continues to be disjointed provincially. Data is not sufficient to allow for site specific water quality objectives. Pilot water quality objectives and load apportionment work is lagging.</td></tr>
<tr><td>Spill Management: Develop a spill management and communication plan with regular internal and external drills to ensure communication lines are operational.</td><td>Training and drills occur within EPCOR and regular meetings with GoA take place to ensure lines of communication remain open

Maintenance of a ‘time of travel’ calculation tool in case of spill that will allow operations to determine how soon the spill will reach Edmonton.

Worked with the City of Edmonton, AEP and their Alberta Environment Support and Emergency Response Team, AER and the Environmental Hotline.</td></tr>
<tr><td colspan="2">Challenges and Barriers: Pipeline GIS data are difficult to obtain and raw data files are time consuming to navigate</td></tr>
<tr><td>Climate Change Planning: Continue to fund and support research on how climate change will impact source water quality and quantity</td><td>Continued implementation of EPCOR’s Climate Change Adaptation Strategy

Financially supported research conducted by the Prairie Adaptation Research Collaborative to better understand the historical variability of the NSR and future runoff scenarios and U of A Groundwater Research understanding climate effects</td></tr>
<tr><td colspan="2">Challenges and Barriers: Data needs to be integrated into future scenarios and communication across stakeholders on effects of climate change</td></tr>
</table>

Monitoring and Modelling	**Monitoring and Modelling**: Support water quality monitoring and modelling on the NSR to quantify and understand non-point source and point source pollution (with a focus on pathogens, organic matter, and sediment). Modelling would be basin wide and investigate changing land cover and land use impacts on tributary and river water quality and quantity. Continue to work with the EPCOR Drainage on quantifying and managing storm water inputs on the NSR and the Integrated Watershed Management Strategy and Storm Water Integrated Resource Plan.	WaterSHED Program: A tributary and mainstem monitoring program for the watershed lead by EPCOR in partnership with the City of Edmonton, NSWA, and AEP. Hosted State of NSR Basin Modelling Workshop Leading the development of a 5-10 Year Modelling Strategy for the NSR with AEP, City of Edmonton, and NSWA Scoping development of an urban watershed model to predict future storm water loads. Run Edmonton Monitoring Program that measures water quality and flow at storm outfalls and WWTPs. Run EPCOR's Creek Program that measures water quality in Edmonton's urban tributaries as they flow through the City
	Challenges and Barriers: Modelling work is underfunded and priority is based on current pressures not long-term planning. Internal resourcing for a designated watershed modeller	
Research	**Research:** Continued support of research that enhances watershed science and knowledge.	*for*Water Project: financial support for the understanding of how forest management practices and events such as forest fires will impact the quality and treatability of source water for drinking water. Groundwater Research: financial support for University of Alberta led work on contribution of groundwater to the NSR Ice Core Study: financial support for University of Alberta led work on ice-core analysis of PFAS and other deposited organic contaminants in upstream glaciers Integrated Modelling for Watershed Evaluations of BMPs: financial and technical support for University of Guelph led work to develop imWEBs model to assess the impacts of BMPs to water quality and quantity in Modeste and Strawberry Creek PARC: financial support for University of Regina work on projections of future flows in the NSR under future climate scenarios and historical variability
	Challenges and Barriers: Research support is not strategically prioritized	

Implementation	**Implementation**: Continue to promote agricultural and urban BMPs to mitigate movement of contaminants to the NSR, for example through the Strawberry Creek Pilot Project or IMWEBs work.	Continued to promote agricultural and urban BMPs to mitigate movement of contaminants to the NSR through work on through financial contributions to Clearwater Landcare and support of IMWEBs research and Riparian mapping of Strawberry and Modeste Creek.
	Challenges and Barriers: There is a lack of a landscape level model that measures beneficial management effectiveness at the basin scale and links to source water quality. Therefore targeting BMPs is difficult.	
Education	**Education and Awareness**: Continue to foster and support educational programs focused on watershed stewardship and expanding water quality knowledge.	Financial support of RiverWatch/CreekWatch and Capital City Clean-up Support EPCOR's RiverFest programming (cancelled in 2020)
	Challenges and Barriers: Need to improve consistent communication to stakeholders within EPCOR	

SECTION 6 - PERIODIC EVALUATION AND REVISION

A review and evaluation of this SWPP will be conducted every three years. This will be led by EPCOR's Watershed Manager and supported by the Environmental Services Senior Manager and the Director of Quality Assurance and Environment. Additional review and comments will be provided by staff at the EPCOR Water Treatment Plants and Drainage Services. The purpose of the review will be to ensure changes which may affect the SWPP are recognized and captured. Those factors which should be considered in the evaluation are listed below:

- Source water delineation
- Risks (frequency and consequences)
- New regulatory initiatives
- Research, data and new results
- Implementation of study recommendations
- New watershed planning documents
- Significant incidents
- Performance of programs and initiatives

The evaluation of the SWPP and associated action plans will be based on the suitability, effectiveness and adequacy with respect to the following:

- Source Water Protection Vision
- Characterization of Watershed
- Implementation of Action Plan

The review and evaluation process should be used as the basis to continually improve the Plan while ensuring it remains current.

SECTION 7 - VERIFICATION

EPCOR will maintain adequate records and documents of its SWPP. These records shall include the following:

- Summaries and minutes of stakeholder meetings
- Minutes of any relevant public hearings with respect to the SWPP
- Technical studies
- Monitoring data
- Any other documents that support or are related to the SWPP

SECTION 8 – REFERENCES

ABMI (Alberta Biodiversity Monitoring Institute). 2010. Wall-to-wall Land Cover Inventory. http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Land-Surface/Land-Cover.html. Accessed December 4, 2017.

ABMI. 2018. Wall-to-Wall Human Footprint Inventory. http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Land-Surface/HF-inventory.html?scroll=true. Accessed December 4, 2017.

ABMI. 2020. “2018 Remotely Sensed Harvest Area Spectral Regeneration – Metadata Document.” Edmonton, Alberta, Canada

AECOM. 2009. Alberta Municipal Wastewater Facility Assessment Project. Phase 2 Final Version. Release 3.0. ftp://ftp.gov.ab.ca/env/fs/MuniWastewaterMgt.

Agriculutre and Agri-food Canada. 2016. Annual Crop Inventory. http://open.canada.ca/data/en/dataset/ba2645d5-4458-414d-b196-6303ac06c1c9

Alberta Agriculture and Forestry. 2017. Sustainable Forest Management: 2016 Facts & Statistics. Spring 2017. ISBN 978-1-4601-2797-1.

Alberta Agriculture and Forestry. 2019a. Rocky Mountain House Forest Area Mountain Pine Beetle Heli-GPS Survey 2019 [map].

Alberta Agriculture and Forestry. 2019b. BurnP3 model results for Rocky Mountain House Wildfire Risk Management Plan provided to EPCOR by Alberta Agriculture and Forestry.

Alberta Energy Regulator. 2017a. Maps, Map Viewers, & Shapefiles. https://www.aer.ca/data-and-publications/maps-and-mapviewers. Accessed November 29, 2017.

Alberta Energy Regulator. 2017b. Pipelines. https://www.aer.ca/rules-and-regulations/by-topic/pipelines. Accessed December 1, 2017.

AENV (Alberta Environment). 1990. Flood Frequency Analysis North Saskatchewan River at Edmonton. Water Resources Management Services, Technical Services Division, Hydrology Branch.

AENV. 2005. Analysis of Water Quality Trends for the Long-term River Network: North Saskatchewan River, 1977-2002. ISBN 0-7785-4412-5.

AENV. 2007. The Water Management Framework for the Industrial Heartland and Capital Region.

AENV. 2009. North Saskatchewan River Water Quality Model: Alberta Environment Technical Report - Version 1.1. ISBN 978-0-7785-8794-1.

AENV, 2011. Synthesis of Recent Knowledge on Water Quality, Sediment Quality, and Non-Fish Biota in the North Saskatchewan River with Special Emphasis on the Industrial Heartland – Capital Region Water Management Framework Reach.

AESRD (Alberta Environment and Sustainable Resources Development). 2010. Mountain pine beetle & cold temperatures: the facts.

AESRD 2012a. Guide to Reporting on Coming Indicators Used in State of the Watershed Reports. Government of Alberta, Edmonton, Alberta.

AESRD. 2012b. Final Report from the Flat Top Complex Wildfire Review Committee. May 2012. ISBN 978-1-4601-0273-2.

AESRD. 2013. Pilot Water Quality Objectives and Allowable Contaminant Loads for the North Saskatchewan River. Version 1.0. ISBN 978-1-4601-1277-9

Alberta Environment and Parks (AEP). 2020. Preliminary results from upcoming North Saskatchewan River Flood Study.

AEW (Alberta Environment and Water) 2012. Guidance For Deriving Site-Specific Water Quality Objectives for Alberta Rivers. http://environment.gov.ab.ca/info/home.asp. ISBN 978-1-4601-0063-9.

Alberta Lake Sturgeon Recovery Team. 2011. Alberta Lake Sturgeon Recovery Plan. 2011 - 2016. Alberta Environment and Sustainable Resources Development. Alberta Species at Risk Plan No. 22. Edmonton, AB. 98 pp.

AMEC. 2007. Current and Future Water Use. Prepared for the North Saskatchewan Watershed Alliance. Available at: http://www.nswa.ab.ca/content/current-and-future-water-use-north-saskatchewan-river-basin-0

Anderson, A.-M. 2012. Investigations of Trends in Select Water Quality Variables at Long-Term Monitoring Sites on the North Saskatchewan River. December 2012.

Associated Engineering. 2017. Blackmud/Whitemud Creek Surface Water Management Group: Blackmud/Whitemud Creek Surface Water Management Study: Final Report. July 2017.

AWC (Alberta Water Council). 2008. Strengthening partnerships: A Shared Governance Framework for Water of Life Collaborative Partnerships. September 2008.

AWC. 2020. Guide to Source Water Protection Planning: Protecting Sources of Drinking Water in Alberta. March 2020.

AWWA (American Water Works Association). 2014. G300-07 Source Water Protection.

AWWA. 2016. Operational Guide for AWWA Standard G300, Source Water Protection.

Barker, A.A., Riddell, J.T.F., Slattery, S.R., Andriashek, L.D., Moktan, H., Wallance, S., Lyster, S., Jean, G., Huff, G.F., Stewart, S.A. and Lemay, T.G. 2011. Edmonton-Calgary Corridor groundwater atlas: Energy Resources Conservation Board, ERCB/AGS Information Series 140, 90p.

Barker, A.A., Moktan, H., Huff, G.F. and Stewart, S.A. 2013a. Maps of fresh groundwater chemistry, Edmonton-Calgary Corridor, Alberta I – surficial sediments aquifer, Alberta Energy Regulator, AER/AGS Open File Report 2013-07, 17p.

Barker, A.A., Moktan, H., Huff, G.F. and Stewart, S.A. 2013b. Maps of fresh groundwater chemistry, Edmonton-Calgary Corridor, Alberta III – Upper 50 metres of the Horseshoe Canyon aquifer; Alberta Energy Regulator, AER/AGS Open File Report 2013-09, 17p.

Barker, A.A., Moktan, H., Huff, G.F. and Stewart, S.A. 2013c. Maps of fresh groundwater chemistry, Edmonton-Calgary Corridor, Alberta IV – Upper 50 to 100 metres of the Horseshoe Canyon aquifer; Alberta Energy Regulator, AER/AGS Open File Report 2013-10, 17p.

Barker, A.A., Moktan, H., Huff, G.F. and Stewart, S.A. 2013d. Maps of fresh groundwater chemistry, Edmonton-Calgary Corridor, Alberta V – Bearpaw aquifer; Alberta Energy Regulator, AER/AGS Open File Report 2013-11, 17p.

Barker, A.A., Moktan, H., Huff, G.F. and Stewart, S.A. 2013e. Maps of fresh groundwater chemistry, Edmonton-Calgary Corridor, Alberta VI – Belly River aquifer; Alberta Energy Regulator, AER/AGS Open File Report 2013-12, 17p.

CABIDF (Canada-Alberta Beef Industry Development Fund). 2002. Relationship between Beef Production and Waterborne Parasites (Cryptosporidium spp. and Giardia spp.) in the North Saskatchewan River Basin, Alberta, Canada.

Conedera, M., Peter, L., Marxer, P., Forster, F., Rickenmann, D., Re, L., 2003. Consequences of forest fires on the hydrogeological response of mountain catchments: a case study of the Riale Buffaga, Ticino, Switzerland. Earth Surf. Process. Landf. 28:117–129.

City of Calgary. 2020. Calgary Wildfire – Source Water Risk Management: Fire Retardant-Based Risks. April 2020.

City of Edmonton. 2011. The Way We Green: The City of Edmonton's Environmental Strategic Plan. July 2011.

City of Edmonton. 2012. River for Life: Strategic Framework. December 2012.

City of Edmonton. 2013. Roadside Truck Survey: Final Report. February 2013.

City of Edmonton. 2015. Edmonton Truck Route Map. https://www.edmonton.ca/transportation/driving_carpooling/truck-routes.aspx.

City of Edmonton. 2018. Climate Resilient Edmonton: Adaptation Strategy and Action Plan.

City of Edmonton. 2019. Connectedmonton: Edmonton's Strategic Plan: 2019 – 2018.

City of Edmonton. 2020. Drainage Outfall Map. https://data.edmonton.ca/Drainage/Drainage-Outfall-Map-/uw7v-usy5/data. Accessed December 12, 2020.

CCME (Canadian Council of Ministers of the Environment). 2002. From Source to Tap: the Multi-barrier Approach to Safe Drinking Water.

CCME (Canadian Council of Ministers of the Environment). 2004. From Source to Tap: Guidance on the Multi-barrier Approach to Safe Drinking Water.

de Loë, R.C. and D. Murray. 2012. Governance for Source Water Protection in Canada Synthesis Report. Water Policy and Governance Group.

Emelko, M.B., U. Silins, K.D. Bladon, and M. Stone. 2011. Implications of land disturbance on drinking water treatability in a changing climate: Demonstrating the need for "source water supply and protection" strategies. Water Research 45: 461 – 472.

Emelko, M.B., M. Stone, U. Silins, D. Allin, A.L. Collins, C.H.S. Williams, A.M. Martens and K.D. Bladon. 2016. Sediment-phosphorus dynamics can shift aquatic ecology and cause downstream legacy effects after wildfire in large river systems. Global Change Biology. 22: 1168 - 1184.

Emmerton, C.A., C.A. Cook, S. Hustins, U. Silins, M.B. Emelko, T. Lewis, M.K. Kruk, N. Taube, D. Zhu, B. Jackson, M. Stone, J.G. Kerr, J.F. Orwin. 2020. Severe western Canadian wildfire affects water quality even at large basin scales. Water Research. 183. https://doi.org/10.1016/j.watres.2020.116071

Farr, D., A. Braid, A. Janz, B. Sarchuk, S. Slater, A. Sztaba, D. Barrett, G. Stenhouse, A. Morehouse and M. Wheatly. 2017, Ecological Response to Human Activities in Southwestern Alberta; Science Assessment and Synthesis. Alberta Environment and Parks, Government of Alberta. ISBN No. 978-1-4601-3540-2.

Farr. D., Mortimer, C., Wyatt, F., Braid, A., Loewen, C., Emmerton, C., and Slater, S. 2018. Land use, climate change and ecological responses in the Upper North Saskatchewan and Red Deer River Basins: A scientific assessment. Government of Alberta, Ministry of Environment and Parks. ISBN 978-1-4601-4069-7. Available at: open.alberta.ca/publications/9781460140697.

Fiera (Fiera Biological Consulting Ltd.). 2014. Environmentally Significant Areas in Alberta: 2014 Update. Report prepared for the Government of Alberta, Edmonton, Alberta. Fiera Biological Consulting Report Number 1305.

Fiera. 2018a. Strawberry Watershed Riparian Area Assessment. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, Alberta. Fiera Biological Consulting Report Number 1773.

Fiera. 2018b. Modeste Watershed Riparian Area Assessment. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, Alberta. Fiera Biological Consulting Report Number 1652.

Godfrey, J.D. ed. 1993. Edmonton Beneath Our Feet: A Guide to the Geology of the Edmonton Region.. Edmonton Geological Society

Golder Associates Ltd. 2008a. Water Supply and Assessment for the North Saskatchewan River Basin. Prepared for the North Saskatchewan Watershed Alliance. Available at: http://www.nswa.ab.ca/content/water-supply-assessment-north-saskatchewan-river-basin

Golder Associates Ltd. 2008b. Assessment of Climate Change Effects on Water Yield from the North Saskatchewan River Basin. Available at: http://nswa.ab.ca/userfiles/NSWA_NSRB_ClimateChange_Final%20Report_23Jul2008.pdf

GoA (Government of Alberta). 2013a. Stardards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems. Part 3: Wastewater Systems Standards for Performance and Design of a Total of 5 Parts. March 2013.

GoA (Government of Alberta). 2013b. The Water Management Framework for the Industrial Heartland and Capital Region: Five years of Implementation 2007 – 2012.

GoA. 2015. Water Management Framework for the Industrial Heartland and Capital Region Effluent Characterization Program.

GoA. 2016. The Water Management Framework for the Industrial Heartland and Capital Region: 8 years of Implementation.

GoA. 2018. Environmental Quality Guidelines for Alberta Surface Waters. Water Policy Branch, Alberta Environment and Parks. Edmonton, Alberta.

GoA. 2020. Open Government Program. https://open.alberta.ca/opendata. Accessed December 2020.

GoA. 2019. Alberta Wildfire. Spatial Wildfire Data. http://wildfire.alberta.ca/resources/historical-data/spatial-wildfire-data.aspx. Accessed November 2, 2020.

GoA. 2021. Alberta Regional Dashboard. https://regionaldashboard.alberta.ca. Accessed January 15, 2021.

Gurrapu, S., J.-M. St-Jacques, D.J. Sauchyn, and K.R. Hodder. 2016. The influence of the Pacific Decadal Oscillation on annual floods in the rivers of western Canada. Journal of the American Water Resources Association 1 – 15.

Health Canada. 2013. Providing safe drinking water in areas of federal jurisdiction. Version 2. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario (Catalogue No. H128-1/05-440-1E-PDF).

Health Canada 2017. Guidelines for Canadian drinking water quality: guideline technical document - cyanobacterial toxins in drinking water. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario. (Catalogue No H144-38/2017EPDF).

Health Canada. 2020a. Guidelines for Canadian Drinking Water Quality Summary Table. August 2020.

Health Canada. 2020b. Guidelines for Canadian Recreational Water Quality Cyanobacteria and their Toxins. Guideline Technical Document for Public Consultation. August 2020.

Hutchinson Environmental Sciences Ltd. 2014. North Saskatchewan River: Water Quality and Related Studies (2007 – 2012). August 2014

INAC (Indigenous and Northern Affairs Canada). 2014. First Nations On-Reserve Source Water Protection Plan: Guide and Template.

Kienzle, S.W. M.W. Nemeth, J.M. Byrne, and R.J. MacDonald. 2012. Simulating the hydrological impacts of climate change in the upper North Saskatchewan River basin, Alberta, Canada. Journal of Hydrology 412-413: 76-89.

Kovachis, N., B.C. Burrell, M. Huokuna, S. Beltaos, B. Turcotte, and M. Jasek. 2017. Ice-jam flood delineation: Challenges and research needs. Canadian Water Resources Journal. DOI: 10.1080/07011784.2017.1294998

Kuo, C.-C., T.Y. Gan, and M. Gizaw. 2015. Potential impacts of climate change on intensity duration frequency curves of central Alberta. Climatic Change 130: 115-129.

Lorenz, K.N., Depoe, S.L., and Phelan, C.A. 2008. Assessment of Environmental Sustainability in Alberta's Agricultural Watersheds Project. Volume 3: AESA Water Quality Monitoring Project. Alberta Agriculture and Rural Development, Edmonton, Alberta, Canada. 487 pp. Available at:

http://www1.agric.gov.ab.ca/$Department/deptdocs.nsf/all/irr12914/$FILE/vol3_aesa_waterqualitymonitoringproject_rtw.pdf

Madaeni, F., R. Lhissou, K. Chokmani, S. Raymond, and Y. Gauthier. 2020. Ice jam formation, breakup and prediction methods based on hydroclimatic data using artificial intelligence: A review. https://doi.org/10.1016/j.coldregions.2020.103032

McLoughlin, N. 2018. Personal communication with Mike Christensen, EPCOR, July 24, 2018.

Meigs, G.W., J.L. Campbell, H.S.J. Zald, J.D. Bailey, D.C. Shaw, and R.E. Kennedy. 2015. Does wildfire likelihood increase following insect outbreaks in conifer forests? Ecosphere 6: 118.

Meigs, G.W., H.S.J. Zald, J.L. Campbell, W.S. Keeton, and R.E. Kennedy. 2016. Do insect outbreaks reduce the severity of subsequent forest fires? Environmental Research Letters 11: 045008.

NSWA. 2010. Proposed Site-Specific Objectives for the Mainstem of the North Saskatchewan River.

NSWA. 2012a. Atlas of the North Saskatchewan River Watershed in Alberta. North Saskatchewan River Watershed Alliance Society, Edmonton, Alberta.

NSWA. 2012b. Integrated Watershed Management Plan for the North Saskatchewan River in Alberta. The North Saskatchewan Watershed Alliance Society, Edmonton, Alberta.

NSWA. 2017. An Update on Water Allocation and Use in the North Saskatchewan River Basin in Alberta. Presented at the Partners for the Saskatchewan River Basin Conference. October 17 – 19, 2017.

PPWB (Prairie Provinces Water Board). 2016. Long-Term Trends in Water Quality Parameters at Twelve Transboundary River Reaches. Report # 176. December, 2016.

Pollution Probe. 2004. The Source Water Protection Primer.

Ritson, J.P., N.J.D. Graham, M.R. Templeton, J.M. Clark, R. Gough, and C. Freedman. 2014. The impact of climate change on the treatability of dissolved organic matter (DOM) in upland water supplies: a UK perspective. Science of the Total Environment 473-473: 714-730.

Robinne, F.-C., K.D. Bladon, U. Silins, M.B. Emelko, M.D. Flannigan, M.-A. Parisien, X. Wang, S.W. Kienzle, and D.P. Dupont. 2019. A regional-scale index for assessing the exposure of drinking-water sources to wildfires. Forests 2019, 10, 384; doi:10.3390/f10050384

Rokaya, P., L. Morales-Marín, B. Bonsal, H. Wheater and K.-E. Lindenschmidt. 2019. Climatic effects on ice phenology and ice-jam flooding of the Athabasca River in western Canada. https://doi.org/10.1080/02626667.2019.1638927

Sauchyn D., J. Vanstone, and C. Perez-Valdivia. 2011. Muodes and Forcings of Hydroclimatic Variability in the Upper North Saskatchewan River Basin Since 1063. Canadian Water Resources Journal 36: 205-218.

Sauchyn, D. and N. Ilich. 2017. Nine Hundred Years of Weekly Streamflows: Stochastic downscaling of ensemble tree-ring reconstructions. Water Resources Research, 53.

Sauchyn, D, M.R. Anis, S. Basu, Y. Andreichuk, S. Gurrapuu, S. Kerr, J.M. Bedoya Soto. 2020. Naturaul and Externally Forces Hydroclimatic Variability in the North Saskatchewan River Basin: Support for EPCOR's Climate Change Strategy. Final Report. September 2020

Sawyer, M., and D. Mayhood. 1998. Cumulative effects of human activity in the Yellowstone to Yukon. A Sense of Place

Sham, C.H., M. E. Tuccillo, and J. Rooke. 2013. Effects of Wildfire on Drinking Water Utilities and Best Practices for Wildfire Risk Reduction and Mitigation. Water Research Foundation, 2013. [Online]. Available: http://www.waterrf.org/publicreportlibrary/4482.pdf

Simms, G., D. Lightman, and R. de Loë. 2010 Tools and Approaches for Source Water Protection in Canada. Governance for Source Water Protection in Canada.

Silins, U., M. Emelko, M. Stone, CHS Williams, E. Cherlet, S.A. Spencer, V. Adamowicz, A. Anderson, A. Colins, D. Dupont, M. Dyck, B. Krishnappan and S.M. Quideau. 2020. The Future of Water Supply and Watershed Management in Alberta: Best Source-To-Tap Practices for Source Water Protection in the Eastern Slopes. Alberta Innovates Water Innovation Connect Series. October 22, 2020. Available at: https://albertainnovates.ca/programs/water-innovation/water-innovation-webinar-series/

St. Jacques, J-M., Sauchyn, DJ. and Zhao, Y. 2010. Northern Rocky Mountain streamflow records: Global warming trends, human impacts or natural variability? Geophysical Research Letters, 37(6).

Statistics Canada. 2011. Population and Dwelling Count Highlight Tables, 2011 Census.

Statistics Canada. 2016. Census Profile, 2016 Census.

Statistics Canada. 2017. 2016 Census of Agriculture. May 10, 2017.

Stantec. 2017. North Saskatchewan River Oil Spill Mitigation Plan for Water Supply. Final Report to EPCOR.

Thomas, D. 2020. Wildfire Management Specialist, Rocky Mountain House Forest Area, Alberta Agriculture and Forestry. Personal Communication via electronic email to Mike Christensen, EPCOR. October 13, 2020. Re: Wildfire fighting foam.

Turcotte, B., B.C. Burrell, and S. Beltaos. 2019. The Impacts of cliamte change on breakup ice jams in Canada: state of knowledge and research approaches. Conference: 20th workshop on the hydraulics of ice covered rivers.

US EPA. 2002. Consider the Source: A pocket guide to protecting your drinking water

US EPA. 2019. Recommended Human Health Recreational Ambient Water Quality Criteria or Swimming Advisories for Microcystins and Cylindrospermopsin. May 2019. EPA 822-F-19-001

van Beers, I., R. Maal-Bared, and D. Long. 2014. Water quality variables impacting Cryptosporidium spp. and Giardia spp. concentrations in the North Saskatchewan River. 16th National Conference on Drinking Water, Gatineau, Quebec, October 26 – 29, 2014.

Weaver, J.L. 2017. Bighorn Backcountry of Alberta: Protecting Vulnerable Wildlife and Precious Waters. Wildlife Conservation Society Canada Conservation Report No. 10. Toronto, Ontario, Canada.

Water Research Foundation. 1991. Effective Watershed Management for Surface Supplies.

Water Research Foundation. 2015. Core messages for chromium, medicines and personal care products, NDMA, and VOCs. Report # 4457.

Water Survey of Canada. 2020. Historical Hydrometric Data. https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html. Accessed December 18, 2020.

World Health Organization: 2003. Polynuclear aromatic hydrocarbons in drinking-water. Geneva : World Health Organization.

World Health Organization: 2012. Pharmaceuticals in drinking-water. Geneva : World Health Organization.

Cover Photo : Shawn Fonseca