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Information in support of a recovery potential assessment of Rainbow Trout, *Oncorhynchus mykiss* (Athabasca River populations)

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Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

Research documents are produced in the official language in which they are provided to the Secretariat.

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ABSTRACT

In May 2014, a meeting of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) recommended that Rainbow Trout, *Oncorhynchus mykiss*, (Athabasca River populations) be designated Endangered. The reason given for this designation is: “Quantitative sampling over the last two decades demonstrates that the majority of sites are declining in abundance with an estimate of >90% decline over three generations (15 years). Threats are assessed as severe due to habitat degradation associated with resource extraction and agricultural practices. Additionally, ongoing climatic change and associated altered thermal regimes and hydrology, habitat fragmentation, introgression from non-native Rainbow Trout, and fishing threaten the species. Potential impact of invasive Brook Trout is a concern” (COSEWIC 2014, p. iii). This was the first assessment of Rainbow Trout (Athabasca River populations) and it has not yet been listed under the Species at Risk Act (SARA).

The Recovery Potential Assessment (RPA) provides information and scientific advice needed to fulfill various requirements of the SARA, including informing both scientific and socioeconomic elements of the listing decision and permitting activities that would otherwise violate SARA prohibitions, and the development of recovery strategies. This Research Document describes the current state of knowledge of the biology, ecology, distribution, population trends, habitat requirements and threats to Rainbow Trout (Athabasca River populations). Mitigation measures and alternative activities related to identified threats, which can be used to protect the species, are also presented. The information contained in the RPA and this document may be used to inform the development of recovery documents and for assessing permits, agreements and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of the SARA. It may also be used to prepare for the reporting requirements of SARA s.55. The scientific information also serves as advice to the Minister of Fisheries and Oceans Canada regarding the listing of the species under the SARA and is used when analyzing the socio-economic impacts of adding the species to the list as well as during subsequent consultations, where applicable. This assessment considers the available scientific data pertaining to the recovery of Rainbow Trout (Athabasca River populations) in Alberta. The advice generated via this process will update and/or consolidate any existing advice regarding Rainbow Trout (Athabasca River populations).

Renseignements appuyant l'évaluation du potentiel de rétablissement de la truite arc-en-ciel (Oncorhynchus mykiss), populations de la rivière Athabasca

RÉSUMÉ

Après sa réunion en mai 2014, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a recommandé que la truite arc-en-ciel (Oncorhynchus mykiss) de la rivière Athabasca soit désignée comme espèce menacée. La raison de cette désignation est qu'« un échantillonnage quantitatif au cours des vingt dernières années démontre que la majorité des sites connaissent une baisse d'abondance estimée à plus de 90 % sur 3 générations (15 ans). Les menaces sont évaluées comme étant graves à cause de la dégradation de l'habitat associée à l'extraction de ressources et aux pratiques agricoles. De plus, les changements climatiques en cours et les modifications des régimes thermiques et hydrologiques qui leur sont associés, la fragmentation de l'habitat, l'introgression par la truite arc‑en‑ciel non indigène, et les pêches menacent l'espèce. L'impact potentiel de l'omble de fontaine envahissant est une préoccupation. » (COSEPAC, 2014, p.iii). Il s'agit de la première évaluation de la truite arc-en-ciel de la rivière Athabasca, et l'espèce n'a pas encore été inscrite en vertu de la Loi sur les espèces en péril (LEP).

L'évaluation du potentiel de rétablissement (EPR) fournit les renseignements et les avis scientifiques nécessaires pour répondre aux diverses exigences de la LEP. Cette évaluation permet notamment d'éclairer les aspects scientifiques et socioéconomiques de la décision relative à l'inscription, de réaliser des activités qui autrement enfreindraient les interdictions de la LEP et d'élaborer des programmes de rétablissement. Le document de recherche décrit les connaissances actuelles au chapitre de la biologie, de l'écologie, de la répartition, de l'état des populations, des besoins en habitats et des menaces de la truite arc-en-ciel de la rivière Athabasca. On y présente également les mesures d'atténuation et les autres activités associées aux menaces déterminées que l'on peut utiliser afin de protéger l'espèce. Les renseignements contenus dans l'EPR et le document peuvent servir de base à l'élaboration de documents relatifs au rétablissement et à l'évaluation des permis, des ententes et des conditions connexes, conformément aux articles 73, 74, 75, 77, 78 et au paragraphe 83(4) de la LEP. Ces renseignements peuvent également servir à la préparation des rapports conformément à l'exigence énoncée à l'article 55 de la LEP. On s'en sert aussi pour conseiller le ministre de Pêches et Océans Canada au sujet de l'inscription de l'espèce en vertu de la LEP, analyser les répercussions socioéconomiques de l'inscription de l'espèce sur la liste ainsi que pour les consultations subséquentes, le cas échéant. Cette évaluation examine les données scientifiques relatives au rétablissement de la truite arc-en-ciel de la rivière Athabasca en Alberta. L'avis élaboré par l'intermédiaire de ce processus permettra de mettre à jour et de consolider les avis déjà formulés au sujet de la truite arc-en-ciel de la rivière Athabasca.

SPECIES INFORMATION

Scientific Name – *Oncorhynchus mykiss*

Common Name – Rainbow Trout (Athabasca River populations)

Current COSEWIC Status (Year of Designation) – Endangered (2014)

COSEWIC Reason for Designation – This fish is an obligate resident of clear, cold flowing water in the upper Athabasca River drainage of Alberta. Quantitative sampling over the last two decades demonstrates that the majority of sites are declining in abundance with an estimate of >90% decline over three generations (15 years). Threats are assessed as severe due to habitat degradation associated with resource extraction and agricultural practices. Additionally, ongoing climatic change and associated altered thermal regimes and hydrology, habitat fragmentation, introgression from non-native Rainbow Trout, and fishing threaten the species. Potential impact of invasive Brook Trout is a concern (COSEWIC 2014, p. iii).

Canada *Species at Risk Act* – New Species, No Schedule, No Status

Alberta *The Wildlife Act* – Threatened

BACKGROUND

Rainbow Trout (*Oncorhynchus mykiss*) (Athabasca River populations), hereafter Athabasca Rainbow Trout, belongs to the Salmonidae family and is native to rivers of the upper Athabasca watershed in west-central Alberta. This species exhibits stream resident and river-migrant (fluvial) life history strategies. Athabasca Rainbow Trout is not a distinct subspecies of Rainbow Trout (McCusker et al. 2000, Taylor et al. 2007), but does represent a unique 'ecotype'. They are uniquely adapted to cold, unproductive headwater streams which generally lack competitors and predators (COSEWIC 2014). This has resulted in differences in the morphology, biology and habitat use compared to other populations (e.g., west slope) of Rainbow Trout (COSEWIC 2014). Due to a large decline in abundance (est. >90% over three generations [15 years]) and multiple severe threats, COSEWIC (2014) ranked Athabasca Rainbow Trout as Endangered. As such, these populations are now being considered for listing under the *Species at Risk Act* (SARA). This document provides biological information to be used in evaluating the potential for recovery of Athabasca Rainbow Trout in Alberta.

BIOLOGY, ABUNDANCE, AND DISTRIBUTION

SPECIES DESCRIPTION

Physical characteristics of Rainbow Trout are described in Scott and Crossman (1973) and Nelson and Paetz (1992). Athabasca Rainbow Trout, however, exhibit several phenotypic differences from Rainbow Trout in other areas. The maximum size of Athabasca Rainbow Trout is typically less than 50 cm (or 1.25 kg) (George Sterling, pers. comm. in COSEWIC 2014). The largest recorded Athabasca Rainbow Trout is a 58.8 cm, 2.86 kg, age 5+ male that was stocked as a 30 mm young-of-the-year (YOY) (Wampus Creek origin) into an isolated, reclaimed end pit lake (G. Sterling, pers. comm. in COSEWIC 2014). As with other Rainbow Trout, Athabasca Rainbow Trout have a silvery-blue to green dorsal surface covered in black spots that extend towards the fins and sides of the body (Figure 1). The sides of the body are yellow-green to silvery in colour. The dorsal, caudal and adipose fins have radiating rows of black spots, while the remaining fins have few spots. The front tips of the pelvic, dorsal and anal fins are whitish in colour (Alberta Athabasca Rainbow Trout Recovery Team 2014). The midpoint on the dorsal surface has a horizontal pink band that increases in colour intensity as the fish matures. Juveniles have 8–12 oval-shaped parr marks along their lateral surface. Stream-resident Athabasca Rainbow Trout often retain these parr marks throughout life, likely as an adaptation to predation (cryptic colouration) (G. Sterling, pers. comm. in COSEWIC 2014) as they primarily reside in small headwater streams with gravel, boulder and cobble substrates. This may result in mis-identification as immature non-native Rainbow Trout (Alberta Athabasca Rainbow Trout Recovery Team 2014). Larger individuals (>30 cm), or river-migrants may have lighter parr marks (Alberta Athabasca Rainbow Trout Recovery Team 2014). Rainbow Trout in other areas do not retain parr marks as adults. Spawning fish often have a bright reddish lateral band that is most apparent in males (Alberta Athabasca Rainbow Trout Recovery Team 2014).

Athabasca Rainbow Trout are physically similar to interior 'Columbia Redband Trout' (O. m. gairdneri) (Behnke 1992) and Westslope Cutthroat Trout (O. clarkii lewisi) and are often mistaken for the latter (COSEWIC 2014). Distinguishing features include the lack of red slashes under the throat and basibranchial teeth of Rainbow Trout and the comparatively smaller scales of Westslope Cutthroat Trout. Westslope Cutthroat Trout are native to the Bow and Saskatchewan rivers and have been introduced into the range of Athabasca Rainbow Trout (COSEWIC 2014).

Figure 1. Athabasca Rainbow Trout (192 mm). Photographed by Ward Hughson, Parks Canada (used with permission).

DISTRIBUTION

Rainbow Trout are native to northwestern Siberia and North America (McPhail 2007). In North America, the range of freshwater resident Rainbow Trout extends from the Kuskokwim River, Alaska to Baja, California, including coastal and inland regions of British Columbia, Washington, Idaho and Oregon and east of the Continental Divide in the Arctic drainages of the Liard, Peace and Athabasca rivers (Behnke 1992, Nelson and Paetz 1992, McPhail 2007, Alberta Athabasca Rainbow Trout Recovery Team 2014, COSEWIC 2014). Anadromous 'steelhead' populations are restricted to the west coast of North America and have become established in the Laurentian Great Lakes (COSEWIC 2014). Due to their popularity as a sport and food fish, hatchery-reared Rainbow Trout have been widely stocked into lakes and rivers and now occur on all continents with the exception of Antarctica (COSEWIC 2014).

Athabasca Rainbow Trout are distributed throughout the headwaters of the Athabasca River system, including the Athabasca River (downstream of Sunwapta Falls) and it's major tributaries – the McLeod, Wildhay/Berland, Sakwatamau and Freeman rivers (Figure 2) (Alberta Sustainable Resource Development and Alberta Conservation Association 2009). They are found in the lower reaches of the Snaring, Maligne, Rocky and Snake Indian rivers below major waterfalls and in most of the Miette River watershed (Miller and Macdonald 1949, Nelson and Paetz 1992, Alberta Sustainable Resource Development and Alberta Conservation Association 2009, COSEWIC 2014). Non-native, domesticated strains of Rainbow Trout from hatcheries in the Pacific Northwest have been widely stocked in Alberta, including in the Athabasca River watershed with the first instance dating to 1919 in Jasper National Park (Ward 1974). The headwaters of all major drainages of the Nelson/Churchill and Mackenzie River basins, including the upper Athabasca River watershed, now contain naturalized populations of non-native Rainbow Trout (Nelson and Paetz 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014).

This species commonly occurs in second- to fourth-order tributaries of the Upper and Lower Foothills Natural Subregions between >900 and <1500 m above sea level (Alberta Athabasca Rainbow Trout Recovery Team 2014). The Athabasca River main stem is the only area where they occur that is below 800 m above sea level, likely due to the temperature-moderating effects of summer glacial meltwater in Jasper National Park (Alberta Athabasca Rainbow Trout Recovery Team 2014). The presumed historical distribution of Athabasca Rainbow Trout covered approximately 29,500 km^2 (Alberta Athabasca Rainbow Trout Recovery Team 2014). Current habitat occupancy has been estimated at 11,711 linear km of stream or 102.25 km^2 (including Jasper National Park) by Alberta Athabasca Rainbow Trout Recovery Team (2014) (Table 1) and at 6,890 linear km of stream (including an estimate for only a portion of Jasper National Park) by COSEWIC (2014) (Table 2). The reported value in COSEWIC (2014) is 16,890 linear km, however this is based on an incorrect entry for tertiary watershed 07AC (11,650.2 km occupied of 8,938.1 total stream length km). Based on the percent occupied value in Table 4 of COSEWIC (2014) of 18.5, the value for tertiary watershed 07AC should have been entered as 1,650.2 km occupied stream length. This has been corrected in Table 2 below.

Table 1. Estimated habitat occupancy for Athabasca Rainbow Trout within the native range, including Jasper National Park. Reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014).

Strahler Stream Order	**Total Stream Length[1] (km)**	**Occupied Habitat[2] (km)**	**Wetted Channel Width[3] (m)**			**Occupied Habitat (ha)**
			Mean	**n**	**SE**	
1	20,739	100	1.5	594	0.1	15
2	7,923	3,800	2.4	765	6.8	899
3	4,768	3,500	3.6	855	11.2	1,272
4	2,596	1,854	6.2	535	12.8	1,143
5	1,659	1,400	13.3	138	17.6	1,868
6	446	396	19.1	123	11.6	756
7	693	512	46.7	126	27.1	2,390
8	240	149	126.5	11	9.7	1,885
Total	**-**	**11,711**	**-**	**3,147**	**-**	**10,228**

[1] Derived from AESRD spatial data 2013

[2] Excludes water above known barrier falls; based on proportion of stream order sampled where Athabasca Rainbow Trout were present (AFWMIS 2013)

[3] Derived from AESRD spatial data (AFWMIS 2014)

Table 2. Length (km) of habitat occupied by Athabasca Rainbow Trout in tertiary watersheds of the Athabasca River drainage, excluding 07AB. Modified from COSEWIC (2014).

Tertiary Watershed	Major Basin	Total Stream Length (km)	Occupied Stream Length (km)	Percent Occupied (%)
07AA	Solomon Creek[1]	3,293.8	379.2	11.5
07AC	Berland / Wildhay	8,938.1	1,650.2	18.5
07AD	Upper Athabasca	2,637.9	659.5	25.0
07AE	Mid Athabasca	3,920.2	706.6	18.0
07AF	Upper McLeod	6,436.9	1,958.5	30.4
07AG	Lower McLeod	4,488.7	778.2	17.3
07AH	Lower Athabasca	4,229.5	757.9	17.9

TAXONOMY AND GENETIC DESCRIPTION

Rainbow Trout was first described as *Salmo gairdnerii* in 1836 from the Columbia River at Fort Vancouver by Sir John Richardson (Nelson and Paetz 1992). In 1910 and 1911, employees of the Grand Trunk Pacific Railway reported catching trout (identified as *Salmo irideus*, an early name for Rainbow Trout; Bean 1894) that were present in large numbers near Jasper and Hinton, Alberta (Nelson and Paetz 1992). This confirms the presence of Athabasca Rainbow Trout in the streams and main stem Athabasca River in and around Jasper National Park as stocking of Rainbow Trout in these waters did not begin until 1921, after the completion of the Grand Trunk Pacific Railway in 1917 (Alberta Athabasca Rainbow Trout Recovery Team 2014). Smith and Stearley (1989) advocated placing Rainbow Trout and Cutthroat Trout in the genus *Oncorhynchus* (Pacific Salmon) based on studies of osteology and biochemistry that showed these species to be more closely related to *Oncorhynchus* than *Salmo* (Atlantic Salmon [*Salmo salar*] and Brown Trout [*S. trutta*]). This was accepted by the American Fisheries Society – American Society of Ichthyologists and Herpetologists Committee on Names of Fishes (Robins et al. 1991).

Athabasca Rainbow Trout are geographically separated from other native Rainbow Trout in North America by the Continental Divide. East of the Continental Divide, native Rainbow Trout occur in three drainages (Athabasca, Peace and Liard). These drainages are geographically separated, thus there is no movement of fish between them (COSEWIC 2014). Athabasca Rainbow Trout were considered by Behnke (1992) to be included as redband trout of Columbia and Fraser basin origin, having populated the Athabasca River via post-glacial dispersal from the upper Fraser River. Based on genetic and meristic comparisons of Wampus Creek Athabasca Rainbow Trout to other Rainbow Trout populations, Carl et al. (1994) proposed that Athabasca Rainbow Trout were isolated in a southwestern Alberta refuge for >65,000 years and thus, are pre-glacial in origin. It was later found that several alleles that distinguished Athabasca Rainbow Trout from other Rainbow Trout in the study by Carl et al. (1994) also occurred in coastal Cutthroat Trout (*O. clarkii*) from Puget Sound (an inlet of the Pacific Ocean along the

[1] Solomon Creek data exclude areas above major waterfalls and occupied length was estimated based on total percent occupied habitat and stream order

northwestern coast of Washington, USA), and this may explain the differences observed by Carl et al. (1994) (McCusker et al. 2000). Taylor et al. (2007) assayed Rainbow Trout from the Athabasca drainage and British Columbia and found that Athabasca Rainbow Trout were very similar to Rainbow Trout in the Fraser River, BC. They concluded that Athabasca Rainbow Trout are not pre-glacial relicts, but rather are post-glacial in origin as originally suggested by Behnke (1992). Analysis showed larger variation between groups in the Athabasca drainage (i.e., Athabasca River vs. McLeod River vs. Wildhay/Berland rivers) than between populations within these groups (above summarized by Alberta Athabasca Rainbow Trout Recovery Team 2014).

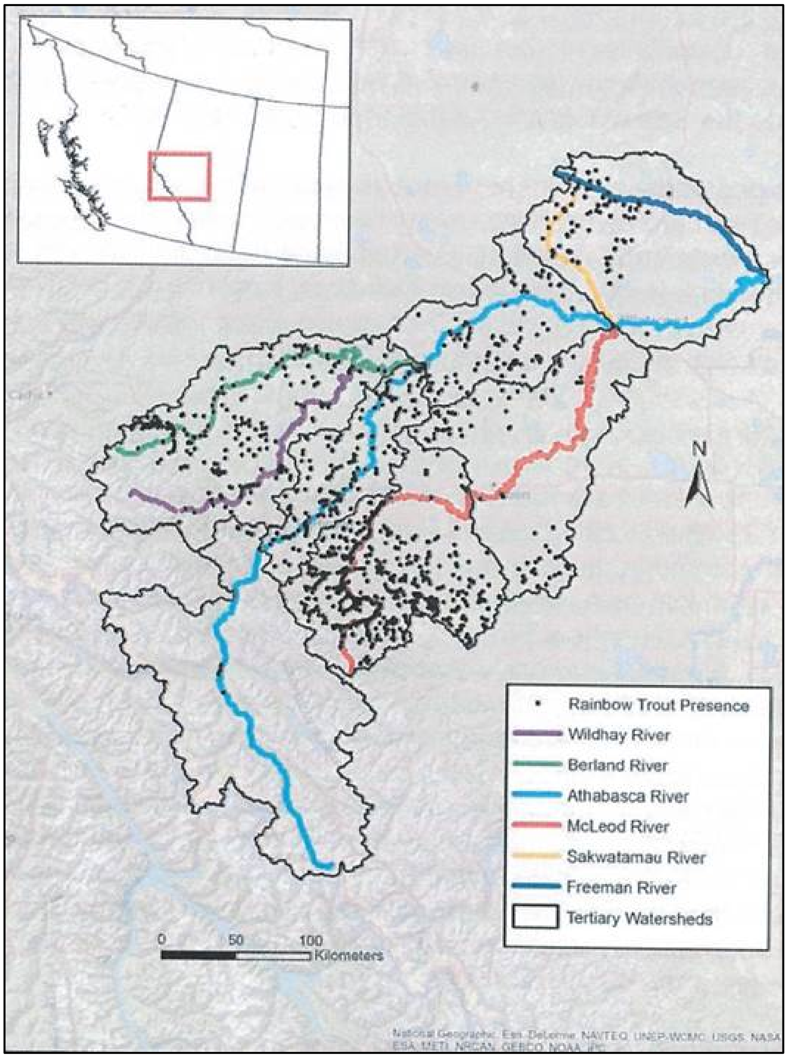


Figure 2. Distribution of Athabasca Rainbow Trout and major rivers in the Athabasca River watershed. Reproduced from COSEWIC (2014).

Amid concerns about the hybridization of ‘pure’ Rainbow Trout (Athabasca Rainbow Trout) with stocked, non-native Rainbow Trout, Taylor and Yau (2013) calculated admixture coefficients (Q_i = proportion of an individual fish’s genome inferred to be of indigenous origin) of populations in the upper Athabasca watershed (Appendix 1). Populations where introgression was ≤1% (Q_i ≥0.99) were considered genetically pure (Allendorf et al. 2004, Taylor and Yau 2013). Populations where introgression was 1–5% were considered to have limited hybridization and those where introgression was >5% (Q_i <0.95) were considered compromised (Alberta

Athabasca Rainbow Trout Recovery Team 2014). Thirty-three streams with a history of stocking were assayed (Figure 3). Of these, nine showed no introgression, 12 had limited introgression, and 12 showed significant introgression. Forty unstocked streams were assayed and of these 29 showed no indications of introgression, eight had limited introgression and three showed significant introgression. In Jasper National Park, one of the six populations assayed was considered 'pure' Athabasca Rainbow Trout (Buffalo Prairie) and two were naturalized Rainbow Trout populations above barrier falls in water that was previously fishless. Rainbow Trout in the Athabasca River main stem downstream to the Berland River confluence had a mean Q_i <0.80, indicating a greatly compromised native genome (Alberta Athabasca Rainbow Trout Recovery Team 2014). Due to the high degree of introgression, the populations in Jasper National Park were excluded from the COSEWIC assessment. More recently, another pure population was found in Minaga Creek in Jasper National Park (M. Sullivan, AEP, pers. comm.). It is possible that additional pure populations will be found within the park in the future, thus all populations in Jasper National Park were included in this assessment. New types of hybridization (e.g., with other *Oncorhynchus* species such as Cutthroat Trout, Golden Trout [*O. aguabonita*] and/or Steelhead Trout [anadromous *O. mykiss*]) may also be found as new samples are analysed.

LIFE HISTORY DIVERSITY

Athabasca Rainbow Trout exhibit both stream-resident and river-migrant (fluvial) life history strategies. Both life history types may occur in the same population (e.g., upper McLeod watershed). No naturally occurring lake-dwelling (adfluvial) populations are known to exist within the native range (Alberta Athabasca Rainbow Trout Recovery Team 2014). Stream-residents are smaller than river-migrants, rarely growing larger than 250–300 mm fork length (FL) (Sterling 1990). River-migrants are often greater than 400 mm FL and 0.5–1.3 kg in weight (AFWMIS 2012 in Alberta Athabasca Rainbow Trout Recovery Team 2014). Most populations of Athabasca Rainbow Trout are likely ≥ 90% stream-resident (M. Sullivan, AEP, pers. comm.) Spawning and early rearing generally occur in similar habitat for both stream-residents and river-migrants (Sterling 1980), typically in streams with a Strahler Order (Strahler 1952) of two to four (Alberta Athabasca Rainbow Trout Recovery Team 2014).

PHYSIOLOGY

Rainbow Trout are a cold-water species and those native to the Athabasca River watershed are uniquely adapted to the cold headwater streams and upper reaches of main stem rivers they inhabit. Water temperatures ranging from 7–18 °C are preferred (Raleigh et al. 1984). Optimum embryo incubation temperature ranges from 7–10 °C (Kwain 1975) with increased mortality occurring at temperatures <3 °C or >18.5 °C (Alberta Athabasca Rainbow Trout Recovery Team 2014). Optimum growth temperatures for fry range from 10–15 °C (Raleigh et al. 1984, Bjornn and Reiser 1991). The upper lethal temperature for adults is approximately 27 °C (Lee and Rinne 1980), but temperatures from 22–24 °C are considered life threatening (Alberta Athabasca Rainbow Trout Recovery Team 2014).

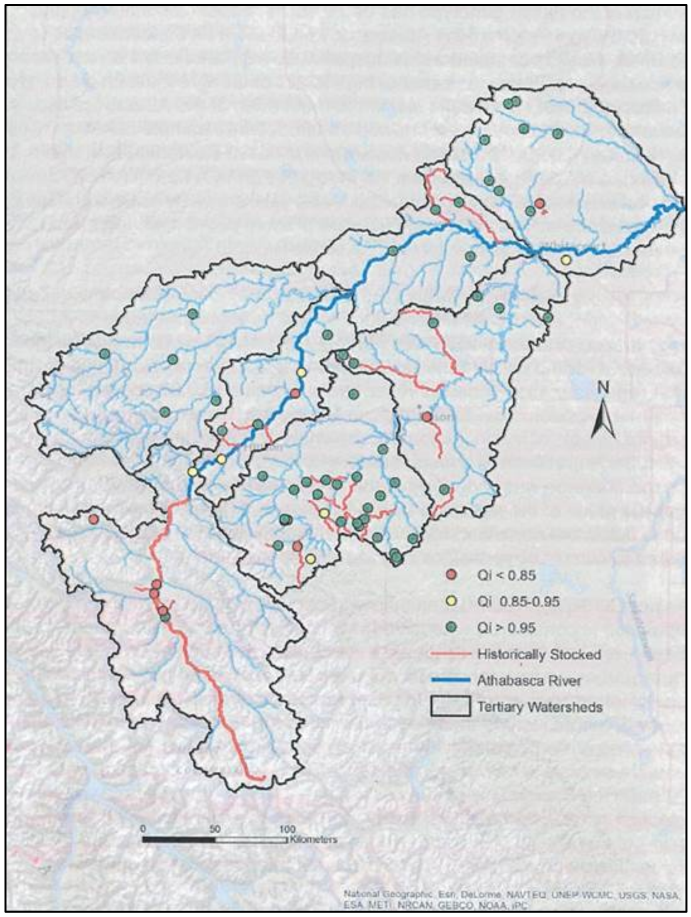


Figure 3. Rainbow Trout sampling locations for which admixture coeffiecients (Q_i) were calculated. Genetically 'pure' indigenous samples are defined as having a Q_i value greater than 0.95. Decreases in Q_i values indicate an increase in non-native alleles. Data was sourced from Taylor and Yau (2013). Map reproduced from COSEWIC (2014).

FEEDING AND DIET

Athabasca Rainbow Trout are opportunistic feeders and strong generalists, primarily consuming aquatic and terrestrial insects throughout the summer (Alberta Athabasca Rainbow Trout Recovery Team 2014). Diet composition was studied in the Tri-Creeks drainage (the area encompassing Wampus Creek, Deerlick Creek and Eunice Creek in the McLeod River watershed) of Alberta. Stomach analysis showed that heaviest feeding occurred during dawn and dusk when aquatic invertebrate drift was greatest (Tri-Creeks unpublished data cited in Alberta Athabasca Rainbow Trout Recovery Team 2014). The diet of Athabasca Rainbow Trout in stream reaches dominated by boulder/cobble substrates mainly consisted of aquatic insects, whereas in reaches with finer gravel substrates, terrestrial insects tended to form the majority of the diet (Tri-Creeks unpublished data cited in Alberta Athabasca Rainbow Trout Recovery Team 2014, G. Sterling pers. comm. cited in COSEWIC 2014). Early instars of a small mayfly (*Baetis* spp.) were present in late summer and early fall and were an important food source for Rainbow Trout fry (Tri-Creeks unpublished data cited in Alberta Athabasca Rainbow Trout Recovery Team 2014). Land use activities that threaten this food source could impact Athabasca Rainbow Trout. In winter, stomach contents of resident fish generally contained a small number of prey items or were empty, even though the fish were active under the ice surface (Alberta Athabasca Rainbow Trout Recovery Team 2014).

REPRODUCTION

A small percentage of females mature by age 3 and approximately 50% are mature at age 5. Males reach maturity as early as age 1 and most are mature by age 4 (COSEWIC 2014). Fecundity is related to body size. Stream resident females produce approximately 300 eggs (COSEWIC 2014), whereas the larger river migrant females produce approximately 500 eggs and up to 730 eggs have been reported (McLeod River) (Alberta Athabasca Rainbow Trout Recovery Team 2014). Athabasca Rainbow Trout typically live to age 8 (Alberta Athabasca Rainbow Trout Recovery Team 2014) and the oldest recorded in the Tri-Creeks watershed was age 10 (COSEWIC 2014).

Athabasca Rainbow Trout spawn annually and they spawn later than most other Rainbow Trout in southern Alberta. In upper Deerlick Creek, AB for example, spawning began in late June and fry emerged as late as September, whereas in lower elevation areas spawning usually occurs between late April and May (Sterling 1990, 1992, COSEWIC 2014). Sterling (1992) observed Athabasca Rainbow Trout spawning from late May to early June after the peak of the snowmelt hydrograph and the accumulation of approximately 115 degree days (from ice off) and once a maximum daily water temperature of 6 °C had been reached.

Sterling (1980) noted that stream-resident females showed little movement to spawning areas, while stream-resident males moved intensely for short distances (<1 km). River-migrants from the McLeod River have been captured moving upstream in tributaries prior to spawning (Dietz 1971, Sterling 1980) but none were observed further than approximately 2 km upstream (Sterling 1980). Adults were captured returning to the McLeod River shortly after spawning (Sterling 1980) and a large group of YOY were captured moving downstream in the McLeod River in late September (unpublished data cited in Alberta Athabasca Rainbow Trout Recovery Team 2014).

Spawning behaviour is summarized in COSEWIC (2014) and Alberta Athabasca Rainbow Trout Recovery Team (2014). Females select spawning sites in areas with subgravel flow. Prior to spawning, the female excavates a nest by turning on her side and forcefully moving her caudal fin, causing gravel to be moved downstream by the current. A few larger stones are usually retained and used to form a pocket to hold the eggs. During nest construction, the female is accompanied by a dominant male and one to several satellite (or sneaker) males. Once nest excavation is complete they descend into it and eggs and sperm are released simultaneously. The female then moves immediately upstream and begins excavating another nest. In doing so, she covers the fertilized eggs in the previous nest. The female may excavate three to four nests sequentially, forming a redd. The female guards the redd usually for less than two days (Dietz 1971) and then abandons the site. Dominant males remain active and may spawn with several females. The eggs, and later alevins, remain in the nest until emergence, which usually occurs in mid-summer (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014).

SPECIAL SIGNIFICANCE

Athabasca Rainbow Trout are one of the only native Rainbow Trout populations found east of the Continental Divide. They are adapted to cold, unproductive headwater streams. Due to these adaptations they exhibit several differences in morphology, biology and habitat use when compared with other Pacific drainage Rainbow Trout populations and are thought to be a unique ‘ecotype’ (COSEWIC 2014). Moreover, Athabasca Rainbow Trout are an important cultural resource.

INTERSPECIFIC INTERACTIONS

Twenty-three species of fish have been documented within the range of Athabasca Rainbow Trout (Table 3; Alberta Athabasca Rainbow Trout Recovery Team 2014). In fourth- and fifth-order tributaries they may be found with Burbot (*Lota lota*), naturalized Brook Trout (*Salvelinus fontinalis*), Bull Trout (*S. confluentus*), Longnose Dace (*Rhinichthys cataractae*), Spoonhead Sculpin (*Cottus ricei*), Mountain Whitefish (*Prosopium williamsoni*), Arctic Grayling (*Thymallus arcticus*), Longnose Sucker (*Catostomus catostomus*) and White Sucker (*C. commersonii*) (Alberta Athabasca Rainbow Trout Recovery Team 2014). In smaller second- and third-order streams where channels are 0.75–2.0 m wide, Athabasca Rainbow Trout are commonly the only species present (Alberta Athabasca Rainbow Trout Recovery Team 2014). The Athabasca River main stem has the most diverse fish community within the range, and Athabasca Rainbow Trout make up only a small portion of this diversity (<5% observed relative abundance) (AFWMIS 2012 cited in Alberta Athabasca Rainbow Trout Recovery Team 2014).

Bull Trout are present in low numbers in many watersheds within the range of Athabasca Rainbow Trout and are significant predators of all life stages. Burbot, Brook Trout and sub-adult and juvenile Bull Trout prey upon YOY and sub-adult Athabasca Rainbow Trout. Where they occur together, Brook Trout appear to be at the same trophic level as Athabasca Rainbow Trout (Popowich 2005) and the species compete for space and food (Alberta Athabasca Rainbow Trout Recovery Team 2014). In the Athabasca watershed, Brook Trout have been documented to grow rapidly as fry and sub-adults and spawn at younger ages than Athabasca Rainbow Trout (AESRD unpublished data cited in Alberta Athabasca Rainbow Trout Recovery Team 2014). Brook Trout spawn in fall and embryos are therefore not subject to the extreme spring and summer variation in flow, temperature and sediment which can negatively impact recruitment in spring spawners, such as Athabasca Rainbow Trout (Fausch 2008, Alberta Athabasca Rainbow Trout Recovery Team 2014).

Table 3. Fish species present within the range of Athabasca Rainbow Trout (modified from Alberta Athabasca Rainbow Trout Recovery Team 2014). Common and scientific names follow Page et al. (2013).

Common Name	Scientific Name
Northern Pike	*Esox lucius*
Walleye	*Sander vitreus*
Burbot	*Lota lota*
White Sucker	*Catostomus commersonii*
Longnose Sucker	*Catostomus catostomus*
Trout-perch	*Percopsis omiscomaycus*
Lake Chub	*Couesius plumbeus*
Finescale Dace	*Chrosomus neogaeus*
Northern Pearl Dace	*Margariscus nachtriebi*
Longnose Dace	*Rhinichthys cataractae*
Fathead Minnow	*Pimephales promelas*
Flathead Chub	*Platygobio gracilis*
Spoonhead Sculpin	*Cottus ricei*
Mountain Whitefish	*Prosopium williamsoni*
Lake Whitefish	*Coregonus clupeaformis*
Pygmy Whitefish	*Prosopium coulterii*
Non-native Brook Trout	*Salvelinus fontinalis*
Non-native Brown Trout	*Salmo trutta*
Bull Trout	*Salvelinus confluentus*
Lake Trout	*Salvelinus namaycush*
Non-native Cutthroat Trout	*Oncorhynchus clarkii*
Non-native Rainbow Trout	*Oncorhynchus mykiss*
Arctic Grayling	*Thymallus arcticus*

ABUNDANCE AND TRENDS

Sampling effort and methods are summarized in Alberta Athabasca Rainbow Trout Recovery Team (2014) and COSEWIC (2014). It should be noted that a change in standardized stream survey protocols in the mid-1990s makes it difficult to compare historical population densities with contemporary data. Date, location, length of reach electrofished (m), pass number and number of fish captured (by species) were often recorded, but wetted width, electrofishing effort by pass number, number of passes and site conditions (conductivity, temperature, flow) were generally not recorded prior to the mid-1990s. Moreover, population estimates were calculated based on 2-pass Petersen mark/recapture sampling prior to the mid-1990s, while those since then are based on multiple pass (3 or 4) depletion sampling (Alberta Athabasca Rainbow Trout Recovery Team 2014). Athabasca Rainbow Trout population estimates from both methods from locations with identical spatial and temporal components are not comparable (Sterling et al. 2012).

In order to assess the status of Athabasca Rainbow Trout, Alberta Environment and Parks (AEP) applied the Alberta Fish Sustainability Index (FSI). The three major components of this assessment process are: i) organizing stocks into spatial units; ii) assessing the stock(s) within the spatial unit; and iii) combining those assessments into a province-level strategic information system (Coombs and MacPherson 2013). The spatial units used were 8-digit Hydrological Unit Codes (HUC8). HUCs are “successively smaller hydrologic units that nest within larger hydrologic units, creating a hierarchical watershed boundary dataset” (AESRD 2014, p. 1). This system is used by the United States Geological Survey (USGS) (Seaber et al. 1987, 1994, USGS and USDA 2012), and the same guidelines were followed for delineating HUCs with a few modifications (AESRD 2014). A total of 19 HUC8s were delineated within the range of Athabasca Rainbow Trout (Figure 4).

Current adult density estimates (mean catch-per-unit-area [CPUA], # adults/0.1 ha) are summarized by HUC8 in Table 4. Comments on historical adult density and FSI ranks are also included. Current adult density ranges from a high of 7 adults/0.1 ha in the Miette River and tributaries (Jasper National Park, HUC8: 17010104) to 1.7 adults/0.1 ha in the section of the Athabasca River from Whitecourt to Ft. Assiniboine (HUC8: 17010602). Twelve HUC8s received a current adult density FSI rank of 1 (lowest possible abundance without extirpation, adults barely detectable) and three received an FSI rank of 2 (poor abundance, recruitment overfishing). One HUC8 received an historical adult density FSI rank of 1, three received an FSI rank of 2, six received a rank of 3 (moderate abundance, growth overfishing below maximum sustainable yield [MSY]), four received a rank of 4 (very abundant, population at or above MSY with mild growth overfishing) and one received a rank of 5 (highest possible, population at carrying capacity) (Coombs and MacPherson 2013, AEP 2014).

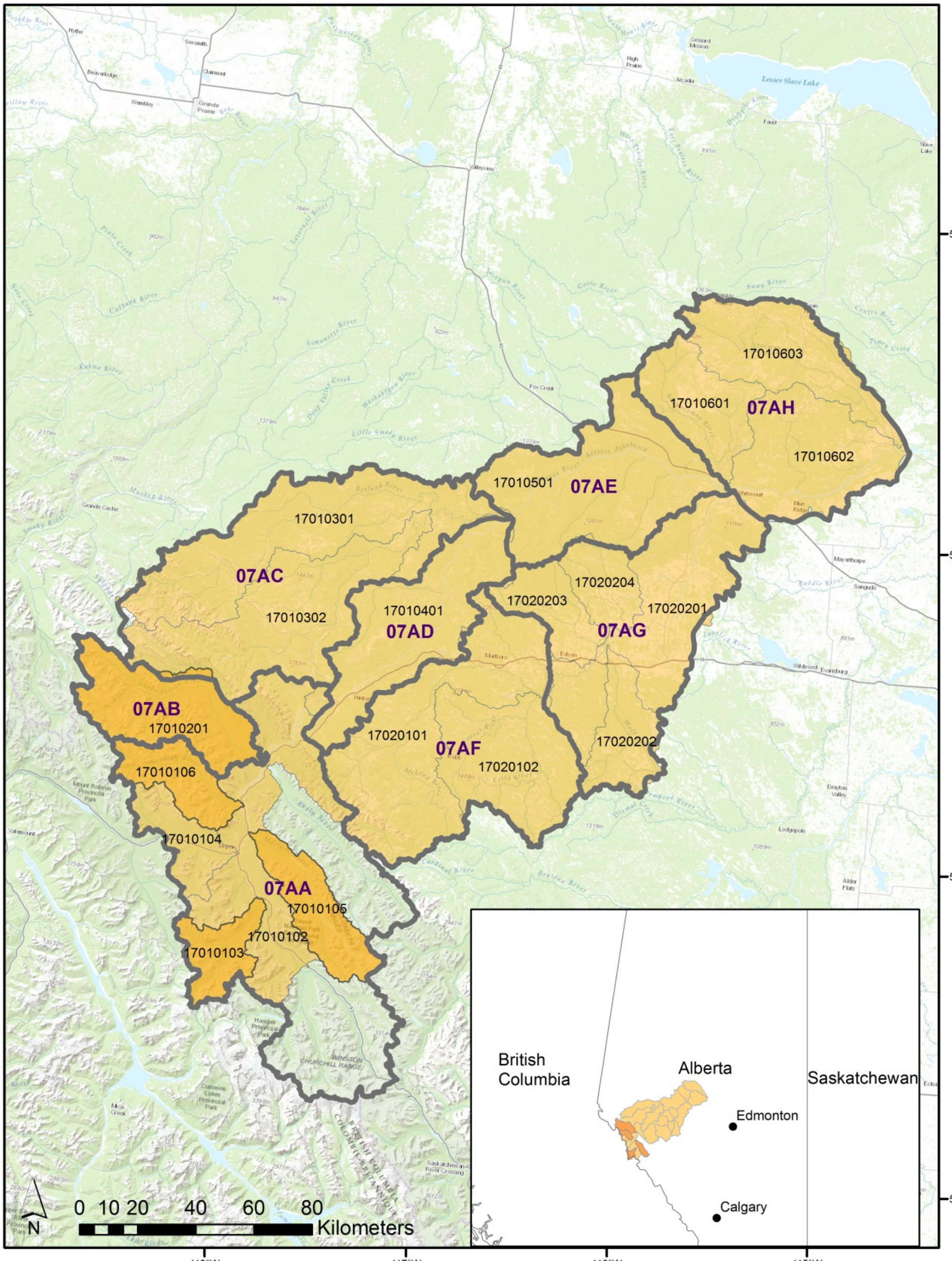


Figure 4. Athabasca Rainbow Trout HUC8s. Darker orange represents populations of suspected non-native origin. HUC8 data were obtained from Alberta Environment and Parks and are based on AESRD (2014). Tertiary watersheds are outlined in bold; 07AA – Solomon Creek, 07AB – Snake Indian, 07AC – Berland / Wildhay, 07AD – Upper Athabasca, 07AE – Mid Athabasca, 07AF – Upper McLeod, 07AG – Lower McLeod, and 07AH – Lower Athabasca (Natural Resources Canada 2003).

Table 4. Current adult Rainbow Trout density, information on historical adult density and associated Fish Sustainability Index (FSI) ranks for each HUC8 within the range of Athabasca Rainbow Trout (source: AEP 2014).

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Athabasca River: Upper Athabasca and Brule Lake (Jasper National Park)	17010102	6.0 (range: 0–27.9, 12 sites) Years: 2003, 2004, 2013	CPUA calculations were for 110 to 447 m electrofishing section	2	The main stem would historically have been unproductive and not core habitat. The creeks in this HUC8 would have generally been moderately productive (M. Sullivan in AEP 2014).	3
Whirlpool River (Jasper National Park) (suspected non-native)	17010103	0.0 (2 sites) Year: 2003	CPUA calculations were based on short electrofishing sections	1	The Whirlpool River main stem and Moab Lake outlet are likely the only waterbodies that historically supported Athabasca Rainbow Trout. However, habitat was likely not ideal with the main stem Whirlpool being fast and unproductive and the Moab Lake outlet being small and fast. Overall, this HUC was likely unproductive historically.	2
Miette River and tributaries (Jasper National Park)	17010104	7.0 (range: 0–17.2, 3 sites) Years: 2003, 2014	CPUA calculations were based on short (96–223 m) electrofishing sections	2[2]	Historical Athabasca Rainbow Trout habitat in this HUC would have been fast, steep and largely unproductive. No Athabasca Rainbow Trout present in Miette main stem above Rink Brook.	2

[1] 1 = lowest possible abundance without extirpation, adults barely detectable; 2 = poor abundance, recruitment overfishing; 3 = moderate abundance, growth overfishing below maximum sustainable yield (MSY); 4 = very abundant, population at or above MSY with mild growth overfishing; 5 = highest possible abundance, population at carrying capacity (Coombs and MacPherson 2013).

[2] Overall, the main stem Miette is unsuitable habitat (fast, unproductive). Rank may be closer to 1 (M. Sullivan in AEP 2014).

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Maligne River (Jasper National Park) (suspected non-native)	17010105	0.8 (range : 0.4–13.4, 3 sites) Year : 2003	CPUA calculations were based on short (100–250 m) electro-fishing sections. A few to moderate numbers of Rainbow Trout were caught in side channels of the Maligne River (M. Sullivan in AEP 2014), therefore density may be higher than current estimate.	1	The main stem Maligne River to the canyon (3 km from confluence) was likely the only available Athabasca Rainbow Trout habitat historically. Overall, the river is fast and unproductive, but some moderate habitat is present near the mouth.	2
Snaring River (Jasper National Park) (suspected non-native)	17010106	n/a	A few small Rainbow Trout were captured in small side channels (none were caught in the upper Snaring River) in July/August 2011 with extensive angling.	1	The main stem Snaring River to the canyon (5 km from confluence) was likely the only available Athabasca Rainbow Trout habitat historically. Overall, the river is fast, unproductive and braided with poor quality habitat up to the mouth.	1
Snake Indian River (Jasper National Park) (suspected non-native)	17010201	n/a	Angling above Snake Indian Falls in July 1998 and August 2008 had moderate results in calm side-channels. Angling was poor (< 1 fish/ha) in Willow Creek (August 2008), Deer Creek (July 1998), and Blue Creek (July 1998 & August 2008). Rainbow Trout densities have likely improved relative to historical densities due to previous stockings of non-native Rainbow Trout.	2	The main stem Snake Indian River to Snake Indian Falls was likely the only available Athabasca Rainbow Trout habitat historically. Overall, the river is fast and unproductive. Blue Creek may have had Athabasca Rainbow Trout prior to it being stocked, but this was likely marginal habitat as well. The Snake Indian main stem above the falls, Will Creek, Deer Creek and Stornoway Creek likely did not have Athabasca Rainbow Trout before the stocking of Blue Creek. The South Fork of the Snake Indian River only contains Bull Trout.	1

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Berland River	17010301	1.8 (range: 0–8.3, 20 sites) Years: 2008, 2009, 2013	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	No pre-1980 data available. Berland River likely held moderately abundant populations of Athabasca Rainbow Trout. Cold temperatures and high gradients in the upper reaches likely limited their distribution.	3
Wildhay River	17010302	2.9 (range: 0–12.3, 26 sites) Years: 2009, 2012	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	Very little pre-1980 data available. Historical surveys and anecdotal evidence indicate widespread reports of good fishing for Athabasca Rainbow Trout. The uppermost reaches have high gradients and cold temperatures, but most of this HUC8 provided suitable habitat.	4
Athabasca River (Hinton to Berland River)	17010401	4.1 (range: 0–24.7, 21 sites) Years: 2008, 2009, 2010, 2012	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	Most streams have records of Athabasca Rainbow Trout. Recent past abundance is likely lower than historical levels due to the long history of land-use and angling in this HUC8.	4
Athabasca River (Berland River to Whitecourt)	17010501	1.8 (range: 0–38, 9 sites Year: 2008	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	Based on historical survey data and anecdotal evidence, the southern tributaries seemed to have healthy populations, but in the main stem and northern tributaries Athabasca Rainbow Trout were likely only moderately abundant.	3

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Sakwatamau River	17010601	1.8 (range: 0–5.5, 20 sites) Year: 2008	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	No pre-1980 data available. Athabasca Rainbow Trout were likely never abundant in the main stem Sakwatamau, but were found in relatively high abundances in some of the tributary streams. Likely moderate historical abundance levels overall.	3
Athabasca River (Whitecourt to Ft. Assiniboine)	17010602	1.7 (based on only one estimate for Mink Creek) Year: 2013	Based on only one electrofishing estimate from Mink Creek in 2013.	1	No data available from pre-1980 or early-mid 1980s. Based on anecdotal evidence, there were likely very few Athabasca Rainbow Trout historically found in this HUC.	1
Freeman River	17010603	1.8 (range: 0–5.5, 13 sites) Years: 2008, 2015 (2015 = preliminary results from a watershed assessment survey. Mean CPUA 2.3 adults/0.1 ha (95% CI = 0.9–3.7) from n = 16 fish sampled in 11 of 50 sites from stream orders 2–4 within Freeman drainage)	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	No pre-1980 data available. Athabasca Rainbow Trout were likely never abundant in the main stem Freeman, but were found in relatively high abundances in some of the tributaries. Likely moderate historical abundance overall.	2

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Upper McLeod River	17020101	2005 watershed survey: 1.88 (92 sites) 2009–2013: 6.1 (range: 0–42.4, 21 sites) 2009–2013 data was not collected in a standardized manner and survey locations favoured sites with Athabasca Rainbow Trout present. FSI rank is based on 2005 data.	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. For newest data (2009–2013), mean CPUA for the HUC8 is potentially biased to the high side due to high CPUA values from Deerlick and Wampus creeks (much higher than other watercourses in the HUC8). Deerlick and Wampus creeks have been closed to angling for 40+ years as part of the Tri-Creeks research project.	1	The upper McLeod contains the best known habitat for Athabasca Rainbow Trout. Catch rates were still high in the 1980s despite high water events, decades of Brook Trout stocking and earlier coal mining and logging. Athabasca Rainbow Trout may have been slightly limited in the lower reaches.	5
Erith and Embarras Rivers	17020102	3.4 (range: 0–12.8, 34 sites) Years: 2009, 2010, 2011	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	Based on historical surveys and anecdotal evidence, this HUC8 may not have had the best habitat for Athabasca Rainbow Trout, but they continued to persist in high numbers. They are currently found throughout the watershed and are some of the best populations in the province.	4
Lower McLeod River	17020201	5.6 (range: 0–15.7, 18 sites) Years: 2010, 2013	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	2	According to historical surveys and anecdotal evidence, this HUC8 was not known to have good quality Athabasca Rainbow Trout habitat nor high densities. However, given the land-use and angling history (early 1900s), the baseline may have shifted and this HUC8 may have supported much healthier Athabasca Rainbow Trout populations than currently thought.	2

Waterbody	HUC8	Current Adult Density (Mean CPUA, adults/0.1 ha)	CPUA Comments	FSI Rank[1] (Current)	Historical Adult Density Comments	FSI Rank (Historical)
Wolf Creek	17020202	3.0 (range: 0–13.5, 7 sites) Years: 2009, 2010, 2013	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	No pre-1980 data available. Historical surveys and anecdotal evidence indicate that Athabasca Rainbow Trout were likely more abundant in the upper reaches, with the lower reaches being less favourable.	3
Edson River	17020203	3.0 (range: 0–18.2, 21 sites) Year: 2010	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	Historical surveys and anecdotal evidence indicate that this was likely a productive system. Athabasca Rainbow Trout are currently restricted to the upper reaches.	4
Trout Creek	17020204	3.3 (range: 0–16.8, 12 sites) Year: 2010	Standardized CPUA calculation on a 300 to 1000 m electrofishing section. Data with lower electrofishing effort was occasionally included if deemed reliable.	1	No pre-1980 data available. Anecdotal evidence indicates Athabasca Rainbow Trout densities in Trout Creek always seemed to be lower compared to Edson River, with only the west branch having occasional good catches. Likely similar to Wolf Creek.	3

Trends in Athabasca Rainbow Trout population abundance for the 45 streams with trend data are shown in Figure 5. Population assessments for streams in the upper Athabasca River watershed have been conducted since the late 1960s using electrofishing gear at more than 2,300 sites on more than 627 streams (AFWMIS 2012 in Alberta Athabasca Rainbow Trout Recovery Team 2014). Six study reaches on streams in the Tri-Creeks Experimental Watershed are considered reference streams (no land use prior to 1980; limited land use after initial forest harvesting; closed to angling; at carrying capacity) (Alberta Athabasca Rainbow Trout Recovery Team 2014). These streams provide ‘benchmark’ Athabasca Rainbow Trout densities and trends. Athabasca Rainbow Trout densities have varied greatly in these streams since 1969 (nearly forty fold) (Alberta Athabasca Rainbow Trout Recovery Team 2014). Population densities in three of the six reference study reaches have shown an increasing trend between 1969 and 2014, and three have shown a decreasing trend. When all 45 streams (59 sites) with trend data are considered (Figure 5), 28 sites (48%) show a decreasing trend, 26 sites (45%) show an increasing trend and four sites (7%) have remained stable (Alberta Athabasca Rainbow Trout Recovery Team 2014).

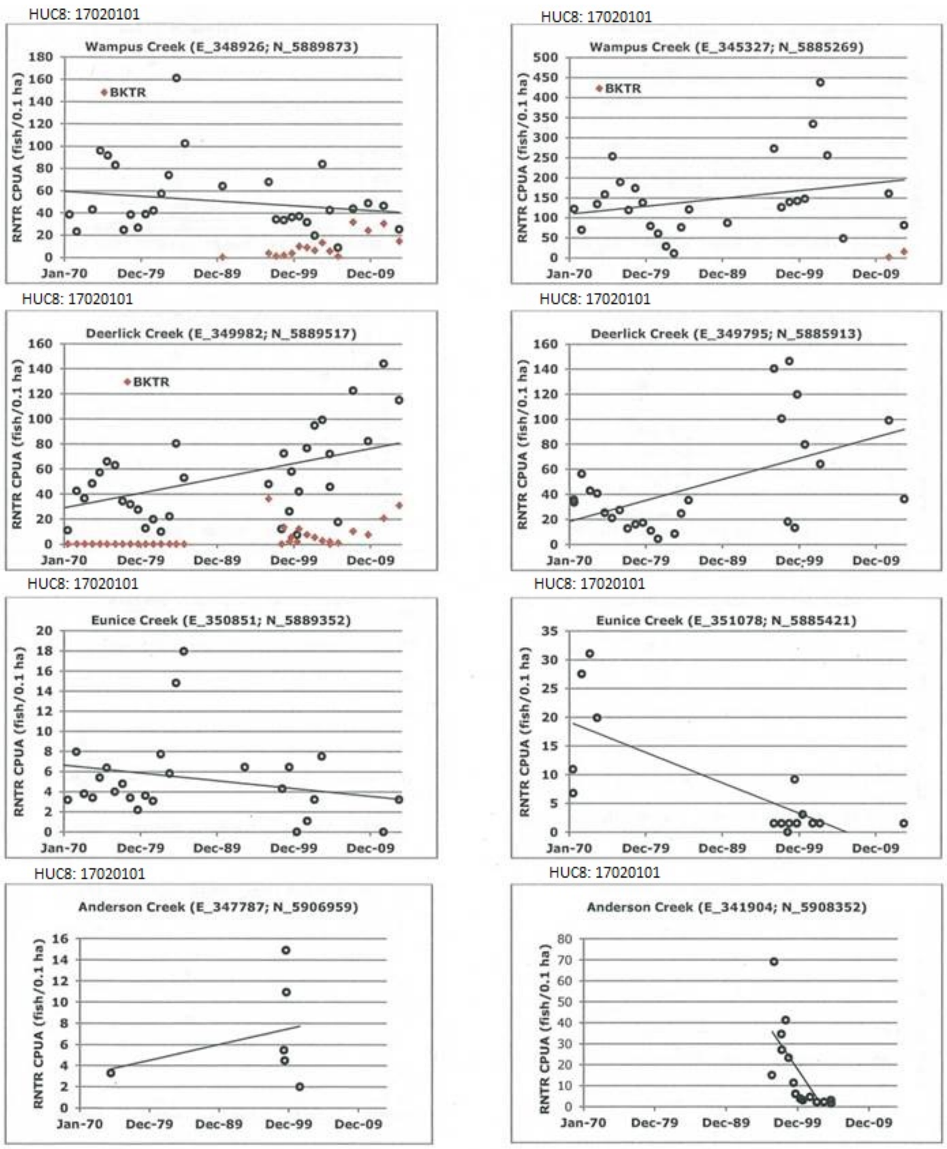
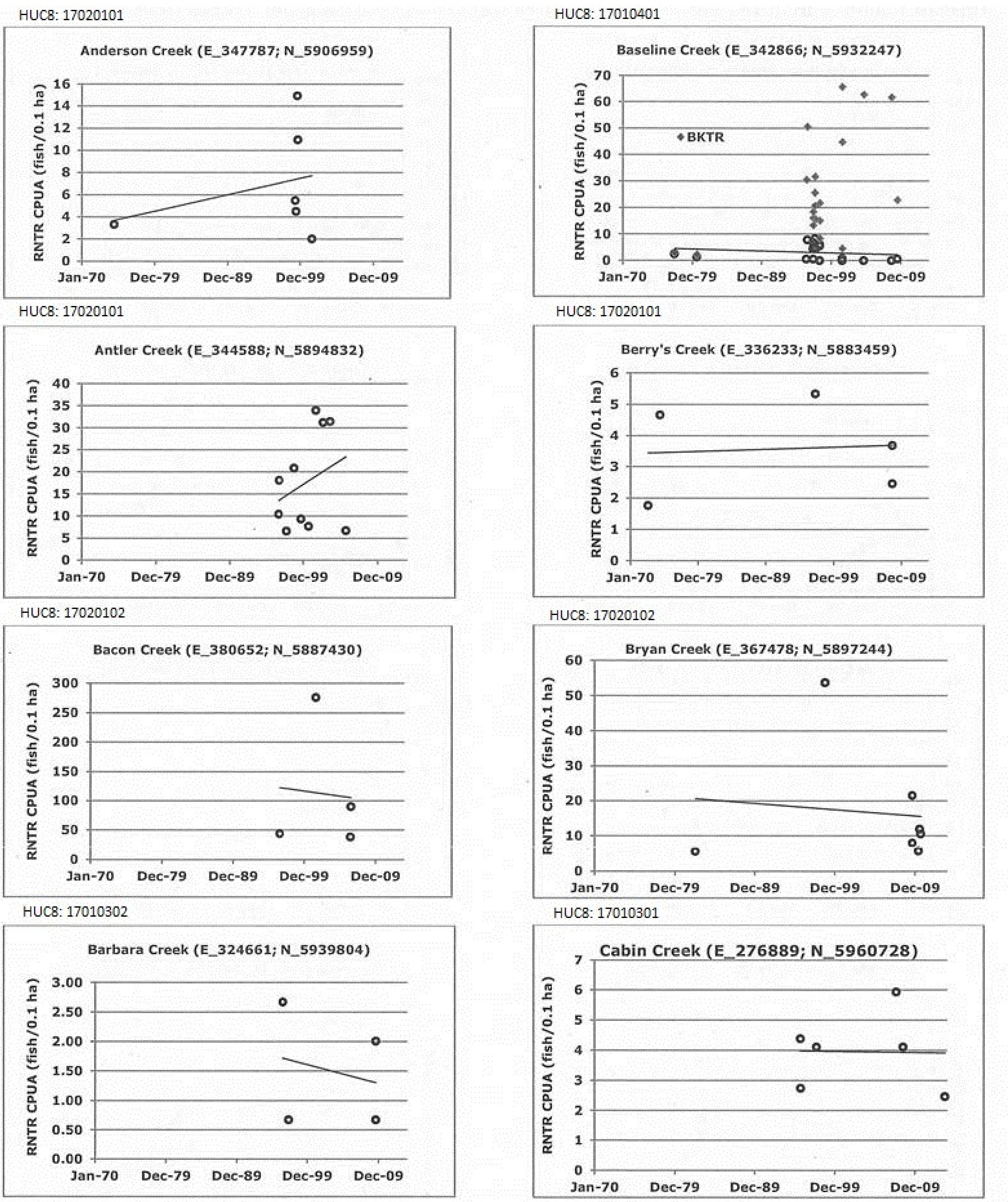


Figure 5. Athabasca Rainbow Trout population trends for 45 streams (59 sampling locations). Open circles represent Athabasca Rainbow Trout or Rainbow Trout (where Q_i is unknown); diamonds represent Brook Trout. Reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014), HUC8 numbers added by author.



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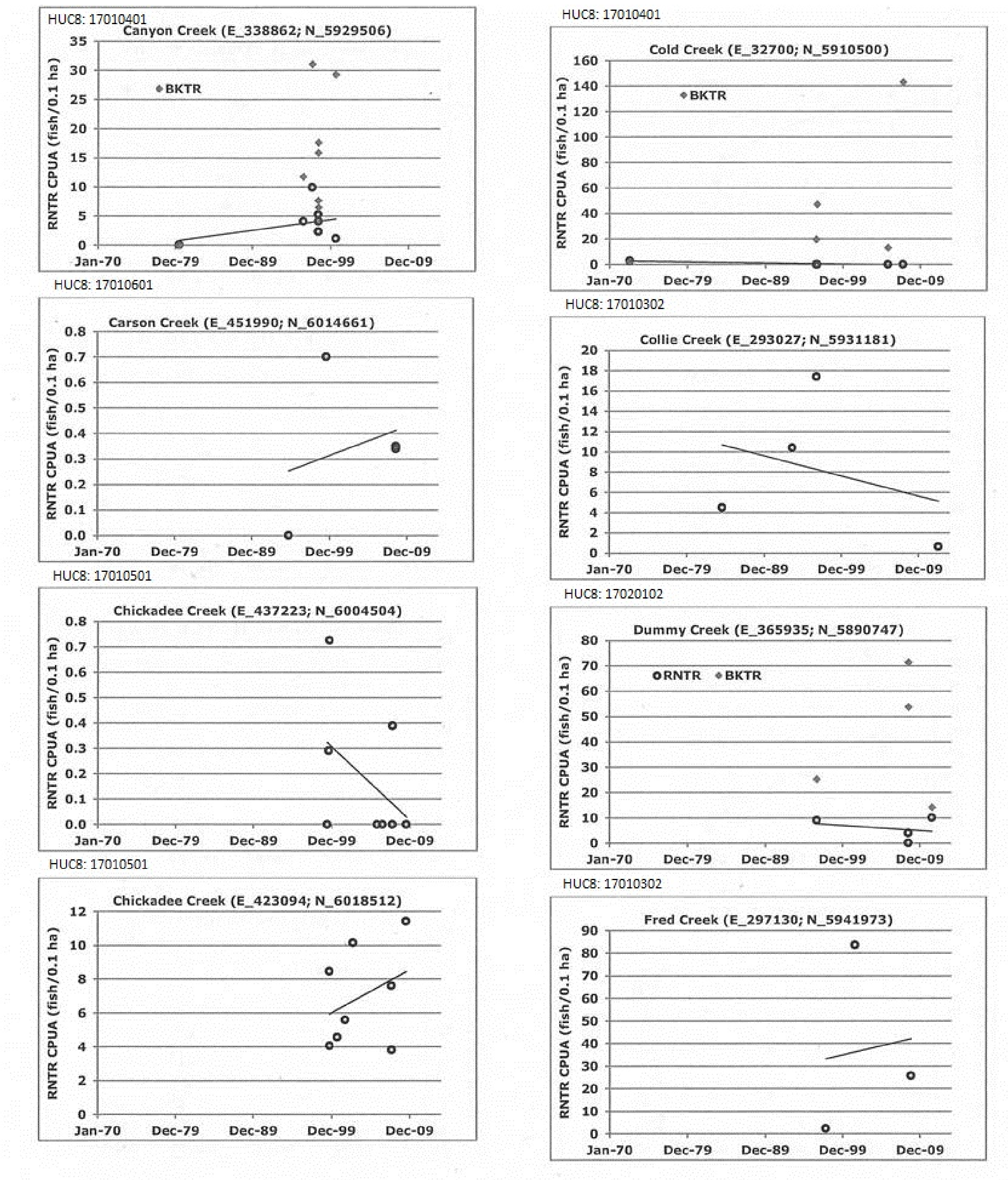

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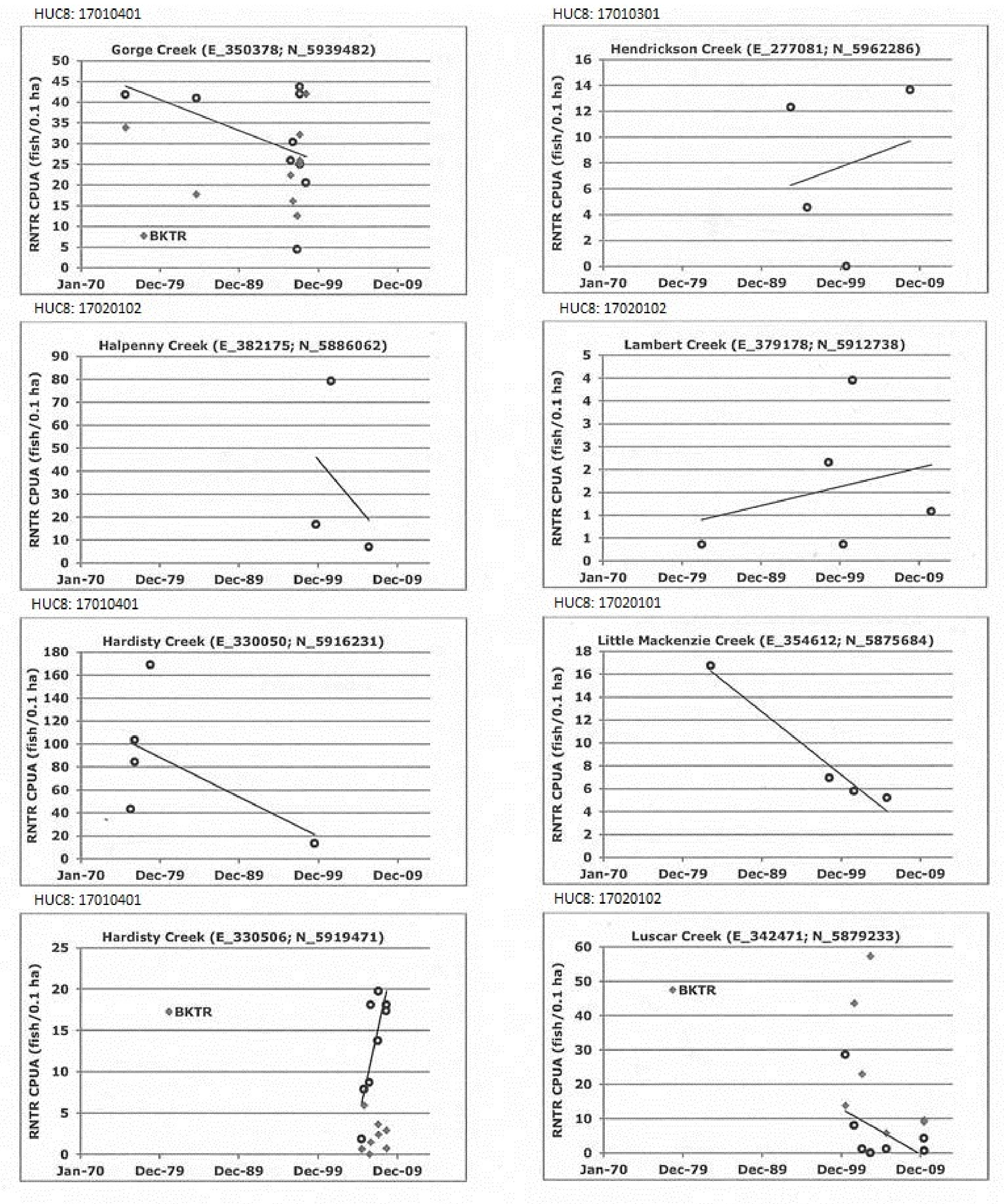

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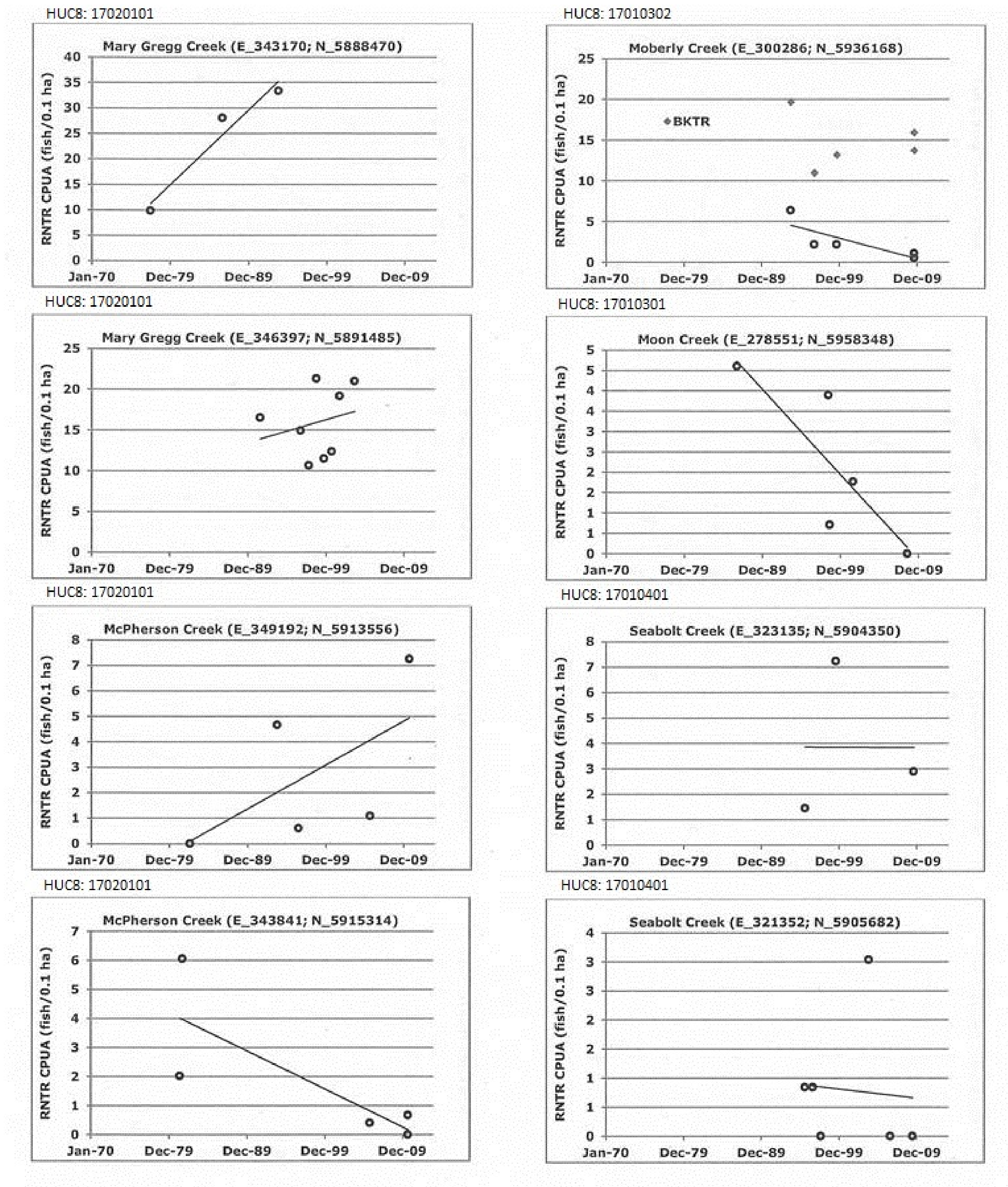

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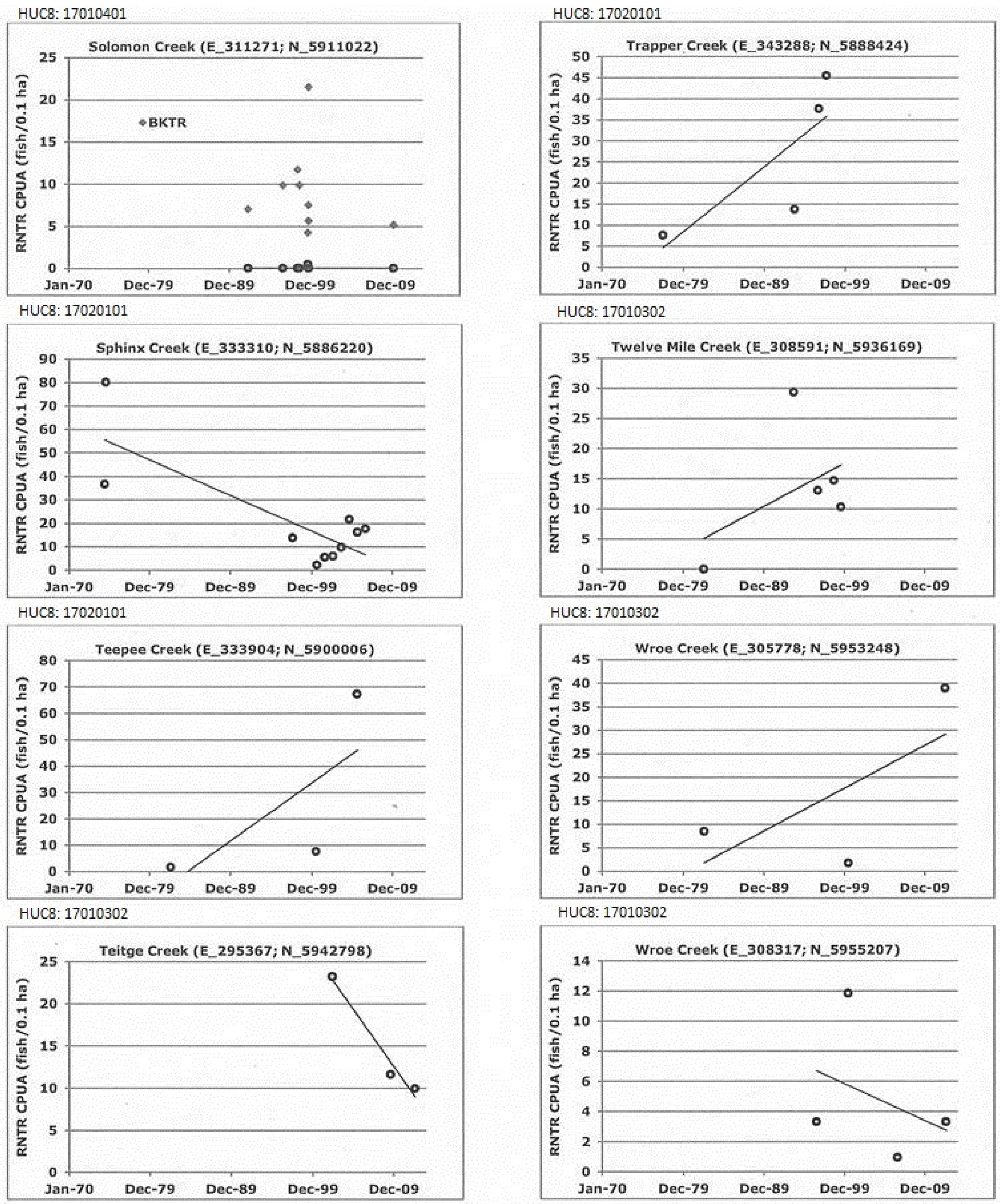

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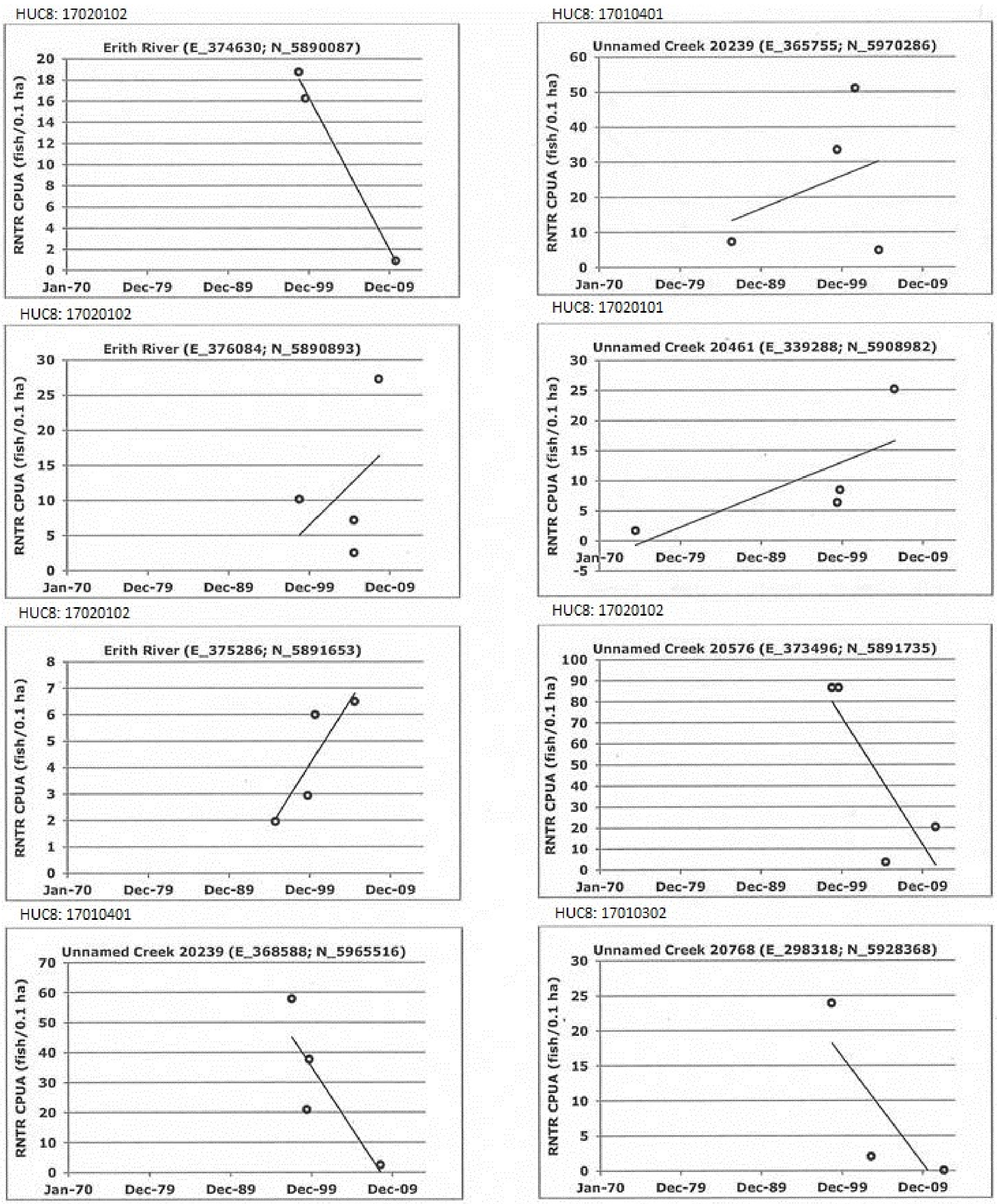

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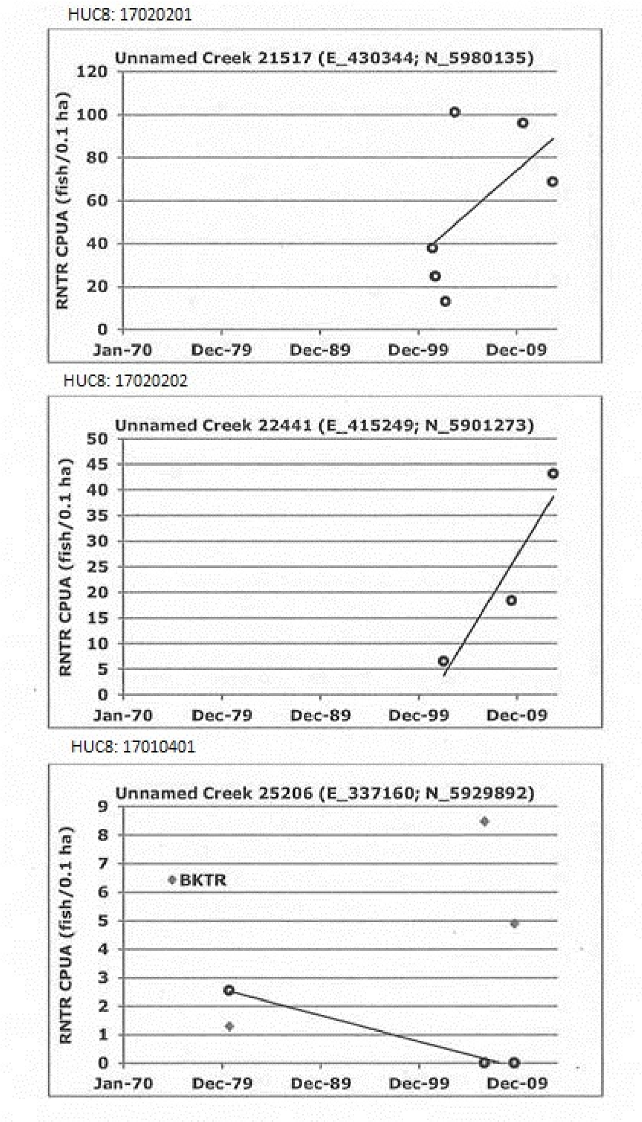

Figure 5. continued.

POPULATION ASSESSMENT

To assess the population status of Athabasca Rainbow Trout, the populations were ranked in terms of their abundance (Relative Abundance Index) and trajectory (Population Trajectory) (Table 3). Trajectory data was only available for 45 streams in nine HUC8s. Abundance was ranked relative to the most abundant population (Wampus Creek; Rainbow Trout density 262.3 fish/0.1 ha from 2000–2004) based on the information presented in COSEWIC (2014, Appendix 1) and Figure 5. Population trajectory was obtained from the trend data in Figure 5. Both were ranked by stream (45 streams) rather than sample location (59 sites) where available. Current adult density from Table 2 was used to determine the relative abundance index for the ten HUC8s for which trend data is not available. Current FSI Rank versus Historical FSI Rank from Table 2 was used to determine the Population Trajectory for the ten HUC8s without trend data. The Relative Abundance Index was assigned as Low (>80% less than the most abundant population), Medium (50–80% less than the most abundant population) or High (<50% of the most abundant population). The Population Trajectory was assigned as Increasing (an increase in abundance over time), Stable (no change in abundance over time), Decreasing (a decrease in abundance over time) or Unknown.

Table 5. Relative Abundance Index and Population Trajectory of Athabasca Rainbow Trout populations in the Athabasca River watershed.

Waterbody	HUC8	Relative Abundance Index	Population Trajectory
Cabin Creek	17010301	Low	Stable
Hendrickson Creek	17010301	Low	Increasing
Moon Creek	17010301	Low	Decreasing
Barbara Creek	17010302	Low	Decreasing
Collie Creek	17010302	Low	Decreasing
Fred Creek	17010302	Low	Increasing
Moberly Creek	17010302	Low	Decreasing
Teitge Creek	17010302	Low	Decreasing
Twelve Mile Creek	17010302	Low	Increasing
Unnamed Creek 20768	17010302	Low	Decreasing
Wroe Creek	17010302	Low	Decreasing
Baseline Creek	17010401	Low	Decreasing
Canyon Creek	17010401	Low	Increasing
Cold Creek	17010401	Low	Stable
Gorge Creek	17010401	Low	Decreasing
Hardisty Creek	17010401	Low	Decreasing
Seabolt Creek	17010401	Low	Decreasing
Solomon Creek	17010401	Low	Stable
Unnamed Creek 20239	17010401	Low	Decreasing
Unnamed Creek 25206	17010401	Low	Decreasing
Chickadee Creek	17010501	Low	Increasing
Carson Creek	17010601	Low	Increasing
Anderson Creek	17020101	Low	Decreasing

Waterbody	HUC8	Relative Abundance Index	Population Trajectory
Antler Creek	17020101	Low	Increasing
Berry's Creek	17020101	Low	Increasing
Deerlick Creek	17020101	Medium	Increasing
Eunice Creek	17020101	Low	Decreasing
Little Mackenzie Creek	17020101	Low	Decreasing
Mary Gregg Creek	17020101	Low	Increasing
McPherson Creek	17020101	Low	Stable
Sphinx Creek	17020101	Low	Decreasing
Teepee Creek	17020101	Medium	Increasing
Trapper Creek	17020101	Low	Increasing
Unnamed Creek 20461	17020101	Low	Increasing
Wampus Creek	17020101	High	Increasing
Bacon Creek	17020102	Medium	Decreasing
Bryan Creek	17020102	Low	Decreasing
Dummy Creek	17020102	Low	Decreasing
Erith River	17020102	Low	Increasing
Halpenny Creek	17020102	Low	Decreasing
Lambert Creek	17020102	Low	Increasing
Luscar Creek	17020102	Low	Decreasing
Unnamed Creek 20576	17020102	Low	Decreasing
Unnamed Creek 21517	17020201	Medium	Increasing
Unnamed Creek 22441	17020202	Low	Increasing
Upper Athabasca River and Brule Lake[1]	17010102	Low[2]	Decreasing[3]

[1] HUC8 name
[2] Based on Current Adult Density in Table 4
[3] Based on Current FSI rank versus Historical FSI rank in Table 4

Waterbody	HUC8	Relative Abundance Index	Population Trajectory
Whirlpool River[1]	17010103	Low[2]	Decreasing[3]
Miette River and tributaries[1]	17010104	Low[2]	Stable[3]
Maligne River[1]	17010105	Low[2]	Decreasing[3]
Snaring River[1]	17010106	Unknown[2]	Stable[3]
Snake Indian River[1]	17010201	Unknown[2]	Increasing[3]
Athabasca River (Whitecourt to Ft. Assiniboine)[1]	17010602	Low[2]	Stable[3]
Freeman River[1]	17010603	Low[2]	Decreasing[3]
Edson River[1]	17020203	Low[2]	Decreasing[3]
Trout Creek[1]	17020204	Low[2]	Decreasing[3]

The Relative Abundance Index and Population Trajectory values were then combined in the Population Status Matrix (Table 6) to determine the Population Status (Poor, Fair, Good, Unknown or Extirpated) (Table 7). The certainty of the Population Status is reflective of the certainty associated with the initial parameters – these were determined using quantitative data. 46 populations are rated Poor, three are rated Fair and two are rated Good.

[1] HUC8 name.

[2] Based on Current Adult Density in Table 4

[3] Based on Current FSI rank versus Historical FSI rank in Table 4

Table 6. The Population Status Matrix combines the Relative Abundance Index and Population Trajectory rankings to establish the Population Status for Athabasca Rainbow Trout. The resulting Population Status has been categorized as Poor, Fair, Good, Unknown or Extirpated.

		Population Trajectory			
		Increasing	Stable	Decreasing	Unknown
Relative Abundance	Low	Poor	Poor	Poor	Poor
	Medium	Fair	Fair	Poor	Poor
	High	Good	Good	Fair	Fair
	Unknown	Unknown	Unknown	Unknown	Unknown
	Extirpated	Extirpated	Extirpated	Extirpated	Extirpated

Table 7. Population Status of Athabasca Rainbow Trout populations, resulting from an analysis of both the Relative Abundance Index and Population Trajectory.

Waterbody	HUC8	Population Status
Cabin Creek	17010301	Poor
Hendrickson Creek	17010301	Poor
Moon Creek	17010301	Poor
Barbara Creek	17010302	Poor
Collie Creek	17010302	Poor
Fred Creek	17010302	Poor
Moberly Creek	17010302	Poor
Teitge Creek	17010302	Poor
Twelve Mile Creek	17010302	Poor
Unnamed Creek 20768	17010302	Poor
Wroe Creek	17010302	Poor
Baseline Creek	17010401	Poor
Canyon Creek	17010401	Poor
Cold Creek	17010401	Poor
Gorge Creek	17010401	Poor
Hardisty Creek	17010401	Poor
Seabolt Creek	17010401	Poor
Solomon Creek	17010401	Poor
Unnamed Creek 20239	17010401	Poor
Unnamed Creek 25206	17010401	Poor

Waterbody	HUC8	Population Status
Chickadee Creek	17010501	Poor
Carson Creek	17010601	Poor
Anderson Creek	17020101	Poor
Antler Creek	17020101	Poor
Berry's Creek	17020101	Poor
Deerlick Creek	17020101	Fair
Eunice Creek	17020101	Poor
Little Mackenzie Creek	17020101	Poor
Mary Gregg Creek	17020101	Poor
McPherson Creek	17020101	Poor
Sphinx Creek	17020101	Poor
Teepee Creek	17020101	Fair
Trapper Creek	17020101	Poor
Unnamed Creek 20461	17020101	Poor
Wampus Creek	17020101	Good
Bacon Creek	17020102	Poor
Bryan Creek	17020102	Poor
Dummy Creek	17020102	Poor
Erith River	17020102	Poor
Halpenny Creek	17020102	Poor
Lambert Creek	17020102	Poor

Waterbody	HUC8	Population Status
Luscar Creek	17020102	Poor
Unnamed Creek 20576	17020102	Poor
Unnamed Creek 21517	17020201	Fair
Unnamed Creek 22441	17020202	Poor
Upper Athabasca River and Brule Lake	17010102	Poor
Whirlpool River	17010103	Poor
Miette River and tributaries	17010104	Poor
Maligne River	17010105	Poor
Snaring River	17010106	Unknown
Snake Indian River	17010201	Unknown
Athabasca River (Whitecourt to Ft. Assiniboine)	17010602	Poor
Freeman River	17010603	Poor
Edson River	17020203	Poor
Trout Creek	17020204	Poor

HABITAT AND RESIDENCE REQUIREMENTS

Rainbow Trout, in general, are a cold-water species with preferred water temperatures ranging from 7 to 18 °C (Raleigh et al. 1984). The upper lethal temperature for adults is approximately 27 °C (Lee and Rinne 1980). Characteristics of foothill streams inhabited by Rainbow Trout in the Athabasca River drainage are summarized in Table 8 (R.L. & L. Environmental Services Ltd. 1996, COSEWIC 2014).

Stream-resident Athabasca Rainbow Trout spend their entire lives in small headwater streams. In the Tri-Creeks drainage, tagged fish made only small movements during spawning (less than 500 m) and did not move between pools during the rest of the year (G. Sterling pers. comm. in COSEWIC 2014). River-migrants inhabit main stem rivers and migrate into smaller tributaries in the spring to spawn. They use the same spawning habitat as the stream-residents, but return to the larger rivers after spawning to summer and overwinter. The fry of river-migrant fish have been observed exiting the small tributary streams in mid- to late September to rear and overwinter in the larger rivers of the Tri-Creeks watershed (COSEWIC 2014).

Table 8. Characteristics of foothill streams of the Athabasca River drainage related to Rainbow Trout presence (source: R.L. & L. Environmental Services Ltd. 1996 in COSEWIC 2014). Data was collected from 34 sample sites in 16 streams in the upper Athabasca River drainage.

Stream Characteristics	N	Mean	95% Confidence Interval	Range
Average Gradient (m/km)	25	14	+/- 3.3	3–33
Elevation (masl)	25	1172	+/- 105	785–1550
Basin Area (km^2)	25	63	+/- 23	7–217
Distance from Mouth (km)	25	9	+/- 4.6	1–42
Distance from Source (km)	25	14	+/- 4.0	2–46
Wetted Channel Width (m)	25	5.4	+/- 0.92	2–10
Channel Depth (m)	25	0.28	+/- 0.05	0.1–0.5
Conductivity (µS/cm)	14	288	+/- 68	158–530

Athabasca Rainbow Trout are not often found in first-order streams as these streams are typically ephemeral; however, first-order streams with perennial flow and channel widths greater than 0.75 m provide suitable habitat and are often occupied solely by Athabasca Rainbow Trout (Alberta Athabasca Rainbow Trout Recovery Team 2014). Important habitat components for Athabasca Rainbow Trout include cold, clean, well oxygenated water, sediment-free substrates, instream cover (e.g., large woody debris), and a variety of habitats with low water velocities (Alberta Athabasca Rainbow Trout Recovery Team 2014). Adult riverine Rainbow Trout occur in habitat with riffles, runs, glides and pool structures and generally occupy deeper, faster moving water than juveniles (McPhail 2007, COSEWIC 2014). In the Nazko River in central British Columbia, adult Rainbow Trout most often occurred in runs with cobble and boulder substrates, at depths between 0.1 and 0.5 m, and at average water velocities between 0.4 and 0.8 m/s (Porter and Rosenfeld 1999, COSEWIC 2014). In small streams, cover (e.g., large woody debris) is a critical habitat component for Rainbow Trout (Flebbe and Dolloff 1995, COSEWIC 2014).

Spawning occurs in late May to early June in small tributaries to rivers or inlet or outlet streams of lakes (COSEWIC 2014). Athabasca Rainbow Trout spawn later than introduced Rainbow Trout (April–May) in southern Alberta (Sterling 1990, Nelson and Paetz 1992, COSEWIC 2014). In the Tri-Creeks watershed, Athabasca Rainbow Trout peak spawning has been reported to occur approximately 104 to 122 days after ice-out (usually the first 10 days of June) (Sterling

1992, COSEWIC 2014) at a mean of 6 °C or maximum 8 °C. The Tri-Creeks watershed is in the center of the range and spawning will occur later at higher elevations and earlier at lower elevations. Suitable water velocity and depth for Rainbow Trout spawning range from 0.30 to 0.90 m/s and 0.15 to 2.5 m, respectively (Raleigh et al. 1984, COSEWIC 2014). Athabasca Rainbow Trout generally spawn in habitat at the lower end of these ranges (COSEWIC 2014) in habitat with small to medium gravel beds, which are typically located upstream of riffle crests in small to medium perennial streams (Sterling 1992, COSEWIC 2014). In the Tri-Creeks watershed, average water velocity at Athabasca Rainbow Trout spawning sites was approximately 0.31 m/s and ranged from 0.10 to 0.68 m/s; mean water depth was approximately 0.14 m and ranged from 0.07 to 0.68 m; and mean substrate particle size was approximately 10 mm and ranged from 3 to 31 mm (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014). Larger females spawned in deeper water with higher velocities over substrates with larger particle sizes (Tri-Creeks unpublished data in Alberta Athabasca Rainbow Trout Recovery Team 2014). Athabasca Rainbow Trout generally spawn in finer gravel substrates than introduced Rainbow Trout in southern Alberta (Sterling 1990, Nelson and Paetz 1992, COSEWIC 2014). The location of spawning substrate (gravel) is variable depending on flow. When stream flow is high during the spawning period, redds are often constructed along stream margins, leaving them vulnerable to exposure (and egg mortality) during summer low flow. When stream flow is low during spawning, redds are often constructed closer to the center of the channel and are therefore vulnerable to scour during summer high flow (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014).

The length of time to emergence in the Tri-Creeks watershed was correlated with water temperature – the accumulation of approximately 590 degree-days was required before fry began to emerge (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014). Emergence usually occurred in mid-summer, but was delayed until late August in some habitats (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014) and may happen as late as September. Fry emerge in flowing water and move to shallow water along stream margins (COSEWIC 2014). Stream margins, un-embedded large gravel and small to medium cobble substrates next to spawning areas are important rearing habitats (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014). In two streams in Montana, age 0+ Rainbow Trout fry were most commonly found at depths less than 0.20 m, water velocities less than 0.01 m/s and over small gravel substrates (Muhlfeld et al. 2001, COSEWIC 2014).

Athabasca Rainbow Trout typically overwinter in primary pools that span the width of the channel in main stem rivers and smaller tributaries. Stream-resident Athabasca Rainbow Trout in the Tri-Creeks watershed overwintered in primary pools in third- and fourth-order streams with a mean maximum depth of 0.63 m and a mean volume of 7.2 m^3 prior to freeze-up (Sterling and Cox unpublished in Alberta Athabasca Rainbow Trout Recovery Team 2014, COSEWIC 2014). By mid-winter (February), this pool habitat was reduced by up to 80%. Generally, stream-residents overwinter in second- to fourth-order streams, while river-migrants overwinter in fifth-order or larger rivers (Alberta Athabasca Rainbow Trout Recovery Team 2014).

FUNCTIONS, FEATURES AND ATTRIBUTES

A description of the functions, features and attributes associated with Athabasca Rainbow Trout habitat can be found in Table 9. The habitat required for each life stage has been assigned a function that corresponds to a biological requirement of Athabasca Rainbow Trout. In addition to the habitat function, features have been assigned for each life stage. A feature is considered to be the structural component of the habitat necessary for the survival or recovery of the species. Habitat attributes have also been provided, which describe how the features support the function for each life stage. This information is provided to guide any future identification of critical habitat for this species. It should be noted that habitat attributes associated with current records may differ from optimal habitat as Athabasca Rainbow Trout may be occupying sub-optimal habitat where optimal habitat is not available.

SPATIAL EXTENT OF HABITAT

The spatial extent of the areas that are likely to have the habitat properties outlined in Table 9 (termed ecologically significant habitat [ESH]) has been mapped by Alberta Athabasca Rainbow Trout Recovery Team (2014). These maps are presented in Figures 6 to 12. Two life history habitat components were considered ecologically significant for population sustainability, namely, spawning and incubation habitat for stream-resident and river-migrant populations and overwintering habitat for stream-resident populations (Alberta Athabasca Rainbow Trout Recovery Team 2014). The health of these habitats is essential and protecting them also ensures good quality habitat is available for rearing; overwintering habitat for river-migrants is not considered limiting as these populations overwinter in fifth-order or larger rivers (Alberta Athabasca Rainbow Trout Recovery Team 2014).

It is important that bankfull stream width and associated riparian habitat (see AESRD 2012a) also be protected. This habitat provides large woody debris which is important in defining and maintaining channel configuration and habitat structure (Faustini and Jones 2003, Alberta Athabasca Rainbow Trout Recovery Team 2014) and maintains and supports aquatic health (Richardson et al. 2010, Alberta Athabasca Rainbow Trout Recovery Team 2014) which is necessary to support the survival and recovery of Athabasca Rainbow Trout.

SPATIAL CONSTRAINTS

Locations of impassable waterfalls are indicated in Figures 6 to 12. Tertiary watershed 07AA (Solomon Creek, Jasper National Park) has seven impassable waterfalls, 07AB (Athabasca River, Jasper National Park; naturalized populations of non-native Rainbow Trout only) has four impassable waterfalls, and 07AF (Upper McLeod River) has two impassable waterfalls. The presence and extent of other spatial configuration constraints in areas occupied by Athabasca Rainbow Trout have not yet been quantified. Further research is needed to determine the current location of instream barriers within Athabasca Rainbow Trout habitat and whether removal of these barriers will facilitate movement between areas of suitable habitat and extend currently occupied reaches. Habitat fragmentation is discussed further in the Threats section.

Table 9. Summary of the essential functions, features and attributes for each life stage of Athabasca Rainbow Trout. Sources include Sterling (unpublished data in COSEWIC 2014), Sterling (1986, 1992), and Bjornn and Reiser (1991) unless otherwise indicated. Modified from COSEWIC (2014).This information is provided to guide the future identification of critical habitat.

Life Stage	Function	Feature(s)	Attributes
Egg / Embryo – spawning through emergence); for resident (non-migratory) and fluvial (migratory) populations	Spawning Incubation and early rearing (mid-May to mid-August)	• Clean, small–medium gravel; gravel beds generally found upstream of riffle crests in small to medium perennial streams (often Strahler Order 2–4[a]) • Redds are often constructed in areas with sub-gravel flow	• Gravel beds with rounded or angular gravel with mean particle sizes ranging from 4–15 mm • Water depth over gravel beds ranging from 5–40 cm, where flow is non-turbulent with velocities ranging from 12–70 cm/s • Fine sediment and silt (<2.0 mm) in spawning gravels does not exceed 15–20% • Optimum dissolved oxygen (DO) saturation >90% and minimum optimum DO concentration >8 mg/L • Fluvial populations migrate on the descending limb of the snowmelt hydrograph at temperatures ranging from 4–6 °C • Mean water temperatures during the spawning period range from 6–10 °C • Optimum water temperature during incubation ranges from 8–12 °C; temperatures <3 °C or >18.5 °C cause increased embryo mortality[a] • Unimpeded access to spawning areas for fluvial Athabasca Rainbow Trout
Fry (Young-of-year to age 1) for resident and fluvial populations	Nursery	• A variety of habitats with reduced water velocity in small to medium perennial streams (often Strahler Order 2–4[a]) including riffles, riffle crests, stream margins, boulders, riparian vegetation and large woody debris	• Optimum growth temperature ranges from 10–15 °C • Temperatures ≥22–24 °C and ≤0 °C are considered life threatening • Shallow stream margins with a variety of abundant cover (aquatic vegetation or woody debris), non-embedded (free of fine sands, silts and clays <2 mm diameter) large gravel and cobble and reduced flow velocities.

[a] Alberta Athabasca Rainbow Trout Recovery Team 2014

Life Stage	Function	Feature(s)	Attributes
Juvenile Adult	Feeding Cover	• Small to medium perennial streams (often Strahler Order 2–4[a]) with riffles, runs, glides and pools and cover (large woody debris or aquatic vegetation). Adults tend to occupy deeper and faster-moving water than juveniles[b].	• Preferred water temperatures range from 7–18 °C[c] • The upper lethal temperature for adults is approximately 27 °C[d] but temperatures from 22–24 °C and as low as 0 °C are considered life threatening • Recommended oxygen concentration for Rainbow Trout in general: 7 mg/L if <15 °C; >9 mg/L if >15 °C • Lower lethal oxygen concentration: 3 mg/L[c] • Preferred water velocity for Rainbow Trout in general ranges from 0.20–0.30 m/s[c] • Adults have been recorded at sites with substrates dominated by medium sized (64–255 mm) cobble[b] • Cover: large woody debris (also important for channel structure) or riparian vegetation[e] (Rainbow Trout in general)
Fry Juvenile Adult	Over-wintering	• Primary pools (complex pools that span the entire channel width), beaver ponds and areas of hyporheic flow in perennial streams	• Primary pools with a mean pre-freeze-up minimum depth of 0.65 m[f] and volume of 7.2 m^3 (Tri-Creeks) • Large cobble, free of fine sands, silts and clays in regions of hyporheic flow • Unimpeded access to/from additional overwintering areas • Water temperatures between 4 °C and 15 °C[a], lower temperatures may be tolerated but frazil ice forms near 0.2 °C • Lower lethal oxygen concentration: 3 mg/L[c] • Water velocities ranging from: 0.01 – >1.0 m/s[a] • Stream-residents overwinter in second- to fourth-order streams[c]; river-migrants overwinter in fifth-order or larger rivers where overwintering habitat is not considered limiting[a] • Landscape function is important to maintain groundwater flow

a Alberta Athabasca Rainbow Trout Recovery Team 2014

b McPhail 2007

c Raleigh et al. 1984

d Lee and Rinne 1980

e Flebbe and Dolloff 1995

f Sterling and Cox unpublished in Alberta Athabasca Rainbow Trout Recovery Team 2014

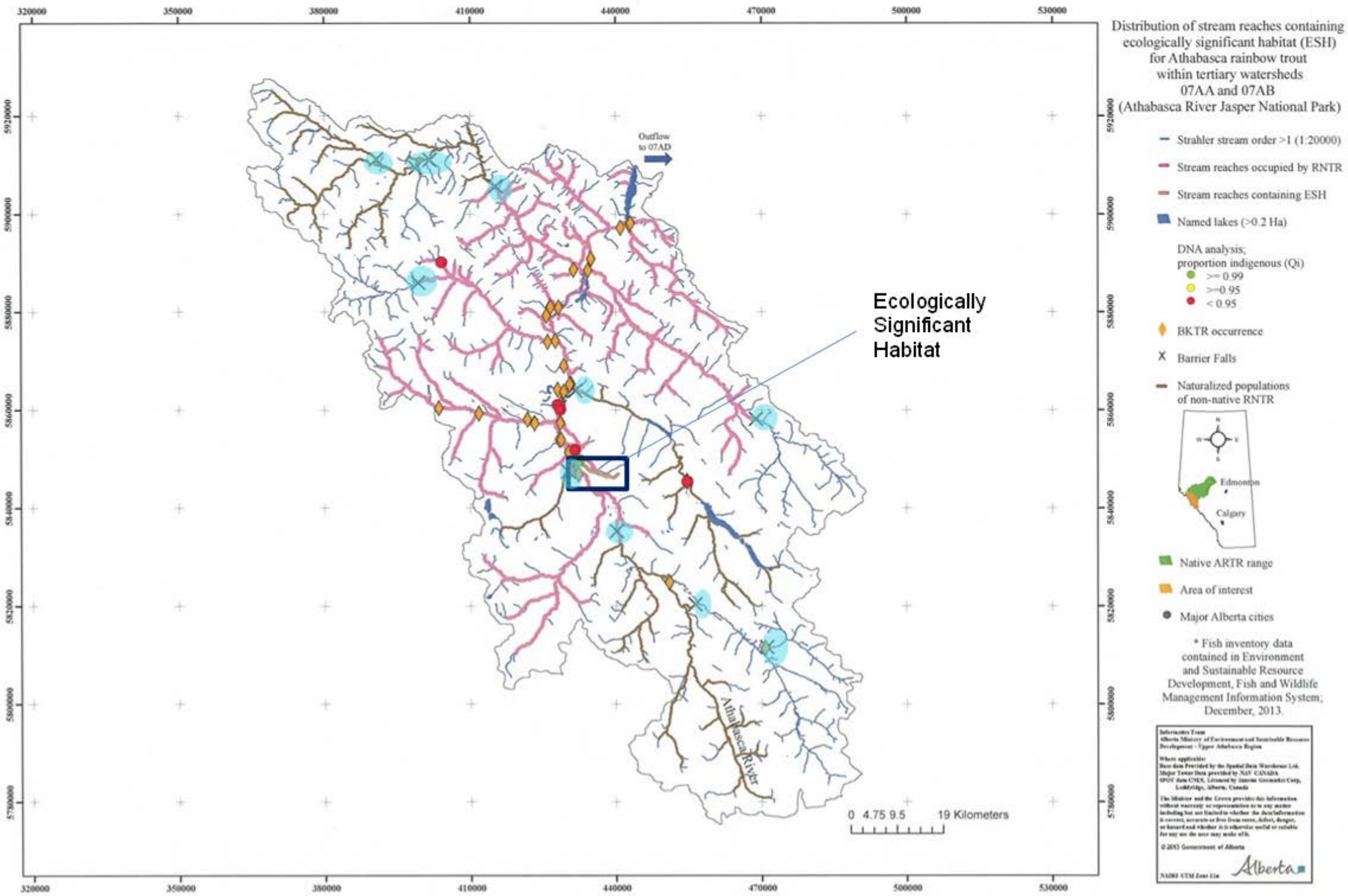

Figure 6. Locations of ecologically significant habitat (ESH) and impassable waterfalls (X) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watersheds 07AA and 07AB (Jasper National Park). 07AA includes HUC8s: 17010102, 17010103, 17010104, 17010105 and 17010106; 07AB includes HUC8: 17010201. Modified from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH includes only streams where native Athabasca Rainbow Trout are present and is based on the best information available at the time of delineation

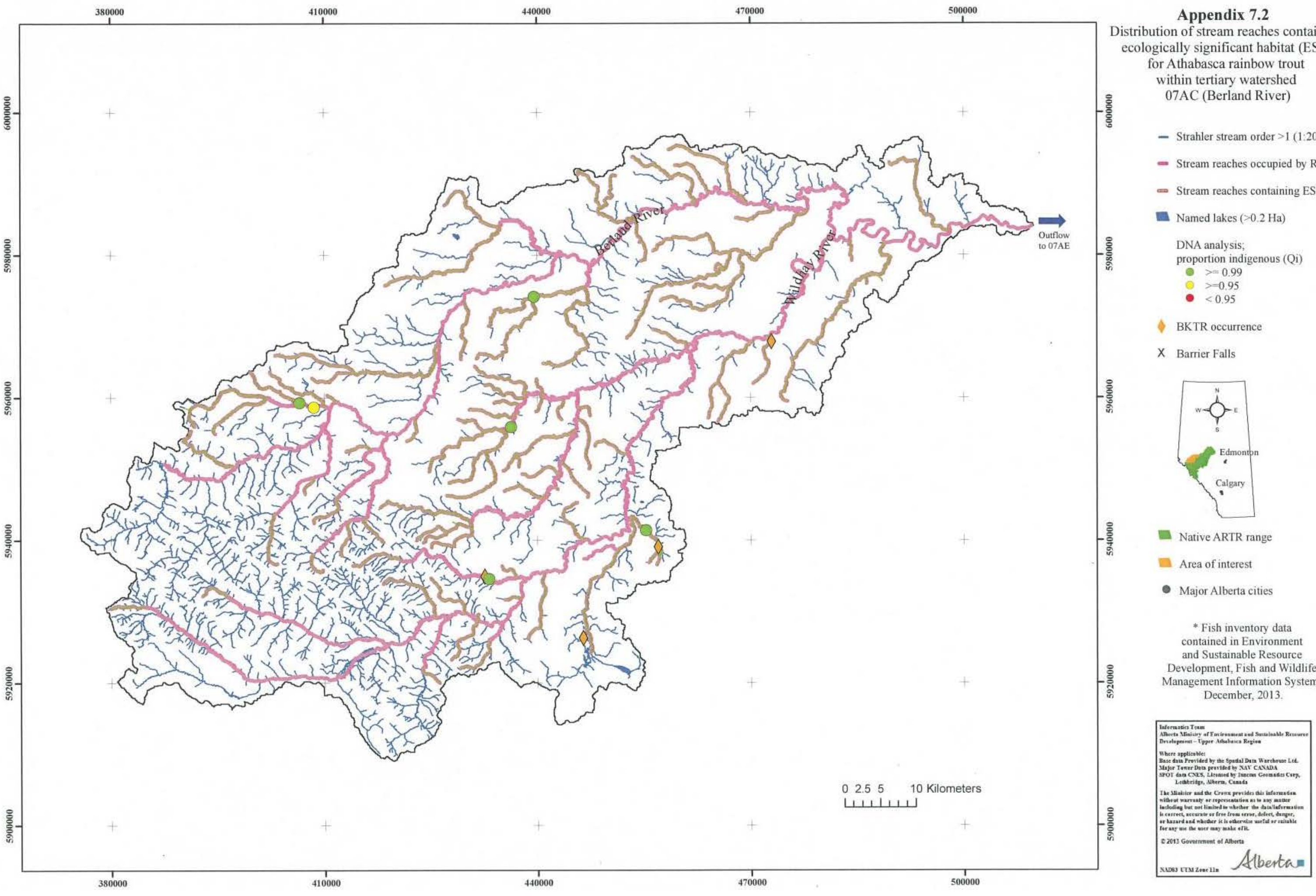

Figure 7. Location of ecologically significant habitat (ESH) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AC (HUC8s: 17010301 and 17010302). Appendix 7.2 was reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

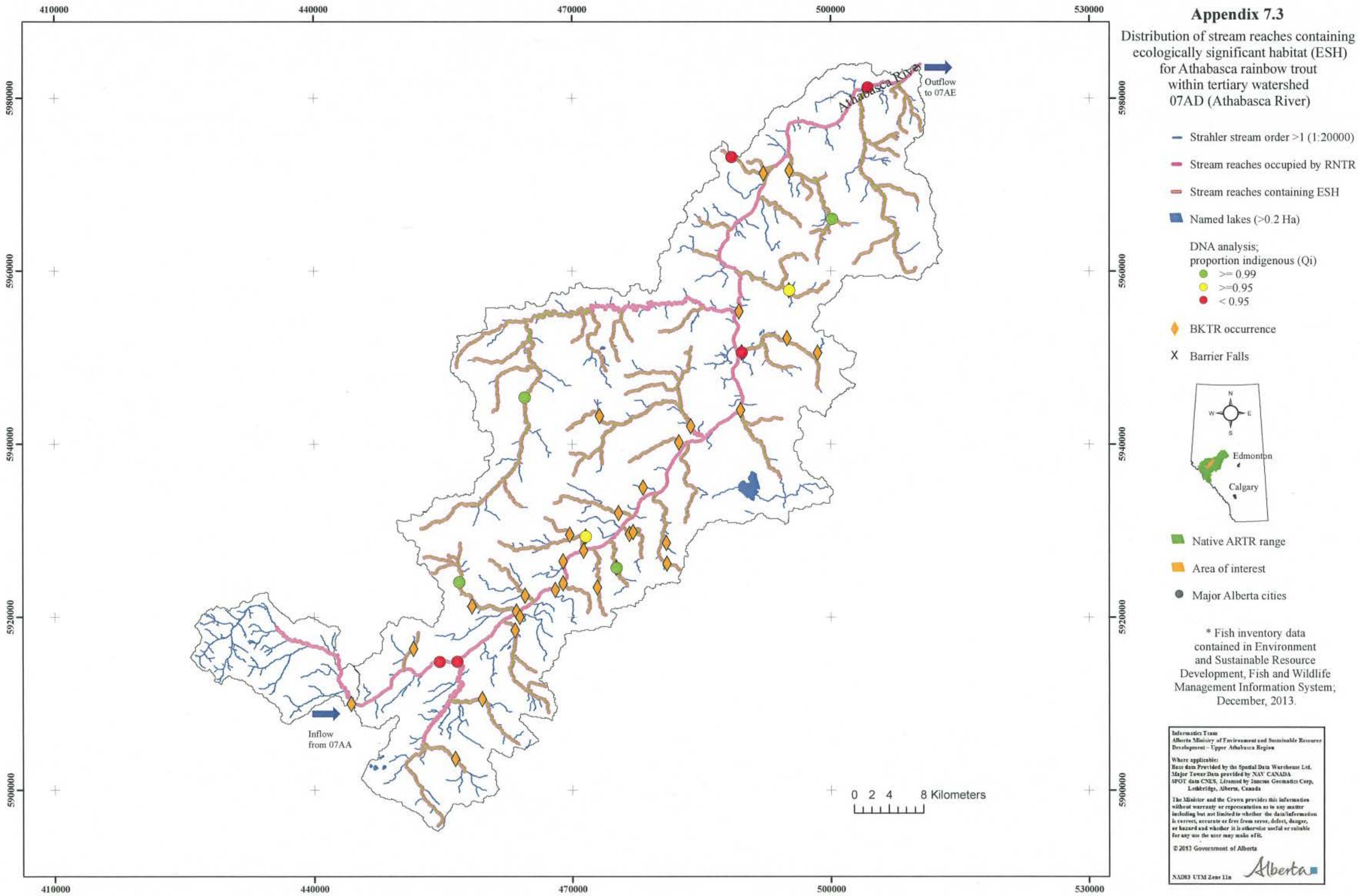

Figure 8. Location of ecologically significant habitat (ESH) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AD (HUC8: 17010401). Appendix 7.3 was reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

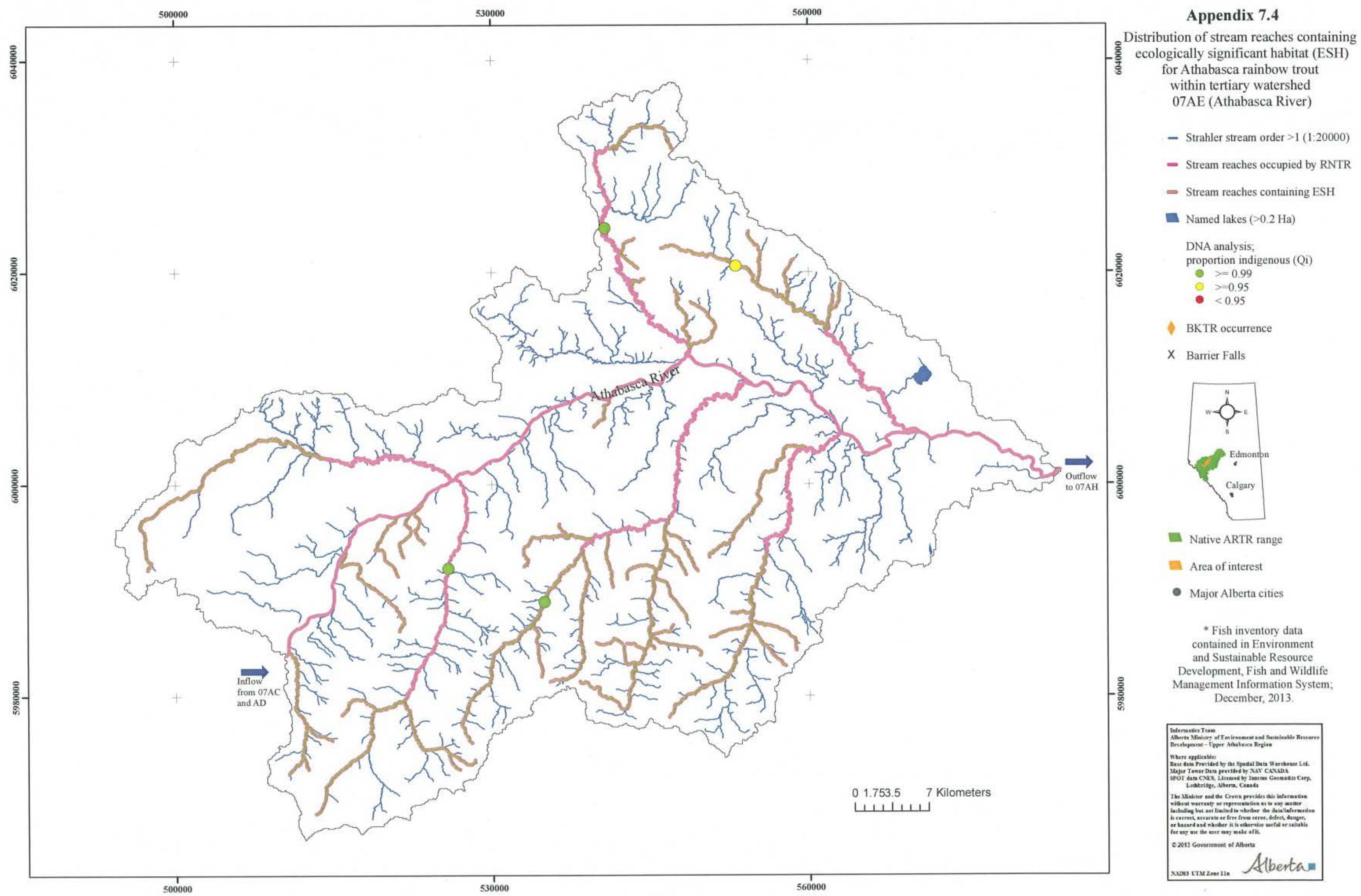

Figure 9. Location of ecologically significant habitat (ESH) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AE (HUC8: 17010501). Appendix 7.4 was reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

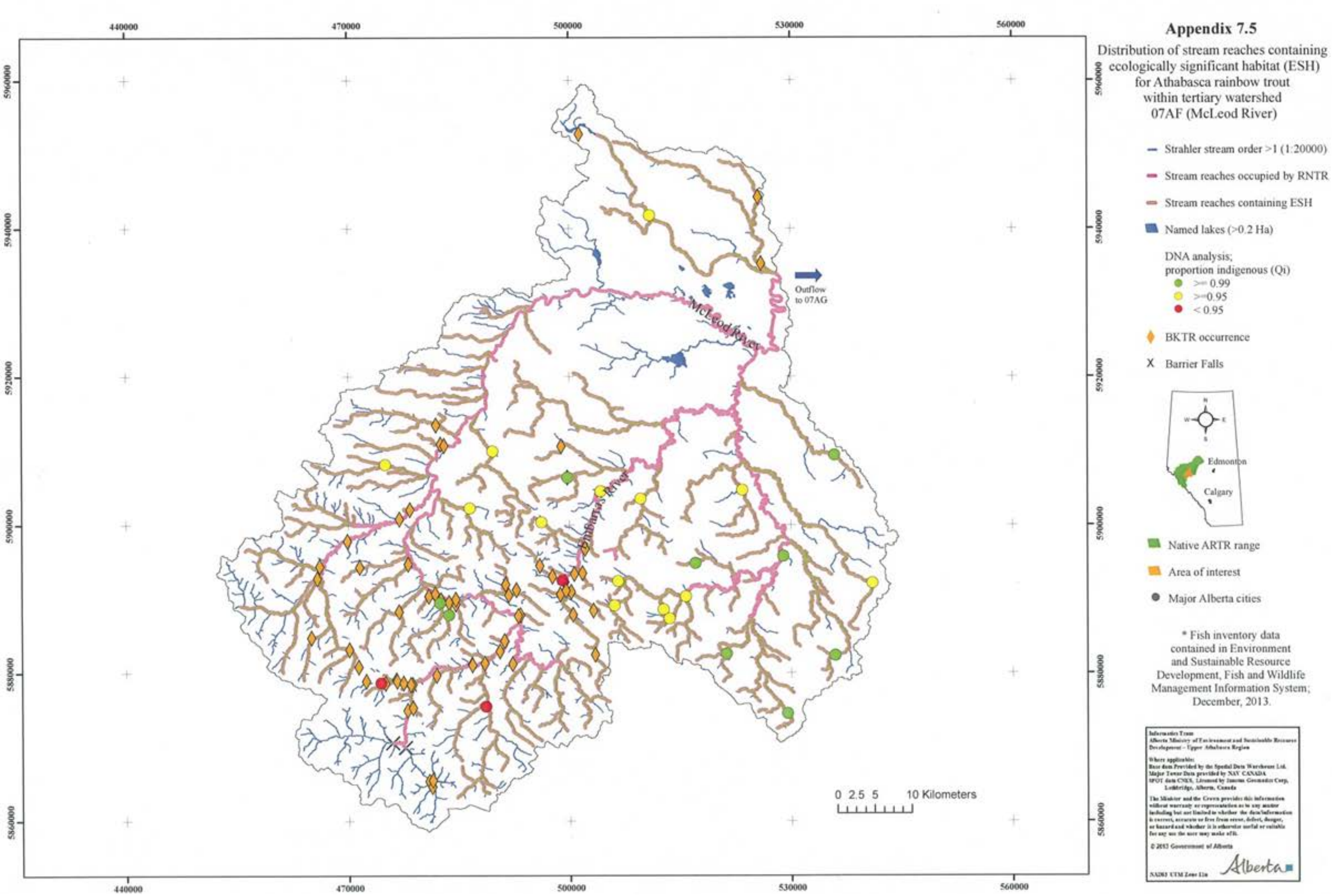

Figure 10. Locations of ecologically significant habitat (ESH) and impassable waterfalls (X) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AF (HUC8s: 17020101 and 17020102). Appendix 7.5 was modified from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

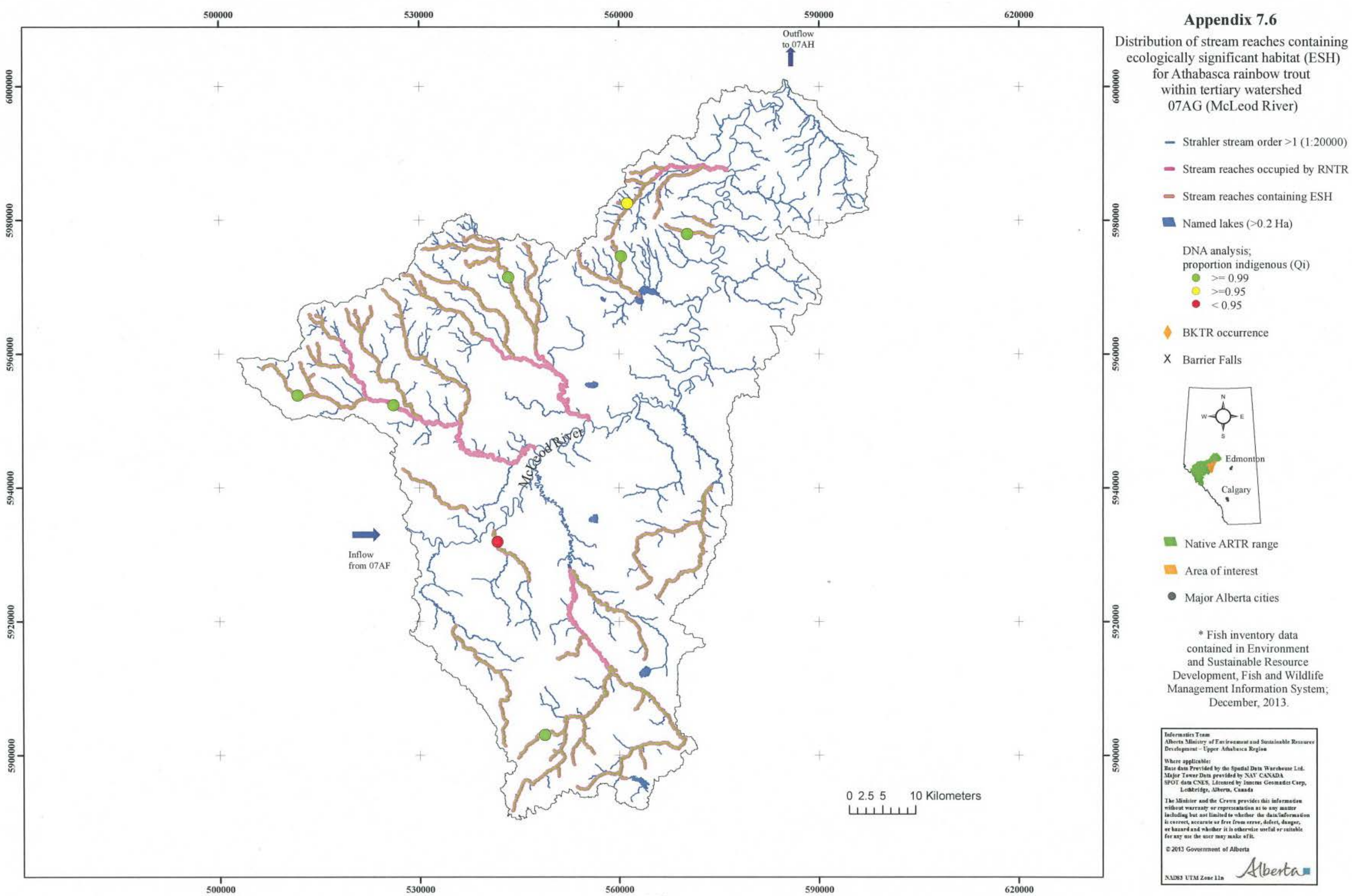

Figure 11. Location of ecologically significant habitat (ESH) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AG (HUC8s: 17020201, 17020202, 17020203 and 17020204). Appendix 7.6 was reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

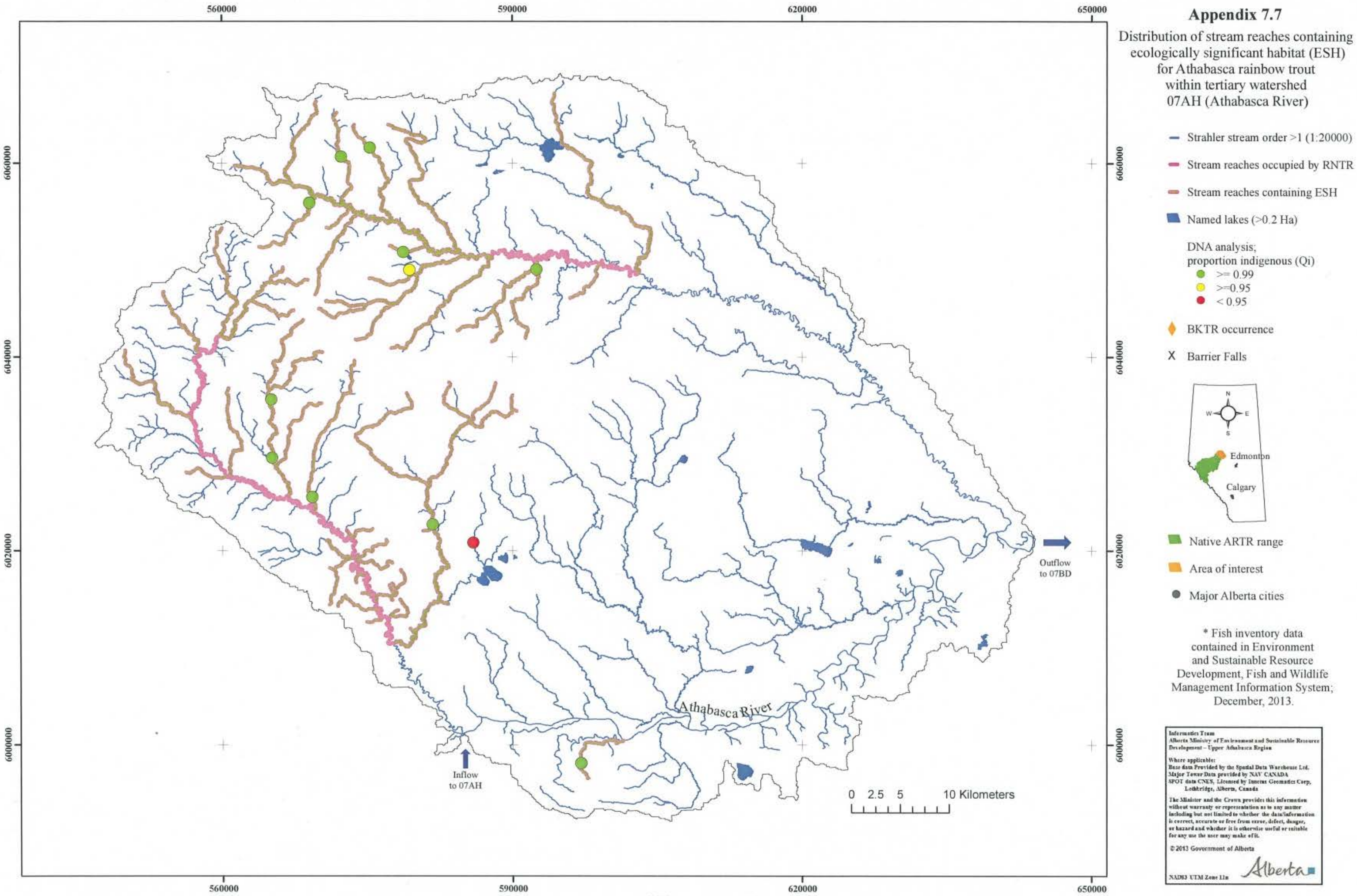

Figure 12. Location of ecologically significant habitat (ESH) identified by Alberta Athabasca Rainbow Trout Recovery Team (2014) in tertiary watershed 07AH (HUC8s: 17010601, 17010602 and 17010603). Appendix 7.7 was reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014). Note: ESH is based on the best information available at the time of delineation.

RESIDENCE

SARA defines a 'residence' as a "dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating" (SARA, Section 2.1). DFO (2015) uses the following four conditions to determine when the concept of 'residence' applies to an aquatic species:

1) there is a discrete dwelling-place that has structural form and function similar to a den or nest;
2) an individual of the species has made an investment in the creation, modification or protection of the dwelling-place;
3) the dwelling-place has the functional capacity to support the successful performance of an essential life cycle process such as spawning, breeding, nursing and rearing; and
4) the dwelling-place is occupied by one or more individuals at one or more parts of its life cycle.

In the context of the information provided in the Reproduction section (p. 9), the redds constructed by Athabasca Rainbow Trout meet all of the conditions for consideration as a residence:

Condition 1: the dwelling-place (redd) is a nest;

Condition 2: the female Athabasca Rainbow Trout made an energy investment in the creation of the redd;

Condition 3: the dwelling-place has the functional capacity to support the successful performance of the essential life cycle processes of spawning, breeding, incubation and alevin development; and

Condition 4: the dwelling-place is occupied by one or more individuals at two parts of the Athabasca Rainbow Trout's life cycle (egg and alevin).

It should be noted that spawning gravel moves from year to year, thus residence locations are temporary.

THREATS AND LIMITING FACTORS TO THE SURVIVAL AND RECOVERY OF ATHABASCA RAINBOW TROUT

NATURALLY OCCURRING LIMITING FACTORS

The most significant natural limiting factor for Athabasca Rainbow Trout is its habitat specificity, particularly water temperature (preferred range: 7–18 °C) and spawning and rearing habitat requirements. These habitat requirements strongly influence the distribution of Athabasca Rainbow Trout (COSEWIC 2014). The restricted distribution of Athabasca Rainbow Trout also makes it vulnerable to stochastic processes. Natural barriers (e.g., waterfalls, beaver dams) may limit distribution. The locations of impassable waterfalls within the range of Athabasca Rainbow Trout are shown in Figures 6 and 10. Additionally, Athabasca Rainbow Trout do not have an outside source of individuals to repopulate (i.e., there is no chance of a rescue effect).

ANTHROPOGENIC THREAT CATEGORIES

Five broad threat categories impacting Athabasca Rainbow Trout have been identified. These include: Invasive Species; Habitat Loss or Degradation; Mortality; Contaminants and Toxic

Substances; and Climate Change. These threats do not occur in isolation and may interact to have cumulative and synergistic effects. The following information has been sourced from Alberta Athabasca Rainbow Trout Recovery Team (2014) and Sawatzky (2017) unless otherwise indicated.

Invasive Species

Non-native species, including fish, aquatic invertebrates, plants and micro-organisms, may become invasive and impact Athabasca Rainbow Trout by contributing to decreased resiliency, range contractions and/or acute mortality. Three subcategories of this threat are considered: Hybridization and Competition; Algae and Aquatic Invertebrate Species; and Pathogens.

Hybridization and Competition

Between 1917 and 2012, an estimated 24 million fish of four main species (non-native Rainbow Trout, Brook Trout, Cutthroat Trout and Brown Trout) were stocked into Alberta waters from which they could escape (i.e., outflow into flowing water). There are no self-sustaining populations of Brown Trout within the range of Athabasca Rainbow Trout. Brown Trout stocking currently only occurs in one minor stream reach (Jarvis Creek between Graveyard and Gregg lakes) with triploid (3N; infertile) Brown Trout. The remainder of these species (non-native Rainbow Trout, Brook Trout and Cutthroat Trout) pose a threat to the survival and recovery of Athabasca Rainbow Trout. Moreover, the range of these species (primarily non-native Rainbow Trout and Brook Trout) has expanded such that they now threaten Athabasca Rainbow Trout and other native Alberta fish species in areas where they have not been stocked. Negative impacts to Athabasca Rainbow Trout include: hybridization/genetic introgression; competition; predation; range constriction; replacement or displacement; and possible exposure to parasites or diseases. Genetic research on hybridization with other species (e.g., Golden Trout, Atlantic Salmon) is continuing.

Non-native Rainbow Trout

Hybridization in the main stem of the Athabasca River has been confirmed downstream to the confluence of Nosehill Creek and in 30 tributary streams. Hybridization has also been confirmed within Jasper National Park in the main stem of the Athabasca River and several tributaries, but many sites remain unsampled. There are also several naturalized lake populations of non-native Rainbow Trout above barrier falls in Jasper National Park (Amethyst, Cabin, Harvey, Maligne, Medicine and Moab lakes). These populations are a source of non-native genes and impact downstream Athabasca Rainbow Trout populations. Current stocking practices exclude lakes with outlets (although there are four exceptions to this), exclude streams and use only 3N domestic strain Rainbow Trout within the range of Athabasca Rainbow Trout; stocking does not currently take place within Jasper National Park. Illegal stocking, however, does occur. Competition is a potential threat, but the impact depends upon the number of non-native Rainbow Trout that escape or are illegally transferred to waters supporting Athabasca Rainbow Trout.

Brook Trout

Outside of Jasper National Park, many streams contain naturalized populations of Brook Trout (Figures 6–12) with the largest distribution in the Embarras, McLeod and Gregg River watersheds and small tributaries to the main stem Athabasca River upstream of the Berland River confluence. In the Berland River watershed, a naturalized population is present in Moberly Creek. Within Jasper National Park, Brook Trout are present in many lakes and most rivers and streams in the Athabasca drainage (Athabasca River above and below Athabasca Falls, Sunwapta River, Miette River and Maligne River). Furthermore, Brook Trout appear to be increasing in proportion in both stocked and colonized streams (Alberta Sustainable Resource Development and Alberta Conservation Association 2009). Competition for space and food is an important factor in community structure as Brook Trout and Athabasca Rainbow Trout appear to function at the same trophic level (Popowich 2005), but Brook Trout grow and reproduce at a higher rate (AESRD unpubl. data in Alberta Athabasca Rainbow Trout Recovery Team 2014). Of 12 streams with trend data and sympatric populations of Brook Trout and Athabasca Rainbow Trout, 10 (83%) showed a decrease in Athabasca Rainbow Trout density associated with an increase in Brook Trout density, while only two streams showed corresponding increases in both species (Figure 5). This indicates that Brook Trout are well-adapted to the habitat in the streams of the upper Athabasca watershed and suggests that replacement of Athabasca Rainbow Trout by Brook Trout poses a significant threat (Alberta Sustainable Resource Development and Alberta Conservation Association 2009).

Cutthroat Trout

Self-sustaining populations of Cutthroat Trout have been established at two locations within Jasper National Park. Cutthroat Trout from the population established in Mowitch Creek colonized Rock Creek (Wildhay River tributary) and potential hybrids have been observed but not genetically confirmed. Cutthroat Trout are also present in the Fiddle River (below Utopia Lake); hybridization with Athabasca Rainbow Trout has not been confirmed. The threat of hybridization is considered moderate due to the current limited distribution of Cutthroat Trout within the range of Athabasca Rainbow Trout.

Algae and Aquatic Invertebrate Species

Invasive invertebrate (e.g., Mud Snails [*Potamopyrgus antipodarum*], Zebra Mussels [*Dreissena polymorpha*]) and algae species have not yet been found in Alberta and generally do not occur in cold streams, but potential exists. *Didymosphenia geminata*, a freshwater diatom native to North America (not considered invasive), has been found in Jasper National Park and one small bloom has been observed (Ward Hughson, pers. comm. in Alberta Athabasca Rainbow Trout Recovery Team 2014). Large blooms decrease habitat for fish and invertebrates, but are unlikely to be found in the small, cold streams inhabited by Athabasca Rainbow Trout. Stocking of invertebrates (e.g., *Mysis* spp.) has occurred in the past and these locations are being monitored.

Pathogens

Pathogens present in Alberta that may impact Athabasca Rainbow Trout include: *Aeromonas salmonicida* (bacterium causing furunculosis), Infectious Pancreatic Necrosis (IPN) virus, and *Myxobolus cerebralis* (parasite that causes whirling disease).

Aeromonas salmonicida

Aeromonas salmonicida is a bacterium which causes furunculosis, an infection of wild and farmed salmonids that is often fatal. There are two main forms of furunculosis – acute and chronic. The acute form is most common and is characterized by widespread haemorrhages and necrosis causing major tissue damage and death within a matter of days (McCarthy 1975). The chronic form is less common and is characterized by the presence of lesions (furuncles) in the muscle and relatively low mortalities (McCarthy 1975). At low water temperatures, onset of infection is delayed and at temperatures below 7–9 °C, the bacteria may remain infectious but fishes are asymptomatic (McCarthy 1975). Stressors, particularly higher water temperatures and overcrowding, increase the fish’s susceptibility to infection (McCarthy 1975). Furunculosis has been confirmed within the range of Athabasca Rainbow Trout, in Obed Lake, likely introduced with stocked trout. Transmission via infected fish and contaminated water is possible

(Ellis 1997), thus introduction to the Athabasca River may represent a significant risk to Athabasca Rainbow Trout, particularly if other stressors are present.

Infectious Pancreatic Necrosis (IPN) Virus

IPN is a viral disease of young salmonids held under crowded rearing conditions. It is highly contagious and often fatal. This virus was introduced into the upper Athabasca watershed through effluent discharge from the Jasper National Park fish hatchery (resulted in closure and decommissioning of the hatchery in 1972). It may also have been introduced into the Wildhay River watershed via Lake Trout stocked in Rock Lake in the mid-1980s. Juvenile Athabasca Rainbow Trout rarely congregate in the densities necessary for the spread of IPN.

Myoxobolus cerebralis

Myxobolus cerebralis is a parasite of salmonids that causes whirling disease. The first case of whirling disease in Canada was confirmed in Johnson Lake in Banff National Park, Alberta in August 2016 (CFIA 2016). It is believed to have been introduced via infected hatchery fish (M. Sullivan, AEP, pers. comm.). It has since been confirmed at an additional 14 locations (Table 10), nine of which are within Banff National Park[1]. Work is continuing to determine the geographic extent of the disease; it has not yet been confirmed within the range of Athabasca Rainbow Trout and severe population declines rarely occur. Moreover, the Athabasca River watershed is the least susceptible to whirling disease of all watersheds in Alberta due to its water temperature and sediment regimes (M. Sullivan, AEP, pers. comm.).

The life cycle of *Myxobolus cerebralis* is complicated and requires two aquatic hosts, namely, the oligochaete worm *Tubifex tubifex* and salmonid fish. This parasite has two important life stages, the myxospore (produced within the salmonid and infective to *T. tubifex*) and the triactinomyxon (TAM) (produced within *T. tubifex* and infective to salmonids) (Elwell et al. 2010). The impacts of the parasite are variable and severe wild trout population declines do not always occur. When high numbers of parasites are present with susceptible fish, however, high mortality rates can result and can lead to severe wild trout population declines (e.g., Upper Colorado River watershed, Colorado [Walker and Nehring 1995, Nehring 2006]; Madison River, Montana [Vincent 1996]) (Elwell et al. 2010). The life cycle of *M. cerebralis* is described by Hedrick and El-Matbouli (2002).

Most salmonid species are susceptible to infection and Rainbow Trout are extremely susceptible, having significantly higher infection rates than Brown Trout and Bull Trout (Hedrick et al. 1999a, Thompson et al. 1999, Baldwin et al. 2000, MacConnell and Vincent 2001). However, one highly domesticated food-fish strain of Rainbow Trout, the GR or 'Hofer' strain, has been found to be resistant to the parasite (Hedrick et al. 2003). Clinical signs of infection are summarized in Australian Department of Agriculture and Water Resources (2016). Signs vary depending on the age of the fish at infection, the infective dose and the species and strain of salmonid. When exposed as fry, Rainbow Trout exhibit the following clinical signs:

- 'Whirling' behaviour (rapid circular/corkscrew swimming) appears approximately 3–8 weeks after infection. This behaviour is caused by lower brain stem and spinal cord compression and constriction (Rose et al. 2000) and may result in death due to exhaustion and/or severe malnutrition.
- 'Black tail' (caudal melanosis) caused by pressure on the caudal nerves controlling pigmentation (Halliday 1976). This may subside under anaesthesia or after death.

[1] As of October 2017, 55 confirmed detections of whirling disease in Alberta are listed on the Canadian Food Inspection Agency website

Whirling behaviour and black tail are rarely exhibited in fish that survive infection, but they may show other signs including:

- Skeletal deformities such as skull depression, misshaped jaws, shortened gill covers and/or spinal curvatures. These deformities can vary significantly in severity and may be difficult to detect.
- Opercular cysts
- Decreased growth rate during the clinical disease stage.

When fish are exposed at older than nine weeks and larger than 4 cm FL, clinical signs are minimal or absent (Ryce et al. 2004, 2005, Elwell et al. 2009). Larger fish may still be infected when parasite doses are high or exposure is sustained for long periods (Bartholomew et al. 2003, Elwell et al. 2009). These signs are not unique to whirling disease, therefore diagnosis must be confirmed by methods that identify the parasite (diagnostic techniques reviewed in Elwell et al. 2009, 2010). Salmonid eggs cannot be infected by the parasite (Putz and Hoffman 1966, Markiw 1991, Elwell et al. 2009) likely because they do not have the physical or chemical cues needed to attract the parasite and they do not contain the tissues required for parasite development (Elwell et al. 2009).

The parasite enters through the skin of the host fish and migrates to the cartilage via the nervous system. This leaves young trout, with a greater amount of cartilage in their skeletons, highly susceptible (MacConnell and Vincent 2001). Susceptibility decreases as fish grow and bone replaces cartilage (Hoffman and Byrne 1974, Halliday 1976, O'Grodnick 1979, Markiw 1991, 1992a, El-Matbouli et al. 1992, Elwell et al. 2009). The likelihood of infection is also affected by life history (when and where spawning occurs, timing of fry emergence, rearing location) and abundance of triactinomyxons (Downing et al. 2002, Kerans and Zale 2002, Elwell et al. 2009). Fry that emerge during the peak release of *M. cerebralis* TAMs from *T. tubifex* are most vulnerable to infection. Peak release of TAMs is dependent on water temperature and usually occurs from June through September (Thompson and Nehring 2000, Downing et al. 2002, Elwell et al. 2009). Athabasca Rainbow Trout generally spawn from late May to June and fry emergence usually occurs in mid-summer (Sterling 1992, Alberta Athabasca Rainbow Trout Recovery Team 2014). The seasonal peak of TAM release is usually in early summer (Elwell et al. 2009). A different pattern of infection has been observed in spring creek systems with year-round moderate or constant water temperatures. In these systems, the highest infection rates were observed in the fall (Anderson 2004, Elwell et al. 2009).

Elevated water temperatures increase the virulence and maturation rate of *M. cerebralis*. TAM production by *T. tubifex* is highest at 10–15 °C (El-Matbouli et al. 1999, Kerans and Zale 2002, Blazer et al. 2003, Kerans et al. 2005, Elwell et al. 2009). The optimum temperature range for parasite growth is 15–17 °C (Halliday 1976, Schisler et al. 2000). Virulence is decreased and TAM production may stop at the 20–25 °C range (El-Matbouli et al. 1999, Blazer et al. 2003, Elwell et al. 2009). Fish infection rates (disease and severity) peak at 10–15 °C and decline rapidly at temperatures above and below this range (Baldwin et al. 2000, Vincent 2002, Hiner and Moffit 2002, Krueger et al. 2006, Elwell et al. 2009). Increased flow rates at the time of emergence may dilute the concentration of TAMs, reducing the parasite dose and lowering the risk to early life stages of trout (MacConnell and Vincent 2001).

Table 10. Locations where whirling disease has been confirmed in Canada as of November 21, 2016 (CFIA 2016).

Date Confirmed	Location
October 26, 2016	Commercial aquaculture facility, licensed by the Government of Alberta
October 26, 2016	Commercial aquaculture facility, licensed by the Government of Alberta
October 21, 2016	Banff National Park – Redearth Creek (upstream from confluence of Bow River and Redearth Creek)
October 21, 2016	Commercial aquaculture facility, licensed by the Government of Alberta
October 17, 2016	Banff National Park – Healy Creek (upstream from confluence of Bow River and Healy Creek)
October 6, 2016	Rocky View County – Lott Creek (upstream from confluence of Lott Creek and Elbow River)
October 4, 2016	Commercial aquaculture facility, licensed by Government of Alberta
September 26, 2016	Banff National Park – Cascade Creek (upstream from confluence of Cascade River and Carrot Creek)
September 26, 2016	Banff National Park – Spray River (upstream from confluence of Bow River and Spray River)
September 26, 2016	Banff National Park – Carrot Creek (upstream from confluence of Cascade River and Carrot Creek)
September 26, 2016	Banff National Park – Bow River (near Tunnel Mountain)
September 26, 2016	Banff National Park – Lower Cascade River (upstream from confluence of Bow River and Cascade River)
September 26, 2016	Banff National Park – Bow River (downstream from confluence of Bow River and Carrot Creek)
September 7, 2016	Banff National Park – Bow River (downstream from confluence Bow River and Cascade River)
August 23, 2013	Banff National Park – Johnson Lake

The presence of multiple stressors may exacerbate the impacts of whirling disease, causing population-level effects (Schisler et al. 2000). Land uses that increase sediment input to streams (e.g., roads, agriculture) have been shown to be positively correlated with whirling disease infection in Rainbow Trout (McGinnis 2007, Elwell et al. 2009). The availability of *T. tubifex* habitat also impacts infection rates. Schisler and Bergersen (2002) found that *T. tubifex* habitat is negatively correlated with elevation. The lower sediment loads and organic content typical of higher elevation waters limits the availability of *T. tubifex* habitat. This confers a certain degree of protection from *M. cerebralis* to many trout populations.

Fully developed myxospores appear in the cartilage of the host fish 52 days after infection at 16–17 °C. The myxospores remain in the cartilage and may be trapped as bone forms around this cartilage. The decomposition of one infected Rainbow Trout can release more than one million myxospores (Hedrick et al. 1999b, Australian Department of Agriculture and Water Resources 2016). Once released from the host fish, myxospores are dispersed into the water where they survive for a variable length of time. Hedrick et al. (2008) found that myxospores remained infective to *T. tubifex* for at least two months at 4, 10, and 20 °C (although infection rates were low at 20 °C). Other studies have shown that they remain infective to *T. tubifex* for up to five months in mud at 13 °C (El-Matbouli and Hoffmann 1991) and for 6–12 months at temperatures from 5–15 °C (Nehring et al. 2015, Australian Department of Agriculture and Water Resources 2016). TAMs released by *T. tubifex* are infective to susceptible fish for 6–15 days or more at 7–15 °C (El-Matbouli et al. 1999, Markiw 1992b, Australian Department of Agriculture and Water Resources 2016).

Migratory salmonids generally return to their natal streams, but they are also known to stray. One infected stray fish can potentially be the source of *M. cerebralis* introduction into a new area, as found for the Deschutes River, Oregon (Engelking 2002, Zielinski 2008, Elwell et al. 2009). Myxospores may also be transported by migratory piscivorous fish which move long distances, releasing viable myxospores in their feces (El-Matbouli and Hoffmann 1991, Arsan and Bartholomew 2008, Elwell et al. 2009). Myxospores can survive passage through the gut of piscivorous birds as well (Koel et al. 2010, Australian Department of Agriculture and Water Resources 2016) and may also be transported on the feet and fur of mammals (mammalian digestion has been shown to deactivate myxospores [El-Matbouli et al. 2005, Elwell et al. 2009]). Other sources of infection include: anglers, boaters and other recreationalists via transport of sediment (e.g., myxospores are able to survive on wading boots; P. Reno, Oregon State University, pers. comm. in Elwell et al. 2009), plant materials and small animals (Elwell et al. 2009), release of infected *T. tubifex* by the aquarium trade (Lowers and Bartholomew 2003, Hallett et al. 2005), improper disposal of infected fish parts, use of infected fish parts as bait, effluent from commercial fish processing (Arsan and Bartholomew 2008) and illegal transfers of infected fish (highest risk human activity) (Elwell et al. 2009).

Habitat Loss or Degradation

All watersheds within the range of Athabasca Rainbow Trout have been impacted by anthropogenic activities to some degree. The main issues associated with the resulting habitat loss or degradation include: alteration of natural flow regimes (alteration of peak flow intensity, roads, dams, water withdrawals), alteration of stream temperature, sediment deposition, and habitat fragmentation.

Alteration of Natural Flow Regimes

Flow regime changes may be caused by natural disturbances (e.g., floods, fire), construction and operation of dams and reservoirs, forest harvesting, the removal of forest for roads, pipelines, other oil and gas infrastructure, urban and agricultural development and water withdrawals in support of these developments. The impacts of the alteration of peak flow intensity, roads, dams and water withdrawals are discussed below.

Alteration of Peak Flow Intensity

Peak flows result from spring runoff and storm events and are fundamental components of fluvial ecosystems affecting channel morphology, sediment transport and instream habitat characteristics. Peak flow intensity increases with increasing water yield. Water yield increases with catchment basin disturbance and the extent depends on forest harvest practices and the ecological region (Ripley et al. 2005). Increased peak flow intensity may destabilize channels, scour gravel beds (Athabasca Rainbow Trout eggs are vulnerable to scour), speed bank and riparian zone erosion, cause stream widening, dislodge stable woody debris and displace fish (particularly early life stages). Small streams are more easily impacted than large streams.

There are six Forest Management Areas comprising over two million hectares currently active in the range of Athabasca Rainbow Trout. In 2012, approximately 27,000 hectares were harvested (AESRD 2012b). A rotation age for sustainable forest management of approximately 75–80 years, similar to the historic fire cycle in the Upper and Lower Foothills Natural Subregions, is followed. Stream flow regime changes caused by forest harvesting may persist for several decades (Hartman and Scrivener 1990) before they subside, and this may not occur before the second or third cutting.

Roads

Roads capture and concentrate surface and subsurface water flow into ditches, increasing delivery of water and sediment to stream channels. This increases the magnitude and frequency of high flows and siltation events. Road density location (hillside vs. valley bottom), watershed characteristics (topography, soils, geology) and watershed size influence the magnitude of impact. Smaller tributary watersheds are more easily affected. The risk of erosion throughout much of the range of Athabasca Rainbow Trout is already very high due to the surficial geology of the region (glacial deposition area).

Dams, Hydro

In addition to fragmenting habitat, dams alter natural flow regimes of large rivers and the littoral zone in reservoirs through seasonal draw down and reservoir filling. There are no major dams within the range of Athabasca Rainbow Trout, and none are currently proposed. A number of potential sites in Alberta were considered in a review of hydroelectric potential, and most sites within the range of Athabasca Rainbow Trout were ranked as having low potential to meet current needs (Alberta Utilities Commission 2010). Future dam construction at any site within the range of Athabasca Rainbow Trout would be significantly detrimental to the entire fish community. Run of the river facilities and low-head dams also pose a threat to Athabasca Rainbow Trout; two such dams were proposed in Jasper National Park in 2016. Pumped hydro facilities are also present in the Athabasca drainage. Water is removed from the Athabasca River and put into a reservoir. From there it is pumped uphill to another reservoir. When the water runs back downhill electricity is created. These are generally closed systems and there are currently four proposed (as of 2016), one in the Canyon Creek area. Impacts may include water loss to evaporation and potential reservoir breaches resulting in sediment loading.

Water Withdrawal

As of 2012, there were 69 Water Act Licenses and 1,474 Water Act Registrations registered within the range of Athabasca Rainbow Trout totalling approximately 131 million m^3. Annually, approximately 26% of this volume is reported as consumed. AEP guidelines recommend avoidance of streams ≤ fourth-order and reduced pumping rates in winter, and mandatory reporting of usage for Temporary Diversion Licenses >1000 m^3 of surface water for road dust control, well drilling, hydrostatic testing and well fracturing. The total annual use of surface water by Temporary Diversion licensees is unknown. Although not a problem at the current time, water withdrawal within the range of Athabasca Rainbow Trout is a great concern for the future (M. Sullivan, AEP, pers. comm.).

Alteration of Stream Temperature

Athabasca Rainbow Trout require cold water for survival of all life stages and are therefore susceptible to watershed disturbances that contribute to increased water temperature. Temperature increases are directly proportional to the area of the stream exposed to sunlight and inversely proportional to stream discharge. Groundwater or hyporheic influences may moderate effects of disturbances that lead to increases in water temperature. Disturbances such as forest harvesting, road development, culverts and grazing on riparian vegetation may increase water temperatures. The greatest changes occur when riparian vegetation alongside small streams is removed, particularly during early summer.

Following forest harvesting, riparian canopy removal and understory disturbance in the Tri-Creeks study area, increases in mean annual water temperature and summer maximum temperatures up to near lethal (24 °C) levels were observed. Higher temperatures decrease thermally suitable habitat for Athabasca Rainbow Trout and lead to decreased abundance and range contraction. Marginal increases may improve productivity, but may also increase the risk of invasion of introduced species with higher temperature tolerances than Athabasca Rainbow Trout (e.g., Brook Trout), alter egg and juvenile development, slow growth, decrease survival, impact timing of life history events, block upstream migrations and increase disease (e.g., whirling disease). Additionally, negative impacts to groundwater, such as those caused by forest harvesting (e.g., reduced groundwater causes lower water temperatures in winter resulting in longer incubation periods) pose a threat to Athabasca Rainbow Trout.

Forest harvesting practices in Alberta stipulate the retention of buffers based on stream classification and this may or may not include the riparian zone. In upland areas of Alberta, harvesting practices follow natural disturbance models that mimic fire frequency. A similar regime has been proposed for riparian areas. Intact riparian zones provide shade and thus reduce the surface area of water exposed to sunlight. Moreover, removal of riparian zones exposes soil adjacent to the water which, by conducting heat, contributes to an increase in water temperature.

Suspended and Deposited Sediments

Excess fine sediment decreases ecosystem productivity, promotes invasive species, damages habitats and has lethal and sublethal effects on fish. Suspended and deposited sediments can degrade spawning, rearing and overwintering habitats and also degrade habitat necessary for the production of aquatic invertebrates. The severity of impact depends on timing, quantity of sediment and size of the affected stream. Sedimentation increases mortality, particularly for young-of-the-year and incubating eggs (through entombment). In the Tri-Creeks study area, a doubling of fine sediment in spawning areas decreased Athabasca Rainbow Trout embryo survival by more than seven fold.

Road stream crossings typically contribute higher loads of fine sediments to streams than all other land use activities combined. Within the range of Athabasca Rainbow Trout, sediment loading downstream of road crossings was found to be higher than upstream. Temporary crossings (< 3 year life-span) constructed during exploration or forest harvesting on small, intermittent and ephemeral headwater streams often cause the most problems because of their high density. Sediment input is highest during construction, but effects are evident until vegetation re-growth occurs. Logging and road construction also increase the frequency of landslides and the resulting sediment increase may cause widening of main stem channels, infilling of coarser substrates and blocking of side channels. Sediment in surface water runoff also increases with infrastructure development around oil well sites.

Off-highway vehicle (OHV) trail crossings and traffic along and within streambeds is a major issue in Alberta. It erodes banks and disturbs streambeds, increasing the levels of suspended sediment. High levels of OHV use cause stream channels to widen, shallow and braid, decreasing habitat quality. Some areas along the eastern slopes in Alberta have required reclamation from the effects of OHV use (e.g., Wapiabi Creek, Ruby Lake, Cardinal River). OHV use also directly destroy redds.

Unmanaged livestock grazing/watering in riparian areas also contributes to sediment loading and may directly destroy redds through trampling.

Habitat Fragmentation

Connectivity (i.e., unobstructed passage through watersheds) is a key habitat requirement for migratory Athabasca Rainbow Trout. It is important in linking spawning, rearing and overwintering habitats and in linking populations to facilitate gene flow and aid in the re-establishment of declining populations. Habitat fragmentation is caused by the creation of migratory barriers including elevated or undersized culverts, dams without fish passage facilities, and land use practices (e.g., mining) that negatively impact habitat making it uninhabitable for Athabasca Rainbow Trout. The impacts to Athabasca Rainbow Trout may include range contractions and population declines and barriers may impede or preclude fish assemblage recovery following a disturbance. In some cases, if habitat fragmentation was reduced, it would allow recolonization in the event of local extirpations; however, it may also allow other competing species (e.g., non-native Rainbow Trout, Brook Trout) access to the same habitat resulting in increased competition and/or hybridization.

Culverts

When the streambed below the downstream end of a culvert erodes, it creates an elevated or hanging outfall that fish are unable to enter. This can also occur when culverts are improperly installed, undersized culverts are used or the downstream streambed is inadequately armoured. Where culverts are elevated or steeply sloped they are often impassable to fish, blocking upstream movements of spawners and removing access of juveniles to seasonal refuges from anchor ice and floods. Culverts may also create velocity barriers, increase sedimentation and disrupt the transport of large woody debris. This is a province-wide issue in Alberta, the scope of which continues to increase as the road network expands. MacPherson et al. (2012) found that Rainbow Trout densities were higher upstream of culverts with the steepest slopes (>5.7%) and upstream of those with larger hang heights (>0.42 m). Upstream passage of Rainbow Trout appeared to be highest when outlet pool depths were greater than 1 m. Although, the authors do caution that the observed densities may be an artefact of self-sustaining populations above complete barriers or that the higher water temperatures, and therefore increased stream productivity, upstream of culverts may be selected for by Rainbow Trout. Park et al. (2008) found that half of the culverts surveyed (187 of 374) in four watersheds in Alberta (outside of the range of Athabasca Rainbow Trout) were hanging and thus represented barriers to upstream movement of fishes.

Dams and Weirs

Dams that do not have fish passage facilities create barriers to upstream fish passage, blocking access to spawning and rearing habitat and isolating populations. Dams may cause direct mortality when fish are not prevented from passing through turbines (entrainment). Dams may also alter or withhold flows from areas that may otherwise have been accessible. There are no major dams present or proposed within the range of Athabasca Rainbow Trout. Locations of the dams and weirs present within the native range (Table 11) are shown in Figure 13. None of these dams represent barriers to Athabasca Rainbow Trout. Settling ponds and berms are an extended feature of industrial activity in this area and are a serious concern.

Table 11. Characteristics of dams and weirs present within the range of Athabasca Rainbow Trout (information provided by the Government of Alberta Dam Safety Office).

Dam Name	HUC8	Height (m)	Capacity (dam^3)	Purpose
Stabilization Pond Main Dam	17010401	Unknown	Unknown	Lake Stabilization
Fickle Lake Stabilization Weir	17020101	Unknown	Unknown	Lake Stabilization, Recreation
Blue Ridge Lagoon Embankment	17010602	3.00	37.0	Municipal Water Supply (Raw)
Effluent Lagoon Main Dam	17010602	Unknown	Unknown	Waste Water Management
Goose Lake Stabilization Weir	17010602	3.65	12,894.9	Lake Stabilization
Sewage Lagoon Cells Embankment	17010603	6.40	249.9	Municipal Water Supply (Raw)

Land Use Practices

Open pit coal mining is expanding in the range of Athabasca Rainbow Trout. Active coal mining operations have caused the loss of nearly 15 km of Athabasca Rainbow Trout spawning and early rearing habitat in the Embarras, Erith, upper McLeod and Gregg River watersheds. Most end pit lakes do not provide adequate habitat for all life stages of Athabasca Rainbow Trout and are thus not considered habitat compensation.

Nutrient Loading

Increases in nutrients from sources such as agricultural runoff, intensive livestock operations, unmanaged livestock grazing/watering, pulp and paper mills, mountain pine beetle management, train derailments, sewage treatment plants and other municipal sources can speed eutrophication thereby causing algal blooms which lead to decreased concentrations of dissolved oxygen (DO) as the blooms die. Low concentrations of DO impact fish survival and reproduction by increasing susceptibility to disease, slowing growth, decreasing swimming ability and changing survival behaviours (e.g., predator avoidance, feeding, migration, reproduction). Furthermore, the acute toxicity of most contaminants is increased under low dissolved oxygen conditions. Fish may also be impacted indirectly through reduced survival of prey. Increased nitrogen and phosphorous can also increase the biodegradation of petrochemicals, aromatic hydrocarbons and pesticides in aquatic ecosystems and can be associated with outbreaks of parasites. Dissolved oxygen levels generally decrease naturally during winter in ice-covered rivers such as the Athabasca; however, effluents have caused marked ‘sags’ in DO below discharge areas and have contributed to increased rates of DO decline over 10s to 100s of kilometres (Chambers et al. 1997). Winter DO levels in the Athabasca River within the range of Athabasca Rainbow Trout have fallen below acceptable thresholds on occasion. There are four major urban centers, two large pulp mills, one newsprint mill, four hamlets and several gas plants within the range of Athabasca Rainbow Trout. Combined, these discharge an estimated 53.807 million m^3 of effluents per year into rivers and streams.

Mortality

Intentional harvest of Athabasca Rainbow Trout has been prohibited in all streams and rivers throughout their range since 2012 with the exception of Jasper National Park where anglers are permitted to keep two per day. Illegal harvest, however, does occur and impacts to small, isolated populations could be severe. Post-release mortality rates for Athabasca Rainbow Trout are unknown, but data for other salmonid populations in Alberta suggests a mortality rate of 3–5% or higher (possibly up to 25% when water temperatures are high or bait is used). Such rates may result in significant population-level impacts. Indigenous fishing within the range of Athabasca Rainbow Trout occurs in specific lakes that support Lake Whitefish and non-salmonids and is not considered a risk to Athabasca Rainbow Trout.

If harvest quotas for Brook Trout were increased to reduce competition with Athabasca Rainbow Trout, the potential for misidentification and therefore mortality could pose a threat to Athabasca Rainbow Trout. Fish caught with bait or artificially scented bait display higher post-release mortality, thus allowing the use of bait in some waters for the harvest of Mountain Whitefish also poses a threat to Athabasca Rainbow Trout. If Rainbow Trout harvest were to be allowed in the future to reduce hybridization between non-native Rainbow Trout and Athabasca Rainbow Trout, restrictions on gear type, fish size and season would be needed to reduce the risk to Athabasca Rainbow Trout.

Scientific research (typically electrofishing surveys) carries a risk of mortality, but this risk is very low provided Alberta provincial standards for protecting fish health are followed. Lethal sampling, necessary to better understand population responses to management strategies (e.g., age, growth, maturity, fecundity), is only considered in areas where populations are at low risk (e.g., Tri-Creeks Experimental Watershed).

Contaminants and Toxic Substances

Contaminants may have lethal or sublethal effects on Athabasca Rainbow Trout. Sublethal effects include decreased egg production, reduced survival, behavioural changes, reduced growth, impaired osmoregulation, and many subtle endocrine, immune and cellular changes. Contaminants and toxic substances may also indirectly harm Athabasca Rainbow Trout by reducing prey availability. Lethal effects are most often caused by spills, whereas sublethal effects occur from land uses (e.g., agriculture, residential/urban, mining, livestock grazing and forestry). Examples of contaminant types from these land uses include pesticides, persistent organic pollutants, mercury and endocrine disrupting substances.

There are approximately 550 pesticide active ingredients registered in Canada under the Pest Control Products Act. Herbicides are the most common type of pesticide sold and applied in Alberta and the agricultural sector accounts for the majority of pesticide sales. As of 2011, the Upper Athabasca region had 4,601 farms on 3,513,316 acres (Alberta Agriculture and Rural Development 2014). The majority of this land (46%) is devoted to crops and 23% to natural land for pasture, 18% to tame/seeded pasture, 1% to summer fallow, and 12% to all other farm land. Of the seven land use regions in Alberta, the Upper Athabasca ranks fifth in terms of the number of acres used for farm land, higher only than the Lower Peace and Lower Athabasca regions. Agricultural pesticides reach surface waters primarily through surface runoff, spray drift/atmospheric deposition and soil erosion. Higher precipitation increases the likelihood of pesticides entering surface waters through runoff, leaching to groundwater and soil erosion. Lower precipitation levels in parts of Alberta suggest a decreased incidence of pesticides entering surface waters, however, when precipitation events do occur, the pesticide concentrations in runoff can be relatively high. Changes in agricultural practices as a result of climate change may alter pesticide use patterns and increased pesticide use may be required to deal with introduced pests.

Herbicide use is a common silviculture practice in Canada, with glyphosate being the most common active ingredient. Glyphosate is used to control plants that compete with pine and spruce following harvesting activity. Glyphosate is also the active ingredient in Roundup® and

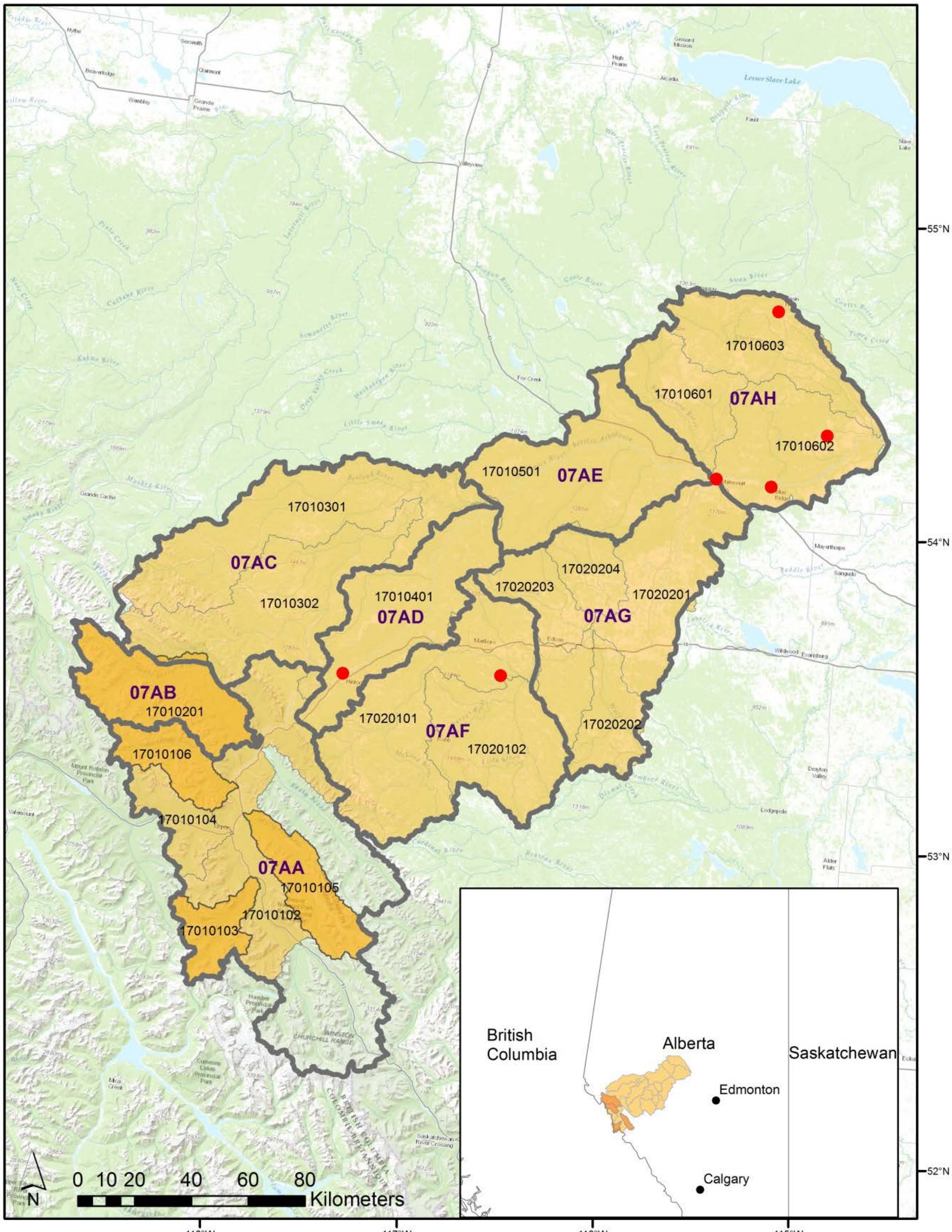

Figure 13. Location of dams and weirs (•) within the range of Athabasca Rainbow Trout. Dam locations were provided by the Government of Alberta Dam Safety Office.

the development and widespread use of genetically modified 'Roundup® ready' crops have allowed the agriculture industry to increase the amount of glyphosate used. For example, between 2008 and 2013, glyphosate use increased 41.5% in the agricultural sector of Alberta (AEP 2015). Amphibians, fish, zooplankton and aquatic plants are sensitive to glyphosate. Risks are minimized by proper training, use of modern application technologies and by establishing protective buffers. In Ontario, toxicologically significant amounts of glyphosate were found approximately 30–50 m outside of target zone boundaries, confirming the protective value of 60–120 m buffers imposed to protect aquatic ecosystems. The buffer for aerial spraying of glyphosate in Alberta is 5 m.

Mercury and other metals, organochlorines (e.g., DDT, PCBs) and fire retardant chemicals enter mountain waterbodies through transport from distant sources in polluted air masses and fall as rain, snow or dry gaseous fallout. Sources include long range transport from Eurasia, the Pacific Northwest and California. Historically deposited contaminants (e.g., DDT, endosulfan, PCT) are also of concern for lakes and rivers receiving glacial melt waters. Additionally, contaminants from landfills, including metals and volatile organics, are often detected in aquifers several kilometers from landfill sites.

Endocrine disrupting substances (EDS) include certain pharmaceuticals, pesticides, industrial chemicals, metals and natural compounds. EDS are found in municipal, agricultural, textile, pulp and paper, and mining effluents. They may have effects on growth, development and reproduction of biota at very low concentrations and these effects may be expressed in future generations.

Municipal wastewater effluents (MWWE) are made up of human waste, suspended solids, debris and various chemicals from residential, commercial and industrial sources. MWWE are the largest source of effluent discharge to Canadian waters and they will continue to increase with population growth and urbanization. The phosphate alone in MWWE has caused major fish kills (M. Sullivan, pers. comm.). Sludges produced by municipal wastewater treatment plants are spread on the land and the effects of this on surface and groundwater are yet to be determined.

Contaminant concerns at active mine sites include chronic effects of metals, bioaccumulation, sediment contamination and endocrine disruption. Abandoned or closed mine sites are also a source of contaminant input to local water systems. Coal mining within the range of Athabasca Rainbow Trout has caused widespread selenium (Se) loading to surface waters in the upper McLeod watershed. Selenium is an essential nutrient, but is toxic at concentrations only slightly higher than the required amount. Selenium bioaccumulates in tissues and may reach levels in fish eggs high enough to impact embryonic development. Embryonic deformities have been documented in Rainbow Trout in the upper Athabasca River watershed. Rainbow Trout may be more sensitive to Se than Cutthroat Trout or Brook Trout. Reclaimed strip mines can continue to discharge Se at the same rates as active mines and there is no evidence that any of the reclamation strategies used in Alberta mitigate this. The Luscar Coal Valley and Cheviot mines currently operate within the range of Athabasca Rainbow Trout and several other mines are proposed in the area.

Oil spills/leaks (e.g., pipeline leaks, train derailments) and mine tailings pond failures are potential threats. Hydraulic fracturing ('fracking') has the potential to impact surface- and ground-water quality. Fracking is an unconventional process to extract oil and gas from shale formations. A mixture of large volumes of water (approximately 4 million gallons per fractured well), chemicals and proppants (e.g., sand) is injected into a drilled well at high pressures, causing the shale to fracture and the natural gas to flow to the surface through the fractured well. Two of the five main shale gas formations in Canada are found in Alberta. Impacts may occur from the spilling of chemicals and/or fracking fluid during transport, storage or use; accidental release of flowback water from the well; leakage of methane gas into groundwater caused by deteriorating wellbore seals; and inadequate storage, treatment or disposal of flowback and/or produced waters. As of 2014, 81 chemicals used in fracking fluid have been identified; however, many others are proprietary and undisclosed. Of these 81 chemicals, mammalian toxicity data does not exist for 30 of them; the majority of the remainder are non-toxic or low toxicity. Water quantity and quality are also impacted by the large water withdrawals. These may decrease stream flow and result in increased concentrations of contaminants. Additionally, sediments in surface water runoff increase as a result of infrastructure development around well sites.

The Government of Canada's Federal Contaminated Sites Inventory lists 59 contaminated sites within the range of Athabasca Rainbow Trout (Figure 14). Types of contaminants include: petroleum hydrocarbons; polycyclic aromatic hydrocarbons; metal, metalloid, and organometallic; other organics; other inorganics; nuisance substances; and other physical/chemical (e.g., pH, temperature, dissolved solids, turbidity, etc.).

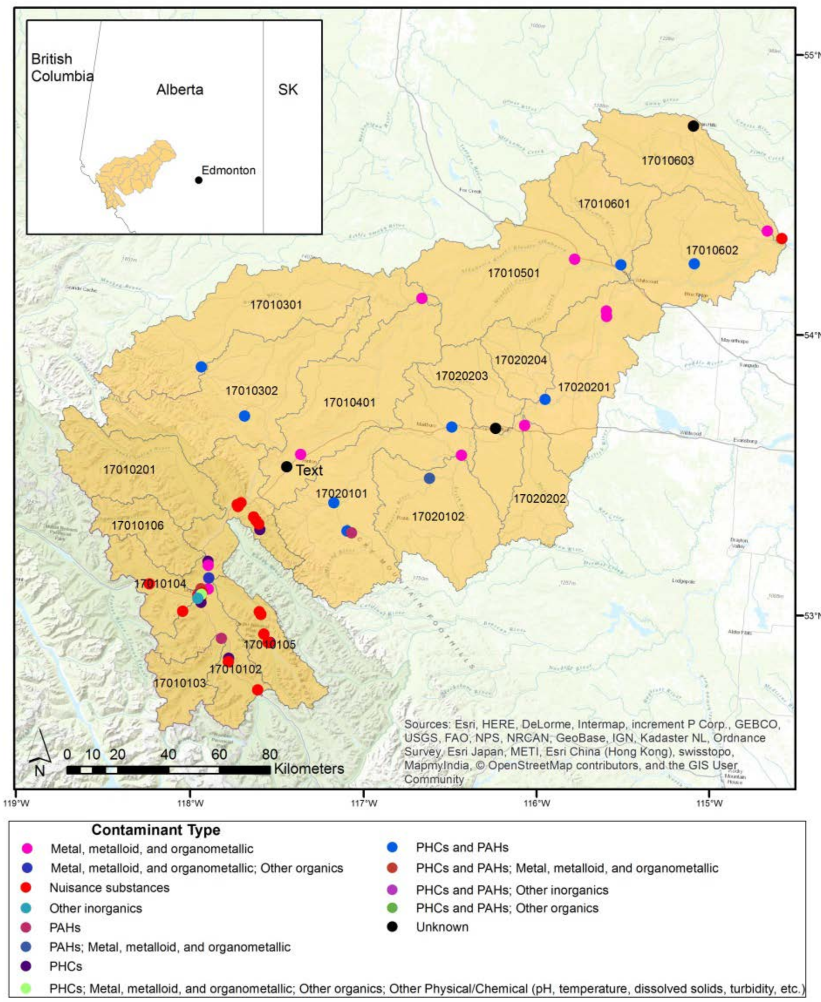

Figure 14. Locations of contaminated sites and types of contaminants within the range of Athabasca Rainbow Trout. PHCs – petroleum hydrocarbons, PAHs – polycyclic aromatic hydrocarbons. Data retrieved from the Federal Contaminated Sites Inventory.

Climate Change

The main ways by which climate change affects Athabasca Rainbow Trout include: altered thermal regimes (and corresponding oxygen levels); altered water volume and delivery schedules that affect snow pack (winter delivery and/or spring freshet) and/or heavy precipitation events that cause flooding (increases sediment and phosphate inputs) and habitat scouring; and effects of late summer flows as a result of glacial drawdown over sequential seasons (Sterling pers. comm. in COSEWIC 2014). In parts of Alberta, the mean temperatures of the warmest month have increased by at least 1 °C, the frost-free period has increased by close to 20 days and growing-degree-days (GDD) have increased by up to 200 GDD >5 °C. One impact of the extended frost-free period is increased access for recreationalists. Precipitation-as-rain has been increasing in the northern mountains, parkland and northern foothills, and has been stable or declining in other areas of the province. Precipitation-as-snow is stable, or possibly declining, in most regions. With little to no increase in precipitation and warmer temperatures, the amount of water lost to evaporation is not being replaced at the same rate, compounding the effects of warmer temperatures on fishes. Furthermore, predicted warming may increase evaporation by as much as 55% in some areas of the western prairie provinces. The Intergovernmental Panel on Climate Change models scaled to Alberta predict that in five regions of the province (boreal, foothills, montane, parkland and prairies) the mean temperature of the warmest month will increase by approximately 3 °C by 2080. The frost-free period is projected to increase by an estimated six weeks (begin approximately three weeks earlier in spring and end approximately three weeks later in autumn). The worst case scenario of the Environment Canada CESM2 climate model downscaled to Alberta predicts that the impacts of climate change will cause the extirpation of Athabasca Rainbow Trout within 100 years (M. Sullivan, AEP, pers. comm.). Thus, while not an immediate threat to Athabasca Rainbow Trout, climate change is a significant future threat.

Climate warming is also causing glacial retreat. Snowpack and glacial meltwater maintain river and groundwater supplies. The Bow, Saskatchewan and Athabasca glaciers now end at least 1.5 km upslope of their position in the early 20th century and are shrinking rapidly. There are no predictions as to when these glaciers may disappear, however, the US Geological Survey predicts that the smaller glaciers in nearby Glacier National Park, Montana will have disappeared by 2030. The glaciers in Alberta will likely persist longer than those farther south. In the Canadian western prairie provinces, it is predicted that due to their decline, winter snowpacks will contribute just over half of the water they presently do. The spring melt is also predicted to occur earlier in the year, compounding the effects of drought. Higher latitudes and altitudes will be most impacted by these conditions as climate continues to warm.

Extreme weather events (e.g., floods, droughts) are predicted to increase as climate warms, but there is uncertainty as to the extent. Large floods may cause bed scour strong enough to destroy Athabasca Rainbow Trout redds, embryos and alevins prior to emergence and may displace newly emerged fry as they are unable to hold their position in high velocity water. Drought conditions may lead to an increase in wildfires which, in turn, may cause loss of riparian vegetation thereby reducing shade and causing an increase in water temperature. Large disturbances following a severe wildfire, such as extreme flooding, silt and ash loading, pH changes, release of toxic organic and inorganic compounds, increased water temperature, decreased dissolved oxygen concentration and debris flow, may cause local extirpations. Furthermore, the fire suppressants and fire retardants used to fight wildfires are toxic to fish populations (including Rainbow Trout) (Gaikowski et al. 1996, Buhl and Hamilton 2000). Longer term effects, such as changes in channel form and increased water temperatures, may cause changes in riverine food webs, have temperature-related physiological impacts on fish and increase mortality or local extirpations if water temperatures increase beyond lethal limits.

Streams with healthy, intact riparian zones and/or groundwater inputs are less likely to be impacted by warmer air temperatures and genetic diversity in populations can offer resilience to the effects of climate warming.

Interactive and Cumulative Effects

FEMAT (1993, p. IX-8) defines cumulative effects as “those effects on the environment that result from the incremental effect of the action when added to past, present and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time”. Effects can cumulate in a number of ways. The Canadian Environmental Assessment Research Council and the US National Research Council identified five key types of perturbations (CEARC and US NRC 1986, p. 161):

- Time-crowded Perturbations – Cumulative effects can occur because perturbations are so close in time that the effects of one are not dissipated before the next one occurs.
- Space-crowded Perturbations – Cumulative effects can occur when perturbations are so close in space that their effects overlap.
- Synergisms – Different types of perturbations occurring in the same area may interact to produce qualitatively and quantitatively different responses by the receiving ecological communities.
- Indirect Effects – Cumulative effects can be produced at some time or distance from the initial perturbation, or by a complex pathway.
- Nibbling – Incremental and decremental effects are often (but not always) involved in each of the above categories.

The impacts of multiple stressors acting at the same time may also interact in various ways. They may be additive (effect is equal to the sum of the impacts when each acts alone), synergistic (effect is greater than the sum of the individual stressor impacts), or antagonistic (effect is less than additive). Several studies examining the impacts of two stressors acting at once found that antagonistic effects are generally more common (e.g., Darling and Côté 2008, Piggott et al. 2015, Jackson et al. 2016, Radinger et al. 2016), however, net effects may still be detrimental. Jackson et al. (2016) found this to be particularly true at the community and organismal levels (antagonistic effects 40.88 and 65.22% of the time, respectively) in freshwater ecosystems. Synergies may be more predominant if there are three or more stressors acting on the same system (e.g., Przeslawski et al. 2005, Mora et al. 2007, Darling and Côté 2008). The impact of cumulative effects may be even greater for species living in less than ideal habitat, nearer to their environmental tolerance limits.

Climate change can interact with other stressors by affecting the timing, spatial extent and/or intensity of effects of those stressors and may also limit the ability of an ecosystem to recover following a disturbance. Some stressors may also make ecosystems more vulnerable to climate change. For example, damage caused by deforestation (e.g., reduction of riparian areas) can decrease the resiliency of an ecosystem to climate change and may even contribute to climate change by releasing stored carbon into the atmosphere. Deforestation may also cause local warming and reduced rainfall, exacerbating climate change impacts. Additionally, land use often changes in response to climate change. For example, water withdrawals for agricultural purposes may increase with reduced precipitation or drought, further exacerbating impacts of climate change on freshwater ecosystems.

THREAT ASSESSMENT

Threats were assessed following the procedures outlined in DFO (2014), Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk. This document defines a threat as “any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur” (DFO 2014, p. 2). In this instance, threats were first assessed at the HUC8 level. The Likelihood of Occurrence (LO; Table 12), Level of Impact (LI; Table 13), Causal Certainty (CC; Table 14), HUC Threat Risk (HTR, product of Likelihood of Occurrence and Level of Impact; Table 15), HUC-level Threat Occurrence (HTO; Table 16), HUC-level Threat Frequency (HTF; Table 17), and HUC-level Threat Extent (HTE; Table 18) were evaluated for each identified threat (Appendix 2 and 3). This assessment relied heavily on information compiled by Alberta Environment and Parks as part of their Fish Sustainability Index and cumulative effects modeling approach to threats assessment.

Table 12. Categories of Likelihood of Occurrence (LO).

Likelihood of Occurrence	Definition
Known or very likely to occur	The threat has been recorded to occur 91–100% of the time
Likely to occur	There is 51–90% chance that this threat is or will be occurring
Unlikely	There is 11–50% chance that this threat is or will be occurring
Remote	There is 1–10% chance that this threat is or will be occurring
Unknown	There are no data or prior knowledge of this threat occurring now or in the future

Table 13. Categories of Level of Impact (LI) linked to a threat.

Level of Impact	Definition
Extreme	Severe population decline (i.e., 71–100%) with the potential for extirpation
High	Substantial loss of population (31–70%) or threat would jeopardize the survival or recovery of the population
Medium	Moderate loss of population (11–30%) or threat is likely to jeopardize the survival or recovery of the population
Low	Little change in population (1–10%) or threat is unlikely to jeopardize the survival or recovery of the population
Unknown	No prior knowledge, literature or data to guide the assessment of threat severity on population

Table 14. Categories of Causal Certainty (CC) linked to a threat.

Causal Certainty	Definition
Very high	Very strong evidence that threat is occurring and the magnitude of impact to the population can be quantified
High	Substantial evidence of a causal link between threat and population decline or jeopardy to survival or recovery
Medium	There is some evidence linking the threat to population decline or jeopardy to survival or recovery
Low	There is a theoretical link with limited evidence that threat is leading to a population decline or jeopardy to survival or recovery
Unknown	There is a plausible link with no evidence that the threat is leading to a population decline or jeopardy to survival or recovery

Table 15. The Threat Risk Matrix combines the Likelihood of Occurrence and Threat Impact rankings to establish the Threat Risk. The resulting Threat Risk is categorized as Low, Medium, High or Unknown.

		Threat Impact				
		Low	Medium	High	Extreme	Unknown
Likelihood of Occurrence	Known	Low	Medium	High	High	Unknown
	Likely	Low	Medium	High	High	Unknown
	Unlikely	Low	Medium	Medium	Medium	Unknown
	Remote	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Table 16. Categories of HUC-level Threat Occurrence (HTO).

HUC-level Threat Occurrence	Definition
Historical	A threat that is known to have occurred in the past and negatively impacted the population
Current	A threat that is ongoing, and is currently negatively impacting the population
Anticipatory	A threat that is anticipated to occur in the future, and will negatively impact the population

Table 17. Categories of HUC-level Threat Frequency (HTF).

HUC-level Threat Frequency	Definition
Single	The threat occurs once
Recurrent	The threat occurs periodically or repeatedly
Continuous	The threat occurs without interruption

Table 18. Categories of HUC-level Threat Extent (HTE).

HUC-level Threat Extent	Definition
Extensive	71–100% of the population is affected by the threat
Broad	31–70% of the population is affected by the threat
Narrow	11–30% of the population is affected by the threat
Restricted	1–10% of the population is affected by the threat

This was then rolled up to the watershed level and the Watershed Threat Risk (WTR; a roll-up of HUC Threat Risk [HTR]), Watershed Threat Occurrence (WTO), Watershed Threat Frequency (WTF) and Watershed Threat Extent (WTE, a roll-up of HUC-level Threat Extent [HTE]) were evaluated (Table 19).

It was then further rolled up to the range level (Table 20). When rolling up HTR to WTR and then to the range level (RTR), a precautionary approach was followed and the highest level of risk for a given HUC/Watershed was retained.

Table 19. Tertiary watershed-level Threat Risk (WTR), Threat Occurrence (WTO), Threat Frequency (WTF) and Threat Extent (WTE). When rolling up from the HUC-level Threat Risk, the highest level of risk for a given HUC was retained for each watershed. Historical (H), Current (C), Anticipatory (A), Continuous (CONT), Recurrent (REC), Extensive (EXT), Restricted (RES).

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	07AA				07AB			
Invasive Species – Hybridization and Competition								
Non-native Rainbow Trout	High	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation								
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Medium	H / C / A	REC	Broad	Medium	H / C / A	REC	Broad
Suspended and Deposited Sediments	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practices	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Mortality								
Angling Mortality	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES	Low	H / C / A	REC	RES
Other								
Contaminants and Toxic Substances	Low	H / C / A	REC	RES	Low	H / C / A	REC	Narrow
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	07AC				07AD			
Invasive Species – Hybridization and Competition								
Non-native Rainbow Trout	Low	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation								
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Suspended and Deposited Sediments	Low	H / C / A	REC	Broad	Medium	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Low	H / C / A	CONT	Broad	Medium	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practices	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Mortality								
Angling Mortality	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES	Low	H / C / A	REC	RES
Other								
Contaminants and Toxic Substances	Low	H / C / A	REC	RES	Low	H / C / A	REC	Narrow
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	07AE				07AF			
Invasive Species – Hybridization and Competition								
Non-native Rainbow Trout	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation								
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Suspended and Deposited Sediments	Medium	H / C / A	REC	Broad	Medium	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Medium	H / C / A	CONT	Broad	Medium	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practices	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Mortality								
Angling Mortality	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES	Low	H / C / A	REC	RES
Other								
Contaminants and Toxic Substances	Low	H / C / A	REC	RES	Low	H / C / A	REC	Narrow
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT

THREAT	WTR	WTO	WTF	WTE	WTR	WTO	WTF	WTE
	07AG				07AH			
Invasive Species – Hybridization and Competition								
Non-native Rainbow Trout	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation								
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Suspended and Deposited Sediments	Medium	H / C / A	REC	Broad	Medium	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Medium	H / C / A	CONT	Broad	Medium	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practices	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT	Low	H / C / A	CONT	EXT
Mortality								
Angling Mortality	Low	H / C / A	REC	Broad	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES	Low	H / C / A	REC	RES
Other								
Contaminants and Toxic Substances	Low	H / C / A	REC	RES	Low	H / C / A	REC	Narrow
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT	High	H / C / A	CONT	EXT

Table 20. Range-level Threat Risk (RTR), Threat Occurrence (RTO), Threat Frequency (RFT) and Threat Extent (RTE). When rolling up from the tertiary watershed-level Threat Risk, the highest level of risk for a given watershed was retained. Historical (H), Current (C), Anticipatory (A), Continuous (CONT), Recurrent (REC), Extensive (EXT), Restricted (RES).

THREAT	RTR	RTO	RTF	RTE
Invasive Species – Hybridization and Competition				
Non-native Rainbow Trout	High	H / C / A	CONT	EXT
Brook Trout	Low	H / C / A	CONT	EXT
Myxobolus cerebralis	Low	A	CONT	RES / EXT
Habitat Loss and/or Degradation				
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Low	C / A	REC / CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Low	C / A	REC / CONT	Broad
Alteration of Stream Temperature	Medium	H / C / A	REC	Broad
Suspended and Deposited Sediments	Medium	H / C / A	REC	Broad
Habitat Fragmentation: Culverts	Medium	H / C / A	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Low	H / C / A	CONT	Broad
Habitat Fragmentation: Land Use Practice	Low	H / C / A	CONT	Broad
Nutrient Loading	Low	H / C / A	CONT	EXT
Mortality				
Angling Mortality	Low	H / C / A	REC	Broad
Entrainment Mortality	Low	H / C / A	CONT	Broad
Research Mortality	Low	H / C / A	REC	RES
Other				
Contaminants and Toxic Substances	Low	H / C / A	REC	Narrow
Climate Change	High	H / C / A	CONT	EXT
Interactive and Cumulative Effects	High	H / C / A	CONT	EXT

MITIGATION AND ALTERNATIVES

Threats to survival can be minimized by implementing mitigation measures to reduce or eliminate potential harmful effects that could result from works or undertakings associated with projects or activities in Athabasca Rainbow Trout habitat. Athabasca Rainbow Trout are currently not protected under the SARA. Research has been completed summarizing the types of works, activities or projects that have been undertaken in habitat known to be occupied by Athabasca Rainbow Trout (Figure 15; Table 21). The DFO Program Activity Tracking for Habitat (PATH) database was reviewed to estimate the number of projects that have occurred between January 2011 and December 2015. A total of 97 projects and activities were found, but this may not represent a comprehensive list of all projects and activities as some may not have been reported to DFO. The works, undertakings and activities that may have directly or indirectly affected Athabasca Rainbow Trout include: watercourse crossings (e.g., bridges, culverts, open cut crossings); shoreline and streambank work (e.g., stabilization, shoreline protection); mineral aggregate, oil and gas exploration, extraction and/or production; instream works (e.g., channel modifications, watercourse realignments, dredging, debris removal); and structures in water (e.g., boat launches/ramps, docks). The category ‘invasive species introductions (authorized and unauthorized)’ was added to the list in Table 21 although this is not tracked in PATH.

As indicated in the Threat Assessment, several threats affecting Athabasca Rainbow Trout are related to habitat alteration and/or fragmentation. Habitat-related threats to Athabasca Rainbow Trout have been linked to the Pathways of Effects developed by DFO Fisheries Protection Program (FPP) (Table 21). DFO FPP has developed guidance on mitigation measures for 19 Pathways of Effects for the protection of aquatic species at risk in the Central and Arctic Region (Coker et al. 2010). This guidance should be referred to when considering mitigation and alternative strategies for habitat-related threats.

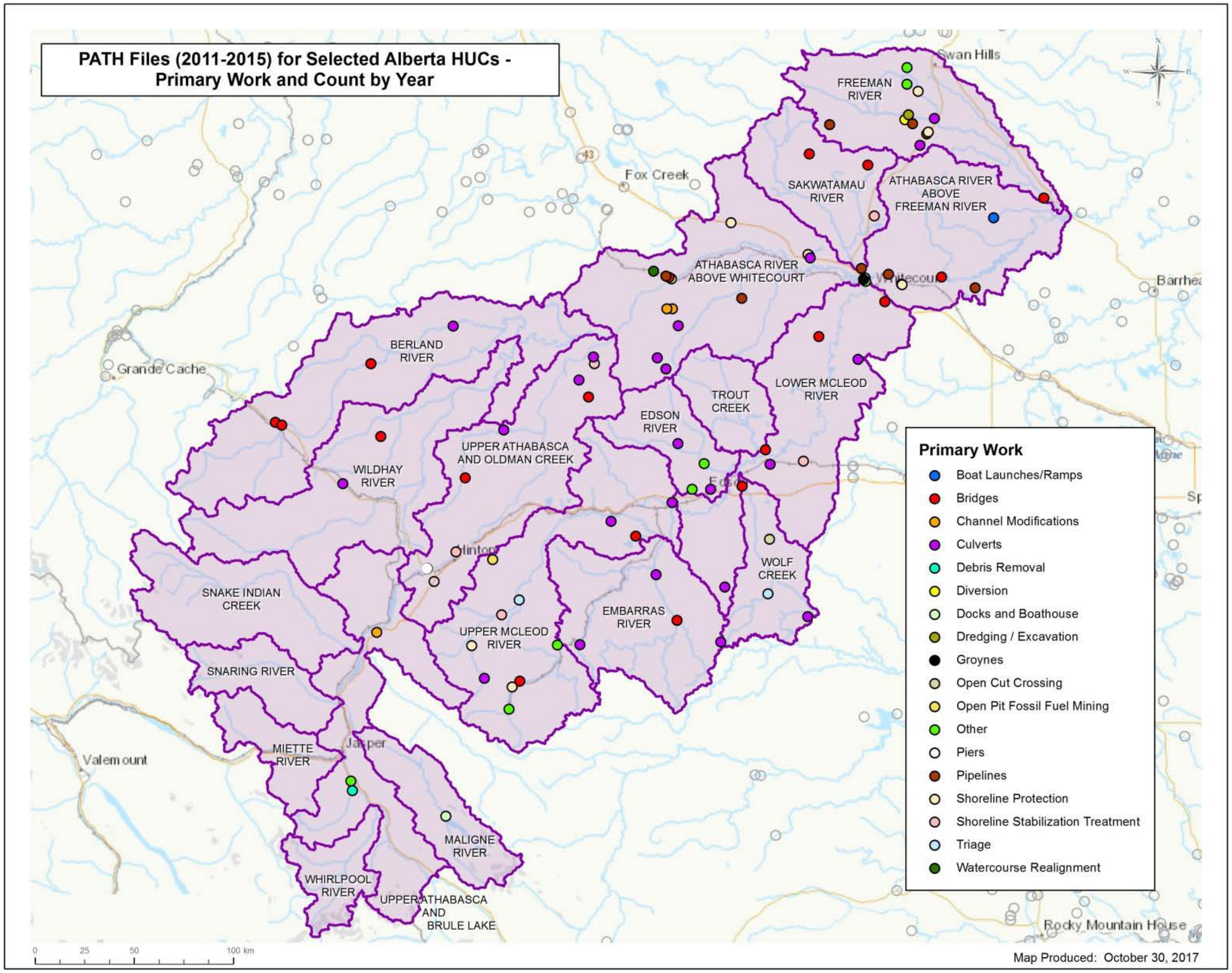

Figure 15. Locations of projects and activities that took place within the range of Athabasca Rainbow Trout and were reported to DFO between January 2011 and December 2015 (source: DFO Program Activity Tracking for Habitat [PATH] database). Activity type is indicated by colour as shown in the legend.

Table 21. Summary of works, projects and activities that have occurred during the period of January 2011 to December 2015 in tertiary watersheds known to be occupied by Athabasca Rainbow Trout. Threats known to be associated with these types of works, projects, and activities have been indicated by a checkmark. The number of works, projects, and activities associated with each Athabasca Rainbow Trout sub-watershed, as determined from the project assessment analysis, has been provided. Applicable Pathways of Effects from Coker et al. (2010) have been indicated for each threat associated with a work, project or activity (1 – Vegetation clearing; 2 – Grading; 3 – Excavation; 4 – Use of explosives; 5 – Use of industrial equipment; 6 – Cleaning or maintenance of bridges or other structures; 7 – Riparian planting; 8 – Streamside livestock grazing; 9 – Marine seismic surveys; 10 – Placement of material or structures in water; 11 – Dredging; 12 – Water extraction; 13 – Organic debris management; 14 – Wastewater management; 15 – Addition or removal of aquatic vegetation; 16 – Change in timing, duration and frequency of flow; 17 – Fish passage issues; 18 – Structure removal; 19 – Placement of marine finfish aquaculture site).

Work/Project/Activity	**Threats** (associated with work/project/activity)							**Sub-watershed** (number of works/projects/activities 2011-2015)							
	Alteration of Natural Flow Regimes	**Alteration of Stream Temperature**	**Suspended and Deposited Sediments**	**Contaminants and Toxic Substances**	**Nutrient Loading**	**Alteration of Groundwater Quality or Quantity**	**Invasive species**	**07AA**	**07AB**	**07AC**	**07AD**	**07AE**	**07AF**	**07AG**	**07AH**
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 3, 7, 8, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16	3	14, 17								
Watercourse crossings (e.g., bridges, culverts, open cut crossings)	✓		✓	✓	✓			–	–	7	7	9	11	13	13
Shoreline, streambank work (e.g., stabilization, shoreline protection)	✓	✓	✓	✓	✓			–	–	–	2	4	3	1	4
Mineral Aggregate, Oil & Gas Exploration, Extraction, Production	✓	✓		✓		✓		–	–	–	–	–	1	–	–

Work/Project/Activity	Threats (associated with work/project/activity)							Sub-watershed (number of works/projects/activities 2011-2015)							
	Alteration of Natural Flow Regimes	**Alteration of Stream Temperature**	**Suspended and Deposited Sediments**	**Contaminants and Toxic Substances**	**Nutrient Loading**	**Alteration of Groundwater Quality or Quantity**	**Invasive species**	**07AA**	**07AB**	**07AC**	**07AD**	**07AE**	**07AF**	**07AG**	**07AH**
Applicable pathways of effects for threat mitigation and project alternatives	16	1, 3, 7, 8, 14, 15, 16, 17	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 18	1, 4, 5, 6, 7, 11, 13, 14, 15, 16, 18	1, 4, 7, 8, 10, 11, 13, 14, 15, 16	3	14, 17								
Instream works (e.g., channel modifications, watercourse realignments, dredging, debris removal))	✓		✓	✓	✓			3	–	–	–	4	–	–	2
Structures in water (e.g., boat launches/ramps, docks, effluent outfalls, water intakes)	✓	✓	✓					1	–	–	–	–	–	–	1
Other (e.g., conduit installation on bridge, bridge washing)								1	–	–	–	–	3	4	3
Invasive species introductions (authorized and unauthorized)							✓	–	–	–	–	–	–	–	–

Additional mitigation and alternative measures related to invasive species, mortality, climate change and interactive and cumulative effects are listed below.

INVASIVE SPECIES

As discussed in the Anthropogenic Threat Categories section, introduction and establishment of invasive species could have significant negative effects on Athabasca Rainbow Trout.

Mitigation

- Use existing Alberta Support Emergency Response Team (ASERT) reporting and action system.
- Physically remove non-native species from areas known to be inhabited by Athabasca Rainbow Trout.
- Monitor range of Athabasca Rainbow Trout for invasive species that may negatively impact Athabasca Rainbow Trout directly or affect Athabasca Rainbow Trout preferred habitat.
- Develop a plan to address potential risks, impacts and proposed actions if monitoring detects the arrival or establishment of invasive species.
- Introduce a public awareness campaign and encourage the use of existing invasive species reporting systems.

Alternatives

- Unauthorized
    - None
- Authorized
    - Use only native species.
    - Use only 3N (i.e., triploid) Rainbow Trout and Brook Trout that have been certified disease-free and only stock in systems with no outflows. This may still pose a risk, however, as only 97% are actually 3N.
    - Follow the National Code on Introductions and Transfers of Aquatic Organisms (DFO 2003) for all aquatic organism introductions.

MORTALITY

As discussed in the Anthropogenic Threat Categories section, mortality caused by angling and scientific sampling is a threat to Athabasca Rainbow Trout.

Mitigation

- Recovery rest periods.
- Catch and release only (intentional harvest of Athabasca Rainbow Trout prohibited throughout range since 2012) with the exception of Jasper National Park where anglers are permitted to keep two per day.
- Public education to reduce misidentification and increase awareness of regulations.
- In 2016 Alberta implemented a total bait ban to reduce hooking mortality. Artificial lures and flies are allowed.

- Collection/sampling licenses are issued by DFO pursuant to Part VII of the *General Fisheries Regulations*, Section 51.
- Collection/sampling licenses are issued by the Government of Alberta under the authority of the *Alberta Fisheries Act* and these are not authorized during spawning and incubation periods as well as during low water and high temperature conditions.
- Temporary sport fishery closures during low water and high temperature conditions.
- Indigenous fishers must have a licence that includes conditions.
- Sampling in National Parks requires a Research and Collection Permit issued by Parks Canada.
- Sampling in Alberta Provincial Parks requires a Research and Collection Permit issued by Alberta Parks.

  Alternatives

- Restrict lethal scientific sampling of Athabasca Rainbow Trout.

CLIMATE CHANGE ADAPTATION AND MITIGATIONS

Strategies to mitigate the negative impacts of climate change are becoming increasingly important. For freshwater trout species, conserving the connectivity, size and extent of high quality habitats and helping to guide habitat restoration efforts are important strategies to mitigate the effects of climate change (Jones et al. 2014). Life history variation (i.e., resident and migratory populations) and existing stressors must also be explicitly considered when developing climate adaptation/mitigation strategies (Kovach et al. 2017). Mitigation/adaptation options that can be undertaken at the provincial level for climate change impacts on fisheries and water in Alberta are summarized below (M. Sullivan, AEP, pers. comm.).

1) Regulation of fisheries – Alberta Fisheries Management Branch can increase or decrease exploitation of fish stocks through seasons, bag and size limits, and quotas. This may be used to protect vulnerable species and increase population resilience or can be used to decrease abundance and range of exotic species.
2) Restoration – Alberta Fisheries Management Branch can stock or transfer native species to new habitats that the species' are unable to access naturally (e.g., moving Westslope Cutthroat Trout to higher elevation lakes). Stocking using native strains of Alberta fishes may also be used to help restore populations that have suffered from extreme events such as floods, droughts and winter/summer kills.
3) Advice to developers – Alberta Fisheries Management Branch can influence watershed development by recommending and streamlining approvals for projects that assist in fisheries climate adaptation. The long-term benefits to fish of projects that reduce risks of extreme events or improve water quality balanced with the risks of short-term disruptions caused by construction should be considered. Resulting economic trade-offs may entice developers to consider climate adaptation projects (e.g., replacing a small culvert with another small culvert should receive strict fish protection construction requirements because both the construction phase and the final product threaten fish, contrasted with replacing a small culvert with a multi-species underpass and having less stringent construction requirements because of the benefits of the final project to fish).

Gray Actions (engineered, concrete/steel solutions)

1) Dams to stabilize flashy flow.

2) Multi-species underpasses to prevent stream fragmentation at road and railroad stream crossings.
3) Convert straight diversion and drainage channels to meanders or linked pools (reduces erosion and increases infiltration).
4) Convert linear concrete and steel retaining walls to complex meandering bank armouring using rock and rubble (adds habitat).
5) Convert weirs and low head dams to rock and rubble rapid and pool complexes (reduces fish migration barriers and entrainment and adds habitat).

Green Actions (ecological-oriented landscape solutions)

1) Large wetlands on main stem to stabilize flashy flow.
2) Small wetlands on watershed and side tributaries to increase groundwater infiltration (cools water and stabilizes flow).
3) Increased main stem meanders to slow erosion.
4) Increased small stream meanders and side channels to increase groundwater infiltration.
5) Upper watershed forest retention to stabilize flashy flow.
6) Reduce roads in upper watershed to stabilize flashy flow.
7) Increase deep-rooted, flood-resistant streamside riparian vegetation (cools water and reduces flood effects).

Soft Actions (legislation, agency actions, public behaviour)

1) Regulate development in upper watershed (reduces floods, increases groundwater, cools temperatures, etc.) to threshold levels (e.g., 20% land clearing, <0.6 km/km^2 roads).
2) Regulate development on flood plain (reduce need for emergency work usually resulting in habitat loss and silt; more groundwater which will provide oxygen and temperature refuges).
3) Restrictive fishing regulations to reduce fishing mortality to compensate for increased natural mortality or decreased production. Population structure should respond with increased longevity and broader representation of mature age classes.
4) Strong and immediate (= effective) responses to first indication of exotic species (e.g., rotenone, capture, etc.).
5) Move cool water fish to vacant higher elevation habitat (will often require eradication of non-native species, e.g., Brook Trout removal in Hidden Creek and Devon lakes in Banff National Park to create new habitat for Westslope Cutthroat Trout and Bull Trout moved from lower Bow and Red Deer rivers).
6) Develop hatchery brood sources of local, native fish for re-stocking after extreme flood or winterkill events.
7) Legislate design of floodplain gravel pits/golf course water traps/water pools to reduce stranding.
8) Create climate-oriented refuges in higher elevation areas of Alberta (e.g., Swan Hills, Christina Hills, Marten Hills) to provide refuges for cool-temperature fish. These refuges

will allow development up to landscape thresholds (e.g., 20% land clearing, <0.6 km/km^2 oil and gas roads).

9) Create non-public motorized travel refuge areas (e.g., Blackfoot Provincial Grazing Reserve, Willmore Wilderness Park, Canadian Forces Base Wainwright and Suffield) to reduce exploitation on long-lived fish (e.g., Walleye, Lake Sturgeon [*Acipenser fulvescens*]) and create population structures that are resilient to periodic year-class failures. These refuge areas will allow industrial development and could allow hunting and fishing.

INTERACTIVE AND CUMULATIVE EFFECTS

Where multiple stressors are impacting the system it is important (and an ongoing challenge) to determine the types of stressor interactions (e.g., additive, synergistic, antagonistic) and to disentangle the pathways by which the stressors are interacting (Piggott et al. 2015). In situations with antagonistic stressors, attempts to reduce or eliminate one stressor may not result in the expected benefits unless it is the dominant stressor that is driving the interaction. In situations with synergistic stressors on the other hand, reducing or eliminating one stressor may result in larger benefits than expected. Additive effects imply stressors that are acting independently, thus mitigation of individual stressors should yield predictable results (Piggott et al. 2015). AEP has recently developed a cumulative effects modelling process to help focus recovery efforts and will be undertaking adaptive management experiments to assess the accuracy of the model.

EXISTING PROTECTION

Within Alberta, native Rainbow Trout in the Athabasca River drainage are listed as 'Threatened'. Athabasca Rainbow Trout are designated catch and release only (intentional harvest is prohibited) throughout their range. The Tri-Creeks experimental streams (Wampus, Deerlick and Eunice creeks) in the McLeod drainage and McKenzie Creek in the upper McLeod drainage are closed to angling year-round. Portions of the range of Athabasca Rainbow Trout are within Jasper National Park and Willmore Wilderness Area and smaller pieces are protected through some provincial parks (Sundance, Switzer), although intentional harvest is still allowed in Jasper National Park (two per day).

SOURCES OF UNCERTAINTY

- Angling pressure is extremely important but difficult to measure. Modelling suggests that nearly undetectable levels can have severe impacts.
- The importance of sediment as a threat is uncertain. Sediment may be less important than indicated by AEP models. It could, however, be an important driver over a certain threshold. Mobilized sediment is a problem, but suspended sediment in the Tri-Creeks area was extremely high and some of the healthiest Athabasca Rainbow Trout populations occur there.
- It is uncertain whether non-native species are replacing or displacing Athabasca Rainbow Trout. Are they a symptom or a cause of population decline?
- There is uncertainty in the productivity of various streams and habitats. Productivity is variable. Streams with the lowest productivity will never support high densities of Athabasca Rainbow Trout and these areas will be particularly susceptible to perturbations.

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APPENDIX 1

Table A1.1. Results of admixture analysis for Athabasca Rainbow Trout sampled from stocked and unstocked locations in the upper Athabasca River watershed (from Taylor and Yau 2013). Easting and Northing are UTM Zone 11 coordinates. Mean Q_i represents probability of indigenous form. Green = core population; Yellow = conservation population; Red = introgressed, stocked or naturalized population. Reproduced from Alberta Athabasca Rainbow Trout Recovery Team (2014).

Region	Watershed	Drainage	Site-ID	Stocking History	Easting	Northing	Year	Sample Size	Q_i (mean)	Q_i (SE)	# of ARTR Q_i <0.99
JNP	Athabasca River	Buffalo Prairie Cr.	BP-2004	Not Stocked	432259	5849822	2004	40	0.992	0.000	1
JNP	Athabasca River	Buffalo Prairie Cr.	BP-2001	Not Stocked	432259	5849822	2011	20	0.991	0.001	2
Alberta	Athabasca River	Emerson Cr.	EmC	Not Stocked	489647	5950635	2000	9	0.906	0.029	7
Alberta	Athabasca River	Lynx Cr.	LnC	Not Stocked	500119	5966053	2000	10	0.990	0.002	2
Alberta	Athabasca River	Mink Cr.	MIN	Not Stocked	597066	5998138	2011	2	0.994	0.000	0
Alberta	Athabasca River	MS – below JNP	Math	Not Stocked	454548	5914836	2000	7	0.939	0.020	4
Alberta	Athabasca River	MS – mouth of Maskuta Cr.	MR-M	Not Stocked	456611	5914876	2011	8	0.883	0.053	4
Alberta	Athabasca River	MS – baseline to Nosehill Cr.	MR-B	Not Stocked	497797	5977176	2011	18	0.795	0.065	15
Alberta	Athabasca River	Oldman Cr.	O1C	Not Stocked	464483	5945410	2000	14	0.994	0.000	0
Alberta	Athabasca River	Pine Cr.	PiC	Not Stocked	525793	5992080	2000	4	0.993	0.001	0
Alberta	Athabasca River	Sakawatamau R.	SakR	Not Stocked	565032	6035621	2000	5	0.994	0.000	0
Alberta	Athabasca River	Windfall Cr.	WiC	Not Stocked	534870	5988932	2000	28	0.993	0.000	1
Alberta	Berland River	Cabin Cr.	CaC-2011	Not Stocked	408487	5958650	2011	20	0.994	0.000	0
Alberta	Berland River	Cabin Cr.	CaC-2000	Not Stocked	408487	5958650	2000	17	0.990	0.003	2
Alberta	Berland River	Jessie Cr.	JeC	Not Stocked	439506	5974142	2004	19	0.991	0.002	2
Alberta	Erith River	Bacon Cr.	BAC	Not Stocked	513514	5887369	2011	10	0.988	0.006	1
Alberta	Erith River	Hanlan Cr.	HAN	Not Stocked	535929	5882398	2011	12	0.994	0.000	0
Alberta	Erith River	Lendrum Cr.	LEN	Not Stocked	521203	5882607	2011	14	0.993	0.001	0
Alberta	Erith River	Lund Cr.	LUN	Not Stocked	529414	5874557	2011	20	0.992	0.002	1

Region	Watershed	Drainage	Site-ID	Stocking History	Easting	Northing	Year	Sample Size	Q_i (mean)	Q_i (SE)	# of ARTR Q_i <0.99
Alberta	Erith River	Raven Cr.	RC	Not Stocked	540948	5892156	2011	20	0.987	0.007	1
Alberta	Erith River	Rodney Cr.	ROC	Not Stocked	535842	5909437	2011	20	0.994	0.000	0
Alberta	Erith River	Unnamed trib.	ERT	Not Stocked	506527	5892408	2011	13	0.988	0.004	2
Alberta	Erith River	Unnamed trib.	UTER	Not Stocked	523368	5904714	2011	21	0.988	0.004	2
Alberta	Erith River	Unnamed-ER	UER	Not Stocked	512665	5885611	2011	20	0.978	0.007	5
Alberta	Erith River	Wickham Cr.	WC	Not Stocked	517032	5894838	2011	20	0.993	0.001	2
Alberta	Freeman River	Layla Cr.	LAY	Not Stocked	578680	6050830	2011	7	0.995	0.000	0
Alberta	Freeman River	Louise Cr.	LOU	Not Stocked	592471	6049058	2011	4	0.994	0.000	0
Alberta	Freeman River	Unnamed – A	UFA	Not Stocked	568993	6055916	2011	4	0.994	0.000	0
Alberta	Freeman River	Unnamed – B	UFB	Not Stocked	579300	6049000	2011	20	0.979	0.009	5
Alberta	Freeman River	Unnamed – C	UFC	Not Stocked	575248	6061621	2011	10	0.994	0.000	0
Alberta	Freeman River	Unnamed – D	UFD	Not Stocked	572290	6060680	2011	6	0.993	0.001	0
Alberta	McLeod River	Anderson Cr.	AnC	Not Stocked	475048	5908154	2000	19	0.986	0.004	4
Alberta	McLeod River	Deerlick Cr.	DC	Not Stocked	483590	5887863	2000	10	0.992	0.002	1
Alberta	McLeod River	Felton Cr.	FeC	Not Stocked	486409	5902258	2000	10	0.977	0.018	1
Alberta	McLeod River	Shiningbank Cr.	SC	Not Stocked	590293	5974614	2011	20	0.994	0.000	0
Alberta	McLeod River	Unnamed – MR1	MR1	Not Stocked	570202	5977959	2011	20	0.993	0.000	0
Alberta	McLeod River	Wampus Cr.	WP-2011	Not Stocked	482377	5889471	2011	20	1.000	0.000	0
Alberta	McLeod River	Wampus Cr.	WP-2004	Not Stocked	482377	5889471	2004	17	0.993	0.000	0
Alberta	Sakwatamau River	Carson Cr.	CC	Not Stocked	581700	6022750	2011	20	0.992	0.001	1
Alberta	Sakwatamau River	Hope Cr.	HC	Not Stocked	565124	6029633	2011	20	0.990	0.002	2
Alberta	Sakwatamau River	Unnamed – SR1	SR1	Not Stocked	569261	6025595	2011	10	0.991	0.001	0
Alberta	Wildhay River	Barbara Cr.	BaC	Not Stocked	455209	5941405	2000	10	0.994	0.000	0
Alberta	Wildhay River	Hightower Cr.	HiC	Not Stocked	436290	5955900	2000	10	0.995	0.000	0
Alberta	Wildhay River	Moberly Cr.	MbC	Not Stocked	433150	5934566	2000	10	0.994	0.000	0

Region	Watershed	Drainage	Site-ID	Stocking History	Easting	Northing	Year	Sample Size	Q_i (mean)	Q_i (SE)	# of ARTR Q_i <0.99
JNP	Athabasca River	Ath. R. @ Lac Beauvert	AthaB	Stocked	428509	5860152	2004	30	0.578	0.055	27
JNP	Athabasca River	Maligne R., upper reaches	MR	Stocked	454632	5845406	2011	19	0.103	0.023	19
JNP	Athabasca River	Wabasso Cr.	WbC	Stocked	431519	5851981	2004	41	0.821	0.027	38
Alberta	Athabasca River	Athabasca R. trib.	AthaT	Stocked	495160	5957813	2000	10	0.986	0.008	1
Alberta	Athabasca River	Canyon Cr.	CYC	Stocked	471535	5929343	2000	4	0.982	0.007	2
Alberta	Athabasca River	Chickadee Cr.	CKC	Stocked	553120	6020584	2000	13	0.970	0.024	1
Alberta	Athabasca River	Cottonwood Cr.	CoC	Stocked	427980	5861058	2004	31	0.416	0.032	31
Alberta	Athabasca River	Fish Cr.	FC	Stocked	456872	5924069	2000	10	0.994	0.000	0
Alberta	Athabasca River	Rainbow L. outlet	RbL	Stocked	488466	5973206	2000	11	0.882	0.017	3
Alberta	Athabasca River	Sandstone Cr.	SS	Stocked	475099	5925697	2000	11	0.993	0.000	0
Alberta	Athabasca River	Two Cr.	TC	Stocked	540705	6024184	2000	11	0.993	0.000	0
Alberta	Embarras River	Bryan Cr.	BC	Stocked	496164	5900395	2011	11	0.955	0.017	5
Alberta	Embarras River	Mitchell Cr.	MiC	Stocked	509632	5903555	2000	1	0.985	0.294	1
Alberta	Embarras River	Prest Cr.	PrC	Stocked	499686	5906430	2000	3	0.992	0.002	0
Alberta	Erith River	Erith R., middle reaches	ER	Stocked	528909	5895782	2011	6	0.994	0.000	0
Alberta	Erith River	Erith R., upper reaches	UE	Stocked	506034	5889121	2011	15	0.964	0.011	7
Alberta	Erith River	Halpenny Cr.	HAL	Stocked	515705	5890329	2011	3	0.973	0.021	1
Alberta	McLeod River	Edson R.	EDR-2011	Stocked	526084	5952396	2011	20	0.993	0.000	0
Alberta	McLeod River	Edson R., upper reaches	UEDR	Stocked	511731	5953830	2000	10	0.994	0.000	0
Alberta	McLeod River	Embarras R., middle reaches	EMR	Stocked	504193	5904556	2011	19	0.959	0.013	12
Alberta	McLeod River	Embarras R., upper reaches	EMU	Stocked	498991	5892531	2011	20	0.926	0.021	16
Alberta	McLeod River	Groat Cr.	GC	Stocked	561217	5982533	2011	20	0.985	0.005	4
Alberta	McLeod River	Lac des Rochel/Luscar Cr.	LdR	Stocked	474399	5878694	2000	36	0.922	0.012	30
Alberta	McLeod River	Luscar Cr.	LuC	Stocked	474600	5878694	2000	17	0.971	0.006	10
Alberta	McLeod River	MacKenzie Cr.	MaC	Stocked	488554	5875491	2000	10	0.831	0.028	9

Region	Watershed	Drainage	Site-ID	Stocking History	Easting	Northing	Year	Sample Size	Q_i (mean)	Q_i (SE)	# of ARTR Q_i <0.99
Alberta	McLeod River	Moose Cr.	MoC	Stocked	541634	5931936	2000	10	0.840	0.023	10
Alberta	McLeod River	Sundance Cr.	SUN	Stocked	510918	5941798	2011	12	0.964	0.014	4
Alberta	McLeod River	Trout Cr.	TrC	Stocked	543341	5971506	2000	24	0.994	0.000	0
Alberta	McLeod River	White Cr.	WhC	Stocked	489502	5909949	2000	10	0.978	0.011	2
Alberta	McLeod River	Wolf Cr., upper reaches	WCUR	Stocked	548712	5903044	2011	20	0.999	0.000	0
Alberta	Sakwatamau River	Mobile Cr.	MOB	Stocked	585879	6020870	2011	5	0.204	0.128	5
JNP	Snaring River	Harvey L.	HvL	Stocked	404036	5890226	2004	30	0.015	0.003	30

APPENDIX 2. DETAILED THREATS ASSESSMENT

TERTIARY WATERSHED: 07AA

HUC8S: 17010102, 17010103, 17010104, 17010105, & 17010106

HUC8: 17010102 – UPPER ATHABASCA AND BRULE LAKE (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 60. This gives an adult abundance fish sustainability index (FSI) value of 2 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 10. This gives an adult abundance FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 1.4%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 11.3 °C and the resulting FSI value is 4.27 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 101% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.024 crossings/km^2, resulting in an FSI value of 4.84 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 104% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 4% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 3), the FSI value for this HUC is 0.8 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout, followed by stream temperature (cooler than optimal range) and Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17010103 – WHIRLPOOL RIVER (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 50. This gives an FSI value of 2.55 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 10. This gives an FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 1.5%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 10.3 °C and the resulting FSI value is 3.88 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 101% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.002 crossings/km^2, resulting in an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 101% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 2% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 2), the FSI value for this HUC is 0.6 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout, followed by stream temperature (cooler than optimal range) and Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17010104 – MIETTE RIVER (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 75. This gives an FSI value of 1.4 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 10. This gives an FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 0.6%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 10.5 °C and the resulting FSI value is 3.98 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 100% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.005 crossings/km^2, resulting in an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 103% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling

mortality was ranked at 2% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 μg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 2), the FSI value for this HUC is 0.3 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout, followed by stream temperature (cooler than optimal range) and Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17010105 – MALIGNE RIVER (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 50. This gives an FSI value of 2.55 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 10. This gives an FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis (parasite that causes Whirling Disease)

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 0.3%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 10 °C and the resulting FSI value is 3.61 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 100% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0 crossings/km^2, resulting in an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 101% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 4% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 2), the FSI value for this HUC is 0.7 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout, followed by stream temperature (cooler than optimal range) and Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17010106 – SNARING RIVER (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 10. This gives an FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 0.04%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 10 °C and the resulting FSI value is 3.61 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 100% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0 crossings/km^2, resulting in an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 101% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling

mortality was ranked at 4% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 1), the FSI value for this HUC is 0.7 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is stream temperature (cooler than optimal range) followed by Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AB

HUC8: 17010201

HUC8: 17010201 – SNAKE INDIAN RIVER (JASPER NATIONAL PARK)

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 10. This gives an FSI value of 4.55 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 0.03%. This gives a negligible index of potential hydrological change and an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). Both February and August flows are 100% of natural for this HUC. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 9.7 °C and the resulting FSI value is 3.50 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 100% of natural. This gives an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0 crossings/km^2, resulting in an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 100% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 2% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on

adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 2), the FSI value for this HUC is 1.4 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is stream temperature (cooler than optimal range) followed by Brook Trout. Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AC

HUC8S: 17010301 & 17010302

HUC8: 17010301 – BERLAND RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis (parasite that causes Whirling Disease)

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 10.4%. This gives a negligible index of potential hydrological change and an FSI value of 4.95 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 97% of natural and August flow is 100% of natural for this HUC. This gives an FSI value of 4.96 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 11.9 °C and the resulting FSI value is 4.91 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 105% of natural. This gives an FSI value of 4.32 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.047 crossings/km^2, resulting in an FSI value of 4.47 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 120% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 5), the FSI value for this HUC is 3.2 (medium impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is sediment loading followed by culverts and angling mortality. The empirical estimate of the adult abundance FSI value for this HUC is 1 (low density) based on electrofishing catch-per-unit-area (CPUA) estimates. The cumulative effects modelling indicates habitat conditions are sufficient to support a higher number of Athabasca Rainbow Trout than the CPUA estimates indicate are present. Further investigation is required to resolve this discrepancy (M. Sullivan, AEP, pers. comm.). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

HUC8: 17010302 – WILDHAY RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 10.8%. This gives a negligible index of potential hydrological change and an FSI value of 4.96 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 98% of natural and August flow is 100% of natural for this HUC. This gives an

FSI value of 4.97 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 11.5 °C and the resulting FSI value is 4.52 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 105% of natural. This gives an FSI value of 4.32 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.054 crossings/km^2, resulting in an FSI value of 4.37 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 119% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 5), the FSI value for this HUC is 2.9 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is sediment loading followed by culverts, stream temperature (cooler than optimal range) and angling mortality. The empirical estimate of the adult abundance FSI value for this HUC is 1 (low density) based on electrofishing catch-per-unit-area (CPUA) estimates. The cumulative effects modelling indicates habitat conditions are sufficient to support a higher number of Athabasca Rainbow Trout than the CPUA estimates indicate are present. Further investigation is required to resolve this discrepancy (M. Sullivan, AEP, pers. comm.). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AD

HUC8: 17010401

HUC8: 17010401 – UPPER ATHABASCA RIVER AND OLDMAN CREEK

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 50. This gives an FSI value of 2.55 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 3. This gives an FSI value of 4.84 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 12.9%. This gives a negligible index of potential hydrological change and an FSI value of 4.82 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 90% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.88 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.1 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 109% of natural. This gives an FSI value of 3.71 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.109 crossings/km^2, resulting in an FSI value of 3.37 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 135% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 8% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on

adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 1), the FSI value for this HUC is 0.1 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by culverts, sediment loading and angling mortality. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AE

HUC8: 17010501

HUC8: 17010501 – ATHABASCA RIVER ABOVE WHITECOURT

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 50. This gives an FSI value of 2.55 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis (parasite that causes Whirling Disease)

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 9.7%. This gives a negligible index of potential hydrological change and an FSI value of 4.94 (minimal impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 94% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.92 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.8 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 111% of natural. This gives an FSI value of 3.53 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.107 crossings/km^2, resulting in an FSI value of 3.35 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 141% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 1), the FSI value for this HUC is 0.2 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by culverts and sediment loading. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AF

HUC8: 17020101 & 17020102

HUC8: 17020101 – UPPER MCLEOD RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 62.5. This gives an FSI value of 1.95 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 6. This gives an FSI value of 4.74 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 11.2%. This gives a negligible index of potential hydrological change and an FSI value of 4.88 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.).

February flow is 94% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.92 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 12.8 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 110% of natural. This gives an FSI value of 3.67 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.099 crossings/km^2, resulting in an FSI value of 3.55 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 132% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 5), the FSI value for this HUC is 0.6 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by culverts, sediment loading, Brook Trout and angling mortality. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020102 – EMBARRAS AND ERITH RIVERS

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 75. This gives an FSI value of 1.4 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 7. This gives an FSI value of 4.66 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 16.3%. This gives a negligible index of potential hydrological change and an FSI value of 4.83 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 94% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.92 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.2 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 111% of natural. This gives an FSI value of 3.53 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.072 crossings/km^2, resulting in an FSI value of 4.1 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 139% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 8% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 5), the FSI value for this HUC is 0.3 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by sediment loading, angling mortality, culverts and Brook Trout. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AG

HUC8S: 17020201, 17020202, 17020203 & 17020204

HUC8: 17020201 – LOWER MCLEOD RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 60. This gives an FSI value of 2 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 13. This gives an FSI value of 4.37 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 19.9%. This gives a negligible index of potential hydrological change and an FSI value of 4.76 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 90% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.88 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 14.1 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 109% of natural. This gives an FSI value of 3.71 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.091 crossings/km^2, resulting in an FSI value of 3.79 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 156% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 8% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical

Adult Density FSI – 5), the FSI value for this HUC is 0.5 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by sediment loading, culverts, angling mortality and Brook Trout. The empirical estimate of the adult abundance FSI value for this HUC is 2 based on electrofishing catch-per-unit-area (CPUA) estimates. The cumulative effects modelling indicates habitat conditions are insufficient to support the number of Athabasca Rainbow Trout that the CPUA estimates indicate are present. Further investigation is required to resolve this discrepancy (M. Sullivan, AEP, pers. comm.).Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020202 – WOLF CREEK

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 12.9%. This gives a negligible index of potential hydrological change and an FSI value of 4.85 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 93% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.94 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.6 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 110% of natural. This gives an FSI value of 3.67 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.048 crossings/km^2, resulting in an FSI value of 4.47 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 145% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 2), the FSI value for this HUC is 1 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is sediment loading followed by culverts, alteration of peak flow intensity and angling mortality. Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020203 – EDSON RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis (parasite that causes Whirling Disease)

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 18.4%. This gives a negligible index of potential hydrological change and an FSI value of 4.82 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 86% of natural and August flow is 98% of natural for this HUC. This gives an FSI value of 4.86 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.6 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 109% of natural. This gives an FSI value of 3.71 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.13 crossings/km^2, resulting in an FSI value of 3 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 154% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 3), the FSI value for this HUC is 1 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is culverts followed by sediment loading, alteration of peak flow intensity, water withdrawals and angling mortality. Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020204 – TROUT CREEK

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 15%. This gives a negligible index of potential hydrological change and an FSI value of 4.79 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 93% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.94 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.8 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 109% of natural. This gives an FSI value of 3.71 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.099 crossings/km^2, resulting in an FSI value of 3.55 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 149% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling

mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 3), the FSI value for this HUC is 1.2 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is culverts followed by sediment loading, alteration of peak flow intensity and angling mortality. Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

TERTIARY WATERSHED: 07AH

HUC8S: 17010601, 17010602 & 17010603

HUC8: 17020601 – SAKWATAMAU RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 20. This gives an FSI value of 4 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 14.5%. This gives a negligible index of potential hydrological change and an FSI value of 4.88 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 98% of natural and August flow is 100% of natural for this HUC. This gives an FSI value of 4.97 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.7 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 109% of natural. This gives an FSI value of 3.71 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.067 crossings/km^2, resulting in an FSI value of 4.21 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 132% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 4% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on

adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 3), the FSI value for this HUC is 1.2 (high impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is sediment loading followed by non-native Rainbow Trout, culverts and alteration of peak flow intensity. Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020602 – ATHABASCA RIVER ABOVE FREEMAN

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 50. This gives an FSI value of 2.55 (high impact on adult abundance). Threat Impact: High. Likelihood of Occurrence: Known. Threat Risk: High.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 15.3%. This gives a negligible index of potential hydrological change and an FSI value of 4.85 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 94% of natural and August flow is 99% of natural for this HUC. This gives an FSI value of 4.92 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 14.3 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 105% of natural. This gives an FSI value of 4.32 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.1 crossings/km^2, resulting in an FSI value of 3.55 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 143% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 6% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4.87 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical

Adult Density FSI – 1), the FSI value for this HUC is 0.2 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is non-native Rainbow Trout followed by culverts, sediment loading, alteration of peak flow intensity and angling mortality. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

HUC8: 17020603 – FREEMAN RIVER

Invasive Species

Hybridization and Competition

Non-native Rainbow Trout

Percent of carrying capacity equals 15. This gives an FSI value of 4.32 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Brook Trout

Percent of carrying capacity equals 0. This gives an FSI value of 5 (no impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Myxobolus cerebralis *(parasite that causes Whirling Disease)*

Whirling Disease is predicted to have no impact on adult Athabasca Rainbow Trout abundance in this HUC (FSI value of 5). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Habitat Loss and/or Degradation

Alteration of Natural Flow Regimes

Alteration of Peak Flow Intensity

AEP developed an Index of Potential Hydrological Change related to the anthropogenic footprint within the HUC. This qualitative index provides an indication of the differences in magnitude and frequency of peak flow events compared to historical conditions (M. Sullivan, AEP, pers. comm.). The anthropogenic footprint in this HUC is 17.6%. This gives a negligible index of potential hydrological change and an FSI value of 4.84 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Water Withdrawals

February and August flows (change from natural) were used to approximate the impact of water withdrawals on adult Athabasca Rainbow Trout abundance (M. Sullivan, AEP, pers. comm.). February flow is 86% of natural and August flow is 98% of natural for this HUC. This gives an FSI value of 4.86 (low impact on adult abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Alteration of Stream Temperature

The mean air temperature of the warmest month (typically August within the range of Athabasca Rainbow Trout) was used to provide an indication of the impact of stream temperature on the abundance of adult Athabasca Rainbow Trout. The dose response curve suggests an optimal thermal range of 12.5 °C to 15 °C with temperatures below 7.5 °C and above 22 °C being high risk. The mean August air temperature for this HUC is 13.4 °C and the resulting FSI value is 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Suspended and Deposited Sediments

Sediment load was used to describe sedimentation and is equal to the inverse of the ALCES Online © Water Quality Sediment Index (e.g., 0.33 = 3 times the normal sediment load) (M. Sullivan, AEP, pers. comm.). The sediment loading in this HUC is 110% of natural. This gives an FSI value of 3.67 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Habitat Fragmentation

Culverts

The number of road and stream intersections per km^2 was estimated for Order 2 and 3 streams (Athabasca Rainbow Trout often do not occur in Order 1 streams and Order 4 streams typically have bridges which do not limit fish passage) using provincial GIS data (M. Sullivan, AEP, pers. comm.). This HUC has 0.13 crossings/km^2, resulting in an FSI value of 3 (medium impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Medium. Likelihood of Occurrence: Known. Threat Risk: Medium.

Dams and Weirs

A qualitative estimate of the effect of barrier dams was made based on available migration and genetic data included in the Fish Sustainability Index (M. Sullivan, AEP, pers. comm.). The barrier dam effect for this HUC was estimated at 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Land Use Practices

GIS estimates were made of stream habitat lost or converted to non-Athabasca Rainbow Trout habitat (M. Sullivan, AEP, pers. comm.). The habitat loss estimate for this HUC is 0, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Nutrient Loading

The Phosphorous Runoff Coefficient was obtained from ALCES Online © under the assumption that this coefficient is correlated with eutrophication and is a predictor of low dissolved oxygen concentrations (M. Sullivan, AEP, pers. comm.). The phosphorous runoff in this HUC is 137% of natural, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Mortality

Angling Mortality

Angling mortality was ranked based on the proximity of human settlements and the amount of access (e.g., road density, road type, road location) (M. Sullivan, AEP, pers. comm.). Angling mortality was ranked at 8% for this HUC (over and above the assumed natural mortality rate of 35% [Post et al. 2003, Sullivan 2007]), giving an FSI value of 4 (low impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Likely. Threat Risk: Low.

Entrainment Mortality

HUCs with hydroelectric dams or those with proposed hydroelectric dams were assigned a value of 4%, unless data indicating otherwise was available (M. Sullivan, AEP, pers. comm.). Entrainment mortality for this HUC was ranked at 0%, giving an FSI value of 5 (no impact on

adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Research Mortality

Research mortality was set at 0%, unless information to the contrary was available (M. Sullivan, AEP, pers. comm.). This HUC has 0% research mortality, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Remote. Threat Risk: Low.

Contaminants and Toxic Substances

Selenium concentration was used as a proxy for this threat category. Data used were derived from local studies on egg selenium concentration (M. Sullivan, AEP, pers. comm.). Egg selenium concentration for this HUC is 0 µg/g wet weight, giving an FSI value of 5 (no impact on adult Athabasca Rainbow Trout abundance). Threat Impact: Low. Likelihood of Occurrence: Unlikely. Threat Risk: Low.

Climate Change

This threat is only assessed at the DU-level.

Interactive and Cumulative Effects

Based on cumulative effects modelling using STELLA 10.0.2 modelling software and including all of the FSI values above as well as natural mortality (35%) and natural limitations (Historical Adult Density FSI – 3), the FSI value for this HUC is 0.6 (extreme impact on adult Athabasca Rainbow Trout abundance) (M. Sullivan, AEP, pers. comm.). The parameter with the greatest negative impact on Athabasca Rainbow Trout in this HUC is culverts followed by sediment loading, angling mortality, non-native Rainbow Trout, alteration of peak flow intensity and water withdrawals. Threat Impact: Extreme. Likelihood of Occurrence: Known. Threat Risk: High.

APPENDIX 3

Table A3.1. HUC-level Threat Likelihood of Occurrence, Threat Impact, Causal Certainty, Threat Risk, Threat Occurrence, Threat Frequency and Threat Extent. Climate Change assessed at DU level only. Medium (MED), Very High (V High), Extreme (EX), Continuous (CONT), Recurrent (REC), Historical (HIST), Extensive (EXT), Restricted (RES), Single (SIN), Current (CUR), Anticipatory (ANT).

TERTIARY WATERSHED 07AA

1. HUC8: 17010102 – Upper Athabasca River and Brule Lake (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

2. HUC8: 17010103 – Whirlpool River (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

3. HUC8: 17010104 – Miette River (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

4. HUC8: 17010105 – Maligne River (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

5. HUC8: 17010106 – Snaring River (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
0.Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AB

6. HUC8: 17010201 – Snake Indian River (JNP)

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	High	High	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AC

7. HUC8: 17010301 – Berland River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	MED	High	MED	HIST/CUR/ANT	CONT	EXT

8. HUC8: 17010302 – Wildhay River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Unlikely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	High	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AD

9. HUC8: 17010401 – Upper Athabasca River and Oldman Creek

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AE

10. HUC8: 17010501 – Athabasca River above Whitecourt

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AF

11. HUC8: 17020101 – Upper McLeod River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Likely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

12. HUC8: 17020102 – Embarras and Erith Rivers

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Likely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AG

13. HUC8: 17020201 – Lower McLeod River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Likely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

14. HUC8: 17020202 – Wolf Creek

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	High	High	High	HIST/CUR/ANT	CONT	EXT

15. HUC8: 17020203 – Edson River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	High	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	High	High	High	HIST/CUR/ANT	CONT	EXT

16. HUC8: 17020204 – Trout Creek

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	High	High	High	HIST/CUR/ANT	CONT	EXT

TERTIARY WATERSHED 07AH

17. HUC8: 17020601 – Sakwatamau River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Likely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Likely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	High	High	High	HIST/CUR/ANT	CONT	EXT

18. HUC8: 17020602 – Athabasca River above Freeman

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Known	High	V High	High	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT

19. HUC8: 17020603 – Freeman River

THREAT	Likelihood of Occurrence	Threat Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent
Invasive Species – Hybridization and Competition							
Non-native Rainbow Trout	Likely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Brook Trout	Unlikely	Low	V High	Low	HIST/CUR/ANT	CONT	EXT
Myxobolus cerebralis	Unlikely	Low	High	Low	ANT	CONT	RES/EXT
Habitat Loss and/or Degradation							
Alteration of Natural Flow Regimes: Alteration of Peak Flow Intensity	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Natural Flow Regimes: Water Withdrawals	Likely	Low	High	Low	CUR/ANT	REC/CONT	Broad
Alteration of Stream Temperature	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Suspended and Deposited Sediments	Known	MED	High	MED	HIST/CUR/ANT	REC	Broad
Habitat Fragmentation: Culverts	Known	MED	High	MED	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Dams and Weirs	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Habitat Fragmentation: Land Use Practices	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Nutrient Loading	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	EXT
Mortality							
Angling Mortality	Likely	Low	High	Low	HIST/CUR/ANT	REC	Broad
Entrainment Mortality	Unlikely	Low	High	Low	HIST/CUR/ANT	CONT	Broad
Research Mortality	Remote	Low	High	Low	HIST/CUR/ANT	REC	RES
Other							
Contaminants and Toxic Substances	Unlikely	Low	High	Low	HIST/CUR/ANT	REC	Narrow
Interactive and Cumulative Effects	Known	EX	High	High	HIST/CUR/ANT	CONT	EXT