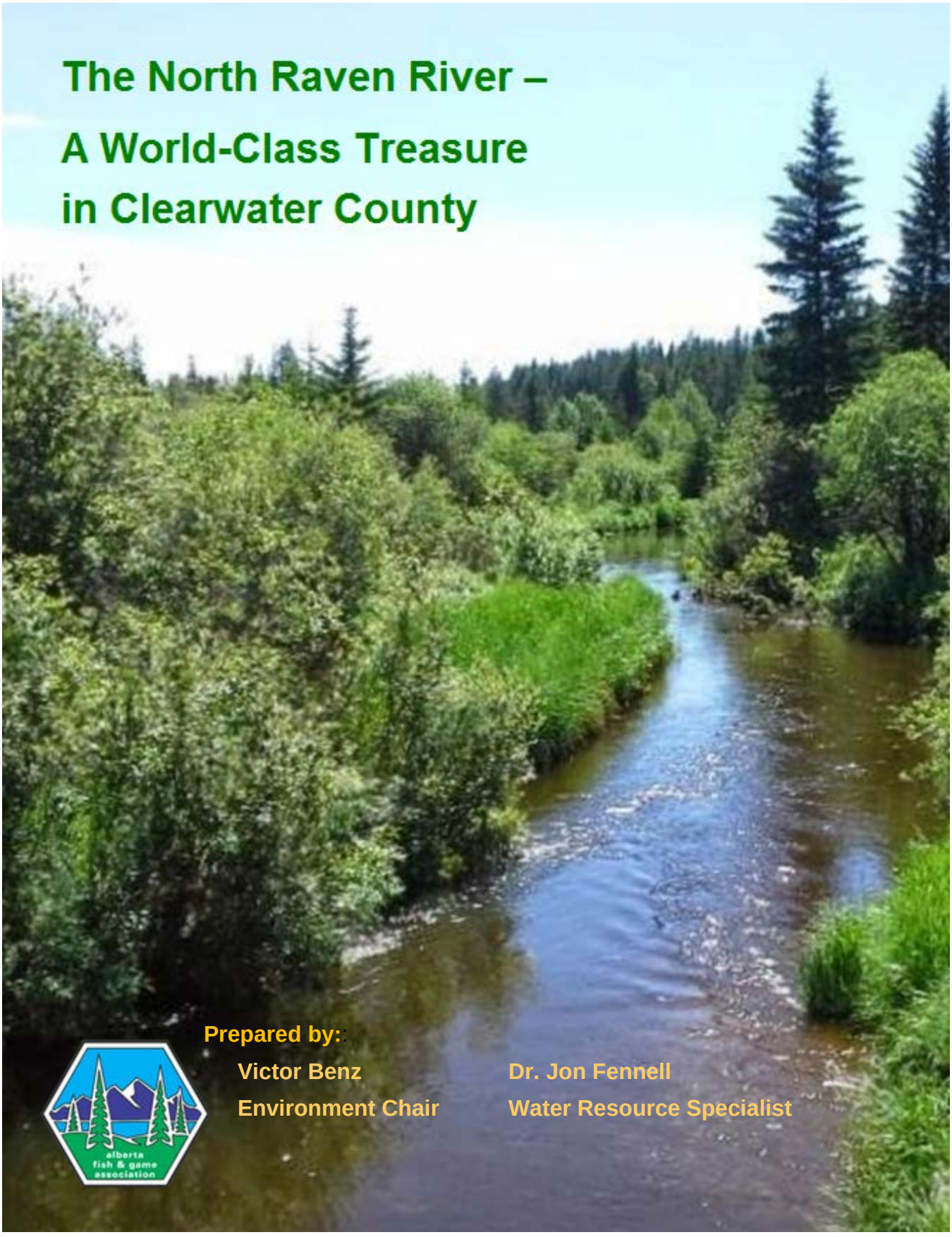
The North Raven River –
A World-Class Treasure in Clearwater County



Prepared by:

Victor Benz
Environment Chair

Dr. Jon Fennell
Water Resource Specialist

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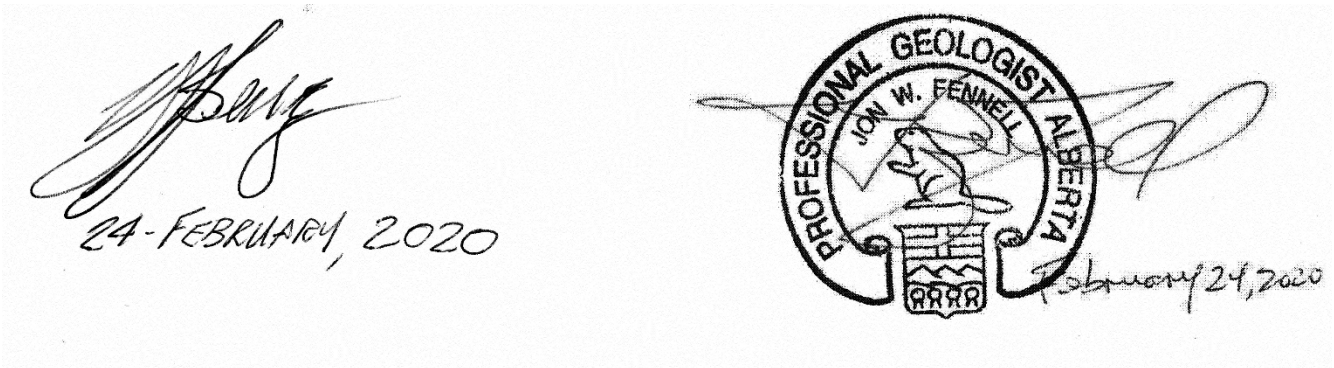
Victor Benz P.Eng., FEC, FGC (Hon.)

APEGA Life Member

AFGA Environment Chair

Jon Fennell M.Sc., Ph.D., P.Geol.

Hydrogeologist and Geochemist



Applies only to hydrogeological and water quality content of this report.

Cover Photo Credit – ACA - Stephanie Fenson

1. EXECUTIVE SUMMARY

The North Raven River and Clear Creek are ecologically unique and environmentally sensitive spring-fed watercourses originating in Clearwater County. Given their sensitivity to surface and subsurface development and the over five decades of rehabilitation that has gone into protecting this system, it is imperative that this special area receives the permanent protection it so richly deserves.

The springs feeding the North Raven River come from an alluvial sand and gravel channel connected to the Clearwater River. They are Meinzer Class III springs. Only a few Alberta springs are larger, most notably Maligne Canyon Springs. Both Miette Hot Springs and Banff Hot Springs are a couple of orders of magnitude smaller than the springs sustaining the North Raven River.

These springs deliver consistent water temperature, high water clarity, and sustained water flow all year around. All three of these critical factors provide exceptional trout spawning and feeding habitat. Having spring sourced water as the primary contribution to overall flow is very rare for a stream of this size in Alberta.

The North Raven River contributes $400,000/yr. to Alberta from direct angling activity alone. In addition, area businesses that depend on the river have indicated that some $350,000 of their annual revenue is derived from the North Raven River.

The North Raven River was first stocked in the 1930s. By 1965, prevailing agricultural, ranching and forestry practices had reduced it to little more than a glorified cattle watering trough. Rehabilitation and restoration began in 1973 with a Buck for Wildlife project. Since then, over $10 million and tens of thousands of volunteer hours have been expended to deliver one of the greatest Alberta conservation stories.

Water quality has been measured at various points along the North Raven River above Secondary Highway 761. Although all measured values generally meet the current Canadian drinking water guidelines, some sample locations exceed those guidelines, as well as the guidelines associated with the protection of freshwater aquatic life.

One of the greatest impacts a development can have is the creation of a large pond or pit. The pond will oxygenate the groundwater, thereby changing how certain trace elements in the sediments (notably chromium) mobilize into the groundwater and move towards the North Raven River.

A review of publicly available literature provides two important aquifer assessments with respect to below water table disturbance. Thermal plumes associated with a sustained disturbance should dissipate in less than a one-year travel time downgradient, <1,920 m. As well, turbidity plumes associated with groundwater disturbance can spread up to 1,830 m downgradient.

To protect this ecologically unique and environmentally sensitive region, the Alberta Fish and Game (AFGA) proposes:

- the creation of a 1.8 km buffer zone surrounding the headwater springs of the North Raven River & Clear Creek, and
- the initiation of a study to identify, inventory and assess all springs and major groundwater discharge areas feeding Clear Creek and North Raven River above Secondary Highway 761. These additional springs, once identified, would then be included in the buffer zone.

2. INTRODUCTION

The AFGA was founded in 1908 and is Alberta's oldest independent conservation group. This report compiled by the AFGA will address the North Raven River, its history, tourism impact, ecological uniqueness and significant environmental sensitivity.

The AFGA is a member of the Alberta Conservation Association (ACA). Along with several partners in conservation, it shares in the ownership and management of nine of the eleven sites in the immediate area. Other partners are Alberta Environment and Parks (AEP), Trout Unlimited Canada (TUC), Clearwater County, Red Deer County and local landowners.

These sites[1], from NW to SE are:

Name	Description	Area	Location	Major Partners
Clear Creek	Purchase	4 acres	SE-26-037-06-WSM	ACA, AEP, TUC
Clear Creek	Riparian Habitat Enhancement Agreements	18 acres	NW-24-36-7W5M SW-25-37-5 W5M	ACA, AFGA, TUC, Clearwater County
Leavitt	Purchase	125 acres	SW-19-03705-WSM	ACA, AFGA, TUC, Clearwater County
Stainbrook Springs	Purchase	17 acres	NW-17-037-05-WSM	ACA, AFGA, TUC
Coulson	Donation	10 acres	Part of NE-35-36-5 W5M	ACA, AFGA
North Raven River	Riparian Habitat Enhancement Agreements	83 acres	SE-19-37-5 W5M NW-9-37-5 W5M N-16-36-4 W5M	ACA, TUC,
North Raven River	Conservation Site	463 acres	Parts of: 30-036-04-WSM 25/36-036-05-WSM 02/09/10/11/16/17-036-05-WSM	ACA, AEP, AFGA, TUC, Clearwater County, Red Deer County,
Raven River	Riparian Habitat Enhancement Agreements	461	E-12-36-7, W5M W, SE-15-36-4 W5M SW-14-36-6 W5M NE-3-36-5 W5M NW-9-36-4 W5M N, SE-12-36-4 W5M NE-36-35-4 W5M S-16-36-4 W5M S-18-36-4 W5M NW-12-36-6 W5M SW-15-36-6 W5M NW-7-36-6 W5M S-14-36-4 W5M	ACA, AFGA, TUC, Red Deer County, Clearwater County
Drake	Purchase	133 acres	SE-17-036-04-WSM	ACA, AFGA
Porter	Purchase	155 acres	SW-17-036-04-WSM	ACA, AFGA
Raven River	Conservation Site	64	Parts of: SE-15-35-7 W5M SW-12-36-7 W5M NE-11-36-4 W5M	ACA, AFGA, TUC

All sites are either in Clearwater County or in Red Deer County.

[1] ACA communication 14 Jan 2020

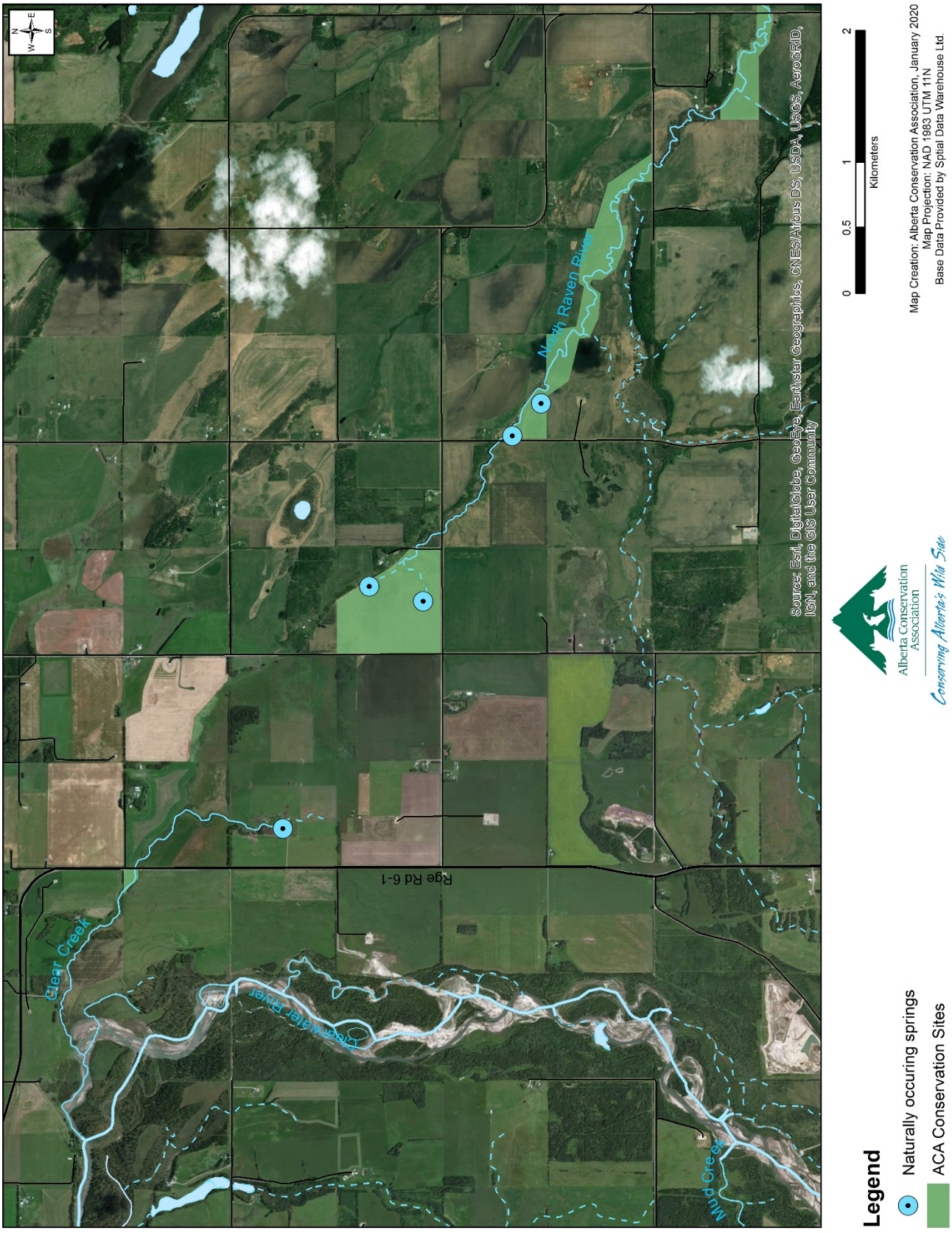


Figure 1. Clear Creek-North Raven River Headwater Springs

3. HISTORY OF THE NORTH RAVEN RIVER

The North Raven River is spring fed from an alluvial sand and gravel channel connected to the Clearwater River[2]. There are four major springs that have been identified to date; two on the Leavitt property and two on the Stainbrook Springs property (Figure 1). Many more minor springs add to the flow over the first few kilometers of the river, with groundwater contributions occurring along the entire length.

The North Raven River originates 3.6 km east of the Clearwater River and flows generally in a SE direction until its confluence with the Raven River 18 km away, "as the crow flies". The actual river is much longer, due to its meandering style.

Photo credit - ACA - Kevin Gardiner

Originally known as Stauffer Creek, it was first stocked with brown and brook trout in the 1930s[3][4].

Following the end of World War II, agricultural, ranching and forestry intensity increased significantly in this region[5]. Livestock grazing destroyed stream bank vegetation and cattle traffic caused erosion and degradation of the stream banks. By the early 1960s, Stauffer creek was little more than a glorified cattle trough. Banks were destroyed and it became a wide, wet, and muddy flat in many places.

In the late 1960s, a stream study was completed that "outlined the problems and proposed ways of rehabilitating the river: basically narrowing the river's channel by rebuilding its banks, replanting willows to stabilize the banks and shade the stream, and fencing cattle away from the creek, except for specified, well-protected watering locations, including some off-stream ponds[6]."

Photo Credit - TUC via Don Andersen

In 1973, the provincial government established the Buck for Wildlife Program (BFW) and the rehabilitation of Stauffer Creek was announced as its first project, as championed by the AFGA. The first land purchase was what is now the Buck for Wildlife parking lot where RR 53 crosses the North Raven River.

[2] Borneuf 1983
[3] Don Andersen discussion 04 Jan 2020
[4] Bob Scammell-Red Deer Advocate 03 July 2014
[5] Komex 2000
[6] Bob Scammell-Red Deer Advocate 10 July 2014

Led by a watershed resident and former AFGA President, Elmer Kure, initial work proceeded quickly.

Photo Courtesy of Bob Vanderwater

The rehabilitation program brought together provincial wildlife biologists, other government workers, streamside landowners, and many other volunteer organizations. Agreements were signed with streamside landowners supporting the construction and ongoing maintenance of livestock exclusion fences and watering/crossing sites to protect streambanks.

An Order-in-Council officially changed the name of Stauffer Creek to the North Raven River.

In 1997, the responsibility for maintenance at project sites was transferred from the BFW to the ACA. The ACA is a delegated administrative organization (DAO), operating at arms-length from the Alberta provincial government through independent directors, some of whom are appointed by the Minister of Environment and Parks.

The ACA is self-funded, and raises revenue through enhancement levies on various hunting and fishing licences and permits issued by the province. The ACA is specifically charged with many elements of conserving the fish, wildlife and habitat resources of Alberta[7].

The ACA has continued the work on the North Raven River, negotiating new habitat lease agreements with landowners and terminating the old BFW agreements.

[7] ACA Mandate & Roles 2014

In the new agreements, landowners are provided with new straightened fences, set further back from the stream and thus increasing the habitat area protected. In addition, landowners receive financial compensation to assist with stewardship of the project sites.

Photo Courtesy of Bob Vanderwater

Over these past 47 years, some $10 million has been spent on the rehabilitation, enhancement and protection of the North Raven River, much of it within Clearwater County. Tens of thousands of volunteer hours have also been accrued and work continues to this day. This is arguably the greatest Alberta conservation story.

Clearwater County's Clear Water Land Care Program (formerly Rocky Riparian Group), has made significant investments in the Raven River drainage system through public outreach and education. Examples include demonstrations of off-site watering systems to agricultural producers, education on water quality, assisting landowners in grant applications targeted at riparian protection and proposing to partner with the ACA on an Eco-buffer project at the Leavitt Conservation Site starting in 2020. In addition, Clearwater County places Environmental Reserves (ER), which are "no disturbance" allowed areas, adjacent to streams, on properties along the North Raven River as a condition of approving natural-feature-related subdivisions.

Surveys conducted by the ACA continue to substantiate the creation of a world-class trout fishery. Most recently, in 2019, ACA counted more than 1600 redds[8] (gravel nests made by spawning trout) between the headwater springs and Secondary Highway 761. The majority were in the stretch from the Stainbrook Springs property to the BFW parking lot on RR 53.

Clear Creek is a small stream (approximately 4 km long) that also originates from ground water flow from the Clearwater River, the same aquifer that feeds the North Raven River springs. The headwater springs of Clear Creek are approximately 1.6 km NW of the North Raven River headwater springs but Clear Creek flows westerly into the Clearwater River due to the minor elevation change between the two systems (Figure 2).

[8] ACA unpublished report-Mike Rodtka email 09 Jan 2020

Significant monetary and volunteer hour investments have also been made on Clear Creek. Rodtka[9] reported the sportfish catch in a 2001 survey represented a 357% increase from a previous survey in 1991. Clear Creek is considered important for sportfish rearing and spawning purposes but is not as an angling destination. In 2001, 70% of the sportfish catch were less than 100 mm fork length and therefore considered young of the year[10]. Also, in 2001, a bull trout was captured in the headwater spring of Clear Creek. This was the first cited capture of a bull trout in Clear Creek. Bull trout in the North and South Saskatchewan river basins in Alberta are listed as threatened under the federal Species at Risk Act (SARA) Committee on the Status on Endangered Wildlife in Canada.

[9] Rodtka 2001
[10] ibid

4. UNIQUE ASPECTS OF THE NORTH RAVEN RIVER

Three elements are critical to the creation of this world-class trout fishery:

- stable temperature,
- high clarity, and
- sustained flowrate.

The North Raven River and Clear Creek are a truly unique aquatic ecosystems due to the consistency in the water quality related to the groundwater springs forming the headwaters. The consistency in water temperature, clarity and flowrate are critical for these sensitive fish populations. For example, overwintering is a major limiting factor in most lotic (flowing water) systems. However, the headwaters of the North Raven River and Clear Creek remain ice free throughout the winter season, mitigating this concern. The steady provision of water by the springs and discharging groundwater, as well as agitation and oxygenation by the flowing water, provide perfect spawning conditions for salmonids. Most biologists consider the headwater reaches of the North Raven River a naturally occurring and unique fish spawning ground.

4.1 WATER TEMPERATURE

The headwater springs moderate the water temperature throughout the year.

> "Water temperature in the North Raven River is relatively cool and stable, which is beneficial for trout. For example, during the summer of 2018 (June – August) ninety-five percent of hourly water temperature measurements taken at the headwaters of the North Raven River (Leavitt Springs) normally ranged between 5°C and 7°C (average: 6°C, minimum: 5°C, maximum: 11°C). For context, the 95th percentiles for air temperature (a driver of stream temperature) over the same timeframe in the general area were 4°C and 28°C (average temperature: 15°C, minimum: 0°C, maximum: 35°C)."(interim ACA report[11])

Trout are a cold-water species. It is very common to see particularly Brook Trout clustered around the headwater springs, where the water is the coolest[12]. Brook Trout, one of the major trout species in the North Raven River[13], prefer a temperature range of 14°C - 17°C[14]. The lethal temperature is 25°C[15]. The upper lethal temperature for developing eggs is listed as 12 °C[16]. Any significant temperature plume would immediately endanger any eggs laid near the headwater springs, which is the primary spawning area.

4.2 WATER CLARITY

Water clarity is a critical factor in the survival of trout eggs. Well-filtered water for the North Raven River is the result of being spring fed via a permeable gravel aquifer. The clear water also allows fish to feed on abundant prey species, all year.

Where most other Alberta streams experience numerous periods of turbid high water, limiting feeding, the North Raven River and Clear Creek do not.

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[11] ACA unpublished report-Mike Rodtka email 09 Jan 2020
[12] Dean Baayens – private communication
[13] Red Deer River State of the Watershed Report 2009
[14] McClane's New Standard Fishing Encyclopedia 1974
[15] ibid
[16] Freshwater Fishes of Canada 1973

4.3 WATER FLOWRATE

Borneuf measured the North Raven River minimum winter flowrate at about 34 cubic meters per minute (0.57 m^3/s)[17]. A study conducted by Komex for PetroCanada in 2000[18] confirmed the flowrate. This makes the North Raven River a Class III spring-fed stream on the Meinzer Classification Scale.

Only a few Alberta springs are larger, notably Maligne Canyon Springs. Miette Hot Springs and Banff Hot Springs are both smaller than the springs sustaining the North Raven River.

The late spring flowrate is dependent on the high-water stage of the Clearwater River due to snow melt, which effectively doubles the winter flowrate.

Rainfall and local snowmelt runoff will contribute to the stream flow and the turbidity of the North Raven River, but the overall consistent spring flow and groundwater discharge from the alluvial gravel system means the river water quickly clears, minimizing turbidity risk to the aquatic ecosystem.

[17] Borneuf 1983
[18] Komex 2000

5. TOURISM IMPACT

The North Raven River sees up to 3,000 angler-days per year. In part, this is because the upper half of the river never freezes due to the headwater spring water temperature. As such, the upper river is open to fishing throughout the year. The angler data is consistent with ACA surveys of 1986 and 1996[19]. For comparison, the Bow River sees about 177,600 angler-days[20] per year.

Photo Credit – TUC

Calculating the economic value of angling is notoriously difficult, as noted by Watson[21]. A literature review has yielded impact numbers with a range of $60 - $180 per fishing day. The primary difference is in the methodology.

A 2016 report[22] identifies the estimated direct economic value of sport fishing in Alberta in 2010 at $138 per fishing day. This value compares favourably with data for trout fishing in North Carolina[23] and New Mexico[24]. Therefore, the estimated direct angling impact attributed to the North Raven River is about $400,000 per year in perpetuity (not including inflationary costs).

[19] Kevin Gardiner email 25 Nov 2019
[20] CRUA 2016
[21] Watson 2007
[22] CRUA 2016
[23] North Carolina 2015
[24] New Mexico 2013

Local businesses have been contacted as well. Tackle and Trails[25] in Rocky Mountain House has stated that they would lose about $15,000 a year in business if the North Raven River were permanently damaged and angling opportunities were lost. Past owners of the Lazy M Guest Ranch[26], located right on the North Raven River, attribute $6,000 - $12,000 annually to trout fishing for the almost 20 years they operated the facility. They have recorded guests from all over Canada and the US; as well as visitors from the UK, EU, and even Russia.

Photo Credit - ACA via Kevin Gardiner

Although the primary economic impact is due to the world-class angling opportunities, the wildlife corridor established through this rehabilitation has become a favorite for birdwatchers and other wildlife enthusiasts, as recounted by the former owners of the Lazy M Guest Ranch.

The current owners of the Lazy M Guest Ranch have submitted a letter of concern to both Clearwater County and the Honourable Jason Nixon, Minister of Environment and Parks[27].

In it, they have stated that the primary reason they purchased the property was the North Raven River ecosystem.

> *"When choosing a location for our business the North Raven river bordering the property played a huge factor in the appraisal process. To have nearly one kilometer of an extremely unique 100% spring fed river within its boundaries made this location very attractive. The wild life and bird life attracted by the constantly flowing river year round also increased the environment to help us create a retreat where guests could escape the city life and live in nature for several days to "Rest Relax and Recharge" the motto for our business model. A 1.3 million dollar investment in the Clear Water County."*

In addition, they state an annual sales revenue of $250,000 and an annual secondary impact on area businesses of $50,000 to $100,000.

We arrive at a figure of approximately $750,000 annually, in perpetuity, for the economic impact of the North Raven River as it exists today.

[25] Kevin Gardiner email – 09 January 2020
[26] Kevin Gardiner email – 09 January 2020
[27] Kevin Gardiner email - 21 January 2020

6. LOCAL SETTING AND WATER QUALITY CONDITIONS

As noted previously, the North Raven River is a tributary stream to the Raven River and eventually the Red Deer River. Situated in the Red Deer River watershed, it is a unique trout stream flowing entirely through Alberta's white zone (settled area). Its existence is owed to contributions of freshwater springs and groundwater discharge from permeable sand and gravel deposits. This extends to the existing conservation areas, which relieve some of the surrounding development pressures.

Clear Creek is fed by the same aquifer, buts flows in the opposite direction into the Clearwater River and eventually the North Saskatchewan River watershed.

To the west (about 3.6 km) is the Clearwater River, which is part of the North Saskatchewan River watershed. The divide between these two watersheds is situated somewhere between these two river systems.

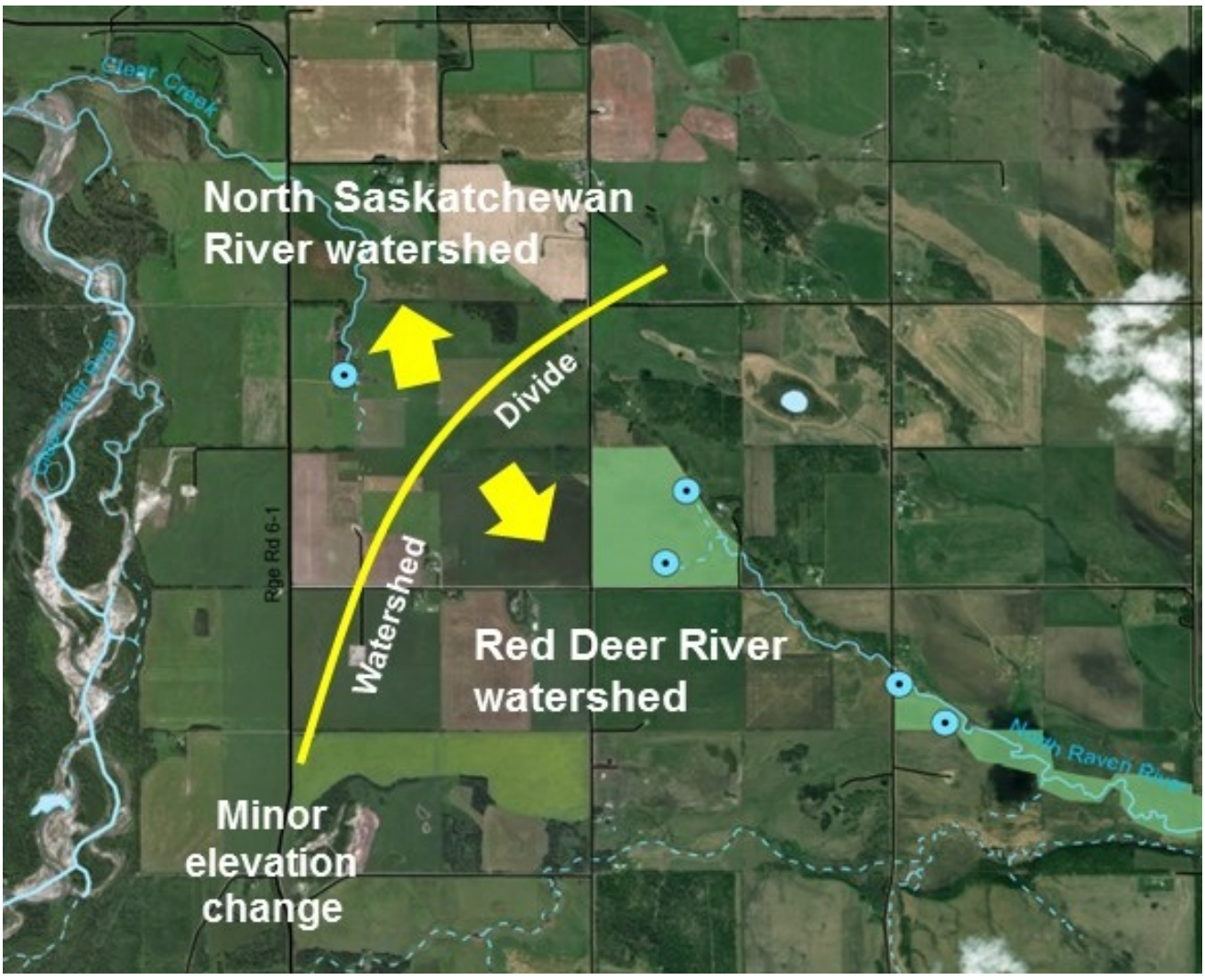

Figure 2. North Saskatchewan River – Red Deer River Watershed Divide

The Clearwater River is situated at a higher elevation than the North Raven River and flows towards the north, while the North Raven River flows from its headwater area in the Leavitt and Stainbrook Springs Conservation Areas towards the southeast eventually joining the eastward flowing Raven River near the town of Raven, Alberta.

Although there is a divide between the two river systems, the elevation difference is not significant (i.e. approximately 1 m) leading to the risk of flood inundation, which has occurred occasionally when the Clearwater River has breached its banks, most recently in 2007.

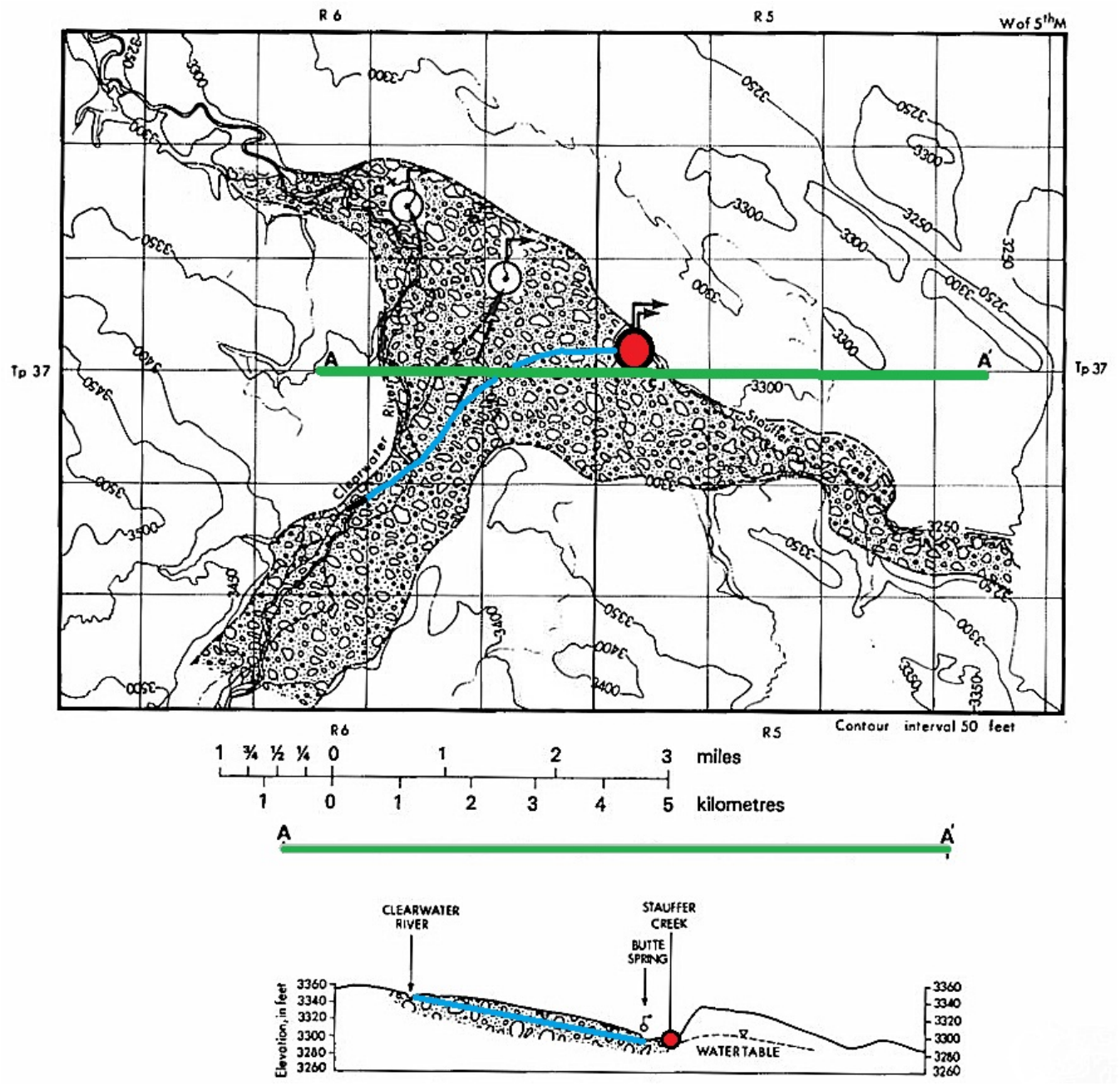

Figure 3. Mapped extent of alluvial sand and gravel within the Clearwater and North Raven River systems (Note: blue arrow = direction of groundwater flow; red dot = location of Stauffer Spring) [28]

In 1983, the presence of a relatively extensive and high yielding (permeable) sand and gravel deposit existing between the Clearwater River and the North Raven River was identified (Figure 3).

[28] Borneuf 1983

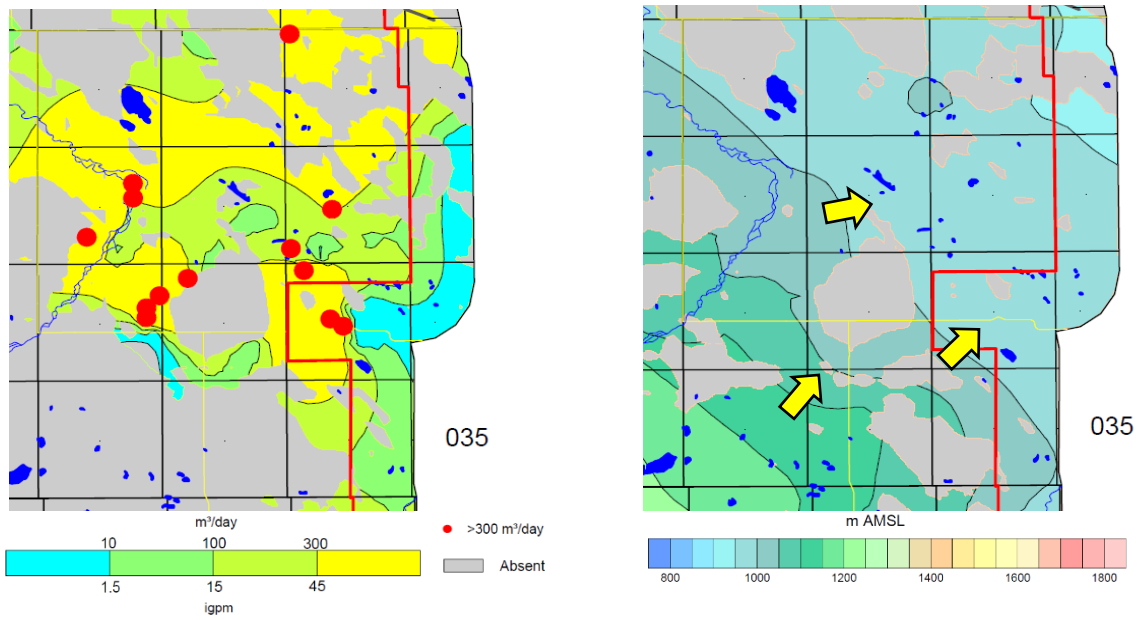

Figure 4. Distribution of sand and gravel deposits and apparent yield characteristics, left, and non-pumping water level elevations in surficial deposits based on water well less than 20 m deep (Note: yellow arrows indicate groundwater flow directions).[29]

This was later confirmed by Hydrogeological Consultants Ltd. [30](Figure 4, left image). In combination with the generally eastward sloping groundwater surface elevations and the shallow upper 20 m groundwater interval (Figure 4, right image), contributions of groundwater from the Clearwater alluvial system into the North Raven River headwater area are consistent with the local setting.

To further substantiate connectivity between these two river systems, a review of water well records from locations between the two rivers was conducted. Figure 5 shows the locations of documented water wells with sand and gravel (S&G) deposits encountered within 10-15 m of the surface. Other than a few wells with no data provided (ND), the presence of a relatively contiguous sand and gravel deposit is substantiated.

[29] HCL 2004
[30] ibid

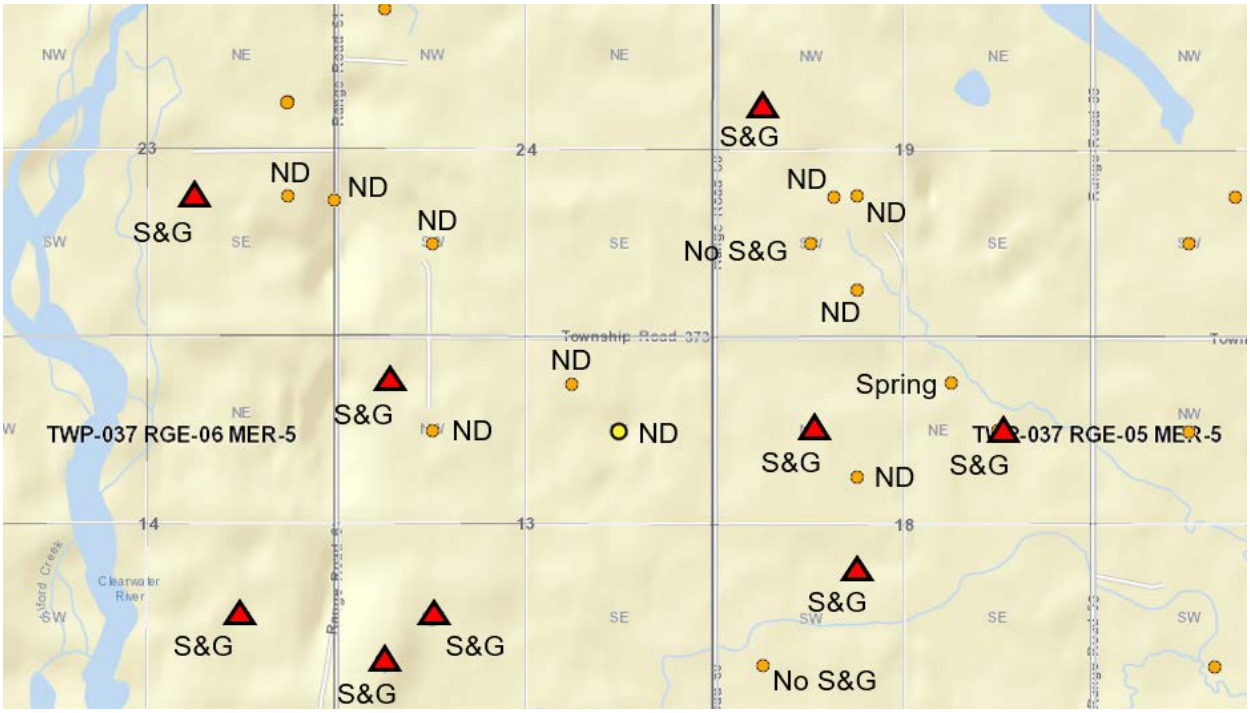

Figure 5. Locations of water wells where sand and gravel (S&G) has been identified at roughly the same depth interval in the upper 20 m of the subsurface. (Note: ND = no data)[31]

Estimates of the groundwater flow velocity in the sand and gravel deposits were made back in 1983 using measured hydraulic values and an assumed effective porosity of 35%. Given the considerable permeability associated with these granular deposits, a notably high travel rate of 5.3 metres per day, or about 2 kilometers per year has been documented[32].

Review of available groundwater quality from water wells located throughout the study area indicates geochemical conditions consistent with a relatively fast flowing aquifer system (i.e. low groundwater mineralization). For example, the TDS (total dissolved solids) content of water sampled from Well 452525, located in SE-05-37-5 W5M, yielded a value of 353 mg/L[33]. Water sampled from the Clearwater River at the same time yielded a TDS value of 315 mg/L. This represents an increase of only 38 mg/L over a distance of about 3 km, and is consistent with a limited amount of water-rock interaction and mineral dissolution.

Of particular note is the presence of comparatively elevated concentrations of certain nutrients and trace elements in the groundwater, in particular nitrate, chromium, copper, manganese, and zinc (Tables 1, 2a and 2b). Although all measured values generally meet the current Canadian drinking water guidelines[34] some sample locations exceed those guidelines, as well as those associated with the protection of freshwater aquatic life (FWAL)[35]. This has implications for the North Raven River since that groundwater is the sustaining mechanism of flow in that river, whether it be from spring discharges or diffuse contributions through the base of the river (i.e. baseflow).

[31] http://groundwater.alberta.ca/WaterWells/d/
[32] Borneuf 1983
[33] Komex 2000
[34] Health Canada 2019
[35] GoA 2018

Review of water quality at local springs along the North Raven River, as well as water samples from the river itself (Tables 2a and 2b), similarly show elevated levels of nutrients (i.e. phosphorous and nitrate), as well as cadmium, chromium, and iron compared to anticipated background conditions. In some cases, the concentrations are approaching, or exceed, established long-term guideline values for the protection of freshwater aquatic life (FWAL).

With respect to phosphorous, the concentration noted at the Alberta Environment and Parks Stauffer Creek station AB05CB0030, measured at 0.028 mg/L in 1991, is consistent with meso-eutrophic conditions.[36] This is unexpected for such a pristine headwater area.

The suspected source and cause of the trace elements in the groundwater and receiving surface water is natural weathering of the aquifer sediments and dissolution of minerals containing these elements. As for the nutrients (nitrate and phosphorous), impacts from agricultural activities are the likely reason. The detection of faecal and total coliforms also suggests impacts from human and/or animal wastes on this sensitive river system (Tables 2a and 2b). Unfortunately, there is no water quality data available for the nearby Clear Creek, which is similarly spring-fed and groundwater-sustained, but the situation is likely the same.

[36] http://st-ts.ccme.ca/en/index.html?lang=en&factsheet=167

7. SENSITIVITY TO DISTURBANCE

The North Raven River and Clear Creek both originate from the extensive sand and gravel deposit beneath the area. Both water courses are sustained by groundwater that flows out of this sand and gravel deposit via springs and diffuse baseflow contributions, which serves to:

- maintain a wetted environment conducive to ensuring a healthy riparian buffer
- regulate stream temperatures and deliver nutrients to the aquatic species dependent upon and inhabiting those streams, and
- provide suitable and sustainable spawning and overwintering habitat to ensure the viability and proliferation of existing fish species and associated feedstock.

These two water features depend on the local groundwater and any changes to how and where this groundwater flows, as well as changes to the quality of that groundwater, will have ramifications. These streams originate in the local area unlike other rivers and streams, which are sustained by larger watersheds. The lack of any upstream contributions creates a sensitivity to disturbance that is not experienced by other river systems. Human development activities will have a more immediate impact on the local water balance and the smaller catchment areas.

Many types of surface and subsurface development have the ability to negatively impact shallow groundwater quality, quantity and flow conditions through direct and indirect means. These are expanded upon in the following section along with some challenges to consider post-development.

8. IMPACT OF SURFACE AND SUBSURFACE DEVELOPMENT (INCLUDING CREATED PONDS & LAKES)

It is evident that the North Raven River is already experiencing some degree of low-level impact to the groundwater and surface water from surrounding land development. By extension, future development can only be seen to exacerbate this situation and increase the risk profile for the local streams relying on the provision of clean, temperature-regulated groundwater. Future risk to the local streams and their reliant ecosystems is therefore associated with events such as:

- Spills and leaks of fuels or chemicals that may be used to support industrial activity.
- Subsurface releases of hydrocarbons and produced water from oil and gas wells, as well as related underground infrastructure (e.g. pipelines).
- Seepage and/or surface runoff of contaminated wastes from above or below ground waste management facilities (e.g. landfills) and confined feeding operations.
- Overuse of fertilizers and pesticides to promote crop yield.
- Physical disturbance of the subsurface by the removal of protective soil layers and excavation of the underlying sediments.

These risks have implications for both the quality of water discharging to local streams and water bodies as well as the local groundwater flow conditions. For example, Mead[37] studied the implications of gravel mining on local groundwater turbidity and found that in highly permeable aquifer systems turbidity levels remained elevated at values of around 2 NTU (Nephelometric Turbidity Unit) in water wells located up to 6,000 feet from these operations, or roughly 1.8 km. This matches the FWAL long-term exposure criterion for rivers like the North Raven River. Blackport and Golder[38] also found that thermal plumes from gravel pits generally dissipated in less than a one-year travel time downgradient of such subsurface disturbance. Although the thermal risk to nearby water bodies may be low for slower flowing groundwater systems, the same may not hold true for faster flowing systems, like the alluvial sand and gravel beneath this study area (i.e. 5.3 m/day, or 1,935 m/year).

Large excavations can also have an impact on local groundwater flow directions and water balance conditions. For example, when an excavation occurs below the water table and results in an open water surface, the water table will flatten. This results in a lowering of the water table on the upgradient side of the excavation and an increase in the water table on the downgradient side. Depending on how far the water table is lowered below the land surface, this could have implications for crop development. Similarly, the resulting increased drop from the land surface to pond increases the risk of land erosion and compromising of the pond edges by cascading runoff water, if inundated by an overland flood. Conversely, an increase in the water table at the downgradient end of the pond can lead to land stability issues, reduced accessibility for heavy machinery and increased geotechnical risk.

[37] Mead 1995

[38] Blackport Hydrogeology Inc. and Golder Associates 2006

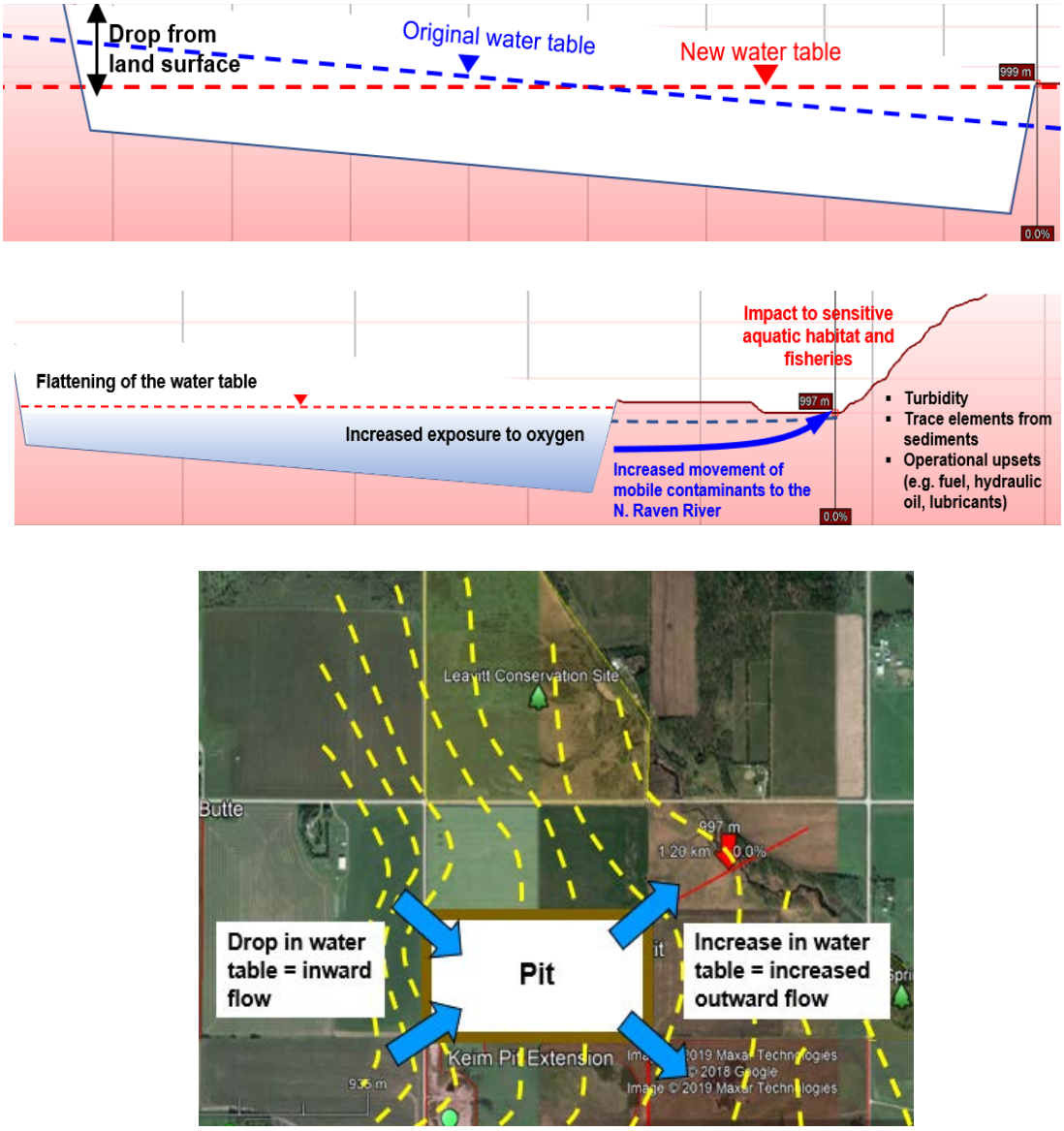

Figure 6. Influences on the physical and chemical conditions around a large excavation below the water table

Alteration of the local groundwater flow conditions and enhanced evaporative loss will also occur, which may adversely affect downgradient groundwater/surface water interactions (i.e. springs and baseflow discharges). In addition to the turbidity "migration" risk identified earlier, enhanced oxygenation of the groundwater being captured by the pond has the ability to alter local geochemical conditions and enhance the mobilization of naturally-occurring constituents like chromium, copper, zinc, etc. and increase their already elevated concentrations in the groundwater (and by extension the springs and local streams).

There are also residual issues that typically occur after the completion of excavation activities and the development of large artificial ponds and lakes. Notwithstanding the usual cost to maintain such constructions (which would fall to the County once a reclamation certificate is granted), the introduction of nutrients from nearby agricultural developments has the ability to alter water quality in such impoundments by enhancing the growth of algae, cyanobacteria and other oxygen-depleting organisms, reducing oxygen levels and shifting geochemical conditions. This can again change the mobility characteristics of certain constituents in the surrounding sediments and increase the risk to downgradient receptors to compromised groundwater.

The implications for receiving water bodies like the North Raven River and Clear Creek are obvious. Increased turbidity levels and temperature conditions can be harmful to sensitive aquatic habitat. This can, in turn, have negative effects on other reliant organisms and sensitive fish species. The release of contaminants, either directly or through alterations to subsurface conditions, can also result in adverse effects if generated at high enough concentrations. The most dangerous type of release would be a gradual, sustained, low-level release leading to long-term exposure without any mitigation.

The fact that the North Raven River and Clear Creek are sustained by discharge from springs and groundwater baseflow, that the local groundwater already contains elevated levels of certain potentially harmful constituents (i.e. trace elements), and the fact that the water flowing in the North Raven River is already showing signs of impact from area development (i.e. elevated nutrients) places these sensitive water courses at high risk compared to other less unique water bodies.

Based on the preceding, the following challenges with future development near the North Raven River and Clear Creek exist, which underscores the need to protect these sensitive and unique water courses:

- Further surface or subsurface development will disturb the natural groundwater flow conditions and alter important contributions from local springs and groundwater baseflow.
- Spills, leaks, and subsurface releases of natural or development-related contaminants (including turbidity from invasive activities) will adversely initially impact groundwater quality, and eventually the connected surface water systems sustaining the unique aquatic habitat.
- Large surface disturbances exposing the subsurface below the water table to oxygen and surface drainage will initially affect the chemistry of the groundwater and eventually the water quality in connected streams.
- The area is already heavily developed for agricultural purposes and is showing signs of influence on the local groundwater and surface water quality. Further development will not reduce this effect and will contribute to the cumulative impact.
- Future developments that may impact the local groundwater are not consistent with sustainable development goals and the need to “make room for nature” in our continuously developing watersheds.
- There are plenty of other less sensitive areas in Clearwater County that can accommodate development needs, while protecting the sensitive aquatic ecosystems of the North Raven River and Clear Creek.
- The provision of a 1.8 km protection zone around the known North Raven River and Clear Creek headwater springs will provide the necessary buffer against future development threats and ensure sustainability of these unique riverine settings.

9. PROTECTION PROPOSAL

Over the past decade, there have been a number of development applications submitted to Clearwater County that infringe upon the recommended buffer to protect the North Raven River and Clear Creek. Given the sensitivity of Clear Creek and the North Raven River to disturbances from land and subsurface development, and the efforts that have gone into protecting these types of lotic systems, it is imperative that this special area receives the permanent protection it so richly deserves.

A literature review on the impact of a significant disturbance of a gravel deposit below water table has yielded important recommendations.

- A 1995 study[39] from Thurston County, Washington stated that a 1978 Oregon Department of Environmental Quality study "… found a turbidity plume that extended more than a mile to the north (downgradient) of the gravel operation. … Nearly all wells sampled within the first 6,000 feet of the turbidity plume were measured at 5 NTU or more. Many wells within the first 3,000 feet of the plume had turbidity levels of 10 NTU or more. Nearly all wells outside the plume had turbidities of 2 NTU or less." 6,000 feet converts to 1,829 m. Long-term (>24h) increases of greater than 2 NTU over background levels are considered to have unacceptable negative impacts on the aquatic environment.[40]
- A 2018 Technical Memorandum[41] from Thurston County, Washington stated that "… groundwater needs to be monitored up to 6,000 feet downgradient of the mine in gravel deposits."
- A 2006 study[42] co-authored by Blackport Hydrogeology Inc. and Golder Associates "… reviewed additional thermal modeling assessments from unpublished reports and concluded that the thermal plumes from gravel pits generally dissipated in less than a one-year travel time downgradient of the gravel pit pond." The aquifer feeding the North Raven River has a calculated groundwater flow velocity through the gravel system of 5.3 m/day. This gives a one-year travel distance of 1920 m.

We therefore recommend a 1.8 km environmental buffer be implemented around the known headwater springs and sensitive reaches along North Raven River and Clear Creek. (Figure 7)

Secondly, a study should be conducted to identify, inventory and assess all springs and major groundwater discharge areas feeding Clear Creek and North Raven River above highway 761. These additional springs, once identified, would then also be buffered.

This environmental buffer zone would grandfather current approved agricultural and commercial developments at their current intensity levels.

[39] Mead 1995
[40] https://www.dfo-mpo.gc.ca/Library/255660.pdf
[41] Hansen 2018
[42] Blackport Hydrogeology Inc. and Golder Associates 2006

Under such a new regime, new developments or development amendments would be actively discouraged and would require a full environmental impact assessment that addresses, at a minimum:

- The protection of groundwater resources, both quality and quantity (including flow conditions)
- The protection of the North Raven River and Clear Creek aquatic ecosystems
- The protection of the North Raven River and Clear Creek wildlife habitat
- The potential impact on the 1.8 km riparian buffer from cumulative development effects

Several opportunities exist for more formal protection under Clearwater County's Land Use Bylaw.

- Modify the existing Agriculture Land Use District 'A' to include this 1.8 km buffer zone.
- Create a new, additional Agriculture Land Use District based on this 1.8 km buffer zone.
- Define this 1.8 km buffer zone as either an Environmental Reserve or Environmental Reserve Easement.

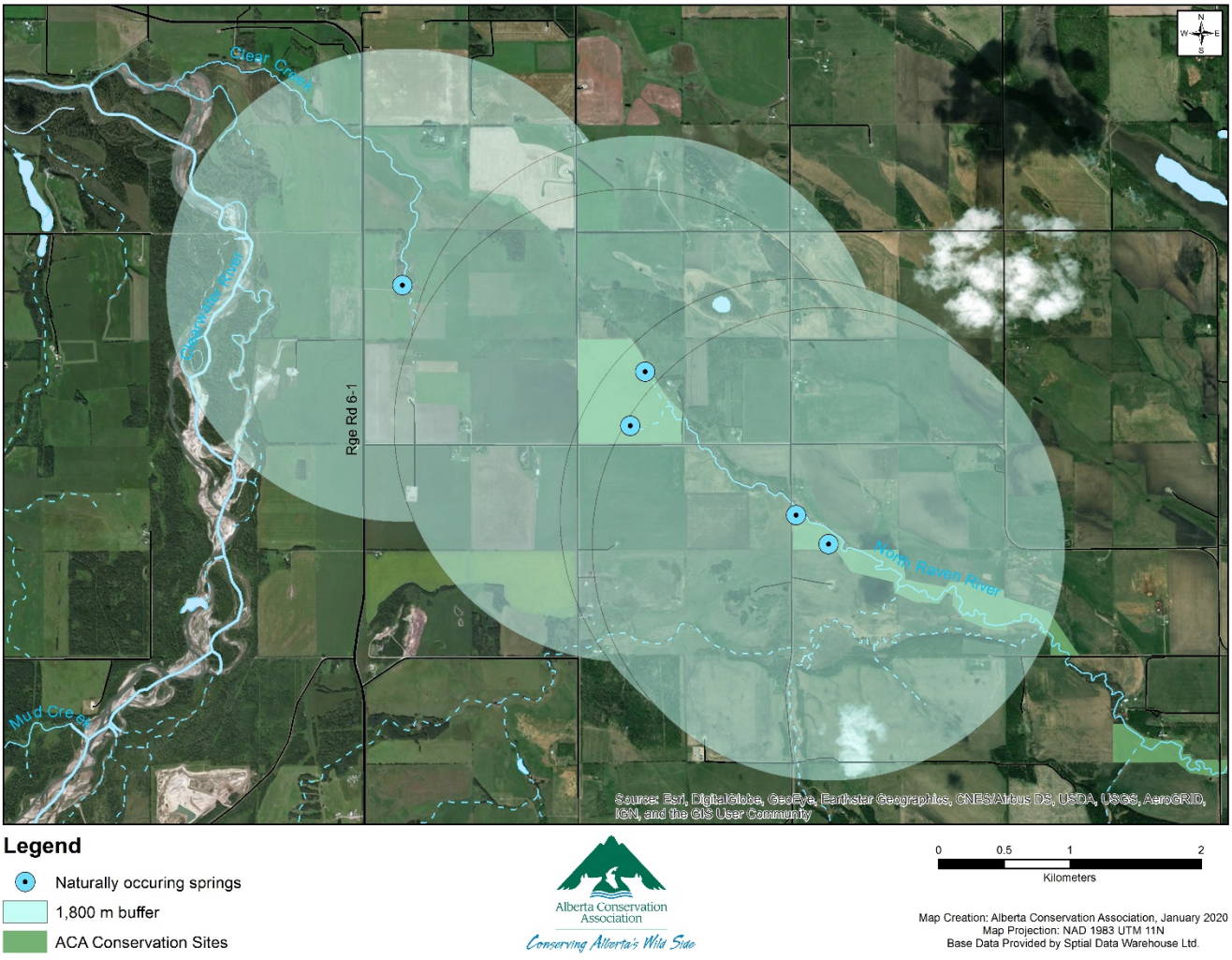

Figure 7. Proposed 1.8 km buffer around the known headwater springs

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Alberta Environment and Parks, swq.requests@gov.ab.ca, data request for surface water quality on the North Raven River Stations AB05CB0030: Staffer Creek and AB05CB0040: North Raven River at Hwy 761, received January 8, 2020.

11. TABLES

Table 1. Selected metals and trace element concentrations in local groundwater

Location	Date	TDS	ANTIMONY (Sb)	CHROMIUM (Cr)	COPPER (Cu)	MANGANESE (Mn)	ZINC (Zn)
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
CDWQG 2019			0.006	0.05	2	0.12	5
GoA FWAL			--	0.001 (6+) 0.0089 (3+)	0.039		0.03
SE-37-06 W5M	19-Oct-95	--	0.001	0.0051	0.005	0.014	0.014
NW-17-36-06 W5M	12-Mar-09	--	0.001	0.0005	0.014	0.001	0.021
27-36-06 W5M	19-Oct-95	--	0.203	0.0043	0.066	0.002	0.061
15-36-05 W5M	19-Oct-95	--	<0.001	0.0035	0.009	0.001	0.002
NE-01-36-05 W5M	23-Jul-07	--	0.001	0.0005	0.002	0.062	0.007
NE-08-36-05 W5M	04-Sep-07	--	0.001	0.0005	0.002	0.153	0.004
NW-03-36-05 W5M	11-Aug-07	--	0.001	0.0005	0.009	0.006	0.001
SE-05-35-05 W5M	24-Feb-00	353	<0.0002	0.005	0.0036	0.040	0.012
NW-32-36-05 W5M	24-Feb-00	358	<0.0002	0.001	0.0003	0.030	0.003
NW-33-36-05 W5M	24-Feb-00	323	<0.0002	0.050	0.0008	0.080	0.006

Notes: CDWQG = Canadian drinking water quality guidelines
FWAL = freshwater aquatic life guidelines
yellow shading = values above CDWQG criteria;
green shading = values above FWAL guidelines
Cr^{6+} = hexavalent (more toxic form)
Cr^{3+} = trivalent (less toxic form)

Table 2a. Selected constituents measured in surface water (including springs) located within the study area.

STATION NAME	DATE	TDS	DISSOLVED P	TOTAL P	FECAL COLIFORMS	TOTAL COLIFORMS
		mg/L	mg/L	mg/L	# per 100 mL	# per 100 mL
GoA FWAL guidelines						
Komex 2000						
Clearwater River	7-Mar-00	315	<0.1	--	--	--
Stauffer Ck. Spring No.1	1-Mar-00	297	<0.1	--	--	--
Stauffer Ck. Spring No.2	1-Mar-00	298	<0.1	--	--	--
Stauffer Ck. Spring No.3	3-Mar-00	308	<0.1	--	--	--
Stauffer Ck. @ Sg-4	1-Mar-00	306	<0.1	--	--	--
AEP Stations						
Stauffer Creek	9-Feb-91	309	--	0.028	--	--
North Raven River @ Hwy 761	11-Apr-91	293	0.013	0.029	--	--
North Raven River @ Hwy 761	6-Jun-91	306	0.007	0.017	--	--
North Raven River @ Hwy 761	18-Jul-91	302	0.008	0.013	--	--
North Raven River @ Hwy 761	5-Sep-91	291	0.005	0.007	36	48
North Raven River @ Hwy 761	7-Oct-91	288	0.004	0.005	8	135

Notes: FWAL = freshwater aquatic life; yellow shading = values above FWAL criteria; green shading = above anticipated baseline values
Metals for Komex study = dissolved
Metals for AEP stations = total
TDS = total dissolved solids
P = phosphorous

Table 2b. Selected constituents measured in surface water (including springs) located within the study area.

STATION_NAME	DATE	NO_3 + NO_2	CADMIUM (Cd)	CHROMIUM[43] (Cr)	COPPER (Cu)	IRON (Fe)	ZINC (Zn)
		mg/L as N	mg/L	mg/L	mg/L	mg/L	mg/L
GoA FWAL guidelines		**3**	**0.00037**	**0.001 (6+) 0.0089 (3+)**	**0.043**	**0.03**	**0.03**
Komex 2000							
Clearwater River	7-Mar-00	0.097	<0.0002	0.007	0.0050	<0.01	0.007
Stauffer Ck. Spring No.1	1-Mar-00	0.149	<0.0002	0.008	0.0012	<0.1	0.006
Stauffer Ck. Spring No.2	1-Mar-00	0.156	<0.0002	0.006	0.0005	<0.1	0.012
Stauffer Ck. Spring No.3	3-Mar-00	0.160	<0.0002	0.007	0.0015	<0.1	0.013
Stauffer Ck. @ Sg-4	1-Mar-00	0.151	<0.0002	0.006	0.0005	0.05	0.011
AEP Stations							
Stauffer Creek	9-Feb-91	0.240	0.0070	0.002	<0.001	0.235	<0.001
North Raven River @ Hwy 761	11-Apr-91	0.115	<0.001	0.002	<0.001	0.571	<0.001
North Raven River @ Hwy 761	6-Jun-91	0.032	0.0020	0.004	0.0100	0.393	0.002
North Raven River @ Hwy 761	18-Jul-91	0.017	0.0030	0.005	0.0020	0.222	0.001
North Raven River @ Hwy 761	5-Sep-91	0.005	0.0020	0.002	<0.001	0.155	<0.001
North Raven River @ Hwy 761	7-Oct-91	0.046	0.0010	0.003	0.0030	0.157	0.002

Notes: FWAL = freshwater aquatic life; yellow shading = values above FWAL criteria; green shading = above anticipated baseline values
Metals for Komex study = dissolved
Metals for AEP stations = total
Cr^{6+} = hexavalent (more toxic form)
Cr^{3+} = trivalent (less toxic form)

[43] Hexavalent Cr has not been specifically differentiated. According to information from https://www.carexcanada.ca/profile/chromium_hexavalent/: *"Mean or median total chromium concentrations from rivers and streams in British Columbia, Alberta, Ontario, and Quebec were found to be between 4 – 7 µg/L, with 10 – 60% of the chromium as chromium [VI]".* For the purpose of this assessment 30% of the measured Cr value has been assumed to be present with the hexavalent form.