

Preliminary Lake Trout Restoration Investigations



Prepared For

**Yukon Fish & Wildlife
Enhancement Trust Fund**
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Down to Earth Biology

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EXECUTIVE SUMMARY

During 2015, EDI was contracted by the Yukon Fish and Wildlife Enhancement Trust Fund to conduct preliminary investigations related to the concept of lake trout stock restoration through the use of in-lake incubation of lake trout eggs. Lake trout form the basis of an important freshwater fishery throughout much of the Yukon and during recent years, conservation measures have been put into place to protect a number of lakes/stocks. These measures have included reductions in catch limits and in some cases implementing non-retention regulations for lake trout all together. Such changes have been required to ensure that harvest levels remain within sustainable limits; however, this has resulted in concerns from some stakeholders in regards to the maintenance of angling opportunities for lake trout. With these considerations in mind, the current project aimed to collect baseline information on lake trout spawning in a small number of candidate lakes to potentially lead to a proactive method of lake trout restoration.

The seven candidate lakes included: Braeburn, Chadburn, Fox, Louise, Pine, Tarfu and West Twin lakes. All of these lakes are currently (or being considered as) Special Management Waters under the Yukon freshwater fishing regulations and have conservation measures in place to protect lake trout stocks which in some cases are considered to be in a 'depleted' state or have harvest levels which are currently or have been unsustainable in the recent past. Each of the candidate lakes was visited during late June/early July of 2015 to attempt to locate potential lake trout spawning areas through observations of the available habitat and targeted sampling for young-of-the-year (YOY) lake trout via beach seining. Lake trout were captured on two of the candidate lakes (Fox and Louise) and general spawning areas were identified in these lakes. On the remaining five lakes, no lake trout were captured and the spawning areas are currently unknown. It is possible that alternative spawning strategies are used for spawning on these lakes given the lack of typical lake trout spawning habitat in the form of wave washed, rocky shorelines in exposed portions of the lakes.

In theory, an in-lake incubation program could help in cases where the number of juvenile lake trout being produced is below the carrying capacity of the lake. As carrying capacity is difficult to determine, any such work in the Yukon would likely have to be completed on an experimental basis. Before such a project is considered there is additional baseline data which would be required and there are a number of risks associated with such a project that need to be taken into consideration.



ACKNOWLEDGEMENTS

Dennis Zimmerman and Shirley Ford of the Yukon Fish & Wildlife Enhancement Trust administered the project and provided feedback on the field methods and overall project direction. Oliver Barker (Yukon Environment – Fisheries Section) shared information on lake trout restoration/productivity and provided useful discussion components related to these topics including outlining his concerns with this form of lake trout restoration.

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1 INTRODUCTION

Lake trout (*Salvelinus namaycush*) form the basis of important recreational and subsistence fisheries throughout the Yukon. Most Yukon lakes have a low overall productivity and therefore, the sustainable yield of lake trout is relatively low and with increases in fishing pressure and advances in fishing technology, there currently is a conservation concern for many of the stocks. This concern is particularly apparent in smaller lakes which have easy access and therefore receive notable angling pressure.

Yukon Environment manages freshwater fishing in the territory and lake trout lakes are classified into the following categories: general waters, conservation waters, and special management waters. General waters provide the default fishing regulations and for lake trout, this includes a daily limit of three and a possession limit of six with only one lake trout over 65 cm allowed. Conservation waters are identified based upon a number of reasons including stocks in need of recovery, maintenance of high quality angling opportunities and/or vulnerability of overharvest due primarily to access (Environment Yukon 2015). In these waters, the daily and possession limit is two lake trout with all lake trout between 65 and 100 cm to be released with only one allowed over 100 cm. Special management waters are those where addition protection is required for fish stocks including declined or depressed stocks (Environment Yukon 2015). In general, these waters include a daily and possession limit of one lake trout only with larger fish (over 100 cm) being required to be released. In a portion of these waters (Mandanna, Pine, Snafu and Tarfu lakes) all lake trout retention is zero.

As of January 2016, there is also a regulation change proposal being considered to close lake trout retention in two additional lakes (Frenchman, Twin Lakes) and the reclassification of Fox Lake from a general water to special management water and Kusawa Lake from a general water to conservation water. The implementation of these regulation changes is a positive direction in the conservation of lake trout stocks; however, the implementation of a non-retention regulation is a relatively new management tool for Yukon lake trout populations. Prior to 2015 when Pine, Tarfu and Snafu lakes were closed to lake trout retention, the only example of the implementation of such regulation was the closure of Mandanna Lake during the 1990s due to overharvest of the population.

Much of the existing information on lake trout spawning in the Yukon is from the larger lakes in the region, most notably Mayo and Tagish Lakes where detailed studies have been undertaken due to the use of these lakes as reservoirs from electricity generation. There is also an extensive amount of information on lake trout spawning ecology from elsewhere in the species' range, most notably from Ontario. Lake trout are broadcast spawners and do not dig a redd as other salmonids such as salmon do. Due to this behaviour, they rely on the deposition of eggs over substrate with interstitial spaces in which the eggs may incubate and be safe from predators. Spawning habitat is variable between lakes although these areas are typically characterized by broken rubble and angular rock (McPhail 2007) located in areas of lakes including islands, offshore reefs and points of land located in portions of the lake exposed to the prevailing wind direction. The depth of spawning is equally variable between lakes and is related to lake size, although the depth of spawning appears to be a trade-off between the forces required to maintain substrate cleanliness and the variables which influence egg mortality and disturbance (Legault et al. 2004). Larger lakes typically have



deeper spawning due to more influence on wind induced waves on the maintenance of spawning areas and in smaller lakes, spawning may even occur so shallow that the spawner's backs are exposed (McPhail 2007). Lake trout have also been found to be adaptable in the selection of spawning areas and are capable of spawning on new areas in the event that the spawning grounds are unavailable. For example, Gunn and Sein (2004) used tarpaulins to cover up the most suitable spawning habitat and found that the fish spawned in new/adjacent areas in the study lakes despite these areas appearing to be unsuitable.

The goal of the current project was to collect preliminary baseline data on a subset of Yukon lakes and to determine if a lake trout restoration initiative could be logistically conducted using some form of in-lake incubation of lake trout eggs. This baseline investigation included a general investigation of potential spawning sites in the study lakes paired with beach seining targeted at the capture of YOY (young-of-the-year) lake trout in the vicinity of potential spawning areas. This baseline data was required to identify potential spawning areas and determine the logistics of using in-lake incubation on site specific spawning locations (*i.e.*, substrate type and depth, access, etc.).

The concept of in-lake egg incubation could provide a method to increase egg survival with the goal of increasing the abundance of juvenile lake trout without the use of conventional supplementation (hatcheries) and the avoidance of most negative consequences associated with such activities. Increased egg survival could be accomplished by maximizing the egg fertilization rate by completing egg takes/on-site fertilization and protecting the eggs from predation during the incubation period by placing the eggs in some sort of egg incubation media. Studies on natural lake trout egg fertilization are limited; however, available information suggests that the rate is in the range of 40 to 60%. With assisted fertilization, lake trout egg incubation conducted by EDI at Mayo Lake has had fertilization rates between 85 and 95% (EDI 2015a).

During natural lake trout spawning, egg predation is relatively high. Eggs are predated by species such as round whitefish and longnose sucker when the eggs do not fall into the interstitial spaces of the spawning substrates. Even for eggs within the substrate, species such as burbot and slimy sculpin are still able to prey upon the eggs. Stauffer and Wagner (1979) documented that the species which consume the greatest proportion of lake trout eggs in the Great Lakes include burbot, sculpin and round whitefish. Given that these species are present in most Yukon lakes, it is expected that there is considerable predation on lake trout eggs. Modelling of early life stage lake trout predation by Jones et al. (1995) found that approximately 50% of lake trout eggs/fry are expected to be predated and that the majority of this predation (81%) occurs during the egg stage.

The concept of conducting an on-site egg incubation and deployment in the lake has been done successfully on an experimental basis at Mayo Lake (central Yukon) to study the effect of winter water level fluctuation on egg survival (EDI 2015a). Across all four years of the study, the average rate of egg survival was 84% (95% confidence interval of 2.3%) in Jordan-Scotty incubators deployed in secure areas below the limit of winter water level reductions. A different form of incubation media (astro turf sheets) developed by Swanson (1982) has been used successfully in Lake Superior to restore a natural spawning population of lake trout to a particular spawning reef. Across 15 years of this study, over sixteen million eggs were planted using this method with an average egg hatching rate of 69% (Bronte et al. 2002). The astro turf incubators



were also used on a trial basis in two Alaskan lakes where egg hatching success was 66% and 50% between the two lakes (Viavant 1998).

The methods of in lake incubation have been used successfully in the Yukon and elsewhere; however, these methods have not been applied to restore a depleted lake trout stock in an individual lake. The ability to collect lake trout eggs and incubate them successfully has been demonstrated although uncertainties remain regarding the applicability of increasing egg survival to restore numbers of adult lake trout. The use of hatchery supplementation has been attempted to restore lake trout stocks in other jurisdictions with very limited success. This method has some similarities to in lake incubation but there are many differences. The primary difference between the two methods is that in lake incubation allows the eggs to incubate under natural conditions and once the eggs hatch, they are subjected to natural conditions within the lake. In a hatchery setting, the goal is to produce as many fish as possible under conditions which relax natural processes such as competition and predation. The end result with conventional hatchery supplementation is that large numbers of juvenile fish can be released; however, they often negatively contribute to the genetic diversity population and may be of a lower 'quality' than would be expected with wild spawning (and likely in lake incubation).



2 METHODS

2.1 LAKE SELECTION

The selection of lakes for the field investigation component of the project was based upon a number of factors including the current angling regulations for each lake, lake size and the status of lake trout populations. Given that the goal of this project was to investigate potential methods of restoring lake trout populations and maintaining angling opportunities, a particular emphasis was placed on lakes which have had recent changes/restrictions made to conserve lake trout stocks. The status of the lake trout populations in each of these lakes was also taken into consideration and incorporated information from the Status of Yukon Fisheries report (Environment Yukon 2010) and lake trout population assessment reports available on the Environment Yukon website (Table 1). A total of 7 seven lakes were investigated during the field component of this project, all of which were located in the southern portion of the Yukon (Figure 1). It is also important to note that given the timelines to select the candidate lakes and conduct the field assessments, there were limited opportunities to involve Yukon Government fisheries biologists in the selection of these lakes and that there may additional candidate lakes where field investigations could be focused in the future.

Table 1. Summary of lake trout population status and angling regulations visited during the field component of the preliminary lake trout restoration investigations.

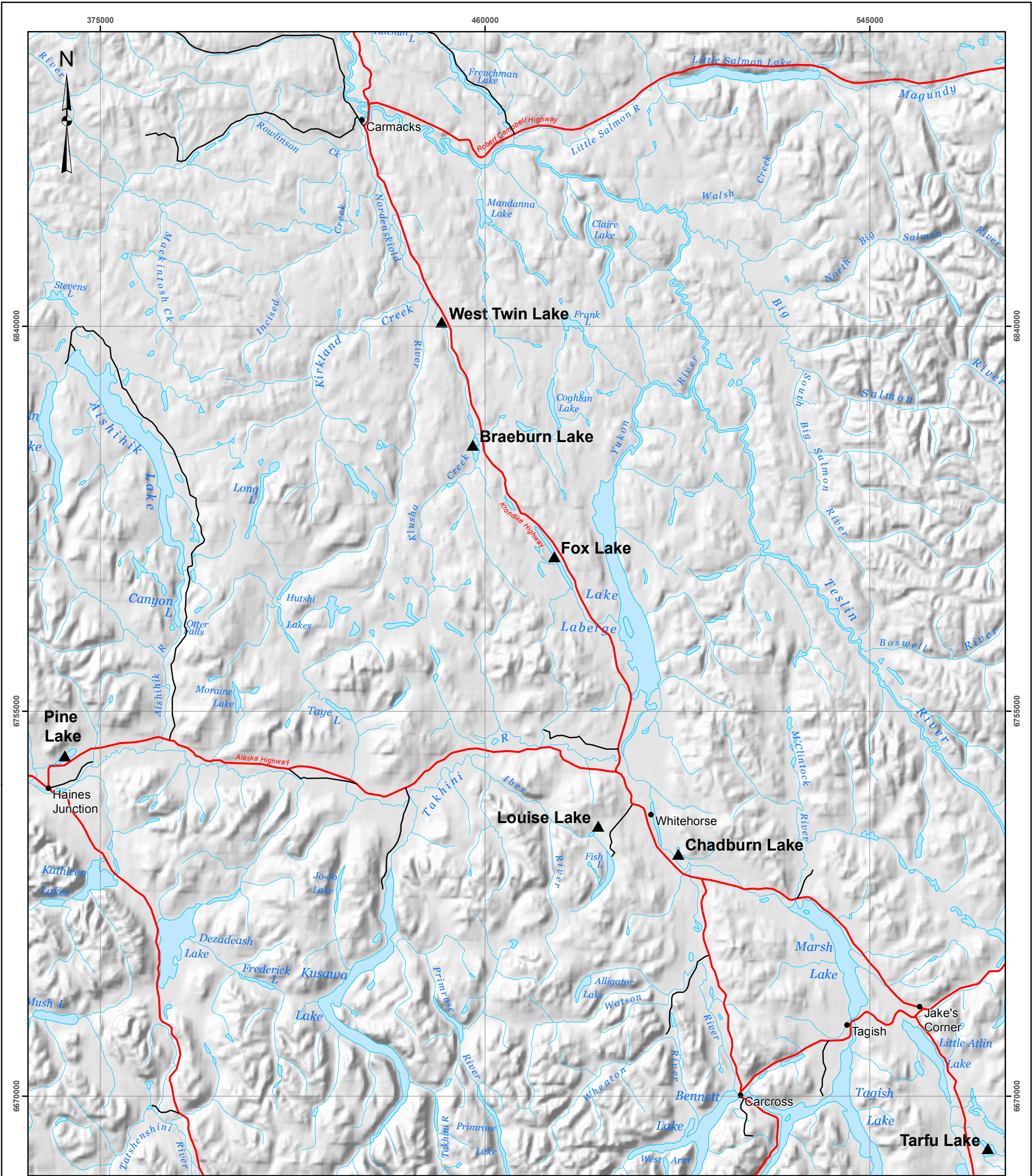
Lake	Area (ha)	Status of Yukon Fisheries – Lake Trout Population Status ¹	Current Lake Trout Angling Regulations
Braeburn	558	Red	Special management water; daily catch and possession limit of one, all over 65 cm must be released.
Chadburn	185	Red	Special management water; daily catch and possession limit of one, all over 65 cm must be released.
Fox ²	1,660	Yellow	General water, daily catch limit of three and a possession limit of six with only one over 65 cm. As of January 2016, there is a proposed regulation change to move to a special management water with a daily catch and possession limit of one and none
Louise	53	Red	Special management water; daily catch and possession limit of one, all over 65 cm must be released.
Pine	548	Red	Special management water; non-retention of lake trout.
Tarfu	419	Red	Special management water; non-retention of lake trout.
West Twin	160	Red	Special management water; daily catch and possession limit of one, all over 65 cm must be released. As of January 2016, there is a proposed regulation change to move towards non-retention for lake trout

¹ Green – low risk of impacting the resource, fishery is currently sustainable.

Yellow – medium risk of impacting the resource, fishery could easily become unsustainable.

Red – high risk of impacting the resource, fishery is currently unsustainable.

² A recent lake trout population survey of Fox Lake (2013) indicated that the population is likely depleted and fewer lake trout were captured than would be expected, particularly for large fish (Barker et al. 2014).

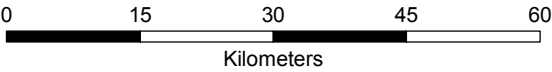


Legend

- ▲ Lake Trout Investigation Site
- Primary Road
- Secondary Road

Lake Trout Investigations
Beach Seining Sites Overview

Data Sources
1:50,000 Topographic Spatial Data provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca.
Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2015) was obtained using Garmin GPS technology. Reference Scale: 1:850,000
Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.



Reference Scale: 1:850,000
Map Projection: North American Datum 1983 UTM Zone 8N

Drawn: MS	Checked: MP/BSc	Date: 29/02/2016	FIGURE 1
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2.2 FIELD METHODS

The methods for the field component of this project involved visiting each of the candidate lakes during the early summer to attempt to locate potential lake trout spawning habitat and conduct targeted sample for young-of-the-year (YOY) lake trout. Previous beach seining conducted by EDI on Mayo Lake (EDI 2015a) and Tagish/Bennett lakes (EDI 2015b) has indicated that YOY lake trout can be captured in the vicinity of spawning locations during the early summer. Given that the candidate lakes are smaller lakes than those aforementioned, the timing of the field investigations would have ideally been earlier (closer to ice off); however, due to the project implementation date and the need to obtain fish collection licenses, the fieldwork was delayed until very late June and early July (Table 2). A total of 96 beach seining hauls were sampled collectively across the seven lakes investigated (sampling sites presented in Appendix A).

Table 2. Summary of field investigations and beach seining effort on the seven candidate lakes during 2015.

Lake	Field Investigation Dates	Number of Beach Seining Hauls Conducted
Braeburn	3 July	6
Chadburn	30 June	10
Fox	2 – 3 July	32
Louise	28 June	11
Pine	30 June	15
Tarfu	2 July	16
West Twin	3 July	6

The margin of each lake was boated at a slow speed to identify potential lake trout spawning areas. In larger lakes, lake trout spawning areas typically include islands, offshore reefs and other areas exposed to the prevailing wind direction. Descriptions of the shoreline were recorded with an emphasis on lake trout spawning potential including depth and location of suitable lake bed material for egg incubation. Sampling for YOY lake trout was conducted in proximity to potential spawning areas and in other areas where suitable sampling conditions (beaches) were present. The beach seine used was 10 m long and 1.5 m deep and constructed of 5 mm mesh. The length of shoreline sampled was determined by site conditions and ranged from 15 to 100 m. All fish captured were identified to species, assigned to age categories (YOY, larger juvenile, adult) and a subsample of up to 10 individuals of each species measured to fork length (with the exception of slimy sculpin which were not measured). Additional information collected at each beach seining site included: GPS coordinates, date and time of sampling, weather conditions, photo documentation, lake bed material characteristics and sampling area dimensions (length, width, depth). Beach seining captures were converted to a measure of catch-per-unit effort (CPUE) to standardize the captures to the number of fish captured per 100 m² of area sampled.

Water temperature loggers were deployed on two of the candidate lakes (Fox and Louise) to collect year round water temperatures at probable spawning locations. The temperature loggers deployed were Tidbit V2 models set to record hourly water temperatures continuously. Two loggers were deployed in Fox Lake



and one in Louise Lake (Map A3 and A4 in Appendix A) with each logger anchored in place with a cinder block and tied off to a tree on the shoreline using wire cord. Each logger was located at a depth which likely represented a lake trout spawning area (~ 1 m on Louise Lake and ~ 1.5 m on Fox Lake). Loggers will be retrieved during the 2016 open water season.



3 RESULTS AND DISCUSSION

Eight species of fish were captured during the beach seining component of this project with slimy sculpin being the only fish species captured in all lakes sampled (Table 3). Lake trout were captured in two of the lakes sampled (Fox and Louise) and the highest number of species were captured in Fox Lake (7 species) followed by Chadburn, Louise and Tarfu lakes (4 species).

Table 3. Summary of fish species captured in the seven candidate lakes sampled by beach seining during 2015.

Lake	Fish Species Captured							
	Slimy Sculpin	Lake Trout	Arctic Grayling	Lake Whitefish	Round Whitefish	Northern Pike	Burbot	Rainbow Trout
Braeburn	✓					✓		
Chadburn	✓		✓		✓		✓	
Fox	✓	✓	✓	✓	✓	✓	✓	
Louise	✓	✓	✓					✓
Pine	✓			✓			✓	
Tarfu	✓		✓			✓	✓	
West Twin	✓					✓		

The results in the following sections summarize the results of the field investigations conducted on each of the seven candidate lakes. Maps of the sampling locations including those where YOY lake trout were captured are shown in Appendix A, representative photos of the shorelines within each of the lakes are shown in Appendix B and all raw fish sampling data is shown in Appendix C.

3.1 BRAEBURN LAKE

Braeburn Lake was visited on 3 July 2015 and a total of six beach seine hauls were conducted at five sites in various portions of the lake (Map A1 in Appendix A; Photos B1 in Appendix B). No lake trout were captured and fish captures were relatively low overall with slimy sculpin and northern pike the only species captured (Table 4).

Table 4. Summary of fish captured by beach seining on Braeburn Lake on 3 July 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
6	15.5	2,040	Slimy sculpin	4	12	0.69	0.61
			Northern pike	1	1	0.07	0.00

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.



Braeburn Lake has a complex geomorphology with numerous islands, offshore reefs and exposed points which could provide suitable lake trout spawning habitat. However, closer examination of the lake bed materials indicated that the majority of the nearshore habitat of the lake was covered in marl (organics and algae) which filled the interstitial spaces where lake trout eggs would incubate (Photos B2-3 in Appendix B). Charophytes were observed in Braeburn; however, the extensive charophyte beds observed in some of the other lakes investigated were absent. Despite the presence of suitably sized substrate (cobbles/boulders) in some areas, it is unclear where lake trout would spawn in Braeburn Lake and further study would be required to locate spawning areas.

3.2 CHADBURN LAKE

Chadburn Lake was visited on 30 June 2015 and a total of ten beach seine hauls were conducted at eight sites in various portions of the lake (Map A2 in Appendix A; Photos B4-5 in Appendix B). No lake trout were captured during this sampling and fish captures were relatively low overall with slimy sculpin, round whitefish and burbot being the only species captured (Table 5).

Table 5. Summary of fish captured by beach seining on Chadburn Lake on 30 June 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
10	16.3	1,009	Slimy sculpin	5	10	1.08	0.47
			Round whitefish	1	2	0.13	0.00
			Burbot	3	12	1.54	0.00

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

Chadburn is a relatively small lake with a limited fetch for waves to develop; as such, limited wave induced cleaning of the lake bed materials was evident in the nearshore areas. One possible lake trout spawning area (near an island in the southwest corner) was identified however the substrate appeared to be relatively small (large gravel) and as such the interstitial spaces don't appear to be suitable for lake trout egg incubation. Extensive charophyte beds were observed around the lake and given that lake trout have been documented spawning on charophytes in 'deep' water in other portions of the species' range (Beauchamp et al. 1992), it is possible that the population in Chadburn is using such habitat for spawning in the absence of the more typical rocky spawning areas. Additional study would be required to confirm this prediction and could include additional beach seining earlier during the summer (cooler water temperatures) and/or spawning specific studies such as targeted sampling for adults during the spawning period or underwater (SCUBA) observations of potential spawning areas to document egg deposition.



3.3 FOX LAKE

Fox Lake, the largest lake investigated, was visited on 2-3 July 2015. A total of 32 beach seine hauls were conducted at 30 sites throughout the lake (Map A3 in Appendix A; Photos B6-9 in Appendix B). A total of 227 YOY lake trout were captured in 19 of the hauls conducted (Table 6) with the highest capture rates around the middle portion of the lake on both the east and west shores. The YOY lake trout captured ranged in fork length from 24 to 53 mm with average and median of 42 and 38 mm. Arctic grayling were also relatively common with over 500 individuals captured. The highest capture rate for this species was at site FO-18 on the west shore of the lake where seining was conducted near the mouth of a small creek. The shorelines of Fox Lake were highly suited to beach seining which allowed for sampling to be completed throughout the lake. Many additional sites could be beach seined throughout the lake if there is a future need to monitor the abundance of juvenile lake with a higher level of statistical confidence.

Table 6. Summary of fish captured by beach seining on Fox Lake on 2 and 3 July 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
32	13.3	10,885	Lake trout	19	227	2.04	0.31
			Slimy sculpin	27	125	1.19	0.92
			Arctic grayling	23	526	4.81	0.85
			Lake whitefish	2	4	0.04	0.00
			Round whitefish	5	78	0.81	0.00
			Northern pike	2	3	0.03	0.00
			Burbot	4	79	0.64	0.00

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

The distribution of the YOY lake trout captures suggests that lake trout spawn on the west and east sides of Fox Lake, away from the north and south end of the lake. These areas are commonly characterized by cobble/boulder bed material located along exposed shorelines of the lake including points which are exposed to winds from both the north and south. The depth of suitable spawning bed material was somewhat variable but appeared to extend to a maximum depth of 1.5 to 2.0 m with some areas extending as deep as 2.5 m. Based upon the relationship between lake size and spawning depth developed by Fitzsimons (1994), the predicted spawning depth for a lake with the size of Fox Lake would be 2.5 to 3.0 m.

Two temperature loggers were deployed in Fox Lake (Map A3 in Appendix A) at depths of approximately 1.5 m on two probable lake trout spawning areas. Following retrieval of these loggers in future years, data will be available on the seasonal fluctuation of water temperatures and would be useful in the event that the concept of in-lake incubation of lake trout eggs is pursued in the future.



3.4 LOUISE LAKE

Louise Lake was visited on 28 June 2015 and a total of 11 beach seine hauls were conducted. The seining sites were clustered at the northwest end of the lake as suitable site conditions for sampling were relatively limited elsewhere in the lake (Map A4 in Appendix A; Photos B10-13 in Appendix B). A total of 23 YOY lake trout were captured in 7 of the hauls conducted (Table 7). The YOY lake trout captured ranged in fork length from 42 to 59 mm with average and median of 48 and 43 mm, respectively. A single 1+ individual was also captured and this individual measured 85 mm in length. All lake trout captures were located within the vicinity of the spawning area at the northwest end of the lake which has been identified during field studies for the recent relicensing of the Fish Lake Hydroelectric Project (AECOM 2012).

Table 7. Summary of fish captured by beach seining on Louise Lake on 28 June 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ²	Median CPUE ²
11	17.0	2,440	Lake trout ¹	7	24	0.97	0.48
			Slimy sculpin	11	161	6.83	5.24
			Arctic grayling	3	4	0.16	0.00
			Rainbow trout	1	1	0.04	0.00

¹ The values shown include a single 1+ lake trout captured at site LO-11. This was the only 1+ individual captured across all lakes sampled in 2015.

² Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

The results of the 2015 sampling found YOY lake trout near the identified spawning area at the northwest end of Louise Lake. This area is characterized by cobbles intermixed with boulders/gravels and appears to provide suitable lake trout spawning habitat to a depth of approximately 1.5 m. Based upon the relationship between lake size and spawning depth developed by Fitzsimons (1994), the predicted spawning depth for a lake with the size of Fox Lake would be 1.6 m. Adjacent to this spawning area, there is a large beach which provides ideal beach seining conditions (where the majority of the lake trout were captured during the 2015 sampling; Photo B11 in Appendix B).

3.5 PINE LAKE

Pine Lake was visited on 30 June 2015 and a total of 15 beach seine hauls were conducted at ten sites throughout the lake (Map A5 in Appendix A; Photos B14-16 in Appendix B). No lake trout were captured during this sampling and fish captures were limited to slimy sculpin, lake whitefish and burbot with the latter being the most frequently captured species (Table 8).

**Table 8. Summary of fish captured by beach seining on Pine Lake on 30 June 2015.**

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
15	17.4	4,485	Slimy sculpin	5	23	0.53	0.00
			Lake whitefish	1	125	2.97	0.00
			Burbot	14	134	3.53	2.14

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

Rocky bed material which provides suitable lake trout spawning habitat appeared to be very limited in Pine Lake. and similar to Chadburn Lake (Section 3.2). The few rocky areas which are present along the shoreline are either very shallow (< 0.5 m) or are in the form of smooth, unfractured bedrock which does not provide the necessary interstitial spaces for egg incubation. Charophyte beds are very extensive in Pine Lake and are located in areas with a suitable depth and gradient for lake trout spawning.

3.6 TARFU LAKE

Tarfu Lake was visited on 2 July 2015 and a total of 16 beach seine hauls were conducted at 13 sites throughout the lake (Map A6 in Appendix A; Photos B17-20 in Appendix B). Fish species captured included Arctic grayling (YOY), slimy sculpin, northern pike and burbot (Table 9).

Table 9. Summary of fish captured by beach seining on Tarfu Lake on 2 July 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
16	16.0	5,885	Slimy sculpin	3	8	0.19	0.00
			Arctic grayling	6	45	0.68	0.00
			Northern pike	4	6	0.09	0.00
			Burbot	1	2	0.03	0.00

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

The shoreline/bed material of Tarfu Lake did appear to provide some potential lake trout spawning habitat in the form of wave washed gravels/cobbles. However, these areas appeared to provide marginal spawning habitat due to a combination of small substrate size, minimal interstitial spaces and detritus/organic material within the substrate. It is possible that lake trout in Tarfu Lake may use alternative spawning habitats such as charophytes; however, additional field studies would be required to better understand the spawning ecology of lake trout in Tarfu Lake.



3.7 WEST TWIN LAKE

West Twin Lake was visited on 3 July 2015 and a total of six beach seine hauls were conducted at five sites throughout the lake (Map A7 in Appendix A; Photos B21-23 in Appendix B). No lake trout were captured and fish captures in general were very low with only a single slimy sculpin and one northern pike being captured (Table 10).

Table 10. Summary of fish captured by beach seining on West Twin Lake on 3 July 2015.

Number of Seining Hauls	Average Water Temperature (°C)	Total Area Sampled (m ²)	Fish Captured				
			Species	# of Hauls Captured	# of Individuals Captured	Average CPUE ¹	Median CPUE ¹
6	16.8	2,465	Slimy sculpin	1	1	0.03	0.00
			Northern pike	1	1	0.04	0.00

¹ Where CPUE = catch-per-unit effort measured in the number of fish captured per 100 m² sampled.

Among the seven candidate lakes visited, West Twin Lake appeared to have the least potential for lake trout spawning habitat in the form of wave washed rocky areas. Given that there is a self-sustaining population of lake trout in the lake, it seems highly probable that alternative spawning habitats (i.e., charophytes) are being used for spawning.

3.8 SUMMARY

The field investigations conducted during 2015 were able to locate lake trout spawning areas on two of the seven candidate lakes visited. Additional field studies would be required to locate and characterise potential lake trout spawning areas on the other five lakes. Such studies could include additional beach seining earlier during the season when water temperatures are lower and YOY lake trout are more likely to be in the vicinity of the spawning areas.

An early spring combined with a later than desired sampling period resulted in warm water temperatures during the beach seining component. Despite the capture of lake trout in the warmest lake, (Louise Lake, 17.0 °C on average), beach seining earlier in the year would likely increase the probability of catching lake trout in the other lakes investigated. Regardless, it is possible that additional beach seining in the five candidate lakes may not capture any lake trout due either to the presence of low densities of individuals or differences in spawning locations and habitat preference of the YOY fish.

Targeted sampling for adults during the spawning period using short set, small mesh gillnetting could also be effective in locating ripe fish, thus indicating spawning areas. In lakes such as Chadburn, Pine and West Twin where spawning in alternative habitats (charophyte beds) is suspected, more detailed studies may be required to confirm these predictions. On such method could include the use of SCUBA during the



spawning period to locate areas where eggs are deposited. Such information from small Yukon lakes would provide a value contribution to the existing literature on lake trout spawning as there are very few studies on lake trout egg deposition on alternative substrates (ie, not the typical rocky substrates).

3.8.1 IN-LAKE INCUBATION AS A RESTORATION METHOD

Many of the lakes studied are considered depleted or have a lower abundance of lake trout than would be expected based upon overall lake productivity. With careful management of harvest, it is expected that these populations will recover over time; however, the timeframe for a full recovery is not clear. In theory, a short-term in-lake incubation project has the potential to speed up the recovery by producing a higher number of fry which may result in the restoration of the abundance of adult fish in a shorter time period than would be expected naturally. However, there is contradictory information on this subject in the literature as to whether boosting juvenile recruitment will increase adult abundance (Myers 2002, Myers and Bowerman 1996).

It is generally accepted that in general, a small number of spawners are required to sustain a population and that each lake has a carrying capacity of the number of fish which can be produced (Myers 2002). Within this capacity, only a certain number of juvenile lake trout can be produced/sustained within a given lake due to limited availability of food sources and both interspecific and intraspecific competition. The potential for increased egg survival to boost juvenile abundance is thus dependent on the carrying capacity within the lake and the current number of juveniles present. If the current number of juveniles is near the carrying capacity, then in-lake incubation would not be beneficial in the restoration of lake trout stocks. However, if the number is well below the carrying capacity, in-lake incubation could be effective in increasing lake trout numbers over a faster time frame than would be expected naturally.

Determining carrying capacity of juvenile lake trout in each lake would require extensive study and likely requires data from baseline conditions (i.e. prior to depleted adult abundance). As this data is not available, it is likely not feasible to remove the uncertainty of whether or not in-lake incubation would be successful on any of the lakes studied. As such, any in-lake incubation project for the purpose of the lake trout restoration in Yukon would have to be based on indicators such as depressed adult numbers and relative low juvenile abundance. Given the uncertainty in such an approach, any project should be designed to be experimental in nature so that the success of the program can be monitored and documented.

There are also a number of potential risks associated with the in-lake incubation concept which have been highlighted during discussions of the concept with Yukon Government. Such risks include genetics, representation of spawning populations, fish capture effects and spawning site attraction. Although these risks can be at least partially mitigated by proper design and implementation, these factors should be taken into consideration if the concept of in-lake incubation is pursued further in the future. A discussion of some of these potential risks and potential methods of mitigation are summarized in Appendix D.



4 CONCLUSION

Based upon the field investigations conducted during 2015, a good understanding of spawning locations and habitat was gained at Fox and Louise lakes. Such information provides some base information that would be required for the logistical design and implementation for the in-lake restoration program; however, additional investigations would be required to determine spawning microsites, egg deposition and incubation depths and possibly the testing of in-lake incubation methods. The current level of information is not as substantial in the other five lakes and additional investigations would be required before any testing of in-lake incubation methods is completed on these lakes. It appears an in-lake incubation program could have the potential to help speed up the recovery in a situation where the number of juvenile lake trout being produced is below the carrying capacity for the lake. In the absence of clear information on carrying capacities, selection of a candidate lake would have to be based on a consideration of various factors such as adult numbers and relative abundance of juveniles.

It must be acknowledged that an in-lake incubation program has never been implemented to restore a depleted lake trout population in an individual lake and as such, the method remains unproven. There are potential risks with this method (Appendix D); however, the risks can be at least partially mitigated and are notably reduced from a conventional hatchery supplementation program. The risks and the unknowns to achieving success (e.g. carrying capacity) makes in-lake incubation a difficult program to initiate. If there is a desire to implement such a program, careful selection of candidate lake(s) would be required and restoration efforts should be completed on an experimental basis where the benefits and the risks can be monitored. Regardless, a clear restoration plan that mitigates risks would have to be developed prior to the implementation of any in-lake incubation program.



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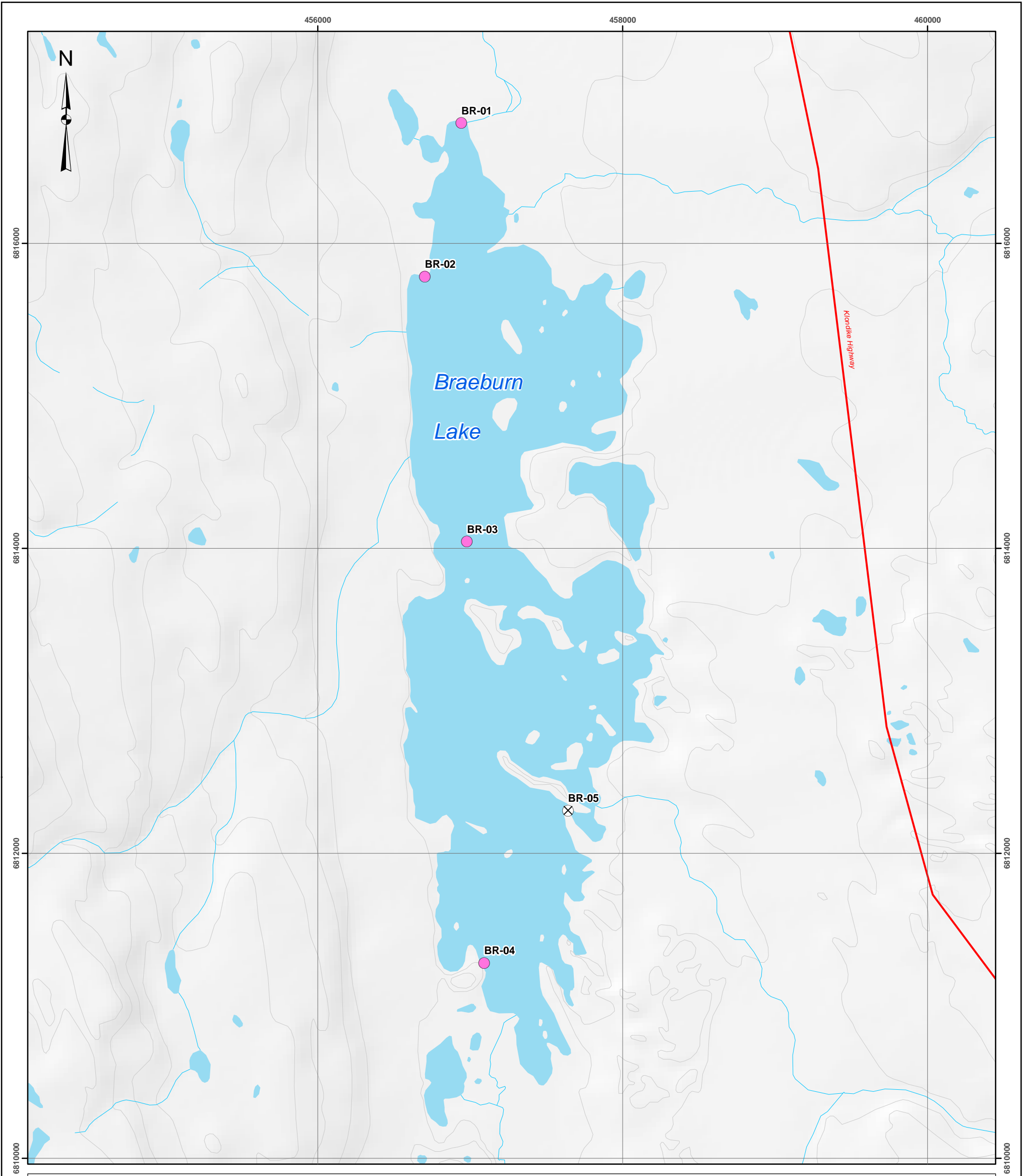


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**APPENDIX A. MAPS OF BEACH SEINING
SITES IN THE SEVEN
CANDIDATE LAKES**

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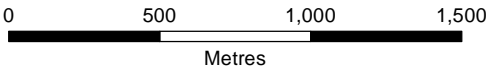


Legend

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- Other Fish Species Captured Only
- ⊗ No Fish Captured
- Highway

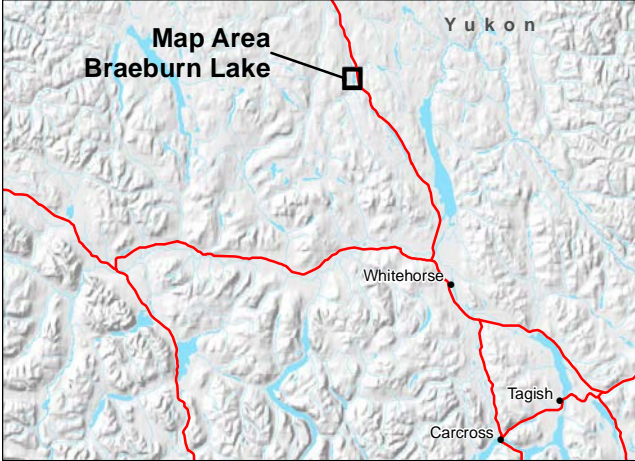
Lake Trout Investigations
Beach Seining Sites at Braeburn Lake

Data Sources
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Project data displayed is site specific. Data collected by EDI Environmental Dynamics Inc. (2015) was obtained using Garmin GPS technology.
Disclaimer
This document is not an official land survey and the spatial data presented is subject to change.



Reference Scale: 1:25,000
Map Projection: North American Datum 1983 UTM Zone 8N

Drawn: MP	Checked: BSc	Date: 29/02/2016	MAP A1
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Prepared for



Prepared by





Legend

- Young-of-the-Year Lake Trout Captured
- Other Fish Species Captured Only
- ⊗ No Fish Captured

Lake Trout Investigations
Beach Seining Sites at Chadburn Lake

Data Sources
1:50,000 Topographic Spatial Data provided by Geomatics Yukon - Yukon Government via online source (Corporate Spatial Warehouse) www.geomaticsyukon.ca. Background imagery provided by ESRI Basemaps.

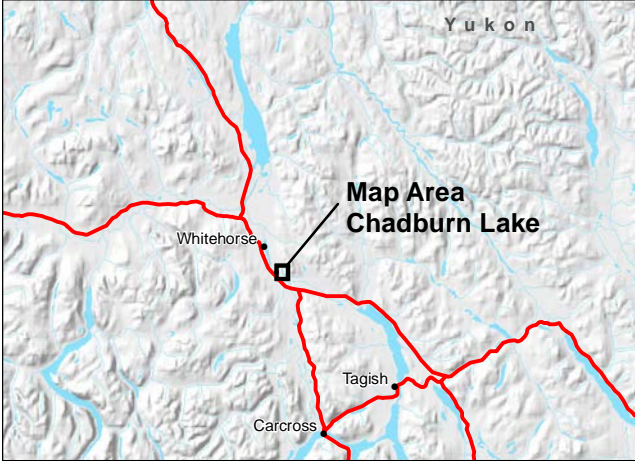
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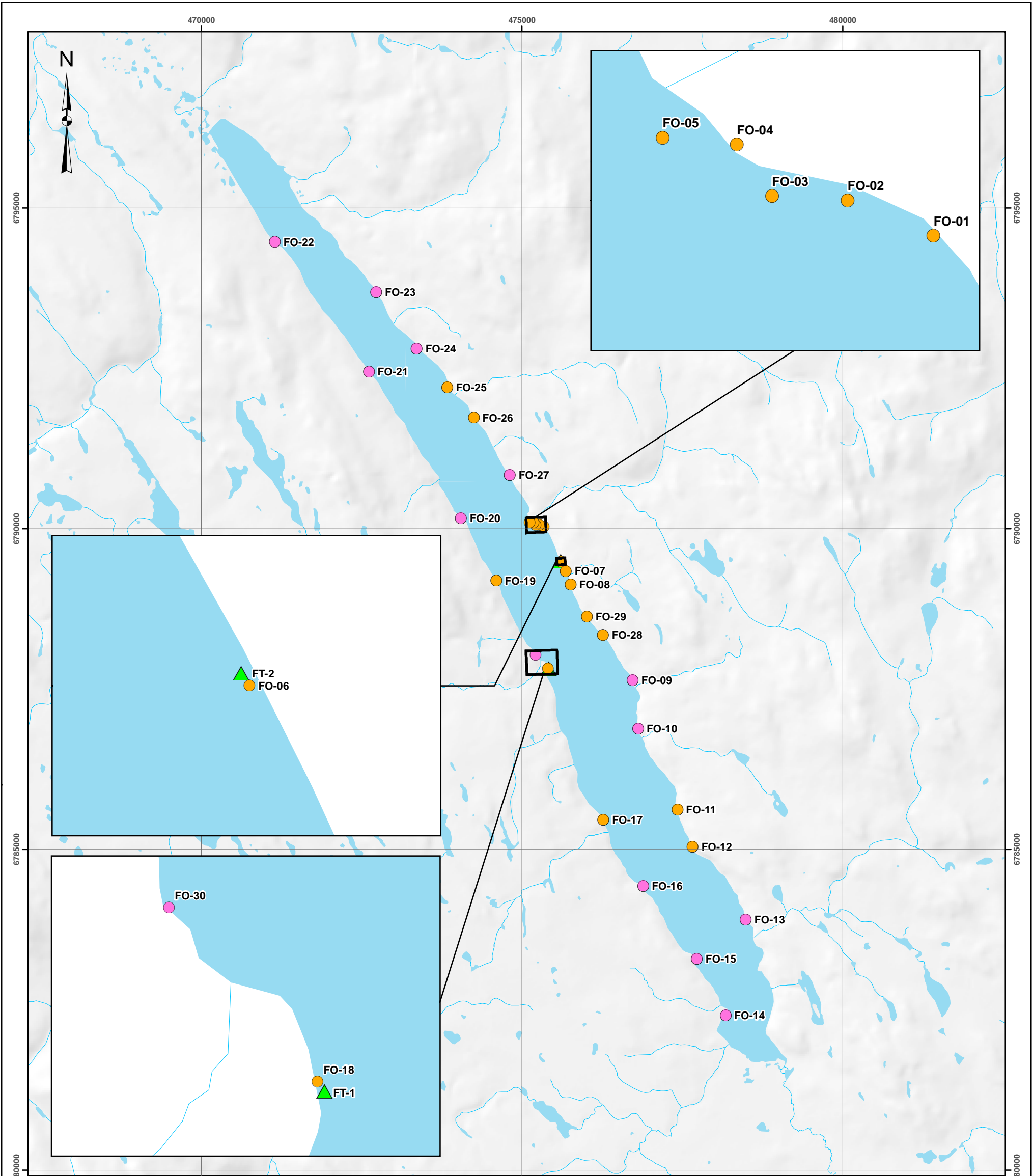
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Drawn: MP	Checked: BSc	Date: 29/02/2016	MAP A2
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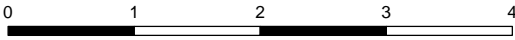



Legend

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- Other Fish Species Captured Only
- ⊗ No Fish Captured
- Access Road

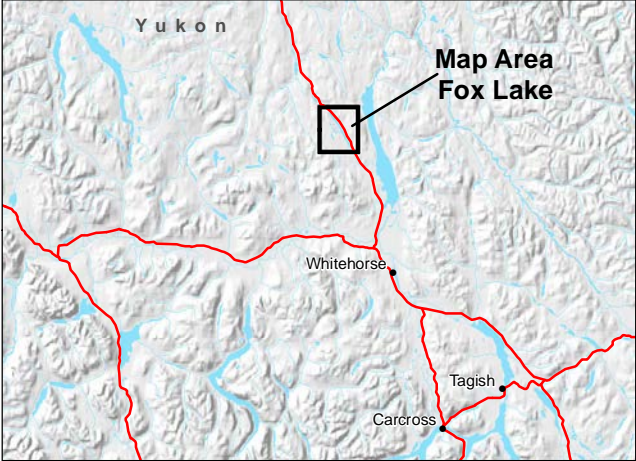
Lake Trout Investigations
Beach Seining Sites at Fox Lake

Data Sources
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Reference Scale: 1:53,000
Map Projection: North American Datum 1983 UTM Zone 8N

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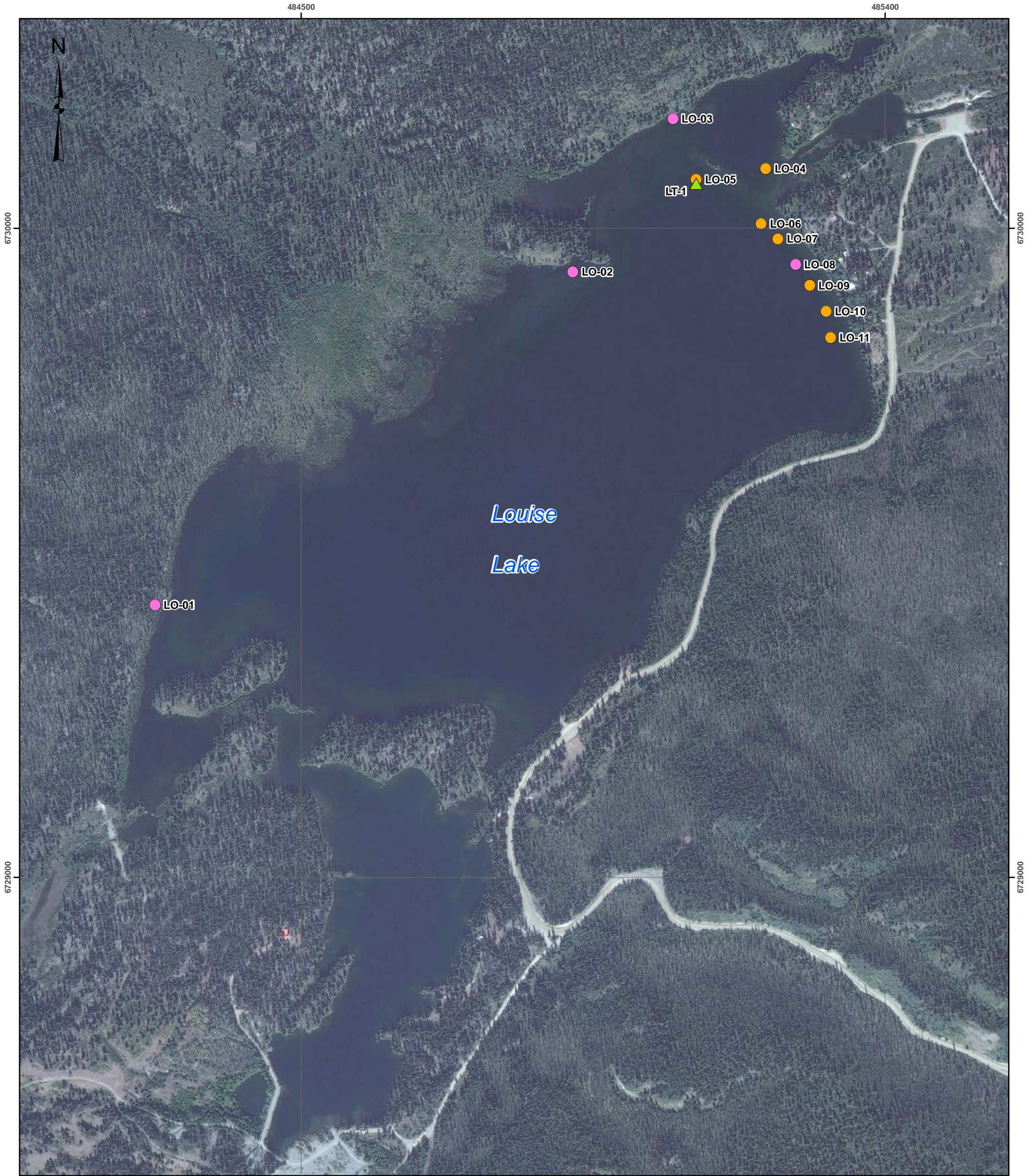


Prepared for



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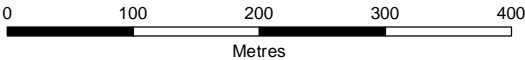


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- ⊗ No Fish Captured
- ▲ Water Temperature Logger

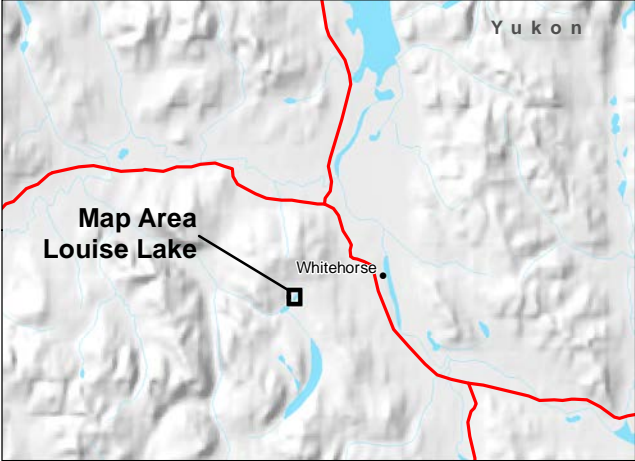
Lake Trout Investigations:
Beach Seining Sites at Louise Lake

Data Sources
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Map Projection: North American Datum 1983 UTM Zone 8N

Drawn: MP	Checked: BSc	Date: 29/02/2016	MAP A4
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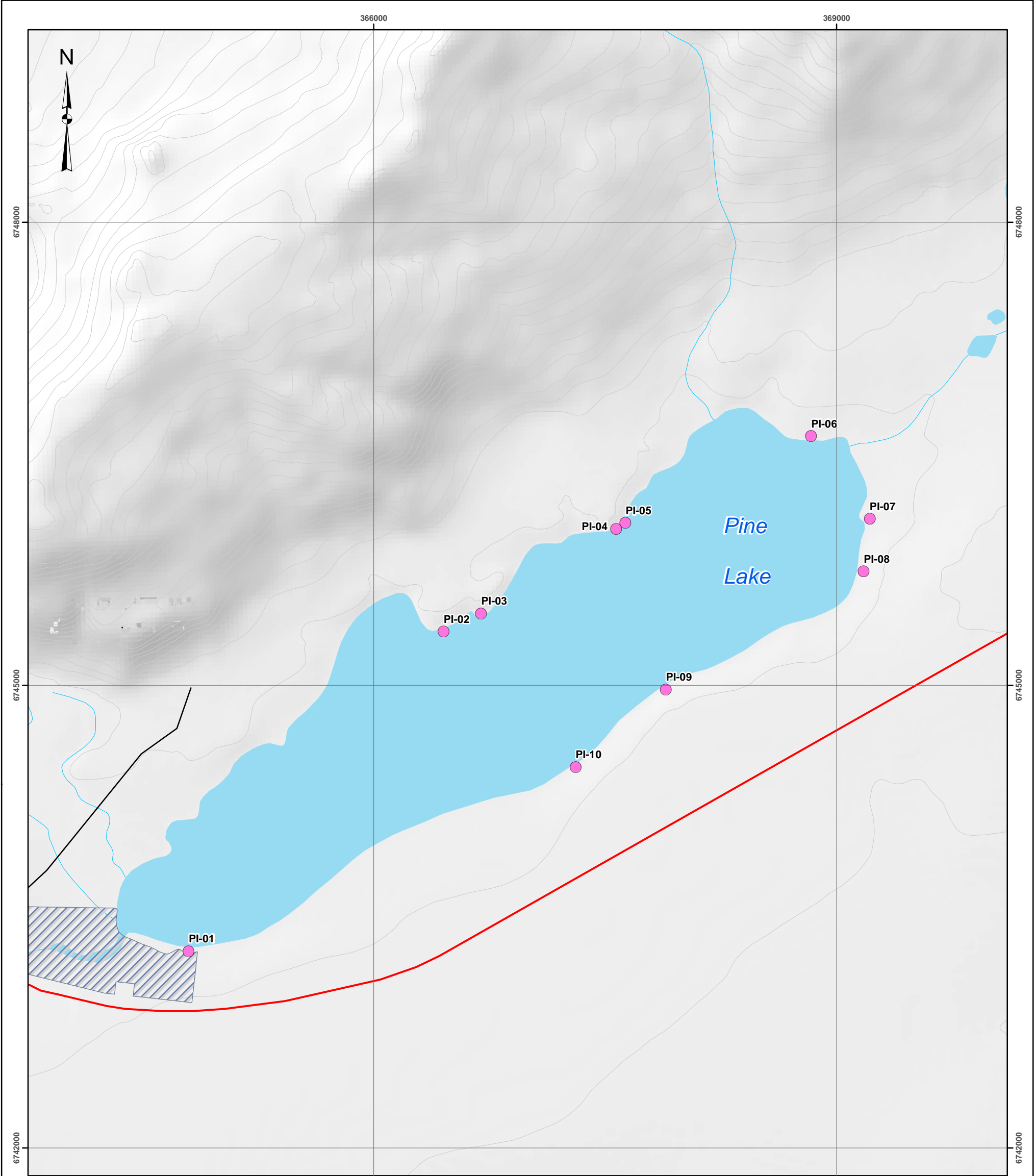


Prepared for



Prepared by



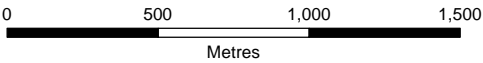


Legend

- Young-of-the-Year Lake Trout Captured
- Other Fish Species Captured Only
- ⊗ No Fish Captured
- Highway
- Secondary Road
- ▨ Territorial Park/Campground

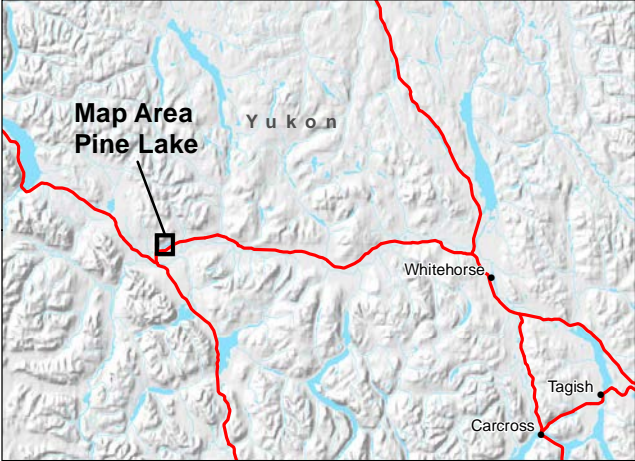
Lake Trout Investigations
Beach Seining Sites at Pine Lake

Data Sources
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Reference Scale: 1:25,000
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Drawn: MP	Checked: BSc	Date: 29/02/2016	MAP A5
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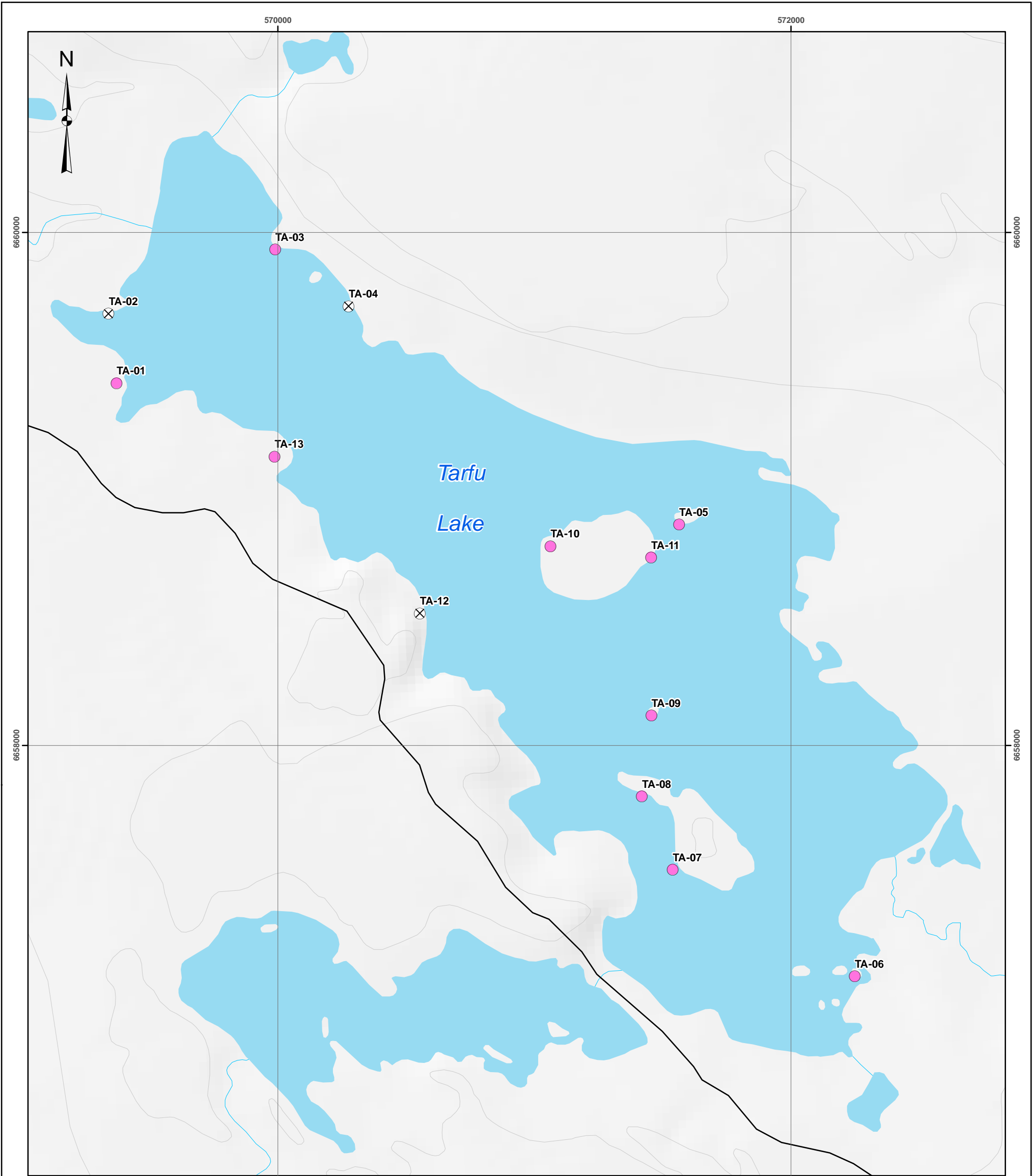


Prepared for



Prepared by



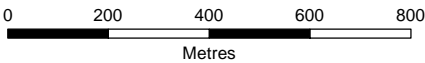


Legend

- Young-of-the-Year Lake Trout Captured
- Other Fish Species Captured Only
- ⊗ No Fish Captured
- Secondary Road

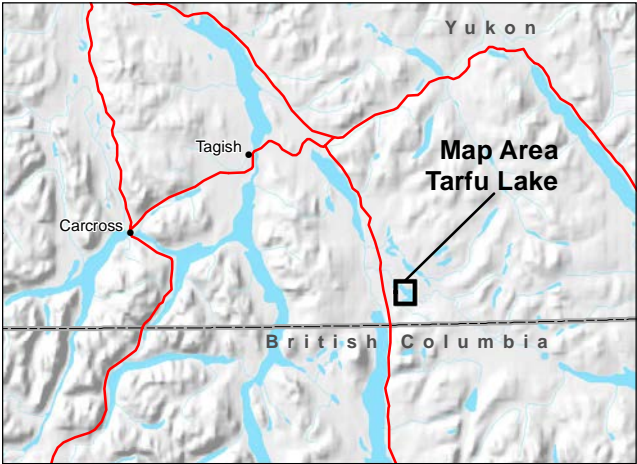
Lake Trout Investigations
Beach Seining Sites at Tarfu Lake

Data Sources
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Reference Scale: 1:15,000
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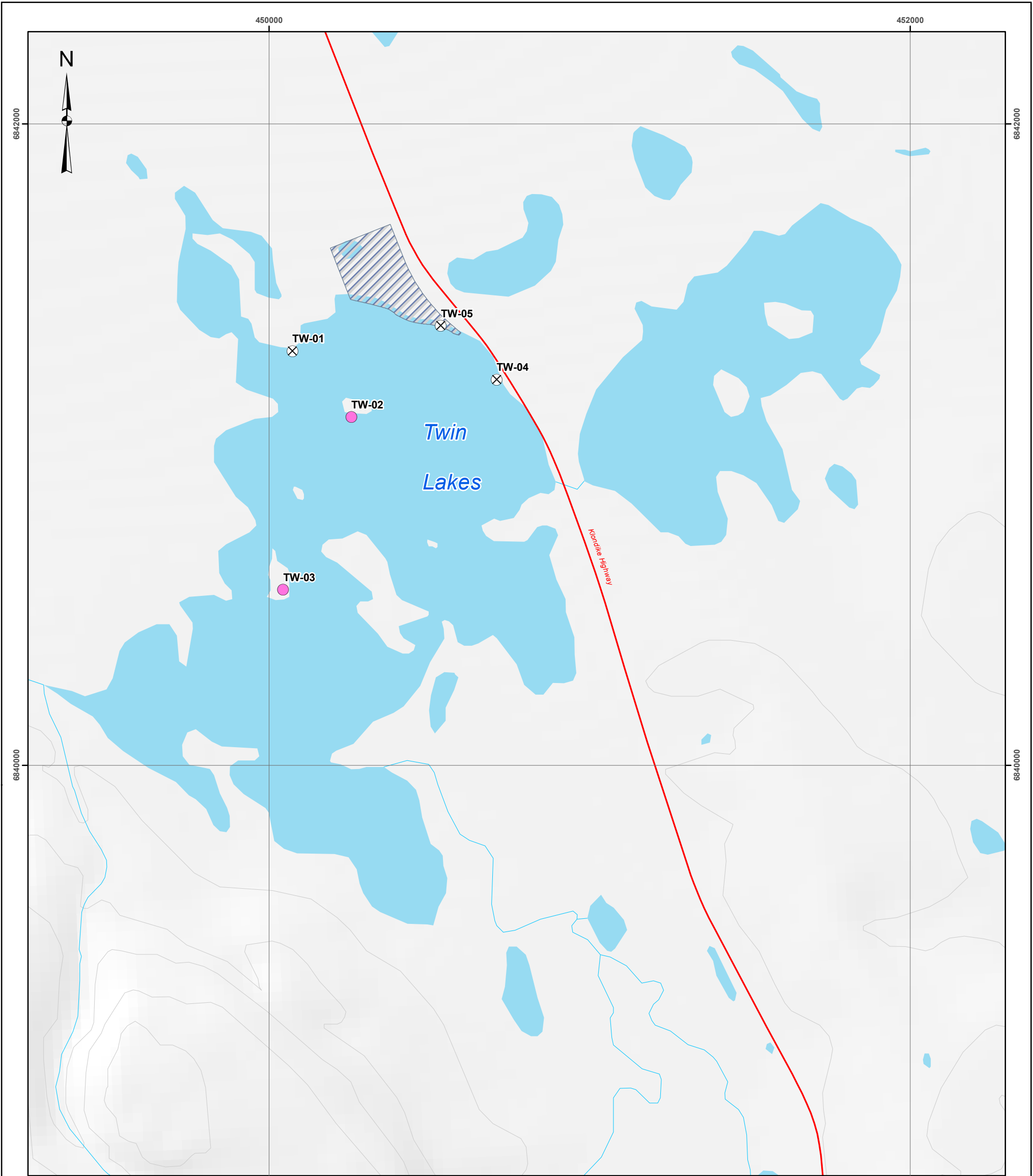


Prepared for



Prepared by



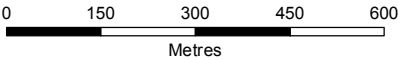


Legend

- Young-of-the-Year Lake Trout Captured
- Other Fish Species Captured Only
- ⊗ No Fish Captured
- Highway
- ▨ Territorial Park/Campground

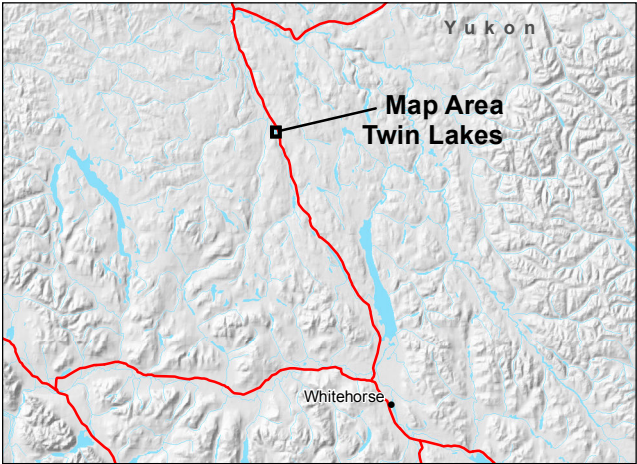
Lake Trout Investigations
Beach Seining Sites at Twin Lakes

Data Sources
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Reference Scale: 1:12,000
Map Projection: North American Datum 1983 UTM Zone 8N

Drawn: MP Checked: BSc Date: 29/02/2016 **MAP A7**



Prepared for
 Yukon Fish & Wildlife Enhancement Trust

Prepared by
 EDI



**APPENDIX B. REPRESENTATIVE
PHOTOGRAPHS OF THE
SEVEN CANDIDATE LAKES**

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Photo B1. View of a typical Braeburn Lake shoreline (site BR-02 shown; 3 July 2015).



Photo B2. View of an offshore reef in Braeburn Lake (site BR-03 shown; 3 July 2015).



Photo B3. View of extensive marl/algae covering on rocky substrate in Braeburn Lake (site BR-05 shown; 3 July 2015).



Photo B4. View of gravel/cobble shoreline in a wind exposed area in the central portion of Chadburn Lake (site CH-03 shown; 30 June 2015).



Photo B5. View of gravel/cobble shoreline in a wind exposed area in the south basin of Chadburn Lake (site CH-08 shown; 30 June 2015).



Photo B6. View of typical shoreline along the east shoreline of Fox Lake (site FO-11 shown; 2 July 2015).



Photo B7. View of typical shoreline along the west shore of Fox Lake near a creek mouth where high numbers of juvenile Arctic grayling were captured (site FO-18 shown; 2 July 2015).



Photo B8. View of probable lake trout spawning area on Fox Lake; note steep dropoff in the foreground with cobbles and boulders (site FO-27 shown; 3 July 2015).



Photo B9. Young-of-the-year lake trout captured in Fox Lake (site FO-7 shown; 2 July 2015).



Photo B10. View of probable lake trout spawning site at the northwest end of Louise Lake (site LO-4 shown; 30 June 2015).



Photo B11. View of highly suitable beach seining area at the northwest end of Louise Lake (site LO-6 shown; 30 June 2015).



Photo B12. Young-of-the-year lake trout captured in Louise Lake (site LO-9 shown; 30 June 2015).



Photo B13. Juvenile rainbow trout captured in Louise Lake (site LO-9 shown; 30 June 2015).



Photo B14. View of Pine Lake shoreline near the prominent bedrock outcrop on the north shore of the lake; note the inadequate bed material size and lack of interstitial spaces for egg incubation (site PI-3 shown; 30 June 2015).



Photo B15. Underwater view of Pine Lake bed material; note the frequent woody/organic debris and lack of interstitial spaces for egg incubation (site PI-6 shown; 30 June 2015).



Photo B16. View of an exposed point at the east end of Pine Lake, note the lack of slope and inadequate bed material for lake trout egg incubation (site PI-7 shown; 30 June 2015).



Photo B17. View of an exposed point at the north end of Tarfu Lake, note the lack of slope and inadequate bed material for lake trout egg incubation (site TA-3 shown; 2 July 2015).



Photo B18. View of the shoreline around the margin of a small island in the central portion of Tarfu Lake, note the lack of slope and inadequate bed material for lake trout egg incubation (site TA-5 shown; 2 July 2015).



Photo B19. View of the shoreline around the margin of a small island in the central portion of Tarfu Lake, note the lack of slope and inadequate bed material for lake trout egg incubation (site TA-9 shown; 2 July 2015).



Photo B20. View of a juvenile (YOY) Arctic grayling captured in Tarfu Lake (site TA-8 shown; 2 July 2015).



Photo B21. Typical view of the shoreline of West Twin Lake (site TW-1 shown; 3 July 2015).



Photo B22. View of the shoreline around the margin of a small island in the central portion of West Twin Lake; note the lack of gradient and typical rocky bed material for lake trout spawning (site TW-2 shown; 3 July 2015).



Photo B23. Close-up of the lake bed material around the margin of a small island in the central portion of West Twin Lake; note the small substrate and lack of interstitial spaces for egg incubation (site TW-2 shown; 3 July 2015).



APPENDIX C. BEACH SEINING DATA

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Table C1. View of the shoreline around the margin of a small island in the central portion of West Twin Lake; note the lack of gradient and typical rocky bed material for lake trout spawning (site TW-2 shown; 3 July 2015).

Date	Time	Site	Lake	Haul	Water Temp.	Wind Conditions	UTM	Substrate	Turbidity	Weather	Area Sampled (m²)	Fish Captured ¹												Mortalities
												NFC	CCG	LT_0+	LT_1+	GR_0+	GR_1++	LW_0+	RW_0+	NP_0+	NP_1++	BB_0+	RB_1++	
03-Jul-15	13:15	BR-01	Braeburn	1	16	N wind, site calm	8/456942/6816789	sand/cobble	clear	sunny	360		6											
03-Jul-15	13:30	BR-02	Braeburn	1	15.9	N wind, site calm	8/456702/6815783	cobble/gravel algae covered	clear	sunny	240		3								1			
03-Jul-15	13:30	BR-02	Braeburn	2	15.9	N wind, site calm	8/456702/6815783	cobble/gravel algae covered	clear	sunny	320	NFC												
03-Jul-15	13:40	BR-03	Braeburn	1	15.5	N wind, medium waves	8/456979/6814045	cobble/gravel, algae covered	clear	sunny	300		2											
03-Jul-15	13:55	BR-04	Braeburn	1	14.6	N wind, medium waves	8/457093/6811281	gravel/cobble, algae covered	clear	sunny	180		1											
03-Jul-15	14:10	BR-05	Braeburn	1	14.9	N wind, medium waves	8/457642/6812282	gravel/cobble, algae covered	clear	sunny	640	NFC												
30-Jun-15	11:30	CH-01	Chadburn	1	16	light breeze	8/501660/6724121	finest	clear	sunny	70		4									8		
30-Jun-15	11:45	CH-02	Chadburn	1	17	SW breeze	8/502288/6723800	finest/cobbles	clear	sunny	84	NFC												
30-Jun-15	12:52	CH-03	Chadburn	1	17	SW breeze	8/502292/6723738	cobble/gravel	clear	sunny	90		1											
30-Jun-15	13:25	CH-04	Chadburn	1	16	SW breeze	8/502288/6723468	cobble/gravel	clear	mixed sun and cloud	105		1											
30-Jun-15	13:30	CH-04	Chadburn	2	16	SW breeze	8/502288/6723468	cobble/gravel	clear	mixed sun and cloud	115	NFC												
30-Jun-15	13:55	CH-06	Chadburn	1	16	SW breeze	8/502325/6723229	gravel/finest/cobble	clear	mixed sun and cloud	100		1											
30-Jun-15	15:15	CH-07	Chadburn	1	16	SW breeze	8/503434/6723219	cobble/gravel	clear	mixed sun and cloud	160											1		
30-Jun-15	15:20	CH-07	Chadburn	2	16	SW breeze	8/503434/6723219	cobble/gravel	clear	mixed sun and cloud	45	NFC												
30-Jun-15	15:30	CH-08	Chadburn	1	17	SW breeze	8/503395/6733315	cobble/gravel	clear	mixed sun and cloud	90											3		
30-Jun-15	16:30	CH-09	Chadburn	1		SW breeze	8/501611/6724250	gravel/finest	clear	mixed sun and cloud	150		3						2					
02-Jul-15	9:45	FO-01	Fox	1	13.2	S wind, medium waves	8/475337/6790035	cobble/gravel/some charaphytes	clear	mostly cloudy	360		2	9		3								
02-Jul-15	9:55	FO-02	Fox	1	13.4	S wind, medium waves	8/475269/6790060	cobble/gravel	clear	mostly cloudy	385			57		7								
02-Jul-15	10:00	FO-03	Fox	1	13.2	S wind, medium waves	8/475210/6790061	gravel/cobble	clear	mostly cloudy	270			4		1								1 LT
02-Jul-15	10:10	FO-04	Fox	1	13.3	S wind, medium waves	8/475181/6790100	cobble/gravel	clear	mostly cloudy	450		2	5		31								
02-Jul-15	10:20	FO-05	Fox	1	13.4	S wind, medium waves	8/475123/6790103	gravel/cobble	clear	mostly cloudy	360		7	3		2								
02-Jul-15	10:40	FO-06	Fox	1	13.4	S wind, medium waves	8/475607/6789488	gravel/cobble	clear	mostly cloudy	350		2	63		3								
02-Jul-15	11:15	FO-07	Fox	1	13.2	S wind, medium waves	8/475686/6789336	gravel/cobble	clear	mostly cloudy	250		6	13		11								
02-Jul-15	11:45	FO-08	Fox	1	13.2	S wind, medium waves	8/475760/6789130	gravel/cobble, finest/plants > 1.2 m	clear	mostly cloudy	360			8		2								
02-Jul-15	12:00	FO-09	Fox	1	12.9	S wind, medium waves	8/476728/6787643	boulder/gravel/sand	clear	mostly cloudy	300		5			74		1	1					
02-Jul-15	12:15	FO-10	Fox	1	13	S wind, medium waves	8/476810/6786883	boulder/sand/cobble	clear	mostly cloudy	360		18			1								
02-Jul-15	12:45	FO-11	Fox	1	12.8	S wind, medium waves	8/477425/6785627	gravel/cobble	clear	mostly cloudy	360		9	1		4								
02-Jul-15	13:05	FO-12	Fox	1	12.6	S wind building, med waves	8/477662/6785046	gravel/cobble/finest/few plants	clear	rain/hail	300		4	1						2				
02-Jul-15	13:18	FO-13	Fox	1	12.1	S wind, small waves	8/478489/6783908	gravel/sand/silt	clear	rain	276		2			11	2			1				
02-Jul-15	13:28	FO-13	Fox	2	12.1	S wind, small waves	8/478489/6783908	gravel/sand/silt	clear	rain	364		2											
02-Jul-15	13:46	FO-14	Fox	1	12.1	calm	8/478177/6782414	finest/gravel/some emergent plants	clear	rain	480								2					
02-Jul-15	14:00	FO-15	Fox	1	10.3	calm	8/477729/6783297	gravel/finest	clear	overcast	360		6			21						25		6 BB
02-Jul-15	14:15	FO-16	Fox	1	11.2	calm	8/476892/6784432	gravel/silt	clear	rain	360		4			19		3						
02-Jul-15	14:30	FO-17	Fox	1	12.1	S wind, small waves	8/476269/6785464	gravel/cobble	clear	rain	240		3	1		5								
02-Jul-15	14:45	FO-18	Fox	1	13	calm	8/475404/6787826	gravel/cobble	clear	overcast	300		6	12		7			1					
02-Jul-15	15:00	FO-18	Fox	2	13	calm	8/475404/6787826	gravel/cobble	clear	overcast	350		8	18		175			28					6 GR, 1 LT
02-Jul-15	15:15	FO-19	Fox	1	14.1	S wind, small waves	8/474601/6789192	cobble/gravel/some charaphytes	clear	mostly cloudy	390		9	1		10								
02-Jul-15	15:30	FO-20	Fox	1	14.9	S wind, site calm	8/474051/6790164	gravel/cobble/finest/charaphytes	clear	mostly cloudy	350					7								
02-Jul-15	15:45	FO-21	Fox	1	15.3	S wind, medium waves	8/472614/6792447	gravel/cobble/finest/charaphytes	clear	mostly cloudy	240		2											
02-Jul-15	16:00	FO-22	Fox	1	15.6	S wind, medium waves	8/471147/6794468	gravel	clear	mostly cloudy	500		2			1						30		1 BB
02-Jul-15	16:15	FO-23	Fox	1	15.4	S wind, medium waves	8/472730/6793687	gravel/finest/charaphytes	clear	mostly cloudy	360		4									14		
03-Jul-15	9:20	FO-24	Fox	1	13.8	N wind, small waves	8/473359/6792809	gravel/finest/plants	clear	light rain	270		1									10		
03-Jul-15	9:40	FO-25	Fox	1	14.2	N wind, small waves	8/473837/6792203	gravel/finest	clear	light rain	275		11	2		9			46					
03-Jul-15	10:15	FO-26	Fox	1	13.8	N wind, small waves	8/474250/6791733	gravel/cobble, sand deeper	clear	light rain	360		2	1		1								
03-Jul-15	10:25	FO-27	Fox	1	13.7	N wind, small waves	8/474813/6790835	cobble/gravel, sand deeper	clear	light rain	200		2									3.0647		
03-Jul-15	10:35	FO-28	Fox	1	13.3	calm	8/476264/6788341	cobble/gravel	clear	light rain	360		1	2										
03-Jul-15	10:45	FO-29	Fox	1	13.4	calm	8/476014/6788631	cobble/gravel	clear	light rain	385		1	2										



Date	Time	Site	Lake	Haul	Water Temp.	Wind Conditions	UTM	Substrate	Turbidity	Weather	Area Sampled (m²)	Fish Captured ¹												Mortalities
												NFC	CCG	LT_0+	LT_1+	GR_0+	GR_1++	LW_0+	RW_0+	NP_0+	NP_1++	BB_0+	RB_1++	
03-Jul-15	11:00	FO-30	Fox	1	14.3	calm	8/475212/6788034	cobble/gravel	clear	light rain	360		4	24		119								
28-Jun-15	14:10	LO-01	Louise	1	16.3	SE breeze, small waves	8/484275/6729420	cobble/gravel/fines	clear	partly cloudy	175		12											
28-Jun-15	14:40	LO-02	Louise	1	17.9	SE breeze, small waves	8/484919/6729933	gravel/cobble/fines	clear	partly cloudy	150		1											
28-Jun-15	15:00	LO-03	Louise	1	17.1	SE breeze, small waves	8/485073/6730169	cobble/boulder/gravel/fines	clear	partly cloudy	315		10											
28-Jun-15	15:15	LO-04	Louise	1	17.1	SE breeze, small waves	8/485216/6730092	gravel/cobble/fines	clear	partly cloudy	270		10	4		1								
28-Jun-15	15:44	LO-05	Louise	1	16.5	SE breeze, small waves	8/485109/6730075	cobble/gravel	clear	partly cloudy	270		2	3										
28-Jun-15	15:51	LO-06	Louise	1	17.5	SE breeze, small waves	8/485209/6730007	gravel	clear	partly cloudy	210		23	7		2								
28-Jun-15	16:04	LO-07	Louise	1	16.9	SE breeze, small waves	8/485235/6729984	gravel	clear	partly cloudy	210		33	1										
28-Jun-15	16:15	LO-08	Louise	1	16.9	NW breeze, site calm	8/485262/6729944	gravel	clear	partly cloudy	210		35											
28-Jun-15	16:20	LO-09	Louise	1	17	NW breeze, small waves	8/485284/6729912	gravel	clear	partly cloudy	210		15	3		1							1	
28-Jun-15	16:25	LO-10	Louise	1	17	NW breeze, small waves	8/485309/6729872	gravel	clear	partly cloudy	210		11	1										
28-Jun-15	16:30	LO-11	Louise	1	16.9	NW breeze, site calm	8/485316/6729832	gravel	clear	partly cloudy	210		9	4	1									
30-Jun-15	10:50	PI-01	Pine	1	16.4	calm	8/364800/6743277	gravel/fines/plants	clear	sunny	360											26		
30-Jun-15	11:35	PI-02	Pine	1	16.9	calm	8/306452/6745349	bedrock, gravel/cobble covered in fines	clear	sunny	175											11		
30-Jun-15	11:35	PI-02	Pine	2	16.9	calm	8/306452/6745349	bedrock, gravel/cobble covered in fines	clear	sunny	210											30		
30-Jun-15	11:50	PI-03	Pine	1	17.1	calm	8/366696/6745466	gravel/sand/plants/wood debris	clear	sunny	280							125				11		
30-Jun-15	12:20	PI-04	Pine	1	17.4	W wind, small waves	8/367573/6746013	boulder/cobble covered in sediment	clear	sunny	245		2									20		
30-Jun-15	12:20	PI-04	Pine	2	17.4	W wind, small waves	8/367573/6746013	boulder/cobble covered in sediment	clear	sunny	105											2		
30-Jun-15	12:35	PI-05	Pine	1	17.3	W wind, small waves	8/367632/6746054	fines/cobble/plants	clear	sunny	315		6											
30-Jun-15	13:10	PI-06	Pine	1	17.8	W wind, small waves	8/368836/6746617	cobble/gravel/fines	clear	sunny	280											7		
30-Jun-15	13:10	PI-06	Pine	2	17.8	W wind, small waves	8/368836/6746617	cobble/gravel/fines	clear	sunny	280											9		
30-Jun-15	13:10	PI-06	Pine	3	17.8	W wind, small waves	8/368836/6746617	cobble/gravel/fines	clear	sunny	280		9									6		
30-Jun-15	13:33	PI-07	Pine	1	17.9	calm	8/369216/6746080	cobble/gravel/charaphytes	clear	sunny	350		4									5		
30-Jun-15	13:45	PI-08	Pine	1	17.9	calm	8/369177/6745738	cobble/gravel/woody debris	clear	sunny	240		2									1		
30-Jun-15	14:00	PI-09	Pine	1	17.9	calm	8/367895/6744973	cobble/gravel/sand	clear	sunny	385											3		
30-Jun-15	14:20	PI-10	Pine	1	17.2	calm	8/367309/6744471	cobble/gravel/woody debris	clear	sunny	490											2		
30-Jun-15	14:20	PI-10	Pine	2	17.2	calm	8/367309/6744471	cobble/gravel/woody debris	clear	sunny	490											1		
02-Jul-15	9:22	TA-01	Tarfu	1	16.1	SW wind, small waves	8/569371/6659413	sand/cobble	clear	partly cloudy	540					1				1	1			
02-Jul-15	9:58	TA-02	Tarfu	1	16.3	SW, medium waves	8/569340/6659683	gravel/cobble	clear	overcast	630	NFC												
02-Jul-15	10:26	TA-03	Tarfu	1	16	SW, medium waves	8/569990/6659933	gravel/cobble	clear	overcast	420					28						2		
02-Jul-15	10:55	TA-04	Tarfu	1	16.3	SW, medium waves	8/570276/6659712	gravel/cobble	clear	overcast	240	NFC												
02-Jul-15	11:20	TA-05	Tarfu	1	16.3	SW, medium waves	8/571565/6658862	cobble/gravel	clear	mixed sun and cloud	245													
02-Jul-15	11:20	TA-05	Tarfu	2	16.3	SW, medium waves	8/571565/6658862	cobble/gravel	clear	mixed sun and cloud	420					1								
02-Jul-15	12:11	TA-06	Tarfu	1	15.4	SW, medium waves	8/572249/6657101	cobble/charaphytes	clear	overcast	420									2				
02-Jul-15	12:48	TA-07	Tarfu	1	15.5	SW, medium waves	8/571539/6657516	cobble/gravel	clear	overcast	300	NFC												
02-Jul-15	12:48	TA-07	Tarfu	2	15.5	SW, medium waves	8/571539/6657516	cobble/gravel	clear	overcast	275									1				
02-Jul-15	13:15	TA-08	Tarfu	1	15.6	SW, medium waves	8/571419/6657802	cobble/gravel	clear	overcast	420					2	1				1			
02-Jul-15	14:00	TA-09	Tarfu	1	16	SW, medium waves	8/571456/6658117	cobble/gravel/sand	clear	mixed sun and cloud	360					7								
02-Jul-15	14:36	TA-10	Tarfu	1	16.4	SW, medium waves	8/571063/6658777	gravel	clear	overcast	270	NFC												
02-Jul-15	14:36	TA-10	Tarfu	2	16.4	SW, medium waves	8/571063/6658777	gravel	clear	overcast	225		2											
02-Jul-15	15:10	TA-11	Tarfu	1	16.3	SW, medium waves	8/571455/6658733	gravel/cobble	clear	overcast	210		3											
02-Jul-15	15:30	TA-12	Tarfu	1	16	SW, medium waves	8/570553/6658515	sand/cobble	clear	overcast	490	NFC												
02-Jul-15	15:50	TA-13	Tarfu	1	16.3	SW, medium waves	8/569987/6659126	sand/gravel	clear	overcast, light rain	420		3			5								
03-Jul-15	15:16	TW-01	West Twin	1	16.8	calm	8/450073/6841292	gravel/fines	clear	sunny	360	NFC												
03-Jul-15	15:35	TW-02	West Twin	1	16.3	calm	8/450257/6841086	fines/charaphytes	clear	sunny	270	NFC												
03-Jul-15	15:35	TW-02	West Twin	2	16.3	calm	8/450257/6841086	gravel/fines	clear	sunny	480		1											
03-Jul-15	15:50	TW-03	West Twin	1	16.9	calm	8/450044/6840548	gravel/cobble sediment covered	clear	sunny	385									1				



Date	Time	Site	Lake	Haul	Water Temp.	Wind Conditions	UTM	Substrate	Turbidity	Weather	Area Sampled (m²)	Fish Captured ¹											Mortalities	
												NFC	CCG	LT_0+	LT_1+	GR_0+	GR_1++	LW_0+	RW_0+	NP_0+	NP_1++	BB_0+		RB_1++
03-Jul-15	16:05	TW-04	West Twin	1	17	calm	8/450710/6841203	gravel/fines, sediment covered	clear	sunny	250	NFC												
03-Jul-15	16:20	TW-05	West Twin	1	17.3	calm	8/450536/6841371	clean gravel	clear	sunny	720	NFC												

¹ Fish species codes as follows: NFC – no fish captured, CCG – slimy sculpin, LT – lake trout, GR – Arctic grayling, LW – lake whitefish, RW – round whitefish, NP – northern pike, BB – burbot, RB – rainbow trout. Age determinations (0+, 1+, 1++) based upon fish size and knowledge of seasonal spawning timing (spring and fall spawners).



**APPENDIX D. CONSIDERATIONS
REGARDING IN-LAKE
INCUBATION OF LAKE TROUT
EGGS FOR RESTORATION**

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INTRODUCTION

This appendix is intended to provide additional information on the concept of in-lake egg incubation of lake trout to facilitate stock restoration in lakes with depleted stocks. Some considerations and risks associated with this concept are also included to provide context on how these risks may or may not be relevant to the concept as proposed. Many of these risks and concerns arose through discussions with the Yukon Government regarding the concept and here we also provide some information of methods which could be used to mitigate these risks but not eliminate them.

POTENTIAL METHOD OF IN-LAKE INCUBATION

The methods for in-lake incubation are relatively simple in that a small number of adults are captured during the spawning period, the eggs collected/fertilized and then deployed back into the lake within some form of incubation media. The adults (brood stock) can be collected relatively easily using short set, small mesh gillnets to minimize mortality. After the eggs and milt are collected from the required number of spawners, the fish would be returned to the lake. Enumeration and fertilization of the eggs can be conducted on-site at the lake using a water pump and a heath stay to recirculate lake water around the eggs (i.e. no transport to a hatchery). Deployment of the fertilized eggs into the lake could include 3 different methods: (1) direct placement in the spawning substrate, (2) placement of eggs into a commercial available incubation media such as the Jordan-Scotty salmonid incubator or (3) placement of eggs into a custom made astroturf egg incubator. Each of the methods have benefits and drawbacks and if in-lake incubation was to proceed, a combination of the three methods may be used initially to test the effectiveness of each in achieving the desired outcome. If some form of incubator is used, this would provide a direct measure of egg survival when the incubators are retrieved the following spring as any dead eggs would remain in place.

Monitoring of the effectiveness of the in-lake incubation could be challenging given the life history of lake trout. As noted in the previous paragraph, success could be tracked over time by determining the proportion of eggs that hatch (dead ones remain in the incubators). Young-of-the-year juveniles may be monitored through beach seining; however, obtaining a statistically robust estimate of juvenile abundance before and after the in-lake incubation may not be possible without a very large amount of sampling effort. Monitoring of sub-adult lake trout may also be possible through the use of hydroacoustics (sonar) although this method may be costly and may require some additional development on a lake specific basis to be effective. Monitoring of adult abundance via Summer Profundal Index Netting (SPIN) should provide an effective method of tracking changes in adult abundance; however, this method does not capture lake trout until they are at least 8 years old so there would be a considerable amount of lag time before the success of the in-lake egg incubation could be determined. Perhaps the most challenging component of monitoring the success of the in-lake incubation would be the inability to distinguish a successful outcome from that of other changes on the study lake, most notably changes in fishing regulations and subsequent reduction in harvest.



RISKS/CONSIDERATIONS OF IN-LAKE EGG INCUBATION AND POTENTIAL MITIGATION METHODS

The following includes a summary of the risks of in-lake egg incubation which have arisen during discussions of the concept with the Yukon Government. This should not be considered a comprehensive list but rather a summary of some of the risks discussed to date. Some potential mitigation methods are also included to demonstrate how the potential effects of this concept could be minimized.

Prior to discussing the risks of the in-lake egg incubation concept, some additional background is required to provide perspective for this concept. The supplementation of lake trout stocks for the purpose of restoration has been conducted extensively in other regions; however, these initiatives have almost exclusively involved the use of hatchery raised fry. In-lake incubation is very different from conventional stocking of lake trout fry and the differences have to be considered in any evaluation of risk. This concept allows for eggs to incubate naturally and as such many of the negative consequences of conventional fish stocking are avoided. In-lake incubation has been used successfully to restore a spawning population (Bronte et al. 2002), however, the lake wide restoration of a stock using this method has not been conducted previously.

GENETICS

The maintenance of genetic integrity is a very important consideration with any form of fish supplementation or restoration activity. A diverse genetic pool is important to allow fish populations to be able to adapt to changes in their environment and to occupy ecological niches within their habitats. The genetic consequences associated with conventional stocking methods have been well documented. In some cases, lakes can be restored to have a high number of fish; however, the population is less genetically diverse. This issue may arise from stocking a lake with fry which originate from a small number of brood stock because in a hatchery environment, egg to fry survival is maximized and can be very high. The loss of genetic integrity and diversity could occur with the in-lake incubation concept; however, if properly planned, it would not be expected to be as large of a concern as through the use of conventional stocking.

The concept of in-lake incubation could be designed to target an increase in lake wide egg survival by a maximum of 20 to 30% and would ensure that the majority (70 – 80 %) of juvenile lake trout produced each year are spawned naturally. Different brood stock would be used each year and the brood stock should be collected throughout the spawning season (this could be accomplished by tagging the brood stock so that they are not used in subsequent years). The concept would also only involve intervention during the very early egg stage and once the eggs hatch, they would be subjected to natural conditions in the lake. This would ensure that the natural processes (competition/predation) which act to remove unsuitable traits from the population continue to be in place.

Another key mitigation measure would be to limit the timeframe (number of years) that an in-lake incubation program would take place. As the ultimate goal is to restore the number of adults, completing the program for a few years (i.e. < 6 years) should be all that is required. Stopping after a short term (combined with the above



mitigation measure of increasing a small percentage of egg survival) should keep the genetic diversity relatively high and allow the more favourable genetic characteristics to balance out post restoration.

REPRESENTATION OF SPAWNING POPULATIONS

Within the same lake, there are often different forms of lake trout present. These forms may have a different appearance, depend of different food sources and have slightly different spawning ecology (depths, locations, etc). Such variation is related to lake size with larger lakes generally having more variation than smaller lakes. The risk with in-lake incubation is the potential for the restoration activities to focus on a subset of the spawning population which could exacerbate changes in the genetic integrity of the population. This risk can be mitigated by restricting the concept to smaller lakes only, having the best available information on spawning sites (baseline data) and collecting brood stock throughout the spawning location(s) and period.

FISH CAPTURE IMPACTS

The concept of in-lake incubation would require the annual capture of a number of spawning lake trout to collect the eggs and milt. As with all fish species, the lake trout spawning period is a sensitive time of year when large numbers of adults tend to congregate in a small area. This concern is even more relevant for lakes which are in a depleted state where there is an existing conservation concern for the stock. There is potential for the fish capture (brood stock collection) to result in some incidental mortality of a small number of adult lake trout and fish of other species. This can be mitigated through the use of appropriate gear to tangle the adult fish only and not capture them over the gills thus lowering the risk of mortality. This risk can also be carefully managed by ensuring that the net sets are very short in duration to ensure that fish are not caught in the nets for a prolonged period of time.

The concept also involves handling a large number of lake trout eggs at once and there is potential for a large failure in hatching success of the handled eggs. If this was to occur, it could result in a considerable reduction in lake wide egg survival within a given year. This risk can be mitigated by ensuring that a small scale trial of the in-lake incubation is conducted on the lake of interest to ensure that the eggs can incubate successfully using the proposed methods. Breaking up the egg collection into small batches would also provide a means to mitigate this risk by not handling all of the eggs at once.

SPAWNING ATTRACTION

The selection of microsites for egg deposition by lake trout spawners is complex and based upon a number of factors including substrate type, cleanliness and the presence of chemosensory cues (scent). Research on lake trout spawning has indicated that lake trout prefer to deposit their eggs in locations where eggs have incubated successfully in the past and that they cue on the scent left behind by empty egg membranes and the by-products left behind by juveniles. The risk with in-lake egg incubation is that natural lake trout spawning could inadvertently be attracted to microsites with conditions which are unsuitable for natural egg incubation by providing scent cues for spawning. This potential risk can be at least partially mitigated by ensuring the best



possible information on spawning sites is available and that eggs are only placed in areas where natural lake trout spawning/incubation occurs.