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developing hydroelectric potential in northern ontario

HATCH

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project description

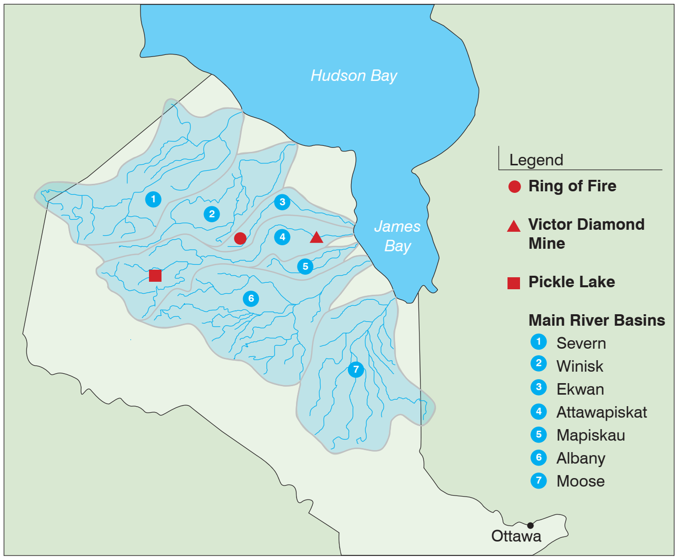
The Government of Canada, the Province of Ontario, Ontario Power Generation (OPG) and the Ontario Waterpower Association (OWA) have all studied the undeveloped waterpower potential in Ontario at various points in time. These studies have concluded that a large portion of this potential is contained in the Moose, Albany and Attawapiskat Rivers flowing north towards James Bay, and in the Severn and Winisk Rivers flowing into Hudson's Bay.

Introduction

In 2010, ENERGY's "Long Term Energy Plan" (LTEP) established an initial objective of 9,000 MW of waterpower to be in service by 2018. The LTEP also established a priority for new transmission in north-western Ontario as well as the provision of service to diesel dependent communities.

Consistent with the iterative nature of power system planning, ENERGY and the Ontario Power Authority (OPA) are leading a cyclical review of the LTEP, considering current energy, economic and environmental drivers. This study provided an objective evaluation of the costs and energy potential of Ontario's waterpower situated in the Far North, both to help inform the next LTEP and to support key provincial socioeconomic priorities in the north. The study also provided an update on the potential for greenfield waterpower development, with a focus on size for long-term planning, on locations linked to Far North Aboriginal communities, and opportunities in reasonable proximity to the Ring of Fire mining area.

Project Area



objectives

The study was designed to provide information on the following broad topics.

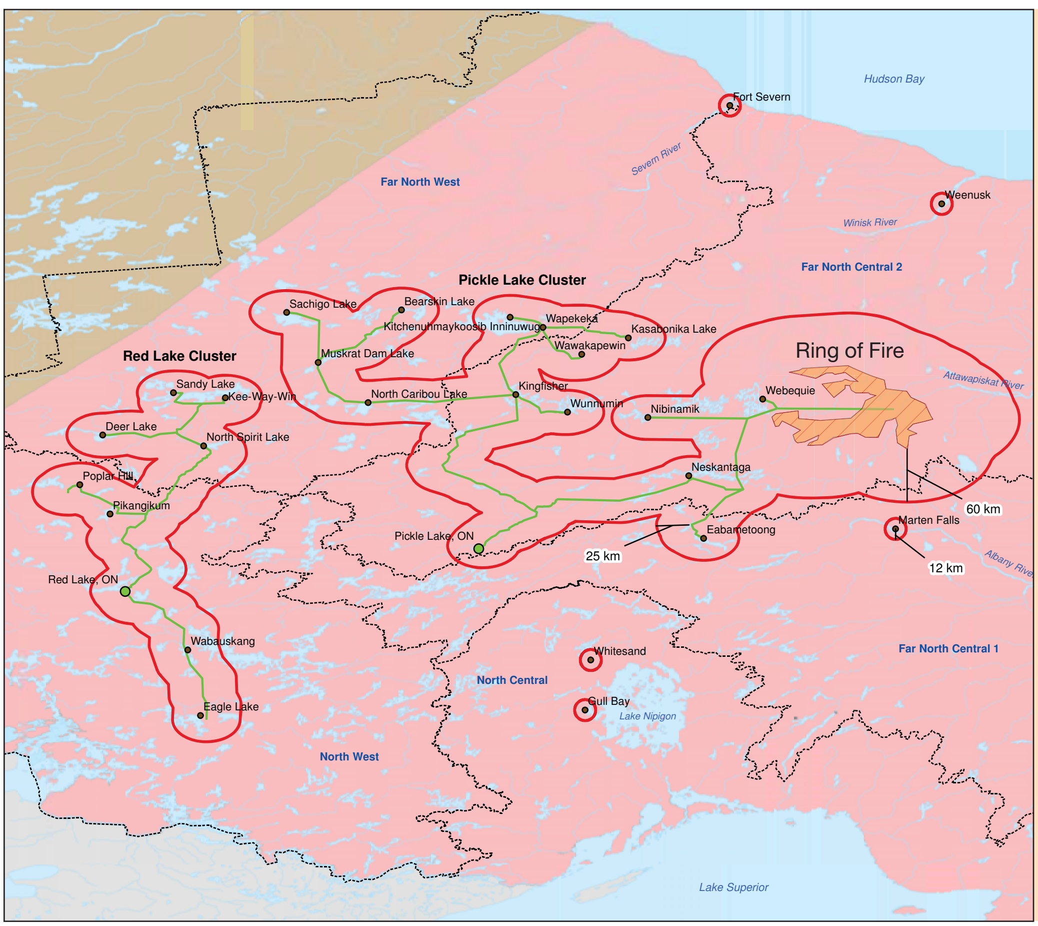
Review of Northern Waterpower Potential

Although the Province's energy supply is currently adequate, there will be supply challenges as thermal plants are retired and nuclear plants enter into a program of planned refurbishment. In the longer term, load is expected to grow in the province and demand will eventually outstrip supply.

Supply to Remote Communities

There are more than two dozen First Nations communities scattered across Ontario's Far North. More than 20 depend entirely on diesel generation for their energy supply. The Province has placed a priority on eliminating dependence on diesel generation for a significant number of these communities and the OPA is actively engaged with First Nations on the development of a business case for transmission expansion. The development of waterpower potential concurrently with transmission expansion will not only contribute to grid stability but also to the achievement of the socioeconomic objectives of Aboriginal communities. Therefore, there is a need to identify and assess both small and larger waterpower potential to support system planning and broader provincial objectives.

Waterpower Potential Enabled by the Development of the Ring of Fire



This area of mineral-rich deposits is located in the center of the Hudson and James Bay drainage basins. It is currently under exploration and ultimately will require significant amounts of energy.

Diesel generation is the current energy supply proposal, which is costly and harmful to the environment. Alternatively, a transmission extension from the planned transmission line to Pickle Lake could be developed.

approach and methodology

Approach

The study approach involved the following steps:

1) Review all available data and reports.
2) Costing:
   - Assess current costs for the development of waterpower on the basis of a review of the implementation costs of recently completed northern waterpower projects.
   - Determine average annual operating expenditures (OPEX) and annual sustaining capital expenditures (CAPEX) on the basis of a review of actual costs for similar facilities.
3) Hydrology – undertake a regional hydrology study to define runoff characteristics of watersheds.
4) Screening – develop and apply a geographic information system (GIS) model and undertake a screening for waterpower projects to determine head, flow, energy and the average costs for the defined opportunities, as well as the levelized unit cost of energy (LUEC).
5) Review and update the project cost and LUEC for previously identified sites.

Assessment and Update of Costs

Project Implementation Costs

For this study, the methodology to develop a reasonable assessment of costs for waterpower development involved:

- Review of available data and reports, including review of recent cost data for projects in Canada's north that have been completed, under construction or have feasibility level costing to calibrate current cost price points.
- Selection of specific, previously studied waterpower sites and preparation of updated cost estimates for each of the facilities using two or more methods of estimation.
- Estimation of the time requirements and costs for environmental assessments and permitting.

Operating Costs

Annual OPEX was assessed from a review of the actual operating costs for a number of northern Canadian waterpower facilities and compared with standard benchmark formula for waterpower facilities across North America. Annual CAPEX were determined for greenfield sites in Canada's Far North by a review of actual and planned CAPEX for facilities less than six years old.

Screening of Waterpower Potential

Due to the extremely large area of interest and the complex nature of waterpower projects, two principal activities were undertaken – a hydrological study of the region, and the development and application of a GIS screening tool.

Regional Hydrology Assessments

A regional hydrology assessment was undertaken to determine the quantity of water that would be available at a specific potential site, as well as the proportion of the flow that would be usable for power generation purposes. The study was based on the flow records available from 41 flow gauging stations located in Northern Ontario. The specific runoff in litres per second (l/s) per square kilometre at any location in northern Ontario varies from 7 l/s to 13 l/s with a mean of 10 l/s. The mean annual runoff, Q_{mean}, in m^3/s, can be estimated with the following equations.

- Western and Central Region (Severn, Winisk and Attawapiskat Rivers).
  $Q_{mean} = 0.02342\ (DA)^{0.9}$, where DA = drainage area (km^2)
- Eastern Region (Albany and Moose Rivers).
  $Q_{mean} = 0.03513\ (DA)^{0.9}$

The statistics of flow at the flow gauging stations was then analyzed to determine the proportion of time that flows occurred at different flow values between zero and the maximum flow recorded i.e., the "flow duration curve." Predictive equations were determined for small (less than 2500 km^2), medium and large watersheds (greater than 10,000 km^2). For run-of-river waterpower sites these data can be used to determine the proportion of the runoff that can gainfully be used for power production ("turbineable" flow, Q_T) and the amount that would be spilled.

GIS Software

ArcGIS produced by ESRI was used to create a model to assist in the assessment of hydropower potential. ModelBuilder, a module of ArcGIS, was used to develop the model, as well as 3D Analyst and Spatial Analyst extensions and the ArcGIS Toolbox. The model was further customized by Hatch with the addition of extensive python code. The model makes use of GIS hydrological tools and incorporates them into an automated tool capable of assessing hydrological parameters. The parameters are calculated in the GIS attribute table, based on defined hydrotechnical criteria, which can then be exported to a database of potential waterpower sites or to other interfaces such as Google Earth.

Hatch staff reviewing the GIS analysis

GIS Digital Elevation Model

- The inputs for the model are Provincial Radar Digital Surface Model (DSM), consisting of a 30 m x 30 m grid elevation model for the entire region.
- Ontario Integrated Hydrology data.
- Land use information provided in a raster format.
- First Nations information.

GIS Screening Tool

Hatch developed a screening model, making use of GIS hydrological tools and an automated process capable of assessing, at user defined points along the watercourse, the following parameters:

- Drainage basin area (DA); and using the hydrological study results -- associated Q_{mean}, and mean annual power flow (Q_p).
- Volume of dam at various heights.
- Distance to closest transmission line and distance to closest First Nations community.
- Calculated waterpower installed capacity (IC) and average annual energy production (E_{avg}), for specified head (H) and design flow ratio ($QD/_{Qmean}$).
- Project capital cost including power facilities, dam, access and local interconnection.
- Annual operating expenditures (OPEX) and annual capital expenditures (CAPEX).
- Economic indicators; both LUEC in $/kWh, and unit cost of capacity, in $/KW.

The above parameters are calculated in the GIS attribute table and are used to create a database of potential waterpower sites based on defined hydrotechnical criteria. The last four bulleted items are discussed in more detail in the following sections.

Conceptual Waterpower Design

For screening purposes, the following methodology was applied related to the characteristics of a potential waterpower project:

1) Power design flow (Q_D) was taken as 1.5 times Q_{mean}.
2) Usable power flow was derived from the hydrological study and for Q_D/Q_{mean}= 1.5.
3) Freeboard was taken as 1 m for a 5 m head, and 2 m for higher dams.
4) Full supply level (FSL) located below the dam crest elevation by the freeboard.
5) Tailwater level (TWL) was taken as contour crossing at the river location.
6) Head (H) was taken as FSL – TWL.
7) Minimum operating level (MOL) was taken at 80% of the head.
8) Installed capacity (IC) in MW is given by IC = 9.812 x QD x H x η / 1000; where η is the plant aggregate efficiency including head losses and turbine/generator efficiency.
9) Average energy production, E_{avg}, = (9.812 x Qp x H x η / 1000) in MW x 8766h per year.
10) Capacity factor, CF = E_{avg} / (IC x 8766).
11) Spill recapture and equivalent energy computed to augment E_{avg}.

Conceptual Cost of Identified Waterpower Sites

To establish the site specific cost of development for the identified waterpower sites, the overall average costs were adjusted by removing variable site specific costs (costs of dams and dykes, access costs, interconnection costs, and reservoir clearing costs). The base cost remaining represents the fixed capital cost of power facilities. The variable costs were estimated by the GIS model as follows: a) Dam cost = dam volume x $45/m^3; b) Access cost = access distance x $230,000/km; and, c) Interconnection cost = interconnection distance x $150,000/km.

Establish Capital Site Costs

Overall site costs are established for the identified projects using the adjusted cost formula and calculated capacity, and the site specific variable costs using quantities derived by the GIS model.

Establish the Levelized Unit Energy Cost

For each site, the LUEC was established using the site capital costs, the net present value of OPEX and CAPEX, and the calculated energy.

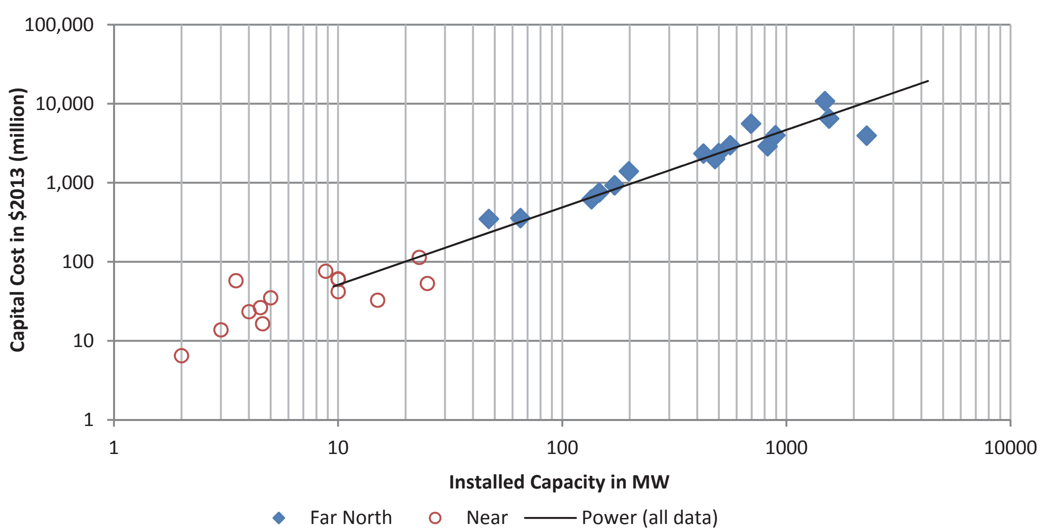
Screening Model Application

The tool was then applied to three areas of interest in the Far North to identify potential waterpower sites.

assessment and update of costs for waterpower development in the Far North

Review of Recent Cost Data from Northern Waterpower Projects

There have been a number of recent projects in Northern Ontario and elsewhere across Northern Canada that have been constructed, are being constructed or have had feasibility level cost estimates prepared. Hatch undertook a detailed assessment of these projects to assess the generally fixed costs for waterpower development including concrete structures and generation equipment to develop a relationship between the installed capacity and the construction costs associated with these components. The results were a surprisingly consistent relation that indicated the fixed costs associated with waterpower construction in Canada's North was about 30% higher than costs in the south.

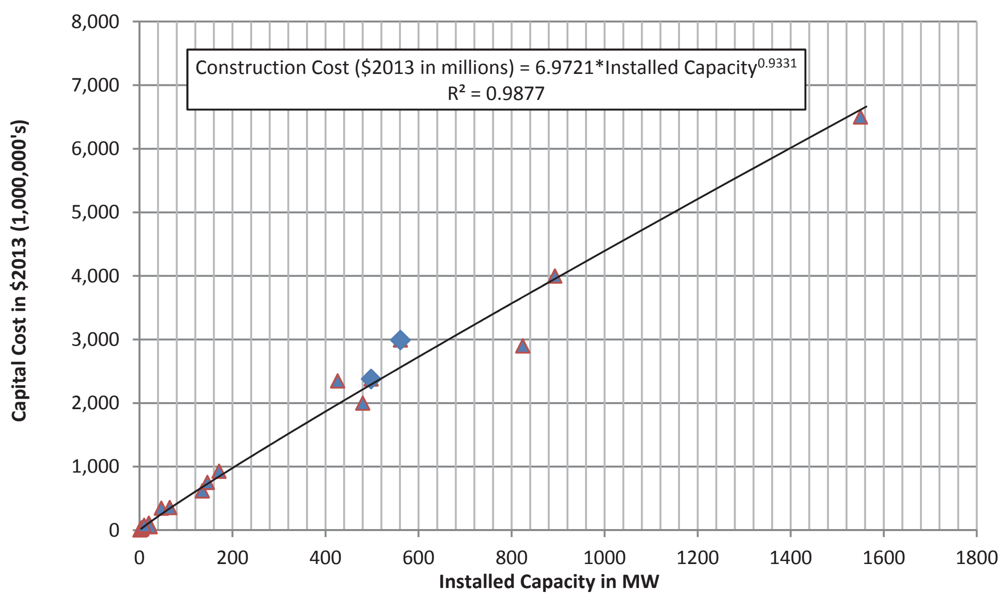


With costs for the fixed components of a northern plant established, definition of site-specific relationships to account for the size of dam needed, the length of access road and the distance to transmission, were developed based on dam height and distances established within the GIS model.

Cost Updates for Selected Sites

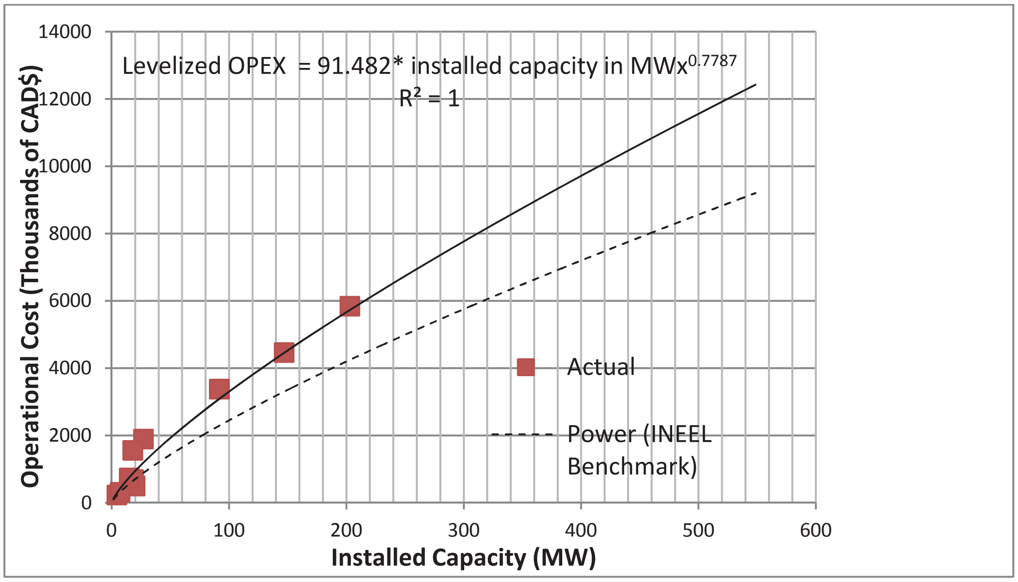
Ten projects previously studied were selected for updated cost assessment. Four methods of analysis were used as follows:

- First Principles -- For two projects, where pre-feasibility information was available, a first principles estimate was undertaken.
- USBR Method -- The United States Bureau of Reclamation (USBR) has previously established an empirical cost methodology for estimating conceptual power plant costs based on proration of turbine-generator equipment cost.
- Cost per kW -- Based on the information assessed on recent waterpower projects, cost curves were developed relating estimated capital cost to installed capacity.
- Escalation -- Escalation indices were applied to previously determined costs.

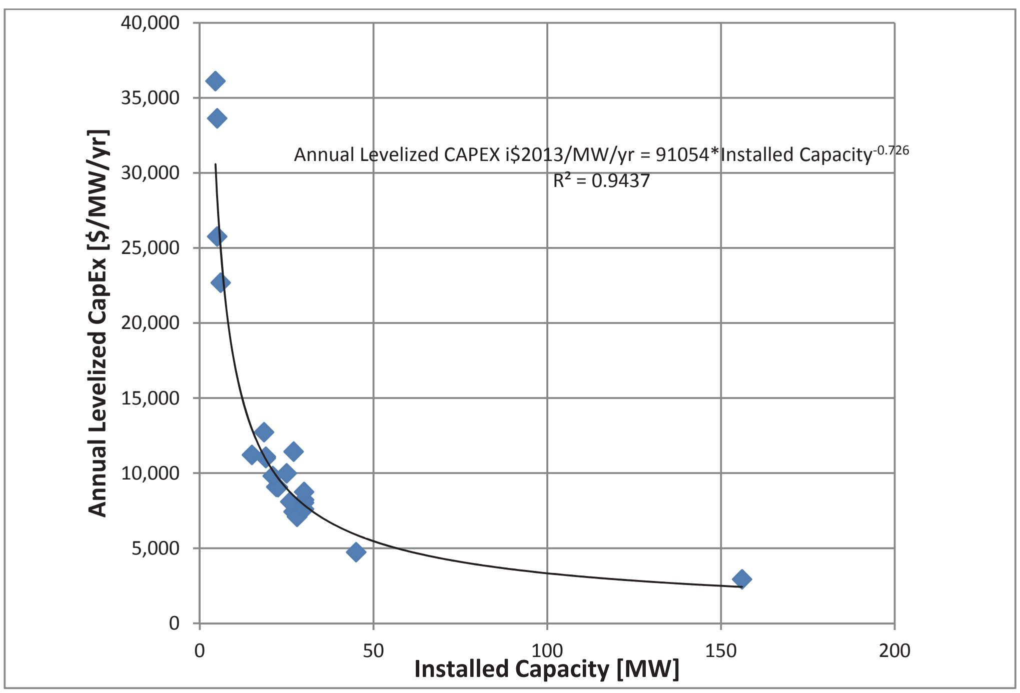


Assessment of Operating Costs

OPEX costs were defined by a proration of the methodology outlined by the Idaho National Engineering and Environmental Laboratory (INEEL) detailed in "Estimation of Economic Parameters of U.S. Waterpower Resources," June 2003. An assessment of recent Northern Ontario projects indicates that OPEX costs are roughly 35% higher than the average benchmarked costs for plants located in the United States.



A review of actual and planned CAPEX was performed for a number of waterpower facilities less than 10 years old, with the following results.



Review of Environmental Assessment and Permitting Requirements for Waterpower Projects in Ontario

Waterpower projects in Ontario are subject to the environmental assessment (EA) requirements of the provincial Ontario Environmental Assessment Act and, depending on generating capacity, may also be subject to the requirements of the federal Canadian Environmental Assessment Act, 2012 (CEAA 2012).

waterpower potential to supply remote communities and the ring of fire

Demand

The primary demand for power in Northern Ontario is for mining developments and First Nations communities. The most important mining development is the Ring of Fire, which is located north of Pickle Lake.

First Nations Communities

There are 25 remote First Nations communities in Northern Ontario that are not currently connected to the provincial grid and generally do not have all-season road access. They are currently supplied by isolated diesel generators.

The six communities north of Red Lake can be served by a single 115 kV radial line from Red Lake. These communities have an existing load of 6 MW that is forecast to grow to 13 MW by 2033. The 14 communities north and east of Pickle Lake can be served by several lines from Pickle Lake. These communities have an existing load of 9.5 MW and are forecast to grow to about 20 MW by 2033.

Ring of Fire

The OPA load forecast for the Ring of Fire's mining demand, anticipates about 25 MW by 2020, growing to 35 MW by 2030. A high growth scenario involves a demand in the mid-2030s of 60 MW.

Supply to Red Lake Cluster

The GIS screening tool identified a large number of potential sites on watercourses that were flowing within 50 km of the Red Lake transmission lines, which will connect six First Nations communities; and the most cost-effective projects identified. All potential projects are illustrated in Figure 5-1.

Site #	Community Name	Dist (km)	Size (MW)	Energy (GWh/y)	CF	Capital Cost ($M)	LUEC ($/kWh)
1	Pikangikum	10	8.2	36.1	0.50	44	0.071
2	Poplar Hill	3	11.8	57.8	0.56	65	0.064
3	Deer Lake	6	5.4	23.8	0.50	32	0.080
4	North Spirit Lake	13	2.6	9.9	0.44	16	0.104
5	Sandy Lake	0	15.5	76.1	0.56	86	0.062
6	Kee-Way-Win	26	24.1	119	0.56	140	0.063

Supply to Pickle Lake Cluster

The GIS screening tool identified a large number of potential sites on watercourses that were flowing within 50 km of the Pickle Lake transmission lines, which will connect 14 First Nations communities and the Ring of Fire mining area. The most cost-effective projects were identified. All potential projects identified are illustrated in Figures 5-2a, 5-2b, 5-2c.

Site #	Community Name	Dist (km)	Size (MW)	Energy (GWh/y)	CF	Capital Cost ($M)	LUEC ($/kWh)
7	Eabametoong	11	26	129	0.56	141	0.059
8	Neskantaga	19	23	114	0.56	123	0.059
9	Webequie	17	23	114	0.56	142	0.066
10	Nibinamik	13	17	85.3	0.56	96	0.062
11	North Caribou Lake	n/a	n/a	n/a	n/a	n/a	n/a
12	Kingfisher Lake	28	2.4	13.9	0.44	16	0.108
13	Wawakepewin	9	4.3	18.9	0.50	37	0.109
14	Kasabonika Lake	7	6.9	30.4	0.50	50	0.091
15	Wapekeka	11	6.0	26.3	0.50	54	0.109
16	Bearskin Lake	18	5.6	24.4	0.50	36	0.086
17	Kitchenuhmaykoosib Inninuwug	19	5.5	24.1	0.50	43	0.099
18	Sachigo Lake	16	5.3	23.4	0.50	36	0.089
19	Muskrat Dam	25	38	185	0.56	196	0.056
20	Wunnumin Lake	22	13.5	66.5	0.56	83	0.068
ROF	Ring of Fire	20	31	152	0.56	172	0.060

Supply to Remote Communities

The GIS screening model was applied to an area within 12 km of the five remote First Nations communities not anticipated to be connected to the transmission grid at this time. Three of the five communities had opportunities within 5 km to develop a waterpower project, with a head of 5 m, of between 2 MW and 5 MW.

innovation

To assess the waterpower potential of this vast region to meet these varied needs, a new tool was needed that could collectively assess all of the issues that affect the selection of cost-effective sites. The issues included proximity to the transmission corridors and end-users, the required installed capacity in relation to the needs of the end-user, environmental and geological constraints, the costs of building the facility, the energy production, and operating costs.

Much of the needed geographic, environmental and geological data was available in databases that had already been compiled by the Province. However, making sense of these data and then determining the life cycle costs and energy potential of thousands of potential sites is a significant task. The solution to this complex task was the development and application of a customized GIS model that could process all of the available information efficiently and accurately.

To establish the life cycle costs, Hatch evaluated data from more than 50 constructed or planned waterpower facilities located in Canada's North, and established cost functions that accounted for the environmental assessment costs, "fixed" costs of generating equipment and concrete structures, site specific costs for such items as access, sub-transmission and dam construction, and annual operating costs.

Site-specific energy potential was established on the basis of an assessment of Water Survey of Canada records at 40 locations throughout Northern Ontario. These data were assessed to develop relationships between watershed area and mean annual runoff, and the proportion of the annual flow volume that could be captured for power supply, for a range of installed plant capacities.

The new GIS-based model drew on all of the existing background geographic information and newly developed Hatch relationships to automatically evaluate all feasible locations along each of Ontario's major Northern waterways.

A post-process evaluation was then executed to assess the thousands of potential projects to determine the optimum development scheme along any given watercourse, accounting for the fact that the characteristics of a development for a small First Nations community would be very different from the needs of the Ring of Fire.

complexity

Establishing relationships between the project capacity and the costs to construct a facility required the evaluation of a complex set of site-specific and interrelated variables that are difficult to quantify in the Far North. Data from more than 50 constructed or planned waterpower projects located in northern Canada were collected and evaluated to produce a surprisingly consistent relationship for the fixed components of a waterpower facility. Definition of relationships for site-specific construction costs, accounting for dam size, access, and the distance to transmission, were then incorporated into the relationships and calibrated against known estimates. To these costs, estimates of operating expenses based on 40 new facilities, and the costs to undertake the environmental assessments needed to ensure sustainable development were established; completing a life cycle cost relationship that was incorporated in the model.

The GIS screening tool was customized to process the vast store of geographic information available and the Hatch-derived data on costs and hydrology. A variety of built-in ArcGIS processes and custom Python scripts, utilizing more than 1,000 individual processes, determined watershed area, access distance, sub-transmission distance, dam volume and reservoir volume for a range of feasible dam heights for each of the potential sites. The model then computed the mean annual flow, installed capacity, average annual energy and project life cycle cost, and finally, the Levelized Unit Energy Cost (LUEC). The LUEC was used to guide the determination of the optimum development plan for the river

social and economic benefits

The results of the assessment identified promising waterpower opportunities for most of the 20 remote off-grid First Nation Communities in the Far North of Ontario. Development of these sites will reduce the communities' reliance on increasingly expensive diesel generation, reduce emissions in an environmentally-sensitive region, provide employment opportunities during construction, provide a long-term source of revenues and, most importantly, sustainable employment when the projects are completed.

The screening tool identified opportunities of a size that would meet the needs of the community at a cost that the community could afford. In addition, the communities can take a significant role in the project development in conjunction with a third-party development partner.

Improved access to the communities and a more reliable power supply will enhance the quality of life in these communities significantly and provide a share in the economic benefits for the next century.

Projects identified in the vicinity of the Ring of Fire mining area, of a size suited to industrial demands, were found to be very attractive with an all-in supply cost under $0.07 per kWh. This potential will encourage the development of this resource -- enhancing economic development throughout the North.

Finally, the Province's need for large-capacity waterpower to help offset issues created by the introduction of non-dispatchable renewable energy resources was met with the identification of a number of potential sites.

environmental benefits

Ontario's Far North is already being stressed by the effects of climate change, which is recognized as one of the greatest threats to this ecosystem. In addition, as communities grow and economic development moves forward in this region, the impacts of the increasing reliance on diesel generation will become significant. Such issues as degradation of local and regional air quality the need for fuel supply flights into the remote communities and the increasing costs associated with the reliance on fossil fuels can impact both social and environmental health.

This landmark study identified more than the Province's stated goal of 9,300 MW of renewable power that can be developed at a reasonable life-cycle cost. If developed, this would eliminate the need for diesel plants in Ontario's North, and displace over 20,000,000 tones of Green House Gas emissions annually, assuming displacement of generation by natural gas generation plants.

This new tool also has the potential to provide the same benefits in other regions. In the few months since the development of the new tool, a panel of provincial and federal government energy executives have met to discuss the study results, private developers have asked Hatch to apply the tool in other areas of Canada, and First Nations communities have engaged Hatch to discuss the results of the study and how it pertains to their community.

meeting the clients' needs

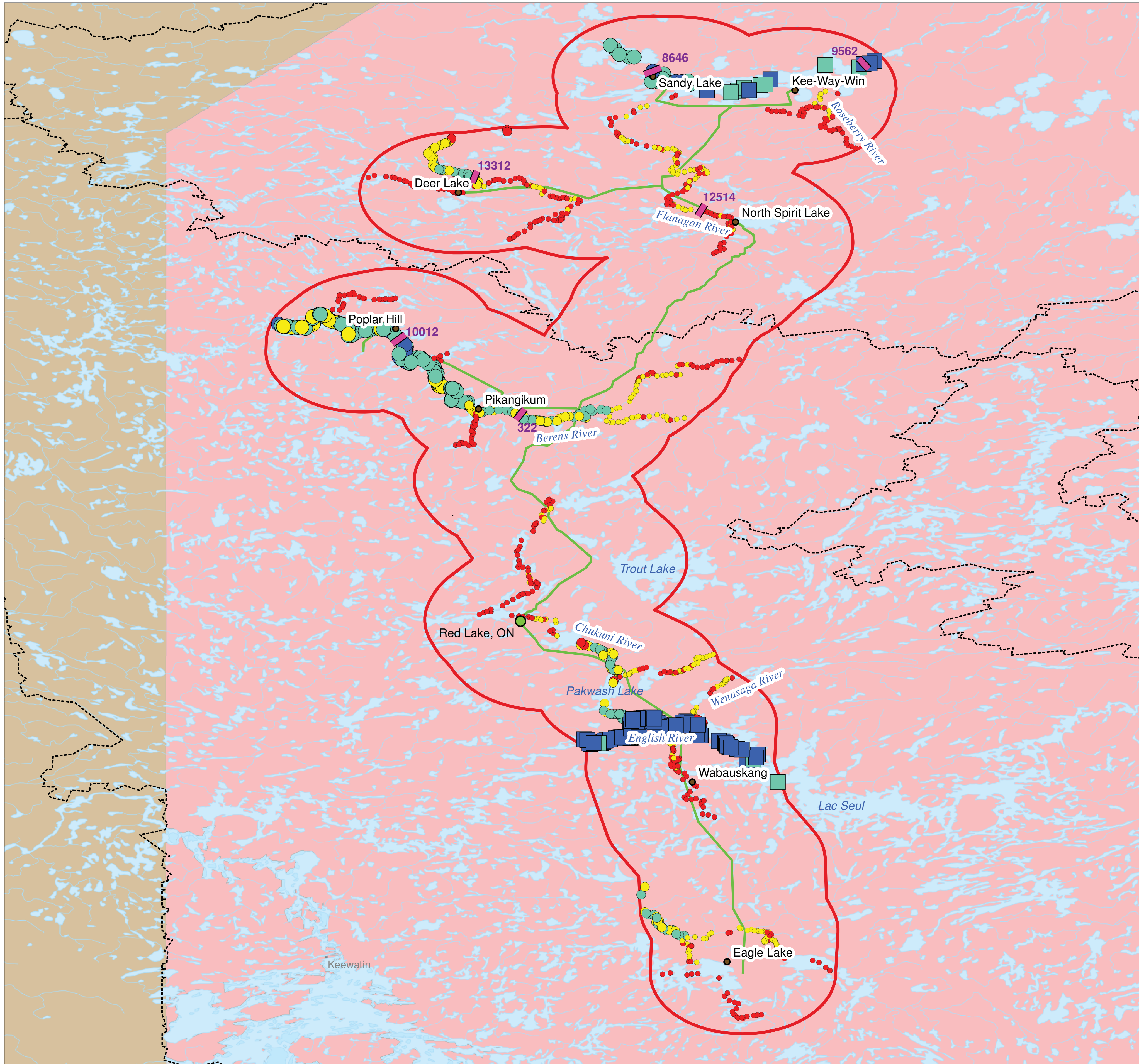
The project was undertaken for the Ontario Waterpower Association (OWA), the Ontario Ministry of Natural Resources (OMNR), and the Ontario Ministry of Energy (ENERGY).

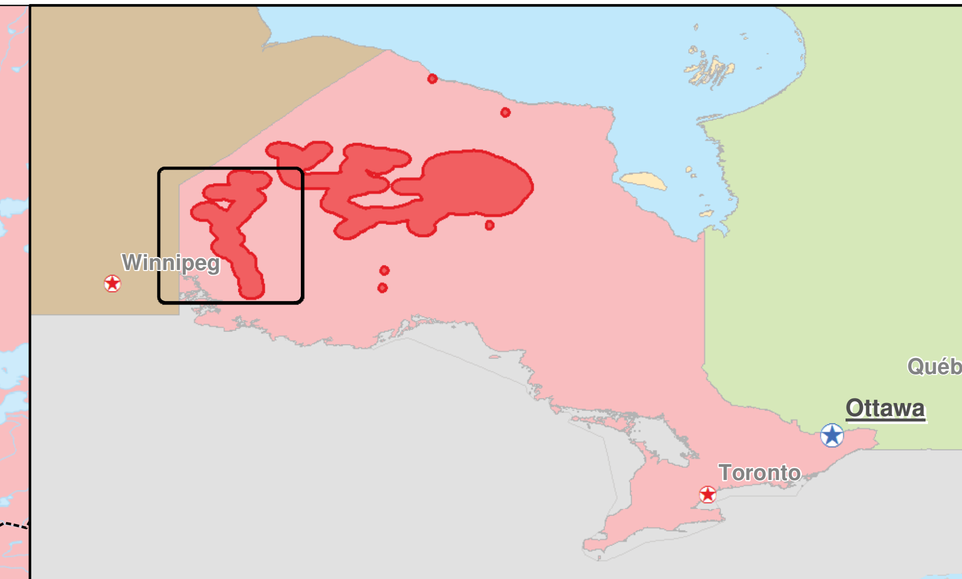
All of the clients' objectives were met and exceeded. The clients now have a well-defined hydroelectric resource identified throughout the study area. Specifically, the benefits to the various Ontario entities are as follows:

ENERGY – *"I am very pleased with the outcome of this initiative," said the Honourable Bob Chiarelli, Minister of Energy. "Our 2013 Long-Term Energy Plan expands the target for waterpower to 9,300 megawatts and establishes a priority for connecting remote communities. This report helps identify opportunities for hydroelectric projects that can help Ontario be ready to generate power when and where we need it."*

OMNR -- *"I am pleased to support the release of the OWA report on the evaluation and assessment of waterpower potential in the Far North of Ontario," said the Honourable David Orazietti, Minister of OMNR. "This report will provide additional information to support community-based land use planning in the Far North."   OMNR will update its GIS-based atlas of renewable power potential.*

OWA -- *"While Ontario's North has long been recognized for its significant untapped potential, this is the first time we've specifically focused on questions of socioeconomic opportunities in the region," added Paul Norris, President of OWA. "This product will help enable planning for the province, First Nations and industries."*





Legend

- First Nation Community of Study
- Selected Waterpower Opportunity
- Transmission Line
- Study Area
- Watershed

Potential Waterpower Opportunity

LUEC	Installed Capacity
> 0.130	< 5 MW
0.129 - 0.090	5.0 - 10.0 MW
0.089 - 0.070	10.0 - 20.0 MW
< 0.070	> 20 MW

Notes:
1. Study Area defined as 25 km from transmission line,
2. Produced by Hatch under licence from Ontario Ministry of Natural Resources, Copyright (c) Queens Printer 2011.
3. Spatial referencing WGS 84.
4. Base geographical information provided from ESRI, and WMS provided by Natural Resources Canada.

0 15 30 60 90 Km

1:1,750,000

Figure 5-1
Northern Hydro Assessment
Waterpower Potential in the Far North
LUEC - Red Lake Cluster

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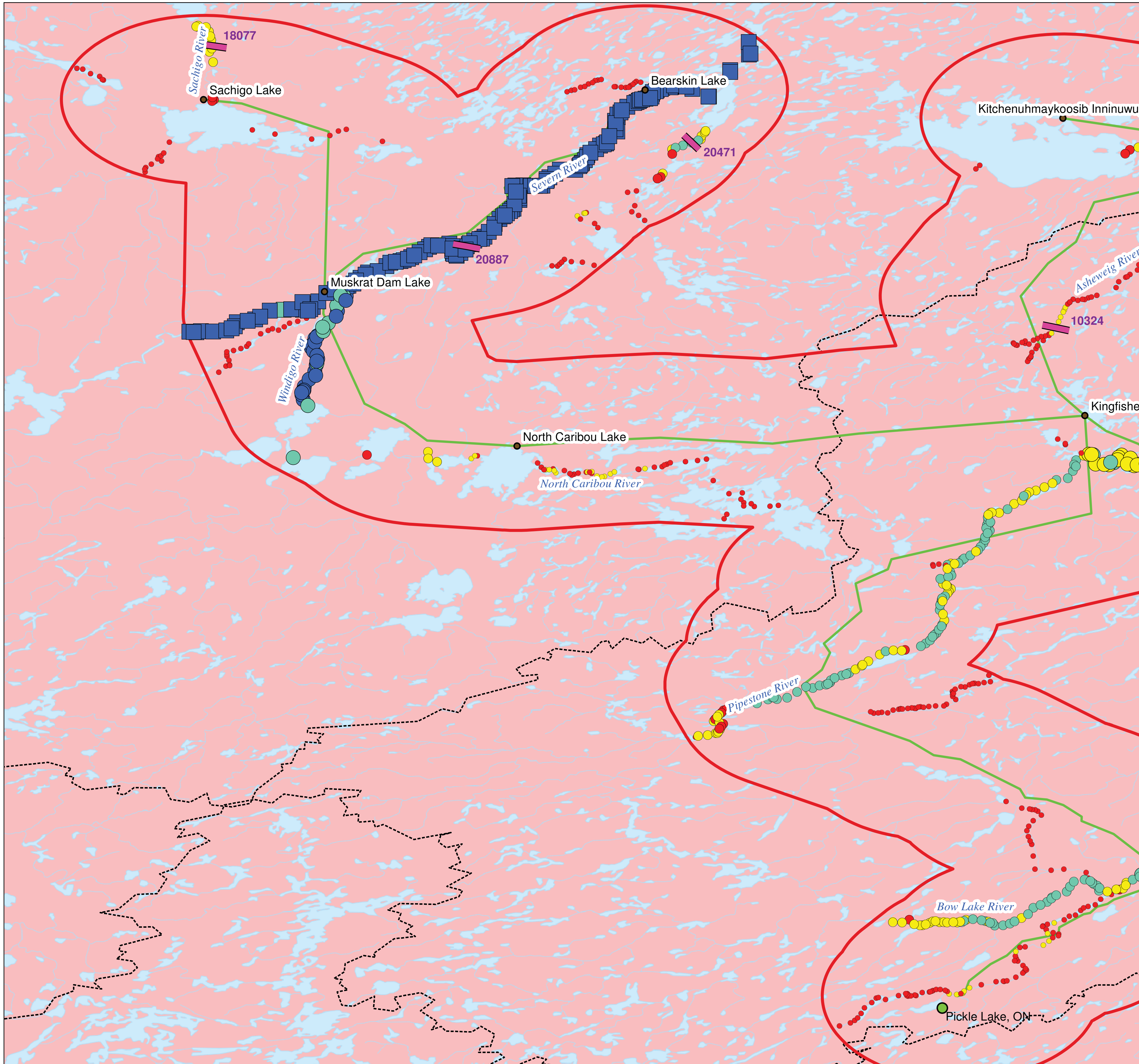

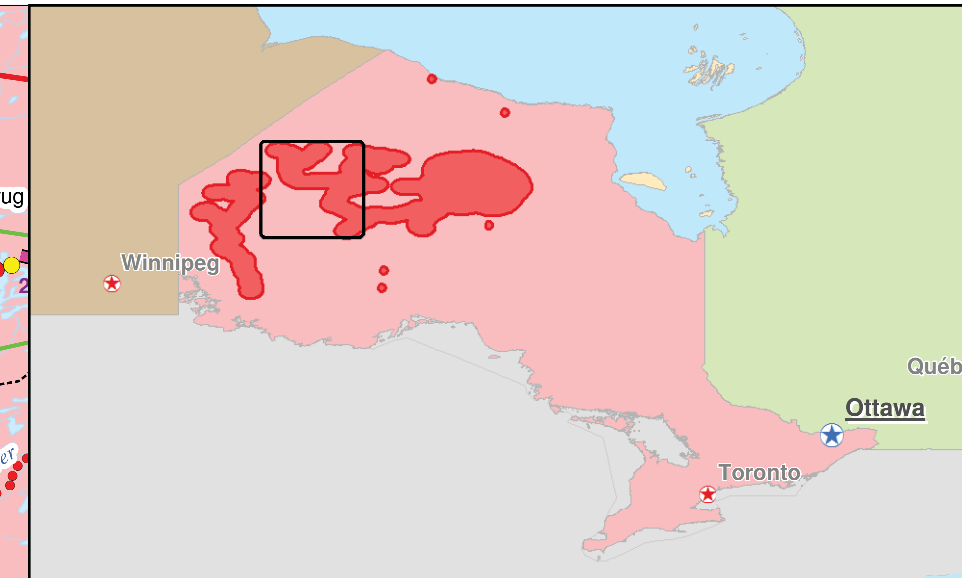

Legend

- First Nation Community of Study
- Selected Waterpower Opportunity
- Transmission Line
- Ring of Fire
- Study Area
- Watershed

Potential Waterpower Opportunity

LUEC	Installed Capacity
> 0.130	< 5 MW
0.129 - 0.090	5.0 - 10.0 MW
0.089 - 0.070	10.0 - 20.0 MW
< 0.070	> 20 MW

Notes:
1. Study Area defined as 25 km from proposed transmission line, and 60 km from the Ring of Fire region (whichever is greatest).
2. Produced by Hatch under licence from Ontario Ministry of Natural Resources, Copyright (c) Queens Printer 2011.
3. Spatial referencing WGS 84.
4. Base geographical information provided from ESRI, and WMS provided by Natural Resources Canada.

0 15 30 60 Km

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Figure 5-2a
Northern Hydro Assessment
Waterpower Potential in the Far North
LUEC - Pickle Lake Cluster - West

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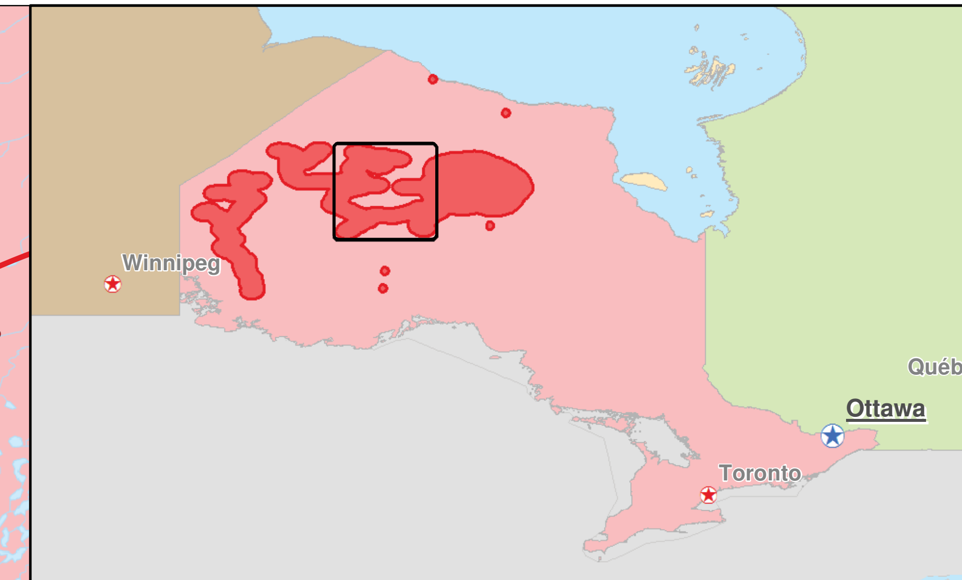

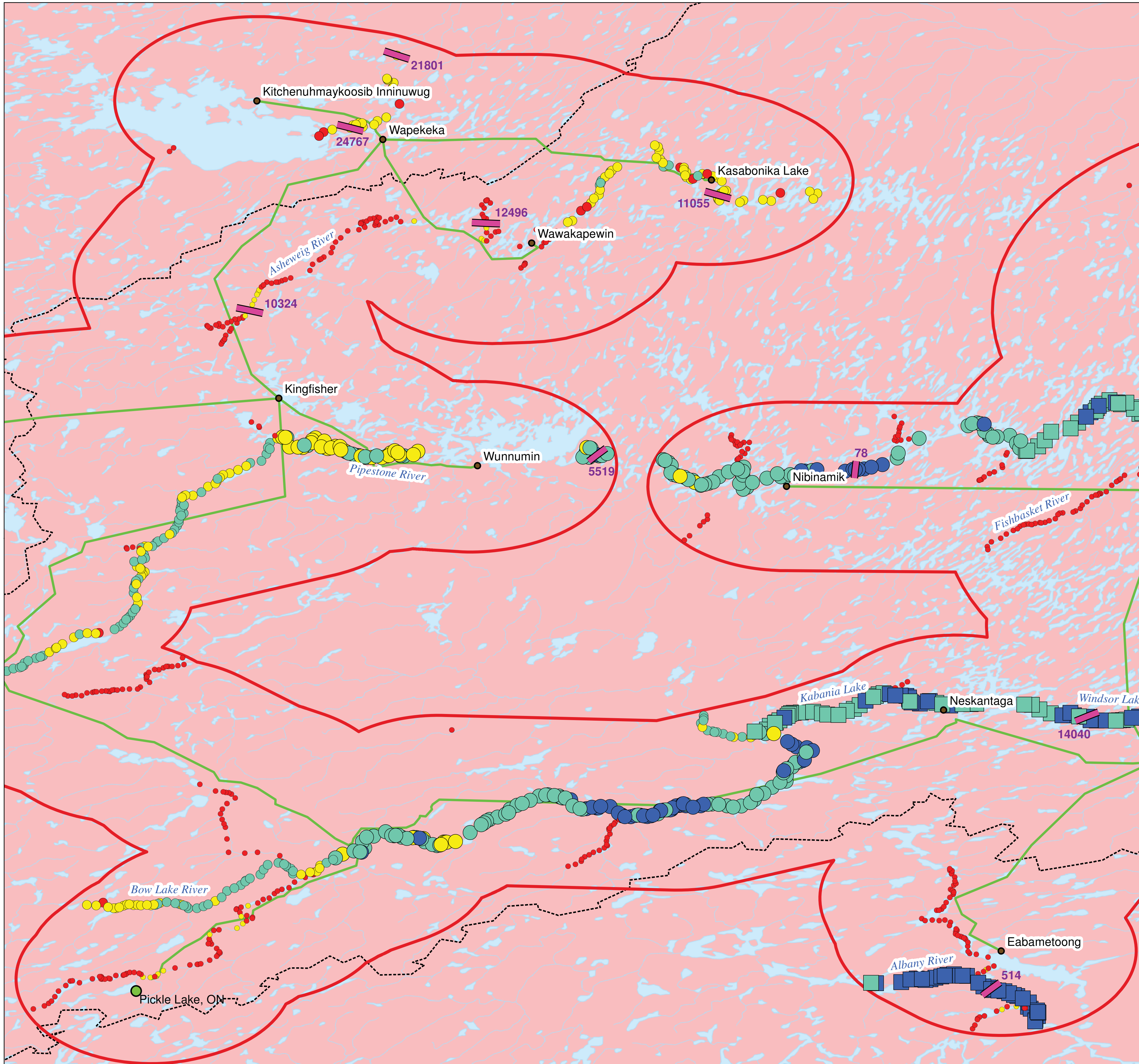

Legend

- First Nation Community of Study
- Selected Waterpower Opportunity
- Transmission Line
- Ring of Fire
- Study Area
- Watershed

Potential Waterpower Opportunity

LUEC		Installed Capacity
> 0.130		< 5 MW
0.129 - 0.090		5.0 - 10.0 MW
0.089 - 0.070		10.0 - 20.0 MW
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Notes:
1. Study Area defined as 25 km from proposed transmission line, and 60 km from the Ring of Fire region (whichever is greatest).
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4. Base geographical information provided from ESRI, and WMS provided by Natural Resources Canada.

0 15 30 60 Km

1:1,250,000

Figure 5-2b
Northern Hydro Assessment
Waterpower Potential in the Far North
LUEC - Pickle Lake Cluster - Central

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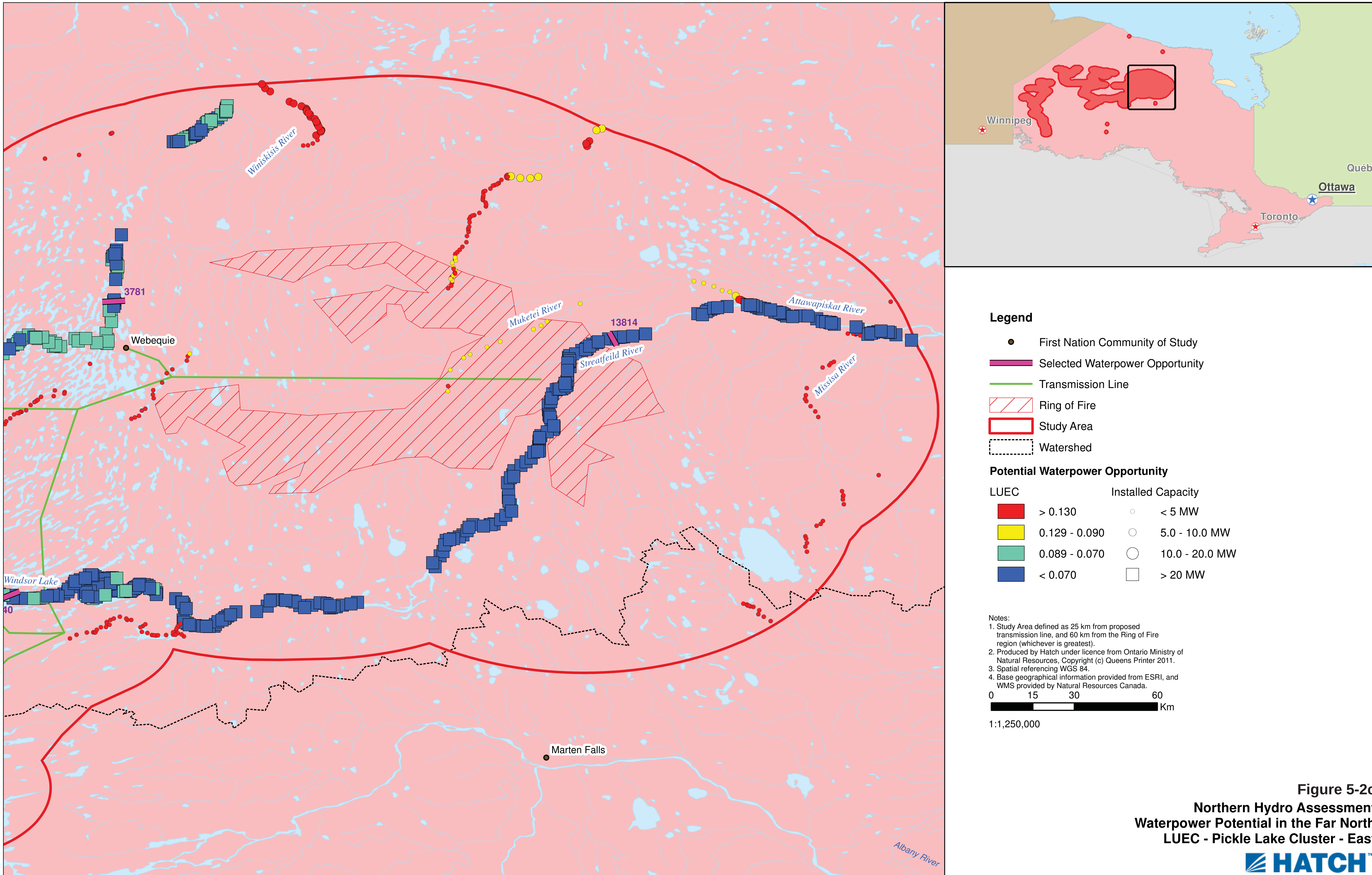

Figure 5-2c
Northern Hydro Assessment
Waterpower Potential in the Far North
LUEC - Pickle Lake Cluster - East

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