DRAFT WAPITI WATERSHED SOURCE WATER PROTECTION PLAN

November 2020

PROJECT TEAM

- Aquatera Utilities Inc. – Ashley Rowney, Liam Cross & Tamara Wuttunee-Campbell, Joel Kisner
- Canadian Association of Petroleum Producers – Sandra Miller
- County of Grande Prairie – Peter Harris
- Mighty Peace Watershed Alliance – Adam Norris
- Municipal District of Greenview – Quentin Bochar
- Sturgeon Lake Cree Nation – Rosalynn Goodswimmer (Consultation Coordinator)

Executive Summary

The reason for undertaking a Source Water Protection Plan is the need to proactively manage the critical water resource in the Wapiti Watershed. Both human health and ecosystem health fall within the scope of source water (Dunn et al., 2014) and we examined this throughout the Alberta portion of the Wapiti Watershed (Figure 1. Map of the Alberta portion of the Wapiti Watershed). Land use in the watershed influences the hydrology of the rivers that they supply including the quantity and quality of the water as well as the timing of the flows. This Source Water Protection Plan has as its vision, a Wapiti Watershed where proactive watershed management ensures a stable and reliable water resource for the many uses of water in the Wapiti Watershed.

Identified hazards constitute a list of potential events that could negatively impact source water in the Wapiti Watershed. These potential events were identified as existing within the Wapiti Watershed, for example diamond mining is not identified because it does not occur within the Wapiti Watershed, and the presence of a pathway by which the hazard impacts source water. Potential hazards to source water in the Wapiti Watershed were identified and then assessed for risk. All hazards were assessed for risk based on the likelihood of a given hazard occurring **AND** water being negatively affected.

For each identified hazard where a risk assessment could be completed, recommended management actions were identified. Many of the identified management actions involve education to promote awareness and understanding as well as motivate desired behaviours. Although the risk of individual activities may not appear to be all that great, it is critical to place this within the context of an ever-increasingly developed watershed with a broad range of stressors; namely the context of cumulative effects. The recommendation here is for the Government of Alberta, ideally in conjunction with the Government of British Columbia, to become the lead organization for the implementation of cumulative effects management in the Wapiti Watershed (Sheelanere et al., 2013).

There are three strategies that would address a range of the hazards identified and accordingly we recommend that the following measures be implemented across the watershed. Functioning riparian zones should be established and maintained around wetlands, lakes, streams, and rivers within the Wapiti Watershed. It is recommended that the municipalities develop a riparian buffer requirement as a by-law similar to the riparian buffer setbacks used in Forestry. Sediment delivery from roads should be evaluated with the READI model developed by fRI and the TerrainWorks Inc. (fRI Research & TerrainWorks Inc., 2018) to identify those areas providing the most sediment to the Wapiti and its tributaries. Once this evaluation is complete and there is an understanding of where the most sediment is coming from, specific projects could be initiated to mitigate sediment for these road segments. Wetlands are widely recognized for the value of their capability to sequester nutrients and other constituents that can lead to water quality issues (see chapter 6 of (Mitsch, William J, Gosselink, 2015)). Therefore, we recommend a focussed approach to retain wetlands within the Wapiti Watershed and to ensure all wetland compensation activities occur within the watershed.

Contents

DRAFT

List of Figures

List of Tables

Acknowledgements

Thanks to David Spiess and Javed Iqbal from Alberta Agriculture and Forestry, Alina Wolanski and Bonnie Nicolai from Alberta Environment and Parks, Kase DeVries from the City of Grande Prairie, and Traci Carter and Vashti Dunham from Weyerhaeuser for their analysis, input, and review. As well as many others too numerous to mention who provided data and information.

Thank you to the public who provided input on the plan at various stages of its development.

Thanks to the organizations who supplied members to the project team which undertook the creation of this plan. These organizations are Aquatera Utilities Inc., Canadian Association of Petroleum Producers (Seven Generations Energy Ltd.), the County of Grande Prairie, the Municipal District of Greenview, the Mighty Peace Watershed Alliance and Sturgeon Lake Cree Nation.

Source Water Protection Planning

What is a Source Water Protection Plan?

Drinking water quality is still a major issue today, even in countries using advanced technology to monitor and treat water (Hrudey & Hrudey, 2019). The potential for contaminated water increases greatly when water is not provided via a water treatment plant but rather accessed for recreation or through private systems. A Source Water Protection Plan improves the safety of water entering a water treatment plant, and subsequently the quality of the water leaving the treatment plant, and simultaneously improves water quality in the environment and the associated uses.

The multi-barrier approach to water treatment is comprised of six core elements: source water protection; effective water treatment; secure water distribution systems; water quality monitoring (at source, treatment plant, and tap); operator training and an emergency response procedure. Central to the multi-barrier approach is the assessment and management of the risks to water safety that can be addressed by each barrier (Dunn et al., 2014). Source Water Protection focusses on creating a barrier to contamination before water undergoes any treatment (Figure 1. Multi-barrier approach to safe drinking water from The City of Calgary's Source Water Protection Plan). Land use practices and point discharges are better managed to improve the quality and quantity of water upstream of the point of use.

Source Water is untreated water that humans access for use. Often, this is thought of as the water body (wetland, river, lake or aquifer) from which a water treatment plant draws its water.

Municipalities undertake Source Water Protection Planning to proactively manage the risks surrounding community, environmental, health and ecoomic values. In Alberta, both Edmonton and Calgary, as well as smaller communities, have undertaken this process for these reasons.

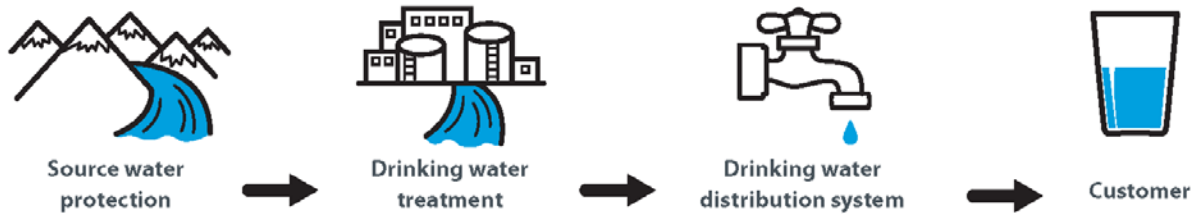

Figure 1. Multi-barrier approach to safe drinking water from The City of Calgary's Source Water Protection Plan

Why a Wapiti Watershed Source Water Protection Plan

The reason for undertaking a Source Water Protection Plan is the need to proactively manage the critical water resource in this watershed. Addressing potential issues before they occur can prevent serious economic impacts, protect aquatic life and manage conflict (Gower, T and Barroso, 2019). Source water protection also aligns with the 3 goals of Alberta's *Water for Life* Strategy: 1) safe, secure

drinking water; 2) healthy aquatic ecosystems, and 3) reliable supplies for a sustainable economy (Government of Alberta, 2003). Specific to the Wapiti Watershed, the Wapiti River Water Management Plan Steering Committee recommended that a watershed scale management plan, of which a Source Water Protection Plan is one type, be undertaken as a complement to the Water Conservation Objectives they developed (Wapiti River Water Management Plan Steering Committee, 2019).

In terms of drinking water, Aquatera Utilities Inc. provides drinking water to an increasing majority of the Wapiti Watershed residents although there are several municipal water utilities in the watershed providing drinking water to end users. Source water protection will support these operations in providing safe, secure drinking water to their end users. There is also the potential to reduce costs of drinking water provision through reduced operational costs or deferred capital costs for future infrastructure upgrades (City of Calgary, 2019). Furthermore, source water protection will support other uses of water including fish habitat, swimming, boating, as well as Agriculture, Energy and Forestry operations.

Wapiti Watershed Source Water Protection Plan Development

Several partners contributed members to a project team to create this plan and input was received from many more. Aquatera Utilities Inc., Canadian Association of Petroleum Producers, the County of Grande Prairie, the Mighty Peace Watershed Alliance, the Municipal District of Greenview and Sturgeon Lake Cree Nation, all provided a member to the project team (Appendix D – Project Team). The project team consisted of both those who work primarily in the water field and may be considered water experts as well as those who did not. This diversity was intentional so that the project team had a broader range of values and understanding involved in the risk assessment, thereby increasing its robustness through contributory expertise. Contributory expertise is defined as "the capacity and skill to interact with participants within a field of relevance" (Boholm & Prutzer, 2017). The reader is referred to (Boholm & Prutzer, 2017) for a discussion of expertise and water management.

Land use refers to the footprint that human activity makes on the earth. Often assessed from a bird's eye view this includes lawns, roads, fields, well sites, and any human activity that alters the soil or vegetation.

The Scope of the Plan

The scope of source water is both human health and ecosystem health (Dunn et al., 2014) and we examined this throughout the Alberta portion of the Wapiti Watershed (Figure 1. Map of the Alberta portion of the Wapiti Watershed). Accordingly, the intent of this plan is to look at the hazards to human heath and ecosystem health, and then to identify strategies to mitigate or prevent impairment of the water resource. Landscape and the land use upon it largely dictate water quality through non-point sources of pollution. These effects are also much more challenging to quantify and mitigate than point sources of pollution (end of pipe). Therefore, the focus for this plan will be the non-point sources of pollution that are more challenging to manage and at present lack a cohesive management framework.

Wapiti Watershed

For this plan, the focus is on the Alberta portion of the watershed, although the effects of the British Columbia portion were considered in principle. Source water was defined as follows: all water in the Alberta portion of the Wapiti Watershed that is accessed by humans for use. This can entail drinking water withdrawals, ecosystem needs, industrial withdrawals, and recreational use, among others. Aquatera Utilities Inc. withdraws water downstream of the Highway 40 bridge over the Wapiti River (Figure 2. Map of the Alberta portion of the Wapiti Watershed). Most water users in the watershed would access water at this point or higher up in the watershed, however this does not cover the Bear Creek or Big Mountain Creek sub-watersheds. This plan addresses the entire watershed including the Big Mountain Creek and Bear Creek sub-watersheds.

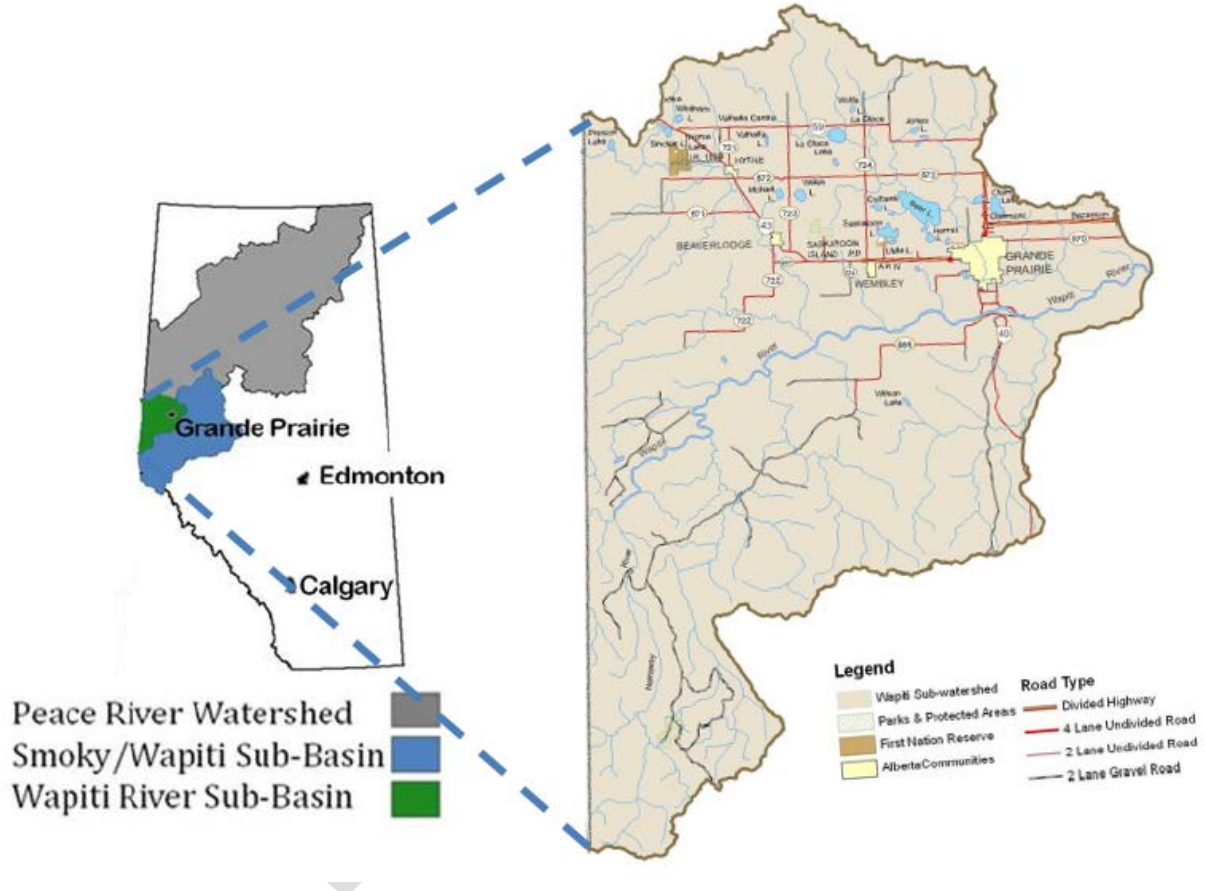

Figure 2. Map of the Alberta portion of the Wapiti Watershed (source: Alberta Environment and Parks)

Geography

The Wapiti Watershed straddles the border between Alberta and British Columbia with the headwaters in British Columbia. Grande Prairie is the major population centre with 69,088 inhabitants in 2018 (City of Grande Prairie, 2020) and located just upstream of the confluence of the Wapiti River with the Smoky River. The Smoky River is part of the Peace/Slave drainage basin and eventually discharges into the Arctic Ocean. In Alberta, the Wapiti Watershed encompasses 10,133 km^2 (Government of

Alberta, 2019) and the watershed area in British Columbia is just over 2400 km^2 (Government of Canada, 2016).

The terrain varies from the Rocky Mountains to Peace River Parklands and the watershed includes 7 natural regions and subregions on the Alberta side. These are Alpine, Subalpine, Central Mixedwood, Dry Mixedwood, Upper Foothills, Lower Foothills and Peace River Parkland. See (Hutchinson Environmental Sciences Ltd., 2018) for a more detailed account of these regions.

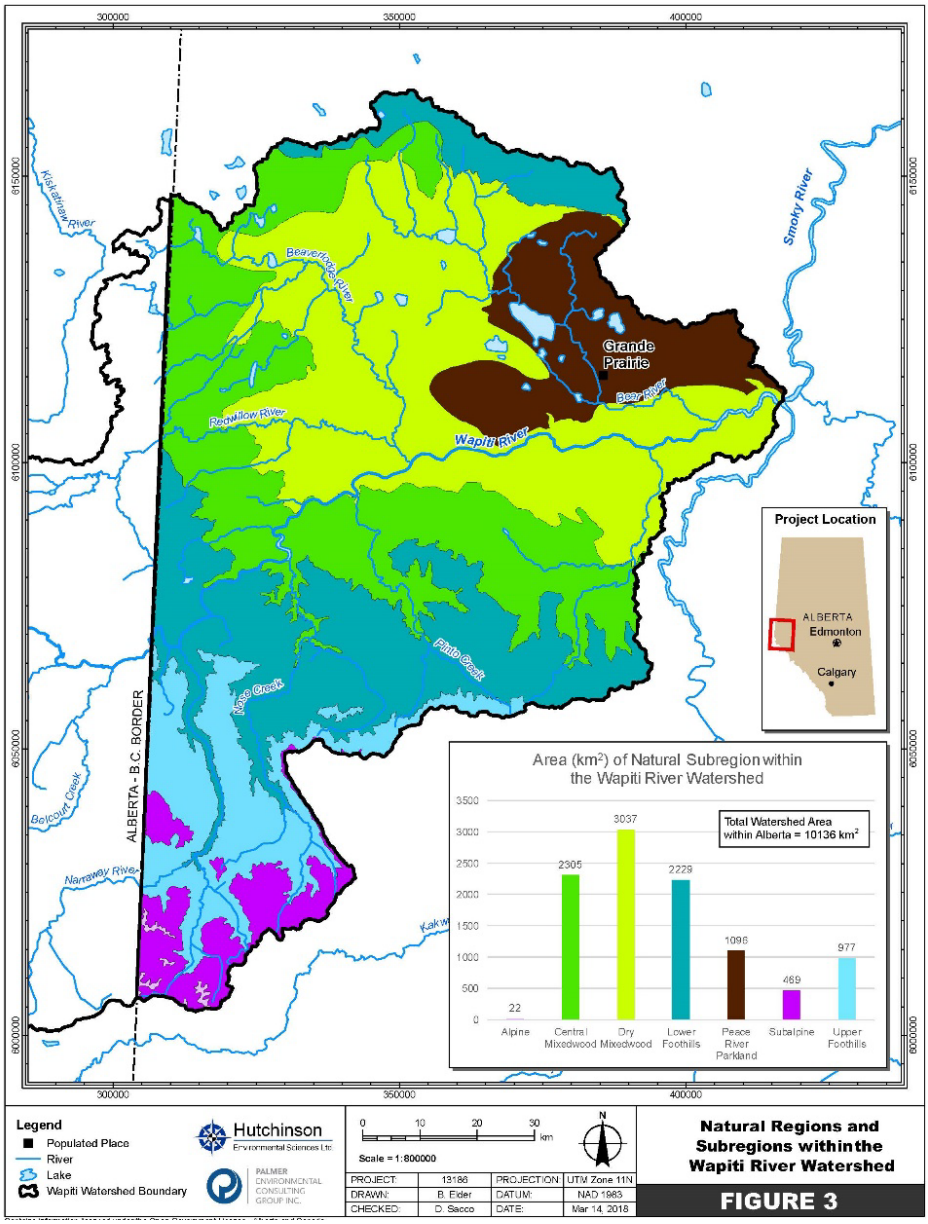

Figure 3. Natural Regions and Subregions within the Wapiti River Watershed from (Hutchison Environmental Sciences Ltd., 2018)

Climate

The Wapiti Watershed generally experiences shorter, warm summers with longer, cold, and snowy winters. However, there is a lot of variation between natural regions and the climate that is

experienced (Hutchison Environmental Sciences Ltd., 2018). There are several weather stations in the watershed and below is a graph of temperature and precipitation averages from the Grande Prairie Station for 1971-2000 (Figure 4. Graph of Temperature and Precipitation from 1971 to 2000 as recorded at the Grande Prairie Weather Station.) This data was retrieved from the Government of Canada's Environment and Natural Resources website (Government of Canada, 2020). January is typically the coldest month with average temperatures of -13.6 °C and the warmest month is July with average temperatures of 16.2°C. Most precipitation falls in July and the least in February with 76.1 mm and 16.4 mm on average, respectively. The yearly average is 445.1 mm of precipitation.

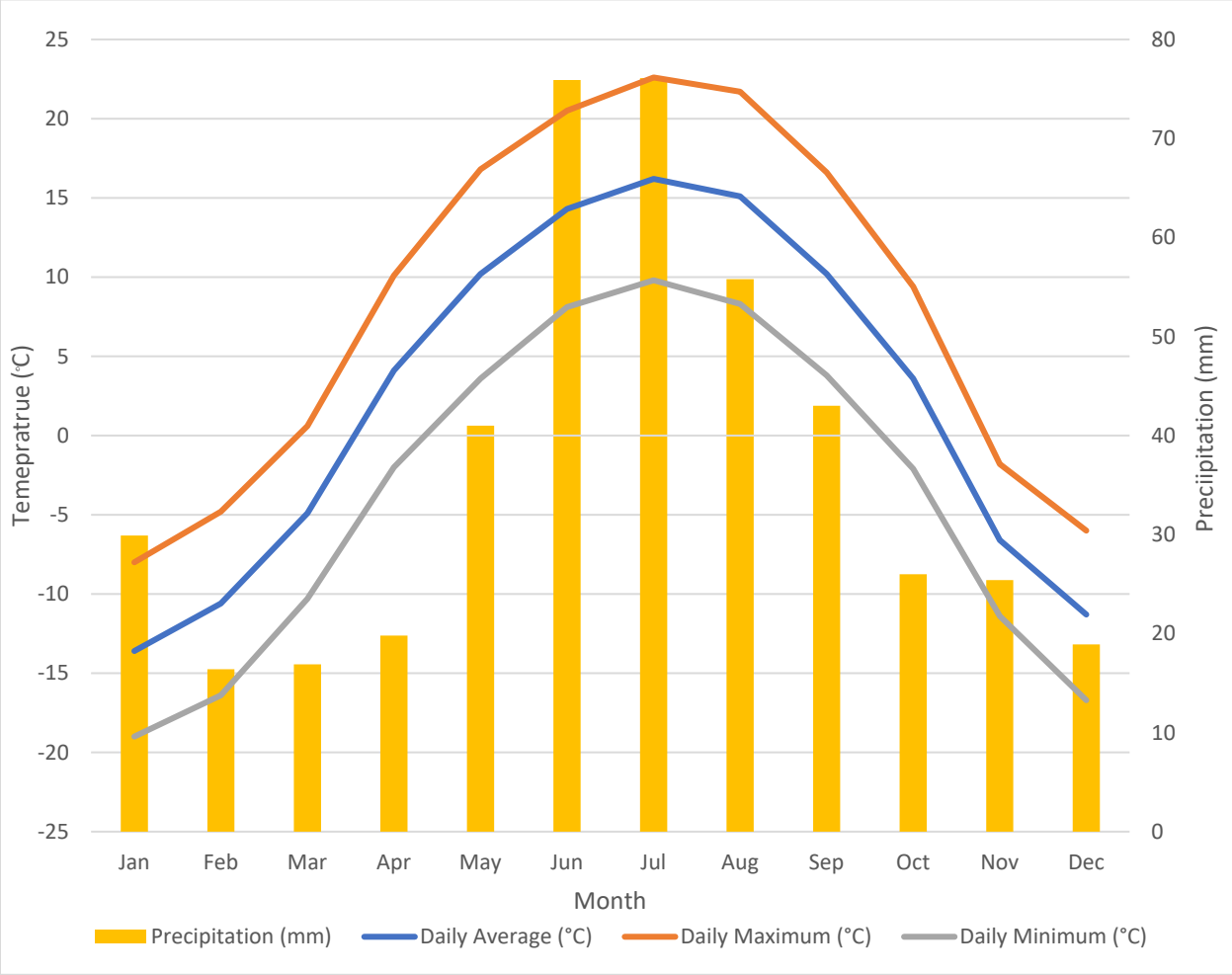

Figure 4. Graph of Temperature and Precipitation from 1971 to 2000 as recorded at the Grande Prairie Weather Station

A review of climate change for the Wapiti Watershed was completed by Kerkhoven in 2014 (Kerhoven, 2014c). In general, the Wapiti Watershed is expected to see the historical trend of warming temperatures continue and this will be noticeable by changes in the mean annual temperature from the 1961-1990 period to 2040-2069 of +2.3˚C. Precipitation is expected to increase driven by an increase in rainfall not snowfall. An increase of 5% is expected in 2040-2069 in comparison to the 1961-1990 baseline and there is a lot uncertainty around what snowfall will look like. River flows are not expected to change much as increasing evapotranspiration offsets increased precipitation.

Hydrology

There are several tributaries that flow into the Wapiti River on the both the British Columbia

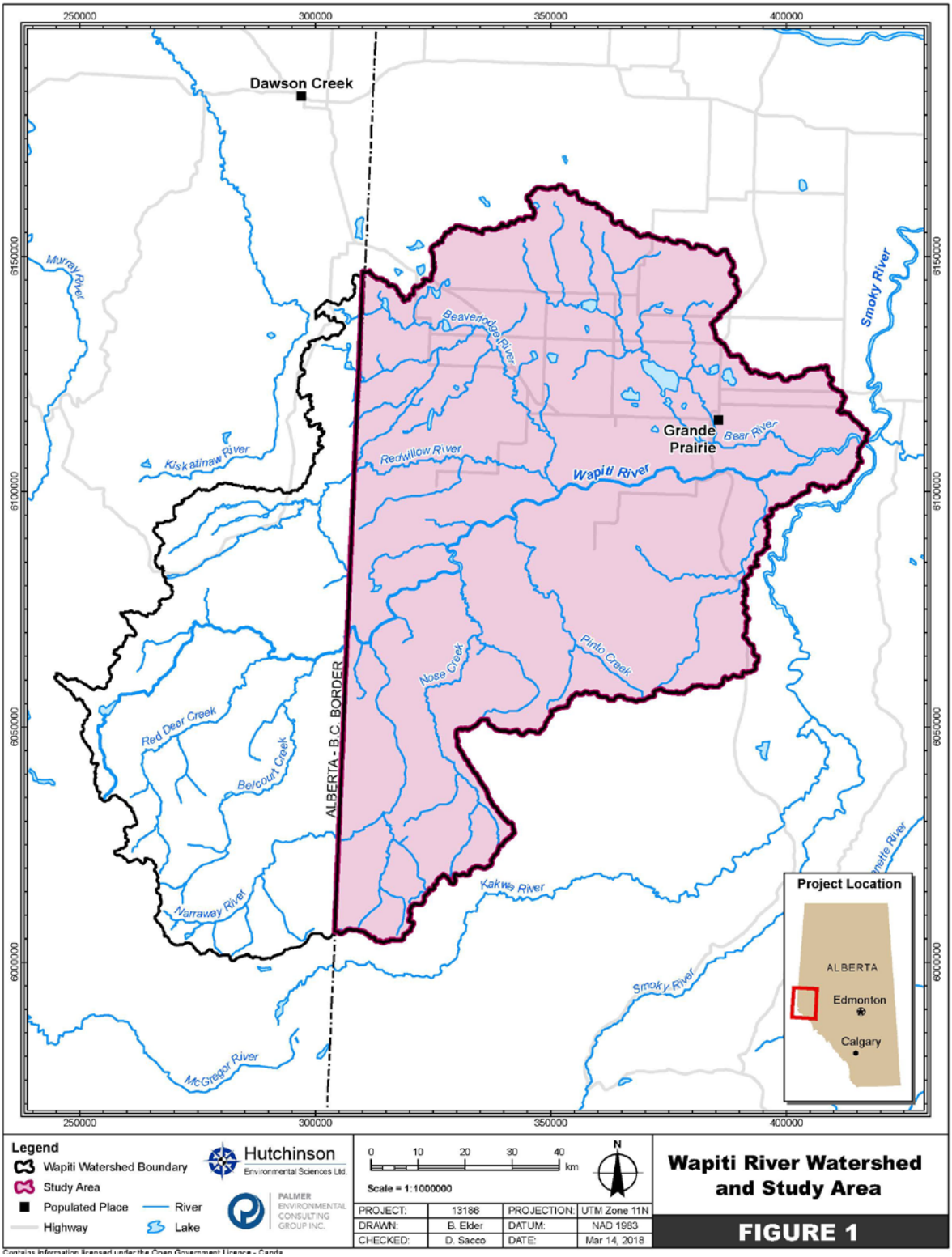

Figure 5. Tributaries to the Wapiti River (Source: Hutchinson Environmental Sciences Ltd., 2018)

and Alberta side. In Alberta, the main tributaries are Bear Creek, Big Mountain Creek, Calahoo Creek, Narraway River, Pinto Creek and Redwillow River (Beaverlodge River is a tributary of the Redwillow River). 80% of the Wapiti River's flows originate upstream of Pinto Creek (Kerhoven, 2014a), therefore a large proportion of water in the Wapiti River originates in British Columbia. Exactly how much is not known as there is no gauging on the upper Wapiti River or its tributaries (eg, Nose Creek, Narraway River) . The largest tributary is the Redwilllow River which contributes 9.4% of the Wapiti River's flow (Kerhoven, 2014a). On the British Columbia side, the main tributaries are Belacourt Creek and Red Deer Creek; the headwaters of Narraway River are also located in British Columbia.

Land use in the watershed influences the hydrology of the rivers that they supply including the quantity and quality of the water as well as the timing of the flows. Human footprint is often another term used to denote land use. See Figure 7 Land use in the Wapiti Watershed for a map of land use in the Wapiti Watershed and Table 4. Land use in the Wapiti Watershed for a breakdown of the land use. Characteristics of the landscape, such as soil type, slope and vegetation, determine how much water is stored in wetlands and soils in the watershed (Brown et al., 2010; Devito et al., 2017; Karlsen et al., 2016). Subsequently, anthropogenic activity that alters these characteristics also changes the water in the rivers. Beyond water storage and release in the watershed, another mechanism for altering flows in rivers is the change in evapotranspiration caused by alteration of land cover. In the Wapiti Watershed this effect is estimated to have caused a 13% reduction from pre-development state in flows in the Beaverlodge River and 21.7% reduction in flows in the Bear Creek (Kerhoven, 2014b).

Point Source Pollution is the input of contaminants to a water body from a pipe such as the releases from a sewage lagoon or mill. This does not mean that the water is untreated simply that it enters the receiving water body at a specific point.

In contrast **Non-point Source Pollution** is contamination that enters the receiving water body at many points making it harder to manage. For instance, phosphorous in runoff from lawns, fields or cutblocks.

Management

Human use in the Wapiti Watershed has an annual authorization of 72 million m^3 but most of this amount has a return requirement, which totals 50 million m^3 of water annually (Table 3. Water allocations in the Wapiti River Basin). Approximately 2/3 of these withdrawals occur downstream of the Highway 40 bridge and upstream of Pinto Creek water withdrawals are negligible. Almost half of the allocated volume is for wetland projects and lake stabilization and therefore does not represent withdrawals but impoundment on the landscape. The maximum allowable net use of water annually is 22 million m^3 of water, however actual water use has consistently been around 5 million m^3 of water annually (Kerhoven, 2014a). It should be noted that water use reporting is neither consistent nor complete and water use values are an estimate. Water intake is completed in compliance with licencing requirements and the availability of water in streams. However, the most water is available during

spring freshet and this is the time of highest contaminant loading (Hutchinson Environmental Sciences Ltd., 2014).

Historically in the Smoky Wapiti Basin, approximately 9% of allocations are for groundwater with a volume of 10,476,478 m^3 (Mighty Peace Watershed Alliance, 2015). In the Wapiti Watershed there are 9,435 registered water wells (Alberta Environment and Sustainable Resource Development Government of Alberta, 2011), however the water use is unknown.

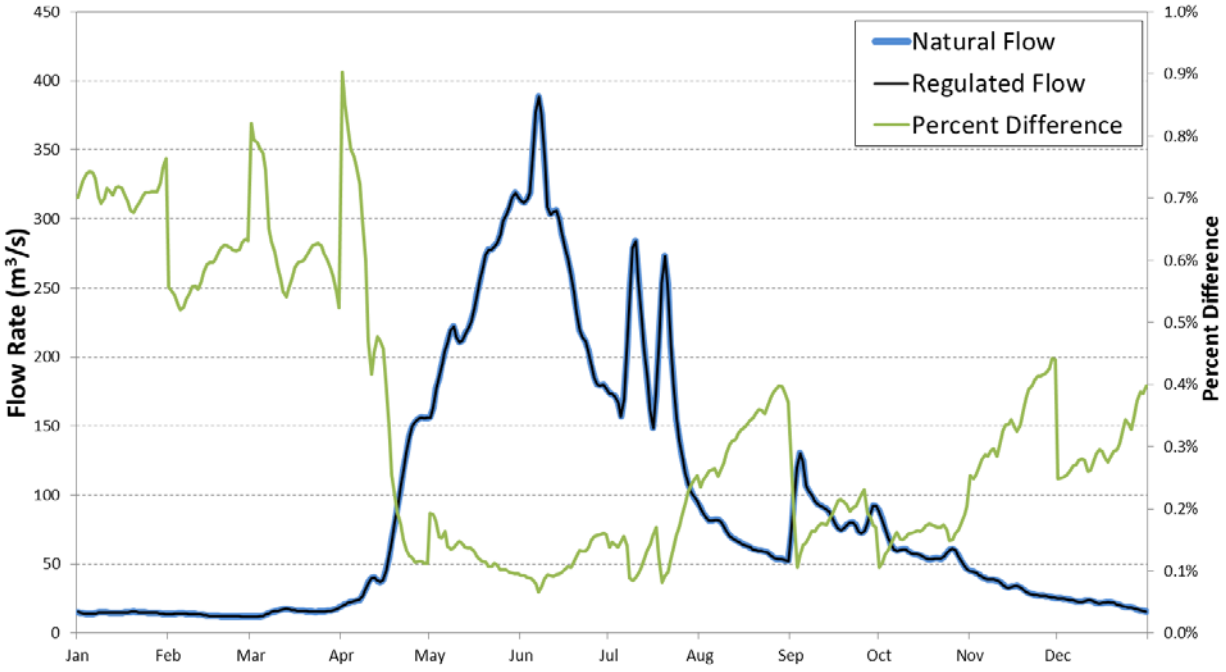

Figure 6. Average daily flow of the Wapiti River at the mouth with the Smoky River under natural and regulated conditions for the period 2000-2010. The percent difference between regulated and natural flows is shown in green. Natural flows are without withdrawals and regulated flows are with withdrawals. Source: (Kerhoven, 2014a)

Point sources of pollution, by definition, discharge from a single point and therefore are easier to monitor. In the Wapiti Watershed there are limited point sources of pollution and the loadings that they contribute to water can be readily measured (Figure 8. Point Sources of Pollution in the Wapiti Watershed. Source: Hutchinson Environmental Sciences Ltd., 2018). As each point source discharge is regulated under Alberta's Environmental Protection and Enhancement Act (R.S.A. 2000, C. E-12), this plan will not focus on them.

Beyond any regular monitoring and management undertaken by the Government of Alberta, there are several management activities that should be noted. There is the monitoring undertaken by Aquatera Utilities Inc. as part of their operations and regulatory compliance, the monitoring undertaken by International Paper as part of their operations and regulatory compliance, and the Wapiti River Water Management Plan. There is also a watershed restoration plan for the Redwillow Watershed (Redwillow Watershed Restoration Project Team, 2015) which takes a watershed approach but is limited to the Redwillow Watershed, a sub-watershed of the Wapiti Watershed.

Furthermore, Aquatera Utilities Inc., Town of Beaverlodge and Village of Hythe have a Drinking Water Safety Plan according to Alberta regulations (Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems. Part 1 Standards for Municipal Waterworks of a Total of 5 Parts, 2012) that is also intended to reduce risk in drinking water systems. Drinking Water Safety Plans tend to focus more on the storage, treatment, and distribution systems, that is how the water is stored, treated, and then delivered to consumers. Nevertheless, there is a component of Drinking Water Safety Plans that considers the source of the water. For instance, the Beaverlodge Drinking Water Safety Plan identifies upstream contaminants and organics as the main hazard to its source water but no non-treatment actions to address this are identified. The Aquatera drinking water safety plan indicates that chemical contamination of raw water as a result of a chemical spill along the upstream transport corridor or upstream pipelines crossing the Wapiti River present a high risk to the raw water component of their water treatment system.

Wapiti Watershed Source Water Protection Vision

Alberta's *Water for Life* Strategy has three goals which this Source Water Protection Plan will help to achieve. These are 1) safe, secure drinking water; 2) healthy aquatic ecosystems, and 3) reliable supplies for a sustainable economy. In support of these goals and the Wapiti River Water Management Plan,

> this Source Water Protection Plan has as its vision, a Wapiti Watershed where proactive watershed management ensures a stable and reliable water resource for the many uses of water in the Wapiti Watershed.

This vision is to be achieved by undertaking hazard identification, risk assessment and the development of mitigative strategies to protect the source waters of the Wapiti Watershed. Upon completion of the plan mitigative strategies will be presented to decision-makers as recommendations to be implemented.

Risk Assessment

Identified Hazards

A **Hazard** is any activity or event that could negatively impact source water. For instance, an automobile accident on the Wapiti River bridge could result in petroleum products or other contaminants entering the river.

Identified hazards constitute a list of potential events that could negatively impact source water in the Wapiti Watershed. These potential events were identified as existing within the Wapiti Watershed, for example diamond mining is not identified because it does not occur within the Wapiti Watershed, and there needs to be a pathway for the hazard to impact source water. These hazards were identified by the Project Team through a literature review, directed questions to subject matter experts, professional judgement and public engagement (Appendix E – Public Engagement). A full list of the identified hazards can be found in Appendix F (Table 5. List of Identified Hazards).

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The hazards were considered under the following categories: General/Other, Agriculture, Forestry, Oil & Gas, Recreational, Rural residential properties, Transportation, Urban and Water/Wastewater infrastructure. Some of the hazards were considered under multiple categories during the risk assessment process due to differences in pathway, constituents, scope or use. For instance, Applications of Chemicals, was assessed for risk in different categories such as Agriculture, Forestry and Yard Care. Additionally, agricultural application of chemicals involves both a range of pesticides and various fertilizers whereas Forestry applications are limited to one herbicide. Therefore, hazards may appear more than once in the Risk Assessment with a different relative risk ranking reflecting different contexts in which the hazard occurs.

Risk Assessment is an evaluation that looks at the probability of a hazard occurring and the severity of the effects on source water if it does occur. Risk ranking is then the product of likelihood of occurrence and severity of impact.

Risk Assessment

Potential hazards to source water in the Wapiti Watershed were identified and then assessed for risk. Below is the assessment completed by the project team for the identified hazards (Table 1. Table of Hazards to Source Water in the Wapiti Watershed ranked by relative risk by sector). All hazards were assessed for likelihood based on the likelihood of its occurrence **AND** water being affected. The severity was assessed in the situation that the hazard had occurred to estimate how detrimental the impact on water would be. To obtain a risk ranking the likelihood and the severity were multiplied. When a hazard is more likely to occur, it received a higher likelihood ranking and when a hazard is more likely to have a negative impact, it received a higher severity ranking. Therefore, a higher risk ranking reflects a greater probability of impacts on water for a given hazard. The reader is referred to the Guide to Source Water Protection Planning for a description of this process (Alberta Water Council, 2020).

The scale used for assessing risk is found in Table 6. Scale used for risk assessment and the risk assessment is found in Table 1. Table of Hazards to Source Water in the Wapiti Watershed ranked by relative risk by sector. For each hazard, the intensity of the event was assumed to be normal or median. If a catastrophic event occurs, the severity for the risk assessment would be much higher. The rationale for the risk assessment is found in Risk Assessment Summary. Please note that this is a relative risk ranking and only indicates the comparative risk of one activity to another. The final risk assessment is depicted in Table 1. Table of Hazards to Source Water in the Wapiti Watershed ranked by relative risk by sector.

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Table 1. Table of Hazards to Source Water in the Wapiti Watershed ranked by relative risk and categorized by sector

	General/Other	Agriculture	Forestry	Oil & Gas	Recreational	Rural residential properties	Transportation	Urban	Water/Wastewater infrastructure
Highest risk	Cumulative effects								
Higher Risk ----------relative source water risk ranking----------	Illegal dumping into waste water systems	Manure disposal	Temporary Harvest Roads	Pipeline releases	Vehicle operation in or near water bodies	Stormwater	Crossings/culverts/ditches	Stormwater	Stormwater
	Illegal dumping rest of watershed	Feedlots/confined feeding operations	Forest fires	Herbicide application	Erosion caused by OHVs	Sediment from rural properties	Highway 40 Bridge Spill	Institutional/commercial/industrial	Flooding
	Development	Application of chemicals	Cutblocks	Old sumps	Boat operation leading to incidental discharge and emissions	Improper Hazardous waste disposal	Road salt/de-icer application	Yard care	Bank slumping
	Wildlife faeces	Ditching/draining	Fire-fighting chemical	Linear disturbance (eg., seismic lines, pipelines)	Recreational development (new & existing)	Water wells	Trucking (primarily TDG)		Intentional discharges
	Wildlife pathogens	Livestock grazing	Rutting	Water access infrastructure	Unauthorized boat launches	Septic systems/private systems	Construction		Lagoons (breach or failure)
	Application of chemcials for weeds	Land clearing/tree location	Wood storage yards	Surface spills	Sediment due to wake or boat disturbing channel	Spill of Hazardous materials	Petroleum from vehicles day to day operation		Camp wastewater
	BC portion of watershed	Storage of chemicals	Spills	Pads	Parks outhouses	Garbage burning (both barrel and otherwise)	Calcium application for dust control		Drought
	Deleterious substances	Garbage burning	Herbicide	Camps			Railway oil/grease/fuel leakage		
	Active Landfills (includes operations, fires and leachate)		Camps	Subsurface spills (casing failures)			De-icing at GP airport		
	Inactive/abandoned landfills		Mountain Pine Beetle/pests	Air emissions/flaring			Road salt storage (includes snow dump)		
	Invasives/weeds			Suspended wells and pipelines			Tarmac run-off		
Lower Risk ----------	Land disposal (from drilling or waste treatment sludge)			New Sumps			Railway spills		
							Creosote Ties		

Cumulative Effects

Currently there is a great emphasis among all industries and levels of government to improve their management practices. Subsequently, we see a decreasing risk associated with the individual instance of many identified hazards. Nevertheless, there is substantial risk present due to the cumulative, additive nature of all these hazards. Moreover, it is very difficult to define and assess the potential interactive and additive effects of so many different contaminants from so many different sources (Van den Brink et al., 2019; Villanueva et al., 2014). Any single cutblock, field, pipeline or lawn is likely to have an insignificant effect on the source water of the watershed, but the sum of every cutblock, every field, every pipeline and every lawn may have a significant impact. Although the risk of individual activities may not appear to be all that great, it is critical to place this within the context of an ever-increasingly developed watershed with a broad range of stressors.

A study commissioned by Alberta Environment and Parks provides an effective management tool for understanding the potential for cumulative effects. Inventory and Evaluation of Non-Point Pollution Sources in the Wapiti River Basin (Hutchison Environmental Sciences Ltd., 2018) explores the potential for contaminants to be transported off the landscape and into source water by examining factors such as topography, soil characteristics and drainage density. Through a detailed modelling exercise, a model for the cumulative export of contaminants from the landscape into the water has been developed. A few key maps from this report are presented in Appendix H – Average Annual Export Coefficients for the Wapiti Watershed. In Appendix I – Runoff Management Classification for the Wapiti Watershed, there are maps of management priority that have added land use, i.e., human activity, to identify those areas where we can do the most to reduce contaminants from reaching source water (Hutchison Environmental Sciences Ltd., 2018).

> "Knowledge of the relationships between land-use and river condition can be used to predict the extent of change in river condition in response to human development and plausible alternative futures."
>
> (Stevens & Council, 2008)

The modelling done in this study sits well within the normal range for this type of modelling that are found in the literature. A challenge was the paucity of water quality data that is to be found for the Wapiti River (Hutchinson Environmental Sciences Ltd., 2018). This model allows us to identify key areas for management focus due to underlying geologic, topographic, hydrologic, and anthropogenic factors. However, it is important to bear in mind that this work reflects a model and not ongoing field measurements.

The north central part of the watershed has the highest nutrient (nitrogen and phosphorus) export coefficients (Figure 9. Average Annual Export Coefficients for the Wapiti Watershed – Nitrogen. Source: Hutchinson Environmental Sciences Ltd., 2018; Figure 10. Average Annual Export Coefficient for the Wapiti Watershed – Phosphorus. Source: Hutchinson Environmental Sciences Ltd., 2018). This aligns with more erodible soil types and textures (Hutchinson Environmental Sciences Ltd., 2018; Stadnyk et

al., 2005) and the most intense agricultural land use occurring in this area. The Grande Prairie environs and the eastern portion of the watershed south of the Wapiti River have the highest export coefficients for sediment (Figure 11. Average Annual Export Coefficient for the Wapiti Watershed - Total Suspended Sediment. Source: Hutchinson Environmental Sciences Ltd., 2018). The area around Grande Prairie has erodible soils and a high density of roads contributing to the high export of sediment. South across the Wapiti River, steeper slopes and a comparatively high road density contribute to the high levels of sediment export. South of the Wapiti River, soil types, slope, and industrial footprint (including roads) contribute to the high sediment export.

Recommended Management Actions

Mitigative Strategies

For each identified hazard where a risk assessment could be completed, recommended management actions were identified. A complete list of these can be found in Appendix J – Recommended Management Actions. Many of the identified management actions involve education to promote awareness and understanding as well motivate behaviour. These types of actions were often identified where adequate regulations are in place and improving Beneficial Management Practices have been identified. Many of these hazards were assessed a low risk to source water in the Wapiti Watershed. This does not mean that there is no negative impact on source water, however, the likelihood, the severity or both are very small. Thus, identifying more or stricter regulations is a cumbersome and ineffective approach to managing source water due to the number of hazards in the watershed. A further challenge in managing water quality through Beneficial Management Practices is obtaining compliance levels high enough to achieve the desired outcome (Centner et al., 1999). We, therefore, suggest that these myriad hazards be managed through a cumulative effects approach (see Cumulative Effects Management).

> "In a watershed context, the cumulative effects manifest by way of incremental changes to surface runoff, channel modification, sedimentation, and alterations to the functioning of ecological components resulting from both in-stream and landscape disturbances."
>
> (Kristensen et al., 2013)

The recommended management actions for the hazards with the highest risk assessment will be described below and the remaining recommendations can be found in Appendix K – Recommended Management Actions.

As one tool in the toolkit, Beneficial Management Practices are critical to making progress towards improved Source Water Protection. In order to promote the use of the Beneficial Management Practices to mitigate risk, Communities of Practice will be identified and targeted. Communities of Practice are self-organizing social structures that are safe places to learn and to share tacit and cultural knowledge (Allen et al., 2011). In the Wapiti Watershed, this could include groups such as the Alberta

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COMMUNITES OF PRACTICE – GROUPS OF PEOPLE THAT COME TOGETHER BECAUSE OF A COMMON TASK OR JOB. THEY LEARN TOGETHER, SHARE THEIR EXPERIENCES AND BECOME A POOL OF KNOWLEDGE FOR THEIR AREA OF INTEREST.

Institute of Agrologists local branch, the Evergreen Wetland Centre, or the Wapiti Area Synergy Partnership, among others.

Cumulative Effects Management

Ultimately, the cumulative effect of all identified hazards presents the greatest risk to source water in the Wapiti Watershed. In order to provide source water protection, there needs to be a watershed monitoring system that will identify the combined effects of all different uses on the water. Monitoring water quality and quantity just above the confluence of the Wapiti River with the Smoky River would allow an assessment the reflects cumulative effects. The greatest challenge in cumulative effects management is more an institutional constraint than a scientific one; where cumulative effects management initiatives have been undertaken in Canada they often lack integration into broader watershed management (Sheelanere et al., 2013).

Managing to cumulative effects requires setting environmental limits or thresholds and then managing to that. This approach to management needs the involvement of the different sectors active on the landscape in order to achieve an environmental outcome at this scale (Schuwirth et al., 2018). An Alberta example of this approach for water quantity are the closed basins in the south, such as the South Saskatchewan River Basin. No new water licenses are issued because a watershed threshold has been reached. Individuals water uses are not considered in terms of how efficient or progressive they are, rather it is evaluated against a watershed scale threshold. For water quality this would mean that water quality parameters would be set as well as limits for the different parameters. As limits are approached, often thresholds are set to indicate the need to engage in management actions, human activity would be adjusted to ensure the limits are not surpassed. Thus, activity is approved not on the basis of a site by site evaluation or a demonstration of employing Beneficial Management Practices, but by the capacity of the watershed to handle it.

Cumulative effects can be described as "**progressive nibbling**"—the accumulation of effects that occurs through many often small-scale activities…

For each action, the effects are deemed marginal or relatively insignificant when compared to other types or scales of change or disturbances. But, over time, insignificant effects can result in significant cumulative environmental change.

(Noble et al., 2014)

The recommendation here is for the Government of Alberta, ideally in conjunction with the Government of British Columbia, to become the lead organization for the implementation of cumulative effects management in the Wapiti Watershed (Sheelanere et al., 2013). Sheelanere et al. (2013) identify the

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following 8 requisites for implementing and sustaining watershed cumulative effects management in a transboundary context: 1) Lead agency, 2) Multi-stakeholder collaboration, 3) Watershed baselines, indicators, and thresholds, 4) Multi-scale monitoring, 5) Data management and coordination, 6) Vertical and horizontal linkages, 7) Enabling legislation, and 8) Financial and human resources (Appendix K – Requisites for Cumulative Watershed Assessment and Management). A lot of these pieces are partially or wholly present in the Wapiti Watershed and simply require the formalization of a cumulative effects management approach for source water. Below is an overview of the New York City's Watershed program review and examines the success of a cumulative effects watershed management program.

Municipal water for the City of New York is supplied from several watersheds at a rate of 1 billion gallons a day to more than 8.5 million people (National Academies of Sciences Engineering and Medicine, 2020). The Croton watershed supplies about 10% of the raw water and the Catskill/Delaware watersheds supplies the rest and is the largest unfiltered water supply in the United States of America. The United States Environmental Protection Agency granted this exception for filtration to New York City based on their watershed protection program which included agriculture, forestry, and stormwater management activities. The requirements for treatment infrastructure were much lower due to the watershed work which improved water quality and the source. Thus, the watershed protection program brought significant cost savings Another great feature of this program was the focus on upstream community vitality and economic development. A review after 2 decades indicated that this program has achieved its intended outcomes and it is expected to continue do so with some adaptive management (National Academies of Sciences Engineering and Medicine, 2020).

> The Watershed Protection Program overall appears to have admirably supported watershed water quality sufficient for compliance with the Surface Water Treatment Rule, with strong indications that it will remain effective into the future.
>
> (National Academies of Sciences Engineering and Medicine, 2020)

Land use planning in Alberta has been divided into seven regions and when the Upper Peace Regional Land Use Plan is created, there will be the opportunity to implement cumulative effects watershed management for the Wapiti Watershed. Cumulative Effects management is addressed and committed to in the Land Use Framework which provides a legislative framework in which to incorporate watershed cumulative effects management (Government of Alberta, 2008). We recommend that the Upper Peace Regional Land Use plan be moved forward and incorporate a cumulative effects management approach for the Wapiti Watershed. This Cumulative Effects approach would address all the identified hazards by focussing on water quality.

Environmental indicators could be used to set thresholds, limits and targets. For instance, the Government of Alberta recently commissioned a trend analysis for the existing water quality data on the Wapiti which would support the identification of baselines (Hatfield Consultants, 2019). We recommend the development of Thresholds, Limits and Targets for the Wapiti River to support Cumulative Effects Management in the Wapiti Watershed.

Specific Strategies

There are three strategies that would address a range of the hazards identified and accordingly we recommend that the following measures be implemented across the watershed.

Riparian zones, as noted by Hutchinson Environmental Sciences Ltd. (Hutchinson Environmental Sciences Ltd., 2018) provide a buffer against the export of nutrients. Riparian zones should be established and maintained around wetlands, lakes, streams, and rivers within the Wapiti Watershed. It is recommended that the municipalities develop a riparian buffer requirement as by-law similar to the riparian buffer setbacks used in Forestry.

Sediment delivery to streams causes many water quality issues as excessive sediment itself constitutes a degradation of water quality but also because of the many other contaminants correlated with sediment (Mallin et al., 2009). Sediment delivery from roads should be evaluated with the READI model developed by fRI Research and TerrainWorks Inc. (fRI Research & TerrainWorks Inc., 2018) to identify those areas delivering the most sediment to the Wapiti and its tributaries. Once this evaluation is complete and there is an understanding of where the most sediment is coming from, specific projects could be initiated to mitigate sediment for these road segments. Focussed efforts to mitigate the road segments yielding the most sediment would then provide the greatest improvement to water quality for the smallest investment.

Wetlands interact greatly with the chemical constituents in incoming water and can transform, store, or release these constituents. Accordingly, wetlands are widely recognized for the value of their capability to sequester nutrients and other constituents that can lead to water quality issues (see chapter 6 of (Mitsch, William J, Gosselink, 2015)). Therefore, we recommend a focussed approach to retain wetlands within the Wapiti Watershed and to ensure all wetland compensation activities occur within the watershed.

Crossings/culverts/ditches

This hazard is the intersection of linear transportation routes and water courses, providing a direct pathway for contaminants to enter the water. Bridges pose challenges to water in the contaminants that can enter the waterway from the bridge surface and the changes to drainage caused by the ditches on the roads approaching the bridge.

Culverts cause particular problems because the constriction of the water course that increases water velocity and subsequently increase the erosive power of the water. Road maintenance and plowing can also lead to sediment and other contaminants from the road surface being pushed into the watercourse. New technologies or a directed maintenance optimizing the source water protection value of culverts that are repaired or installed (see Tetreault et al., 2018).

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Options to improve the water quality of water entering the Wapiti River and tributaries from ditches include promote more vegetation in ditches (less mowing), strategically placing bioswales or created wetlands before water enter the Wapiti River or tributaries.

It is recommended to engage with the Alberta Watercourse Crossing Collaborative to access the best ideas regarding mitigating the effects of crossings. In particular, this could be useful once the high sediment yielding road segments are identified. Additionally, the Alberta Watercourse Crossing Inventory (AbWCI) app should be promoted. This app allows the user (open to the public) to identify and document the problem crossings. Again, identification of issues is the first step to addressing the problems.

Flooding

Flooding is a constituent component of riverine systems and it is not expected that management to protect source water would attempt to prevent flooding. Rather a resiliency approach needs to be developed to allow the Wapiti River and tributaries to function well at a variety of flows. Flood resiliency includes providing room for flood plains so that flooding does not cause increased erosion. Also, well managed floodplains reduce the contaminants present in flood plains reducing the risk of water contamination when waters flow from the flood plain into streams or rivers. For instance, removing residential properties from flood plains reduces the risk of household and yard chemicals as well septic or bacterial contamination entering the river. Our recommendation is to focus on flood damage mitigation by increasing the retention of water on the landscape to reduce flood peaks. This can include, among other things, maintaining or restoring wetlands and riparian zones, development setbacks and reducing impervious surfaces.

Additionally, it should be noted that the Aquatera Utilities Inc. facilities are identified as being at moderate risk for vulnerability to flooding exacerbated by climate change (Associated Engineering, 2020). We recommend that the recommendations of the report be addressed.

Forest Fires

Forest fires are an important part of the ecosystems found in the Wapiti Watershed and constitute a critical historical disturbance agent. Firefighting of wildfires has changed the disturbance regime in forests and altered stand dynamics (Chavardès et al., 2018). As the Government of Alberta and the Government of Canada work on the Caribou Management plans to address the Caribou's endangered status, it conceivable that there may an increased risk of wildfire due to less harvest. Robinne et al (Robinne et al., 2019) identify the communities in Alberta that are susceptible to wildfires affecting their source water and the Wapiti Watershed falls into a mid-risk category. The recommendation here is to ensure that planning for drinking water withdrawals and treatment post-wildfire has been undertaken. In the case of a severe fire, revegetation in to order speed up forest re-establishment and restore hydrology is recommended (Rhoades et al., 2019). Aquatera has identified ash and fire retardants introduced into the Wapiti River due to upstream forest fires as a medium risk in their Drinking Water Safety Plan. In case of an upstream forest fire, raw water quality monitoring would be increased and would focus on potential contaminants associated with forest fires. Where conditions arise so that the raw water quality may be compromised, Aquatera would close its raw water intake and rely on its siltation ponds to provide potable water to its customers. Additional raw water storage capacity is being planned which will increase the duration with which Aquatera can provide water to its customers without diverting water from the Wapiti River.

Herbicide application

Cosmetic application of herbicides should be targeted for reduction through education and awareness programs. These programs would communicate the effects of herbicide application, detail situations when it is not helpful and suggest alternatives, for example mechanical control. Communities of Practice should be identified to promote Beneficial Management Practices for commercial applications (e.g., Agriculture, Forestry, Municipal, Oil & Gas). In general, buffers will aid in reducing the cumulative effect of the herbicide application that occurs in the watershed.

The County of Grande Prairie has a stormwater pond at the Crosslink County Sportsplex that also provides recreational opportunities such as non-motorized boating, walking trails, and a stocked fishery. The stormwater pond is part of stormwater management in the area. Unfortunately, it had to be closed for a time due to the illegal dumping of industrial oil into a curbside drain around May 23, 2019.

Illegal dumping into wastewater systems

This risk is best mitigated by targeted education for those whose transport wastes. Education must point out the negative impacts of dumping, the potential legal consequences, and the proper means of disposing of waste. Both employers and employees need to be targeted for education.

Improper hazardous waste disposal

Education regarding this hazard must be directed both towards households and commercial and/or industrial audiences. There is the challenge that household users may not identify a substance as hazardous, for examples old pesticides. Again, education needs to point out the negative impacts of dumping, the potential legal consequences, and the proper means of disposing of waste

Manure disposal

Manure production per area is depicted in Figure 13. Manure production map for the Wapiti Watershed. The areas of highest manure production should be the focus of BMP education and the creation of buffers as described above. The Government of Alberta has released a manual for good practices (Alberta Agriculture and Rural Development, 2010) and this can be found along with many other resources at https://www.alberta.ca/manure-and-nutrient-management.aspx. The recommendation is to support Agricultural Services Boards and other Ag organizations (e.g., Peace Country Beef and Forage Association) in their promotion of BMPs (Centner et al., 1999).

Old sumps

Engage the Communities of Practice in the Oil & Gas sector to help identify and remediate old sumps. We recommend the development of a factsheet to help detail the process for dealing with an old sump if encountered.

Pipeline releases

Engage the Community of Practice in the Oil & Gas sector to continue improving practices and technology in order to reduce and mitigate pipeline releases. In particular, there should be a focus on casing pipelines at water crossings, early identification of releases and containment of released substance dispersion (Belvederesi et al., 2018). Monitoring and reporting of releases needs to be continued to identify hot spots or trends and track progress.

Sediment from rural properties

We recommend the promotion of BMPs to rural landowners through initiatives such as the Green Acreages Guide (Grenwal, 2017). Education efforts should focus on reducing the delivery of sediment to ditches or streams (Mallin et al., 2009) by promoting maintaining or re-establishing native vegetation, reducing channelization or ditching, reducing the amount of bare soil and maintaining wetlands.

Stormwater

Stormwater is the collection of runoff from an area into a central conveyance system and so contains all the contaminants (Mallin et al., 2009; Suryawanshi et al., 2016). We recommend reducing the rate and volume of stormwater in order to reduce the conveyance of contaminants into the Wapiti River and tributaries. This can be accomplished through reducing impervious surfaces, maintaining wetlands, rain water harvesting, vegetated buffers, biorentention and water reuse (Burns et al., 2012; Collins et al., 2009).

Temporary Harvest Roads

Temporary Harvest Roads have the potential to contribute large amounts of sediment to receiving water bodies and impact source water (Weyerhaeuser Company Ltd., 2020). Accordingly, Weyerhaeuser Company Ltd. has developed extensive Operating Ground Rules to manage this risk. We recommend that the Beneficial Management Practices for Temporary Harvest Roads continue to be reviewed and improved. At the broader watershed scale, maintenance of wetlands and riparian zones is critical as is the development of cumulative effects management approach.

Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)

Recent proliferation of Off Highway Vehicles has led to increased impacts of Off-Highway Vehicle operation, which has been demonstrated to have an impact water quality (fRI Research & TerrainWorks Inc., 2018; Miniat et al., 2019; Nosrati & Collins, 2019). Increasing prevalence of OHVs and their increasing power mean that there is a greater impact on water resources. We recommend the establishment of official trails according to a land use plan that avoid water bodies and provided designated areas for "mudding". The Community of Practice for this group would include the Wapiti Off-Road Association and they should be targeted for education about BMPs.

Implementation

The recommendations in this plan are ambitious because they focus on watershed-wide, cumulative effects based, collaborative governance. Given the complex landscape that exists today in the Wapiti Watershed and the expectation that the complexity and extent of use will only increase, this is the best approach moving forward. Below are the key recommendations for the protection of Source Water in the Wapiti Watershed.

Table 2. Implementation actions for recommendations. Short Term: 1-2 years; Medium Term: 2-5 years; Long Term: 5+ years

Hazard	**Management Action**	**Proposed Lead**	**Proposed Partners**	**Proposed Starting Timeframe**
Cumulative Effects	Cumulative Effects Management	Government of Alberta	Government of British Columbia,	Long term

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		Mighty Peace Watershed Alliance	
Riparian zone maintenance promotion	Government of Alberta	Municipalities, Mighty Peace Watershed Alliance, Landowners, Public	Short term
Develop a riparian zone by-law	Mighty Peace Watershed Alliance	Municipalities	Medium term
Sediment delivery evaluation	Government of Alberta	Mighty Peace Watershed Alliance	Medium term
Wetland Retention	Municipalities	Government of Alberta, Mighty Peace Watershed Alliance, Public, Landowners	Medium term
Develop a wetland retention by-law	Municipalities	Government of Alberta, Mighty Peace Watershed Alliance, Landowners	Medium term
Develop water quality Indicators, Thresholds and Targets for the Wapiti River	Government of Alberta	Mighty Peace Watershed Alliance, Aquatera, International Paper, Municipalities	Long term

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`Crossings/culverts/ditches	Promote more vegetation in ditches (less mowing), strategically placing bioswales or created wetlands before water enter the Wapiti River or tributaries.	Municipalities	Alberta Watercourse Crossing Collaborative, Foothills Stream Crossing Partnership, Alberta Energy Regulator	Short term
	Promote use of Alberta Watercourse Crossing Inventory app	Government of Alberta	Public	Short term
Flooding	See Cumulative Effects Management, Riparian zone maintenance, riparian zone by-law, Wetland retention, and wetland retention by-law above	Government of Alberta	Mighty Peace Watershed Alliance, Municipalities	Long term
Forest Fires	Check with water utilities to ensure post-wildfire planning for withdrawals and treatment	Mighty Peace Watershed Alliance	Municipalities	Short term
Herbicide application	Promote BMPs with Communities of Practice	Municipalities	Industry*, Landowners , Public,	Short term
	See Riparian zone maintenance, Riparian zone by-law, Sediment delivery evaluation, Wetland retention, and Wetland retention by-law above	Municipalities	Government of Alberta, Mighty Peace Watershed Alliance	Medium term
Illegal dumping into wastewater systems	Education through Communities of Practice	Government of Alberta	Aquatera, Mighty Peace Watershed Alliance	Short term
Improper hazardous waste disposal	Education	Government of Alberta	Aquatera, municipalities	Short term

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Manure disposal	Education	Agricultural Services Board	Municipalities	Short term
	See Riparian zone maintenance, Riparian zone by-law, Wetland retention, and Wetland retention by-law above	Government of Alberta	Municipalities, Mighty Peace Watershed Alliance	Medium term
Old sumps	Education	Alberta Energy Regulator	Canadian Association of Petroleum Producers, Oil & Gas sector	Short term
Pipeline releases	Education	Alberta Energy Regulator	Canadian Association of Petroleum Producers, Oil & Gas sector	Short term
	See Riparian zone maintenance, Riparian zone by-law, Wetland retention, and Wetland retention by-law above	Alberta Energy Regulator	Canadian Association of Petroleum Producers, Oil & Gas sector, Alberta Environment and Parks	Medium term
Sediment from rural properties	Promoting maintaining or re-establishing native vegetation, reducing channelization or ditching, reducing the amount of bare soil, and maintaining wetlands	Municipalities	Mighty Peace Watershed Alliance, Government of Alberta	Short term
	See Riparian zone maintenance, Riparian zone by-law, Wetland retention, and Wetland retention by-law above	Municipalities	Government of Alberta, Mighty Peace Watershed Alliance	Medium term
Stormwater	Reduce impervious surfaces, maintaining wetlands, rainwater harvesting, vegetated buffers, biorentention and water reuse	Municipalities	Government of Alberta	Medium term

Temporary harvest roads	Recommend that BMPs for Temporary Harvest Roads continue to be reviewed and improved	Forestry	Government of Alberta	Medium term
	See Cumulative Effects Management above	Government of Alberta	Forestry	Long term
Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)	Create a land use plan identifying designated trails.	Government of Alberta	Municipalities, Community groups	Long term
	Education	Government of Alberta	Municipalities, Community groups, Mighty Peace Watershed Alliance	Short term

*Industry refers to different sectors of the economy

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Appendix A – Water allocations in the Wapiti River Basin

Table 3. Water allocations in the Wapiti River Basin

Name	Start Date	Specific Use	Water Body	Allocation (m^3/year)	Return (m^3/year)	Net (m^3/year)
AQUATERA UTILITIES INC.	3-Feb-1965	Urban	Wapiti River	21,470,767	12,919,267	8,551,500
WEYERHAEUSER COMPANY LIMITED	30-Jun-1971	Other	Wapiti River	40,504,910	36,434,420	4,070,490
ERIC & CARMEN DE SCHIPPER	22-Dec-1975	Crop	Redwillow River	23,440	0	23,440
WAPITI GRAVEL SUPPLIERS (N.P.A. LTD.)	25-Jul-1978	Aggregate	Bear River	19,730	0	19,730
DUCKS UNLIMITED CANADA, EDMONTON	21-Jun-1979	Wetlands	Beavertail Creek	407,050	0	407,050
TISSINGTON FARMS	25-Feb-1980	Crop	Wapiti River	27,140	0	27,140
TOWN OF BEAVERLODGE	6-Jul-1981	Urban	Beaverlodge River	690,760	536,570	154,190
ANDREWS, ROBERT	27-Feb-1984	Garden	Dimsdale Lake	76,480	0	76,480
GOOD-TO-FARE RANCH LTD., THE	25-Jun-1986	Crop	Barr Creek	18,500	0	18,500
ERCO WORLDWIDE	9-Aug-1990	Other	Wapiti River	271,360	57,970	213,390
RICHMOND HILL GOLF CLUB LIMITED	23-Oct-1991	Golf Course	Bear River	98,670	0	98,670
BEAR CREEK GOLF CLUB LTD.	22-Oct-1992	Golf Course	Bear River	83,000	0	83,000
NEWALTA CORPORATION	5-Jul-1994	Other	Wapiti River	14,800	0	14,800
AINSWORTH ENGINEERED CANADA LIMITED PARTNERSHIP	23-Sep-1994	Other	Surface Runoff	117,180	0	117,180
AINSWORTH ENGINEERED CANADA LIMITED PARTNERSHIP	4-Feb-1999	Other	Unnamed Lake - Noncontributing	25,000	0	25,000
1031266 ALBERTA LTD.	13-Sep-1999	Golf Course	Beaverlodge River	60,000	0	60,000
PIPESTONE GOLF COURSE	14-Oct-2004	Golf Course	Surface Runoff	55,300	0	55,300
HUTTERIAN BRETHREN CHURCH OF GRANDVIEW	29-Dec-2008	Co-op	Bear Lake	33,000	0	33,000
			Total - Top 18	63,997,087	49,948,227	14,048,860
			Total Other	8,092,962	313,300	7,779,662
			Total	72,090,049	50,261,527	21,828,522

Source: *(Kerhoven, 2014a)*

Appendix B – Land Use in the Wapiti Watershed

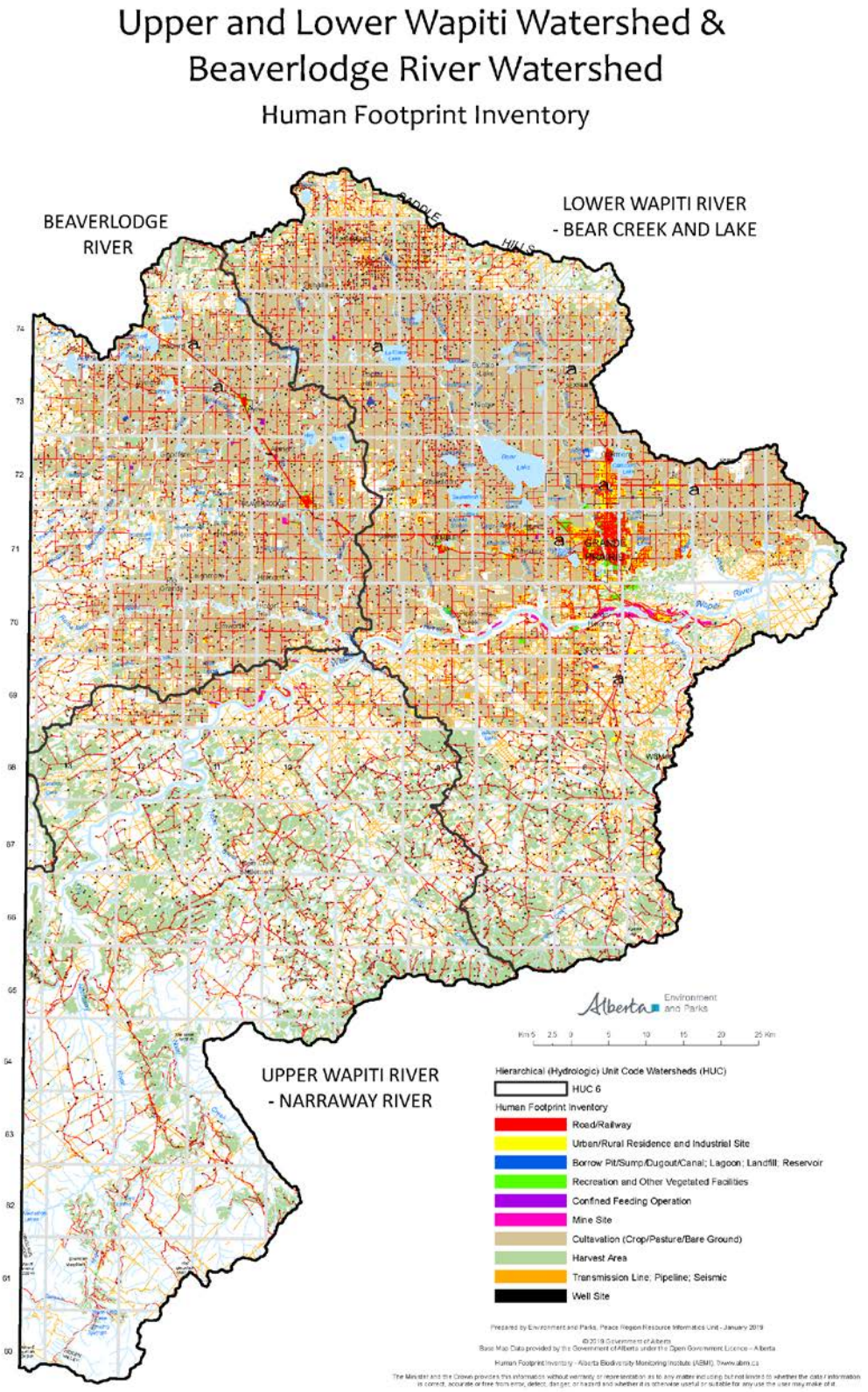

Figure 7 Land use in the Wapiti Watershed

Table 4. Land use in the Wapiti Watershed

WATERSHEDS HUMAN FOOTPRINT INVENTORY OVERVIEW

			BEAVERLODGE RIVER 215,780.55 ha		LOWER WAPITI RIVER - BEAR CREEK AND LAKE 416,326.01 ha		UPPER WAPITI RIVER - NARRAWAY 381,237.93 ha	
			ha		ha		ha	
Industrial and Rural Areas Footprint	Reservoirs	Reservoir	46.66	0.0%	75.41	0.0%	0.00	0.0%
	Municipal (Water and Sewage)	Lagoon	59.28	0.0%	89.08	0.0%	0.03	0.0%
	Borrow Pits, Sumps, Dugouts	Borrow Pit	135.14	0.1%	214.66	0.1%	255.03	0.1%
		Borrow Pit - Dry	4.67	0.0%	30.76	0.0%	64.81	0.0%
		Borrow Pit - Wet	20.76	0.0%	84.21	0.0%	88.51	0.0%
		Sump	18.64	0.0%	179.27	0.0%	46.37	0.0%
		Dugout	216.17	0.1%	265.16	0.1%	24.70	0.0%
	Canals	Canal	35.93	0.0%	51.00	0.0%	1.06	0.0%
	Mine Sites	Gravel/Sand Pit	58.63	0.0%	599.38	0.1%	186.29	0.0%
		Open Pit Mine	0.00	0.0%	52.37	0.0%	22.34	0.0%
	Industrial Site Rural	Industrial Camp	0.00	0.0%	5.78	0.0%	10.19	0.0%
		Unknown Clearning	66.38	0.0%	302.98	0.1%	219.45	0.1%
		Unknown Facility	37.37	0.0%	573.19	0.1%	8.53	0.0%
		Miscellaneous Oil/Gas Facility	67.03	0.0%	387.42	0.1%	82.95	0.0%
		Facility - Other	8.67	0.0%	162.11	0.0%	0.02	0.0%
		Urban - Industrial	187.66	0.1%	2,571.00	0.6%	0.00	0.0%
		Oil-Gas-Plant	13.95	0.0%	65.47	0.0%	25.05	0.0%
		Mill	0.00	0.0%	172.69	0.0%	0.00	0.0%
		Wellpad Clearing Unconfirmed	18.17	0.0%	46.94	0.0%	30.67	0.0%
	Landfill	Transfer Station	1.13	0.0%	11.15	0.0%	0.00	0.0%
		Landfill	0.00	0.0%	186.26	0.0%	0.00	0.0%
	Well Sites	Gas Well	1,514.14	0.7%	1,827.15	0.4%	1,820.32	0.5%
		Oil Well	204.90	0.1%	1,469.29	0.4%	151.73	0.0%
		Other Well	130.50	0.1%	521.68	0.1%	155.17	0.0%
		Well Sites - Abandoned	650.38	0.3%	1,244.78	0.3%	350.41	0.1%
	Other Vegetated Facilities and Recreation	Campground	1.97	0.0%	23.73	0.0%	4.59	0.0%
		Golf Course	0.00	0.0%	65.52	0.0%	0.00	0.0%
		Green Space	4.51	0.0%	104.99	0.0%	0.00	0.0%
		Recreation	105.43	0.0%	1,225.89	0.3%	5.37	0.0%
		Surrounding Vegetation	24.33	0.0%	0.00	0.0%	0.00	0.0%
		Runway	0.00	0.0%	0.00	0.0%	21.29	0.0%
	Confined feeding operations (CFO)	CFO	127.24	0.1%	100.21	0.0%	0.00	0.0%
	Urban and Rural Residential	Country Residence	223.49	0.1%	2,894.74	0.7%	9.64	0.0%
		Rural Residence	2,085.01	1.0%	4,624.46	1.1%	141.43	0.0%
		Urban Residence	112.78	0.1%	1,736.67	0.4%	0.00	0.0%
		Residence Clearing	0.20	0.0%	710.69	0.2%	0.00	0.0%
		Sub Total	**6,181.13**	**2.9%**	**22,676.07**	**5.4%**	**3,725.98**	**1.0%**
Linear Footprint	Road – Hard Surface	Paved Road Divided	14.43	0.01%	276.26	0.1%	0.00	0.0%
		Paved Road - 1 Lane	0.00	0.00%	12.34	0.0%	1.16	0.0%
		Paved Road - 2 Lane	62.69	0.03%	635.96	0.2%	0.00	0.0%
		Paved Road - 3 Lane	0.00	0.00%	3.14	0.0%	0.00	0.0%
		Paved Road - 4 Lane	0.00	0.00%	15.88	0.0%	0.00	0.0%
		Undivided Paved Road - 1 Lane	4.14	0.00%	110.95	0.0%	0.00	0.0%
		Undivided Paved Road - 2 Lane	353.21	0.16%	789.56	0.2%	28.84	0.0%
		Undivided Paved Road - 4 Lane	0.00	0.00%	3.63	0.0%	1.07	0.0%
		Interchange Ramp	0.48	0.00%	22.89	0.0%	0.00	0.0%
		Gravel Road - 1 Lane	961.45	0.45%	1,588.48	0.4%	777.16	0.2%
		Gravel Road - 2 Lane	621.60	0.29%	1,093.24	0.3%	594.24	0.2%
		Unclassified Road	215.34	0.10%	544.80	0.1%	19.66	0.0%
		Unimproved Road	504.88	0.23%	1,206.15	0.3%	562.96	0.1%
		Truck Trail	71.04	0.03%	98.13	0.0%	77.08	0.0%
		Winter Road	0.34	0.00%	125.76	0.0%	489.82	0.1%
		Airport Runway	2.93	0.00%	34.63	0.0%	0.00	0.0%
		ATV Trail	0.00	0.00%	0.00	0.0%	0.60	0.0%
	Railway - Hard Surface	Railway	46.69	0.02%	101.36	0.0%	0.00	0.0%
	Vegetated Surfaces of Roads, Trails and Railways	Vegetation alongside road edge	2,735.08	1.27%	6,300.64	1.5%	2,374.93	0.6%
		Vegetation alongside railway edge	103.41	0.05%	318.42	0.1%	0.00	0.0%
	Transmission Lines	Transmission Line	271.77	0.13%	894.76	0.2%	3.66	0.0%
	Pipelines	Pipeline	1,402.89	0.65%	3,018.07	0.7%	2,804.39	0.7%
	Seismic Lines and Trails	Low Impact Seismic	0.00	0.00%	0.21	0.0%	1.65	0.0%
		Pre Low Impact Seismic	1,927.30	0.89%	3,261.95	0.8%	2,117.18	0.6%
		Trail/ATV	386.32	0.18%	642.07	0.2%	414.58	0.1%
		Sub Total	**9,685.99**	**4.49%**	**21,099.31**	**5.1%**	**10,268.98**	**2.7%**
Agriculture Footprint	Cultivation (Crop/Pasture/ Bare Ground)	Crop	71,420.20	33.10%	138,820.82	33.3%	3,769.62	1.0%
		Tame Pasture	24,561.14	11.38%	23,035.56	5.5%	733.71	0.2%
		Rough Pasture	5,580.51	2.59%	3,351.64	0.8%	861.46	0.2%
		Abandoned Cultivation	5.06	0.00%	154.79	0.0%	44.83	0.0%
		Sub Total	**101,566.90**	**47.07%**	**165,362.82**	**39.7%**	**5,409.61**	**1.4%**
Forestry Footprint	Cut Blocks	Harvest Area	9,981.82	4.63%	35,317.15	8.5%	66,636.71	17.5%
		Grand Total	**127,415.85**	**59.05%**	**244,455.34**	**58.7%**	**86,041.28**	**22.6%**

Appendix C - Point Source of Pollution in the Wapiti Watershed

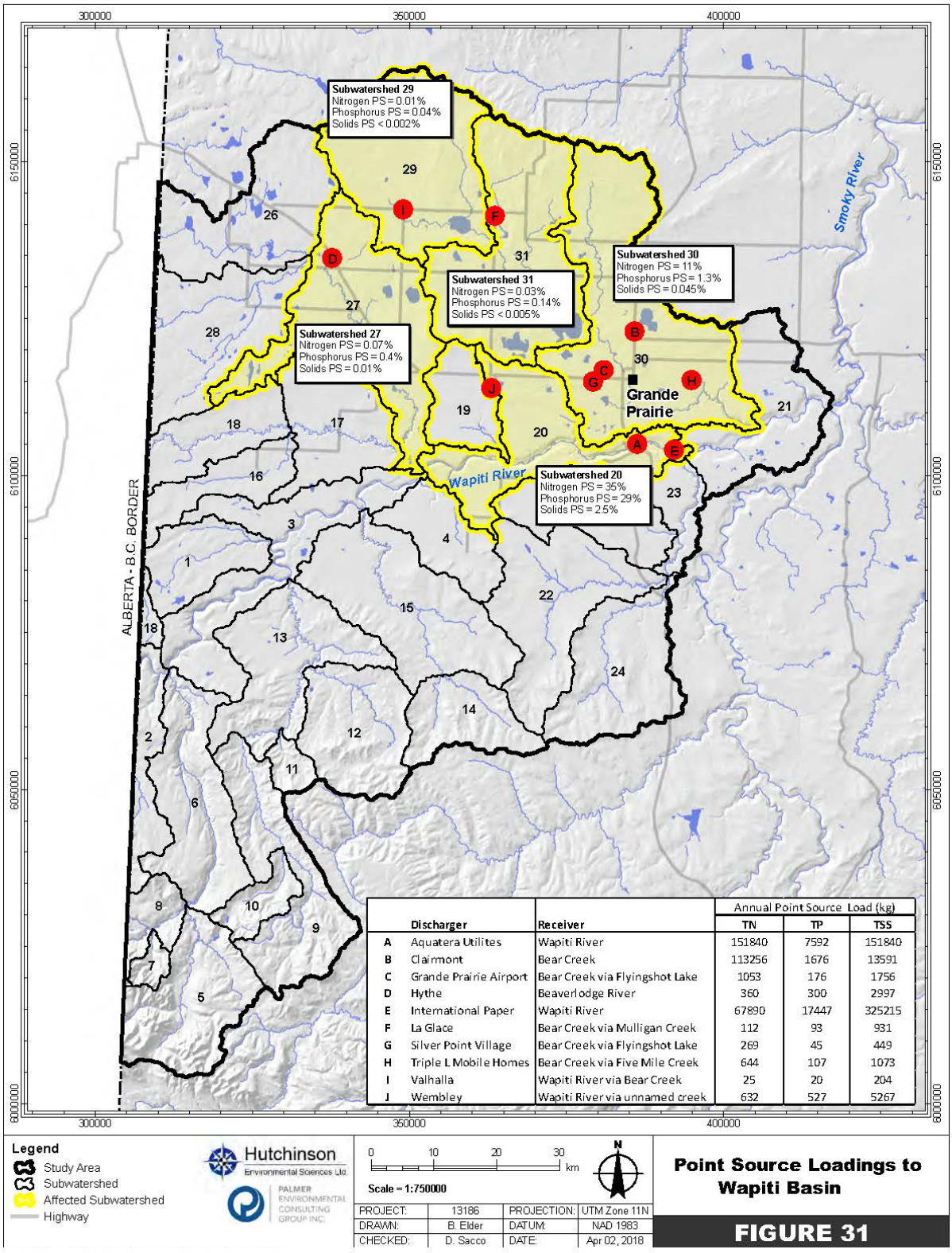

Figure 8. Point Sources of Pollution in the Wapiti Watershed. Source: Hutchinson Environmental Sciences Ltd., 2018

Appendix D – Project Team

The Mighty Peace Watershed Alliance initiated this project and invited partners to participate in the process. Originally, the Canadian Association of Petroleum Producers, the City of Grande Prairie, the County of Grande Prairie, the Mighty Peace Watershed Alliance, the Municipal District of Greenview, and Sturgeon Lake Cree Nation joined the project. Alberta Environment and Parks was unable to provide a member to this project team but provide technical support as they could.

The municipalities of Beaverlodge, Hythe, Sexsmith and Wembley were all invited but they decided not to participate as team members. Throughout the process these municipalities received regular updates and were offered opportunities for input. Horse Lake First Nation was also invited to participate as a team member but no response was received. Weyerhaeuser Grande Prairie was invited to be a part of the project team but declined due to capacity issues. Nevertheless, they took time to review relevant hazards, risk assessment, and mitigative strategies and attended project team meetings to discuss these things. Due to capacity issues, the City of Grande Prairie ceased to participate as a project team member in August of 2019. They continued to provide feedback on the plan at various points. Efforts were made to find a representative from British Columbia to provide input on that part of the watershed but without success.

The Project Team established both a Terms of Reference which the organizations approved and an Operating Guidelines and Procedures which the Project Team approved. The Terms of Reference laid out purpose, responsibilities, roles and relationships for organizations and the project. The Operating Guidelines and Procedures detailed specific processes on how the Project Team functioned operationally. Both in-person and remote meetings were held and background work was completed between meetings to support the work of the Project Team.

The following organizations were actively participating when the plan was released: Aquatera, Canadian Association of Petroleum Producers, County of Grande Prairie, Mighty Peace Watershed Alliance, Municipal District of Greenview and Sturgeon Lake Cree Nation.

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Appendix E – Public Engagement

The list of identified hazards and risk assessment were taken to the public in March of 2020. Due to COVID-19 public health measures no in-person engagement was done. All engagement and input was undertaken through direct contact and online. Those who had requested to be kept informed of the project were notified of the opportunity for review, input and engagement directly. The general public was informed through posts on websites, Twitter, and Facebook.

Direct feedback was received as well as anonymous public input through the online survey hosted on SurveyMonkey and 6 people completed this survey. Concerns about the risk ranking for agricultural chemical application, runoff from agricultural land, deposition of chemicals and manure into watercourse, water withdrawals for hydraulic fracturing, pipeline spills, fugitive emissions from hydraulic fracturing, Oil & Gas development and a focus on Aquatera's issues were identified. The project team reviewed this input and adjusted the risk ranking as deemed appropriate.

Appendix F – Identified Hazards

Table 5. List of Identified Hazards

Active Landfills (includes operations, fires, and leachate)	Garbage burning	Road salt/de-icer application
Air emissions/flaring	Highway 40 Bridge Spill	Rutting
Application of chemicals	Illegal dumping into wastewater systems	Sediment due to wake or boat disturbing channel
Bank slumping	Illegal dumping rest of watershed	Sediment from rural properties
BC portion of watershed	Improper Hazardous waste disposal	Septic systems/private systems
Boat operation leading to incidental discharge and emissions	Inactive/abandoned landfills	Spill of Hazardous materials
Calcium application for dust control	Institutional/commercial/industrial	Storage of chemicals
Camp wastewater	Intentional treated wastewater discharges	Stormwater
Camps	Invasives/weeds	Subsurface spills (casing failures)
Construction	Lagoon breach or failure	Sumps new
Creosote Ties	Land clearing/tree location	sumps old
Crossings/culverts/ditches	Land disposal of drilling or waste treatment sludge	Surface spills
Cumulative effects	Linear disturbance incl seismic lines and pipelines	Suspended wells and pipelines
Cutblocks (includes normal operation, runoff, etc.)	Livestock grazing	Tarmac run-off
De-icing at GP airport	Manure disposal	Temporary Harvest Roads
Deleterious substances	Mountain Pine Beetle/pests	Trucking (primarily Transportation of Dangerous Goods)
Development	Pads	Unauthorized boat launches
Ditching/draining	Parks outhouses	Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)
Drought	Petroleum from vehicles day to day operation	Water access infrastructure
Erosion caused by OHVs	Pipeline releases	Water wells
Feedlots/confined feeding operations	Railway oil/grease/fuel leakage	Wildlife faeces
Fire-fighting chemical	Railway spills	Wildlife pathogens
Flooding	Recreational development (new & existing)	Wood storage yards
Forest fires (not controlled)	Road salt storage (includes snow dump)	Yard care

Appendix G – Scale for Risk Assessment

Table 6. Scale used for risk assessment

Likelihood	Numeric value	Probability of occurrence
The probability of a Hazard occurring and affecting water.	1	most unlikely
	2	unlikely
	4	possible
	8	probable
	16	almost certain

Severity	Numeric value	Severity of impact
The level of impact on source water due to occurrence.	1	insignificant
	2	minor
	4	moderate
	8	severe
	16	catastrophic

Appendix H – Average Annual Export Coefficients for the Wapiti Watershed

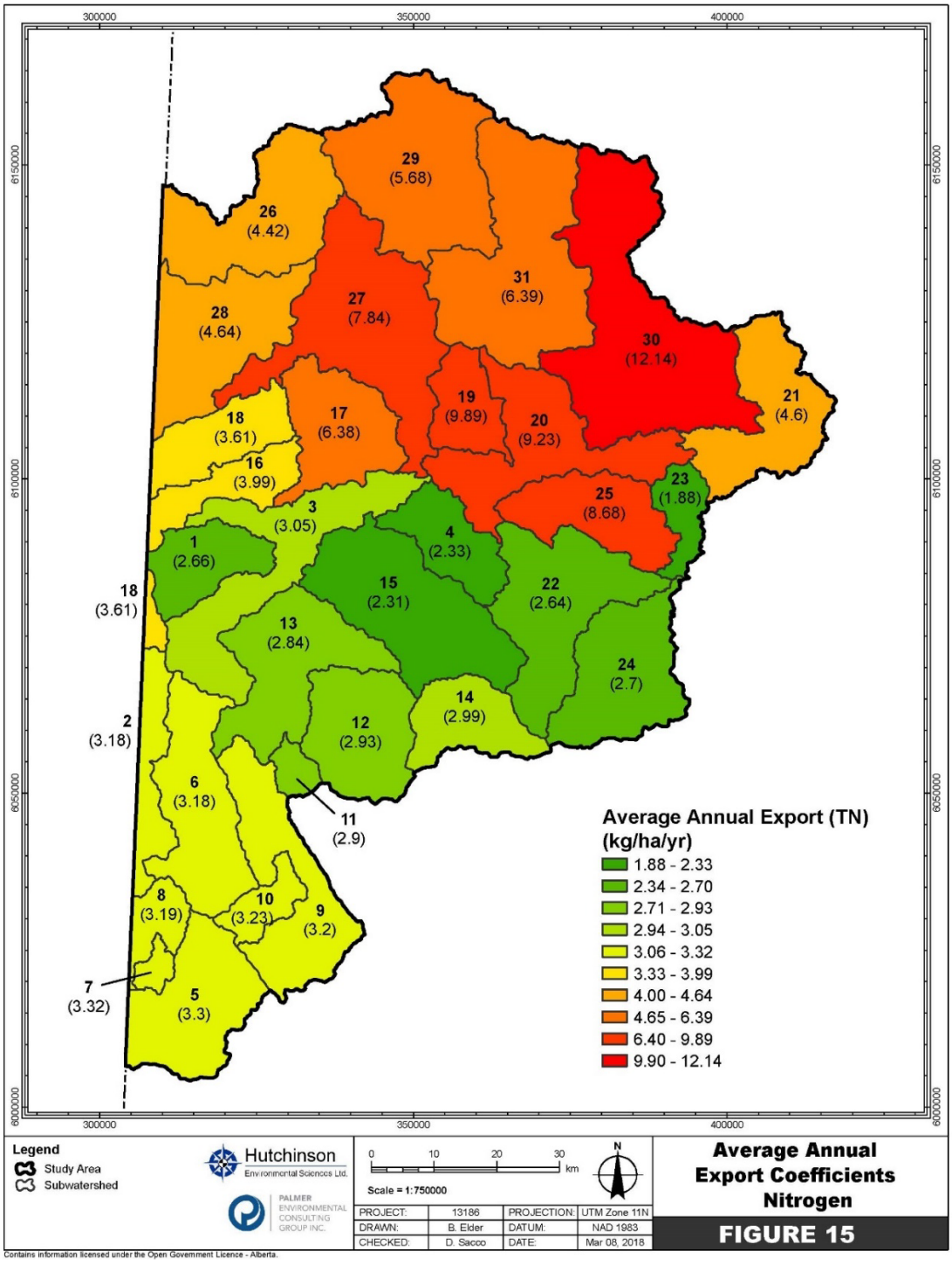

Figure 9. Average Annual Export Coefficients for the Wapiti Watershed – Nitrogen. Source: Hutchinson Environmental Sciences Ltd., 2018

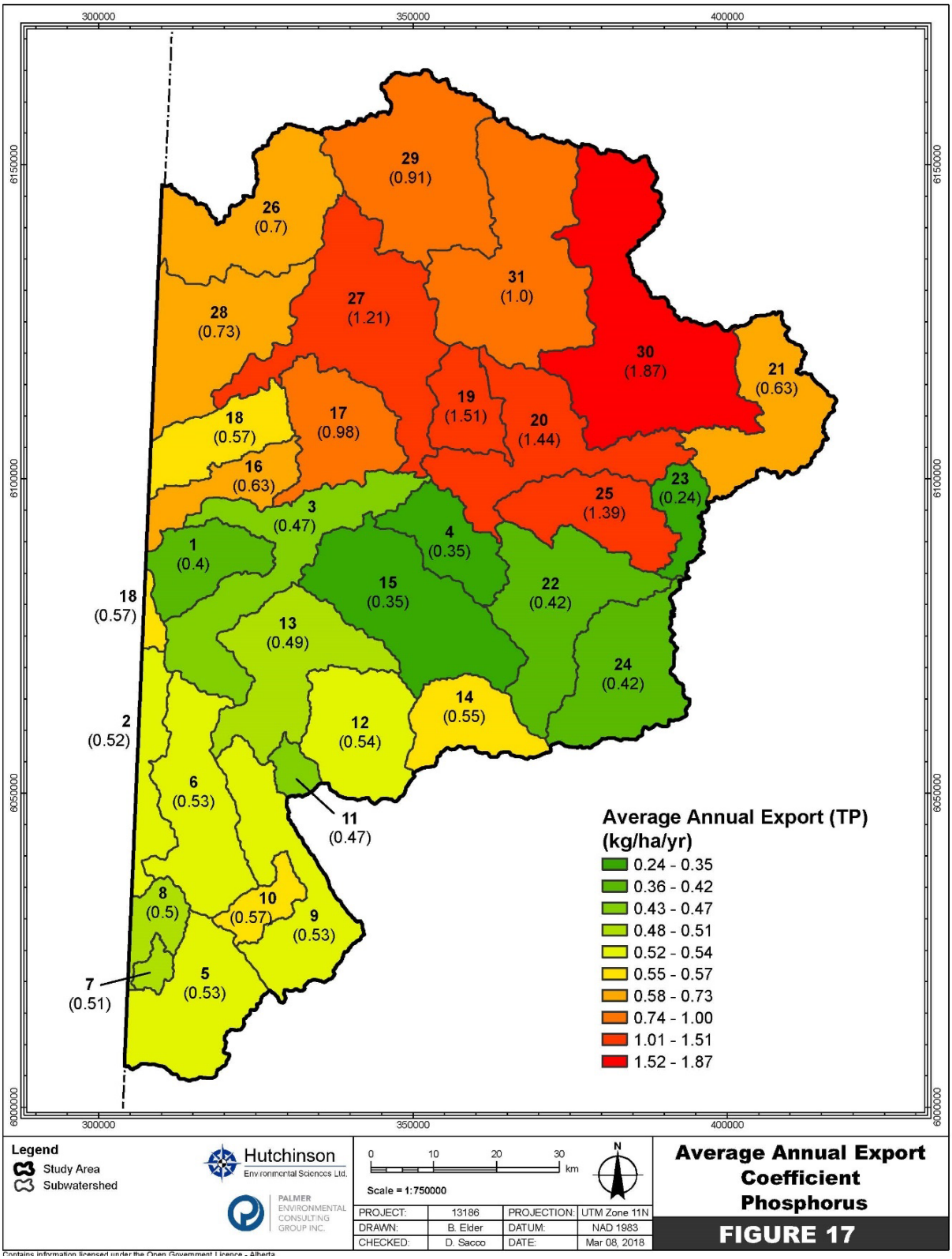

Figure 10. Average Annual Export Coefficient for the Wapiti Watershed – Phosphorus. Source: Hutchinson Environmental Sciences Ltd., 2018

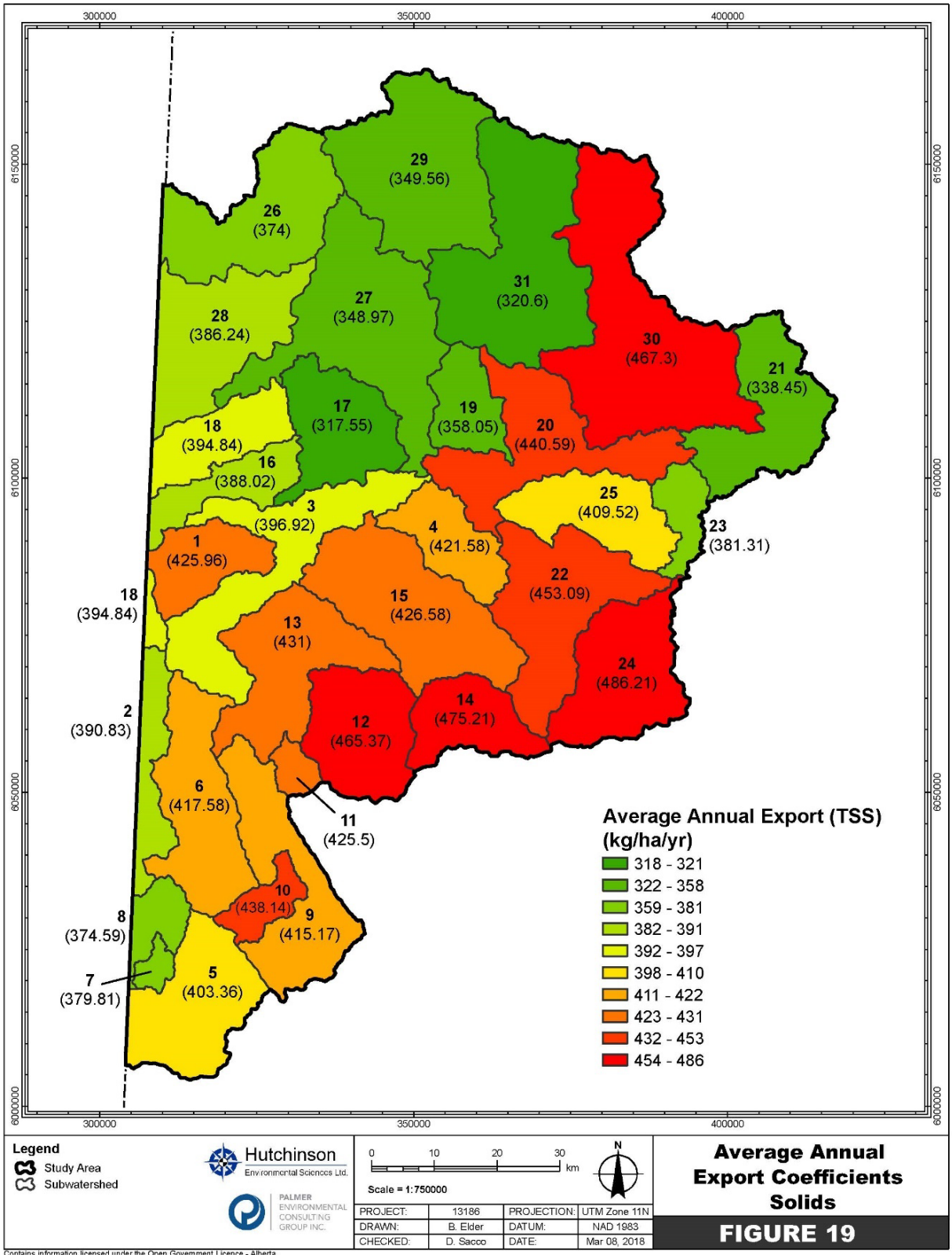

Figure 11. Average Annual Export Coefficient for the Wapiti Watershed - Total Suspended Sediment. Source: Hutchinson Environmental Sciences Ltd., 2018

Appendix I – Runoff Management Classification for the Wapiti Watershed

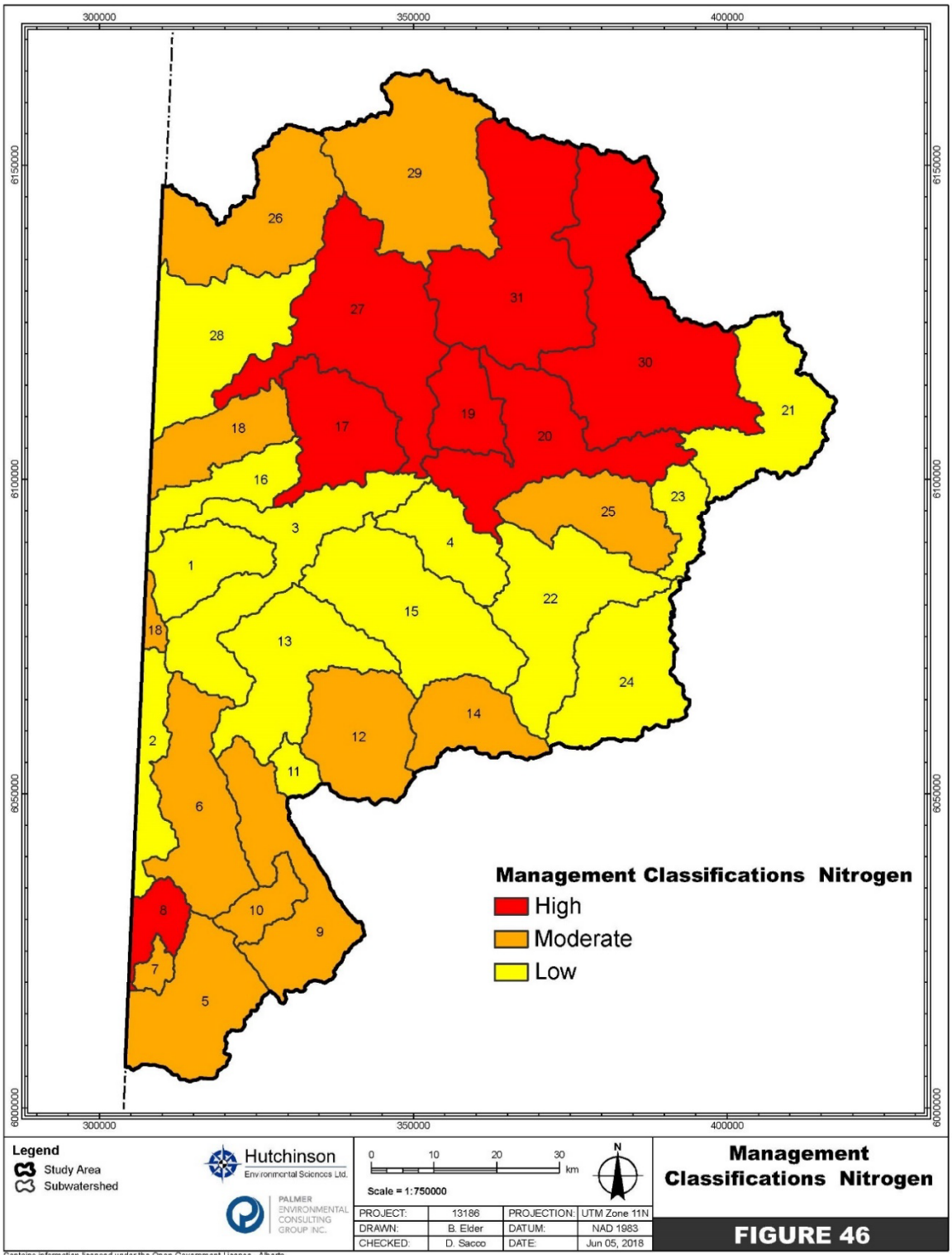

Figure 12. Nitrogen Runoff Management classification for the Wapiti Watershed. Source: Hutchinson Environmental Sciences Ltd., 2018

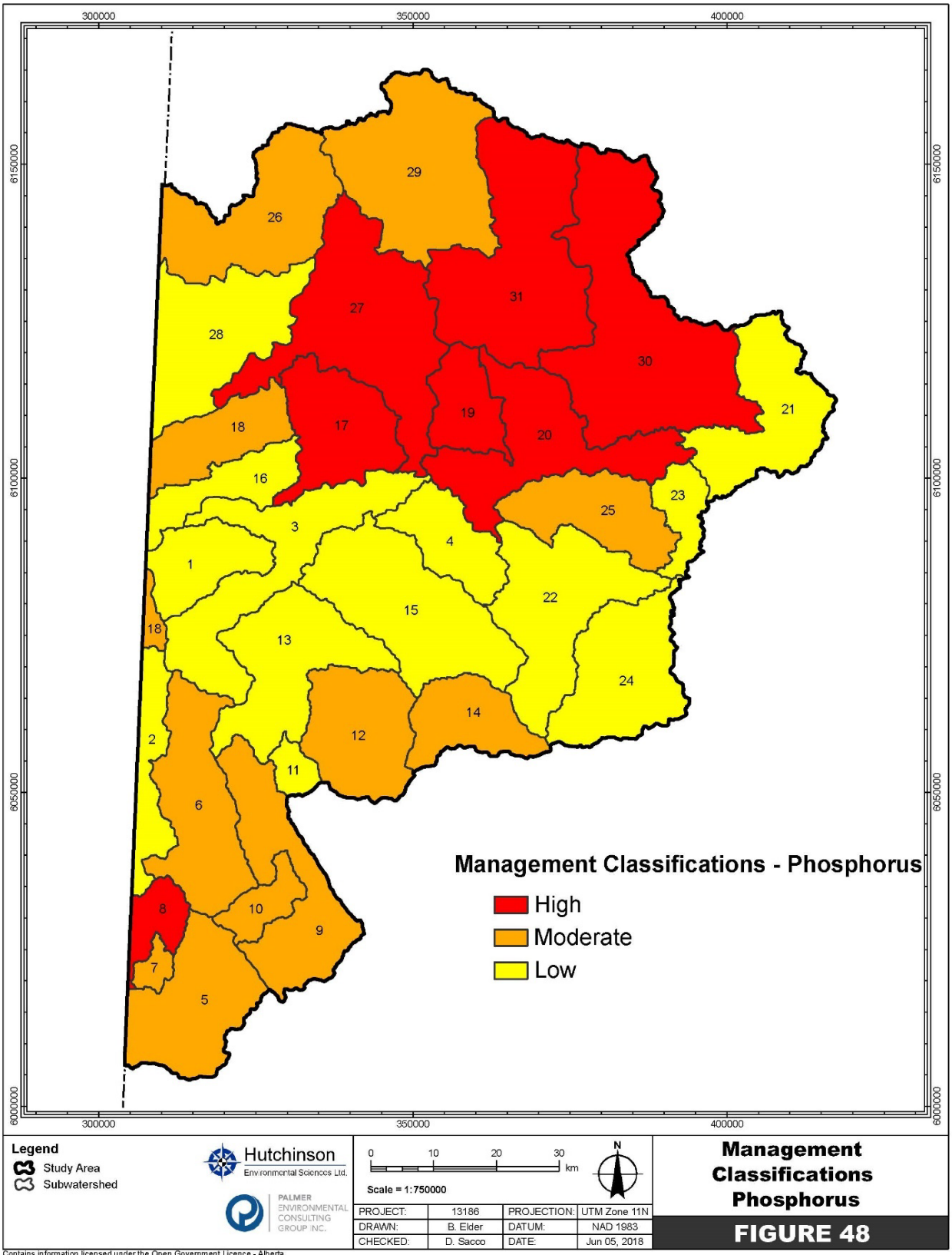

Figure 13. Phosphorus Runoff Management Classification for the Wapiti Watershed. Source: Hutchinson Environmental Sciences Ltd., 2018

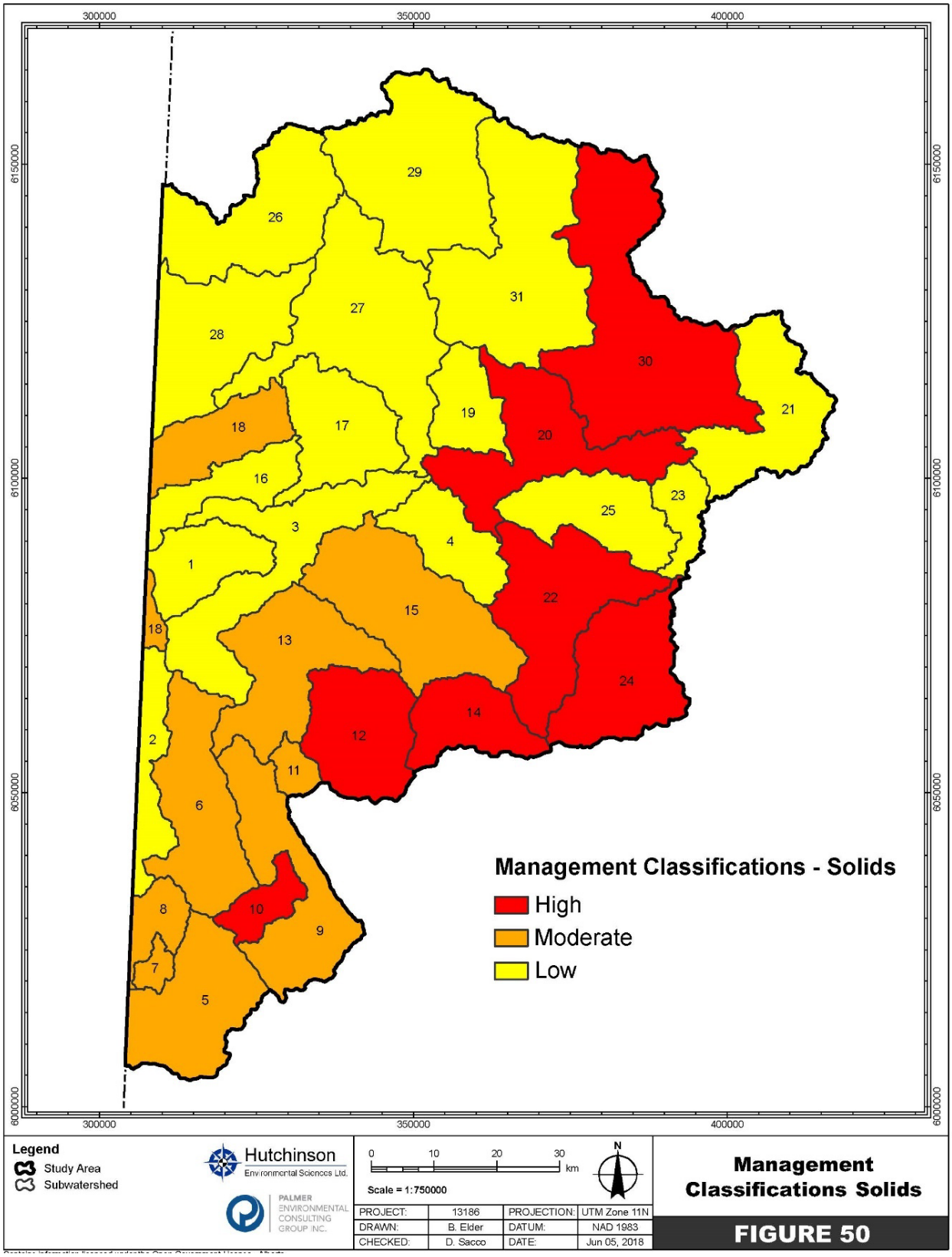

Figure 14. Sediment Runoff Management Classification for the Wapiti Watershed. Source: Hutchinson Environmental Sciences Ltd., 2018

Appendix J – Wapiti Watershed Manure Index Map

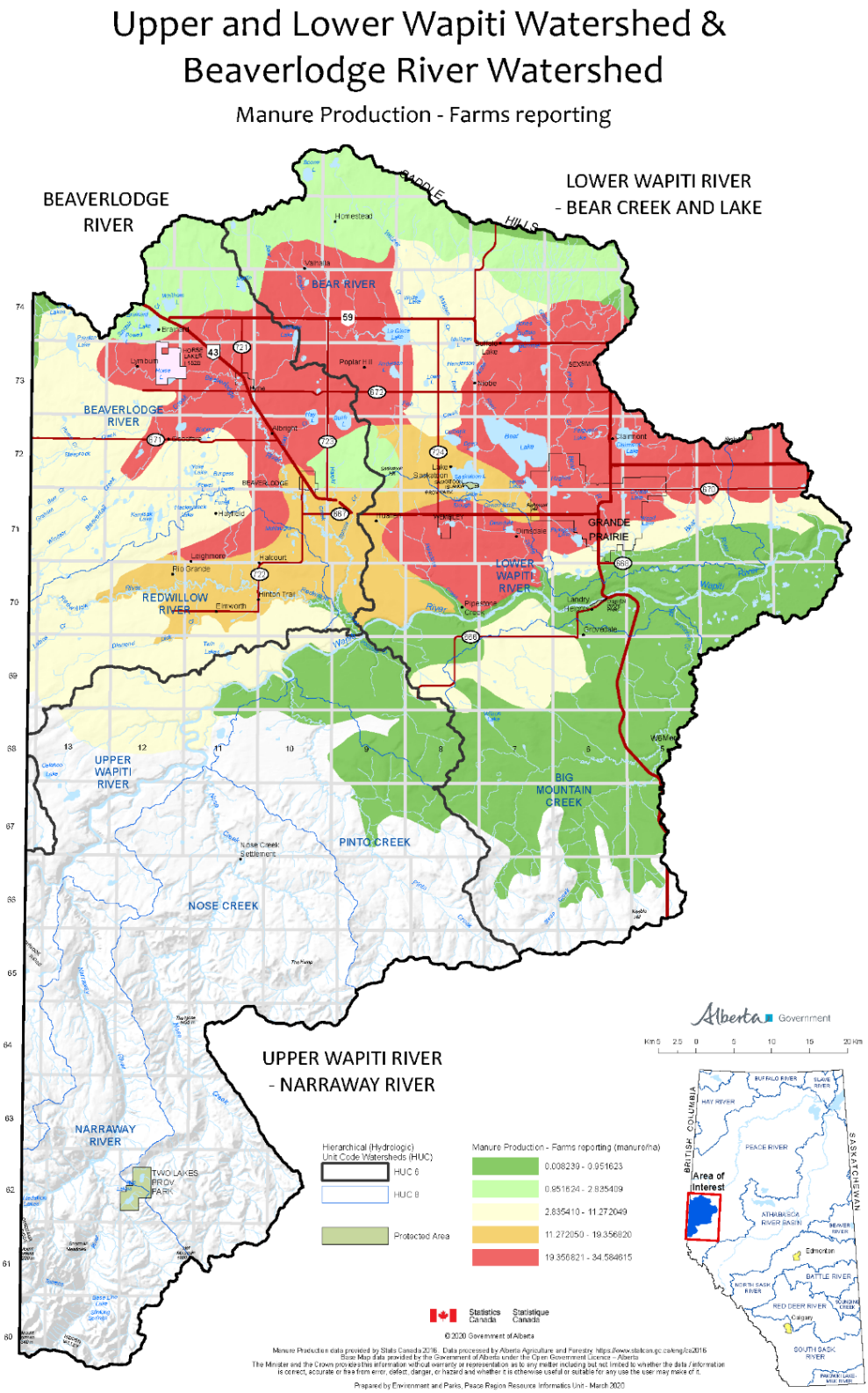

Figure 15. Manure production map for the Wapiti Watershed

Appendix K – Recommended Management Actions

Table 7. Recommended Management Actions

Hazards	Potential Risk to Source Water	Existing Management Actions	Recommended Management Actions
1. Illegal dumping into wastewater systems	- Industrial chemicals	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Signage	a) Education - http://www.stormwater.allianceforthebay.org/take-action/habits-to-help/dont-dump-into-drains -yellow fish road -fluid haulers b) Enforcement (GoA, municipality) -Taking Care of Your Drinking Water and Wastewater: A Guide for Members of Municipal Councils
2. Illegal dumping rest of watershed	- Household chemicals, paint, industrial chemicals, petroleum products, metals	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Signage	a) Education b) Janine Higgins c) Enforcement (GoA, municipality) d) Incentives (deposit on appliances, etc.)

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3. Deleterious substances	- Salts, PAHs, metals, hydrocarbons, sediment	- Fisheries Act (R.S.C., 1985, c. F-14) - Environmental Protection and Enhancement Act (RSA 2000 c. E-12)	a) Education about aquatic ecosystems -hydrological cycle
4. Development	- sediment	- Municipal Government Act (M-26 RSA 2000) - Municipal Development Plans, Land Use bylaws	a) Education -developers, development officers and property owners -Alberta Low Impact Development Partnership -promote runoff friendly yards - https://www.pac.dfo-mpo.gc.ca/publications/pdfs/hometips_2000_e.pdf -NPS Urban Facts b) Enforcement (GoA, municipal) c) Land use planning (environmental reserves, setbacks) d)
5. Wildlife faeces	- Bacteria, viruses, nutrients	- None	a) Treatment at water plants
6. Wildlife pathogens	- Bacteria, viruses, fungi, parasites	- Wildlife Act (W-10 RSA 2000) - Don't let it loose campaign - Clean, Drain, Dry campaign	a) Education -outdoor recreationalists Clean, drain, dry b) Enforcement c) Reducing barriers by providing means of compliance d) Incentives
7. Active Landfills (includes operations, fires, and leachate)	- Heavy metals, PAHs, hydrocarbons, salt	- Provincial regulation	a) Education b) Enforcement c) Innovation of better practices d) Funding to bring all landfills up to best standards

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8. Inactive/abandoned landfills	- Heavy metals, PAHs, hydrocarbons, salt	- Provincial regulations - Some are being monitored	a) GoA should continue monitoring these sites
9. Application of chemicals for weeds	- Herbicides, insecticides, fungicides	- Environmental Code of Practice for Pesticides [Environmental Protection and Enhancement Act (RSA 2000 c. E-12)]	a) Education -yard owners and gardeners https://www.pac.dfo-mpo.gc.ca/publications/pdfs/hometips_2000_e.pdf b) Promote Best Industry Practices -mechanical control where feasible -Practices that reduce fugitive chemicals and drift
10. Invasives/weeds	- Whirling disease, zebra and quagga mussels, flowering rush, hawkweed, and spotted knapweed - https://abinvasives.ca/invasive-species/fact-sheets/#!prettyPhoto	- Species at Risk Act (S.C. 2002, c. 29) - Weed Control Act (2008, c. W-5.1) - Don't let it loose campaign - Clean, Drain, Dry campaign	a) Education -yard owners and gardeners -outdoor recreationalists -Alberta Invasive Species Council b) Enforcement c) Promote Best Industry Practices -cleaning machinery before moving it
11. BC portion of watershed	- Change in flow - Change in quality	- Transboundary (Bi-lateral Water Management Agreement negotiations are ongoing)	a) Request to have communication with BC b) Take our concerns to BC - Transboundary secretariat
12. Land disposal (from drilling or waste treatment sludge)	-Nutrients, metals, salts organic compounds and pathogens in runoff or leaching into groundwater	- Guidelines for the Application of Municipal Wastewater Sludges to Agricultural Lands	a) Promote guidelines

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13. Feedlots/confined feeding operations	-nutrients and bacteria in runoff or leaching into groundwater	- Agricultural Operation Practices Act (A-7 RSA 2000)	a) Education b) c) Enforcement d) Promote Best Management Practices
14. Application of chemicals	-pesticides or fertilizers entering surface or groundwater	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Pesticide (Ministerial) Regulation - Pesticide Sales, Handling, Use and Application Regulation - Environmental Code of Practice for Pesticides -	a) Promote regulations - Crop Protection 2020 (Blue Book)
15. Storage of chemicals	-pesticides or fertilizers entering surface or groundwater	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Pesticide (Ministerial) Regulation - Pesticide Sales, Handling, Use and Application Regulation - Environmental Code of Practice for Pesticides -	a) Education b) Enforcement c) Promote Best Management Practices - Crop Protection 2020 (Blue Book)
16. Livestock grazing	-bacteria, nutrients, and sediment in surface runoff, deposited directly into water or leaching into groundwater	- Agricultural Operation Practices Act (A-7 RSA 2000)	a) Education -Riparian Areas – Important Natural Assets -Riparian Rights Shoreline Modification -Watercourse Crossings Factsheet b) Enforcement c) Promote Best Management Practices 1. Riparian zone protection 2. Off-site watering
17. Manure disposal	-bacteria, nutrients, and sediment in surface runoff, deposited directly into water or	- Agricultural Operation Practices Act (A-7 RSA 2000)	a) Education 1. Beneficial Management Practices: Environmental Management Practices for Livestock Producers in Alberta b) Promote new technology and practices

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	leaching into groundwater		
18. Ditching/draining	-Sediment via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Water Act (RSA 2000, c. W-3)	a) Education b) Municipal by-laws
19. Land clearing/tree location	-Sediments and nutrients via surface runoff	-	a) Education -Values of Trees (AWES) b) Riparian zone BMPs -Eco-buffer factsheet -Riparian Areas – Important Natural Assets -Riparian Rights Shoreline Modification c) Municipal by-laws
20. Garbage burning	- Aerial deposition, surface runoff of plastics and PAHs	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -Prohibited Debris: Before you Burn … Learn!
21. Cutblocks (includes normal operation, runoff, etc.)	-Nutrients and sediment in surface runoff	- Weyerhaeuser Forest Management Plan Chapter 6.16.7 and 6.17 - Weyerhaeuser Operating Ground Rules 6.0 - Weyerhaeuser Operating Ground Rules 7.6 - Weyerhaeuser Operating Ground Rules 9.0 - Weyerhaeuser Operating Ground Rules 11.3 and 11.4	a) BMP promotion
22. Temporary Harvest Roads	-increased sediment delivery via surface runoff	- Weyerhaeuser Operating Ground Rules 6.0 - Weyerhaeuser Operating Ground Rules 7.6	a) BMP promotion

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		- Weyerhaeuser Operating Ground Rules 9.0 - Weyerhaeuser Operating Ground Rules 11.3 and 11.4	
23. Wood storage yards	-Sediment, nitrogen, phosphorous, hydrocarbons, metals, petroleum via surface runoff	- Weyerhaeuser Operating Ground Rules 6.0.6 - Weyerhaeuser Operating Ground Rules 6.0.8	a) BMP promotion
24. Spills	-fuels, pesticides, grease via surface runoff, direct deposit or leaching into groundwater	- Weyerhaeuser Operating Ground Rules 6.0.6	a) BMP promotion
25. Rutting	-sediment via surface runoff	- Weyerhaeuser Operating Ground Rules 9.0	a) BMP promotion
26. Forest fires (not controlled)	-Changes in hydrology; increased sediment and nutrient delivery via surface runoff	- Fire Control Objective is to reduce preventable fires and extinguish all harmful fires	a) Development of Wildfire Management Plan that addresses Ecological Benefits of Fire and Watersheds and Sensitive Soils
27. Fire-fighting chemical	-PHOS-CHECK®LC95a -PHOS-CHECK®WD881C	- Avoid watercourses during application	a) Follow application guidelines b) Development of Wildfire Management Plan that addresses Ecological Benefits of Fire and Watersheds and Sensitive Soils
28. Herbicide	-Glyphosate	- Environmental Code of Practice for Pesticides [Environmental Protection and Enhancement Act (RSA 2000 c. E-12)]	a) BMP promotion

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		- Weyerhaeuser only applies herbicides approved for use in forest operations and applies them as per label and registration requirements.	
29. Camps	-Bacteria (wastewater) -Nutrients (wastewater) -Chemicals release (e.g., fuels, grease, solvents etc.) via surface runoff or leaching into groundwater	- Weyerhaeuser Operating Ground Rules 11.6 - Public Health Act- Work Camp Regulations	a) BMP promotion
30. Mountain Pine Beetle/pests	-changes in hydrology	- There is currently no Mountain Pine Beetle harvest planned	a) Ecological resilience approach to forest management
31. Pipeline releases	-hydrocarbons and salt leaching into groundwater or entering surface water	- Pipeline Act (AR 91/2005) - Environmental Protection and Enhancement Act (RSA 2000 cE-12) - Oil and Gas Conservation Act (AR 151/71) - AER Directive 077: Pipelines – Requirements and Reference Tools	a) Promote BMPs
32. Surface spills	-hydrocarbons, salts via direct deposit, surface runoff or leaching into groundwater	- Oil and Gas Conservation Act (AR 151/71) - Environmental Protection and Enhancement Act (RSA 2000 cE-12) -	a) Promote BMPs

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33. Subsurface spills (casing failures)	- hydrocarbons and salt leaching into groundwater or entering surface water	- Oil and Gas Conservation Act (AR 151/71) - Environmental Protection and Enhancement Act (RSA 2000 cE-12) -	a) Promote BMPs
34. Air emissions/flaring	-aerial deposition of hydrocarbons	- Oil and Gas Conservation Act (AR 151/71) - AER Directive 060 Upstream Petroleum Industry Flaring, Incinerating, and Venting	a) Promote BMPs
35. Suspended wells and pipelines	Hydrocarbons and salts leaching into groundwater	- Oil and Gas Conservation Act (AR 151/71) - Pipeline Act (AR 91/2005) - - AER Directive 001: Requirements for Site-Specific Liability Assessments in Support of the ERCB's Liability Management Program - AER Directive 013: Suspension Requirements for Wells - AER Directive 020: Well Abandonment	a) Promote BMPs
36. Linear disturbance incl seismic lines and pipelines (pathway)	-sediment via surface runoff	- Fisheries Act (R.S.C., 1985, c. F-14) - Environmental Protection and Enhancement Act (RSA 2000 c. E 12) -	a) Promote BMPs
37. Pads	- Sediment, hydrocarbons, heavy metals, TDG materials via surface runoff	- Oil and Gas Conservation Act (AR 151/71) -	a) Promote BMPs
38. Water access infrastructure	- Sediment, glycol, motor oil, diesel, gasoline, hydraulic oil, salts, propagules via	- Fisheries Act (R.S.C., 1985, c. F-14) - Water Act (RSA 2000, c. W-3)	a) Promote BMPs

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	surface runoff or direct deposition		
39. Herbicide spraying	-Glyphosate via surface runoff	- Weed Control Act (W-5.1) - Environmental Code of Practice for Pesticides [Environmental Protection and Enhancement Act (RSA 2000 cE-12)] -	a) Promote BMPs
40. Camps	-sediment, hydrocarbons, salts, bacteria via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12)	a) Promote BMPs
41. Sumps new	-salts	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12)	a) Promote BMPs
42. Sumps old	-hydrocarbons, heavy metals, salts, bacteria, TDG materials	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12)	a) Promote clean up of old sumps that are discovered
43. Erosion caused by OHVs	Sediment entering water	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Wheels out of Water - Quick Fact Off-Highway Vehicles - Know Before you Go	a) Education -Know Before You Go -Wheels out of Water b) Develop a land use plan for high use recreation areas
44. Vehicle operation in or near water bodies (includes erosion and deposition of a deleterious substance)	-Petroleum products, sediment, invasive seeds/propagules, heavy metals, litter via direct	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) - Wheels out of Water - Quick Fact Off-Highway Vehicles - Know Before you Go	a) Education -Know Before You Go -Wheels out of Water b) Develop a land use plan for high use recreation areas

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	deposition or surface runoff		
45. Unauthorized boat launches	- Sediment, hydrocarbon, invasive seeds/propagule via direct deposition	- Fisheries Act (R.S.C., 1985, c. F-14) - Water Act (RSA 2000, c. W-3) - Riparian Rights and Shoreline Modification	a) Education
46. Boat operation leading to incidental discharge and emissions	- Hydrocarbons, litter, invasive seeds/propagules via direct deposition	- Canada Shipping Act, 2001(s.c. 2001, c. 26) o Vessel Operation Restriction Regulations (SOR/2008-120)	a) Education
47. Sediment due to wake or boat disturbing channel	-sediment due to direct deposition	- Canada Shipping Act, 2001(s.c. 2001, c. 26) o Vessel Operation Restriction Regulations (SOR/2008-120)	a) Education
48. Recreational development (new & existing)	- Sediment, hydrocarbons, nutrients, yard care products via surface run-off, direct deposition or leaching into groundwater	- Municipal Government Act (M-26 RSA 2000) - Municipal Development Plans, Land Use bylaws - Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Watershed based land use planning approach b) Education -NPS Urban facts
49. Parks outhouses	-Fecal coliforms, bacteria, nutrients leaching into groundwater or surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs

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50. Sediment from rural properties	-sediment via surface runoff	- Fisheries Act (R.S.C., 1985, c. F-14) -	a) Education -https://www.pac.dfo-mpo.gc.ca/publications/pdfs/hometips_2000_e.pdf -NPS Urban Facts
51. Runoff in stormwater management systems	- Sediment, hydrocarbons, yard care products, heavy metals, chemicals, salt via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -NPS Urban Facts -Go with the Flow: Teaching and Taking Action for a Healthier Watershed
52. Spill of Hazardous materials (lawnmower, recreational vehicles, chainsaws, etc.	- petroleum, paint, yard care chemicals via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -NPS Urban Facts
53. Garbage burning (both barrel and otherwise)	- PAHs, heavy metals via aerial deposition or surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education
54. Improper Hazardous waste disposal	- Sediment, hydrocarbons, yard care products, heavy metals, chemicals, salt via aerial deposition, surface runoff or direct deposition	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education

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55. Water wells	- Yard-care chemicals, well-maintenance chemicals, salt, fecal matter, animal pathogens entering groundwater via wells	- Working Well Program	a) Promote Working Well Program
56. Septic systems/private systems	- Fecal coliforms, bacteria, household chemicals, nutrients via leaching into groundwater or surface runoff	- Septic Sense Program	a) Promote Septic Sense Program
57. Highway 40 Bridge Spill	- Salt, TDG material (materials transported on highway) via direct deposition or surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Confirm emergency planning is in place b) Promote BMPs
58. Road salt/de-icer application	- Salts, glycol via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs
59. Road salt storage (includes snow dump)	- Salts, glycol via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs

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60. Crossings/culverts/ditches (this more of a pathway)	- Sediment, metals, hydrocarbons, salt via surface runoff	- Water Act (RSA 2000, c. W-3) o Water (Ministerial) Regulation (AR 205/1998) o Code of Practice for Watercourse Crossings	a) Promote BMPs -Stepping back from the Water -Administrative Guide for Approvals b) Education c) Promote regional planning to reduce crossings d) Complete READI modelling to understand where most sediment is coming from
61. Trucking (primarily Transportation of Dangerous Goods)	- TDG materials, salt, propagules via direct deposition or surface runoff	- Transportation of Dangerous Goods Act, 1992 (1992, c. 34) o Transportation of Dangerous Goods Regulations (at Transport Dangerous Goods Directorate) (SOR/2001-286) - Dangerous Goods Transportation and Handling Act (RSA 2000 c. D-4) o Dangerous Goods Transportation and Handling Regulation (AR 157/1997)	a) Promote BMPs b) Ensure source water concerns are addressed in long-term transportation planning
62. Construction	-sediment via surface runoff or aerial deposition	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs -Stepping back from the Water -Administrative Guide for Approvals
63. Petroleum from vehicles day to day operation	-hydrocarbons via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education
64. Calcium application for dust control	-salts, glycol via surface runoff or direct deposition	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs
65. Railway spills	- TDG materials, motor oil, salt via direct deposit or surface runoff	- Railway Safety Act (R.S.C., 1985, c. 32(4th Supp.)) - Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Confirm Emergency Planning is in place

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66. Railway oil/grease/fuel leakage	- Hydrocarbons via direct deposit or surface runoff	- Railway Safety Act (R.S.C., 1985, c. 32(4th Supp.)) - Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs
67. Creosote Ties	-creosote via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote expedited removal and proper disposal of creosote ties
68. De-icing at GP airport	-glycol via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs b) Install a treatment wetland for tarmac runoff
69. Tarmac run-off	-metals, hydrocarbons, salt via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Promote BMPs b) Install a treatment wetland for tarmac runoff
70. Institutional/commercial/industrial	- Bacteria, nutrients, salts, hydrocarbons, TDG materials, heavy metals, suspended solids via surface runoff or direct deposition	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -NPS Urban Facts b) Promote BMPs c) Begin treating stormwater
71. Stormwater (pathway)	- Sediment, hydrocarbons, salts, herbicides, and heavy metals (all contaminants in surface runoff) via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -NPS Urban Facts -Actions to improve water quality -Actions to improve water quality (lake) -Go with the Flow: Teaching and Taking Action for a Healthier Watershed

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72. Yard care	- Herbicides, fertilizers via surface runoff or leaching into groundwater	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -Actions to improve water quality -Action to improve water quality (lake) -Hometips -NPS Urban facts
73. Lagoons (breach or failure)	- Coliforms, nutrients, hydrocarbons, heavy metals, ammonia via direct release	- Water Act (RSA 2000, c. W-3)	a) Promote BMPs including regular inspections
74. Stormwater (pathway)	- Sediment, hydrocarbons, salts, herbicides, and heavy metals (all contaminants in surface runoff) via surface runoff	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a) Education -NPS Urban facts -Actions to improve water quality -Actions to improve water quality (lake) -Go with the Flow: Teaching and Taking Action for a Healthier Watershed
75. Camp wastewater	-bacteria or nutrients via surface runoff or leaching into groundwater	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12) -	a)
76. Drought	-lack of water	- Building Resiliency to Multi-Year Drought (Alberta Water Council)	a) Promote drought planning
77. Flooding	- sediment, salts, hydrocarbons, heavy metals, bacteria via overland surface flows	- Peace River Basin Flood Mitigation Feasibility Study - (Associated Engineering, 2020)	a) Promote flood resilience b) Complete Flood Mapping c) Municipal by-laws to avoid development in the flood plains

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78. Bank slumping	-sediment via direct deposit	-	a) Municipal development setbacks b) Land use planning
79. Discharges (treated wastewater intentional releases)	-bacteria, nutrients, ammonia via direct release	- Environmental Protection and Enhancement Act (RSA 2000 c. E-12)	a) Ensure communication with downstream intakes b) Promote BMPs

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Appendix L – Requisites for Cumulative Watershed Assessment and Management

Table 8. Requisites for Cumulative Effects Management

Requisite	Definition
Lead agency	A clearly identified, overarching agency with the authority and mandate for CEAM, including the means to direct monitoring programs and influence decisions about land use and project development.
Multi-stakeholder	Roles and responsibilities of various stakeholders in watershed management and science are clearly defined, and stakeholders are involved in impact assessment and decision-making processes.
Watershed baselines, indicators, and thresholds	The state of the watershed needs to be known and agreed upon science-based indicators and thresholds for impact assessment and monitoring are required at both the project and watershed scale.
Multi-scaled monitoring	There are monitoring programs at both the individual project and watershed scales, focused on water quality and quantity across the watershed, site specific actions, and land use changes that affect watershed processes.
Data management and coordination	Monitoring data, both spatial and aspatial, that are needed for assessing and understanding watershed cumulative effects must be made available and in common data formats to all watershed stakeholders.
Vertical and horizontal linkages	There are formal management linkages across watershed management policies and plans as well as between watershed CEAM and project-based assessments, monitoring and decision-making.
Enabling legislation	There is a means to implement watershed CEAM initiatives, enforce monitoring programs and compliance and ensure influence over development decisions taken at the individual project level.
Financial and human resources	Sufficient financial and human resources are available to implement and sustain, over the long term, CEAM programs and requirements (e.g., monitoring programs, landscape modeling, reporting, communication and data management and coordination).

Source: Sheelanere et al., 2013