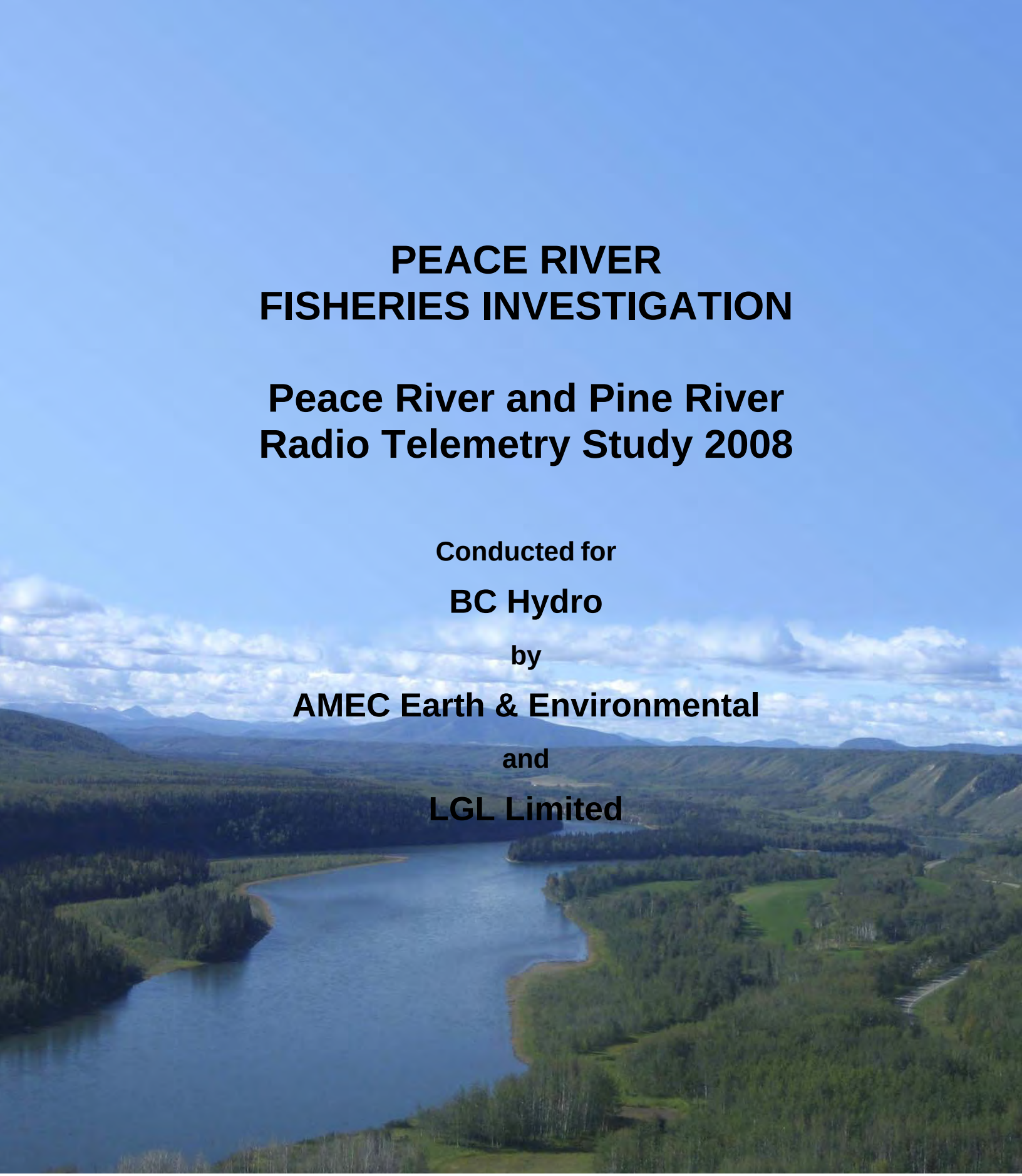

PEACE RIVER FISHERIES INVESTIGATION

Peace River and Pine River Radio Telemetry Study 2008

Conducted for

BC Hydro

by

AMEC Earth & Environmental

and

LGL Limited

amec

LGL LIMITED
environmental research associates

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FISHERIES INVESTIGATION

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July 2009

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EXECUTIVE SUMMARY

BC Hydro operates two hydroelectric facilities located on the Peace River in northern British Columbia. To meet future power demands, BC Hydro is investigating the potential for further hydroelectric development on the Peace River at Site C in the vicinity of Fort St. John. BC Hydro commissioned AMEC and LGL Ltd. in 2005 to initiate a radio telemetry study on adult large-bodied fish species in the Peace River mainstem and its tributaries. AMEC and LGL continued the radio telemetry program in 2006 and 2007 and have produced annual reports. The main objective of the 2008 program was to monitor the seasonal movements and variability for Pine River bull trout, Arctic grayling and rainbow trout in the study area. The present report summarizes the findings of 2008, compares them to previous results, and provides a synopsis of the results to date.

Between 2005 and 2008, 442 large-bodied fish were tagged in the Peace River drainage below Peace Canyon Dam. In total, 116 mountain whitefish, 82 Arctic grayling, 61 rainbow trout, 58 walleye and 105 bull trout were tagged, by AMEC and LGL, Golder, and the BC Ministry of Environment. Mountain whitefish, walleye and some Arctic grayling (60%) and rainbow trout (52%) were captured, tagged and released into the Peace River mainstem. All of the bull trout and the remainder of the Arctic grayling (40%) and rainbow trout (48%) were tagged in the Pine River system.

Movements of radio-tagged fish were monitored from early spring through fall in 2006, 2007 and 2008 with a network of fixed-station receivers and aerial telemetry surveys. In 2008, a total of seven fixed-stations were strategically located throughout the Peace River drainage in the following locations:

- Halfway River confluence with the Peace River;
- Peace River at the Moberly River confluence;
- Peace River at the Pine River confluence;
- Peace River at the Beatton River confluence;
- Halfway River at the Graham River confluence;
- Pine River at the Murray River confluence; and
- Pine River at the Sukunka River confluences.

In addition to monitoring the movements using fixed-station receivers, 12 aerial flights were conducted in 2008 between April and October to determine the location of radio-tagged fish. The flight path typically included:

- Peace River mainstem from Peace Canyon Dam to Peace River, Alberta;
- Beatton River to the Doig River; and,

- Pine River system including the Murray, Sukunka, Wolverine and Burnt rivers.

Extensive tracks were also conducted in the Halfway River system including the Graham, Cypress and Chowade rivers in the spring and fall. In 2008, aerial surveys were conducted biweekly in the spring and fall and monthly in the summer.

The main radio telemetry conclusions for Arctic grayling, rainbow trout, mountain whitefish, and walleye tagged in the Peace River mainstem from 2005 to 2008 are as follows:

1. Arctic grayling

- Occur primarily between the Halfway and the Beatton rivers;
- Spend most of their time in the Peace River but spawning occurs in specific tributaries (mainly the Moberly, and occasionally the lower Halfway and Beatton rivers) in spring (April-May);
- Some (19% of tagged fish in 2007) spawning occurs above the zone of inundation in the Moberly River; and,
- Current studies indicate that they are more likely to pass Site C than any other species studied (72% and 29% of the Peace River-tagged Arctic grayling in 2006 and 2007, respectively).

2. Mountain whitefish

- Are widely distributed in the Peace River mainstem from the Peace Canyon Dam downstream to the Alberta border;
- Do not move great distances (average of 6 km/year in 2007);
- Spawning occurs in autumn and appears to be widespread including Peace mainstem and lower reaches of tributaries in the Site C study area; and,
- Movement through Site C included 29% (32 fish) in 2006 and 8% (8 fish) in 2007.

3. Rainbow trout

- Occur mainly from the Peace Canyon Dam to the vicinity of the Halfway River;
- Spawning occurs primarily in the smaller streams upstream of the Halfway River (e.g., Maurice, Lynx, Farrell creeks), and subsequently the fish return to the Peace River mainstem to forage and overwinter; and,
- Movement through Site C included 15% (4 fish) and 3% (1 fish) in 2006 and 2007, respectively.

4. Walleye

- Move extensively within and between the Peace River mainstem and major tributaries (Beatton and Pine rivers);
- Approximately 50% of the tagged population in 2006, 2007 and 2008 spawned in the Beatton River in May and then returned to the Peace mainstem in June;
- Approximately 50% of the tagged population remained mostly downstream of the Beatton River as far as Peace River, Alberta; and,
- Only a small proportion (<10%) of the population moves upstream past Site C.

Some tentative conclusions for bull trout, rainbow trout, and Arctic grayling radio-tagged in the Pine River watershed are as follows:

1. Pine River Arctic grayling are resident and as such are not likely to exit the Pine River watershed or pass Site C.
2. The majority of tagged rainbow trout in the Pine River move very little but some fish conducted longer migrations.
3. Bull trout comprise mainly of resident fish, but approximately 5% are migratory. The migratory population migrates seasonally between the Pine, Peace and Halfway rivers.
4. Our first three tentative conclusions will be confirmed after completion of the 2009 radio telemetry program. If the results of the 2009 program are similar to the above conclusions, then only a small proportion of the Pine River bull trout population that are migratory will move past Site C, whereas other species are not likely to do so.

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1.0 INTRODUCTION

BC Hydro operates two hydroelectric facilities, the Peace Canyon and W.A.C. Bennett dams, on the Peace River in northern British Columbia. To meet future power demands, BC Hydro is investigating the potential for further hydroelectric development on the Peace River at Site C in the vicinity of Fort St. John (Figure 1).

The proposed Site C dam has the potential to alter upstream and downstream migrations of fish through the Site C area of the Peace River. Inundation of the Peace River and the lower reaches of upstream tributaries by Site C dam would change fish habitat from riverine to more lacustrine and alter the upstream fish community as it adapts to the new environment. The inundation of these tributaries has the potential to change local fish populations (i.e., species composition, abundance and distribution) by changing hydraulic conditions of their habitat, as well as increasing sedimentation in inundated areas.

BC Hydro has conducted fisheries baseline studies and investigated the potential environmental impacts of Site C dam at various intervals over the last 30 years. Previous studies have shown that a number of large-bodied fish species in the Peace River, including bull trout (*Salvelinus confluentus*) Arctic grayling (*Thymallus arcticus*), rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), and longnose sucker (*Catostomus catostomus*), use tributaries upstream of Site C for spawning and rearing (ARL 1991a, 1991b, R.L.&L. 1991a, 1991b). Another study also suggested that Peace River tributaries provide most of the annual recruitment for many large-bodied fish species in the river (P & E 2002).

More recently, BC Hydro conducted literature reviews and gap analyses regarding the Peace River fish community. These reviews by AMEC and others (Valenius 2001, Pottinger Gaherty 2001) sought to identify what additional information is needed for on-going Water Use Planning (WUP) and to develop a defensible baseline database upon which to base a potential environmental impact assessment of Site C dam. Two of these potential information gaps include the utilization of upstream tributaries by fish species in the Peace River and the determination of how the proposed Site C dam would affect fish migrations in the Peace River mainstem. Long-term baseline studies to address these concerns were initiated by AMEC and LGL in 2005 and have continued annually to present (AMEC & LGL 2008a, 2008b, 2008c, 2008d).

As part of these baseline studies, a radio telemetry study was initiated in 2005 to determine the potential impact Site C dam might have on migrations of large-bodied fish in the Peace River (AMEC & LGL 2008a, 2008b, 2008c, 2008d). Arctic grayling, walleye, rainbow trout and mountain whitefish were radio-tagged in fall 2005 and early summer 2006 in the mainstem of the Peace River between the Peace Canyon Dam and the Kiskatinaw River. Movements of tagged fish have been tracked each year using fixed stations and aerial tracking flights. The objectives of the 2005/2006 radio telemetry program were to determine the magnitude, direction, and seasonality of fish movements in the mainstem and into Peace River tributaries with a focus on movements past the potential Site C dam location and above the potential zone of inundation in the tributaries.

The 2006 preliminary results suggested that:

- Arctic grayling spend most of their time in the Peace River between the Halfway and Beatton rivers but spawn in Peace River tributaries, mainly the Moberly River;
- Mountain whitefish are widely distributed in the Peace River and their spawning locations are also widespread, including the Peace River mainstem and lower reaches of most tributaries upstream of the potential Site C dam;
- Rainbow trout are found mainly from the Peace Canyon Dam to the vicinity of the Halfway River and spawning occurs primarily in the smaller streams upstream of the Halfway River (e.g., Maurice, Lynx, Farrell creeks); and,
- Walleye are distributed downstream of the Moberly River and move extensively within and between the Peace River mainstem and major tributaries (Beatton and Pine rivers; AMEC and LGL 2008c).

In 2007, the radio telemetry program was expanded to track sportfish in the Pine River and investigate their utilization of the Peace River and its tributaries upstream of the potential Site C dam location. Movement of Pine River bull trout population between the Pine River, the Peace River, and the Halfway River was previously unknown. However, bull trout were known to move between the Halfway River and the Peace River and a portion of Halfway River bull trout were known to make extensive migrations in the Peace River including downstream movements past the proposed Site C dam location (AMEC & LGL 2006b). In order to investigate movement of Pine River sportfish in 2007, bull trout, Arctic grayling and rainbow trout were tagged in the Pine River system in the fall of 2006.

Based on 2007 tracking results, Arctic grayling and rainbow trout in the upper Pine River watershed appear to be resident populations that remain in the drainage year round; no radio-tagged Arctic grayling or rainbow trout moved from the Pine River into the Peace River in 2007. However, these results should be viewed with caution because only small numbers of rainbow trout (15) and Arctic grayling (8) were tagged.

Data from radio-tagged bull trout indicates that there may be two separate populations of bull trout in the Pine River drainage. These include one population that rears and forages primarily in the Pine River system and spawns in the Burnt River and another population that forages and over-winters in the Pine River but spawns and rears in the upper Halfway River drainage upstream of the potential Site C dam location.

The proportion of bull trout in the Pine River drainage that conduct this long distance, round-trip (>400 km) migration between the Pine and Halfway rivers is unclear. Initial results suggest that the proportion may be low as only two of the 54 bull trout tagged in 2006 showed this migration behaviour. However, our ability to more accurately determine this proportion from the 2006 tagged fish is currently limited because tagging was conducted in upper regions of the Pine River system in mid-August, after the date when bull trout would have shifted into spawning locations and we only have a single year of tracking data.

1.1 Objectives

Radio tags implanted in fish in the Peace River mainstem in 2005 and 2006 are now inactive, with the exception of some tags placed in walleye, and study objective for these species have been accomplished (AMEC and LGL 2008d). However, radio tags implanted into sportfish in the Pine River system in 2006 and 2007 remain active and were, therefore, the focus of the current year's investigations.

The specific objectives of the 2008 Peace River radio telemetry program were:

- To increase the number and geographic distribution of radio tagged bull trout, rainbow trout, and Arctic grayling in the Pine River watershed;
- To monitor the magnitude, direction, and seasonality of these movements, for Pine River bull trout, Arctic grayling and rainbow trout, and remaining walleye tags in the Peace River;
- To determine the extent of movements of Pine River fish into the Peace River mainstem and its tributaries upstream of Site C;

- To provide a synopsis of the findings from all previous years (2006-2008) of the Peace River radio telemetry program with emphasis on the results of 2008; and,
- To monitor water temperatures in Peace River tributaries upstream of the potential Site C dam.

1.2 Study Area

The overall study area includes the Peace River mainstem and its tributaries, extending from Peace Canyon Dam downstream to Peace River, Alberta (Figure 1).

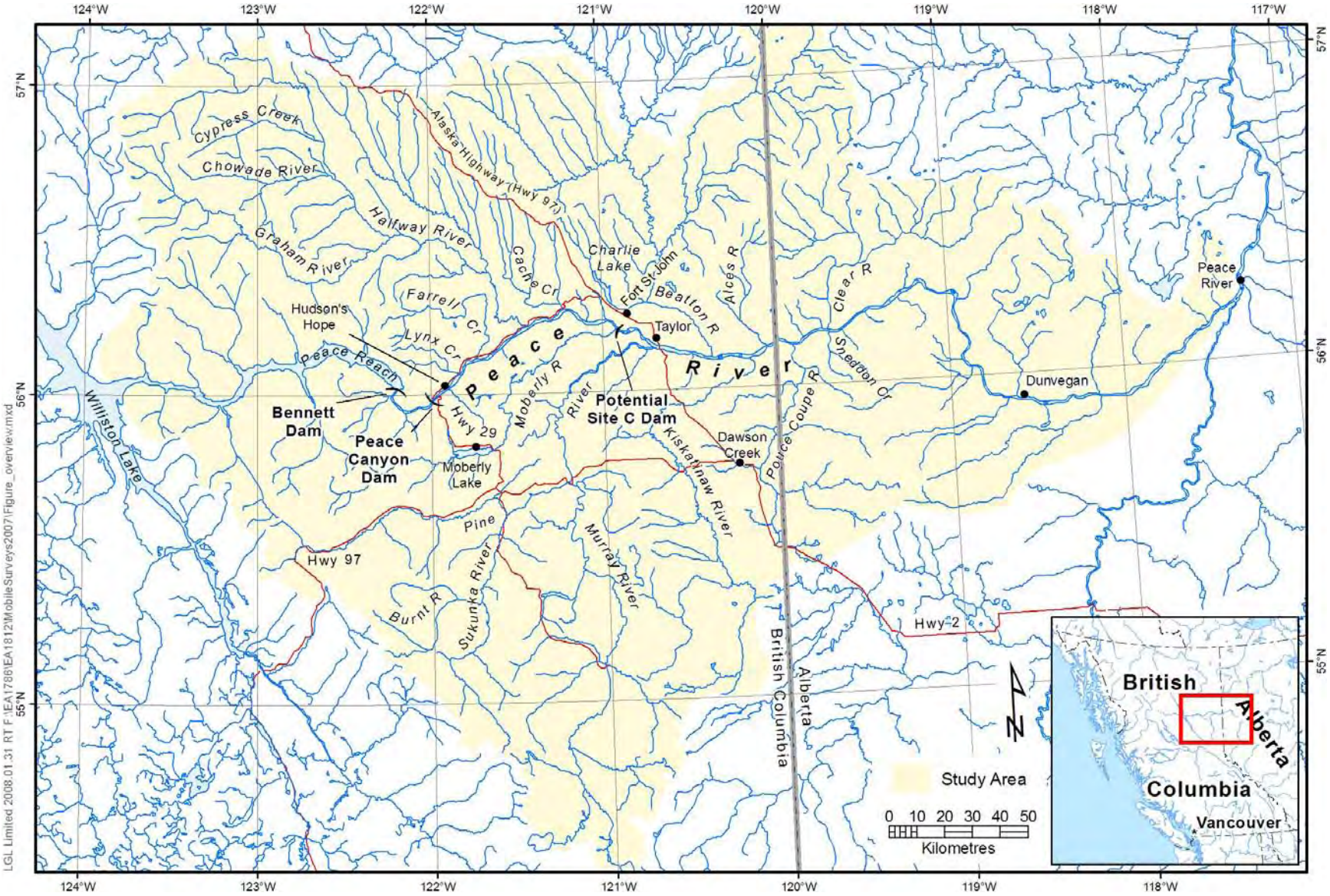

Figure 1: Peace River and its tributaries in northeast British Columbia

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The distance upstream from the proposed Site C dam site, the length potentially inundated, and the total watershed area of each upstream tributary is presented in Table 1.

Table 1: Location and length of upstream tributaries potentially inundated by Site C dam

Tributary	Watershed Area (km^2)	Distance Upstream from Site C Dam (km)	Length of Tributary Inundated by Site C Reservoir (km)
Moberly River	1833	1.0	10.0
Wilder Creek	100	14.0	2.5
Cache Creek	899	25.0	8.0
Red Creek	238	28.5[1]	1.5
Halfway River	9402	41.0	14.0
Farrell Creek	620	63.0	2.5
Lynx Creek	307	73.0	0.8
Maurice Creek	266	79.0	0.3

Note: [1]Red Creek is a tributary of Cache Creek with its confluence 3.5 km upstream from the mouth of Cache Creek.

2.0 METHODS

2.1 Discharge

Discharge information for the Peace (near Taylor, BC; station 07EF001), Pine (station 07FB001), Moberly (station 07FB008), Halfway (station 07FA006) and Beatton (07FC001) rivers was obtained from the Water Survey of Canada (WSC 2008a, 2008b; Figure 2). Average daily maximum and minimum discharge was calculated for a 10 year period of record (1996-2005). Discharge records were also compared between 2006, 2007 and 2008, where available. Most of the 2008 discharge data was not available for the present report. Any 2008 discharge data are considered preliminary, since they have not been calibrated by the Water Survey of Canada.

2.2 Water Temperature

Tidbit® temperature loggers were placed in the Peace River mainstem at the Site C Dam location and in all of the major tributaries of the Peace River from Peace Canyon Dam to the Beatton River (Figure 2). Most of the loggers were located within 1 km of the confluence with the Peace River. Daily water temperatures were logged every hour from the onset of deployment to the retrieval for downloading. The timing of deployment varied among sites because of high discharge and debris and resulted in some loggers being lost

or relocated during the course of the 2005 to 2008 study. Final downloading of all temperature loggers occurred during fall 2008.

Temperature loggers in the Peace River mainstem and the Pine, Beatton and Moberly rivers were lost due to high spring flows in 2007. In addition, the temperature logger located in the Halfway River was buried by sediment in spring 2008 and resulted in erroneous water temperatures. Missing water temperatures were augmented by data provided by Golder (Mike Galesloot, pers. com). This augmented temperature data provided daily water temperatures that were logged every 15 minutes from November 2006/March 2007 to October 2008; loggers were downloaded periodically throughout this period.

Data from all temperature loggers was carefully reviewed to ensure data quality and eliminate outliers/erroneous data. Daily mean, minimum and maximum water temperatures were graphed to identify any time periods where the loggers were out of water as a result of desiccation or tampering. Any time periods with suspicious data were eliminated from the data set. Daily means for the remaining data were graphed by day for 2005, 2006, 2007 and 2008.

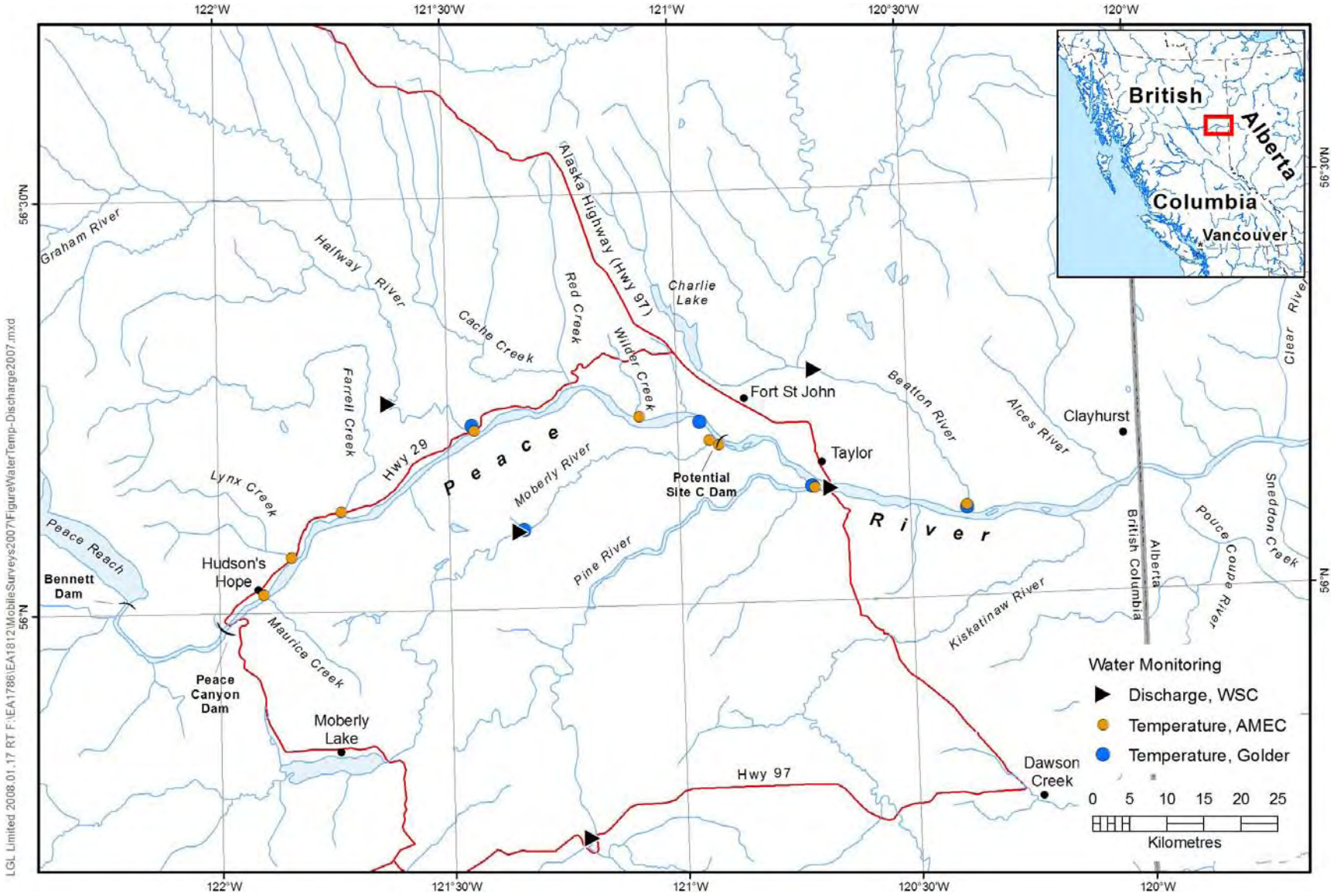

Figure 2: Temperature and discharge monitoring locations in the Peace River and its tributaries

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2.3 Radio Telemetry

2.3.1 Radio Transmitters

Pulse-coded microprocessor radio transmitters were used to monitor fish movements in 2008 and were similar to those used in previous years (2005, 2006, 2007; refer to AMEC & LGL 2008a, 2008c, and 2008d). Radio transmitters were fabricated by Lotek Engineering Inc. Two transmitter sizes (see below) were used depending on the size of the fish, with both having a 400 mm long antenna and a 3 volt battery to transmit a pulsed signal every 5 to 5.5 seconds (set by the manufacturer).

Smaller fish (250-400 mm fork length) were tagged with model MCFT-3FM tags, which were 11 mm in diameter, 59 mm in length, and weighed 10 g in air (4.6 g in water). Larger fish (>400 mm fork length) were tagged with model MCFT-3A, which were 16 mm in diameter, 46 mm long, and weighed 16 g in air (6.7 g in water). The estimated operational life was 378 and 761 days for small and large tags, respectively. In 2005, transmitters were pre-programmed and become activated 20 weeks (±1 h) after the tags were implanted; these were also used to tag bull trout in 2006. The remainder of the tags that did not get used in bull trout tagging in 2006, were applied to some of the fish tagged in 2008; these tags were pre-activated (magnet removed in winter 2008) so that they would be pinging at about the time of implant, or shortly thereafter.

All tags used in 2008, with the exception of those indicated above, were model MCFT-3FM; these tags were activated when implanted by removing their respective magnets. Further tag detail was provided in AMEC & LGL 2008c, and 2008d. All tags implanted on or before June 2006 were expected to have reached the end of their battery life prior to our 2008 tracking surveys. However, approximately 10% of these tags were still active at the beginning of the 2008 tracking season, which had been mostly implanted in walleye during our 2005 studies.

2.3.2 Mobile Zones and Fixed-Stations

The upper Peace River watershed system and associated watershed zones used during mobile tracking is illustrated in Figure 3. Watershed zones and delineations are further described in AMEC & LGL 2008c and 2008d. Fixed-station receiver sites were also installed to monitor fish movements. In total, nine stations were used in 2006, 10 in 2007, and 7 in 2008 (Figure 4). Two of the fixed stations, operated in 2006, were discontinued in 2007 because their detection capability overlapped with adjacent stations. Three additional fixed-

station receiver sites were added in 2007: i) Moberly River at the inundation line; ii) Pine River at the Murray River confluence; and, iii) Pine River at the Sukunka River confluence. In 2008, investigations focused primarily on fish tagged in the Pine River watershed, so three fixed-station receivers deployed in 2007 were not deployed in 2008 (Moberly River at the inundation line; Lynx Creek; and Farrell Creek). Detailed information on the set-up, installation, and decommissioning of these fixed-stations is provided in AMEC & LGL 2008a, 2008c and 2008d.

Each fixed station consisted of two or three antennas, antenna switching hardware, a receiver, a 12 V battery, an enclosure to protect the equipment, and a solar panel to charge the battery. Antennas were placed more than 10 m above the water level in a tree. Antennas were aimed to detect radio-tagged fish that were present downstream of the station, up a tributary, and upstream of the station. Since each fish detection is associated with a particular antenna, sequential detection data can be used to determine the direction of a fish's movements.

Both the reception and directionality of each fixed-station receiver site was thoroughly tested at the time the telemetry equipment was first installed (AMEC and LGL 2008a). The testing procedure involved two people with hand-held radios and use of an inflatable boat at the deeper water sites. From a position in the middle of the mainstem, a live radio tag (same as those implanted in the fish) attached to a weight was lowered to a depth of 5-10 m. With the other person positioned at the receiver station and in communication with the hand-held radios, the signal reception and strength of a radio tag were determined at different locations and depths in the river. Typically, testing started from 500-700 m upstream of the receiver station and continued downstream for approximately the same distance below the station.

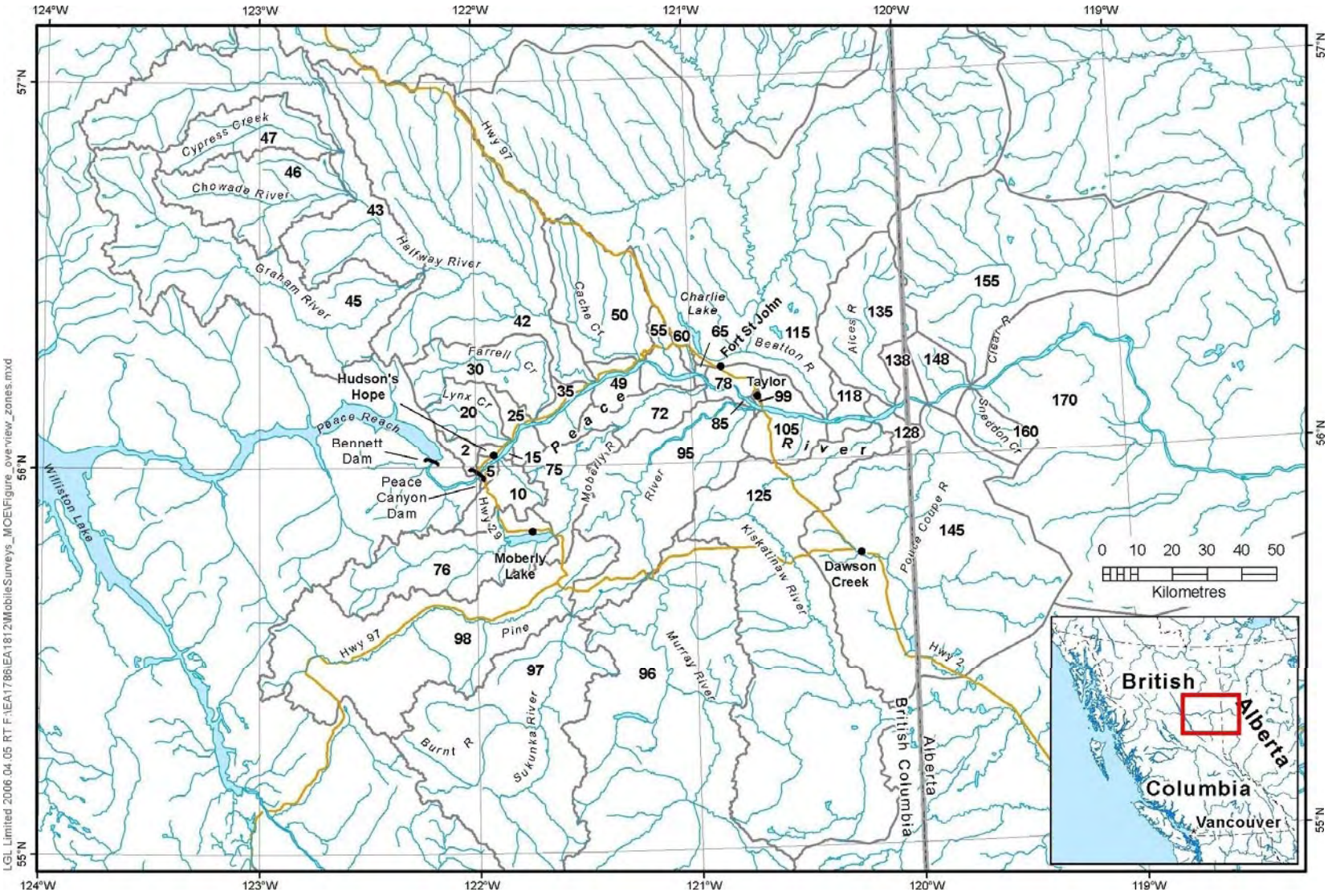

Figure 3: **Upper Peace River system showing the zones of watersheds used in fish mobile tracking; numbered watershed zones are listed in Appendix B. See Figure 4 for sites used in fixed-station tracking.**

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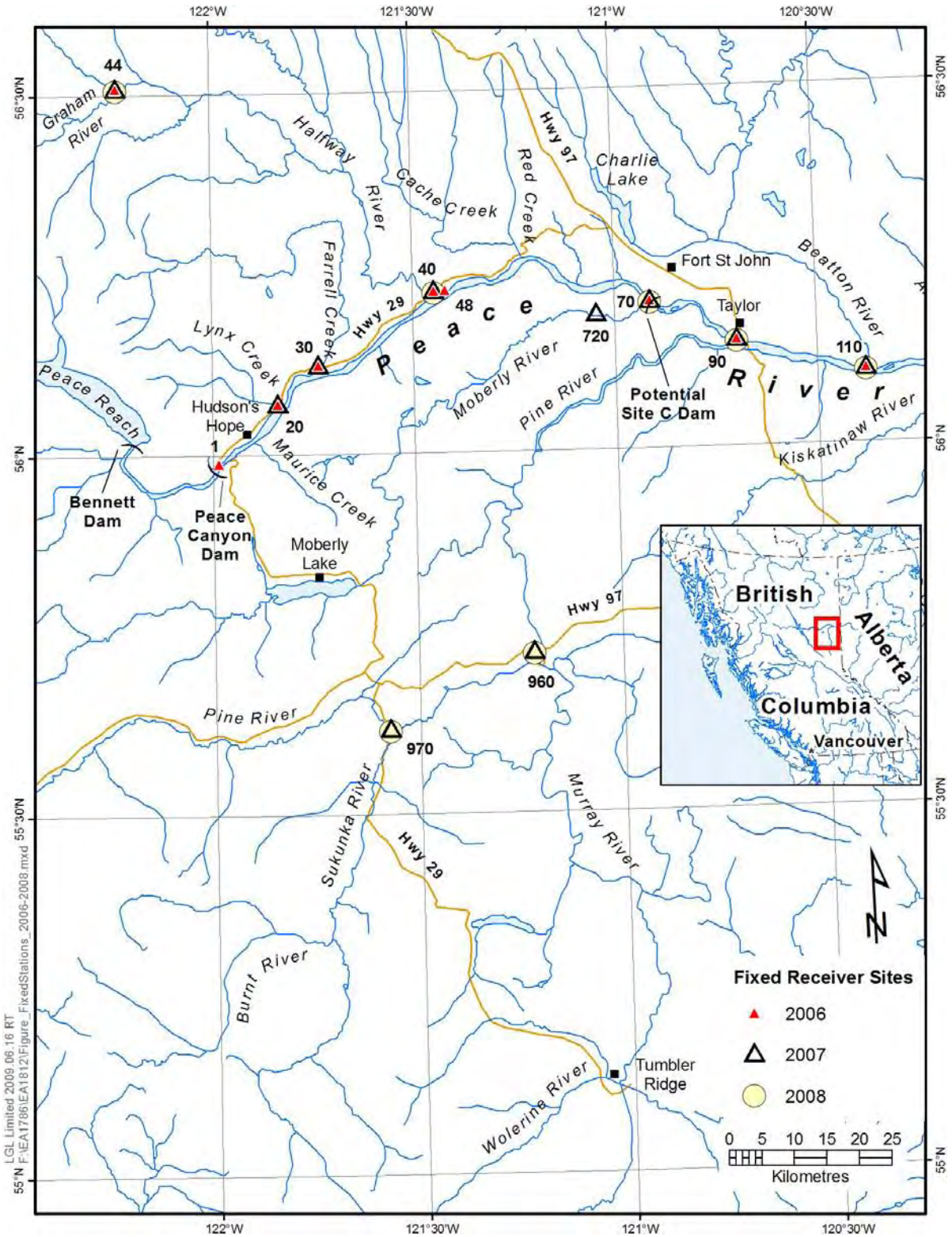

Figure 4: **Locations of fixed-station receivers in the Peace River watershed, 2006 to 2008; each station is identified by a specific number.**

2.3.3 Fish Capture, Tagging and Release

All of the fish tagged by AMEC and LGL were collected by a Smith-Root electrofisher operated from a jet boat, except the fish collected by angling in July 2008 in the Pine River. Golder also collected fish with the use of a boat-mounted electrofisher and angling whereas those tagged by MOE were collected solely by angling. Each fish was measured and implanted with a radio transmitter in the peritoneal cavity while under anaesthesia, with the antenna exiting ventrally in the caudal peduncle area and trailing posteriorly. The transmitters used by AMEC and LGL in 2005 and by Golder in 2006 had a factory-built 20-week delay after they were first activated, so that they remained inactive during the first winter. Unused tags from the batch of transmitters used by Golder in 2006 were available for use by AMEC and LGL in 2008; the magnets on these tags were removed well in advance to ensure that they would be active by early August 2008. All of the other tags used in 2008 were activated at implant. For more details on collection, tagging and releasing procedures for fish tagged in 2005, 2006 and 2007 refer to AMEC & LGL (2008a, 2008c, 2008d). There was no mortality during tagging operations in 2008. Information on tagging procedures used by MOE is not included in this report.

In 2008, fish tagged included 25 Arctic grayling, 14 rainbow trout, and 42 bull trout, all of which were captured, tagged and released from June to August in the Pine, Murray, and Sukunka rivers. Of the 42 bull trout, 17 were tagged in June and July by AMEC and LGL, and the remainder were tagged in August by MOE. An intensive and widespread effort was applied to capture bull trout in the Pine River watershed, which included the Pine River mainstem reaches (i.e., lower: mouth-Murray River confluence; mid: between Murray and Sukunka confluences; upper: upstream of Sukunka confluence), Sukunka River, and the Murray/Wolverine system.

Length and weight details of the fish radio-tagged between 2005 and 2008 are summarized by species in Table 2 and more details are available in Appendix B, Tables B1 and B2. Among the five species tagged, walleye and bull trout were the largest fish tagged in terms of body length and weight.

Table 2: Summary of lengths and weights of radio-tagged fish released in the upper Peace River system, 2005-2008

Species	n	Fork Length (mm)		Mean Weight (g)[1]
		Mean	Range	
Mountain whitefish	116	336	252-480	476
Arctic grayling	82	314	251-400	425
Rainbow trout	61	337	256-452	505
Walleye	58	416	275-574	919
Bull trout	105	456	348-684	1059
Total	422			

Note: [1]Golder-tagged Arctic grayling and rainbow trout and MOE-tagged bull trout were not weighed.

Fish tracked in 2008 consisted predominantly of sportfish that were radio-tagged in the Pine River in 2006, 2007 and 2008. Tracking also included a few tags that remained active for sportfish tagged in the Peace River in 2005 and 2006. The total number of fish tagged in the Peace and Pine rivers since 2005 is presented in Table 3. The locations and numbers of released radio tagged fish since 2005 are presented in Figures 5 to 8. Additional information regarding radio tagging in previous study years is provided in AMEC & LGL (2008c, 2008d).

Table 3: Summary of radio-tagged fish released in the upper Peace River system, 2005-2008

Species	Number of fish				
	2005	2006	2007	2008	Total
Mountain whitefish	0	116	0	0	116
Arctic grayling	39	10, 8[1]	0	25	82
Rainbow trout	29	3, 15[1]	0	14	61
Walleye	58	0	0	0	58
Bull trout	0	54[1]	9[2]	17, 25[3]	105
Total	126	206	9	81	422

Notes: [1] fish tagged by Golder Associates in the Pine River system, August-September, 2006; [2] fish tagged by MOE in Wolverine River (8) and upper Moberly River (1), July-September, 2007; [3] fish tagged by MOE in the Pine and Wolverine Rivers, August, 2008

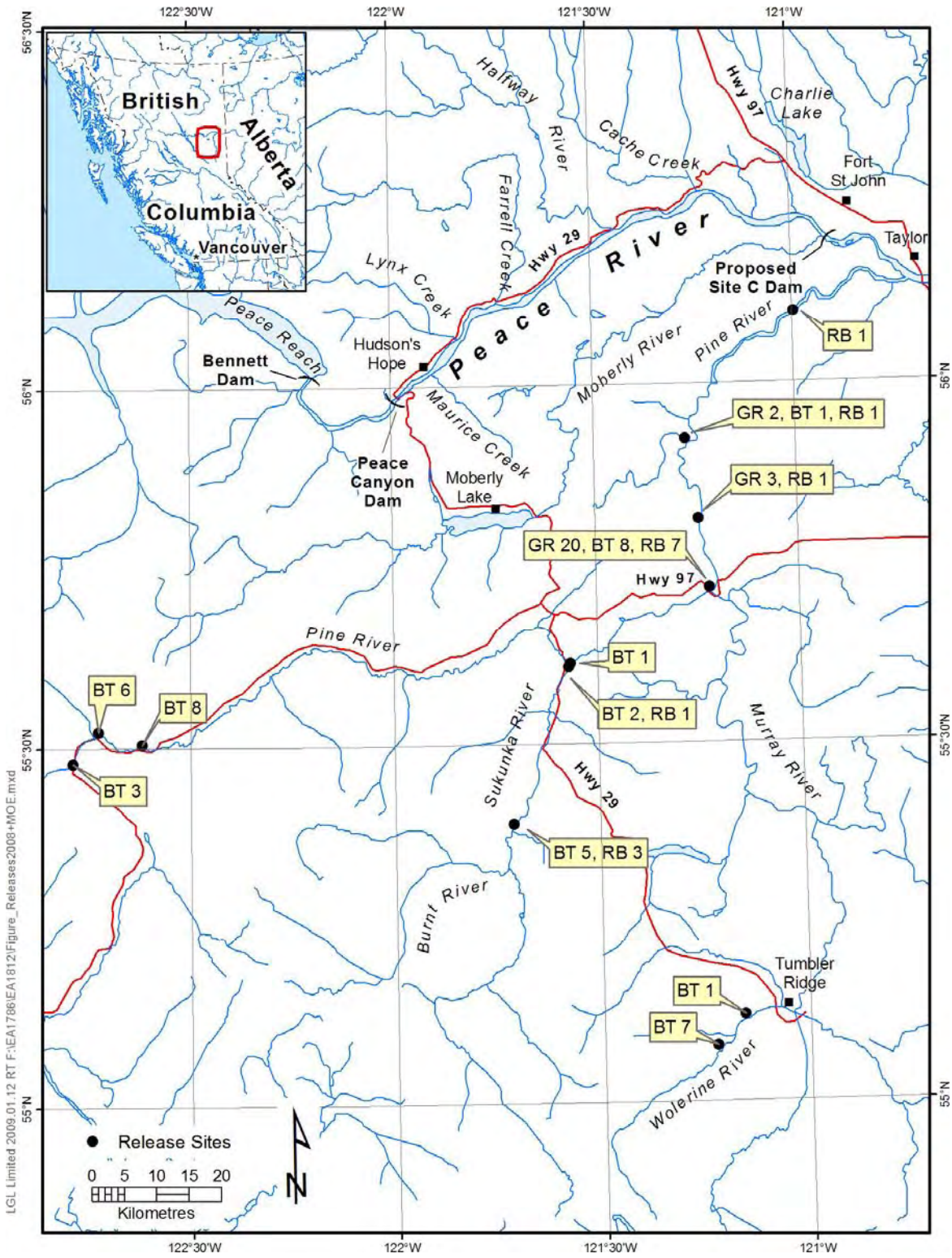

Figure 5: **Locations and numbers of radio-tagged Arctic grayling, rainbow trout and bull trout released in the Pine River watershed, June-August 2008**

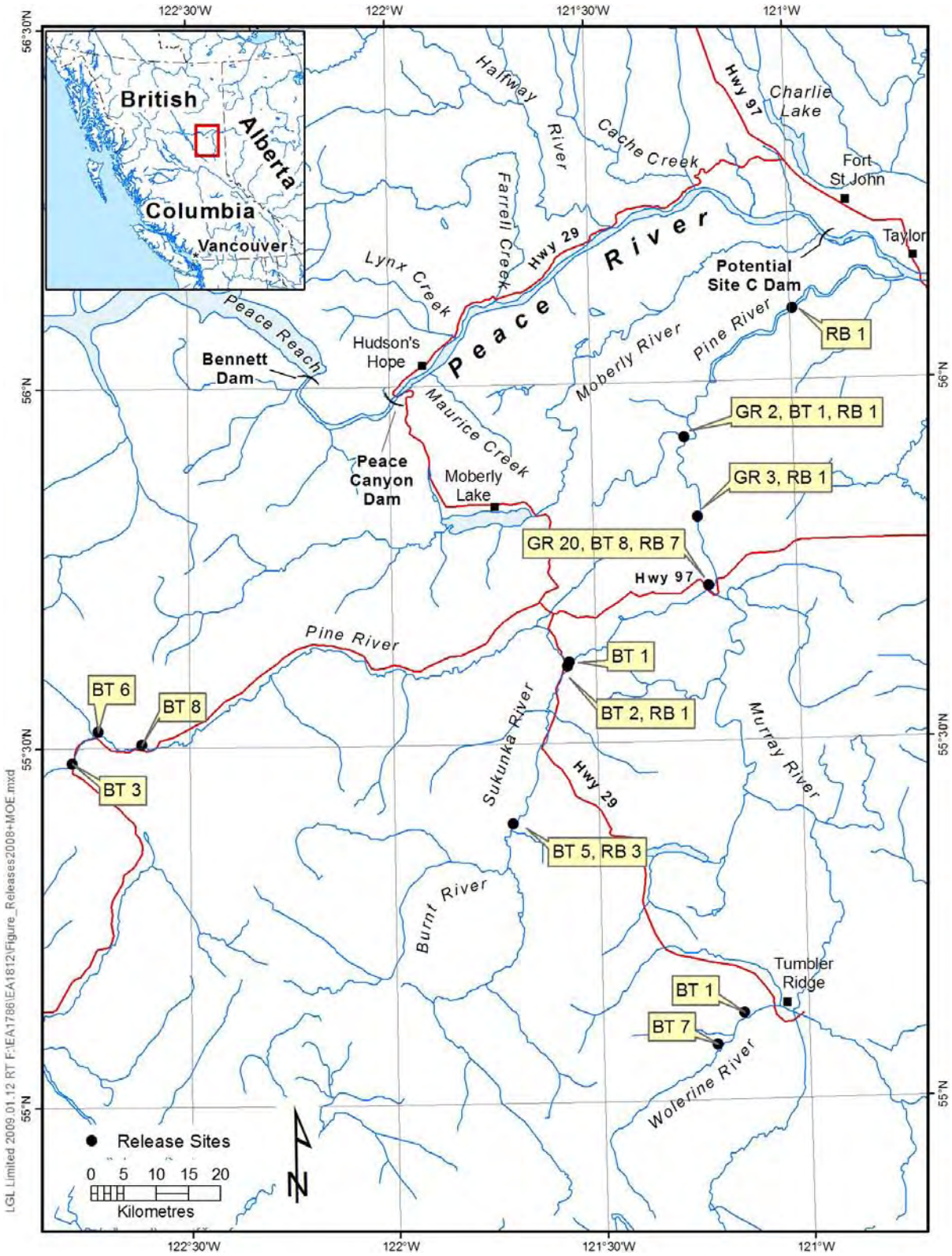

Figure 6: **Locations and numbers of radio-tagged bull trout, Arctic grayling and rainbow trout released in the Pine River watershed and the Upper Moberly River in 2006 and 2007.**

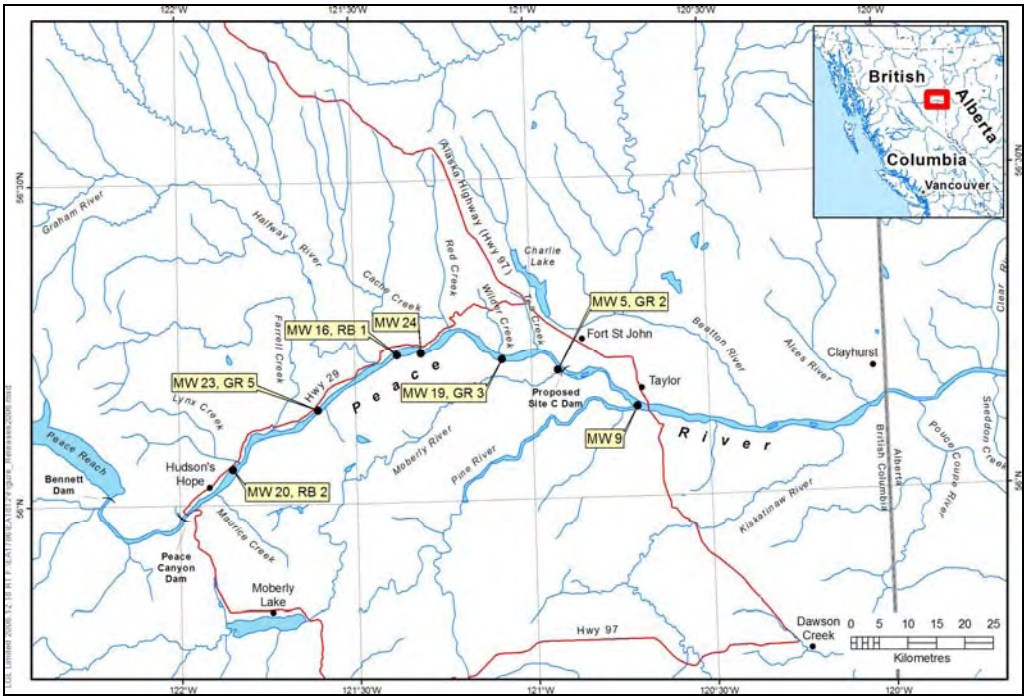

Figure 7: **Locations and numbers of radio-tagged mountain whitefish, Arctic grayling and rainbow trout released in the Peace River mainstem, June 2006.**

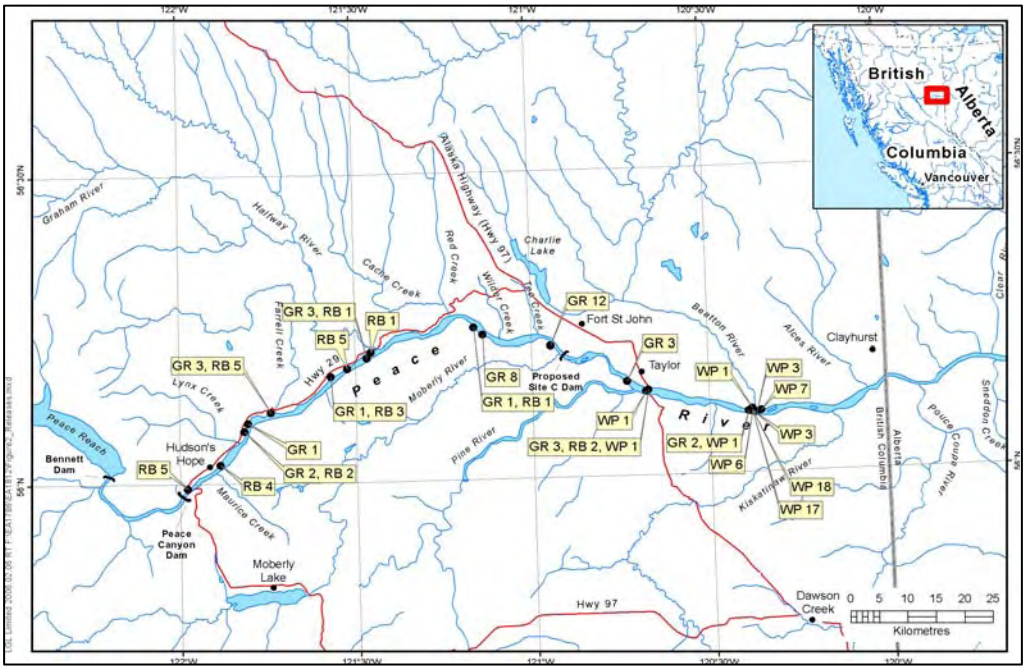

Figure 8: **Locations and numbers of radio-tagged Arctic grayling, rainbow trout and walleye released in the Peace River mainstem, September 2005.**

2.3.4 Monitoring Fish Movement

2.3.4.1 Fixed-stations

For the 2008 monitoring period, all fixed-stations were set up in late March, similar to previous years. Lotek SRX600 receivers were installed at the mouths of the Moberly and Halfway rivers, while all other fixed stations utilized SRX400 receivers. Receivers were downloaded bi-weekly from the beginning of April to end of October. Downloading procedures were similar to previous years and are detailed in AMEC & LGL 2008c, 2008d.

2.3.4.2 Mobile Tracks

In total, 12 aerial tracks of the Peace River mainstem (from the Peace Canyon Dam to Peace River, Alberta) and associated tributaries were conducted from late March to late October 2008. As in previous years, mobile tracking effort was increased in April-May and September-October in order to improve our understanding of the movements of both spring-spawners (Arctic grayling, rainbow trout, walleye) and autumn-spawners (mountain whitefish, bull trout).

Mobile tracks were conducted using either a fixed wing aircraft, or a helicopter. Three Lotek SRX400 receivers were used in mobile tracking (see below). Other tracking procedures were the same as those used in 2007 (AMEC & LGL, 2008d). As in previous years, surveying the whole study area often required multiple days. For tracks that were completed over several days, the daily detections were combined to produce a single synoptic map of the total survey area.

Typically, mobile surveys were conducted along the Peace River mainstem from the Peace Canyon Dam to Peace River, Alberta. As for the tributaries, variable distances were tracked up the Halfway, Moberly, Beatton and Pine rivers and the lower reaches of several creeks (Maurice, Lynx, Farrell, Cache). Strategically located fixed-station receivers were downloaded prior to flights so that this information and previous tracks could determine which tributaries needed to be surveyed. Although no fish were detected moving into the Halfway River, aerial tracks were extended into the headwaters twice to confirm the absence of tagged fish in the upper reaches of this tributary system.

All radio-tagged fish detected during mobile surveys were assigned to zones of the Peace River watershed as outlined in Figure 3. Data were accessed for analysis with LGL's *Telemetry Manager* and a combination of ArcGIS and

Visual FoxPro software to plot the distribution of fish detections on maps for each of the mobile surveys.

2.3.5 Data Processing

Telemetry Data Processing

The data from mobile tracks and fixed-station downloads were processed and analyzed using LGL's custom database software, "*Telemetry Manager*". *Telemetry Manager* facilitates data organization, record validation, and analysis through the systematic application of user-defined criteria. Raw data were archived so that the temporal or spatial resolution and noise filtering criteria could be changed by the user at any time without altering the raw data. An important aspect of radio telemetry is the removal of false records in receiver files, for example, those that arise from electronic noise. In this study, the following criteria were set for records to be considered valid:

- Power levels had to be greater than 50 (on a 1 to 232 scale);
- For fixed-station data, multiple detections had to be recorded within a single zone, within 20 minutes of each other, and with no records at other zones interspersed (i.e., single records, or records separated by more than 20 minutes were rejected); and
- Detections had to be recorded at zones that were geographically located between the locations of previous and subsequent valid detections.

Once false records were removed, *Telemetry Manager* created a compressed "operational" database of sequential detections for each fish. Each record included the tag number, zone number (antenna number, fixed-station number, or a general location), the first and last time and date for sequential detections in a specific zone, and the maximum power for all detections in that interval. The compressed operational database was used for all subsequent analyses of fish behaviour and survival.

Movement Calculations and Data Cleanup

The result of data processing was an operational database file containing a summary of all release and recovery information, with all valid fixed-station and mobile track detections in chronological order for each fish. For each location record in the database, UTM co-ordinates were appended. For mobile detections, the position of the fish was assumed to be that of the aircraft (downloaded from the GPS unit) at the time of the most powerful detection event. Fish detections recorded by fixed-station receivers were assigned the co-ordinates of the receiver, with the direction of movement determined from the antenna number containing the detection information.

From the dataset containing sequential positions for each fish, movements, displacements and travel speeds could be calculated.

Movement distances were estimated using a Foxpro script, which either connected sequential UTM co-ordinates with a straight line, or, when sequential positions were in different zones, via a series of nodes thereby forcing the movements to approximately follow the geography of the river system. For each movement event, the start and end timestamps were used to determine the "time at large" (i.e., the duration) of the movement event. Also, the start and end positions of each movement event were used to determine if the direction of movement was upstream or downstream. On occasion, a fish would move both downstream and upstream within the same movement event. For example, a fish detected in the Beatton River and subsequently in the Alces River had to move downstream in the Beatton River, downstream in the Peace River, and then upstream into the Alces River. In these events, the direction of the final leg of the movement was assigned to the whole of the movement. For each movement, a displacement was calculated as the magnitude of the movement multiplied by 1 for upstream movements, or by -1 for downstream movements. Displacement rates were calculated as the displacement divided by the time at large.

Once the distance, direction, and duration were calculated, it became apparent that no records were obviously invalid. Specifically, there were no cases in which detection sequences that made fish appear to move unrealistically quickly, and there were no sequences that made fish appear to move too far, especially without being detected by fixed-station receivers in between. The only challenge that arose was that of simultaneous mobile and fixed-station detections. Fish that remained in the detection field of a fixed-station receiver at the time of a mobile track would show artificially high displacement rates because they would be recorded at the UTM co-ordinates of the fixed-station receiver, then instantly appear at the UTM co-ordinates of the mobile survey aircraft, and then immediately return to the UTM of the fixed-station receiver. To avoid this problem, mobile detections were ignored (for the purposes of movement and displacement analyses) if they occurred simultaneously to a series of fixed-station detections.

Once all of the artificial movements were cleared out of the database, the movement distances, directions, and durations were recalculated. For these final calculations, movement distances were estimated using ARC-GIS software. For each fish, all detection positions were plotted, and each sequential position was connected with a straight line (making *n-1* lines joining *n* detection positions). Tracking tools in the software were used to

confine each of these connector-lines to within the river contours, hence taking all river-curvatures into account. Time at large, movement direction, displacement and displacement rates were all calculated using the methods as previously described.

All movement events, with their associated direction, displacement, time at large, and displacement rate, were linked to an individual fish (and hence a species) and a timestamp for subsequent analyses. Analyses included comparisons among species, between years and among months for displacement rates, overwinter displacement, displacement during monitoring periods, and the effects of time at large on displacement.

Basis for Tag Exclusion

Radio-tagged fish confirmed or presumed to be dead and those that were never detected were filtered from the dataset and excluded from further analysis.

Potential Mortality

From position-based telemetry data, it is not possible to determine if a fish is living or dead. A live, sedentary fish would "track" the same as a dead fish, or as an expelled tag on the riverbed. It is generally acceptable to assume, when movements are observed, that an individual is alive. For this study, tags that never changed positions were called "potential mortalities" (thus, fish that were detected one or fewer times were excluded from the potential mortality calculations). The error associated with our method of position estimation was determined (see below), and used as the minimum movement threshold below which any observed "movements" might be spurious. Any fish that did not move a distance greater than this threshold was called a potential mortality, and was excluded from subsequent analyses.

The error associated with mobile track-derived position estimates can be expressed as a function of aircraft speed, receiver scan time, the number of scanning receivers, and the number of channels being scanned by each receiver. As an aircraft flies along the river, it is possible to detect a single tag multiple times. The strength of the tag detection is greatest when the aircraft is in close proximity to the tag, and weakens as the distance increases. In this study, the position of the fish was estimated by using the UTM co-ordinates of the aircraft at the time when the most powerful of these detections was recorded. Thus, it should be apparent that an aircraft containing a single telemetry receiver (scanning 4 channels for 6 seconds each), moving at speed, may travel a considerable distance between detections of any given tag; and the most powerful detection of a given tag

may be recorded several hundred metres away from the “actual” position of the fish.

In this study, three receivers were operated onboard the aircraft. Each receiver scanned 4 channels for 6 seconds each. In the worst case scenario, in which all three receivers scanned the same channel simultaneously, there would be an 18 second interval between scans of a given channel. In the best case scenario, in which the three receivers never duplicated each other during scanning operations, the interval would be 6 seconds. The aircraft pilots were asked to travel from 70 to 80 mph, thus moving 36 m/s in the worst case and 31 m/s best case. Combined, the error bounds of the mobile track-based position estimates can be set between 188 m (in the best case) and 644 m in the worst case.

It should be noted that every effort was made to ensure that at all times the three receivers were scanning different channels. Also, when mobile tracks were conducted from a helicopter, the aircraft could slow down or hover, and fixed-wing aircrafts could circle back to do a second pass. Position error is likely to be less than that calculated above given that measures were taken to collect the most accurate position. Based on these “unquantifiable” factors, we believe that 644m is too large, and the threshold should lie closer to the best-case (188 m) scenario.

A conservative threshold, set at 350 m (double the lowest scenario), resulted in potential mortalities of 0%, 10%, 0%, 4%, and 0% for bull trout (0 of 90), Arctic grayling (3 of 29), mountain whitefish (0 of 1), rainbow trout (1 of 25), and walleye (0 of 12), respectively (Figure 9). A slightly more liberal threshold of 300 m produced identical mortality estimates. Based on the mobile tracking crew’s efforts to pin-point fish locations, and the observed plateau in the mortality curves, it is felt that a mortality threshold of 300 m is adequate. This is the same threshold that was used in previous years (AMEC & LGL 2008d).

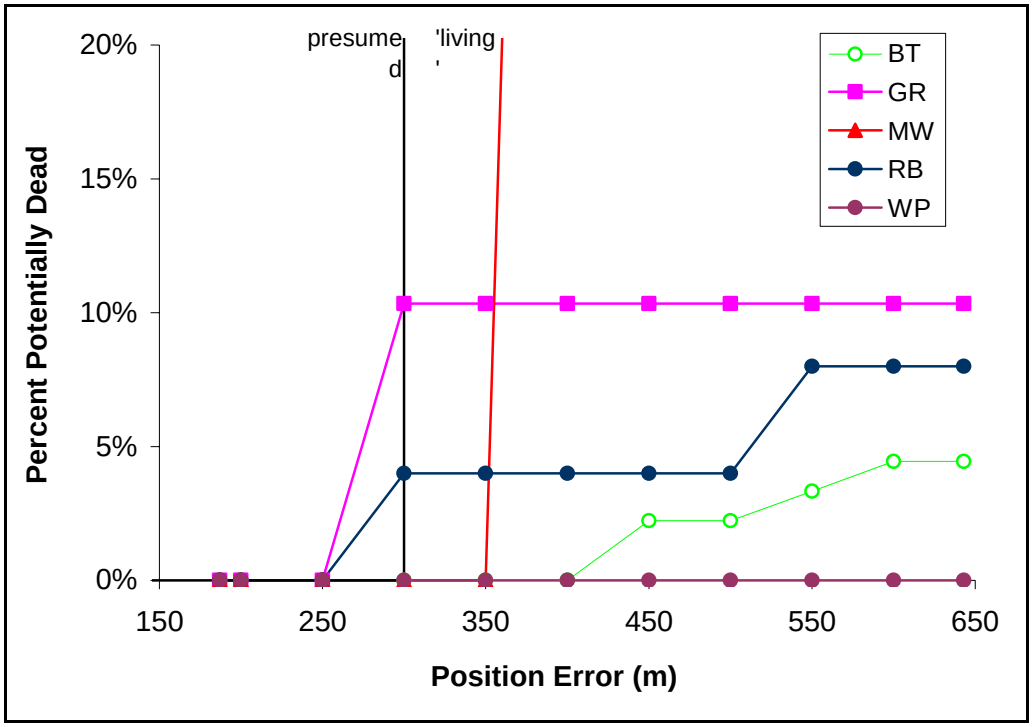

Figure 9: **Potential mortalities of radio-tagged fish in 2008, by species. Note that fish detected only once, never detected, or recovered by fishermen were excluded from this analysis**

Known Mortalities

All fish (or tags) that were recovered from anglers (or found on the riverbank) and returned to us were classified as “known mortalities”. These fish, together with the potential mortalities (described above) were excluded from all subsequent analyses. In total, 19 fish were excluded (Table 4) for reasons of mortality. Of these, 15 were known mortalities, and remaining 4 fish were presumed mortalities in 2008. No effort was made to collect/retrieve stationary tags as usually they are covered over with bed materials or discoloured with algal growth and not easily spotted.

Undetected Tags

Several tags were not detected in 2008 tracking (Appendix B, Table B3). Of the tags deployed in 2005, 87% (109 of 126) were not detected in 2008, largely as a result of the expected decay in battery life of the transmitters. Given the expected battery life reported by the tag manufacturer, it was surprising to see that 13% of the fish tagged in 2005 were detected in 2008 (17 of 126). Similarly for fish tagged in 2006, 67% (138 of 206) were not detected in 2008.

In contrast, the fish tagged in 2007 and 2008 were expected to have fully-functional batteries during the 2008 survey year. Only six of these 90 tags were never detected. These six fish (1 tagged in 2007 and 5 tagged in 2008) may have moved out of the study area, may have been removed by a predator or an angler, or some of these tags may have failed prematurely. Expected tag failure based on information from past LGL studies is approximately 0.3%. Note that the survey efforts were adequately intense to expect that tags associated with dead fish would be detected at least once. For this reason, tags that were never detected were not considered as 'mortalities', but were nevertheless censored from subsequent analyses.

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Table 4: Radio-tagged fish presumed or confirmed dead

Species	Tag #	Date Tagged	Tag Site[1]	FL (mm)	Weight (g)	Recovery Date	Comments[1]
Bull Trout	303	08/21/06	Pine	44	740	09/03/07	Caught by an angler
	304	08/20/06	Pine	47	1010	09/19/07	Caught by an angler
Arctic grayling	349	06/19/08	Pine, near Murray	285	250	- -	Stationary; presumed dead
	360	06/21/08	Pine, near Murray	307	350	- -	Stationary; presumed dead
	376	06/22/08	Pine, near Murray	283	250	- -	Stationary; presumed dead
Mountain Whitefish	139	06/24/06	Peace	372	575	09/09/06	Eaten by bull trout, caught by angler
	232	06/27/06	Peace	337	425	09/02/06	Tag found on riverbed
	252	06/26/06	Peace	326	350	07/15/06	Tag found on riverbed
Rainbow Trout	74	09/26/05	Peace	276	300	05/17/06	Tag found on riverbed
	88	09/27/05	Peace	396	825	08/28/06	Eaten by bull trout, caught by angler
	95	09/28/05	Peace	341	450	06/01/06	Caught by an angler
	371	06/21/08	Pine, near Murray	308	350	- -	Stationary; presumed dead
Walleye	3	09/21/05	Beatton mouth	473	1350	06/08/07	Caught by an angler
	10	09/21/05	Beatton mouth	411	800	02/10/06	Fish found dead at Pouce Coupe River
	28	09/21/05	Beatton mouth	439	1100	01/31/06	Caught by an angler
	102	09/29/05	Beatton mouth	361	575	07/08/06	Fish found dead at Beatton River mouth
	113	09/29/05	Beatton mouth	441	1050	04/07/06	Caught by an angler
	121	09/29/05	Beatton mouth	446	825	08/26/08	Caught by an angler
	126	09/29/05	Beatton mouth	507	1725	10/11/07	Caught by an angler

Note: [1]Confirmed deaths are based on tag recoveries and presumed deaths are based on the stationary position of the tag over the study duration.

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Fish Movement Past Site C

The fixed-station receiver that was closest to the potential Site C Dam location was deployed about 0.5 km upstream from it, at the confluence of the Moberly and Peace rivers. For each fish, any sequence of movements that showed detections both upstream and downstream of the Moberly River mouth was included as a Site C Dam passage event. Passage events were associated with a date and an individual (and hence a species) for subsequent analyses. Fish that approached the Moberly River mouth from upstream, but immediately returned back upstream (without being detected downstream of the Moberly River mouth) were not considered to have passed Site C, since Site C is located downstream of the fixed-station receiver. Conversely, fish that approached the Moberly River mouth from downstream must have passed Site C, regardless of their subsequent movements. Analyses included comparisons of movement events among species, between years and among months.

Statistical analyses

For any statistical comparisons among species or among years of movements, displacements, and displacement rates, nonparametric analyses were performed since the data were non-normally distributed (normality is required for the use of standard statistical tools). Typical tests included the Kruskal Wallis H test (one-way ANOVA non-parametric equivalent), and the Scheirer-Ray-Hare (SRH) two-way non-parametric ANOVA (Zar 1984). The main exception was the analysis of displacement as a function of time at large, for which slopes were compared between years and among species using first and second order ANCOVA. For all analyses, statistical significance was declared when *P* values were less than 0.05.

3.0 RESULTS

3.1 Environmental Characteristics

3.1.1 Discharge

Flow data at Water Survey of Canada stream gauges on the Peace River at Taylor, Halfway, Moberly, Pine and Beatton rivers for 1996 to 2008 (WSC 2008a; 2008b) are presented in Appendix A (Tables A1 to A5). The 1996 discharge for the Peace River is not included in Figure 10 because there was a spill event from W.A.C. Bennett Dam in the summer of that year which does not reflect natural flow conditions. In 2008, data was only available for the Peace River mainstem at reporting time.

Peace River discharge in 2006 generally ranged between the 1997-2005 daily mean and daily minima (Figure 10). In contrast, discharge in 2007 was generally between the 1997-2005 daily mean and the maxima indicating higher overall flows in 2007. In 2008, daily mean discharge was relatively similar to the 1997-2005 maximum over winter and spring. Water discharge lowered to 1997-2005 mean levels in late May and June and then lowered again toward the 1997-2005 minimum in the summer. Although flow regulation is attenuated downstream by discharge from unregulated tributaries, Peace River flows at Taylor, B.C. are largely dictated by flows out of Peace Canyon Dam.

In the major Peace River tributaries, flow patterns were similar among tributaries but varied between 2006 and 2007 (Figures 11-14). In 2006, discharge was consistently below the 1996-2005 daily mean flow; they were slightly above the 10 year minima in spring but were frequently less than the minima following June. In 2007, the major tributaries had discharge between the 1996-2005 daily mean and maxima in the spring while flows after June fluctuated around the daily mean. Discharge data for 2008 was not available at report time for all the tributaries.

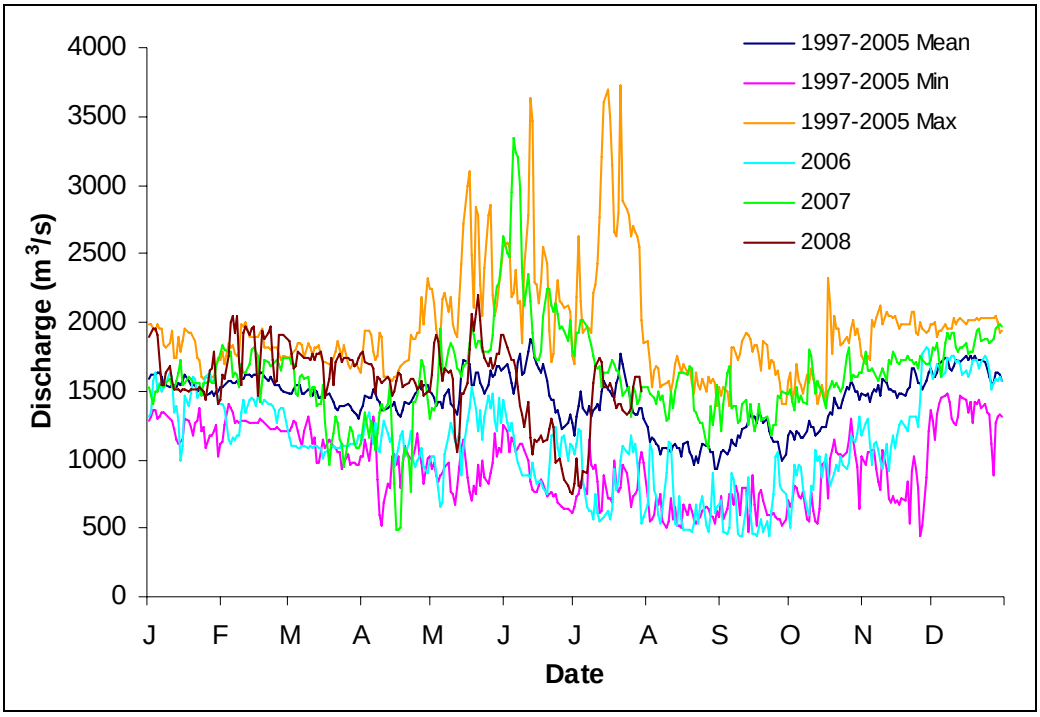

Figure 10: Daily discharge (m^3/s) of the Peace River near Taylor, BC for 2006, 2007, and 2008 compared to 1997 to 2005

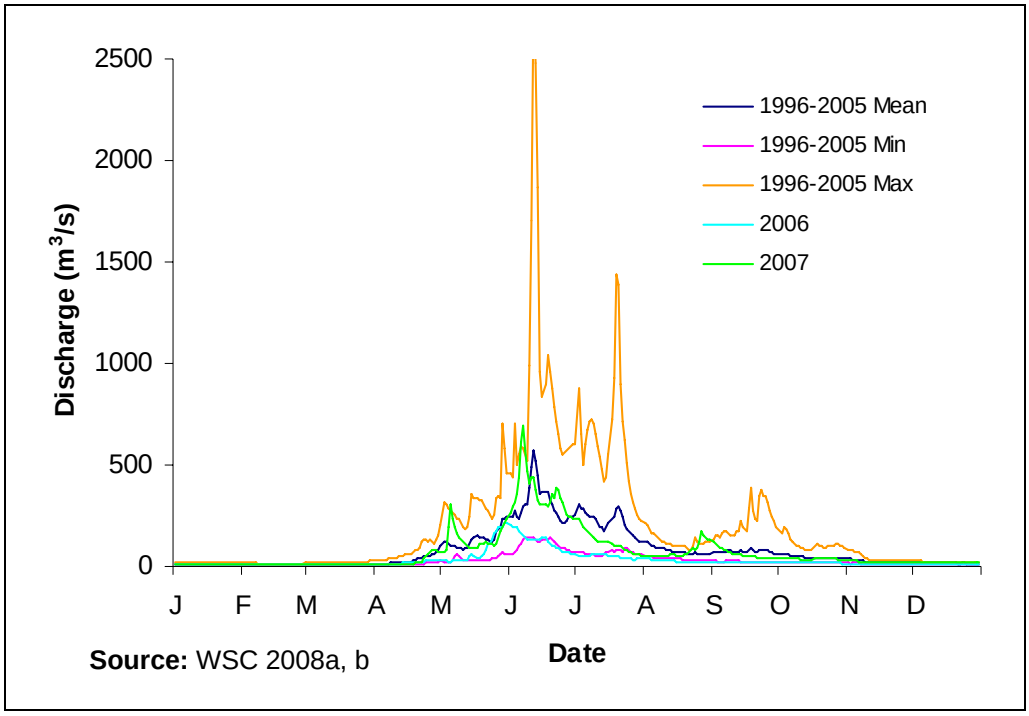

Figure 11: **Daily discharge (m^3/s) of the Halfway River for 2006, and 2007, compared to 1996 to 2005**

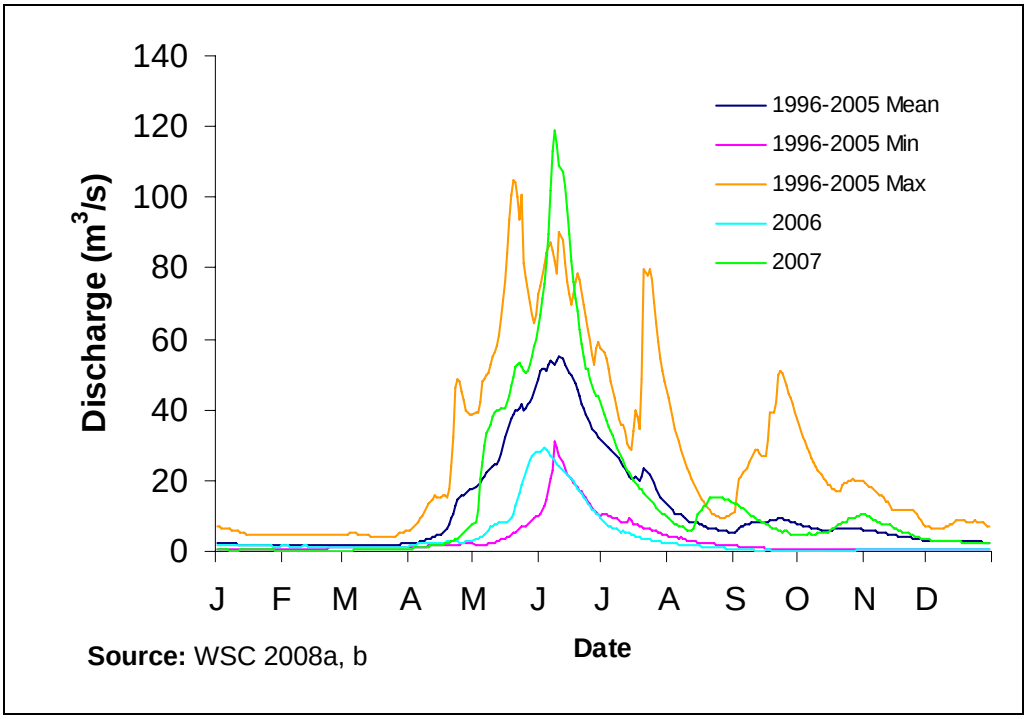

Figure 12: **Daily discharge (m^3/s) of the Moberly River for 2006 and 2007, compared to 1996 to 2005**

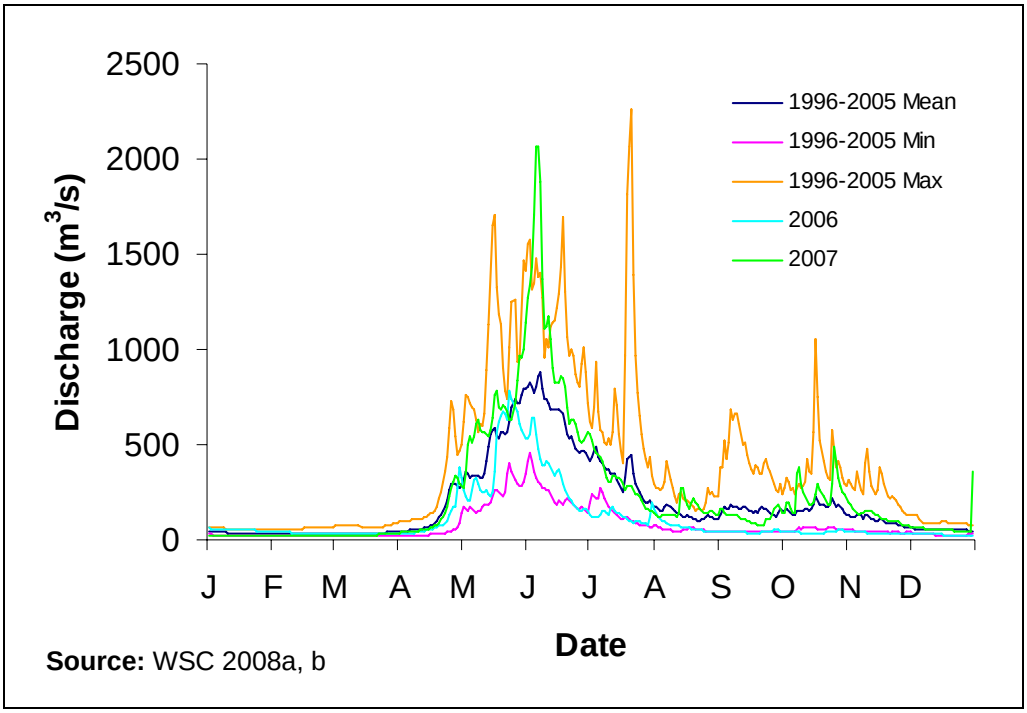

Figure 13: **Daily discharge (m^3/s) of the Pine River for 2006 and 2007, compared to 1996 to 2005**

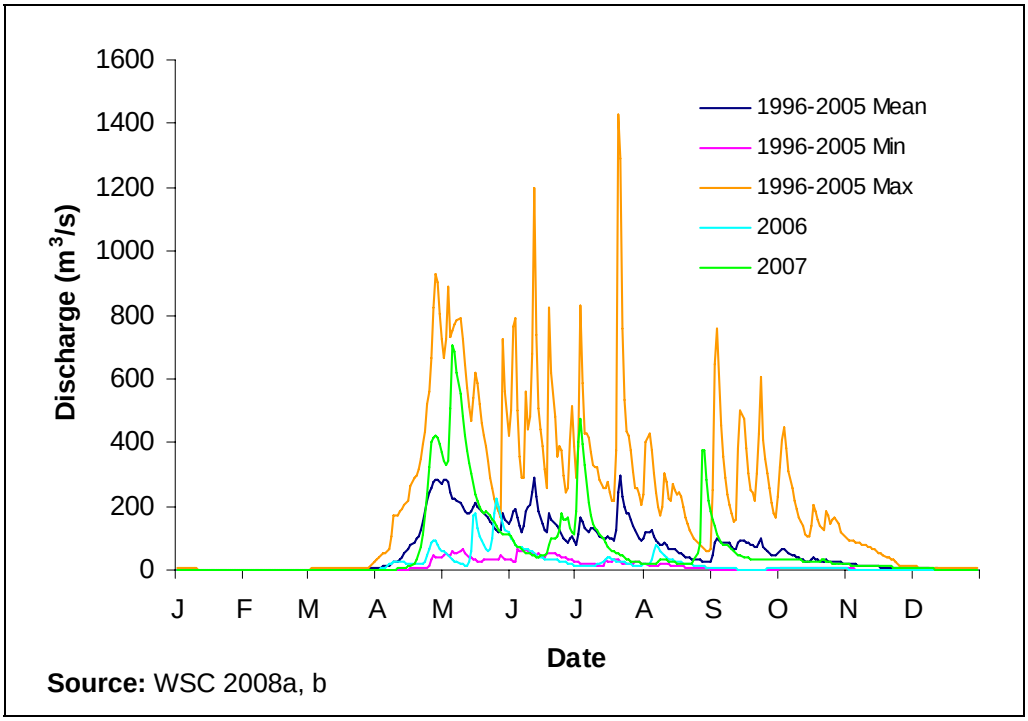

Figure 14: **Daily discharge (m^3/s) of the Beatton River for 2006, and 2007, compared to 1996 to 2005**

3.1.2 Water Temperatures

Mean daily water temperatures in the Peace River at the proposed Site C dam, and near the mouths of the Beatton River, Pine River, and Moberly River, Wilder Creek, Cache Creek, Halfway River, Farrell Creek, Lynx Creek, and Maurice Creek for the 2005, 2006, 2007 and 2008 are presented in Appendix A (Table A6), and in Figures 15 to 24, respectively.

A common pattern was apparent between 2006, 2007 and 2008 for the Peace, Beatton, Pine and Moberly rivers, although water temperatures varied among locations. In the Peace River and its major tributaries, mean daily water temperatures were at least two degrees cooler in summer of 2007 than in 2006. In 2008, water temperatures were mostly similar with 2007 values. However, temperatures in the larger tributaries were slightly cooler in April/May suggesting later spring melt than in earlier years. In the smaller tributaries, like Cache, Farrell, Lynx and Maurice creeks, water temperatures were similar between 2006, 2007 and 2008. In 2008, water temperatures were similar to the other years but, as with the bigger tributaries, temperatures were slightly cooler in April suggesting later spring melt than in 2005 and 2006.

Mid-summer temperatures in the Peace River were more moderate (<17ºC) than in any of the Peace River tributaries which, in the smaller creeks, neared 25ºC in summer. Water temperatures in the Peace River are largely dictated by the temperature of water released through Peace Canyon Dam and, hence, by temperatures in Dinosaur Reservoir. Water temperatures were highest in Farrell and Cache creeks in all sampled years.

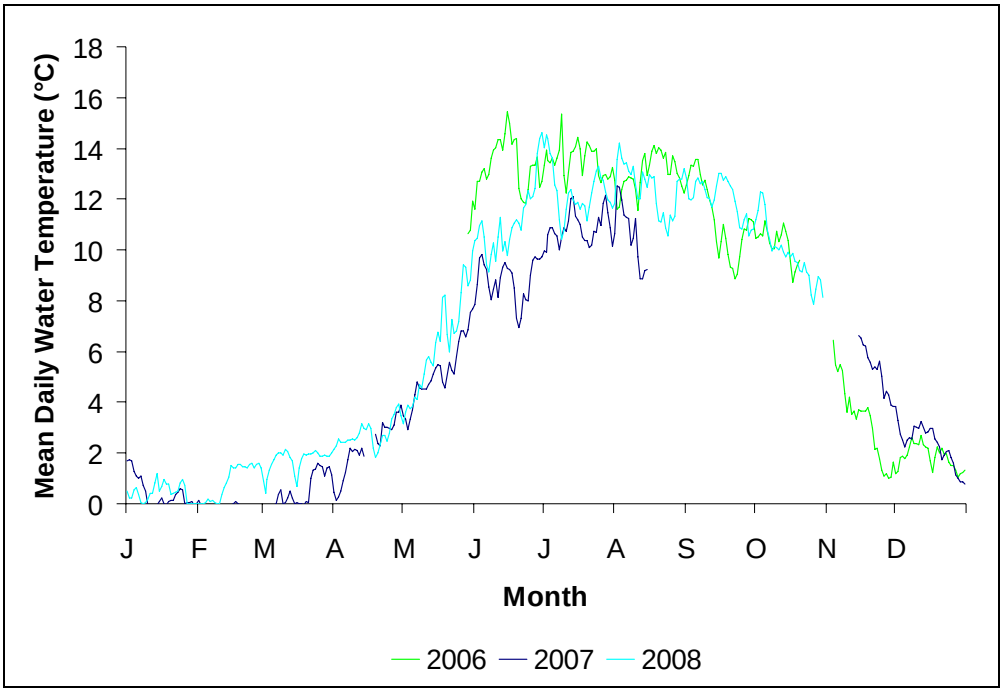

Figure 15: **Water temperatures for Peace River near the proposed Site C dam location**

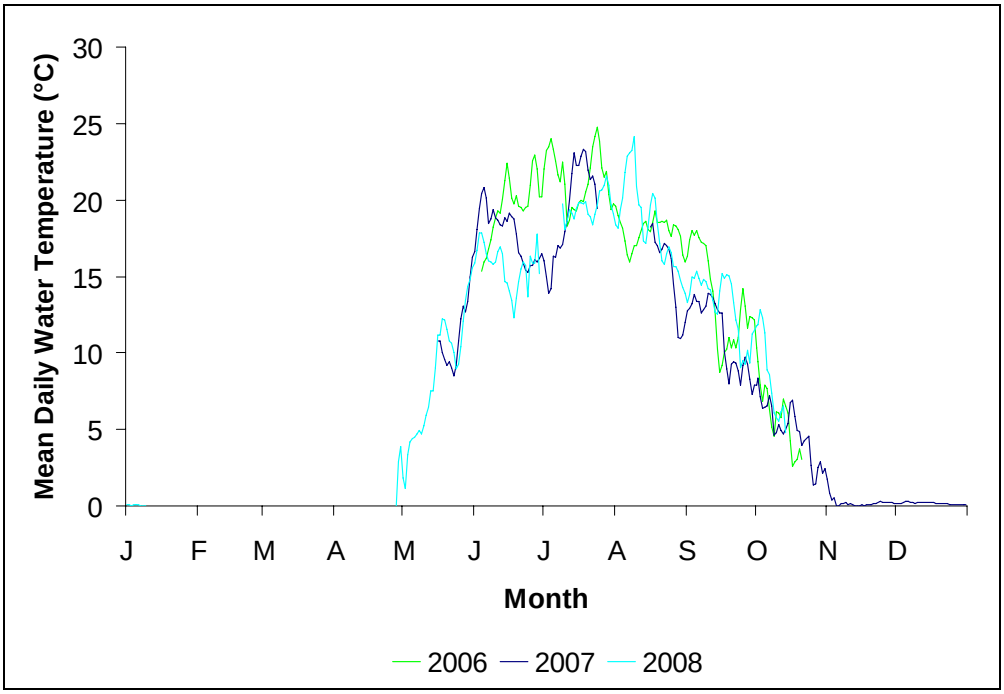

Figure 16: **Water temperatures for the Beatton River**

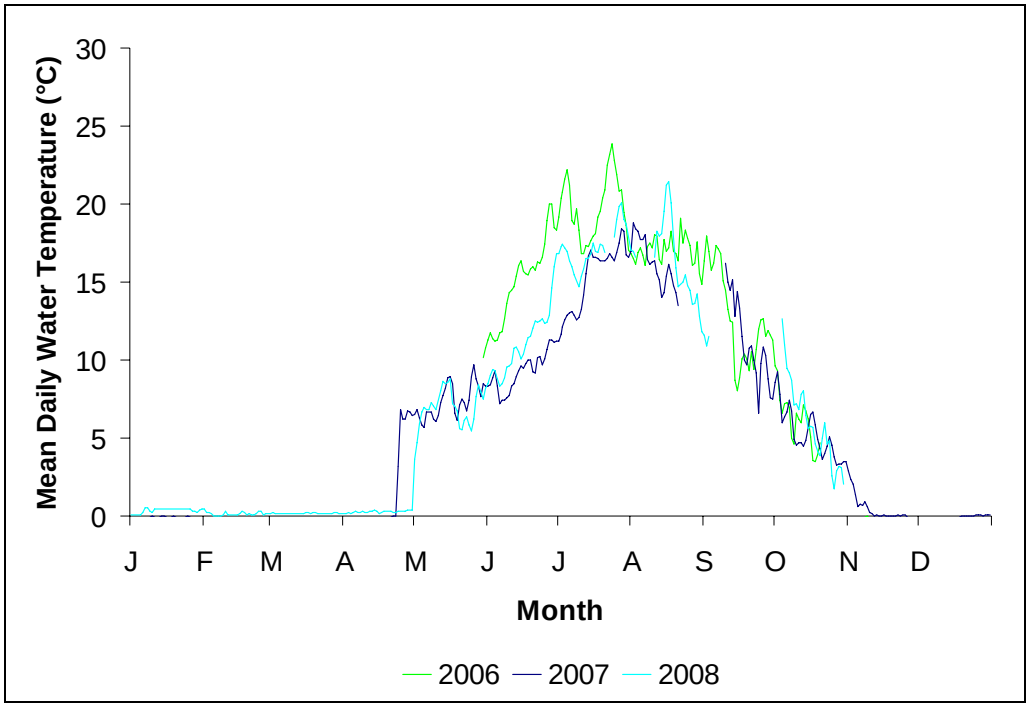

Figure 17: Water temperatures for the Pine River

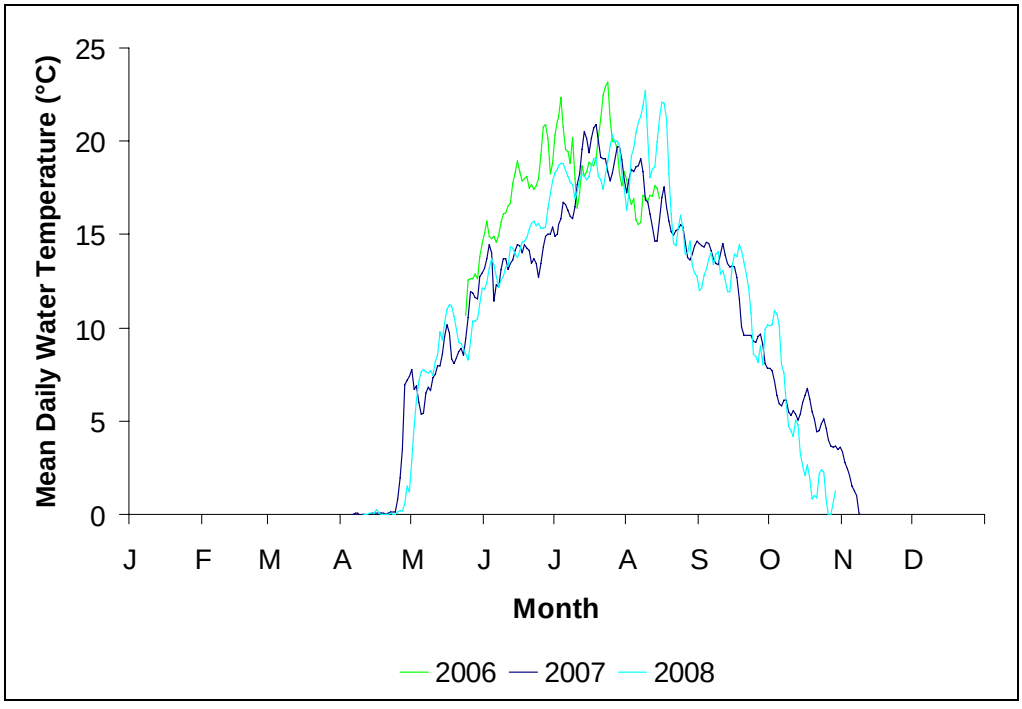

Figure 18: Water temperatures for the Moberly River

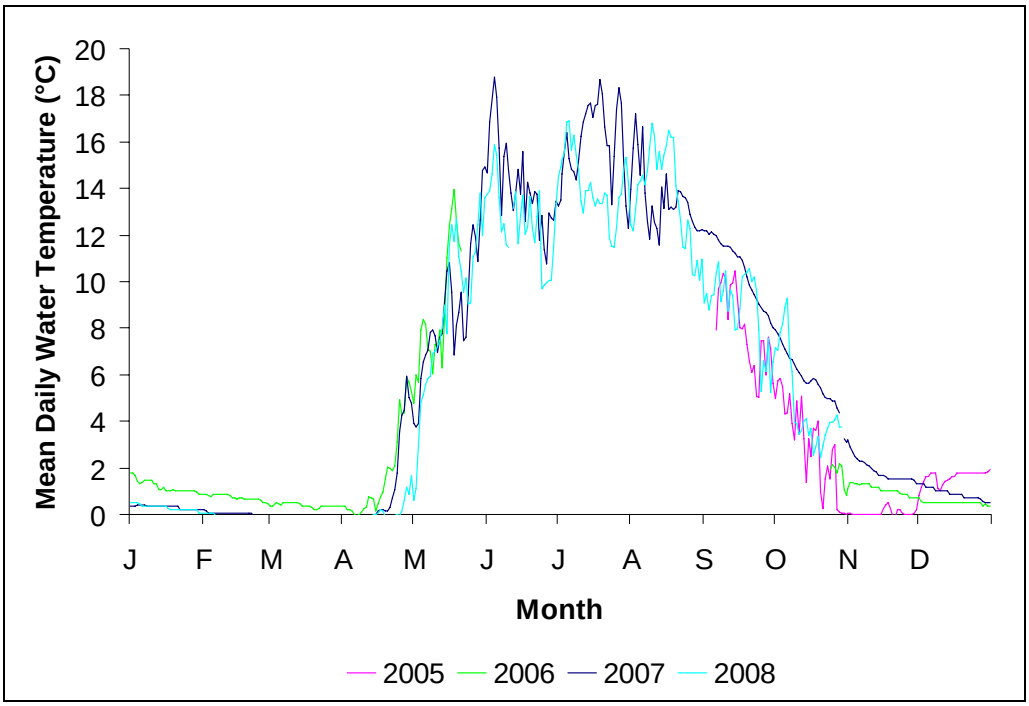

Figure 19: Water temperatures for Wilder Creek

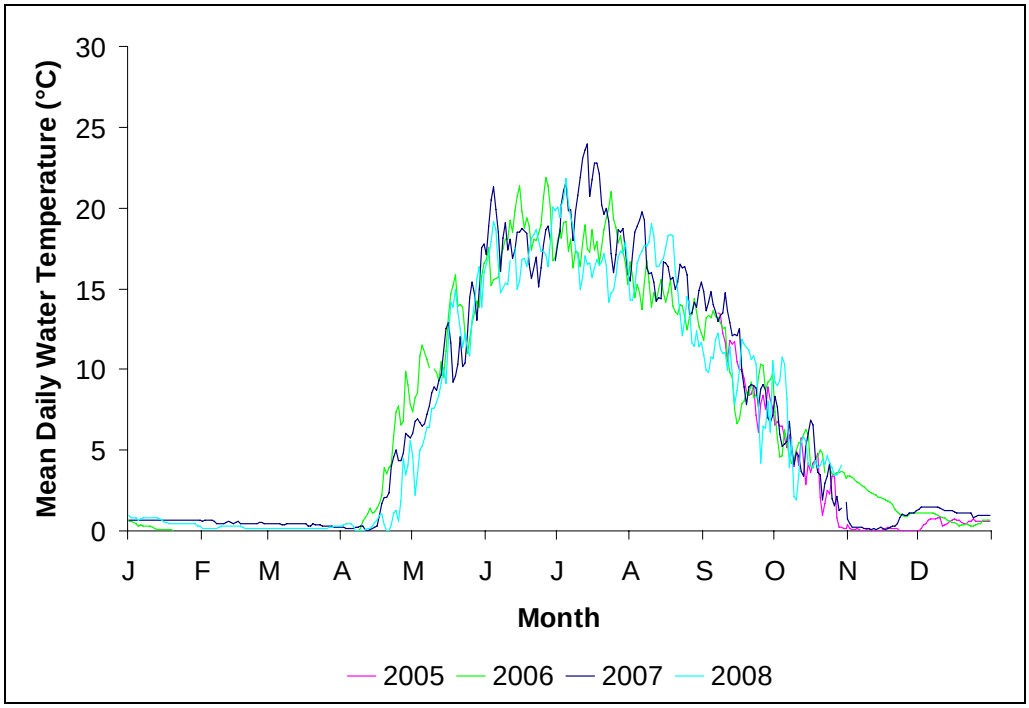

Figure 20: Water temperatures for Cache Creek

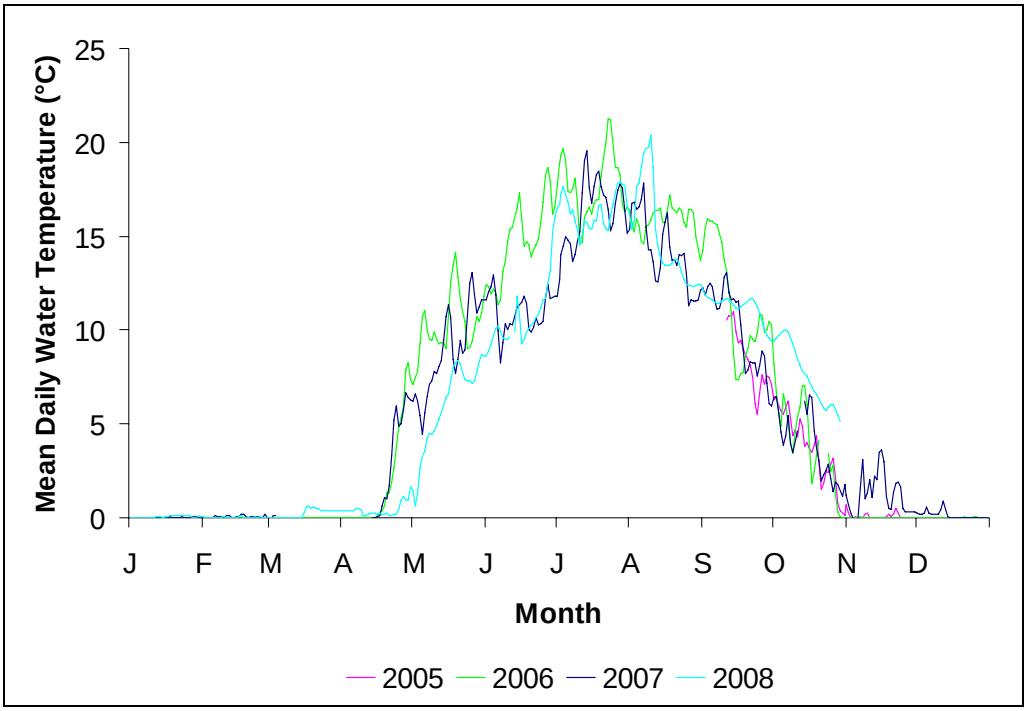

Figure 21: Water temperatures for the Halfway River

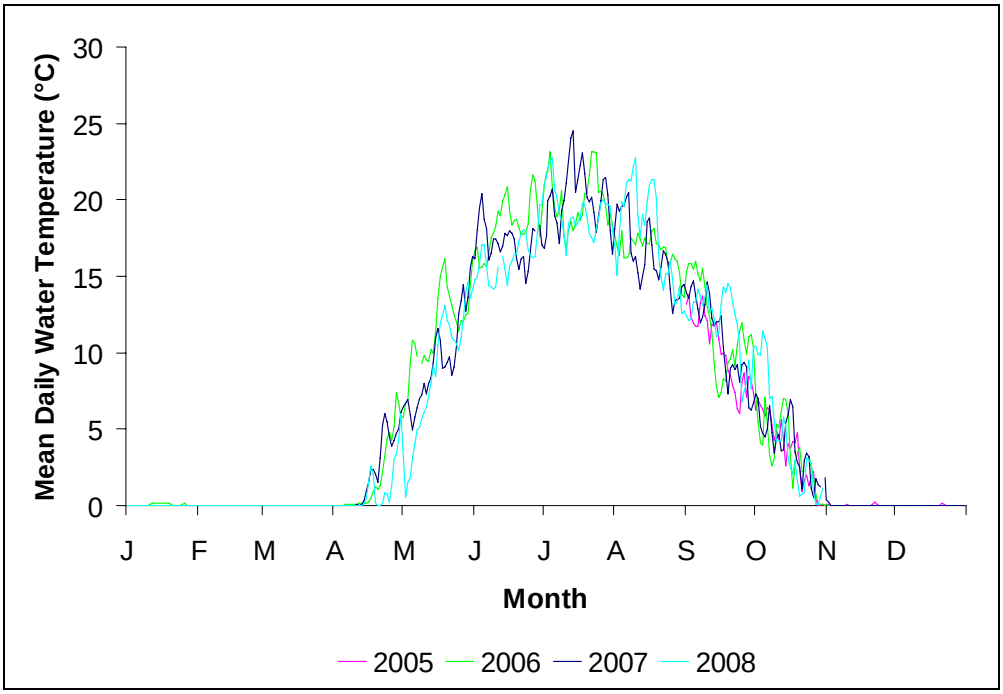

Figure 22: Water temperatures for Farrell Creek

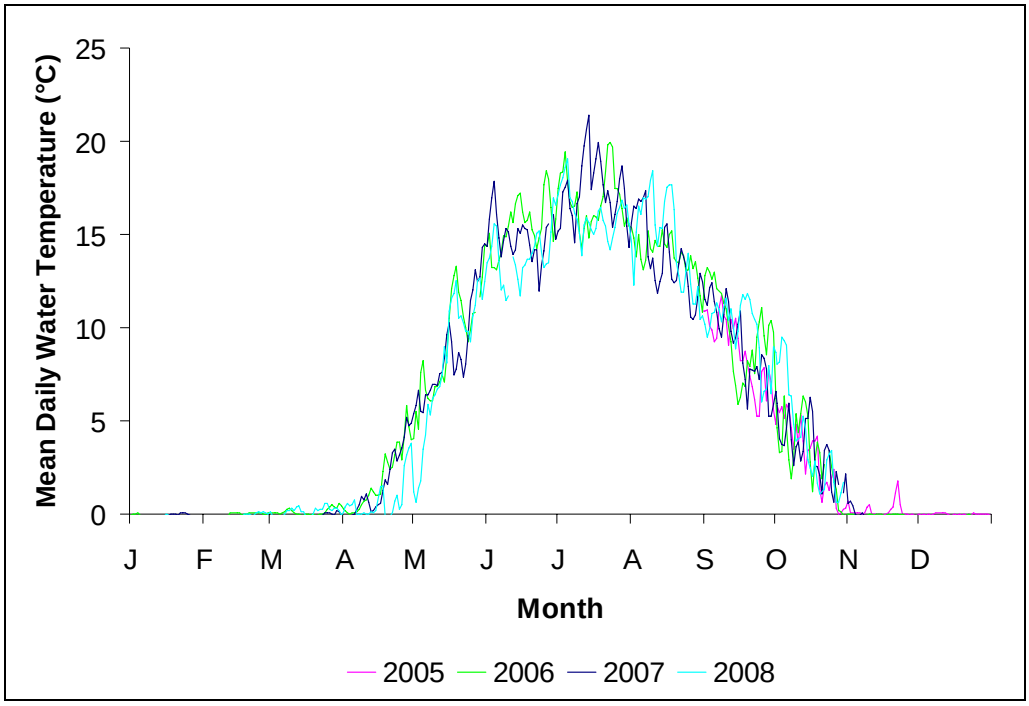

Figure 23: Water temperatures for Lynx Creek

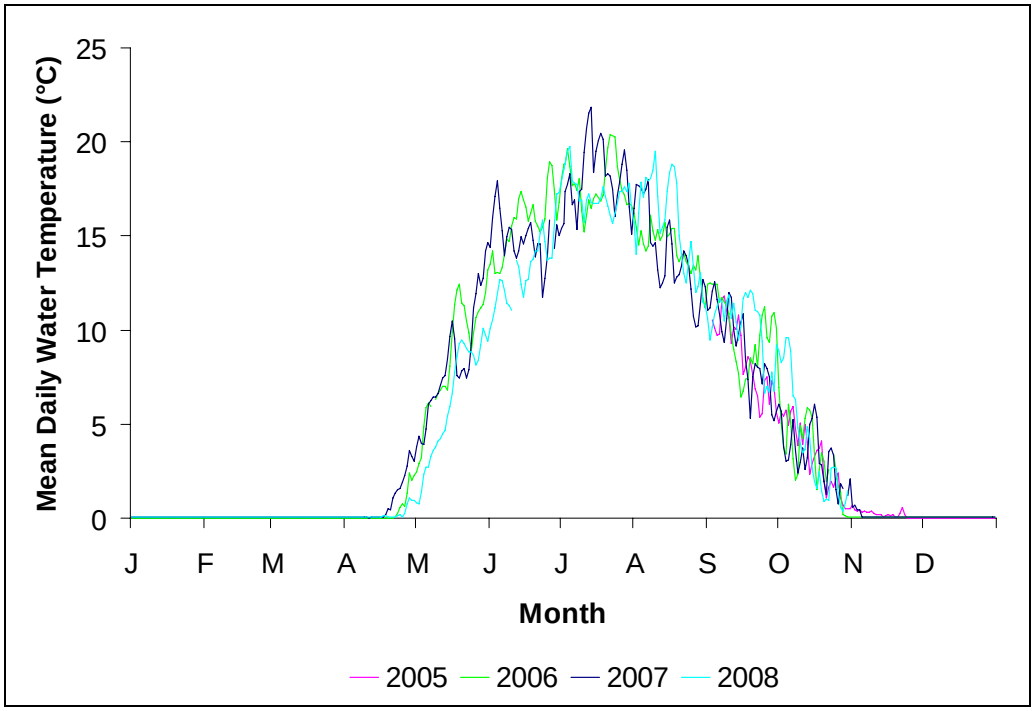

Figure 24: Water temperatures for Maurice Creek

3.2 Radio Telemetry

Very few Arctic grayling, rainbow trout, and mountain whitefish that were released in the Peace River mainstem during the 2005-2006 period were detected in 2008 as the tags were beyond the expected battery life. Because so few of these fish were detected in the first survey in 2008, their results are not discussed in subsequent surveys. On the other hand, several walleye tagged in 2005 continued to be detected during the 2008 tracking period, and the detections of these fish are included in the discussion of subsequent 2008 surveys results. A summary of the date, time, location and distance moved for all fish detected in 2008 is available in Appendix B, Table B4

3.2.1.1 Fixed-stations

During the 2008 study period, a total of 74 of the 170 fish (44%) were detected at the fixed-station receiver sites, indicating that more than half of the tagged fish moved relatively little. The percent of radio-tagged fish that was detected at each of the fixed-station receiver is presented by species in Table 5. A greater proportion of bull trout was detected at stations set within the Pine River system compared to elsewhere. For walleye, fixed-station detections were mostly at the mouth of the Beatton River, although some fish moved to the mouth of the Pine River. Detections of Arctic grayling and rainbow trout were mostly at the Pine-Murray confluence. For the most part, the bulk of the detections for each species was in the vicinity of the tagging and release locations, again indicating that fish moved relatively little.

Table 5: The percent of radio-tagged fish that was detected at each fixed-station receiver, 2008

	Species				
	Bull trout	**Arctic grayling**	**Mountain whitefish**	**Rainbow trout**	**Walleye**
Fixed-station	**n=95**	**n=31**	**n=4**	**n=25**	**n=15**
Halfway River					
Graham River					
Moberly River	3%	3%		4%	
Pine River	6%			4%	27%
Beatton River					60%
Pine at Murray	17%	58%		24%	7%
Pine at Sukunka	19%	3%		8%	

3.2.1.2 Mobile Tracks

The number and percentage of tags detected at large in each of the 12 mobile tracks conducted in 2008 are summarized in Table 6. The low percentages for some species in July were due to delayed tag activation.

Table 6: Number and percentage of radio tagged fish detected by species for each mobile track

	Bull trout			Arctic grayling			Mountain whitefish			Rainbow trout			Walleye		
Survey Date	**%**	**$n^{detections}$**	**n^{total}**	**%**	**$n^{detections}$**	**n^{total}**	**%**	**$n^{detections}$**	**n^{total}**	**%**	**$n^{detections}$**	**n^{total}**	**%**	**$n^{detections}$**	**n^{total}**
Mar 31-Apr 2	92	47	51	100	5	5	100	1	1	100	12	12	100	12	12
Apr 28-29	94	48	51	100	5	5	100	1	1	92	11	12	100	12	12
May 13-14	84	43	51	100	5	5	100	1	1	83	10	12	83	10	12
May 27-28	92	47	51	100	5	5	0	0	1	100	12	12	100	12	12
Jun 10-11	88	45	51	100	5	5	0	0	1	100	12	12	92	11	12
Jul 1-2	82	49	60	19	5	26	0	0	1	54	13	24	83	10	12
Jul 30-31	73	48	66	19	5	26	0	0	1	42	10	24	92	11	12
Aug 26-27	52	43	82	85	22	26	0	0	1	71	17	24	92	11	12
Sep 9-10	51	46	90	85	22	26	0	0	1	71	17	24	58	7	12
Sep 25-26	53	48	90	85	22	26	0	0	1	67	16	24	50	6	12
Oct 9	52	47	90	73	19	26	0	0	1	63	15	24	42	5	12
Oct 27-28	66	59	90	73	19	26	0	0	1	63	15	24	33	4	12

Note: Percentages are based on the total number of known active tags remaining in the tagged population at the time of survey (ignoring single detections and 'potential mortalities').

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Flight path and tag detection distribution by species for each track is illustrated on Maps 1 to 12. For clarity purposes, flight paths and tag detections are divided into three maps for each of the 12 tracks including: i) flight paths on maps A; ii) detections of bull trout on maps B; and, iii) remaining species on maps C. Red italic numbers depict 2008 tag detections for bull trout, rainbow trout, and Arctic grayling in the Pine River watershed, where as black numbers on the maps represent tag detections of fish tagged in previous years.

In 2008, ice had melted in many Peace River tributaries by mid-April and this was similar to conditions observed in 2006. In contrast, spring was later in 2007. Higher discharge and cooler water temperatures were observed in spring and summer 2007 than in 2006 or 2008. A comparison between years for spring conditions (i.e., discharge and ice/snow cover) in the Peace River mainstem and major tributaries within the study area is provided in Section 3.1 and Plates 1 to 11 in Appendix A.

March/April Tracks (Maps 1 & 2)

First Track, 31 March-2 April (Map 1)

The first track represented the winter distribution of radio-tagged fish in the Peace River study area due to tributary ice-cover. Extensive coverage occurred to ensure that the winter locations of fish were adequately identified. The survey included the Peace mainstem from the Peace Canyon Dam to Peace River, Alberta, and all major tributaries and their headwaters where fish were detected in previous years (Halfway, Pine, Beatton and Moberly rivers). Overall, most of the fish that were detected were in the Pine River system, with some in the Beatton River (mostly at the mouth), and a few widely scattered in the Peace mainstem from the Fort St John area to Dunvegan (Map 1A).

Bull trout, Arctic grayling and rainbow trout initially released in the Pine River were detected only in the Pine River with the exception of one bull trout (tag # 334) that was detected in the Peace mainstem upstream of the Moberly River. Bull trout in the Pine watershed were widely distributed and of the 46 fish detected, 41% (19 fish) were in the Pine mainstem from the Sukunka confluence to the mouth; 28% (13 fish) in the Sukunka; and the remaining bull trout were in the Burnt (11%, 5 fish), Murray (11%, 5 fish), and Pine (9%, 4 fish) rivers. Similarly, rainbow trout were widely scattered, with three in the mid-lower portion of the Pine River mainstem, two in the upper Pine River mainstem, and the remainder (7 fish) in the Sukunka and Burnt. Of the few (6 fish) Arctic grayling detected, three were in the Sukunka and three in the Pine mainstem below the Sukunka.

Overall, the distribution of bull trout, rainbow trout and Arctic grayling detected in the Pine watershed in March 2008 was similar to that recorded at the end of the tracking season in 2007 (AMEC & LGL 2008d).

A total of 12 walleye was detected in this survey; the majority (66%, 8 fish) were in the Beatton River (mainly near the mouth), and a few were widely scattered downstream in the Peace mainstem.

Second Track, 28-29 April (Map 2)

The second track and the majority of 2008 flights were less extensive than the first track in April (Map 2A), since information from track one and fixed-station data indicated that surveys did not need to include the Halfway and Moberly watersheds because fish were not located in these tributaries.

Overall, the distribution and number of fish detected for each of the tagged populations in late April were similar to that recorded in late March. Of the bull trout detected, one individual was still in the Peace mainstem upstream of the Moberly; all other tagged fish were distributed similarly in the Pine River system as for track one. Tagged rainbow trout and Arctic grayling were distributed similarly in the Pine River as per the first survey; walleye were also still congregated at the mouth of the Beatton River at this time.