John Maissan

TOPIC: **Introduction to Application**

REFERENCE: Page 5 Re: Non-Fuel Operating and Maintenance Costs**.**

QUESTION:

a) What portion of the requested increase in non-fuel O&M costs is due to the amortization of the balance in the RFID and the vegetation management deferral accounts?

b) What portion of the rate increase requested is this?

ANSWER:

(a)

11% as calculated by:

Amortization of RFID balance	$	212
Amortization of Brushing balance	$	222
Total amortization of RFID and Brushing balances	$	433
Increase in non-fuel O&M Costs	$	3,905
Amortization of Balance Portion		11%

(b)

0.6% as calculated by:

2018 Non-Fuel O&M Costs	$ 22,016
2013 Compliance Filing Non-Fuel O&M Costs	$ 18,111
Increase in Non-Fuel O&M Costs	$ 3,905
Revenue at Existing Rates - 2018	$ 49,864
Revenue at Existing Rates - 2013	$ 43,279
Required Increase in Rate Revenue	$ 6,585
Increase in Non-Fuel O&M Costs	$ 3,905
Required Increase in Rate Revenue	$ 6,585
Non-Fuel O&M Portion of Rate Increase	59%
Consolidated Revenue Rate Increase	9.08%
Non-Fuel O&M Rate Impact	5.4%

Non-Fuel O&M Rate Impact	5.4%
Amortization of Balance Portion	11%
Impact of Amortization of Balance on Rates	0.6%

TOPIC: **Section 1 Introduction**

REFERENCE: Page 1-3 Re. Mayo Flexible Debt Financing last sentence "Lower Loads in 2014 resulted in negative interest payments from YDC to YEC of $0.112 million, further reducing the impact to ratepayers in that year."

QUESTION:

a) Please explain how reduced or negative interest payments to YDC were a direct benefit to ratepayers as opposed to improving YEC's ROE?

ANSWER:

(a)

Lower interest payments for YEC in 2014 helped reduce pressure for YEC to seek a new GRA with rate increases; however, no other direct benefit was provided in 2014 to ratepayers by such a YEC cost reduction.

TOPIC: **Section 1 Introduction**

REFERENCE: Page 1-9 Re: Continued planning to meet other future supply requirements.

QUESTION:

a) Please detail the demand side initiatives YEC is planning to undertake with respect to addressing the growth in peak demand. In particular please detail the initiatives aimed at reducing the peak demand from electric space heating.

b) Which of these initiatives will commence in 2017 and which in 2018?

ANSWER:

(a)

YEC is planning to conduct the capacity DSM feasibility study in 2018 to help design a suite of new peak load reduction aimed DSM programs to complement the existing inCharge program. In addition, as a part of developing peak load reduction DSM programs, YEC is involved in the electric thermal storage (ETS) pilot project with the Energy Solutions Centre of the Energy, Mines and Resources department of the Yukon Government.

(b)

YEC's involvement in the ETS pilot project with the Energy Solutions Centre of the Energy, Mines and Resources department of the Yukon Government started in 2017, while the capacity DSM feasibility study will be initiated in 2018.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-1 “Starting in 2014, firm load supplied by Yukon Energy to non-industrial customers on the Integrated System has fallen below the actual and approved forecast load for 2013 …”

QUESTION:

a) Please explain why the 2012-2013 GRA sales forecasting failed to identify the significant downturn in sales that started in 2014.

b) Please provide a copy of the sales forecast that was part of the 2013 LNG Application and please provide any updated provided in the 2014 LNG proceeding.

c) Did the LNG proceeding forecast recognize the downturn that appeared to begin with Alexco’s shutdown in 2013?

d) Given the significant downturn in sales in 2014 from forecasted levels, please explain why YEC did not come forward with a 2014- 2015 GRA to address this matter rather than wait until 2017.

ANSWER:

(a)

The 2012-13 GRA addressed changes in mine load forecasts as these were then known. The overall 2013 actual firm sales at 384.4 GW.h were slightly higher than the approved forecast at 383.1 GW.h.

The 2012/13 GRA was not forecasting sales beyond 2013. The subsequent sales downturns reflected mainly the loss of Alexco load and the impact of warmer than normal temperatures, plus (to a much lesser extent) the economic decline. Sales forecasts do not address forecasts for variances from normal temperatures.

(b)

Table 2.1 of the current Application provides the approved sales forecast for 2013 GRA.

The forecast in the 2013 Part 3 LNG Application (Appendix C to that filing) focused on a Base Case load scenario with no Alexco mine load after the fall of 2013. This Base Case load forecast was described as follows in that application (it was not updated in the 2014 proceeding):

a. **Base Case no Alexco after fall 2013:**

   i. Updated non-industrial forecast load for 2013 and 2014[1], reflecting the following:

      - Non-industrial growth at 2.26%/year for 2015, at 2.45%/year for 2016-2020 inclusive, at 2.82%/year for 2021-2025 inclusive, at 3.13%/year for 2026 and thereafter; and

      - DSM/SSE assumed at 32% of annual load growth based on Yukon Electricity Conservation and Demand Management Potential Review (CPR) report prepared by ICF Marbek (January 2012); to reflect proposed DSM plans (YECL 2013-15 GRA goal of 8.5 GW.h/year sustained electricity savings by 2018), impact reduced for the first year (2015) taking ¼ of the assumed 32%, 2/3 for 2016, and at full 32% starting from 2017.

   ii. Minto generation load (includes grid losses) at 34.6 GW.h/2013, 38.0 GW.h/2014, 40.2 GW.h/2015 and at 43.5 GW.h/year for 2016-2022 (no load thereafter)[2]; and

[1] Non-industrial load forecast for 2013 is based on January-October preliminary actuals and November-December updated forecasts. The 2013 updated YEC non-industrial load forecast (340 GW.h excluding grid losses) is about 2 GW.h lower than 2013 GRA approved forecast due to lower wholesales; however, the GRA approved wholesales forecast included 5.1 GW.h related to WHCT (which did not connect in 2013), i.e., overall updated non-industrial load for 2013 is forecast about 3 GW.h higher than the approved GRA forecast with January-October actuals as reported reflecting warmer than normal temperature conditions. The 2014 forecast is based on YEC's latest update which uses 2.26% growth rate over weather normalized 2013 full-year-forecast wholesales (308.5 GW.h) reduced by 4.36 GW.h to reflect Fish Lake Unit #1 being in operation in 2014. The non-industrial growth rates remain unchanged from the March 2013 update: 2011 Resource Plan forecast annual growth rate for non-industrial load for 2014 and 2015; annual growth rates for 2016-2020, 2021-2025 and 2026-2030 are from Marbek's final CPR report.

[2] Minto generation load forecast reflects updates reviewed with Minto in fall 2013.

iii. Alexco generation load (includes grid losses) at 9 GW.h for 2013 and no load thereafter[3].

Table 1: 2013 Part 3 LNG Application Base Case Load Forecast (Appendix C of the December 9, 2013 filing)

Forecast Years	Base Case no Alexco			
	Non-industrial Load (GW.h)	Industrial Load (GW.h)	Total Generation (GW.h)	Diesel (GW.h)
2013	369.9	43.5	413.4	11.2
2014	377.9	38.0	416.0	12.3
2015	386.1	40.2	426.3	17.0
2016	393.9	43.5	437.3	22.9
2017	400.9	43.5	444.3	26.9
2018	408.0	43.5	451.5	31.4
2019	415.4	43.5	458.9	36.1
2020	422.9	43.5	466.4	41.1
2021	431.8	43.5	475.3	47.4
2022	441.0	43.5	484.4	54.7
2023	450.4		450.4	33.1
2024	460.0		460.0	39.8
2025	470.0		470.0	46.8
2026	481.3		481.3	55.0
2027	493.0		493.0	63.6
2028	505.1		505.1	72.7
2029	517.6		517.6	82.3
2030	530.4		530.4	92.5

[3] In July 2013 Alexco Resource Corp. announced that it will close Bellekeno mine for winter and will reopen in spring of 2014 assuming the silver market has improved. Although the project could reopen in 2014, there is no current basis for addressing a 2014 forecast update - and the time of reopening of the mine is very uncertain. To address this uncertainty, two separate cases were prepared for the Base Case with and without Alexco. The case with Alexco assumes mine re-opening in 2015.

(c)

The response to (b) above indicates that the forecast for the Part 3 LNG Application did not forecast the impact of warmer than normal weather or other factors accounting for the reduced sales after 2013.

(d)

Please see section 1 of the current GRA Application, and in particular section 1.1 and Table 1.1 for a review of the factors affecting YEC revenues and costs after 2013, and in particular the impact starting in 2015 of the YDC debt refinancing.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-6 to 2-9 Re firm wholesale sales and public information from the media that Victoria Gold Corp. (discussed on page 2-8) has now started development work.

QUESTION:

a) Please explain how Victoria Gold will likely change wholesale sales in 2018 and how YEC will adjust their application to reflect this change.

b) Please explain how YEC's firm retail sales will change as a result of this development work and how the application will be adjusted to reflect this change.

c) For Victoria Gold please provide a table by month and year the energy loads that YEC understands the mine will require (by year of operation if applicable).

d) In a similar table please provide the monthly peak demands that YEC understands that Victoria Gold will require of the grid (again by year if applicable).

e) Media coverage around the time of Victoria Gold's announcing the start of development included interviews with YEC officials. It was understood that YEC said that there was an adequate supply of power available on the grid for Victoria Gold. Please provide YEC's official position on grid power – energy and capacity – available for Victoria Gold.

f) Please provide a table of the additional (to the forecasts provided in the Application) monthly hydro, diesel, and LNG generation that would be required to meet Victoria Gold's requirements in its first year of operation.

g) How will service to Victoria Gold affect residential and General Service customer rates?

ANSWER:

(a) and **(b)**

YEC has no estimates or assessments as to the potential impacts of Victoria Gold development work on AEY retail sales (and therefore on YEC wholesales) or on YEC firm retail sales in the GRA test years. According to the latest mine development plan, the mine is not expected to be operational until after the test years and therefore no impact on firm sales is expected. No adjustments are proposed in the YEC GRA Application to reflect changes of this nature that occurred after the test year forecasts were prepared.

(c) through **(g)**

The Application at page 2-8 summarized the status (when the Application was prepared) of Victoria Gold's Eagle Gold mine, and noted that a Power Purchase Agreement (PPA) would be required between YEC and Victoria Gold Corp. (with approval of the YUB), and plans confirmed to replace the existing 69 kV line between Mayo and Keno.

YEC is currently in discussions with Victoria Gold Corp. regarding the required PPA. When the PPA is concluded, it will be filed with the Board for its review and approval along with necessary supporting assessments regarding potential impacts on YEC's operations, revenues and costs. Prior to completion of the PPA and the related filing with the Board, YEC is not able to provide more than the following updates:

- The Application noted that the earliest potential operation of this mine would be in late 2018 (if development was to commence by summer 2017). YEC's current understanding is that the earliest potential operation of this mine would be in Q2 2019, assuming construction commenced by Q2 of 2018.

- The Application noted initial industrial power purchases at about 62 GW.h/yr, increasing to about 69 GW.h/yr in years 2 and 3 and to about 92 GW.h/yr by year 6 of operation. YEC's current understanding is that industrial power purchases are likely to be lower than previously stated, e.g., at about 52 GW.h/yr in the initial year, increasing to about 64 GW.h/yr in year 2 and about 74 GW.h/yr by year 6 of operation.

- The mine's load will be sharply reduced (i.e., one half or less of monthly load in other months) during a 90-day stockpile period starting in early December of each operating year.

- Peak load is expected to be about 10 MW in year 1 (5.1 MW during 90-day stockpile period), increasing to about 12.8 MW in year 6 (5.8 MW during 90-day stockpile period).

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-7 and 2-8 Major Industrial

QUESTION:

a) Please provide an estimate of the long term average (LTA) hydro energy that would be spilled by month in each of 2017 and 2018 if all sales are as projected in the application.

b) Please provide a breakdown of the forecasted secondary sales in each of 2017 and 2018 by month.

c) Is the LTA energy available to supply future industrial customers (potentially Victoria Gold in 2018) the sum of the above "spilled" hydro energy plus the forecasted secondary sales figures or more than the sum? Please explain and provide a monthly table if more than the sum.

ANSWER:

(a)

Please see Table 1 provided below.

Table 1: Hydro Energy Long Term Average

Month	2017 Spilled Hydro [GWh]	2018 Spilled Hydro [GWh]
January	0.0	0.0
February	0.0	0.0
March	0.0	0.0
April	0.0	0.0
May	1.5	1.5
June	7.3	7.3
July	13.6	13.5
August	13.2	13.1
September	11.2	11.1
October	5.6	5.6
November	0.1	0.1
December	0.0	0.0
Total	52.6	52.1

(b)

Secondary sales by month for 2017 and 2018 are shown in Table 2:

Table 2: Forecast Secondary Sales by Month (2017, 2018)

(KWh)

Month	Hospital	CGC	Yukon College	Total
January	374,551	425,000	450,000	1,249,551
February	257,888	375,000	400,000	1,032,888
March	116,664	400,000	425,000	941,664
April	242,537	405,000	415,000	1,062,537
May	349,991	340,000	350,000	1,039,991
June	368,411	250,000	250,000	868,411
July	233,327	200,000	217,000	650,327
August	82,893	165,000	175,000	422,893
September	322,360	150,000	175,000	647,360
October	620,159	240,000	250,000	1,110,159
November	604,808	315,000	320,000	1,239,808
December	368,411	405,000	425,000	1,198,411
Total	**3,942,000**	**3,670,000**	**3,852,000**	**11,464,000**

(c)

LTA hydro energy from existing facilities is forecast based on 35 years of water record, using the YECSIM simulation model as reviewed in Appendix 3.4 of the Application. LTA hydro energy available to supply future loads is not assessed based on the sum of recent year spilled hydro energy plus forecasted secondary sales, as suggested in this question.

Appendix 3.4, Attachment 3.4.2 reviews how LTA hydro and LTA thermal generation vary as grid load varies from 380 GW.h/yr to 450 GW.h/yr. Table 3.4-1 in the DCF Term Sheet provides a more detailed indication as to LTA hydro and thermal changes as grid load (net of LTA wind and Fish Lake hydro) varies between 370 GW.h/yr. and 485 GW.h/yr.

As reviewed in response to John Maissan-YEC-1-5, updated information on Victoria Gold indicates that the earliest potential date for start of operation for the Eagle Gold mine is now in 2019.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-8 Alexco Mine

QUESTION:

a) Please provide a table of the metered energy and metered demand for the last 12 months of the Alexco Mine's full operation (prior to shut down in 2013).

ANSWER:

(a)

Please see Table 1 provided below.

Table 1: Alexco Mine Metered Energy

		Primary Sales KWh	Measured Demand Kva
2012	SEP	1,057,400	1,811
2012	OCT	1,060,400	2,428
2012	NOV	1,066,000	1,923
2012	DEC	1,151,900	1,930
2013	JAN	1,114,400	2,036
2013	FEB	985,500	2,239
2013	MAR	964,500	2,312
2013	APR	1,201,100	2,404
2013	MAY	993,600	2,218
2013	JUN	914,100	2,404
2013	JUL	1,090,900	2,221
2013	AUG	1,001,100	2,195

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-10 lines 24 and 25 and footnote 18

QUESTION:

a) Has the Mayo hydro plant not been said by YEC to supply more than 9 MW (11 MW?) of firm generation in past documentation? If so please explain why this has now been reduced to 9 MW.

b) Please explain the down-river icing and flooding issues on the Mayo River.

c) What constraints have these placed on Mayo B and how has the winter energy and dependable capacity available from the Mayo hydro system been affected by this constraint?

ANSWER:

(a)

The 9 MW dependable capacity at the Mayo Hydro facility is capacity that can be reliably provided to meet the demand over two consecutive weeks out of the four "winter" months (November to February) as defined in the 2016 Resource Plan. This value also takes into account the recently implemented ice management protocol developed by Yukon Energy (YEC), the Yukon Government and the Village of Mayo in response to recent icing and flooding issues that occurred near Mayo, starting in late 2010, about a year before Mayo B was put in service.

(b)

The down-river icing and flooding issues that were first observed in 2010 are complex issues that have been the topic of several studies over the past decade. Based on the work of Morrison Hershfield (2015), completed on behalf of the Yukon Government, the *"cause of the flooding is complex, subject to many variables and a wide variety of ever changing of environmental conditions; overall it is highly complex issue and not well understood."*

Their analysis suggested that *"the accumulation of frazil ice in the lower reach of the Mayo River (between Silver Trail Bridge and the Stewart River) is the most likely direct mechanism causing the freeze-up related flooding. Specifically, increased frazil-ice production in the upper reach of the river during freeze-up (between Wareham Dam and the Sliver Trail Bridge) is conveyed to the lower reach of the river. This lower reach no longer has the hydraulic capacity to convey the increased winter flows and its associated frazil-ice, to the Stewart River, causing the frazil-ice to accumulate in the lower reach."*

(c)

Over the past two winter seasons, there hasn't been any incidents of flooding in the Village of Mayo. This coincides with the implementation of the ice management protocol developed in collaboration with the Village of Mayo and the Yukon Government. As per the protocol, YEC sets the ice on the Mayo River by maintaining a low and constant river flow of 15 m^3/s. Once the ice cover is set, YEC can then ramp up flow in defined increments up to 24 m^3/s.

During the 2016-2017 winter season, YEC was able to progressively increase the flows and to achieve high flow, or 24 m^3/s corresponding to about 11 MW, in late January.

In addition to the protocol, Yukon Government has completed in-stream work in 2016 and 2017. The work appears to have assisted with flow management and ice formation but additional monitoring is needed to fully assess and quantify the benefit of the in-stream work.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-10 Re Mayo Hydro

QUESTION:

a) What constraints in energy and capacity does the silted outlet of Mayo Lake impose on the Mayo hydro facilities?

b) When does YEC plan to dredge the outlet of Mayo Lake to remove these constraints?

c) Are there any other constraints on the Mayo hydro plant? If so please explain them and their impact.

ANSWER:

(a)

The silted outlet of Mayo Lake imposes constraints on flows out of Mayo Lake to the Mayo hydro facility during periods when Mayo Lake levels approach current license low supply levels. Enhanced storage at Mayo Lake cannot be effective with these constraints.

Additional modeling completed for the test years using a rating curve at the outlet of Mayo Lake similar to the one assumed during the 2012 GRA indicates that the silted outlet increases thermal requirements under LTA conditions by 0.835 GWh for both 2017 and 2018.

Please see response to YUB-YEC-1-48 for a review of the impacts on YECSIM LTA assessments due to the combined effects of upstream and downstream constraints at Mayo hydro.

(b)

There are 3 key factors affecting the timing of potential dredging of the Mayo Lake outlet to address the historic and on-going aggradation of sediment.

1. The first factor is ensuring sufficient knowledge is gathered to understand the mechanisms and processes that are causing the aggradation to occur and to develop a suitable engineering design to remove the sediment and minimize the frequency of future re-dredging. Cost estimation would also be part of this planning process. This work is proposed to be completed in 2018.

2. The second factor relates to the costs and benefits of proceeding with dredging and also of the 'do-nothing' option. There must be a demonstrated business case to advance a dredging project and until Item 1 above is complete such an analysis and decision to proceed cannot be prudently made. Information necessary to make such a decision could be available by the latter part of 2018, depending on the timing of Item 1, above.

3. The third key factor affecting the timing of dredging relates to the schedule and outcomes of the requisite assessment and permitting processes, which are anticipated to take anywhere from 12-18 months. Should such processes be started in 2019 it may be feasible to commence dredging as early as the open water period of 2020, but more likely in 2021.

YEC will apply the Stagegate Project Development Framework approach for a project of this nature. At the end of 2018, once the business case information has been developed, YEC Board of Directors will review the information as part of a Stagegate and provide a go/no go decision.

Please see response to YUB-YEC-1-78 for additional details on the Stagegate Project Development Framework.

(c)

There is an operational constraint associated with the common water intake used for both Mayo A and Mayo B plants. The decision for the penstock for Mayo A and Mayo B to share a common intake was taken due to cost implications of constructing a separate Mayo B intake. This limits the total flow through the water conveyance at 25 m^3/s, which represents about 11.5 MW.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-11 lines 24 and 25 Spinning reserve

QUESTION:

a) Please describe YEC's policy or policies with regard to spinning reserve, including how that may vary by season if applicable.

b) Around early August there were a series of 3 or 4 quite extensive grid outages. For each of these outages please provide:
   i. The grid load (MW) at the time of the outage;
   ii. A list of the plants operating at the time of the outage and the load supplied by each plant;
   iii. The plant or other facility that tripped to cause the outage;
   iv. The spinning reserve running at the time of the outage and which plant or plants were providing that spinning reserve;
   v. The shortfall in generation as a result of the trip (load less operating generation including spinning reserve);
   vi. The spinning reserve that would have been required to prevent an outage; and
   vii. A list of the diesel generators that were brought on line to assist in restoration from the outage.

c) What forms of spinning reserve (hydro, diesel, LNG, etc.) would have been required at the time of these trips to prevent outages?

ANSWER:

(a)

YEC does not have a formal policy with regard to spinning reserve other than as described in the Application at page 2-11 lines 21-22 as follows:

> "When thermal is generating on the system, Aishihik also provides the spinning reserve which is to provide coverage for the largest thermal unit on line."

(b)

Please see outage reports provided as John Maissan-YEC-1-10 Attachment 1.

With regard to (iv) through (vi), spinning reserve is not intentionally maintained when thermal generation is not on the system.

(c)

Although other forms of generation could provide spinning reserve, YEC typically relies on hydro for this function from an economic perspective. YEC chooses to operate thermal units at full capacity whenever possible for efficiency and asset health reasons.

Yukon Energy Corporation

System Disturbance Report

Date: Aug 3, 2017

System Operator: Myles O'Brien

Weather: 16C clear and sunny

Estimated Load Loss 13.2 MW

Percentage of Grid: 31%

Pre-Disturbance Generation Setup

WH4	18.1
WH3	8.0
WH2	5.3
WH1	2.8
MBH1	2.9
MH1	2.0
AH3	3.5

Total Generation 42.6 Mw

Disturbance:

Time	Event
07:40:13	WH4 Trip – Speed Signal Fail
07:40:14	S150 52-22 Trip U/F 56.1Hz
07:40:15	S6838 Trip U/F 56.1Hz
07:40:15	S6837 Trip U/F 56.1Hz
07:40:15	S250 52-2 Trip U/F 56.1Hz
07:40:18	P158 52-F2 Trip U/F 56.1Hz

Restoration

07:45:16	WD7 Online
07:48:51	P158 52-F2 Closed by SCC
07:49:38	S250 52-2 Closed by SCC
08:05:16	S6838 Close by SCC under ATCO direction
08:05:49	S6837 Close by SCC under ATCO direction
08:32:21	S150-52-22 Close by SCC under ATCO direction

Time Variance

Feeder	Opened / Tripped	Closed	Variance
P158 52-F2	07:40:18	07:48:51	00:08:25
S250 52-2	07:40:15	07:49:38	00:09:15
S6838	07:40:15	08:05:16	00:24:37
S6837	07:40:15	08:05:50	00:25:11

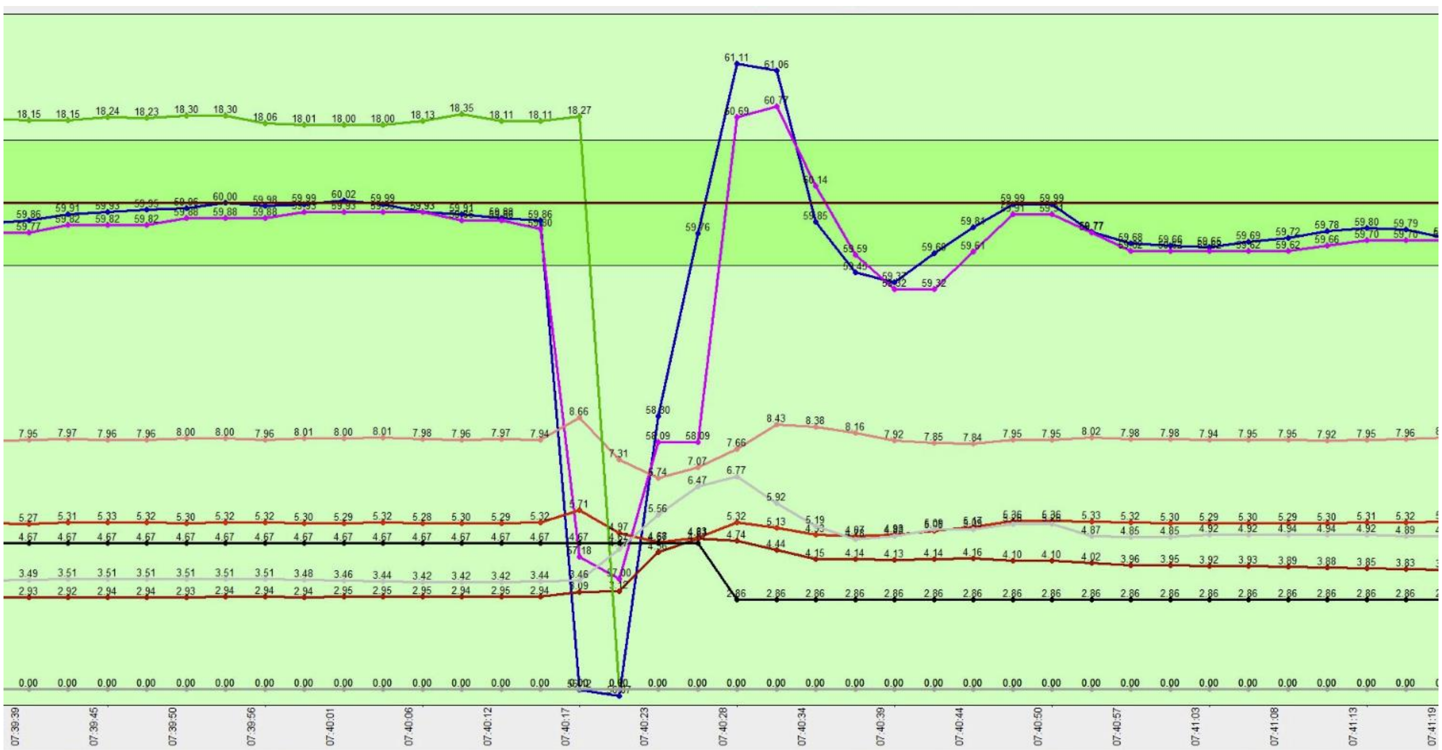
S150-52-22	07:40:14	08:32:21	00:51:18

Target /Flags.

WH4 Secondary Speed Device Failed
WH4 Speed Signal Failed
WH4 86 Lock-out trip

Comments .

WH4 tripped offline at 18.1 MW causing breakers to shed load on U/F.
ATCO personnel start work at 0800 and were still inbound to their compound when the outage occurred.
This caused delays in sectionalizing.



Yukon Energy Corporation
System Disturbance Report

Date: Aug_08_2017

System Operator: Stephen Blysak

Weather: sunny 12 c

Estimated Load Loss Percentage of Grid: 29%

Pre-Disturbance Generation Setup

MBH1	4.4 mw
MBH2	3 mw
MH1	2 mw
MD1	0.8 mw
MD2	0.8 mw
MD3	0.8 mw
DD5	1.1 mw
DD4	1 mw
DD3	0.6 mw
DD2	0.6 mw
DD1	0.3 mw
WH1	4 mw
WH2	5 mw
WH3	7.9 mw
WD7	2.4 mw
WD6	2 mw
WD5	2 mw
WD4	2 mw

Total Generation: 40.7 Mw

Disturbance:

Time	Event
07:24:58	S251 T1 overcurrent Trip
07:24:58	S251 52-5 Trip
07:24:58	S251 52-8 Trip
07:24:58	S251 52-1 Trip

07:25:01	S256 52-1 Trip
07:25:01	S256 52-2 Trip
07:25:01	S250 52-5 Trip
07:24:57	S150 52-22 Trip
07:24:57	S170 S6837 Trip
07:25:00	S170 S6838 Trip
07:25:00	DD1 Trip reverse power
07:25:10	MD1 Trip " "
07:25:10	MD2 Trip " "
07:25:10	MD3 Trip " "

Restoration:

07:32:41	S256 52-1 Closed
07:33:17	S256 52-2 Closed
07:41:36	S250 52-5 Synced Closed
07:43:43	S251 52-5 Closed
07:44:03	S251 52-8 Closed
07:47:36	S251 52-1 Synced Closed
08:02:47	S170 S6838 Closed
08:10:29	S150 52-22 Closed
08:10	WG2 On
08:17	WG1 On
08:39:49	S170 S6837 Closed
08:42	WG2 OFF (glycol spill)
08:35	WG1 OFF " "
09:04	MD1 On
09:05	MD2 On
09:06	MD3 On

Time Variance

Feeder	**Opened / Tripped**	**Closed**	**Variance** hr/min/sec
S256 52-1	07:25:01	07:32:41	0:07:40
S256 52-2	07:25:01	07:33:17	0:08:16
S250 52-5	07:25:01	07:41:36	0:16:35
S251 52-5	07:24:58	07:43:43	0:18:45
S251 52-8	07:24:58	07:44:03	0:19:05
S251 52-1	07:24:58	07:47:36	0:22:38
S150 52-22	07:24:57	08:10:29	0:45:32
S170 S6838	07:24:57	08:02:47	0:37:50
S170 S6837	07:24:57	08:39:49	1:14:52

Targets/Flags

S251 T1 tripped on an overcurrent this caused the system to split and u/f trips on 9L S6837 and S6838

Comments:

S251T1 protection settings at 14MVA, due to lack of gen available on the southern grid we were generating heavy from the north this caused the protection setting on S251 T1 to trip on over current

The cause of the second August 8th outage occurred during the system restoration from the loss of WH4. Northern thermal and hydro generation used to replace the lost generation from WH4 exceeded the protection settings of a transformer located at Stewart Crossing. The transformer protection settings are lower than the transformer capacity. The protection settings will be review and changed.

Yukon Energy Corporation
System Disturbance Report

Date: 08-08-2017

System Operator: Stephen Blysak

Weather: 29°c

Estimated Load Loss Percentage of Grid: 1.282 MW (2.8%)

Pre-Disturbance Generation Setup

WH4	16.5 MW
WH1	4.8 MW
WH2	4.8 MW
WH3	7.9 MW
MH0	2.2 MW
MBH1	3.8 MW
MBH2	4.8 MW

Total Generation: 44.8 MW

Disturbance:

Time	Event
16:30:21	P158 52-F2 U/F Trip (732kW)
16:30:17	S250 52-2 U/F Trip (550kW)

Restoration:

16:33:30	WD7 Online - Group Start
16:34:52	WD4 Online - Group Start
16:34:59	WD5 Online - Group Start
16:35:15	WD6 Online - Group Start
16:39:20	DD4 Online
16:45:11	DD2 Online
16:46:39	P158 52-F2 Closed by SCC
16:47:18	DD1 Online
16:50:13	WH4 Offline - Controlled reduction of load by SCC
17:00:53	DD5 Online
17:05:44	S250 52-2 Closed by SCC

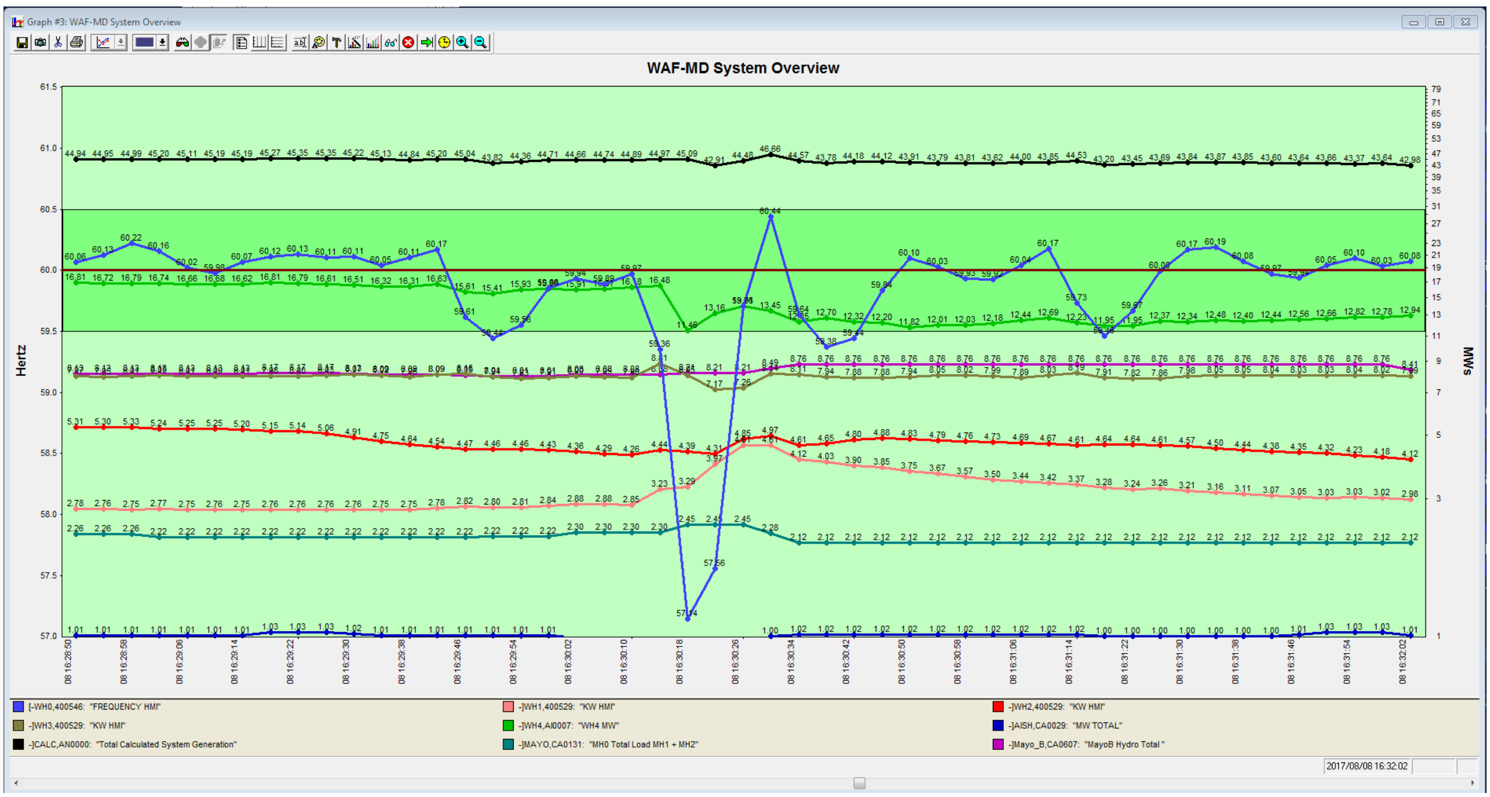
Time Variance

Feeder	Opened / Tripped	Closed	Variance hr/min/sec
P158 52-F2	16:30:21	16:46:39	0:16:18
S250 52-2	16:30:17	17:05:44	0:35:27

Targets/Flags

Dawson feeders tripped on U/F

Comments: WH4 shed around 4MW of load as unit was being brought off line due to speed sensing issues. This caused P158 52-F2 and S250 52-2 to trip on U/F. WH4 was taken offline in a controlled manner by SCC.



Yukon Energy Corporation
System Disturbance Report

Date: Aug 8, 2017

System Operator: Cameron Hoyt

Weather: Clear

Estimated Load Loss (Mw): 3.28MW

Percentage of Grid: 10%

Pre-Disturbance Generation Setup

WH1	1.73MW
WH2	2.94MW
WH3	5.79MW
WH4	11.9MW
MH1	2.14MW
MBH1	2.86MW
MBH2	.88MW
AH3	.82MW
WD5	1.3MW
WD6	1.5MW
WD7	1.1MW

Total Generation: 32.96 Mw

Disturbance:

Time	Event
05:50:20	WH4 P127-52-WH4 Open (11.9MW
05:50:22	S250-52-2 Open (Tripped under frequency 280kW)
05:50:22	S6838 Open (Tripped under frequency 3MW)

Restoration:

05:57:09	S250-52-2 Closed by SCC
06:20:30	S6838 Closed by SCC

Time Variance

Feeder	Opened / Tripped	Closed	Variance hr/min/sec
S250-52-2	05:50:22	05:57:09	00:06:47
S6838	05:50:22	06:20:30	00:30:08

Targets/Flags

Comments:

WH4 HPU pumps could not keep HPU oil pressure at appropriate levels. Diesel units were brought on and load was starting to be shifted to take unit down in a controlled manner, when WH4 tripped offline. WH4 issues are still being investigate at this time.

Yukon Energy Corporation
System Disturbance Report

Date: Aug 9, 2017

System Operator: Cameron Hoyt

Weather:Clear

Estimated Load Loss (Mw): 8.03 MW

Percentage of Grid: 25.91%

Pre-Disturbance Generation Setup

WH1	2.02 MW
WH3	8.02 MW
AH2	14.2 MW
AH3	2.40 MW
MH1	2.3 MW
MBH1	3.3 MW

Total Generation: 32.24 Mw

Disturbance:

Time	Event
04:16:38	P130-52-AH2 Tripped 14.2 MW
04:16:38	S250-52-2 Tripped .29 MW (Hunker Feeder)
04:16:38	S150-52-22 Tripped 2.4 MW (9L Carcross)
04:16:38	S6837 Tripped 2.4 MW (Mnt. View)
04:16:41	P158-52-F2 Tripped .338 MW (Dawson Feeder 2)
04:16:41	S6838 Tripped 2.6 MW (Laberge/Porter Creek)

Restoration:

04:30:42	P158-52-F2 Closed by SCC
04:30:53	S250-52-2 Closed by SCC
05:20:07	S150-52-22 Closed by SCC
05:41:28	S6837 Closed by SCC
05:42:25	S6838 Closed by SCC

Time Variance

Feeder	Opened / Tripped	Closed	Variance hr/min/sec
P158-52-F2 (Feeder 2)	04:16:41	04:30:42	00:14:01
S250-52-2 (Hunker)	04:16:38	04:30:53	00:14:15
S150-52-22 (9L)	04:16:38	05:20:07	01:03:29
S6837 (Mnt. View)	04:16:38	05:41:28	01:24:50
S6838 (Porter Creek)	04:16:41	05:42:25	01:25:44

Targets/Flags

AH2 Upper Guide Bearing Temp Trip (80c)
AH2 86 Lockout Trip

Comments:

At 04:16:38 AH2 tripped offline. The Upper guide bearing temp trip (80c) alarm came in and the unit locked out. All Main breakers were closed at 05:42:25 and load pickups were completed shortly after 07:00. Restoration was done with Whitehorse Diesels and AH2, after it was inspected.

The cause of the August 9th outage was a high temperature bearing trip on Aishihik unit 2 (AH2). AH2 was placed on line on Aug 8th to eliminate the thermal being used to replace WH4 generation. The unit had been inspected after being on line for an hour with no issues found. The bearing over heated due to a clogged cooling water supply to the bearing.

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-12 Drought-Flood Year Constraints

QUESTION:

a) What would be the reductions in LTA annual hydro-generation from a 1 in 100 year drought and from the driest year on record?

ANSWER:

(a)

Drought conditions in each watershed where YEC's hydro generating assets are located are not coincident. For instance, the Mayo Lake watershed could experience a "dry" year but the Aishihik Lake and Southern Lakes watersheds could experience a "wet" year making the water year from a system standpoint an "average" year. When determining the thermal requirement for each water year, YECSIM takes this regional variability into account. The table below presents the hydro generation for the driest system water year and under the long term average water condition for the 2017 and 2018 test years. Yukon Energy does not calculate 1 in 100 year drought for planning or operational purposes.

Test Year	**Total Generation**	**LTA Hydro Generation**	**Driest Water Year**
	[GWh]	[GWh]	[GWh]
2017	420.4	405.7	312.6
2018	421.2	406.1	312.9

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: **Page 2-12 Diesel and LNG Thermal Generation**

QUESTION:

a) For the years 2012 to 2016 inclusive please present a table of actual diesel and LNG generation by month.

b) Please discuss the cold load pick-up capability (i.e. after an outage) of diesel vs. LNG generators.

c) For each year from 2012 to 2016 please list the number of outages on the Yukon integrated system that required the use of the Whitehorse Rapids diesel plant for restoration.

d) What diesel capacity is required for restoring the grid as quickly as reasonably possible, from a grid outage affecting 50% or more of the electrical load?

ANSWER:

(a)

As per below, LNG generation did not commence until June 2015 (which was still commissioning of the plant until July).

		Diesel KWh	LNG KWh
2012	JAN	1,049,135	
	FEB	30,817	
	MAR	52,508	
	APR	31,075	
	MAY	8,688	
	JUN	68,590	
	JUL	53,705	
	AUG	23,343	
	SEP	95,631	
	OCT	125,276	

		Diesel KWh	LNG KWh
	NOV	336,502	
	DEC	1,179,865	
2013	JAN	217,448	
	FEB	35,176	
	MAR	182,266	
	APR	38,977	
	MAY	22,704	
	JUN	101,487	
	JUL	747,132	
	AUG	37,176	
	SEP	37,313	
	OCT	57,754	
	NOV	61,283	
	DEC	370,800	
2014	JAN	49,387	
	FEB	140,038	
	MAR	59,173	
	APR	84,667	
	MAY	27,270	
	JUN	50,287	
	JUL	158,370	
	AUG	114,885	
	SEP	54,202	
	OCT	173,127	
	NOV	540,003	
	DEC	114,189	
2015	JAN	564,599	
	FEB	512,333	
	MAR	57,249	
	APR	23,773	
	MAY	385,530	
	JUN	332,714	310,000
	JUL	94,708	-
	AUG	280,563	12,000
	SEP	476,948	123,000
	OCT	402,476	194,200
	NOV	165,729	235,600
	DEC	276,967	420,100

		Diesel KWh	LNG KWh
2016	JAN	65,483	135,300
	FEB	23,749	68,200
	MAR	28,747	47,900
	APR	27,316	36,000
	MAY	133,108	10,900
	JUN	94,492	9,650
	JUL	507,074	23,950
	AUG	125,687	6,800
	SEP	637,993	1,234,000
	OCT	50,968	198,400
	NOV	71,203	-
	DEC	1,113,601	1,480,100

(b)

Compared to LNG engines, YEC diesel generators are more effective for cold load pickup due to a faster responding governor which is able to recover frequency quicker.

(c)

Year	Outages Requiring Whitehorse Diesel
2012	2
2013	1
2014	3
2015	6
2016	1

(d)

This question cannot be answered without further detail (e.g., specific grid load, definition of “quickly as reasonably possible”).

TOPIC: **Section 2 Sales and Revenue**

REFERENCE: Page 2-18 Table 2.2

QUESTION:

a) Table 2.2 (line below line 17) shows that the total forecasted thermal generation in 2017 and 2018 will be 2,172 and 2,010 MWh respectively. These figures are less than one-half of the actual thermal generation required in 2015, and approximately one-third of the actual thermal generation required in 2016. Please explain this, particularly in light of the increase in peak demand forecast.

b) Line 17 indicates that the actual forecasted LNG generation is approximately 53.9% and 53.5% in 2017 and 2018 respectively. In light of these figures, please explain how YEC calculated a mix of 90% LNG and 10% diesel (Application page 4 and elsewhere) on a go forward basis.

c) If these 2017 and 2018 forecasts include diesel generation required for restoration from outages and diesel maintenance (regular run-ups), please provide separately diesel and LNG consumptions by year for:
   i. Maintenance and outage restoration; and
   ii. The LTA requirements based on hydro energy and/or capacity limitations.

d) If the forecasts for 2017 and 2018 incorporate above LTA water availability please answer (c) above as though LTA water availability applies to 2017 and 2018.

ANSWER:

(a) through **(d)**

The forecasted thermal generation in 2017 and 2018 as shown in Table 2.2 includes the following:

1. Forecast “actual” generation (lines 16 and 17): As noted in footnote 4, this forecast includes generation required for maintenance, capital and peaking (based on short term hydro generation forecasts). Specific amounts included in the forecasts of

total “actual” thermal generation of 2,172 MW.h in 2017 and 2,010 MW.h in 2018 are as follows:

a. Maintenance (as summarized at page 3-4 of the Application):
   i. Diesel at 312.5 MW.h in 2017 and 229.2 MW.h in 2018
   ii. LNG at 133.3 MW.h in 2017 and 100.0 MW.h in 2018

b. Capital at 596.4 MW.h each test year (as noted in footnote 4 to Table 2.2, assumed to be diesel)

c. Peaking at 1,130 MW.h in 2017 and 1,084.4 MW.h in 2018, assumed at 90% LNG and 10% diesel.

2. LTA thermal generation – based on firm generation load (line 6) less LTA wind generation and LTA hydro generation, the LTA thermal generation is 14,146 MW.h for 2017 and 14,480 MW.h for 2018.

3. The following are noted regarding the relationships between the LTA thermal and the forecast actual thermal generation in Table 2.2 (and the related impacts on forecast GRA fuel costs in Table 3.2):

   a. LTA thermal is assumed to include “peaking” as forecast under “actual” generation, i.e., in Table 3.2 the LTA thermal is included at the assumed 90/10 LNG/diesel split, and peaking is not added to this assessment. Accordingly, the peaking thermal generation forecast as such does not affect Table 3.2 forecast GRA fuel costs.

   b. LTA thermal is assumed not to include maintenance thermal generation or capital thermal generation:
      i. Table 3.2 forecast GRA fuel costs includes forecast maintenance LNG and diesel generation (in addition to LTA thermal generation).
      ii. Table 3.2 forecast GRA fuel costs does not include capital-related thermal generation (these fuel costs are assumed in the relevant capital project costs). Accordingly, the capital thermal generation forecast as such does not affect Table 3.2 forecast GRA fuel costs.

The 2017 and 2018 “actual” thermal generation forecasts in Table 2.2 are lower than actual thermal generation in 2015 and 2016 due to lower capital/RFID thermal generation (which was 2,047 MW.h in 2015 and 1,043 MW.h in 2016) and the extent that “peaking” generation (which is affected by a wide range of factors) was higher in these earlier years than in the GRA forecast for the test years. These variances have no impact on the GRA forecast fuel costs in Table 3.2 for the test years.

The proposed 90/10 LNG/diesel split for LTA thermal generation in the test years has no bearing to actual LNG/diesel splits as shown in Table 2.2. Please see response to YUB-YEC-1-25 for a more detailed review.

Outage restoration thermal generation is not forecast for GRA test year thermal generation as shown in Table 2.2 or in forecast fuel costs as shown in Table 3.2.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Page 3-10 Brushing costs and Appendix 3.1

QUESTION:

a) YEC's 2012-2013 GRA said on page 3-9 lines 8 and 9: "In 2012 Yukon Energy is field testing the recommendations (e.g., herbicide treatments) prior to developing a formal policy." Please provide the results of these field testing trials of these species specific herbicides.

b) Appendix 3.1 suggests (Section 9) that YEC is still "studying" the use of these herbicides, please explain in detail. Does "studying" include field trials as were being done in 2012?

ANSWER:

(a)

Please see study attached as John Maissan-YEC-1-14 Attachment 1.

(b)

YEC is still monitoring the established trial plots to provide ongoing validation of study findings.

VEGETATION MANAGEMENT OF POWER LINE RIGHTS-OF-WAY IN NORTHERN CANADA

Vegetation Control Strategies, Including Herbicide-Use, on Power Line Rights-of-Way in the Yukon Territory

Prepared for:
Yukon Energy Corporation
Whitehorse, Yukon

Prepared by:
Dr. Wai Ma and Dr. Katherine Stewart
Yukon College (Whitehorse, Yukon)
University of Saskatchewan (Saskatoon, Saskatchewan)

May, 2017

EXECUTIVE SUMMARY

This technical report summarizes work completed from May 2014-May 2017 in fulfillment of the NSERC ARD grant entitled “Vegetation management of power line rights-of-ways in northern Canada”. Partners on the grant included Yukon Energy Corporation, Environmental Dynamics Inc. and Yukon College with collaboration from the University of Saskatchewan. The summarized findings constitute the requirements from two Master of Science degrees at the University of Saskatchewan (Isbister 2016; Jimmo 2017). A preliminary ecological risk assessment is presented based on the data gathered by Isbister and Jimmo. Finally, the need for effective vegetation mapping and consideration of community and cultural values for responsible vegetation control on Yukon power line rights-of way are discussed.

Utility companies are required to provide safe, reliable service that can be compromised by trees near or underneath the transmission lines. Today, right-of-way (ROW) managers have more complex treatment options to evaluate and implement. Integrated Vegetation Management (IVM) is a decision matrix used to support the development of a vegetation management plan. IVM is an adaptive management approach that implies no one treatment will be effective for all sites and situations and many factors need to be considered. The first step in developing an IVM plan is to establish a thorough understanding of local plant community dynamics and how they are affected by or respond to different management methods. Eight vegetation management methods were evaluated on ROW plant communities one year after treatment in field trials at four Yukon ROW sites. Findings from the field trial include:

- Chemical management with the herbicides triclopyr (Garlon XRT) and imazapyr (Arsenal Powerline) was more effective (75 to 95% reduction of target) at controlling target woody species than mechanical cutting (<50% reduction) one year post treatment;
- Imazapyr caused more damage to non-target plants than triclopyr, and non-target plants damaged by triclopyr recovered one year after treatment;
- Significant non-target plant community changes were not detected; however, selective impacts of treatments on life forms/species are promising as the differences indicate treatments can be designed to meet management objectives; and,
- Further monitoring over the duration of a management cycle (8-10 years) is required to determine the longer-term efficacy of treatments and the nature of the newly developed plant communities.

Aside from treatment efficacy, environmental and socio-economic impacts of chemical treatments must be considered. Chemical persistence in the environment and sensitivity of non-target plants and other ecological receptors to imazapyr and triclopyr were determined to quantify the observed effects in the field. Chemical dissipation rates and characteristics were estimated in field-treated soil and vegetation (*Salix glauca*). Direct chemical sensitivity of non-target plants and soil invertebrates to herbicides were determined using standard Environment Canada or Organization for Economic Cooperation and Development toxicity testing procedures in greenhouse and laboratory trials. Indirect determination of

chemical risk to herbivorous animals (e.g., moose) was estimated through a preliminary ecological risk assessment. Findings include:

- Imazapyr's high phytotoxicity to many non-target species and persistence in soil and vegetation indicates that it is not a suitable product for northern ROWs;
- Soil invertebrates were relatively insensitive to either herbicide;
- The likelihood of risk to herbivorous animals from acute or chronic exposure to either herbicide was low or deemed acceptable; therefore,
- Triclopyr is the better herbicide option for inclusion in an IVM plan when all lines of evidence are considered.

Ecological effects of herbicide use are only one aspect for consideration when designing an IVM plan. Some considerations to improve the public consultation process are presented. These include:

- Integration of GIS and community input to determine buffer zones to water ways, First Nation communities and properties, and other private and public properties that might be impacted;
- Encourage local contractors to direct efforts into training for data acquisition and vegetation monitoring; and,
- Maintain consistent communication between stakeholders to build trust and collaboration, helping to ensure continued stakeholder support.

The summarized studies in this report provided a number of insights to various vegetation management techniques including method efficacy, persistence of herbicidal chemicals, and potential sensitivity of non-target organisms to chemical treatments. However, it is by no means comprehensive. The following issues need to be address in order better formulate IVM strategies:

- Long-term monitoring of the treated plots is necessary to determine the trajectory of developing plant communities;
- Additional data and samples were collected but not analyzed because time limitations;
- Efficacy of alternate/lower herbicide application rates in the field need testing; and,
- Impact of treatments on aquatic organisms and water quality and habit alteration for birds and animals were not considered.

The work completed to date determined that different management techniques can alter northern boreal plant communities, chemical management methods are effective at short-term (up to one-year post treatment) woody species control, and triclopyr is the better chemical control when all lines of evidence are considered. While developmental trajectories of boreal plant communities after treatment require long-term monitoring, results from this study indicate that IVM principles can be applied to northern power line ROWs. Socio-economic and environmental considerations will vary between sites, requiring the integration of Geographic Information System (GIS) with information from public consultation. An IVM strategy can then be formulated to reflect local environmental and socio-economic conditions.

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1.0 INTRODUCTION

Electrical utility rights-of-way (ROWs) present unique and demanding challenges for vegetation management. Utility companies are required to provide safe, reliable service that can be compromised by trees near or underneath the transmission lines. Adjacent forests provide locally adapted seeds and suckers to rapidly recolonize ROWs, which results in a cyclical management regime of tree/tall shrub removal (Berkowitz et al. 1995). Prior to the 1940s, mechanical methods of brushing, mowing, or hand cutting were the only tools utilized. After the Second World War, herbicide use became more common and is now widely used in North America (Sulak and Kielbaso 2000).

Promoting interspecific competition through seeding or enhancing shrubby or grass species is a relatively new technique that may also be used to supplement either mechanical or chemical treatments (Meilleur et al. 1997). With this increased toolbox, ROW managers have much more complex treatment options to evaluate and implement. The term “Integrated Vegetation Management” (IVM) is applied to this decision matrix and implies that no one treatment is going to be effective for all sites and situations and many factors must be taken into consideration. The first step in developing an IVM plan is to establish a thorough understanding of local plant community dynamics and how they are affected by different management methods (Nowak and Ballard 2005).

1.1. Background

There are more than 1000 km of power line ROW in Yukon, Canada. Vegetation management along the 30 m wide corridors has historically been by mechanical methods using heavy equipment to mow or brush the vegetation. In the summer of 2013 Yukon Energy Corporation (YEC) began exploring the potential to use herbicides (glyphosate, imazapyr and triclopyr) as a component of IVM on power line ROWs in Yukon, Canada. Although, initial trials indicated that short-term vegetation control could be achieved with the use of herbicides (EDI 2013) many questions and concerns remain regarding the application, fate and toxicity of herbicides in a northern environment.

Herbicide effectiveness and attenuation have been extensively studied in more temperate climates; however, few studies have examined the impact of herbicides in cold regions (Tilsworth et al. 1991; Nash 1998; Barnes and Seefeldt 2009; Seefeldt et al., 2013). To determine the effectiveness and risk assessment implications associated with herbicide application in northern ROWs further studies are required.

No single method is the most effective method under all site conditions, likely due to the response of different vegetation growth forms and differences in environmental and soil conditions (Tilsworth et al., 1991; Nash 1998). Therefore, vegetation management based upon an understanding of how vegetation and soil communities respond to physical and chemical disturbance in northern boreal ecosystems can provide a means to improve management success, while reducing cost and environmental risk.

1.2. Regulatory Guidance Relevant to Herbicide Usage on Power Line Rights-of-Way

Herbicides were one of several potential tools evaluated for incorporation into IVM strategies to control vegetation in Yukon power line ROWs. A detailed review of the legislations and standards applicable to the use of herbicides for vegetation control on ROWs is provided by EDI, 2013 (**Appendix A**). The work involving the use of herbicides reported herein was completed in accordance with applicable guidance from various regulatory jurisdictions where available. Primary guidance from the following documents was applied:

- Yukon Environment Act (2002) – Pesticide Regulations (1994) (Yukon Government, 2002);
- Pest Control Products Act (2002);
- Transportation of Dangerous Goods Act (1992);
- Fisheries Act (1985);
- Migratory Birds Convention Act (1994);
- Species at Risk Act (2002); and,
- Transmission Vegetation Management (NERC, 2006); and,

1.3. Objectives and Overview of this Technical Report

Based on the recommendations from EDI (2013), a research project investigating potential IVM strategies for Yukon ROWs began in 2014 to examine potential management impacts on target and non-target vascular plants one year after treatment. Specifically, this involved documenting how mechanical, chemical and biological management techniques influenced ROW plant communities, the short-term efficacy of treatments on target species control, and the response of non-target species in terms of cover change and herbicide induced damage in a field trial. This research was conducted in collaboration between YEC, EDI, Yukon College, and the University of Saskatchewan. This research resulted in two dissertations completed in fulfillment of the Master of Science requirements at the University of Saskatchewan. The report in-hand is a technical summary (**Section 4.0**) of the following dissertations:

- Isbister, K.M. 2016. Early Responses of Northern Boreal Vegetation to Power Line Right-of-Way Management Techniques including the Acute Toxicity of Imazapyr and Triclopyr to Non-Target Plants. M.Sc. Thesis, University of Saskatchewan, pp.147 (refer to **Appendix B** of this report). Parts of this thesis were assembled into a manuscript, peer reviewed and accepted for publication. The citation for the published manuscript is "Herbicide toxicity testing with non-target boreal plants: the sensitivity of *Achillea millefolium* L. and *Chamerion angustifolium* L. to triclopyr and imazapyr" (Isbister et al. 2017). It is also included in **Appendix B.**
- Jimmo, A. 2017. Linking Herbicide Dissipation to Soil Ecological Risk along Rights-of-Way in the Yukon Territory. M.Sc. Thesis, University of Saskatchewan, DRAFT (refer to **Appendix C** of this report).

Consult these two appendices for full details of the materials presented in this technical summary.

Herbicide usage for vegetation control on ROWs is not common in Yukon because its usage is often met with negative public and government reactions. To date rejection of herbicide use is linked to insufficient assessment of herbicide toxicity to non-target organisms (vegetation, animals, human) and inadequate community engagement. To address the former, a preliminary environmental risk assessment (**Section 5.0**) is provided in this technical report based on the field-based herbicide dissipation results and greenhouse and laboratory-based toxicity testing completed by Isbister (2016, 2017) and Jimmo (2017).

Community engagement is a complex process where scientific results are used to facilitate the conversation between the proponent, the public, and government. A brief framework for incorporating IVM and Geographical Information System (GIS) as an adaptive strategy to meet the community socio-economic values is presented in **Section 6.0**. This framework is a work-in-progress that will require input and revision from all stakeholders.

2.0 LITERATURE REVIEW

The objective of this literature review is to examine the fundamental vegetation management principles behind integrated vegetation management (IVM) and the current management options for power line ROWs. How these principles can be applied and adapted for vegetation management on Yukon ROWs is investigated. Understanding how plant species are impacted by herbicide applications is a critical component of IVM. As a tool for determining individual plant species sensitivities to herbicides, the application and limitations of dose-response relationships and phytotoxicity testing are discussed. In addition to direct impacts of herbicide applications on plants and plant communities, persistence of herbicide active ingredients in plant tissue can provide a vector into other ecosystem compartments. The potential for herbicide persistence in vegetation and soils under northern conditions is briefly discussed. The impact of herbicides on soil ecosystems is further considered through assessing the toxicity of herbicides to soil invertebrates commonly found on northern ROWs. The reviewed information is excerpted from Isbister (2016, 2017) and Jimmo (2017).

2.1. Designing Disturbance to Meet Vegetation Management Objectives

2.1.1. Response of vascular plant species to disturbance

The process of manipulating disturbance type, size and intensity to promote the establishment of desired plant species or communities was first described as “designing” disturbance by Rosenberg and Freedman (1984). To design disturbance and thus promote plant communities to meet management objectives, the first task is to understand the local ecosystem and how plant species respond to disturbance (Pickett et al. 2009).

There are many factors involved in plant community development, but disturbance history consistently has a major influence (Attiwill 1994; Rydgren et al. 2004; Schmitz et al. 2006). In the northern boreal forest, this has been demonstrated by differences in communities after varying fire regimes or harvesting practices (Johnstone 2006; Macdonald and Fenniak 2007). Each plant species will react to disturbance differently. By altering the type, frequency and intensity of disturbance, plant communities can effectively be designed to meet management objectives (Attiwill 1994; Pickett et al. 2009). Integrated Vegetation Management (IVM) was founded on these principles.

2.1.2. The IVM toolbox: vegetation management methods for power line ROWs

One of the fundamental principles of IVM is that methods need to be appropriate for site, environmental and socio-economic conditions and one method is likely not suitable for all sites (Nowak and Ballard 2005). A range of options, therefore, must be available to managers. Prior to the 1940s, mechanical methods of brushing, mowing or hand cutting were the only tools readily available to vegetation managers, but today many strategies can be utilized.

Mechanical control of target species by brushing, mowing or hand cutting physically removes the aboveground vegetation with varying amounts of soil disturbance. Mechanical methods are still widely used across North America (Sulak and Kielbaso 2000), despite significant evidence that mowing or brushing can often increase target species reproduction and growth on ROWs (Luken et al. 1991; Yahner and Hutnik 2004).

After the Second World War, chemical use became more common and is now widely used by many companies for power line ROW vegetation management (Sulak and Kielbaso 2000). There are many formulations and application methods for herbicide use on ROWs. Unlike mechanical mowing, herbicide applications are intended to kill both the above and belowground portions of target species (Egler 1954). The chemicals themselves can be broad-spectrum or selective: impacting only certain plant groups such as dicots (Stephenson and Solomon 2007). Application methods vary from non-selective (broadcast foliar spray or soil dispersal) to selective (cut stump, basal, stem-foliar and foliar) (Stephenson and Solomon 2007).

Seeding or transplanting competitive shrub and forb species – also known as ecological/biological control or manipulation – is a relatively new method with the potential to use interspecific plant competition to the manager's advantage. Transplanting or encouraging natural reproduction of woody shrubs is one of two ecological manipulation strategies for ROWs. This includes layering – the process of anchoring the tips young stems to the ground to promote rooting and expansion of woody shrubs – which was found to be successful in increasing *Cornus stolonifera* cover on a ROW in Quebec (Meilleur et al. 1997). Coppicing – cutting main stems to encourage suckering in woody shrubs – is another enhancement method that was reported to increase stem density but not crown cover of *Viburnum lentago* and *Cornus racemosa* on New York ROWs (Ballard 2006). Seeding cover crops of competitive agronomic or native grasses is another biological manipulation strategy for disturbed sites. The seeding of *Dactylis glomerata*, a highly competitive grass from Eurasia, successfully established and reduced regrowth of tree transplants near Tobermory, Ontario. Though not widely documented on power line ROWs, success with establishing native grass has been reported for abandoned gravel pits and roadsides (Maslen 1989; Tyser et al. 1998; Petersen et al. 2004). These grass communities resisted invasion of other species and persisted for multiple years.

Identifying desirable cover types for Yukon ROWs and management methods that may promote the development of these communities are discussed in the next section.

2.2. Examining Vegetation Management Strategies to Promote Desired Successional Pathways for Yukon ROWs

2.2.1. Identifying desired cover types

Selecting an appropriate cover type for local ecological and environmental conditions is critical for limiting the growth of target species (de Blois et al. 2004) and needs to be completed before potential management methods can be determined. In southern jurisdictions, maintaining or enhancing shrub cover has been identified as the most effective and logistically practical method of inhibiting target species establishment under transmission lines (Niering and Goodwin 1974; Dreyer and Niering 1986; Meilleur et al. 1994). Shrub cover or stem density has been proven to reduce target species invasion on ROWs.

Desirable shrub species on ROWs have been documented in eastern North America (e.g. Ballard et al. 2011), but there are few shared species between eastern deciduous and northern boreal forests. Nevertheless, many northern shrubs share characteristics such as clonal growth and preference for sun exposure that have been linked to the formation of dense cover (Meilleur et al. 1994). Prickly rose (*Rosa acicularis*) and bog bilberry (*Vaccinium uliginosum*) are common shrubs on Yukon ROWs and capable of forming dense, low-growing thickets.

In addition to shrub cover types, aggressive perennial grasses may provide a solution as they are well documented competitors of tree seedlings in the northern forestry industry (Ballandier et al. 2006). The roots and litter of bluejoint reedgrass (*Calamagrostis canadensis*), for example, can directly suppress aspen seedling and sucker development by maintaining cooler soil temperatures and physically preventing sucker penetration through the soil (Landhäusser and Lieffers 1998; Landhäusser et al. 2007).

Two potential cover types, therefore, may be appropriate for Yukon ROWs: a low growing shrub community or a dense mat of competitive native grass species. Which management methods may promote development of these plant communities remains uncertain as community development after disturbance is a site-specific and complex process.

2.2.2. Control methods selection

On Yukon ROWs, *Populus tremuloides*, *Populus balsamifera* and *Salix* spp. are the most common target species though *Betula neoalaskana* is locally dominant at wetter sites. Target species were identified as species that grow quickly after disturbance and to a height that can interfere with transmission lines. *P. tremuloides* and *P. balsamifera* are well known for aggressive suckering after aboveground disturbance (Frey et al. 2003; Ilisson and Chen 2009). Willows such as *Salix bebbiana* are clonal and common in disturbed areas (Amiro and Courtin 1981; Carleton and MacLellan 1994). *Betula* spp. are also colonizers after disturbance (Peinado et al. 1998). Mechanical control by brushing and/or mowing has traditionally been used on Yukon power line ROWs. The abundance of these target species on Yukon ROWs and their life histories strongly indicate that mechanical treatments do not promote the development of plant communities resistant to these species. Herbicide use is a potential tool for Yukon ROWs as many products are registered for the most common target species requiring management.

Many utility companies use herbicides for vegetation management on ROWs (Sulak and Kielbaso 2000). A recent review of forestry-use herbicides was completed by a consulting company, Environmental Dynamics Inc. (EDI), and aminopyralid, glyphosate, imazapyr and triclopyr were identified as candidates for use on Yukon ROWs based on their effectiveness on target species, environmental risk and use by other comparable jurisdictions (EDI 2013). A small-scale field trial by EDI indicated triclopyr and imazapyr as the most effective on northern target species. There is very little information available on herbicide behaviour under northern conditions (Newton et al. 2008) and environmental risks are difficult to estimate. To further investigate herbicide use for vegetation management on Yukon ROWs, Garlon XRT (triclopyr) and Arsenal Powerline (imazapyr) were chosen as candidates for testing.

Triclopyr (commercial formulation Garlon XRT, 755 g L-1 triclopyr butoxyethyl ester; Dow AgroSciences Canada Inc, Calgary, AB) is a pyridine-based herbicide in the carboxylic acid family. It is formulated as a butoxyethyl ether or triethylamine salt, both of which readily dissociate into triclopyr acid in water. It was first registered in Canada in 1989 as a Group 4 selective herbicide for use on broadleaf and woody vegetation in non-crop areas. Similar to the phenoxyacetic acids (e.g. 2,4-D) and benzoic acids (e.g. dicamba), triclopyr acts as an auxin mimic, effectively giving the plant a hormone overdose. As a foliar spray, triclopyr is rapidly absorbed from the leaf and translocated through the plant in as little as 12 hours (Lewer and Owen 1990). It has low leachability and the majority deposited on the forest floor remains in the organic layer (Lee et al. 1986; Thompson et al. 2000). Triclopyr typically degrades rapidly in both soil and water by microbial breakdown or photolysis (Johnson et al. 1995).

Imazapyr (commercial formulation Arsenal Powerline, 240 g L-1 imazapyr acid; BASF Canada Inc., Mississauga, ON) is a broad spectrum herbicide in the imidazolinone family. It is available both as imazapyr acid or isopropylamine salt. First registered in Canada in 1994, imazapyr is a Group 2 herbicide typically used to control grasses, broad-leaf weeds and select perennial shrubs. Like the sulfonylurea family (e.g. metsulfuron), imidazolinone herbicides inhibit the production of three amino acids by binding to the acetolactate synthase (ALS) enzyme and are most effective on young, actively growing plants (Schoenhals et al. 1990). It degrades by both photolysis on the soil surface and by microbial breakdown (Wang et al. 2005; Ramezani et al. 2008). Imazapyr can be applied pre- or post-emergence and may remain active and mobile in soils for an extended period of time (Loux and Reese 1993; Bovey and Senseman 1998; Gianelli et al. 2014).

The literature strongly recommends selective herbicide treatments for preserving non-target species, especially shrubs, as the primary method of creating tree-resistant communities (Dreyer and Niering 1986; Niering et al. 1986; Bramble et al. 1991; Mercier et al. 2001; Yahner and Hutnik 2004). The efficacy of selective herbicide on target species is also a critical component, as even intact shrub communities are susceptible to invasion by suckers from established trees (Dreyer and Niering 1986). The most common selective treatments are basal bark application, cut stump/wet-blading, and targeted low-high volume foliar spray (Nowak and Ballard 2005a). Point injection has also been gaining popularity, especially for woody invasive species control (Lewis and McCarthy 2008). Non-selective herbicide treatments also change plant community structures, but generally favour annual species that do not persist long enough to inhibit target species growth (Bramble et al. 1991; Luken et al. 1994). In Alaska however, shrub control with broadcast spray applications of triclopyr resulted in higher graminoid cover as triclopyr's mode of action does not affect monocots (Seefeldt et al. 2013). It is unknown whether this grass cover persisted for more than two years or inhibited reestablishment of woody species. The complexity of vegetation dynamics after disturbance makes predictions very difficult, but by trying both selective and non-selective herbicides applied by selective and non-selective methods new community development trajectories may be induced.

Establishing graminoid cover may also be improved by direct seeding. Species selection for native grass seeding depends on species characteristics as well as site conditions and seed availability (Karim and Mallik 2008). Two prominent competitors of tree species in the boreal forestry industry, bluejoint reedgrass (*Calamagrostis canadensis*) and tufted hairgrass (*Deschampsia caespitosa*), are native to Yukon and have the potential to reduce target species regrowth under power lines (Ballandier et al. 2006). *C. canadensis* is a grass that aggressively develops a thick mat of roots and rhizomes and can out compete both woody and herbaceous species for soil nitrogen (Hangs et al. 2003; Landhäusser and Lieffers 1998). In Yukon, *C. canadensis* can aggressively colonize disturbed areas where mineral soil is exposed, and stagnate ecosystem development (Simpson 2012). *D. caespitosa* is a slower growing grass, but once established it can successfully compete with woody species for moisture (Collet et al. 1996). Rapid colonization after disturbance is also an important characteristic for herbaceous cover crop species (Brown 1995) and slender wheatgrass (*Elymus trachycaulus*) is a rapidly establishing native grass often used for revegetation purposes (Buss et al. 1997; Petersen et al. 2004). Glaucus bluegrass (*Poa glauca*), violet wheatgrass (*Elymus violaceus*; previously *E. alaskanus*) and rocky mountain fescue (*Festuca saximontana*) are recommended for grass cover on dry sites in Yukon and are already found on Yukon ROWs (Matheus and Omzigt 2011). By applying a mix of species, graminoid covers can be designed to establish quickly, provide adequate ground cover and potentially out compete undesirable tree and tall shrub species.

2.3. Special Management Considerations: Phytotoxicity of Herbicides to Non-Target Organisms and Persistence of Active Ingredients in Plant Tissue and Soil

In northern Canada, herbicide use for woody species control is not widespread nor are its effects on northern native plant species in local soils well understood. In Alaska, applications of triclopyr and 2,4-D for shrub control had species-specific impacts on non-target vascular plants (Seefeldt et al. 2013). Forb cover overall did not decline two years after treatments; however, certain species such as *Chamerion angustifolium* significantly declined in triclopyr broadcast spray plots and *Erigeron acris* was highly sensitive to 2,4-D broadcast spray. It is likely that Yukon ROW non-target plant species will also have a large range of sensitivities to herbicides. Terrestrial plant acute toxicity tests provide a standardized method to assess potential impacts on important non-target species from chemical vegetation management strategies.

2.3.1. Assessing phytotoxicity of herbicides to non-target terrestrial plants

Ecotoxicity testing to assess environmental risks of pest control products is a key component of pesticide regulation. Toxicity is the degree to which a substance causes negative effects on an organism and phytotoxicity refers to the toxicity of a substance specifically to plants. Test organisms are subjected to a series of increasing doses and a predetermined endpoint such as surviving individuals, size or biomass is measured at the end of the test. The tests typically use non-linear regression techniques to model dose-response relationships and generate percent growth inhibition (Inhibition Concentration: ICx) or percent mortality of individuals (Effective Concentration: ECx) (EC 2013). The estimates provide standardized values to compare toxicities of chemicals or sensitivities of organisms (Seefeldt et al. 1995). There are two tests used to characterize acute toxicity of herbicides to terrestrial plants: the vegetative vigour test and the seedling emergence and seedling growth test (OECD 2006, USEPA 2012). The vegetative vigour test evaluates sensitivity of young plants to foliar spray, while the seedling emergence and seedling growth test assesses the effect of herbicide concentrations in soil on the germination of seeds and early seedling growth. For regulatory purposes, testing is typically completed on 6-10 annual field/row crop species from multiple families with the intention of encompassing the range of any non-target plant sensitivity.

There is considerable debate whether non-target species sensitivities are adequately represented by regulatory testing (McKelvey et al. 2002; Boutin et al. 2004; Clark et al. 2004; White and Boutin 2007). Greater sensitivities of wild species than crop species to multiple herbicides have been reported (Boutin et al. 2004), though similar sensitivities between wild and crop plants have been demonstrated as well (Carpenter and Boutin 2010; White and Boutin 2007). Within a single plant species, differences in sensitivity between cultivars and ecotypes have also been detected (White and Boutin 2007; Boutin et al. 2010). The range of sensitivities to herbicides can also vary more between wild species than agricultural ones (Olszyk et al. 2008). In addition, plant response to herbicide is also dependent on environmental conditions and even slight variations can impact sensitivity in phytotoxicity testing (Boutin et al. 2010).

The production of homogenous “crops” of wild plants for toxicity testing is a significant challenge. Seed for wild species is less readily available than for field/row crops (White et al., 2009) and quality is less consistent (Pallett et al. 2007). Many wild species’ seeds also have dormancy requirements that must be met to maximize germination percentages (White et al., 2009). Wild plants are often slower to reach the required growth stage for testing (Boutin et al. 2004) and there is higher intrinsic variability in individual plant growth rates and biomass (Pallett et al. 2007). Nevertheless, there are successful examples of wild plant species meeting regulatory criteria for valid toxicity testing (Boutin et al. 2004; Olszyk et al. 2008; Boutin et al. 2010; Princz et al. 2012).

2.3.2. Assessing herbicide toxicity to soil invertebrates

Soil ecotoxicology has lagged behind that of aquatic ecotoxicology due to the heterogeneous nature of soil and the difficultly associated with laboratory and field testing (EC 2014). With the expansion of soil ecotoxicological studies, standardized single species toxicity test protocols have been developed to aid in the development of site-specific soil quality guidelines (van Gestel 2012). These standardized tests have aided in the understanding of the life histories, as well as, expanded knowledge of the impact of contaminants on test species (Princz et al. 2012; van Gestel 2012). To gain adequate representations of the risk to different soil ecosystems standardized tests including species with a range of sensitivities have been developed (Princz et al. 2012). In addition, standardized tests also need to be ecologically relevant by incorporating species found at or near the sites being tested (Römbke et al. 2006).

Toxicity assays can aid in the development of site-specific guidelines for herbicide usage, which can help drive application rates. Standardized soil toxicity tests were lacking in Canada until the Canadian Council of Ministers for the Environment (CCME) published a framework for ecological risk assessment. Since publication, the framework has become a fundamental component of ecological risk assessment for terrestrial sites in Canada (Römbke et al. 2006; EC 2014). Recent research has focused on the role of soil dwelling organisms to determine applicability of specific invertebrate species for laboratory toxicity testing of contaminants in Canadian boreal and tundra soils (Römbke et al. 2006; Princz et al. 2012). Conducting tests within a laboratory setting is important as it reduces variability within the results increasing confidence in those results (Stark et al. 1995; Moran 1999; Princz et al. 2012). However, there is still some uncertainty when trying to apply laboratory test results to field conditions (Moran 1999; Princz et al. 2012).

Bioassays using soil invertebrates are important to gauge the toxicity of the bioavailable fraction of the chemicals (Loureiro et al. 2005). However, there is a lack of single species toxicity data for many chemicals (Loureiro et al. 2009). The data that is available tends to focus on earthworms. A range of species with different sensitivities should be included in risk assessments (Frampton et al. 2006; Loureiro et al. 2009). Soil invertebrate species selected for laboratory toxicity assays are generally of ecological relevance and are easy to handle and maintain (Römbke et al. 2006; Princz et al. 2012). Collembola and enchytraeid species are ideal because they are abundant and provide an important ecological service in the decomposition of organic matter and in the structure of soil (Jansch et al. 2006; Princz et al. 2010, 2012). Princz et al., (2010) determined that, due to their prevalence in boreal soil systems, Oribatid mites should be added to ecotoxicity testing in Canada. To assess the effects of herbicides on terrestrial ecosystems along ROWs within the Yukon Territory, three invertebrate groups – enchytraeid (*Enchytreaus crypticus*), collembola (*Folsomia candida*), and mites (*Oppia nitens*) – are evaluated.

2.3.3. Benefits of toxicity testing with ecologically relevant species and substrates

Estimating boreal plant species sensitivities to herbicides is difficult as there is limited background information on herbicide behaviour in northern Canada. It is uncertain whether native boreal species are similarly sensitive to herbicides as crop species. Princz et al. (2012), for example, found boreal plants to be more sensitive to hydrocarbon contaminated soil than crop species but similarly sensitive to soil salinity. Shrub control research in Alaska indicates herbicide sensitivities of boreal plants vary between species and sometimes site specific (Seefeldt et al. 2013). The sensitivities of the two most frequent and abundant native herbaceous species at the Yukon ROW research sites, *Achillea millefolium* and *Chamerion angustifolium*, are of particular concern. *A. millefolium* and *C. angustifolium* are widespread rhizomatous perennials that are ecologically and culturally important. Snowshoe hare (*Lepus americanus*), a keystone boreal species, feeds on both plant species during the late summer (Seccombe-Hett and Turkington 2008). *C. angustifolium* is also particularly attractive to bees and other pollinators (Kevan et al. 1993) and is an important component of moose summer diet (Johanson et al. 1994). Both species are culturally important as edible and/or medicinal plants (Gray 2012). Covering more than 5% of Yukon ROW research sites, the disappearance *A. millefolium* and *C. angustifolium* may have negative effects on ROW plant communities and ecosystems. The use of these two species for phytotoxicity testing provides species-specific toxicity information to increase knowledge of herbicide impacts on non-target plants on Yukon ROWs.

In addition to species variability, bioavailability of herbicide can differ depending on soil characteristics (Loux and Reese 1993; Eliason et al. 2004; Allison et al. 2013). The sorption of herbicide to soil particles can lower the amount of herbicide readily absorbed by plant roots and thus, toxicity to seeds and seedlings may be soil specific. Triclopyr and imazapyr are weak acids and exist mostly in their anionic state in all but the most acidic soils (Johnson et al. 1995; Gianelli et al. 2014). With a negative charge, these chemicals do not sorb strongly to soil particles and are relatively mobile. When deposited on the forest floor, the majority of triclopyr residues remain in the organic soil horizon (Thompson et al. 2000) suggesting triclopyr sorption will increase with organic carbon content. Imazapyr does not readily sorb to organic matter unless soil pH is very low (<5) and bioavailability is not typically affected by soil organic carbon (Pusino et al. 1997). Imazapyr sorption is positively associated with clay, iron and aluminum content and imazapyr is likely less available to plants in clay, iron and /or aluminum rich soils (Gianelli et al. 2014). Both herbicides are degraded in soil primarily through microbial breakdown (Johnson et al. 1995; Gianelli et al. 2014) and the use of native soils with intact microbial communities better represents field conditions than sterilized soil. The use of field collected soils for seedling emergence and seedling growth tests provides a better representation of northern ROW conditions than generic potting soil and incorporates the effects of soil type on herbicide bioavailability into the test.

2.3.4. Persistence of herbicide active ingredient in plant tissue

In addition to acute phytotoxicity of herbicides to plants, the dissipation rates of these chemicals in plant tissue is also of concern. Degradation, persistence and dissipation are all terms related to the residence time of herbicides in soil and vegetation. Degradation is the breakdown of the herbicide molecule from the parent compound to metabolites by a chemical process (Mueller and Senseman 2015). Persistence involves the length of time herbicide residues are present in soil and is considered the inverse of dissipation (Mueller and Senseman 2015). Dissipation is the sum of all possible outcomes of the parent compound (Mueller and Senseman 2015). As the primary producers in intricately connected ecosystems, grasses, forbs and shrubs provide pathways for herbicide residue into the wider environment including transfer to wildlife (Tatum 2004). Foliage can also act as a source for soil contamination when fallen leaves decompose on the forest floor (Thompson et al. 1994). It is widely accepted that the rate of dissipation of herbicides from vegetation is significantly dependent on environmental conditions (Newton et al. 2008); how northern climates will impact dissipation rates is not well understood.

If the herbicide persists on the leaf surface, it can dissipate through volatilization, photolysis or microbial breakdown (Bentson and Norris 1991; Newton et al. 2008). The net effect of northern environmental conditions on these processes is unknown. Long photoperiods in the summer associated with higher latitudes may increase the rate of photolysis on the leaf before it can be absorbed, however, microbial breakdown may be slower due to cooler temperatures. Once absorbed, degradation requires the herbicide be metabolized or deposited in foliage (Newton et al. 1990). The ability to metabolize herbicides is species specific as demonstrated by Sidhu and Feng (1993). Plant metabolic activity is limited in the North partially due to cool soil temperatures (Bonan and Shugart 1989) and this may increase the residency of herbicide in plant tissue in the North. Temperature was identified as a major factor influencing dissipation rate from foliage by Newton et al. (1990). Triclopyr rapidly dissipated from foliage within the first 80 days after application, but concentrations within vegetation changed very little over the winter. In Alaska, however, Newton et al. (2008) found dissipation rates of triclopyr and imazapyr from vegetation similar to those reported at more southern latitudes. The strong influence of environmental conditions on the dissipation of herbicide from plant tissue suggests more research is needed to confirm whether rates are similar to southern regions.

2.3.5. Persistence of herbicide active ingredients in soil

Various soil processes, properties and climatic conditions contribute to the dissipation of herbicide residues in the soil. Soil processes contributing to the degradation of herbicides include adsorption, microbial degradation and photodegradation (Goetz et al. 1990; Baker and Mickelson 1994; Johnson et al. 1995; Gevao et al. 2000; Wang et al., 2006; Remucal 2014). Soil properties such as soil organic matter, clay content and pH influence dissipation rates (MacRae and Alexander 1965; Goetz et al. 1990; Johnson et al. 1995; Jourdan et al. 1998; Gevao et al. 2000; Wang et al., 2005; Douglass et al. 2016). Climatic conditions including temperature and moisture can also influence degradation pathways and thus attenuation rates.

3.0 EXPERIMENTAL DESIGN

The reported research work is categorized as field- or greenhouse/laboratory-based trials. The field-based trial was conducted on study sites located on Yukon power line ROWs. There were two components to the field-based trial. The first was to investigate how plant communities on ROWs responded to treatment with eight vegetation management techniques. This involved describing and quantifying the vegetation community and other ecologically relevant parameters on-site before and one year after treatment.

The second component of the field trial was to quantify the dissipation rates of the two tested herbicides in treated vegetation and soil. This was completed to quantify how persistent the tested herbicides are in the environment. This involved collecting vegetation and soil samples over a period of time and determining the concentration of herbicides in these samples. Because herbicide residue in treated vegetation and soil might impact non-target organisms through translocation and/or consumption, herbicide dissipation information is used for evaluation of the potential risk from the tested herbicides on non-target ecological receptors.

The greenhouse/laboratory-based trial involved testing the two herbicides on a battery of plant and soil invertebrate species to determine the sensitivity of non-target organisms to the tested herbicides in a controlled/standardized environment (i.e., greenhouse). These toxicity tests followed standardized Environment Canada (EC) and Organization for Economic Cooperation and Development (OECD) testing protocols. Seedling emergence and growth and vegetative vigor after herbicide treatment were the life-stages measured for three boreal plant species. Adult survival/mortality and reproduction (number of progenies) were measured for the ecolog**i**cally relevant soil invertebrates.

3.1. Field-Based Trial: Early (One-Year Post Treatment) Response of Plant Communities on Power Line Rights-of-Way to Eight Vegetation Management Techniques

3.1.1. Study areas

Four study sites were established on power line ROWs in Yukon, Canada, in 2014 (**Figure** 1). Sites were distributed across the territory within the Boreal Cordillera Ecozone and were representative of the ecotypes where Yukon ROWs are found (**Table 1**). A fifth site (LS) was established in 2015. Sites were selected for the study by aerial survey to ensure homogeneity of vegetation type and similar development since the last mowing cycle, which occurred between one and six years previously. The more southern sites were bordered by mid-successional boreal forests dominated by white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) and the more northern site (DAW) bisected a mature coniferous stand (*Picea* spp.). Dominant vascular plant covers on the ROWs prior to application of treatment are summarized in **Table 3.2** of **Appendix B**

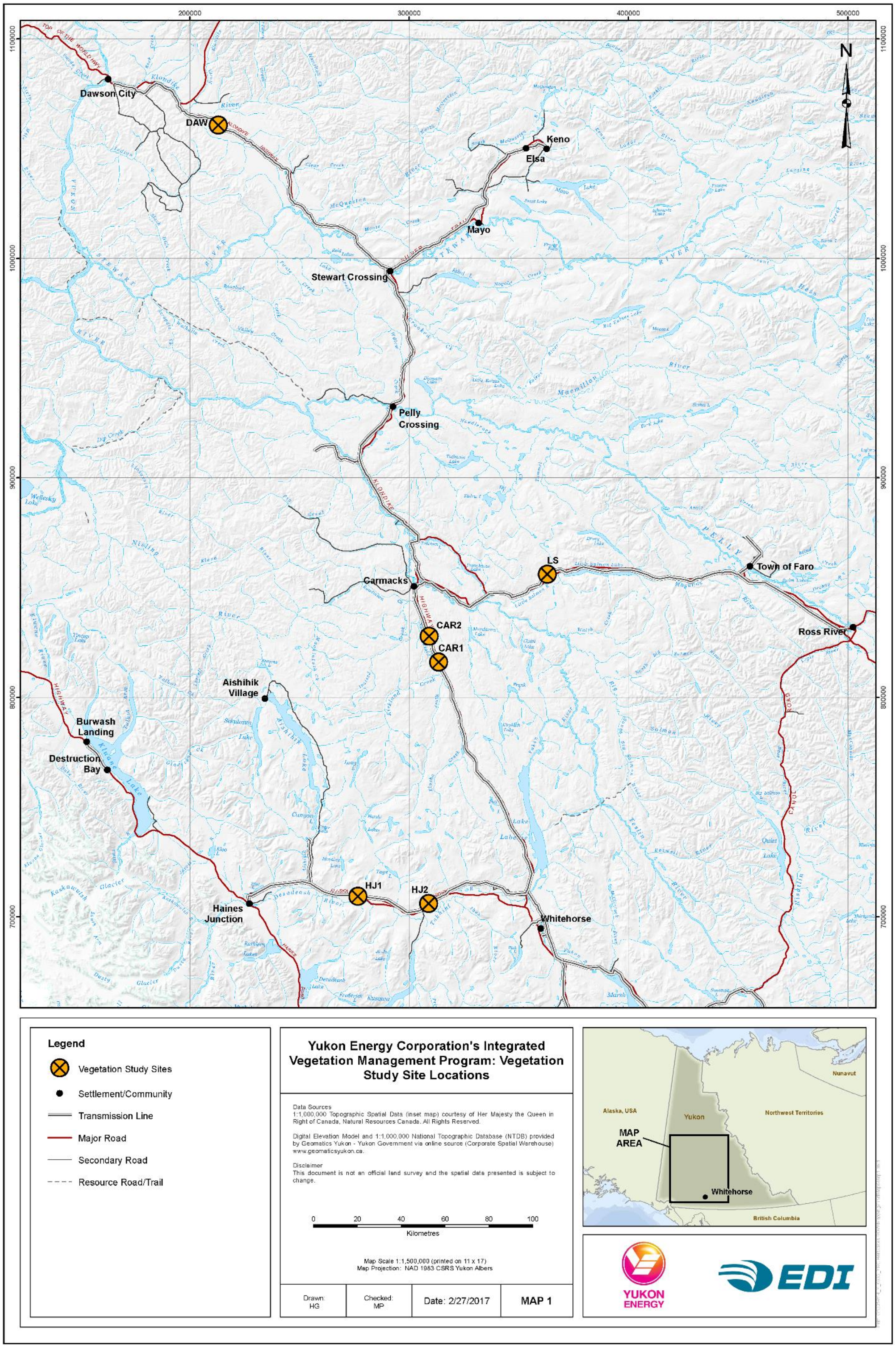

Figure 1 Map of field study locations on power line rights-of-way in Yukon Territory, Canad

Table 1 Summary of site information including GPS co-ordinates, ecoregion, soil type, last mowing cycle, mean annual precipitation, mean January and July temperatures, and treatment application date. Modified from Appendix B and C.

Site (Abbreviation)	Coordinates	Ecoregion†	Soil Type‡	Last Mowing Cycle	Mean Annual Precipitation § (mm)	Mean January Temp§ (°C)	Mean July Temp§ (°C)	Treatment Application (dd-mm-yy)
Carmacks¶ (CAR)	61.8° N, 136.0° W; 61.9° N, 136.1° W	Yukon Plateau - Central	1	2010	323.4	-17.2	14.9	15-07-14
Dawson (DAW)	63.9° N, 138.4° W	Yukon Plateau - North/ Klondike Plateau	1	2008	324.3	-26.0	15.7	03-08-14
Haines Junction 1 (HJ1)	60.8° N, 136.6° W	Yukon Southern Lakes	2	2013	297.3	-16.1	13.0	19-07-14
Haines Junction 2 (HJ2)	60.8° N, 136.0° W	Yukon Southern Lakes	2	2011	297.3	-16.1	13.0	25-07-14
Little Salmon (LS)	62.1° N, 135.1° W	Yukon Plateau - Central	3	2014	319.7	-21.1	14.0	28-07-15

† As per 'Ecoregions of the Yukon Territory: Biophysical properties of Yukon landscapes' (Smith et al. 2004).
‡ Soil Type: 1) Eutric Brunisol on Sand;2) Eutric Brunisol on Clay Loam; and, 3) Eutric Brunisol on Silt Loam.
§ Weather data from Environment Canada 1981-2010 Climate Normals: Mayo Road (CAR), Dawson Airport (DAW), Otter Falls (HJ1 & HJ2) and Drury Creek (LS).
¶ Carmacks site was divided into two sections due to the variability of vegetation types and to avoid surface water drainage on the right-of-way. Blocks 1 & 2 were installed on 15-07-14 while Block 3 was installed 10km north of Blocks 1 & 2 on 21-07-14.

3.1.2. Treatment and sampling design

Each of the four sites was laid out in a randomized complete block design (RCBD). At each site three blocks with eight randomly assigned treatment plots per block were installed (**Figure 2**). The 6 m x 6 m treatment plots were spaced at a minimum of 50 m apart to avoid interference between treatments (i.e., herbicide drift). Four 1-m^2 permanent vegetation cover plots were established within each treatment plot and percent cover data recorded 5-14 days before treatments were applied in July of 2014. Total percent cover of each species was recorded to the nearest percent and all unknown species were collected from outside the plot for later identification (**Table 3.2** of **Appendix B**). Vegetation cover was recorded again in 2015 within ten days of the original observation dates.

Eight treatments were designed to represent mechanical, chemical and biological strategies for ROW vegetation management (**Table 2**). The control was mechanical mowing, the current standard vegetation management treatment. Two common products used for woody species control were selected: Garlon XRT (755 g L^{-1} triclopyr butoxyethyl ester; Dow AgroSciences Canada Inc, Calgary, AB) and Arsenal Powerline (240 g L^{-1} imazapyr acid; BASF Canada Inc., Mississauga, ON). These two herbicides were applied through three methods: broadcast spray, cut stump and point injection at the maximum rates specified on the labels (broadcast spray: 4530 g active ingredient (a.i.) ha^{-1}, 720 g a.i. ha^{-1}; cut stump and point injection: 143.5 g a.i. L^{-1} canola oil, 22.6 g a.i. L^{-1} deionized water). A backpack sprayer was used for the broadcast spray treatment. Cut stump applications were completed by hand cutting all vegetation at 20-30 cm and applying products to all cut stems with a paint brush. Point injections were applied via a syringe inserted into a small drilled hole or incision in the stem of a target species. In selective cutting/ecological manipulation plots, only target species were hand cut and removed. Point injection and selective cutting/ecological manipulation plots were also seeded with native grasses at 50 kg ha^{-1} as high seeding rates have been shown to reduce species invasion of disturbed areas in Yukon (EDI 2009). Litter was raked out of the plot to prepare the seedbed and a native grass seed mix from DLF Pickseed Canada (Lindsay, ON) was broadcast by hand (see **Table 2** seed mix composition). After seeding the plot was lightly raked to enhance seed-soil contact. Treatments were applied between mid-July and early August 2014.

Target species were defined based on two criteria: 1) rapid regrowth after disturbance; and, 2) the ability to grow tall enough to interfere with transmission lines. The main target species identified were trembling aspen (*Populus balsamifera*), balsam poplar (*Populus balsamifera*) and willow (*Salix* spp.) which were present at every site, and Alaska paper birch (*Betula neoalaskana*) was included at the DAW site. Although conifers in the Yukon Territory can grow to a height where they may interfere with lines, they are not considered a management concern by the utility company because of their slow growth rate and were thus not included as target species.

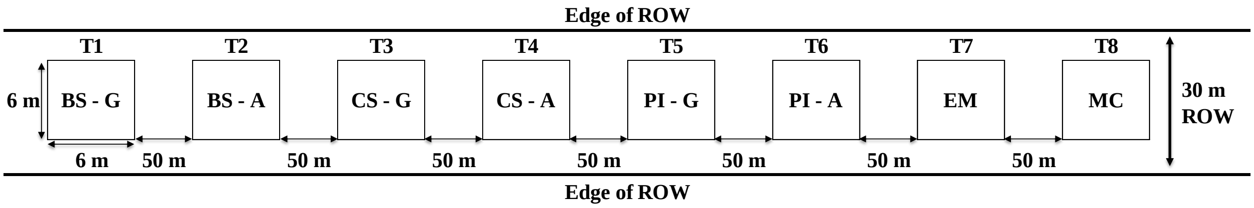

Figure 2 Study design for determining the effect of eight treatment strategies (including two herbicides) for vegetation control and for determination of herbicide dissipation in soils on Yukon power line rights-of-way (ROWs). This is an example of a block within the randomized complete block design with eight treatments: backpack spraying (BS), cut stump (CS), and point injection (PI) with two herbicides (triclopyr = Garlon XRT (G) and imazapyr = Arsenal Powerline (A)), ecological manipulation (EM), and a mowing only control (MC). Three blocks were established at each site for a total of 120 treatment plots (5 sites x 8 treatments x 3 replicates). Figure adapted from **Appendix C**.

Table 2 Description of eight rights-of-way vegetation management treatments applied in field research sites within Yukon in 2014. Table adapted from **Appendix B**.

Treatment	Abbreviation	Strategy	Description
Mowing (Control)	MC	Mechanical	Cut and removed all vegetation at 10-20 cm above soil surface
Broadcast Spray – Triclopyr/Garlon	BS-T/G	Chemical	Applied herbicide with a backpack sprayer to all vegetation; any stems above 1.5 m were cut prior to spraying
Broadcast Spray – Imazapyr/Arsenal	BS-I/A	Chemical	
Cut Stump – Triclopyr/Garlon	CS-T/G	Chemical	Cut all vegetation at 20-30 cm above soil surface and applied herbicide with a paintbrush
Cut Stump – Imazapyr/Arsenal	CS-I/A	Chemical	
Point Injection – Triclopyr/Garlon	PI-T/G	Chemical/Biological	Incised small stems/drilled large stems of targets only and applied herbicide with a syringe; seeded native grasses†
Point Injection – Imazapyr/Arsenal	PI-I/A	Chemical/Biological	
Ecological Manipulation/Selective Cutting	EM/SC	Mechanical/Biological	Hand cut and removed targets; seeded native grasses†

† Litter was raked out of the plot to prepare the seed bed and a native grass seed mix of 42% (b/wt) violet wheatgrass (*Elymus violaceus*), 26% slender wheatgrass (*Elymus trachycaulus*), 8% rocky mountain fescue (*Festuca saximontana*), 6% glaucous bluegrass (*Poa glauca*), 5% bluejoint reedgrass (*Calamagrostis canadensis*) and 2% tufted hairgrass (*Deschampsia caespitosa*) from DLF Pickseed Canada (Lindsay, ON) was broadcast by hand.

Visual herbicide damage assessments were completed one and two year(s) after application in all chemically treated plots for CAR, DAW, HJ1, and HJ2 sites. First year (2015) data for these four sites was analyzed (**Appendix B**). Second year (2016) data has not yet been analyzed but is available. For the LS site, there is only data for one year after treatment (2016) because the site was established in 2015. This data set is available, but it has not yet been analyzed.

Targets were evaluated by species and damage to treated stems and new suckers/seedlings were separated to identify duration of effect. Non-targets were assessed by life form: erect shrubs (<1.5 m in height), prostrate shrubs, forbs and graminoids. A scale of 0-100 was used with 0 being unaffected and 100 being completely dead. Only herbicide-related damage was recorded and untreated areas surrounding the plot were used as a reference to differentiate between natural and herbicide damage.

Species richness and evenness were determined for each treatment plot using the average cover and total number of species from the four vegetation cover subplots. Species richness was defined as the total number of species per plot and evenness was calculated with the EVar index based on the average percent cover of each species per plot (Smith and Wilson 1996).

Refer to **Appendix B** for the detailed description of the statistical analysis of this data.

3.2. Field-Based Trial: Dissipation of Triclopyr and Imazapyr from Treated Soil and *Salix glauca* (White Willow) Foliage

3.2.1. Study areas

Soil sampling for determination of herbicide dissipation rates was conducted at the five sites described in **Section** Error! Reference source not found.. Vegetation was also sampled at the same time; however, herbicide concentration was determined for soil only.

An additional 500 m section along the ROW near HJ2 (60.778°N, 136.071°W) was used to conduct a 30-day field-based triclopyr and imazapyr dissipation experiment in the foliage of *Salix glauca* (white willow). *S. glauca* was chosen because it is commonly found along the power line ROW, and its foliage is consumed by foraging ungulates such as moose. Individual *S. glauca* plants spaced a minimum of 2 m apart and at least 5 m from the edge of the ROW we selected. Vascular plant species within a 1.5 m radius of the selected plant were removed by hand to reduce effects of competition between June 1, 2015 and the end of the experiment. Soil was not sampled in this experiment.

3.2.2. Treatment and sampling design

Soil was collected from each herbicide-treated plot at CAR, DAW, HJ1, and HJ2 on 1, 30 and 365 days after treatment (DAT). At LS, soil samples were collected as soon as herbicides had dried (~ 2 hours after application) and at 1, 3, 7, 14, 21, 30 and 60 DAT. Increased sampling intervals were used at LS to model and determine the dissipation rate of each herbicide. A trowel with a depth gauge was used to sample areas approximately 8 cm in diameter to a depth of 3 cm (upper soil layer) regardless of the depth of the organic layer.

For the herbicide dissipation experiment with *S. glauca* at HJ2, a backpack sprayer was used to apply herbicides at the same rates as other sites (**Section 3.1.2**) to a 1.5 x 1.5 m area around each individual plant. Sampling was done within one hour of the spray drying (~ 2 h post application) and at 1, 3, 7, 14, and 30 days after spraying. Thirty (30) plants for each herbicide were treated. Foliage from five *S. glauca* plants were harvested at each interval, i.e., each individual shrub was only sampled once.

Samples were analyzed by the University of Guelph Laboratory Services following certified method 069 Phenoxy Acid – Soil/Veg. A subsample was also used to determine percent moisture of each sample.

Refer to **Appendix B** and **C** for further details on the sampling method, sample processing method, analytical chemistry method for determining herbicide concentration, and modelling and statistical analysis of the triclopyr and imazapyr dissipation from soil and vegetation chemistry data. The certificates of chemical analyses are also in these two appendices.

3.3. Greenhouse/Laboratory-Based Trial: Herbicide Toxicity Testing with Non-Target Boreal Plants and Soil Invertebrates

The purpose of this study was to assess the toxicity of triclopyr and imazapyr to non-target plants and soil dwelling invertebrates that are of ecological, socio-economic, and cultural relevance in the boreal region of Canada. Specifically, the objective was to determine the sensitivity of the common boreal plants *Achillea millefolium* and *Chamerion angustifolium* and soil invertebrates *Enchytreaus crypticus* (enchytraeid), *Folsomia candida* (collembola/springtail) and *Oppia nitens* (mite) to triclopyr and imazapyr by challenging them over a range of herbicide concentrations through broadcast spraying (plant vegetative vigor test) or applied directly to soils (plant seedling emergence and seedling growth test and all soil invertebrate tests) collected from five field sites representative of ROWs in the Yukon.

With the exception of the *O. nitens* adult survival and reproduction test, all herbicide toxicity tests followed the standard test methods detailed by the Organization for Economic Cooperation and Development (OECD) or Environment Canada (EC). The referenced method for *O. nitens* is currently under review for adoption as the standard method by Environment Canada. Please refer to the following references for further details on the specified test method:

- Plant vegetative vigor test - Test No. 227 (OECD 2006);
- Plant seeding emergence and seedling growth test (EC 2013);
- *E. crypticus* adult survival and reproduction test (OECD 2004);
- *F. candida* adult survival and reproduction test (EC 2014); and,
- *O. nitens* adult survival and reproduction test (Princz et al. 2010).

3.3.1. Soils used in herbicide toxicity testing

Approximately 20 kg of untreated soil from the top 3-cm was collected and processed from each site listed in **Table 1**. The soils collected from each site were used in the seedling emergence and seedling growth tests for plants and in the adult survival and reproduction tests for soil invertebrate. These tests were repeated in a standard “artificial soil”. Testing in artificial soil is necessary to facilitate comparisons between studies with soils of varying properties and assessment of test organism performance within a study (EC, 2014). For the plant vegetative tests, plants were grown in commercial potting soil (Sunshine Mix #4, Sun Gro Horticulture, Agawam, MA).

3.3.2. Herbicide toxicity testing with non-target boreal plants

Achillea millefolium and *Chamerion angustifolium* are common colonizers after anthropogenic disturbance in Yukon (Lister 2009), the dominant herbs on Yukon ROWs (**Appendix B**), and are of ecological and cultural importance in the region. Snowshoe hare *(Lepus americanus*), a keystone boreal species, feeds on both plant species during the late summer (Seccombe-Hett and Turkington 2008). *C. angustifolium* is also particularly attractive to bees and other pollinators (Kevan et al. 1993) and a key component of moose summer diet (Johanson et al. 1994). Both species are also harvested as edible and/or medicinal plants (Gray 2012). If *A. millefolium* and *C. angustifolium* perform well as test organisms, their inclusion in standard toxicity tests for industrial chemicals would better represent plant communities of disturbed boreal sites than the crop species often used for other areas of Canada (Princz et al. 2012).

Seeds for the vegetative vigour test were donated by the Alaska Plant Materials Center (Palmer, AK). *A. millefolium* seed was collected from cultivated plants at the Alaska Plant Materials Center Farm and *C. angustifolium* seed was gathered from a wild stand in western Alaska. The same *A. millefolium* seed was used for the seedling emergence and seedling growth test, but a second lot of wild *C. angustifolium* seed from central Yukon (62.9°N, 139.1°W) was used because of insufficient germination of the first lot. *Calamagrostis canadensis* was included in the seedling emergence and seedling growth test because *C. canadensis* was the only non-target boreal species listed by Environment Canada (2013) that occurred on the ROW research sites. *C. canadensis* seed was donated by Brett Young (Winnipeg, MB).

3.3.2.1. Vegetative vigor test

Refer to **Appendix B** for a detailed description of the procedures, conditions, and statistical analyses used in both the range finding (used to determine the approximate lowest lethal dose for each herbicide-species combination) and definitive tests. A brief description of the definitive test follows. The test was conducted at the University of Saskatchewan Agriculture Greenhouse between January and April, 2015, following OECD Test No. 227 protocol (OECD 2006).

The dose range used to challenge *A. millefolium* and *C. angustifolium* plants grown in the greenhouse followed a logarithmic scale with the lowest lethal dose identified in the range finding test being the highest concentration in the range. An error in calculation for triclopyr doses resulted in testing between 0.25 and 1 times the application rate only. Solutions of imazapyr and triclopyr for both tests were prepared from commercial formulations.

For each species, 10-cm x 10-cm pots were filled with commercial potting soil and five seeds planted in each pot. This was replicated five times for each dose tested. *A. millefolium* was sprayed 22 days after planting at the 2-4 true leaf stage. Because *C. angustifolium* emerged and grew slower, it was sprayed 25 days after planting at the 6-10 true leaves stage. A custom built track sprayer was used for herbicide application (Agassiz Scientific Ltd., Saskatoon). Treatments were applied in sequence starting with the lowest dose, and the equipment was cleaned between herbicide. A visual damage assessment was conducted 28 days after treatment using a 0-100 scale, with 0 being no damage and 100 being dead. Each plant was clipped at the soil surface at 28 days after treatment for dry weight determination.

3.3.2.2. Seedling emergence and seedling growth test

Refer to **Appendix B** for the detailed description of the procedures, conditions, and statistical analyses used in both the range finding and definitive tests. A brief description of the definitive test follows. The test was conducted at the Yukon Research Centre Greenhouse in Whitehorse, Yukon, following the test methods described by Environment Canada (EC 2013).

Because herbicide is usually applied on a per area basis, an equation was used to convert g a.i. ha^{-1} doses to approximate µg a.i. g^{-1} soil for this test. It was assumed that imazapyr and triclopyr remained within the top 3-cm of the upper horizon when applied in the field. Three cm reflects the approximate depth of soil collected from the five field sites (**Table 1**) for the toxicity tests, and it represents the potential “worst case scenario” where herbicide residues concentrate in the upper organic layer.

Doses for each soil were calculated along a logarithmic scale with the highest lethal dose determined from the range finding test and prepared using the commercial formulation of each herbicide. Dosed soils for each site were prepared and placed into 355 mL Styrofoam cups to the predetermined wet weight. Five seeds were planted per cup. After 28 days, emergence (plant shoots ≥3 mm) and damage were recorded. To maintain functional microbial communities, soils were not sterilized and any volunteer plants that emerged from the natural seedbank were also recorded. Cups were either harvested immediately or frozen until processing. The longest plant shoot and root from each cup was measured and recorded. All plants from the pot were collected for dry weight determination. Total biomass was divided by emergence to determine mean biomass per plant.

3.3.3. Herbicide toxicity testing with soil invertebrates

Applied herbicides are known to reach and accumulate at soil surface and can potentially impact the soil invertebrate community. Soil invertebrates serve important ecological functions (e.g., decomposition) and are the key components of the food web. As part of the ERA, the environmental fate and toxicity of a herbicide must be evaluated in natural soils, with similar soil types and climatic condition observed in the proposed use areas (PMRA, 2000). With respect to the toxicological study, no specific species are outlined. Rather, it is up to the risk assessors to specify which species are important based on biodiversity and ecosystem health and sustainability (PMRA, 2000, 2005). A common soil dwelling invertebrate used for pesticide toxicity assessments are earthworms. However, earthworms are not typically found in northern Canada, and, in many cases, are considered an invasive species in the Boreal forest (Addison, 2009; Saltmarsh et al., 2016). As a consequence, the toxicological profile of herbicides in northern ecosystems is largely incomplete (Princz et al. 2012). To improve our understanding of the ecological risk of herbicide use in northern ecosystems, sensitivity of representative soil invertebrates to these chemicals must be determined (Römbke et al. 2006; Princz et al. 2012). In this case, ecologically relevant soil invertebrates *Enchytreaus crypticus* (enchytraeid), *Folsomia candida* (collembola/springtail) and *Oppia nitens* (mite) were challenged over a range of triclopyr and imazapyr concentrations to determine their sensitivity to these two herbicides.

Refer to **Appendix C** (and the reference test methods from OECD (2004), EC (2014), and Princz et al. (2010)) for the detailed description of the procedures, conditions, and statistical analyses used in both the range finding and definitive tests. A brief description of the definitive test follows.

The tests were conducted in the Soil Toxicology Laboratory at the University of Saskatchewan. Soils from the five sites (**Table 1**) were dosed with a series of eight increasing concentrations of each herbicide (as mg a.i. kg^{-1} soil by dry weight) plus a negative control (where no herbicide is added). For testing with imazapyr, a surfactant control was included as well because Hasten™ Spray Adjuvant was need for suspension of the commercial product (Arsenal Powerline) in water. Five replicates were included at each treatment.

All invertebrates were cultured and synchronized to ensure all tested organisms were at the proper life-stage. Each test consisted of adding defined number of individuals to a glass vessel containing a volume of approximately 30-mL of dosed soil. The mass of soil added to the vial was different for each site and depended upon soil density and particle size distributions (EC 2014). Test vessels were maintained in the dark at 20 ± 2°C. Adult survival and reproduction (number of progenies) were assessed for each organism 28 days post treatment.

3.3.4. Chemical analysis

Soil samples were analyzed at the University of Guelph's Food and Agriculture Laboratory using High Performance Liquid Chromatography coupled with tandem Mass Spectrophotometry (HPLC-MS/MS). Soil samples were analyzed to determine the actual concentrations at each nominal dose level in order to accurately establish the toxicity of the herbicides to the test organisms. Refer to **Appendix B** and **C** for further details and the certificates of chemical analysis.

4.0 SUMMARY OF RESULTS AND DISCCUSSION FOR THE FIELD AND GREENHOUSE/LABORATORY TRIALS

4.1. Early (One Year Post Treatment) Response of Plant Communities on Power Line Rights-of-Way to Eight Vegetation Management Techniques

All treatments altered the ROW plant communities one year after treatment. However, control of target species (trembling aspen, balsam poplar, willow, and Alaska paper birch) was significantly greater in chemically treated plots (ranged between 66-94% control) than in mechanically treated plots with or without grass seeding (less than 55% control; **Figure 3**). Mowing was the least effective treatment with approximately 40% control of the target species. Recovery of target species in chemical treatment plots to mowing control levels is unlikely to occur rapidly because damage assessments of treated stems indicated nearly lethal damage. This demonstrates that the efficacy of triclopyr (Garlon XRT) and imazapyr (Arsenal Powerline) for short-term woody species control on northern ROWs are comparable to results reported for more southern/temperate jurisdictions (Bramble et al. 1991; Luken et al. 1991; Mercier et al. 2001; Yahner and Hutnik 2004).

All treatments caused a neutral to minor reduction in percent cover (up to16% for triclopyr broadcast spray) of the four monitored non-target plant life-form groups of erect shrub, prostrate shrub, forb and graminoid cover (**Figure 3.2** of **Appendix B**). Decreases in non-target shrub and herbaceous cover are commonly reported one year after both mechanical and chemical site preparation techniques in boreal clear cuts (Sullivan et al. 1996; Man et al. 2010). Furthermore, as treatments were applied by hand, the observed reduction in percent cover of non-target plants might partly be attributable to trampling.

Imazapyr broadcast spray, though most effective at controlling target species (94% reduction, **Figure 3**), also caused greater visual damage and, in some cases, cover reduction to non-target vegetation than other treatments (**Figure 4**). Prostrate shrubs were the exception and the most common species, kinnikinnick (*Arctostaphylos uvaursi*), appeared to tolerate imazapyr well. Leaf chlorosis, stunted growth and tissue deformity of many species occurred after broadcast spraying. Chlorosis, deformity and stunting of forbs were common in cut stump and point injection plots, but severity was highly species specific. The variability in sensitivity confirms that plant species exhibit a large range of tolerances to imazapyr (Bovey and Senseman 1998; Douglass et al. 2016). Observed damage to non-target species in the imazapyr cut stump and point injection plots indicate that imazapyr persists in the environment at concentration not high enough to prevent non-target species germination, but had sufficient potency to cause visible injury. Alternatively, imazapyr may translocate from target species to non-target species by mechanisms such as mycorrhizal association (Barto et al. 2011).

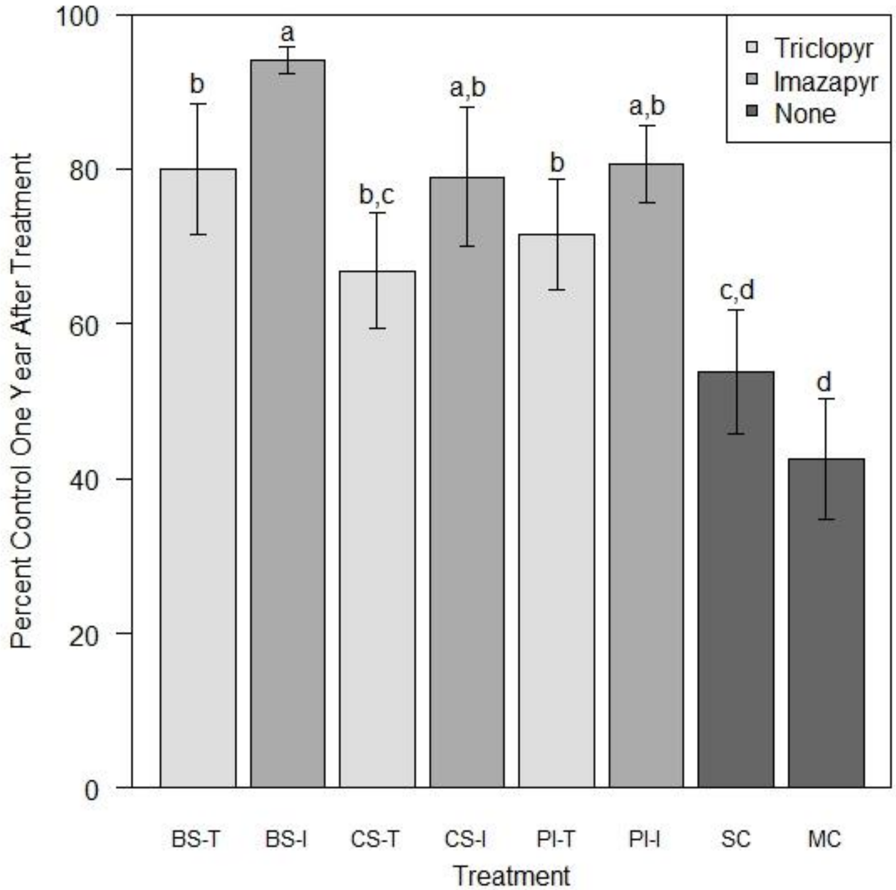

Figure 3 Control of target species (trembling aspen, balsam poplar, willow, and Alaska paper birch) on Yukon power line rights-of-way one year after eight vegetation management treatments. Percent control is defined as the difference in cover between 2014 and 2015, divided by 2014 cover x 100. Shading indicates type of herbicide and treatment codes are described in Table 1. Error bars represent standard error with n= 17, 21, 19, 16, 22, 26, 16, 15 for each treatment; n differs between treatments as all four target species were not present in each plot. Different letters indicate statistically significant differences between least square means ($p < 0.05$). Figure was originally presented in **Appendix B**.

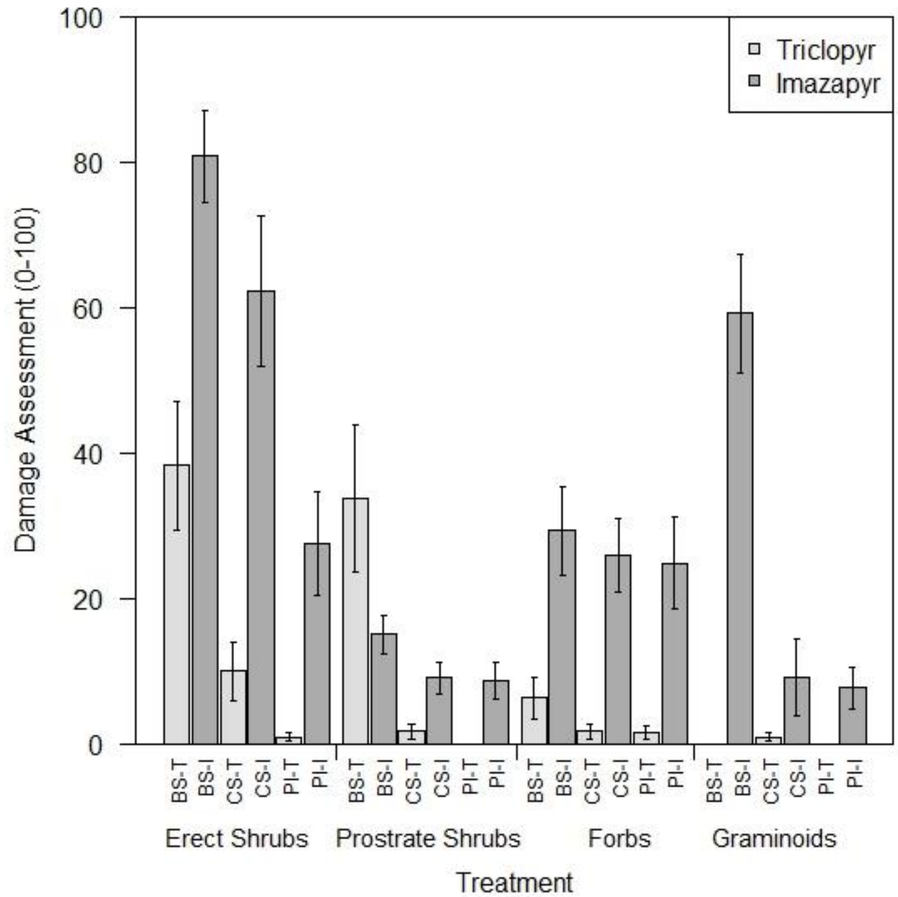

Figure 4 Herbicide damage to non-target vegetation one year after right-of-way vegetation management treatments were applied in Yukon. Mean damage assessment values (0-100) are grouped by life form and shading indicates the different herbicides used. Treatment codes are described in Table 1. Error bars represent standard error and for erect shrubs: n=11,7,9,6,8,10; prostrate shrubs: n=11,12,11,9,10,10; forbs: n=12,12,11,11,11,11; and graminoids: n=12,12,11,11,11,11 Figure was originally presented in **Appendix B**.

In contrast to imazapyr, broadcast spray of triclopyr substantially reduced prostrate shrub cover (up to 16%), but had less effect on percent cover on other non-target plant life-forms. Furthermore, there was limited visual damage from triclopyr using other application methods. The recovery of forbs and substantial increase in grass cover two years after triclopyr broadcast spray and cut stump applications has been demonstrated in both boreal forests and rangelands (Bell and Newmaster 2002; Seefeldt et al. 2013). It is likely that herbaceous species abundance on Yukon ROWs will increase by the second year after triclopyr treatments. Recovery time for shrubs after triclopyr applications is less consistent ranging from 2-5 years (Bell and Newmaster 2002; Seefeldt et al. 2013).

Treatment effects on non-target species, overall, were life form or species specific which is encouraging. Treatments were designed to impact life forms differently based on species' height and physiology (monocot vs. dicot) to induce different recovery trajectories. Evidence of early community changes indicates the initial plant community compositions of treatment plots were altered; hence, the development of new and distinct plant communities can be expected over time (Niering 1987; Strong and Sidhu 2005).

Whether the composition of these new plant communities will be consistent with ROW management goals is unknown at this time. The most important changes in species composition and abundance in boreal forests usually occur in the initial years following disturbance (de Grandepre and Bergeron 1997). This hypothesis likely applies to Yukon ROWs. Data from two years after treatment is available; however, it is unlikely that trends would significantly differ from those observed one year after treatment. The ability to characterize future plant communities and their capacity to resist the regrowth or invasion by target species is limited by the length of the current study. Monitoring vegetation following treatment disturbance for at least one cycle equivalent to the current ROW mowing practice (8 to 10 years) is needed for full evaluation of community development at the field sites.

4.2. Dissipation of Triclopyr and Imazapyr from Treated Plot Soil and *Salix glauca* (White Willow) Foliage

4.2.1. Soil Dissipation

The dissipation rate of triclopyr (**Figure 5**) for broadcast sprayed ROW soil at the LS site was faster than imazapyr (**Figure 6**). Whereas the DT_{50} (time required for herbicide concentration to decrease to 50% of initial) was 1 DAT (day(s) after treatment), it was 16 DAT for imazapyr. This corroborates with the understanding that imazapyr does persist longer in soil than triclopyr (Senseman 2007; Douglass et al. 2016). Rapid dissipation of triclopyr indicates that it is readily lost from soil through volatilization and photodegradation mechanisms (Hill and Schaalje 1985). In contrast, slower imazapyr dissipation indicates its persistence in the environment is likely controlled by soil adsorption and microbial degradation processes (Wang et al. 2005; Gianelli et al. 2014).

The calculated rates for both herbicides in LS soils likely represent best-case scenarios because they are much faster than those reported in other studies. In northern Ontario, triclopyr residues had longer residual periods in soil with a DT_{50} of 14 days (Stephenson et al., 1990). In addition, triclopyr was shown to have half-lives ranging from 5 – 16 days in varying soils from Colorado (Douglass et al. 2016).

Similarly, published imazapyr DT_{50} values ranged from 37 to 144 DAT (Börjesson et al. 2004; Wang et al, 2005; Newton et al. 2008; Gianelli et al. 2014). In addition, we observed higher concentrations of residues for both herbicides applied via backpack spraying at other site soils included in this study (**Table 3**).

Even though dissipation rate as defined by DT_{50} was rapid in this study, persistent concentrations of both triclopyr and imazapyr was detectable at least one year post treatment at all field sites (**Table 3**). These residuals are likely related to observable damages to target and non-target new-growth (**Section 4.1**; **Appendix B**). In Alaska, the majority of residues dissipated during the summer months with residues falling below quantification limits within 100 days of herbicide treatment (Newton et al. 2008). In contrast, triclopyr residues in forest soils in Sweden were observed up to two years after application (Torstenssen and Stark 1982). Imazapyr is known to persist even at 454 and 730 DAT in Alaska and Sweden, respectively (Torstenssen and Stark 1982; Newton et al, 2008).

However, herbicide persistence in soil can be mitigated by application method (**Table 3**). For the cut stump treatment, the concentration of triclopyr was minimal or below detection limits in most soil 365 DAT. This coincides with the hypothesis that the transfer of triclopyr to the soil through root exudation is minimal (Braverman 1995; Wahlers et al. 1997). For point injection the majority of the residues dissipated between 30 and 365 DAT. However, imazapyr residues were above detectable limits for both cut stump and point injection treatments at both time intervals. Residual concentrations for the imazapyr point injection treatment were actually similar to those observed for the spray application technique and are present at concentrations high enough to effectively control target species and also have a pronounced effect on non-target species (**Table 3**). Based on these results point injection may be a viable alternative to broadcast application (Nowak and Ballard 2005a). Furthermore, there is higher risk associated with the use of imazapyr compared to triclopyr from the perspective of soil persistence and effects to non-target species.

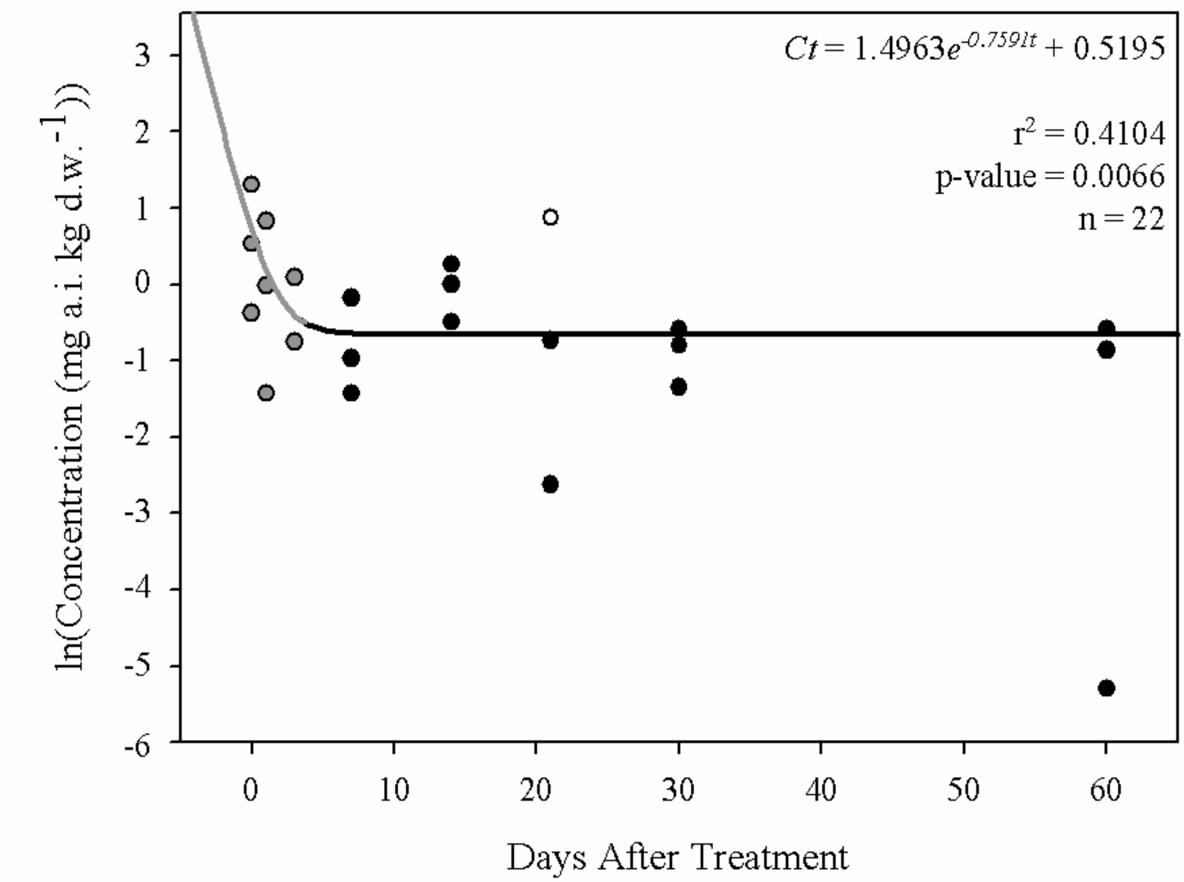

Figure 5 Dissipation model for triclopyr residues in the upper soil horizon at the LS site. A three parameter biphasic dissipation model was the best fit for the data (r^2 = 0.4104). Calculated DT_{50} and DT_{90} values based on this model are 1 DAT and 3 DAT, respectively. The concentration in the persistent phase is 0.52 mg a.i. kg^{-1} soil. Grey line and circles represent the first phase modeled with first order kinetics while the black dots and line represent the persistent phase. The open circle indicates data point that was removed to obtain optimal model fit, but it was not statistically identified as an outlier. Figure adapted from **Appendix C.**

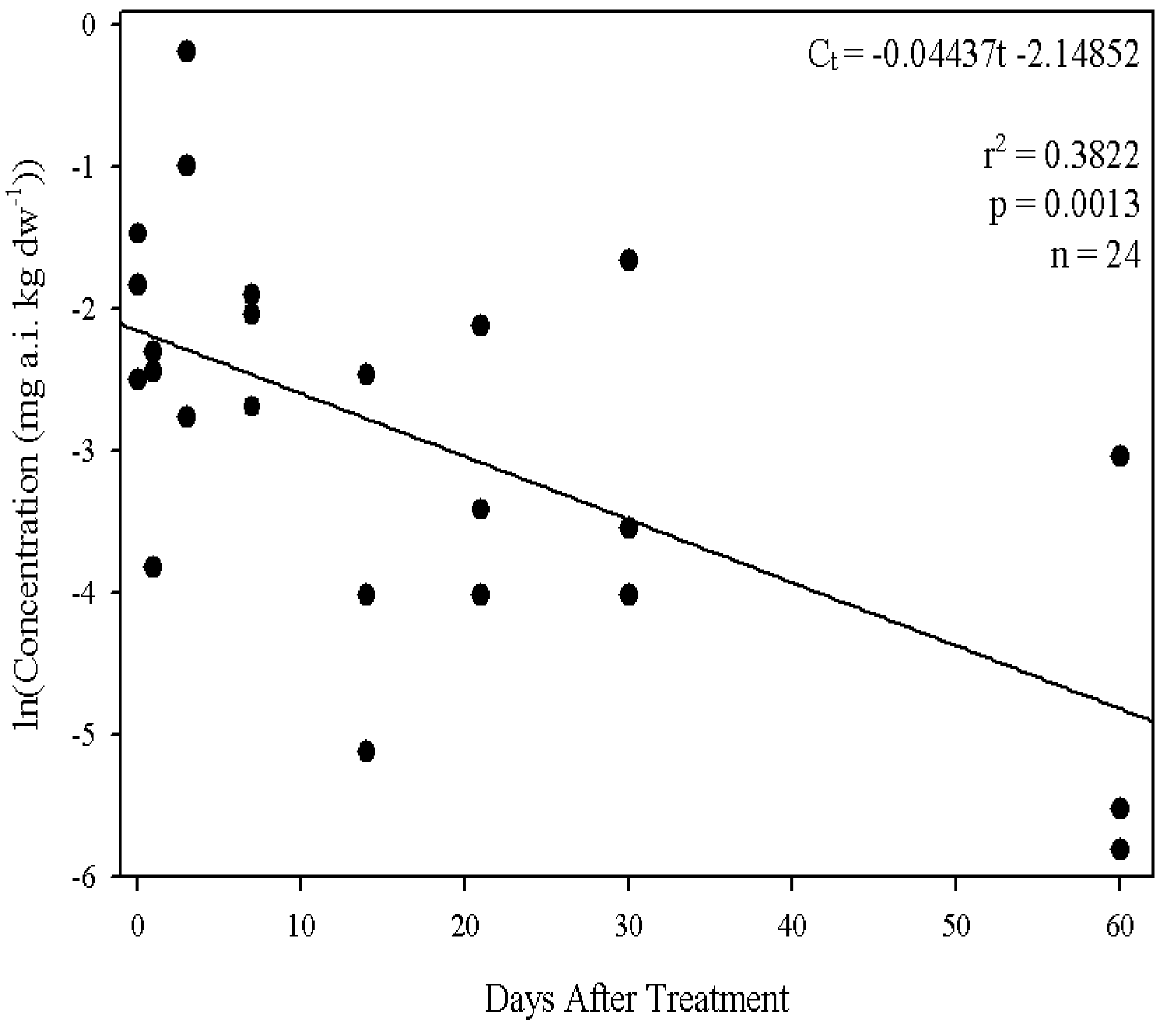

Figure 6 Dissipation model for imazapyr residues in the upper soil horizon at the LS site. First order model best described the dissipation of imazapyr from LS soil (r^2=0.3822) from soils collected from the upper soil horizon (0-3 cm). The DT_{50} and DT_{90} were calculated as 16 and 52 DAT, respectively.

Table 3 Triclopyr and Imazapyr concentrations (mg active ingredient per kg dry weight) for the backpack spray (n=3), cut stump (n=1) and point injection (n=1) treatments at 30 and 365 days after treatment at four sites (CAR, DAW, HJ1, HJ2), as well as, the Mean ± SE for treatment and time interval across all sites. <0.005 indicates concentrations were below detection level for triclopyr. Cut stump and point injection treatments were not analyzed for the LS site. As a result, LS was not included in this table. NA = Not Analyzed.

Herbicide	Site	Days After Treatment					
		Backpack Spray		Cut Stump		Point Injection	
		30	365*	30	365	30	365
Triclopyr	CAR	3.1	NA	0.13	<0.005	0.34	0.05
	DAW	8.0	NA	3.8	<0.005	32	0.09
	HJ1	2.4	NA	<0.005	0.04	0.04	<0.005
	HJ2	0.42	NA	1.1	<0.005	0.25	0.83
	Mean±SE	3.46 ± 1.61	NA	1.26±0.88	0.01±0.01	8.16±7.95	0.24±0.20
Imazapyr	CAR	0.16	0.01	0.02	0.01	1.6	0.08
	DAW	0.12	0.01	0.002	0.01	0.57	0.02
	HJ1	0.07	0.02	0.16	0.01	0.001	0.004
	HJ2	0.12	0.005	0.03	0.003	0.002	0.01
	Mean±SE	0.12 ± 0.02	0.012 ± 0.003	0.05 ± 0.04	0.01 ± 0.002	0.54 ± 0.38	0.03 ± 0.02

* 365 Days After Treatment samples were not analyzed for triclopyr.

4.2.2. Dissipation from *Salix glauca* (White Willow) Foliage

The rate of triclopyr dissipation from *S. glauca* foliage was slower than anticipated. A first order model best described the dissipation of triclopyr from *S. glauca* foliage (**Figure 7**; r^2=0.7647). The initial mean concentration was approximately 1200 ug/g and the final mean concentration on Day 30 was 197 ug/g. The estimated DT_{50} of 11.5 days is slower than the expected 1.5 to 2 days (Whisenant and McArthur 1989; Thompson et al. 1994). This is also slower than what was observed for triclopyr dissipation from soil (**Section 4.2.1**). Cooler temperatures during the study period may have slowed triclopyr metabolism and dissipation from *S.glauca* (Bentson and Norris 1991). Note that an error in the conversion between ppm (part per million) fresh weight and ug g^{-1} dry weight with the data for the dissipation of triclopyr from *S. glauca* foliage occurred during the preparation of the thesis presented in **Appendix B**. The corrected data are presented in **Figure 7**.

Triclopyr in *S. glauca* foliage did not dissipate to low or undetectable levels by the end of the 30 day experiment. Research in Alaska demonstrated near complete dissipation of triclopyr from vegetation within 30-45 days (Newton et al. 2008) which is similar to dissipation published for southern studies (Whisenant and McArthur 1989, Thompson et al. 1994). The results from this study do not support that northern herbicide dissipation rates are similar to rates in warmer climates. Newton et al. (1990) also reported relatively high levels of triclopyr persisting in vegetation; however, their study included conifers with substantially different leaf morphology making comparisons difficult. *S. glauca* leaves were dried and shriveled at 30 DAT suggesting metabolic degradation of triclopyr residues had ceased. The deposition of leaves as litter may provide a secondary input of triclopyr residues into the soil (Tatum 2004; Thompson et al. 1994).

In contrast to triclopyr, imazapyr dissipation from *S. glauca* foliage was initially very rapid (DT_{50} = 1.5 days) followed by a persistent phase from Day 14 onwards. The initial mean concentration was 259 ug/g and the mean concentration by Day 30 was approximately 35 ug/g. The bi-phasic nature of imazapyr dissipation from vegetation is reflected in the rapid herbicidal effect of imazapyr on the treated *S. glauca* where most plants were wilted within seven days after treatment, and no further metabolism of imazapyr was possible from that time forward.

The persistence of both herbicides in soil and vegetation may potentially impact non-target organisms. Even though both triclopyr and imazapyr have relatively rapid initial dissipation rates in soil and *S. glauca* foliage in the field, both herbicides did persist at detectable concentrations in both environmental compartments. Furthermore, visual damage to non-target plant species was observed at one year after treatment (**Section 4.1**). The residual phytotoxic effects is actually desirable from a ROW-management perspective as it provides extended control of target plant species, which might help drive the development desirable floral communities even if some non-target plant species might be affected. However, it also represents potentially longer exposure period to these chemicals for other ecological relevant but non-target organisms. The potential risk from exposure to the residual concentrations of these two herbicides to ecological receptors is evaluated in **Section 5.0.**

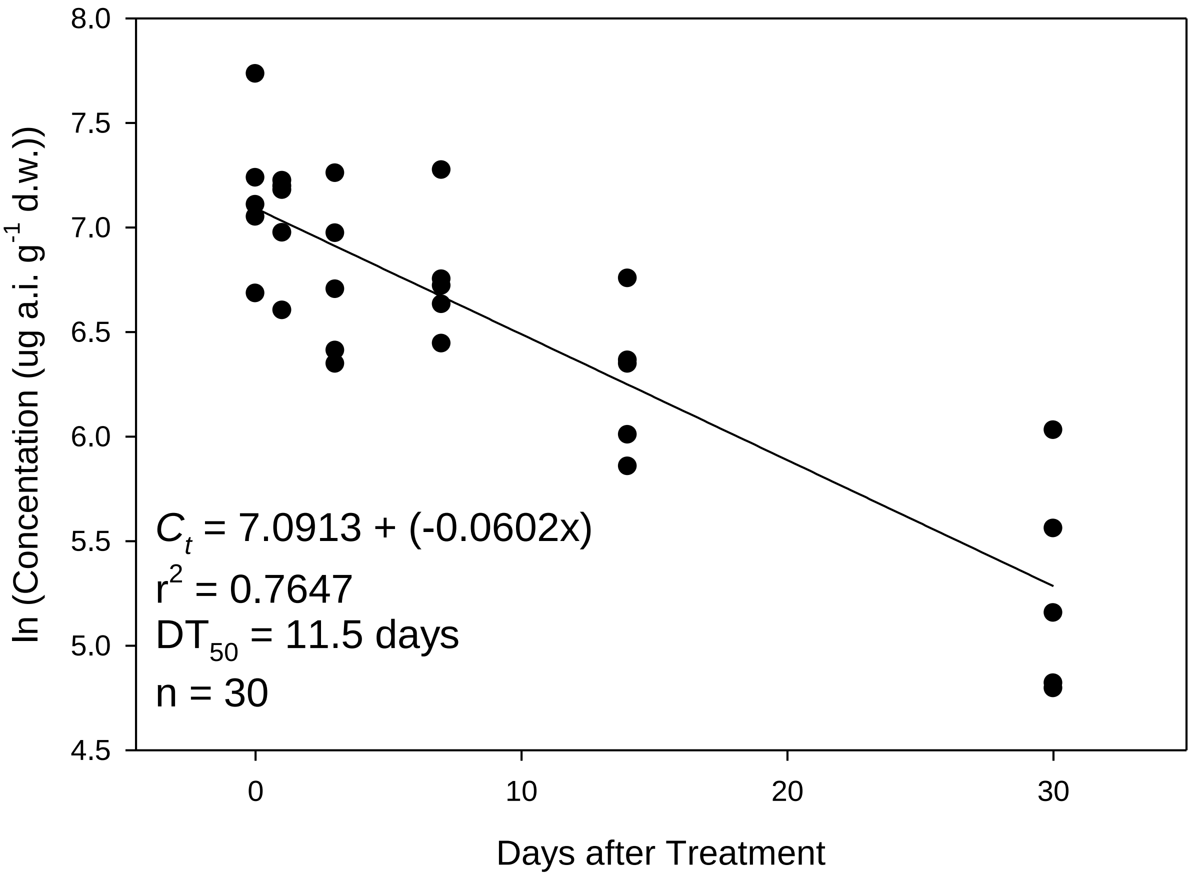

Figure 7 Dissipation of triclopyr residues in *Salix glauca* foliage on a Yukon power line right-of-way over a 30 day period between June 2nd and July 2nd, 2015. A first order model best described the dissipation of triclopyr from *S. glauca* foliage (r^2=0.7647). This indicated triclopyr concentration declined at a constant rate in plant tissue during the monitored 30-day period. The initial mean concentration was approximately 1200 ug/g and linearly declined to 197 ug/g by Day 30. The estimated DT_{50} = 11.5 days. Adapted from **Appendix B.**

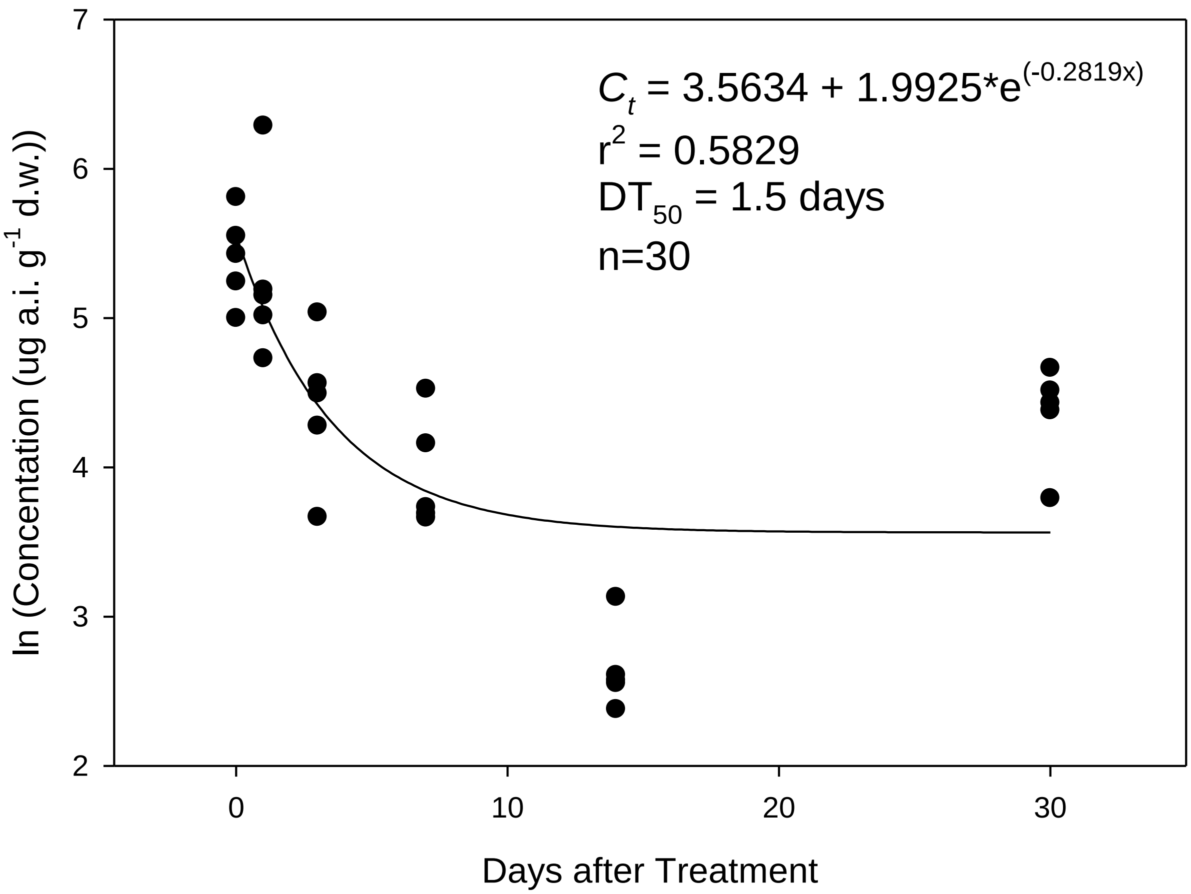

Figure 8 Dissipation of imazapyr residues in *Salix glauca* foliage on a Yukon power line right-of-way over a 30 day period between June 2nd and July 2nd, 2015. A biphasic (two-stage) model best described the dissipation of imazapyr from *S. glauca* foliage (r^2=0.5829). This indicated that imazapyr rapidly dissipated (DT_{50} = 1.5 days) from *S. glauca* tissue within the first seven days of monitoring followed by a persistent phase from Day 14 onwards. The initial mean concentration was approximately 259 ug/g and the mean concentration by Day 30 was approximately 35 ug/g.

4.3. Herbicide Toxicity Testing with Non-Target Boreal Plants and Soil Invertebrates

4.3.1. Plants

The vegetative forms of both tested non-target boreal plant species were very sensitive to either herbicides (**Figure 9**). Imazapyr and triclopyr caused significant damage to *C. angustifolium* with an IC_{50} (inhibitory concentration where 50% of the population is affected) estimate of 1.2% of maximum field application rate for imazapyr. No IC_{50} estimate for triclopyr and *C. angustifolium* was possible because all tested doses were lethal; however, this was a function of a calculation error that resulted in a tested dose range of only 25 to 100%. *Achillea millefolium* was equally sensitive to imazapyr (IC_{50} = 0.7% of maximum field application rate), but showed signs of recovery (new leafs) after damage by triclopyr (IC_{50} = 31.3% of maximum field application rate). The potential for recovery is linked to the field observation where percent cover of *A. millefolium* did not decrease significantly in triclopyr broadcast spray plots one year following treatment (**Section 4.1; Appendix B**) and the more rapid dissipation rates observed from soil and vegetation for triclopyr (**Section 4.2**). The high phytotoxicity of both herbicides on non-target plant species is not unexpected as the herbicides are designed for vegetative control of both herbaceous and woody species. Many desirable species on northern ROWs are categorized as weeds in other settings (e.g. *C. angustifolium* competes with conifer seedlings in the boreal forestry industry (Hangs et al. 2003)).

In the emergence and seedling growth test, germination percentages of all species were reduced when exposed to >10 µg triclopyr g^{-1} soil; however, *C. angustifolium* seeds were the most sensitive (EC_{50} = 1.56 µg g^{-1}). Higher concentrations relative to the application rate of imazapyr (5-12 µg g^{-1} ≈ 1x the maximum application rate) were required to inhibit germination of *A. millefolium* (EC_{50}=63.60 µg g^{-1}). *C. angustifolium* seeds were again more sensitive than *A. millefolium* while *C. canadensis* (EC_{50} = >100 µg g^{-1}) germination was relatively insensitive to imazapyr. In soils, imazapyr was more phytotoxic to seedlings than triclopyr. Where information was available, IC_{50} estimates of the boreal species were typically within the range of standard test species; however, most endpoints of this test were at the more sensitive end of the spectrum. This might indicate greater bioavailability of the herbicides in the ROW soils relative to other studies.

From a vegetation management perspective, broadcast spray application of imazapyr or triclopyr at rates appropriate for woody species control will likely cause significant damage to *C. angustifolium* and *A. millefolium*. The very high sensitivity to imazapyr also indicates both species may be substantially damaged by drift from spray applications. In soil, triclopyr inhibited germination at lower concentrations than imazapyr, but imazapyr was significantly more phytotoxic to seedlings. Even if triclopyr degrades rapidly, residues could potentially limit *C. angustifolium* germination for a short period of time after application. If imazapyr persists in soil, which is common in soils with low pH and high organic matter, the herbicide could cause significant damage to *C. angustifolium* and *A. millefolium* seedlings. If preservation of herbaceous non-target species is a management objective, use of imazapyr for woody species control on northern ROWs is not recommended.

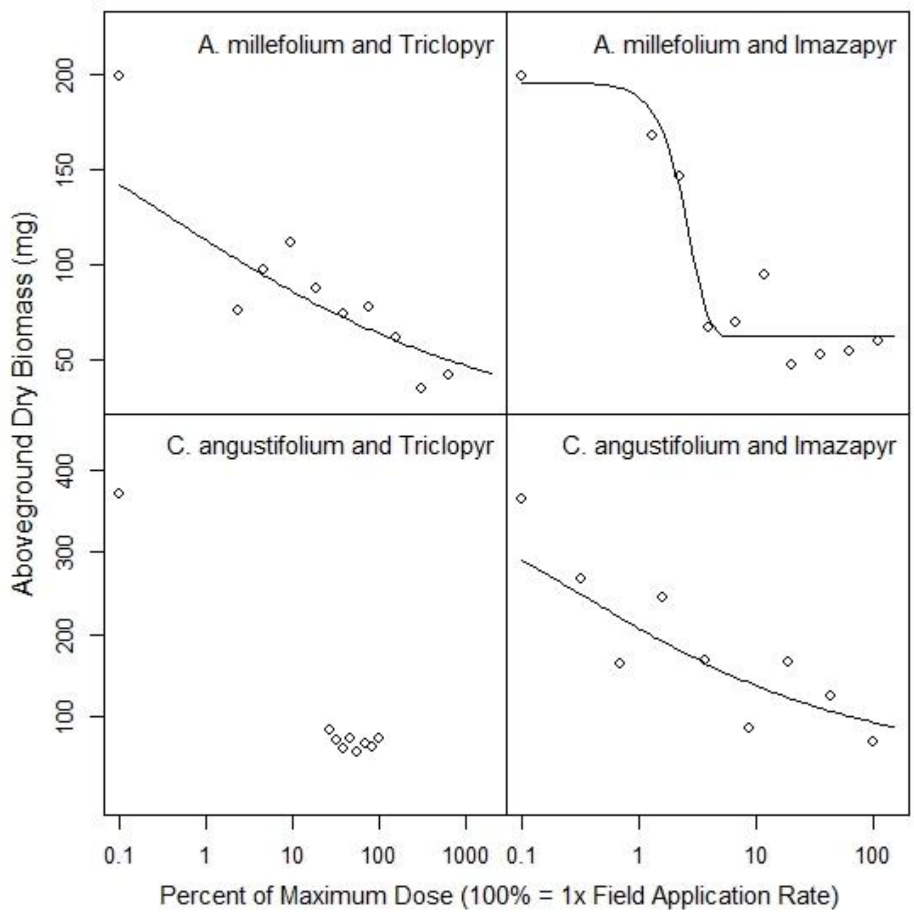

Figure 9 *Achillea millefolium* and *C. angustifolium* dose response curves for the 28 day vegetative vigour test: imazapyr or triclopyr applied as a foliar spray. 100% of maximum dose is equivalent to the maximum field application rate for woody species control (720 g imazapyr ha^{-1}, 4530 g triclopyr ha^{-1}). The IC_{50} estimate for *C. angustifolium* and imazapyr was 1.2% of the maximum field application rate (±0.9SE, n=30). A dose response curve could not be generated for *C. angustifolium* response to triclopyr as all doses were lethal. IC_{50} estimates were 0.7% (±0.3SE, n=49) for *A. millefolium* and imazapyr and 31.3% (±22.4SE, n=55) for *A. millefolium* and triclopyr. Lack-of-fit test comparing dose response curves to a one-way ANOVA indicated adequate fit in all three fitted models (p>0.05). Adapted from **Appendix B**.

4.3.2. Soil Invertebrates

In contrast to the herbicide phytotoxicity tests with the non-target plant species, the three soil invertebrate species tested were insensitive to triclopyr and imazapyr in all five field soils (**Figure 10**). This was reflected by the use of LC_5 (lethal concentration where 5% of the population was affected) or EC_5 to estimate the concentrations for the two herbicides that is needed to elicit a detectable/observable effect on the soil invertebrates. In ecological toxicology, LC_5 and EC_5 estimates are normally reserved for protection of individual organisms or species at risk and endangered species where the loss of a few sensitive individuals from a population will impair that population and the ecological function they serve with high probability. Although these populations serve important ecological functions, there are no known endangered or at-risk soil invertebrate species that require this level of protection.

Soil invertebrates are unlikely to be exposed to levels of triclopyr or imazapyr even at the LC_5 or EC_5 level in the field. For example, the triclopyr EC_5 for reproduction in CAR and DAW soils were estimated at 66.2 and 55.9 mg a.i. kg^{-1} soil dry weight, respectively. However, from the **Appendix C** and **Section 4.2.1**, even when applied as foliar spray, mean soil concentration of triclopyr at CAR and DAW did not exceed 6 mg a.i. kg^{-1} soil dry weight when measured 1 DAT. Field concentration declined rapidly with time. Therefore, any adverse effects observed in these tests are unlikely to occur in the field. For comparative purposes, all LC_{25} and EC_{25} values are available in **Appendix C.**

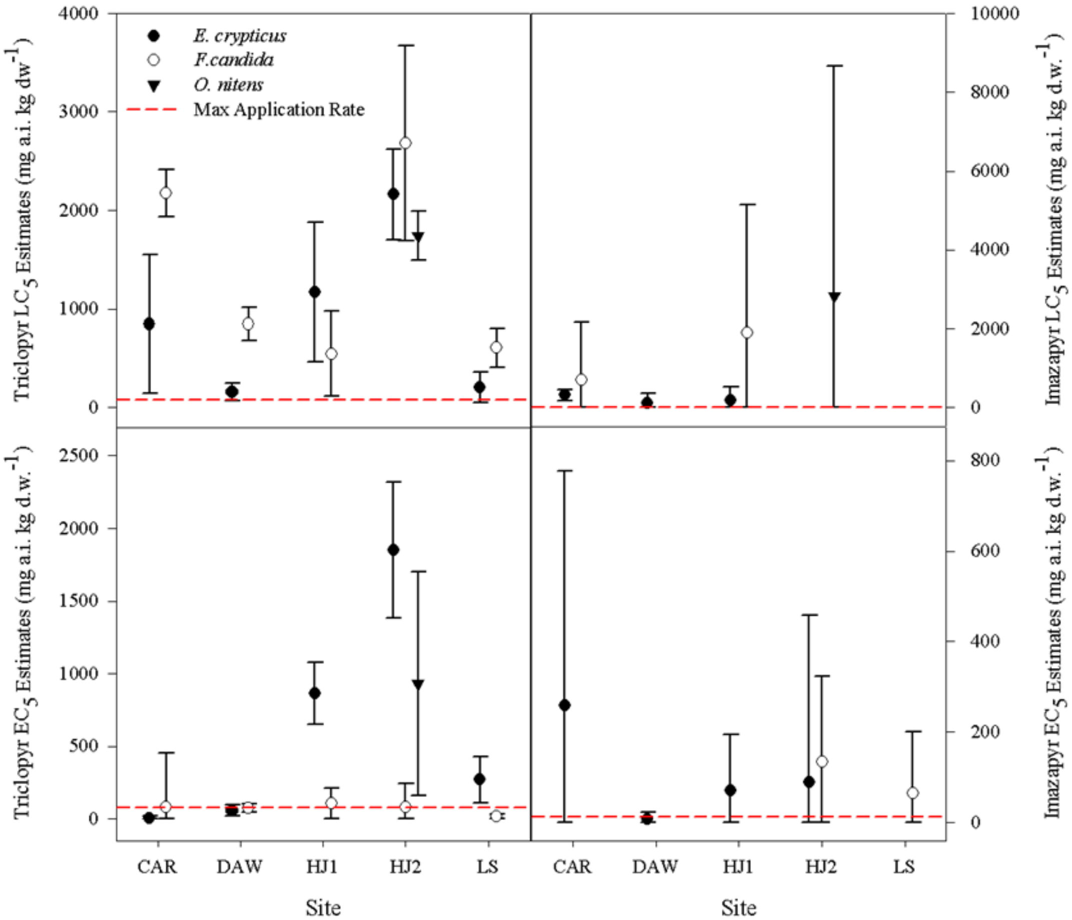

Figure 10 Summary of LC_5 and EC_5 values for *E. crypticus*, *F. candida* and *O. nitens* response to triclopyr and imazapyr from organic soils collected at five ROW sites in the Yukon Territory, Canada. Triclopyr results are on the left and imazapyr are on the right. LC_5 values are in the top panels with EC_5 values in the bottom panels. Symbols represent the species with bars representing the 95% confidence intervals. Negative lower confidence intervals were corrected to 0. The red dashed line represents the maximum field-equivalent application rates of 75.5 mg triclopyr kg dw^{-1} and 12.0 mg imazapyr kg dw^{-1}. Adapted from **Appendix C**.

5.0 PRELIMINARY ASSESSMENT OF RISK FOR IMAZAPYR AND TRICLOPYR RESIDUES TO NON-TARGET ECOLOGICAL RECEPTORS (TERRESTRIAL MAMMALS AND BIRDS)

The dissipation characteristics of both herbicides in soil and vegetation (*S. glauca* in particular) demonstrated in **Section 4.2** indicated that their persistence in both environmental compartments could pose potential risk to the health of ecological receptors if affected soil and vegetation are consumed. This section attempts to quantify these potential risks from imazapyr (Arsenal Powerline) and triclopyr (Garlon XRT) exposure to terrestrial mammals and birds.

Conceptually, for the purposes of this preliminary assessment, only the direct ingestion of herbicide residue in *S. glauca* by herbivorous terrestrial mammals and birds is considered. Alternative exposure pathways (e.g., inhalation, direct dermal contact), exposure media (e.g., affected surface and groundwater, soil invertebrates, insects, etc.), transport and bioaccumulation mechanisms, and ecological receptors (e.g., aquatic organisms, carnivorous organisms) are not considered because: a) herbicides are unlikely to reach groundwater; b) herbicides are not known to bioaccumulate; c) herbicides will not be used within buffer zones to surface water bodies; and, d) insufficient information is available for quantification. In addition, human health risk from consumption of herbicide residue in affected vegetation is not considered.

This preliminary ecological risk assessment (ERA) was prepared in accordance with applicable guidance from various regulatory jurisdictions. Primary guidance was from the following documents:

- Health Canada (2012) – Federal Contaminated Sites Action Plan (FCSAP): Ecological Risk Assessment Guidance;
- Ontario Ministry of the Environment and Climate Change (OMOECC, 2011) – Rationale for the Development of Soil and Groundwater Standards for use at Contaminated Sites in Ontario; and,
- British Columbia Ministry of the Environment, Lands and Parks (1998) – Recommended Guidance and Checklist for Tier 1 Ecological Risk Assessment of Contaminated Sites in British Columbia.

Aside from problem formulation (i.e., quantify potential risk to ecological receptors from consumption of herbicide affected vegetation), the general risk assessment framework is composed of three other elements: 1) toxicity assessment; 2) exposure assessment; and, 3) risk characterization.

Toxicity assessment is concerned with the nature of the chemical of potential concern (herbicides in this case). It involves understanding the toxicological profile of each herbicide and the determination of the dose-response characteristics as quantified by the toxicological reference value (TRV). The acute and chronic TRVs for both herbicides are listed in **Table 4**. Note that based on the acute TRVs, both imazapyr and triclopyr are deemed non-toxic to mammals and birds by the USEPA and Health Canada at this time. Furthermore, the acute and chronic TRVs are calculated with the inclusion of 10-fold and 100-fold safety factors, respectively, to account for trans-species and intra-species variability/uncertainty.

Table 4 Acute and Chronic toxicological reference values of imazapyr and triclopyr

Herbicide	Toxicological Reference Values (mg herbicide kg^{-1} body weight day^{-1})		Reference
	Acute	Chronic	
Imazapyr	500[a]	2.53[b]	USEPA (2006)[a], Health Canada (2016)[b]
Triclopyr	630	5	USEPA (1998)

Exposure assessment is quantifying the amount of herbicide a receptor may absorb into its body over a lifetime. It includes receptor characterization, determination of exposure point concentration, bioavailability assessment, exposure amortization, and exposure analysis. It is numerically summarized by the average daily intake (ADI). The chosen herbivorous receptors, their characteristics, and their ADI are presented in **Table 5**. The ADI for each receptor is calculated by: ADI = food ingestion rate x herbicide concentration in food.

The worst-case scenario is usually first considered when conducting a risk assessment. If the likelihood/probability of risk to ecological receptors is acceptable for the worst-case scenario, other scenarios need not be considered. The worst-case scenario considered here is that the herbivorous ecological receptors will only consume *S. glauca* on the ROW that contains the maximum average observed concentration of imazapyr or triclopyr over the span of their entire lifetime. From **Section 4.2.2**, the maximum average observed concentrations of imazapyr and triclopyr are 0.26 and 1.2 mg herbicide g^{-1} *S. glauca* dry weight, respectively.

The herbivorous receptors chosen for assessment are moose (*Alces alces*), meadow vole/field mouse (*Microtus pennsylvanicus*), and red-winged blackbird (*Agelarius brevicauda*). The food ingestion rate for moose is from McArt et al. (2009) while the rates for the meadow vole and the red-winged blackbird are from OMOECC (2011). It is recognized that the meadow vole and the red-winged blackbird might not be present/relevant in the Yukon; however, they are well characterized receptors that are commonly used as surrogates for uncharacterized herbivorous small mammals and birds that are likely present on the ROW.

Table 5 Ecological receptors, their characteristics and calculated averaged daily intake of herbicides based on worst-case scenario where maximum observed herbicide concentrations persisted in vegetation

Herbicide (max observed concentration)	Average Daily Intake for each Ecological Receptor (mg herbicide kg^{-1} body weight day^{-1})		
	Moose (*Alces alces*)	Meadow Vole (*Microtus pennsylvanicus*)	Red-Winged Blackbird (*Agelarius brevicauda*)
Imazapyr (0.26 mg g^{-1} *S. glauca*)	10.0	0.6	7.4
Triclopyr (1.2 mg g^{-1} *S. glauca*)	46.1	2.8	34.1
Food Ingestion Rate (g *S. glauca* dry weight/day)	38.4	2.3[a]	28.4[a]

[a] Reported values from OMECC (2011) are based on wet weight. Values are expressed based on dry weight by assuming 98% water content in leafs of *S. glauca.*

Finally, risk characterization is the numerical estimation of potential health risks to the receptor from exposure to an herbicide. This is achieved by comparing the estimated site-specific risk levels of a compound (i.e., ADI) to the respective target risk level (i.e., TRV) through the calculation of the hazard quotient (HQ = ADI/TRV). The HQ values for the worst-case scenario are presented in **Table 6**.

Table 6 Likelihood of acute and chronic risk to ecological receptors from consumption of herbicide-affected *S. glauca* based on worst-case scenario where maximum observed herbicide concentrations persists in vegetation.

Herbicide	Receptor	Hazard Quotient = ADI/TRV	
		Acute	Chronic
Imazapyr	**Moose**	0.02	**4.0**
	Meadow Vole	0.001	0.2
	Red-Winged Blackbird	0.01	**2.9**
Triclopyr	**Moose**	0.07	**9.2**
	Meadow Vole	0.004	0.6
	Red-Winged Blackbird	0.01	**6.9**
BOLD	Bold and gray-filled values indicate unacceptable probability of risk		

If HQ < 1, the likelihood of risk is acceptable – no further assessment needed. If HC ≥ 1, the likelihood of risk is not acceptable; therefore, further assessment or integration of study information into the risk scenario is necessary. For example, dissipation rate /persistence of herbicide, proportion of diet/home range of receptors, applicability of/alternative TRV, etc., might be used in revising the calculation of the HQ values.

Acute toxicity to herbivorous animals was unlikely in the worst-case scenario because all calculated acute HQ values are well below the threshold level of 1. This agrees with the current determination by the USEPA and Health Canada that both imazapyr and triclopyr are not acutely toxic to mammals and birds. No further assessment of acute risk is needed for these receptors.

In contrast, the likelihood of risk is not acceptable for moose and red-winged blackbird in the worst-case chronic exposure scenario where the calculated HQ values from chronic exposure to imazapyr or triclopyr are above 1. However, the HQ values calculated for the worst-case scenario is highly conservative. For example, both the moose and the red-winged blackbird are unlike to be exposed to the worst-case scenario for either herbicides throughout their entire lifetime because: 1) both imazapyr and triclopyr dissipates to much lower levels 30 days post treatment (**Figure 7** and **Figure** 8); 2) both animals are unlikely to feed on wilting or wilted herbicide-treated vegetation; and, 3) both animals are unlikely to reside on ROWs exclusively because of relative openness of the area. Furthermore, the 10- and 100-fold safety factors included in the TRV values (**Table 4**) are highly conservative.

By modifying the HQ calculation with the observed mean concentration of imazapyr at 30 days post treatment (0.035 mg g^{-1}), the HQ values for the moose and red-winged black bird becomes 0.5 and 0.4, respectively. The likelihood of risk from chronic imazapyr exposure to these two receptors is considered acceptable in this more realistic scenario. Likelihood of risk from chronic exposure to triclopyr is acceptable with similar alterations to the worst-case scenario.

This preliminary ecological risk assessment is by no means definitive, but based on the available information, exposure to imazapyr and triclopyr at the measured concentrations in *S. glauca* for the representative ecological receptors appear to have minimal risk. The general understanding at this time is that neither imazapyr nor triclopyr is known to have observable acute or chronic effects on terrestrial animals or birds at environmentally relevant concentrations (USEPA and Health Canada). Until further information is available, the results of this risk assessment are in agreement with this consensus.

6.0 COMBINING IVM, GEOGRAPHICAL INFORMATION SYSTEM (GIS), AND COMMUNITY AND CULTURAL VALUES FOR RESPONSIBLE VEGETATION CONTROL ON YUKON POWER LINE RIGHTS-OF WAY

There is clearly no single solution that will be applicable to all situations when managing vegetation over the vast territory represented by the power line ROWs. Each tested method was better than the traditional management method of mowing for controlling target vegetation at least within the one year monitoring period (**Section 4.1**); however, each has issues related to efficacy, persistence (for herbicides), side-effects on non-target plants/animals, and/or public perception. Therefore, it is best to consider each of these tested management methods as tools within the IVM toolbox that is adaptable to stakeholder needs.

6.1. Geographic Information System and IVM

Public consultation and geographical information system (GIS) are too important elements linked to the adaptability of IVM. For example, though herbicides appear to a very promising tool for controlling target plant species on ROWs, even with regulatory approval and license, ROW proximity to or on private properties might preclude its use depending on land-owner consent. Because of such considerations, it is necessary to integrate GIS capacity to help manage and visualize community input to determine buffer zones to water ways, First Nation communities and properties, and other private and public properties.

The following is an example of how GIS can be used for adaptive IVM. **Figure 11** illustrates various sources for potential concern from the public and the government if herbicides were used along this section of the ROW for vegetation control. Potential concerns include the traversing of two water ways by the ROW, proximity to four First Nations properties including an identified trap line, and other private agricultural and industrial sites adjacent to the ROW. Protection of aquatic life and potable or navigable waters is always a primary concern. With the GIS system, aside from identifying obvious buffer zones, additional buffers can be delineated based on topography and the watershed. With changing land claims and other property lines, rapid updates can be managed through GIS. Other important considerations such as potential animal migration routes, First Nation sacred areas, or public recreational areas may be identified through public consultation and be easily located through the GIS process.

Aside from the obvious benefit of quickly and accurately translating consultation information into maps that aids in operational decision-making for IVM, GIS can be used to monitor long-term efficacy of treatment methods, changes in public input over time, and provide quick visual updates for stakeholders. This will demonstrate to the public a commitment to work transparently, cooperatively, and responsibility to adapt and implement the best practices to satisfy vegetation management goals and gain community trust and approval.

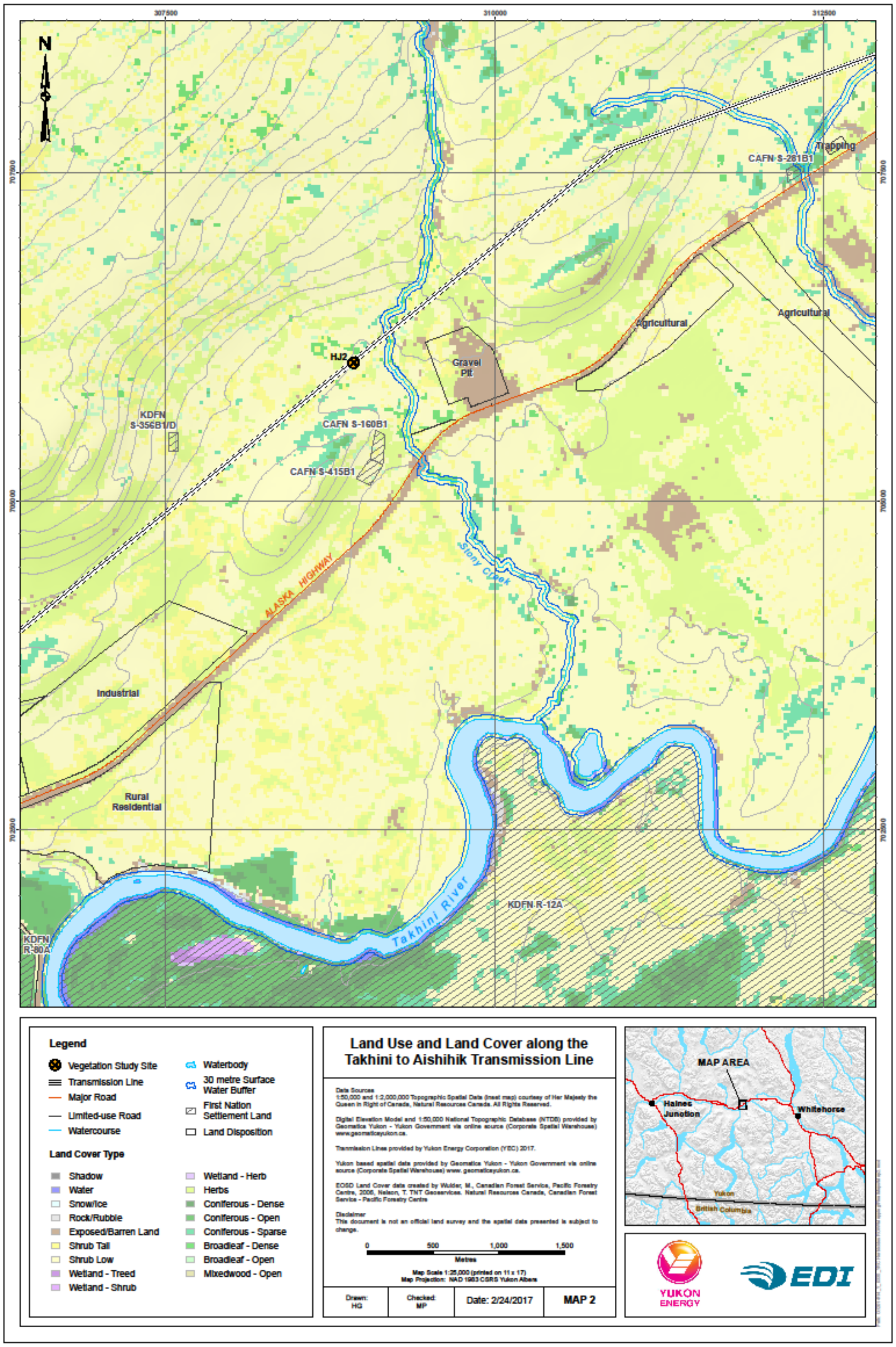

Figure 11 Map of area surrounding the field site at Haines Junction 2 (HJ2). Potential public concerns regarding the use of herbicide for vegetation control may stem from the power line right-of-way traversing two water ways, proximity to four First Nations properties including an identified trap line, and other private agricultural and industrial sites adjacent to this section of the ROW.

6.2. Communication and IVM

Integrated vegetation management can include a combination of chemical, biological, cultural, mechanical, and manual treatments (USEPA 2016). The way in which these methods are combined can dramatically change the communication strategy for use with stakeholders. Communication, within a consultation framework, is defined as an intentional transfer of information designed to respond to public concerns or public needs (Höppner et al. 2010). Effective communication is key to providing land managers in the surrounding areas with all of the necessary information to understand the proposed management strategies. Land managers are people employed with the intention of ensuring there is low risk of serious irreversible harm to the land. In many cases, these are community members themselves who use the land near the ROW and are directly affected by the management strategy.

Vegetation management strategies serve different purposes and should fulfill the various needs of the stakeholders. It is crucial that the target audience for communication be identified and that the means of communication are directed at this audience in order to improve the efficacy of the consultation process (Lahr and Kooistra 2009).

A vegetation management plan can be considered effective if the risk management program addresses liabilities created by trees and other plant life that pose the largest threat to electrical transmission and distribution systems (Cieslewicz and Novembri 2004). However, it is also necessary that regulatory compliance, public and employee safety, and public concerns are understood, engaged, and mitigated. IVM plans need to incorporate communication to be considered a valuable approach.

To carry out an IVM program, information regarding vegetation management operations, treatment efficacy, as well as, on-going monitoring of vegetation community development on the ROW is needed. Furthermore this information can then be used to deploy personnel, forwarded to regulators, and shared with the public (Cieslewicz and Novembri 2004). Another aim of communication is to improve awareness and knowledge of any associated risks of the plan to the community. This is especially crucial when there are contentious aspects to a management plan. To accomplish acceptance and usability of herbicides as part of an integrated vegetation management strategy, involvement from stakeholders is essential.

Co-management is one approach to vegetation management that involves a multidisciplinary group of people working together to develop a strategy. The rationale for this approach has come from the experience of managers struggling to integrate a strategy within the socio-economic fabric of the surrounding region (Lane 2001). An example of this could include developing a technical aspect of IVM, such as selective herbicide application, while considering socio-economic benefits to the local community by providing employment opportunities. Furthermore, a co-management approach could consist of technical representatives from a utility collaborating with First Nations to develop and design baseline vegetation studies on ROWs near their Traditional Territory. Developing cooperative relationships with local stakeholders and sharing the burden of management responsibilities has emerged as a new paradigm (Lane 2001). Stakeholder involvement and public participation are essential for informed decision-making, leading to better awareness and greater acceptance and trust in the end management strategy. This involves developing a framework for interpretation and informed decision-making regarding results.

For example, the Canadian Pacific Railway (CPR 2015) IVM Plan discusses the management of vegetation on properties owned by Canadian Pacific Railway including, but not exclusive to, ROWs. This plan described CPR's planning process and how these approaches ensure vegetation management while considering and incorporating environmental and human health values (CPR 2015). The objectives of the IVM program are to prevent or manage unwanted vegetation, including the control of noxious weeds and invasive plants. Prior to implementing vegetation management, general site conditions and environmental sensitivities are assessed and documented by qualified persons, such as the proximity to water bodies and water sources. A justification of herbicide use for each area is provided, as well as, the different application methods to be used and their rationale. This information is made available to the public through shared documents. A description of the reporting, notifications completed and approaches that will be taken to complete public consultation is also included in the plan. The consultation plan clearly describes its objectives and how and when it will be publicly advertised. A summary of public consultations, as well as, the nature of concerns and/or recommendations is provided. CPR describes in their First Nations Consultation plan wanting to ensure that First Nations have an opportunity to identify concerns and for CPR to address those concerns before the IVM plan is finalized and a Pesticide Use Notice is submitted for confirmation (CPR 2015).

In contrast, the BC Hydro Facilities IVM Plan (BC Hydro 2016) discusses in detail the requirements for responsible treatment options and method selection criteria for suppressing vegetation populations. However, it is limited in its description of communicating this to the relevant public. Before work starts with the use of herbicides, BC Hydro mentions that input from parties who may be significantly impacted will be pursued. However, the management plan does not explain the qualifications for the parties to be deemed significantly impacted, nor does it describe the process by which the input will be collected (BC Hydro 2016). Similar to the Canadian Pacific Railway IVM plan, BC Hydro lists in its IVM plan the descriptions of all approved herbicides and describes the different application methods and their rationale. As well, the report clearly defines the management areas within sites that have different action thresholds for vegetation control and those areas which should remain herbicide-free at all times, such as watersheds, riparian areas, and water sources (BC Hydro 2016). However, while discussing measures to protect community watersheds, it does not mention processes where the communities in question will be engaged on this subject or provided relevant documentation. In order for there to be an engaged public, there must be a clear consultation plan in place within the IVM plan. This includes clearly defined objectives and how and when these objectives will be publicly advertised. To have valuable consultation, the public must then have an opportunity to share their response. This can be completed through many avenues, one of which being public meetings, where the public can share their concerns and/or recommendations with the utility. In **Appendix D** example materials that could be used for communications with the public regarding IVM and herbicide-use are provided.

Despite a wide diversity in circumstances, communication and community engagement should ideally pursue a set of common objectives: 1) to equalize power differences within the research/consultation process; 2) to build trust and ensure transparency; and, 3) to provide opportunities to identify concerns and have time and an appropriate channel to address those concerns.

In on-going work regarding IVM, herbicide-use and community concerns regarding vegetation management strategies in boreal Saskatchewan, research is being conducted to improve informed environmental decision-making among Indigenous communities and a Crown corporation (Brock 2017). This research is a collaboration between SaskPower, Lac La Ronge Indian Band (LLRIB) and the University of Saskatchewan. Through a multi-stage process of literature review, interviews and workshops, primary outcomes from this work will include:

- A foundation for LLRIB, SaskPower and the Ministry of Environment to work together in the future on vegetation management along rights-of-way in traditional territory;
- A modified framework for good-practice engagement that supports on-going, collaborative and respectful relationships, and that contributes to informed decision-making for application in other settings; and
- A good-practices engagement handbook for Industry that provides guidance on establishing respectful partnership between Indigenous peoples and Industry

7.0 CONCLUSIONS

Integrated Vegetation Management incorporates both environmental and socio-economic values into a sophisticated system of power line ROW vegetation management. The first step in developing an IVM program is gathering information on the disturbance dynamics of local ROW plant communities. The research presented was designed to provide northern-specific information for power line vegetation mangers in Yukon considering adopting an IVM model.

Impacts of eight vegetation management methods were evaluated on ROW plant communities one year after treatment at four Yukon ROW sites (**Section 4.1**). The sites were located in three biogeoclimatic zones, and although plant communities differed at each site, treatment effects were consistent among sites. Findings from this field trial include:

- Chemical management with the herbicides triclopyr (Garlon XRT) and imazapyr (Arsenal Powerline) was more effective (75 to 95% reduction of target) at controlling target woody species than mechanical cutting (<50% reduction) one year post treatment;
- Non-target species cover was reduced after all treatments; however, broadcast spray with imazapyr caused the most damage to non-target species;
- Non-target recovery from triclopyr damage was observed;
- Impacts of herbicides on non-target plant species can be mitigated by application where cut-stump and basal-bark application had less impact on non-target plant species than broadcast spraying;
- Although significant vegetation community changes were not detected, numerous life form (e.g., erect shrub, forb, graminoid) or species-specific changes were detected. Selective impacts of treatments on life forms/species are promising as the differences indicate treatments can be designed to meet management objectives;
- Further monitoring over the duration of a management cycle (8-10 years) is required to determine whether the treated vegetation on Yukon ROWs will develop into alternate, distinct plant communities and what cover types best resist target species invasion.

The efficacy of target woody species control by imazapyr and triclopyr applications indicates herbicide use may be a management option for Yukon ROW. However, environmental and socio-economic impacts must also be considered. To further inform on the environmental impacts of herbicide use on Yukon ROWs, chemical persistence in the environment (**Section 4.2**) and sensitivity of non-target plants (**Section 4.3**) to imazapyr and triclopyr were determined to quantify the observed effects in the field.

For imazapyr:

- Dissipation rate of broadcast applied imazapyr from soil was gradual and relatively slow (DT_{50} = 16 days). Slow dissipation of imazapyr might indicate it does not easily volatilize or photo-degrade in the soil environment;

- The dissipation from broadcast treated vegetation (white willow (*S. glauca*)) in the field followed a more rapid decline pattern with a calculated DT_{50} of 1.5 days followed by a persistence concentration in the treated vegetation;
- In the greenhouse trials, sensitivity of non-target plants to imazapyr was high with estimated IC_{50} values ranged from 0.7% to 1.2% of manufacturer's recommended field application rate;
- Its long persistence in the soil and high sensitivity of plants to it indicates imazapyr has long-term potential to impact non-target plant species even at trace amounts. This was reflected in the relatively high level of damage to non-target plants observed in the field one year post treatment; and,
- Its persistence in treated vegetation might be a secondary release mechanism that can impact non-target plants beyond the initial treatment.

For triclopyr:

- The rate of dissipation from soil when applied through broadcast spray in the field was initially rapid (DT_{50} = 1 day) followed by a persistence phase at very low concentration. The rapid dissipation phase of triclopyr might indicate it is readily volatilized or photo-degraded within the soil environment;
- The dissipation from broadcast treated vegetation (white willow (*S. glauca*)) in the field followed a more gradual decline pattern with a calculated DT_{50} of 11.5 days;
- In the greenhouse trials, sensitivity of non-target plants to triclopyr was relatively low in comparison to imazapyr with the estimated IC_{50} value at 31% of manufacturer's recommended field application rate;
- Its relatively rapid dissipation from soil and lower phytotoxicity(than imazapyr) indicate triclopyr has limited impact on non-target vegetation beyond the initial treatment. This was reflected in *A. millefolium* recovery at 21-28 days after application in the greenhouse and non-target vegetation recovery in the field one year after treatment; and,
- Although, triclopyr does persist in treated vegetation, it is not at concentrations that will impact non-target vegetation if released during decomposition.

Imazapyr's high phytotoxicity to many non-target species, ability to transfer between treated and untreated vegetation, and persistence in soil indicates that it is not a suitable product for northern ROWs, if maintaining or directing non-target vegetation development is a management priority. Triclopyr is the better herbicide option.

Neither herbicide appears to have measurable negative impacts on other ecological receptors. Sensitivity of soil invertebrates to both herbicides was determined directly through standardized toxicity testing (**Section 4.3.2**). Potential risk from indirect herbicide exposure for herbivorous animals (where herbicide residues in soil and plants may be consumed) was determined through a preliminary ecological risk assessment (**Section 5.0**). The findings include:

- Soil invertebrates were relatively insensitive to either herbicide. The estimated IC_5 and EC_5 values for the three tested soil invertebrate species were at or above the manufacturers' recommended field application rates;
- Acute (short-term) toxicity to herbivorous animals was unlikely even at the highest residual herbicide concentrations measured in the field for treated soil and vegetation (worst case scenario); and,
- Potential risk to herbivorous animals (e.g., moose) was detected in the worst case chronic (long-term) exposure scenario. However, when input parameters such as dissipation/persistence of herbicides, proportion of diet/home range of the animal, and/or applicability of/alternative reference dose were considered, the likelihood of risk to these animals from chronic exposure to either herbicide was low or deemed acceptable.

Triclopyr is the better herbicide option for inclusion in an IVM plan when all lines of evidence are considered. However, the biological and ecological effects of herbicide use are only one aspect for consideration when designing an IVM plan.

The socio-economic concerns of stakeholders towards herbicide use need to be addressed. This involves an extensive consultation process with the public, First Nations, and the government. Obviously, this is beyond the scope of this technical report. However, some thoughts are presented for consideration in order to improve the public consultation process and likelihood of a positive outcome (**Section 6.0**). These include:

- Integration of GIS and community input to determine buffer zones to water ways, First Nation communities and properties, and other private and public properties that might be impacted. GIS is an relatively simple tool to visualize large quantity of evolving information from stakeholders;
- Transition local contractors (if applicable) away from manual (mowing) ROW maintenance. Mowing will continue to be one tool in the IVM toolbox; however, it is not the only one;
- Local contractors can be trained in safe handling and use of herbicide or alternative strategies for ROW maintenance. They will be needed for long-term field data acquisition to fill identified data gaps (**Section 8.0**). Furthermore, they should be involved with the long-term monitoring of ROW plant community development to gauge the effectiveness a IVM strategies in altering the plant community composition or how well the newly developed plant community might resist invasion by target species over time; and,
- Develop a communication strategy as an integral element of an IVM plan and maintain consistent communication between stakeholders to build trust and reliance. IVM is an iterative approach where strategies might be altered over time as new tools and conditions develop or knowledge of old tools is revised. Communication and collaboration is the only way to ensure continual buy-in from all stakeholders in an ever-changing world.

Integrated Vegetation Management requires an understanding of the disturbance dynamics on power line ROWs to effectively design treatments to meet management objectives. The work completed to date determined that different management techniques can alter northern boreal plant communities, chemical management methods are effective at short-term (up to one-year post treatment) woody species control, and triclopyr is the better chemical control when all lines of evidence is considered. These results support that IVM principles can be applied to northern power line ROWs. The developmental trajectories of boreal plant communities after treatments were not yet clear. Continued monitoring of treatment plots or monitoring of larger-scale treated areas is required to determine if desirable plant communities establish. Once a suitable level of knowledge is achieved, management objectives beyond target woody species control will need to be defined. Socio-economic and environmental considerations will vary between sites. This will require the integration of GIS with information from public consultation. Once consultation is complete, treatments can then be selected to reflect local environmental and socio-economic conditions.

8.0 DATA GAPS AND RECOMMENTDATIONS

The summarized studies in this report provided a number of insights to various vegetation management techniques that might be included in IVM strategies for use on power line ROWs. This included information on the efficacy of various techniques, the persistence of herbicidal chemicals in a northern climate, and potential sensitivity of non-target organisms to chemical treatments. However, there are outstanding questions that the current studies could not address because of their limited scope. The following issues need to be address in order better formulate IVM strategies that will meet the ecological/environmental and socio-economic values of all stakeholders:

1) Long-term monitoring of the treated plots is necessary. It is expected that plant community changes will need several years to be established and detected. One site has already been lost as it underwent scheduled routine vegetation management (mowing). It is recommended at least one out of the five sites be designated for long-term monitoring;

2) Collected non-target vegetation from the field sites could be analyzed for residual herbicide concentration to improve our understanding of herbicide translocation and persistence in non-target vegetation in northern ROWs. This will also improve our estimation of potential risk to ecological receptors that come into contact with or consume these plants. Not all vegetation can be analyzed because of cost; however, in consultation with local communities, candidate species could be identified for analysis based on potential ecological, socio-economical, and cultural significance;

3) From the greenhouse trial, it was demonstrated that non-target boreal plants are sensitive to imazapyr and triclopyr at concentrations well below the manufacturer suggested rate. The efficacy of alternate/lower herbicide application rates in the field should be explored;

4) Impact of treatments on aquatic organisms and water quality was not considered. Both surface run-off and groundwater percolation may lead to herbicides reaching receiving surface water bodies. Alternatively, changes in plant community composition may alter surface and groundwater movement and impact surface water quality in general; and,

5) Habit alteration for birds and animals was not addressed. Potential treatment effects and plant community changes over time might impact the quality and quantity of habitat for birds and animals on the ROW. In combination with long-term vegetation monitoring, habitat monitoring is needed.

9.0 CLOSURE

This report was prepared for the exclusive use of Yukon Energy Corporation and its agents. The summarized work was completed in fulfillment of the Master of Science degree for the University Saskatchewan. As such, the published data and the primary authors' interpretation were peer- reviewed and are available to in the public.

The preliminary risk estimates likely represent upper bound of the estimate of risk based on the level of contaminants detected at the Site and exposure scenarios herein described. Risk estimates might be higher than those provided should future investigations identify areas of soil, groundwater, and vegetation impacts with contaminants greater than those stated or should the exposure scenarios change.

No other warranty, expressed or implied, is made. Any use which a third party makes of this report, or any reliance on or decisions to be made based upon it, are the responsibility of such third parties. The University of Saskatchewan accepts no responsibility for damages, if any, suffered by any third party as a result of the decisions made or actions based on this report.

Submitted by,

Wai Ma, Ph.D.
Project Coordinator
Yukon College

Katherine Stewart, Ph.D.
Principle Investigator
Assistant Professor, Department of Soil Science
University of Saskatchewan

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Appendix A

EDI 2013

(refer to attached electronic files)

Appendix B

Isbister 2016; Isbister et al. 2017

(refer to attached electronic files)

Appendix C

Jimmo 2017 (DRAFT)

(refer to attached electronic files)

Appendix D

Public engagement materials

(refer to attached electronic files)

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Page 3-11 Table 3.8

QUESTION:

a) Please explain what SCADA Communication entails.

b) Please explain why SCADA Communication costs more than doubled in 2014 over previous years and has continued at this higher level.

ANSWER:

(a)

SCADA (supervisory control and data acquisition) Communication is YEC's control system architecture for high-level process supervisory management and interfaces with plant and equipment. It includes YEC's System Control Centre operations as well.

(b)

The change in 2014 resulted from the reclassification of data circuit costs. It was determined that these costs were more appropriately classified under SCADA Communication. Previously, these costs were included under Operation Supervision of Production Costs (Table 3.5).

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Page 3-19 Hearing Cost Reserve Account

QUESTION:

a) YEC requests a decrease in the hearing reserve account appropriation to $250,000 per year from $550,000. Does this mean that YEC is proposing to have a GRA once every 4 years instead of every 2 years?

b) Does YEC not consider a Phase 2 hearing within the next 2 to 4 years a possibility? Would not more stable rates in the long term result from maintaining a modest credit balance by simply reducing the annual appropriations to something under $550,000 but more than $250,000?

ANSWER:

(a)

No. YEC has not established a fixed cycle for GRA's.

(b)

Please see the response provided to UCG-YEC-1-2 regarding considerations governing the timing for any future Phase 2 proceeding.

Maintaining a modest credit balance is a reasonable target. More stable rates would occur in the long-term if YEC was able to accurately predict the timing and costs for future hearings; however, this is difficult given the nature and uncertainties regarding regulatory processes.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: **Page 3-21 and 3-22 Cost of Debt**

QUESTION:

a) Did YEC initiate discussions with YDC to reduce its debt, or did the YDC/Yukon Government initiate these discussions?

b) In January 2011 YEC's debt with YDC was reduced from 4.65% - 7.00% on various debts to 4.25%, and in Board Order 2013-01 the YUB reduced the interest rate to 3.97% for 2012 and to 3.58% for 2013. These were based on long-term (30-year) Canada bond rates plus 120 basis points. Since these interest rates were based on 30-year bond rates, why were these debts refinanced less than 5 years later?

c) In lines 17-20 on page 3-22, the interest rate is forecast at 2.15% "… based on the most recent market rate for such borrowings as at May 2017." Please explain in detail what "market" is being referred to and what is meant by "such borrowings". Does this assume that YEC is a stand-alone utility?

ANSWER:

(a)

YEC initiated discussions on debt with the parent YDC.

(b)

The refinancing was done to take advantage of lower market rates available at the time. This benefit flows directly to ratepayers through lower utility revenue requirements.

(c)

"Market" refers to the commercial long term debt market in this case represented by TD Commercial Banking. "Such borrowings" refers to long-term (25 year) debt. The assessment assumes that YEC income is sufficient to finance debt obligations, and that this debt is guaranteed by YDC and the Yukon government.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Appendix 3.3 reportable outages

QUESTION:

a) Please explain the protection systems that minimize the extent of outages when a generating plant trips off-line.

b) It appears that often certain areas or subdivisions in and around Whitehorse are tripped off whereas others are not. Please explain how these areas are determined and how they fit into the response for (a) above.

c) Are industrial customers treated as a separate group or category for being tripped-off to minimize the impact to residential and general service customers? If not why not?

d) Would the answer to (c) above be different if the Victoria Gold and Alexco mines were grid customers? If not why not?

ANSWER:

(a)

A load shedding scheme is employed to minimize the extent of outages when a generating plant trips off-line. The purpose of Under Frequency Load Shedding (UFLS) is to balance generation and load when an event causes a significant drop in frequency on the system. The activation of UFLS is the last automated reliability measure associated with a decline in frequency in order to rebalance the system. UFLS protection schemes are based on frequency thresholds and on frequency rate of change. Various stages of UFLS are employed on the Yukon power system. YEC utilizes UFLS on the Dawson town feeders. ATCO has UFLS on numerous feeders with staging that can be altered between the feeders. ATCO controls the protection settings on these feeders.

(b)

The specific load shedding scheme in place at any given time in and around Whitehorse is determined by AEY.

(c)

No. The Minto Mine is the only industrial customer on the Integrated System and the infrastructure serving the mine is not configured for load shedding. In addition, tripping a large industrial load can create other issues for grid power supply (i.e. stability of supply).

(d)

Protection settings are established based on individual customer loads and grid characteristics. As both of these factors can change over time, the corresponding settings must similarly be reviewed periodically. At this time, YEC is reviewing the specific load profiles of these customers and assessing different protection schemes. It is possible that both Victoria Gold and Minto will be configured for UFLS in the future.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Appendix 3.4 Page 3.4-6 "Actual LNG unit operation has been constrained by unit size at 4.4 MW, i.e., smaller existing diesel units are relied upon for thermal loads less than 2.6 MW …"

QUESTION:

a) 2.6 MW from a 4.4 MW LNG unit represents 59% of its capacity. Please explain why the LNG units cannot run at a loading less than 59%.

b) IF LNG units are really constrained to 2.6 MW why would YEC not run them at 2.6 MW and conserve water at Aishihik (or elsewhere) when thermal loads are less than 2.6 MW?

c) Are diesel units not also operated this way, i.e. when a diesel unit is required it is operated constantly at or near peak efficiency by reducing the hydro output, thereby saving the water for future use and at the same time increasing the hydro spinning reserve?

ANSWER:

(a)

The 2.6 MW constraint is a direction from the OEM.

(b)

While the LNG units can be run at 2.6 MW, there is a negative impact to fuel efficiency by running at this lower load and running at less than optimal loading has a negative effect on maintenance requirements. YEC would run a smaller diesel at higher loading to achieve greater efficiencies as the main decision criteria. In addition, as noted in the application, the units are also subject to minimum run times which are factored into the decision for next-on generation.

(c)

As described in John Maissan-YEC-1-10, thermal units are run at optimal load while hydro provides load following (spinning reserve).

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Appendix 3.4 Page 3.4-9 “2016 average delivered LNG fuel cost of 18.17 cents per kW.h was actual costs [sic] of LNG used from inventory …”

QUESTION:

a) Please explain how the boil-off gas was used and accounted for, and how the vented LNG is accounted for in these calculations.

b) If the boil-off and the vented LNG in 2016 is not included in the referenced cost, please explain where the costs for this LNG are accounted for.

ANSWER:

(a) and **(b)**

For the configuration at the Whitehorse generation station, boil off gas is either burned in the GE generators or is consumed in the boiler for space heat in the existing diesel plant (P126). Generation fuel is included in Fuel expense (Tab 7, Schedule 10, line 12); fuel consumed for heat in P126 is included in Production expense. Unreconciled amounts (whether from venting or other reasons) are also accounted for in Fuel expense.

Table 1 below illustrates the gas consumption for 2016:

Table 1: Gas Consumption (2016)

	A=B+C	B	C	D	E=B+D
Date	WG1 and WG2 LNG Volume	HP Vapour	HP Sendout	P126 Boiler Boil-Off Gas Volume	Total Boil-off
	[m^3 LNG]	[m^3 LNG]	[m^3 LNG]	[m^3 LNG]	[m^3 LNG]
Jan-16	50.6	12.9	37.6	15.0	27.9
Feb-16	27.1	22.5	4.5	5.9	28.5
Mar-16	18.6	6.0	12.6	9.3	15.3
Apr-16	14.5	13.4	1.1	41.2	54.5
May-16	4.4	3.4	0.9	25.4	28.8
Jun-16	3.9	1.5	2.3	16.8	18.4
Jul-16	9.2	0.3	8.9	35.9	36.3
Aug-16	2.4	1.2	1.2	45.8	47.0
Sep-16	462.7	8.7	453.9	5.3	14.0
Oct-16	79.4	2.3	77.1	0.9	3.1
Nov-16	0.0	0.0	0.0	39.6	39.6
Dec-16	566.2	5.6	560.6	0.0	5.6
	1,238.8	78.0	1,160.8	241.0	319.0

Column A is total gas consumed in the generators and is the sum of columns B and C. Column C represents "normal" run mode for the generators where the LNG is vaporized and fed into the generators; column B – HP vapor is boil off gas that is sent to the generators at the end of the generation run specifically to reduce the pressure in the tank (by design, tank pressure must be brought up to a higher pressure to feed the generators; for storage purposes, the tank pressure is drawn down for optimal storage (i.e., lowest boil off rate)). Column D is "normal" boil off gas that is fed to boilers for heating purposes.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Appendix 3.4 Page 3.4-12 Re. summary highlights impacts with a $16 million DCF cap option.

QUESTION:

a) Please explain how these impacts would change with the addition of the Victoria Gold mine at 62 GWh per year (year 1) to the grid.

ANSWER:

(a)

The 450 GW.h load option examined in this section is a good proxy for the impact of the Victoria Gold mine absent the Minto mine.

Assessment of the 450 GW.h load relative to the 420 GW.h load forecast for 2018 with a $16 million DCF cap option indicates the following changes in impacts (see page 3.4-33):

- Helps to reduce the frequency of rate riders; and

- Increases slightly the peak year charges, i.e., a modest further increase in the DCF cap would likely be needed to remove this change.

TOPIC: **Section 3 Revenue Requirement**

REFERENCE: Appendix 3.4 Page 3.4-13 "The Diesel Contingency Fund ("DCF") operates to smooth customer rate changes … caused by fluctuation of hydro generation due to water conditions or changes in wind conditions."

QUESTION:

a) The water conditions are readily available to the public based on data from Water Survey of Canada gauging stations, however changes in wind conditions (on Haeckel Hill?) are less readily apparent. Please provide the data source that YEC is or will be relying on to determine wind conditions (short term and long term), and indicate whether this is available to the public.

b) How will wind production losses related to operational and maintenance decisions, as opposed to wind "conditions", be determined?

c) The Vestas wind turbine appeared to be shut down for a large portion of August (to the present), what factors are / were involved in it not operating?

ANSWER:

(a) and **(b)**

Wind data used for DCF purposes is based on recent operational (2015-2016) performance of the Vestas unit (WW2). A review of historical performance of WW2 indicates the period selected for DCF purposes yields an average generation higher than the average for all complete years since the unit was put in-service. Wind conditions were not part of this review; the forecast is based on recent actual performance.

(c)

The turbine had been shutting down on over current trips. The OEM was contracted to perform the annual maintenance and investigate the cause of the shutdowns. The test results clearly indicates a failure of the generator rotor.

The OEM recommendation is to replace the generator with a new or refurbished unit.

YEC is reviewing the recommendation from the OEM and will conduct a complete asset assessment before an action plan is determined.

TOPIC: **Section 4 Rates**

REFERENCE: Page 4-9 lines3 to 6 and Appendix 4.2

QUESTION:

a) Please provide a table detailing the revenue requirement reductions in each of 2017 and 2018 resulting from each of the following:
   i. The renegotiation of YEC's long term debt effective 2015;
   ii. The capital contribution of $22.4 million from YDC;
   iii. The Mayo B flexible debt financing compared to conventional debt at the same unreduced interest rate; and
   iv. The $128.5 million in contributions (from page 5-4) towards the cost of various projects.

b) Is it not true that Yukon's power rates are where they are compared to NWT and Nunavut as a result of significant YDC, Yukon government and federal government capital contributions for various infrastructure projects effectively subsidizing the rates through reduced revenue requirements?

ANSWER:

(a)

Please see Table 1 below.

Table 1: Estimated Impact of Government Contributions

Refinancing and Contributions	Impact to 2017 and 2018 Revenue Requirement	Note
Refinancing YDC long term debt in 2015	Reduces interest payments in 2017 and 2018 by $1.5 million and $1.4 million respectively.	2017-18 GRA, Tab 3, page 3-21
Capital contribution of $22.4 million from YDC in 2015	The impact of $18.3 million contributions to the LNG plant is about $1.3 million reduction in revenue requirement for each 2017 and 2018 test years. This reduction will be longer term compared to deferred cost impacts. The impact of remaining $4.2 million contributions is about $0.7 million reduction in revenue requirement for each 2017 and 2018 test years.	$18.3 million used to offset the capital costs of the Whitehorse Diesel Natural-Gas Conversion Project (LNG Project) and the balance of the contribution ($4.2 million) was used to offset amounts for deferred projects in rates [2017-18 GRA, Tab 1, page 1-3]
Mayo B flexible debt	Reduces interest payments in 2017 and 2018 by approximately $0.7 million and $0.6 million respectively.	Calculated based on the maximum face interest of 5.46% and the interest expense based on load forecast for 2017 and 2018.
Total of $128.5 million contributions towards Carmacks-Stewart Transmission Project Stage 2, Mayo B and Aishihik Third Turbine Projects	The estimated impact is about $7.6 million/year reduction in revenue requirement [depreciation and return on rate base].	$41.9 million for Carmacks-Stewart Transmission Project Stage 2; $81.6 million for Mayo B; and $5 million for Aishihik Third Turbine Project [2012/13 GRA, YUB-YEC-1-32 c)]

(b)

Generally, the statement is not correct. It focuses on recent projects and funding and fails to reflect the long established lower costs for Yukon hydro grid generation compared to the generation sources required to supply power in NWT and Nunavut.

Since 2006, Yukon Energy has engaged intensively in planning and development activities required to identify the next generation of lower cost sources of supply for Yukon. The additional major bulk power (generation and transmission) projects have been added to the Yukon system which have enhanced system performance and reduced Yukon diesel generation requirements. It is true that significant contributions from YDC, Yukon Government and funding through federal programs for these various infrastructure projects in Yukon have reduced the revenue requirement today and lowered rates for ratepayers compared with what would be required without such assistance. However, absent such government funding assistance, the full CSTP and Mayo B project developments would not have proceeded when they did and Yukon generation requirements would still have been met mainly with long established hydro generation.

It is also important to note the role of the utility in negotiating and securing funding, as well as initiating the measures taken to help manage ongoing cost pressures. The planning and development activities to refinance the existing high cost debt would be examples of those activities.

Hydro generation remains the predominant source of generation in Yukon with over 95% supplied by hydroelectric generation, and the remaining 5% supplied by natural gas and diesel thermal generations, mostly for the isolated diesel communities. In contrast, the Northwest Territories Power Corporation’s 2016-18 GRA shows approximately 75% of its total generation is from hydroelectric generation and 25% is from thermal generation sources. Qulluq Energy Corporation generation in Nunavut is 100% based on isolated diesel generation.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-7 Section 5.2.1.2 Aishihik elevator shaft

QUESTION:

a) Can YEC confirm that the Aishihik elevator shaft structural steel was installed in approximately 1975?

b) If correct, the useful life of the original structure was far less than 72 years, so how can YEC justify an expectation of 72 years of life from the replacement structural steel?

ANSWER:

(a)

Confirmed.

(b)

Based on the nature of the asset, this project was classified as "Hydro Structures and Improvements" which has an approved depreciation rate of 72 years.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-12 Communications upgrades

QUESTION:

a) Will the installation of the proposed upgrades result in the retirement of the power line carrier communications system? If not, please explain.

ANSWER:

(a)

The power line carrier communications system will not be retired as it is still used for protection communication purposes and control redundancy.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-15 Whitehorse Hydro unit No. 4 overhaul

QUESTION:

a) Has the unit 4 overhaul been completed?

b) Have the spider replacement and the excitation system replacements been completed?

c) If the answers to (a) and / or (b) above are yes, please provide the actual costs of the completed works.

d) Was a capacity increase of WH 4 by the installation of a new turbine ("wheel" or "runner") design a consideration? Please explain.

ANSWER:

(a)

Yes.

(b)

Yes.

(c)

Please see response to YUB-YEC-1-68.

(d)

YEC did not consider installing a new turbine as part of the WH4 overhaul. A study was commissioned to provide a technical and economic review and analysis of the potential options for the uprating of the Whitehorse hydro generating units, however, it was not completed in time to be included in this project. Due to the engineering and planning time required for an uprate of WH4, as well as the emergency nature of the repair, a new turbine design was not feasible for this project.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Pages 5-22 to 5-26 (and page 5-6) LNG plant

QUESTION:

a) Please provide the capital cost estimate for the LNG plant provided in the 2014 LNG Part 3 Application.

b) Please provide the capital cost estimate for the alternative diesel project provided in that Application.

c) Please provide the capital cost estimate for the addition of the third LNG unit in that Application.

d) Please provide the updates to the costs in (a) to (c) provided during the hearing.

e) Please provide the long term oil and gas cost forecasts provided in the LNG proceeding on which the economic analyses and economic justification was based.

f) Please provide the delivered diesel fuel costs and the delivered LNG costs (per litre of diesel equivalent) that result from (e) above.

g) Please provide the forecasted cost per kWh from a new diesel plant and the then proposed LNG plant.

h) Please provide the present (July 31, 2017) actual figures for (e) to (g) above.

i) YEC's LNG Application on page 10 in Figure 3-1, and in the table below it, provides a graphical figure and a table of ratepayer costs for capital and fuel costs with new diesel and with LNG. Please reproduce the graph and the table with costs using actual energy loads and actual fuel prices for the same years, and also both with and without YDC's $18.3 million contribution towards the capital cost.

j) Please confirm that the capital cost estimate for the "diesel" alternative (page 5-26 line 21) was for two 6.7 MW dual fuel engine generators and included infrastructure to distribute gas to the engines within the diesel plant.

k) Please confirm that the capital cost estimate for the "diesel" alternative included electrical switchgear replacements and other building upgrades designed to service three 6.7 MW dual fuel generators.

ANSWER:

(a), (b), (c) and **(d)**

The LNG Part 3 Application filed in December 2013 provided the following capital costs (2013$) estimates (updates provided during the proceeding are also noted):

1. LNG Plant (8.8 MW for 2 units)
    a. Application: $34.4 million (Table 4-3, Ex. A-4)
    b. Update: $36.5 million (Table 1, Ex. B-13)

2. Alternative Diesel Plant (13.4 MW for 2 units)
    a. Application: $33.5 million (Table 4-3, Ex. A-4)
    b. Update: $32.7 million (Table 1, Ex. B-13)

3. LNG third unit (4.375 MW)
    a. Application: $4.4 million (Table 4-3, Ex. A-4)
    b. Update: $5.5 million (Table 1, Ex. B-13)

(e), (f), (g) and (h)

The oil and gas cost forecasts in the LNG Part 3 Application proceeding update (Exhibit B-13) on which the economic analyses and economic justification was based are summarized below along with present (July 31, 2017 where feasible) actual figures:

1. Long term oil and gas cost forecasts
    a. Application: The April 2013 U.S. Energy Information Administration forecast outlook indicated that crude oil price is expected to be 4 times that

of North American natural gas price with the expectation that this would continue for a period extending beyond 2030 (Figure 4-2, Ex. A-4).

b. Current: The National Energy Board of Canada's latest energy market assessment (Canada's Energy Future 2016: Energy Supply and Demand Projections to 2040 – An Energy Market Assessment – October 2016.[1]
   i. Overall, this latest NEB update shows a continued major gap per GJ for oil prices compared to natural gas prices with a wide range to reflect uncertainty.
   ii. For the NEB Reference Price Forecasts (2015$):[2]
      - 2016 Brent crude oil price at US$7.35/GJ is US$5.0/GJ higher (3.2 times) than the 2015 Henry Hub natural gas price at US$2.32/GJ.
      - By 2040, the forecast crude oil price at US$14.71/GJ is US$10.6GJ higher (3.6 times) than the natural gas price at US$4.08/GJ.

2. Delivered (at YEC) fuel prices assumed in the LNG Project update economic assessments (Exhibit B-13) and delivered fuel prices for the current GRA:

   a. LNG Part 3 proceeding update (Table 1, Ex. B-13):
      i. Delivered diesel price at Whitehorse of $1.1265 per litre based on last six months actual prices;
         - 26.3 c/kW.h for new diesel plant (4.28 KW.h/litre assumed) and 30.8 c/kW.h for existing diesel units (3.66 kW.h/litre).
      ii. Delivered natural gas cost at $15.6/GJ (assumed supply from Fortis at Tilbury, B.C. with natural gas commodity cost of $4.55/GJ, Fortis LNG liquefaction costs at $4.79/GJ, and haul cost with A-Train at $6.25/GJ):
         - 14.0 c/kW.h with new natural gas units (assumed 40% HHV energy conversion efficiency in the new units, or 9 GJ per MW.h).

[1] The U.S. Energy information Administration's Annual Energy Outlook 2017 (page 64) similarly forecasts a reference price for crude oil through to 2040 more than three times higher than the natural gas price reference price on an energy equivalent basis.

[2] Assumes 6.12 GJ per barrel for crude oil and 0.948 MMBtu per GJ.

b. Current GRA for 2017 and 2018:
   i. Delivered diesel price at Whitehorse of $0.9163 per litre
      - 21.4 c/kW.h if retain assumption that new diesel unit efficiency at 4.28 kW.h/litre; GRA assumes 3.60 kW.h/litre average efficiency for existing Whitehorse diesel units (equals 25.45 c/kW,h at forecast diesel price).
   ii. Delivered natural gas cost at $15.9/GJ ($0.3767 per litre with 0.02369 GJ/litre).
      - 14.67 c/kW.h at actual average efficiency of 2.57 kW.h/litre (39% HHV)

c. Current pricing as at July 31, 2017
   i. Delivered diesel price at Whitehorse of $0.8583/litre (contract fuel price adjusted as of August 1, 2017);
      - 20.1 c/KW.h @ 4.28 KW.h/litre;
      - 23.8 c/KW.h @ 3.60 KW.h/litre.
   ii. Delivered natural gas cost at $18.96/GJ ($0.4491 per litre with 0.02369 GJ/litre).
      - 17.47 c/kW.h at actual average efficiency of 2.57 kW.h/litre (39% HHV)

(i)

Figure 3-1 and related table in the 2013 LNG Application were derived from the analysis in Table 4.3 of the Application. This information was updated in the 2014 hearing in Ex. B-13.

Figure 3-1 and related table are reproduced using the following information:

1. **Capital costs**: assumed 40-year depreciation for costs other than decommissioning; return on mid-year rate base at 5.45% prior to 2017, and at 5.00% for 2017 and 2018[3]. The following capital costs and timing has been assumed for the LNG Project and the New Diesel Alternative:

[3] The 5.45% return was based on prior GRA and the 2013 Part 3 LNG Application, assuming the 8.25% return on equity approved in the last GRA (40% of capital structure) and 3.6% cost of new debt as then forecast (60% of capital structure). The 5.00% return for 2017 and 2018 reflects the

a. LNG Project
   i. Initial 2 units, in-service July 1, 2015:
      1. Total before YDC contribution: $41.933 million
      2. Net after YDC contribution: $23.633 million
   ii. Third LNG Engine (assumed in-service Q1 2019): NA in Figure 3-1 time period (2015 to 2018).[4]
b. New Diesel Alternative (costs of $32.7 million and timing in 2014 and 2015 retained as per Part 3 Application Update)

2. **Delivered fuel costs**: actual diesel and LNG fuel costs for 2015 and 2016, and 2017-18 GRA forecast diesel and LNG fuel costs for 2017 and 2018:
   a. 2015:
      i. diesel at 20.3 c/kW.h for new diesel and 23.7 c/kW.h for existing diesel.
      ii. LNG at 18.83 c/kW.h per DCF filing.
   b. 2016:
      i. diesel at 18.63 c/kW.h for new diesel and 21.8 c/kW.h for existing diesel at Whitehorse.
      ii. LNG at 18.17 c/kW.h per DCF filing.
   c. 2017 and 2018: per GRA
      i. diesel at 22.0 c/kW.h for new diesel and 25.45 c/kW.h for existing diesel at Whitehorse (new engine efficiency assumed at 39%).
      ii. LNG at 14.67 c/kW.h per DCF filing (new engine efficiency assumed at 39%).

3. **LTA Thermal Generation**: actual and forecast as per Table 2.2 of GRA (10.0 GW.h for 2015, 10.5 GW.h for 2016, 14.1 GW,.h for 2017 and 14.5 GW.h for 2018).

4. **Percent of LTA Thermal**: based on GRA and noted constraints on use of larger units for small and short duration loads, assume 90% LTA thermal supplied by LNG (15% for 2015 due to in-service only after mid-year); for new diesel alternative, assume 50% of LTA thermal supplied by these units (based on similar

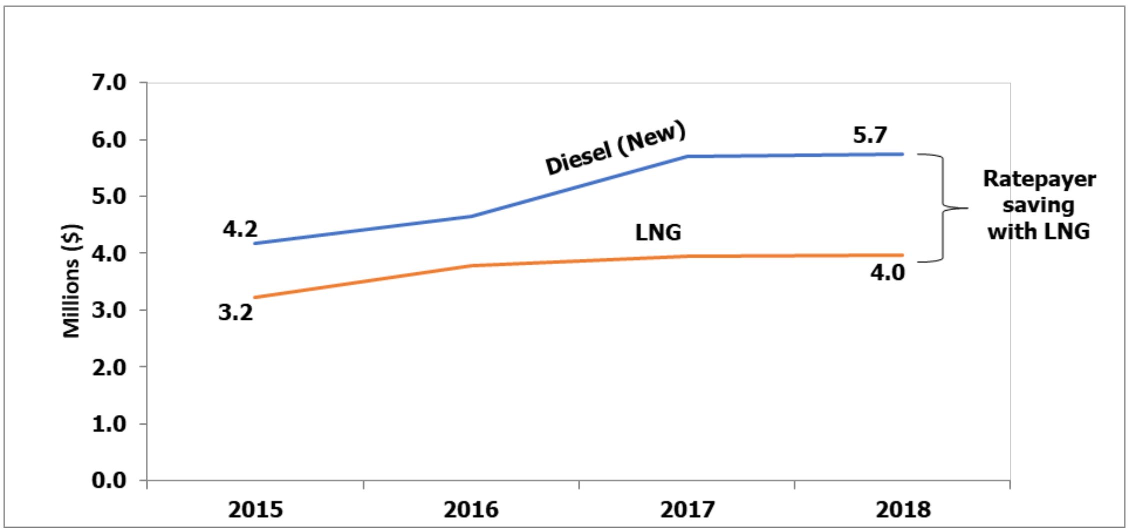
current GRA proposed 8.75% return on equity (40% of capital structure) and an assumed 2.5% cost for new debt (Schedule 11 at page 7-15 shows interest on new debt below this level since 2014).

[4] GRA cost estimate (page 5-26) of $6.2 million; this has been adjusted to $8.9 million; see YUB-YEC-1-71

constraints on use of larger units for small and short duration loads plus assumed low incentive to use for enhanced hydro storage during drought).

Figures 1 and 2 below provided the updated Figure 3-1 with and without YDC's $18.3 million contribution towards the LNG plant capital costs. John Maissan-YEC-1-27 Attachment 1 provides the supporting updated Table 4-3.

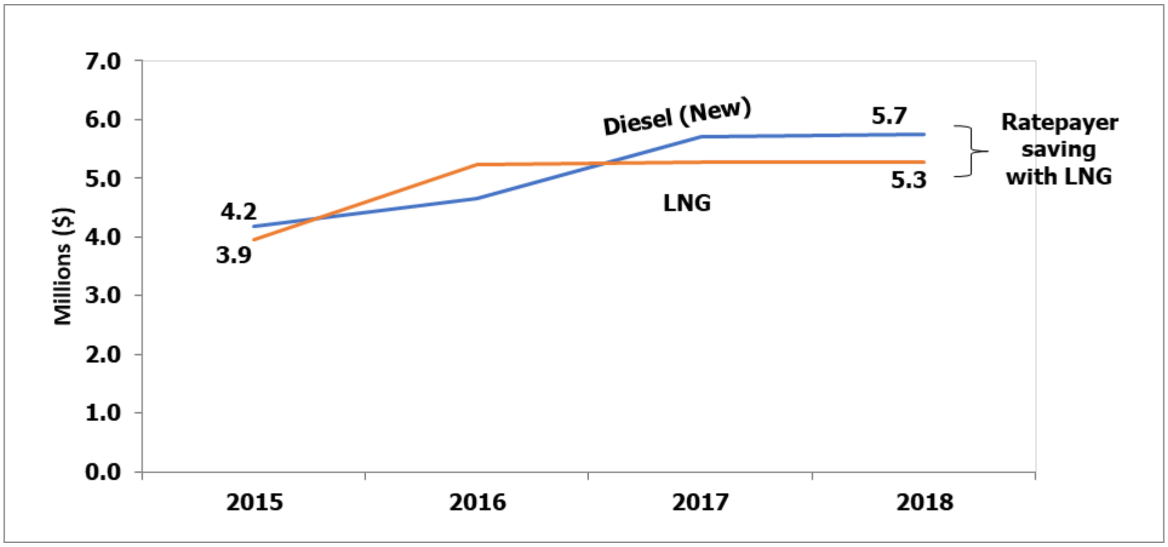
Figure 1: Updated: Annual Ratepayer Costs - LNG vs New Diesel: 2015-2018 (LNG Capital Cost at $23.63 million)



Annual Ratepayer Cost for Capital & Fuel ($million per year)

	2015	2016	2017	2018
Diesel (New)	4.2	4.6	5.7	5.7
Gas/LNG	3.2	3.8	3.9	4.0
Saving (Diesel-LNG)	**1.0**	**0.9**	**1.8**	**1.8**

Figure 2: Updated: Annual Ratepayer Costs - LNG vs New Diesel: 2015-2018 (LNG Capital Cost at $41.93 million)



Annual Ratepayer Cost for Capital & Fuel ($million per year)

	2015	2016	2017	2018
Diesel (New)	4.2	4.6	5.7	5.7
Gas/LNG	3.9	5.2	5.3	5.3
Saving (Diesel-LNG)	**0.2**	**-0.6**	**0.4**	**0.5**

(j) and **(k)**

Confirm that this cost was for two 6.7 MW dual fuel engine generators. Estimates used for the diesel fuel option included building upgrades to service the two new generators. These costs did not assume natural gas use within the diesel plant.

Table 1: Updated Table 4-3 – Capital Costs $23.63 after YDC Capital Contribution

		2014	2015	2016	2017	2018
Capital cost ($million) at yr end						
Total	Diesel (new)	21.60	11.10			
	LNG		23.63			
Net	Diesel (new)	21.60	32.2	31.4	30.6	29.8
	LNG	0.00	23.3	22.7	22.2	21.6
Difference (LNG-Diesel)						
Annual Capital Cost ($million)						
Deprec	Diesel (new)		0.516	0.794	0.794	0.794
	LNG		0.295	0.591	0.591	0.591
Return	Diesel (new)		1.466	1.732	1.550	1.510
	LNG		0.636	1.256	1.123	1.093
Total	Diesel (new)		1.982	2.526	2.343	2.304
	LNG		0.931	1.847	1.713	1.684
Difference (LNG-Diesel)			**-1.050**	**-0.680**	**-0.630**	**-0.620**
Annual Fuel Cost ($million)						
Forecast LTA Diesel (GWh)			10.0	10.5	14.1	14.5
% New	Diesel (new)		50%	50%	50%	50%
	LNG		15.0%	90%	90%	90%
Fuel Cost	Diesel (new)		2.200	2.121	3.356	3.435
	LNG		2.297	1.946	2.228	2.280
Difference (LNG-Diesel)			**0.097**	**-0.175**	**-1.128**	**-1.155**
Net Ratepayer Impact ($million)						
	Diesel (new)		4.182	4.647	5.700	5.739
	LNG		3.228	3.793	3.941	3.964
Difference (LNG-Diesel)			**-0.954**	**-0.855**	**-1.758**	**-1.775**

Notes:

1. Updated capital costs as of 2017-18 GRA ($0.553 million with LNG for decommissioining Mirrlees units is now assumed after 2018). All capital costs (excluding decommissioning) depreciated over 40 years; return on mid-year rate base at 5.45%/year prior to 2017, and 5.00% thereafter.
2. Diesel fuel costs vary by year: for 2015 average Oct-Dec at 20.3 c/kWh new diesel (WH), 23.7 c/kWh existing diesel (grid average), $0.867 per litre; for 2016 average at Whitehorse Jan-Dec at 18.6 c/kWh new diesel (WH), 21.8 c/kWh other diesel, $0.798 per litre; for 2017 and 2018, as per GRA, Whitehorse diesel price at $0.9163 per litre and 22.0 c/kW.h for new diesel and 25.45 c/kW.h for existing diesel at Whitehorse. In 2015 and 2016, assume 4.28 kW.h/l for new diesel and 3.66 kW.h/l average for existing diesel; in 2017 and 2018, GRA assumption of 3.60 kW.h for existing Whitehorse diesel and 4.17 kW.h/litre for new diesel (39% efficiency).
3. LNG delivered fuel costs vary by year: for 2015, at 18.83 c/kWh (DCF Filing) based on May-Dec actual delivered fuel cost of $20.92/GJ and assumed (per DCF filing) 40.0% unit efficiency at 2.683 kWh/litre of LNG and 24.15 GJ/m^3 of LNG; for 2016, at 18.17c/kW.h actual average cost from inventory based on DCF Annual Report filing; for 2017 and 2018, 14.67 c/kW.h per the GRA forecast (cost of $0.3767 per litre, Sept. to Dec. average for deliveries from Ferus with assumed energy content of 0.02369 GJ per litre, efficiency of 2.57 kW.h litre (39%)).
4. Updated LTA Default Diesel (GW.h) as per Table 2.2 of 2017-18 GRA: actual for 2015 and 2016 LTA as reported in DCF filing; 2017 and 2018 LTA as per GRA.
5. Percent of LTA thermal supplied by LNG as per DCF filing for 2015 (partial year impact) and 90% thereafter (per 2017-18 GRA assessments). Percent of LTA thermal supplied by new diesel at 50% based on capacity limits and assumed insufficient incentive to use for enhanced hydro storage during drought.

Table 2: Updated Table 4-3 – Capital Costs $41.93 without YDC Capital Contribution

		2014	2015	2016	2017	2018
Capital cost ($million) at yr end						
Total	Diesel (new)	21.60	11.10			
	LNG		41.93			
Net	Diesel (new)	21.60	32.2	31.4	30.6	29.8
	LNG	0.00	41.4	40.4	39.3	38.3
Difference (LNG-Diesel)						
Annual Capital Cost ($million)						
Deprec	Diesel (new)		0.516	0.794	0.794	0.794
	LNG		0.524	1.048	1.048	1.048
Return	Diesel (new)		1.466	1.732	1.550	1.510
	LNG		1.128	2.228	1.992	1.939
Total	Diesel (new)		1.982	2.526	2.343	2.304
	LNG		1.653	3.277	3.040	2.988
Difference (LNG-Diesel)			**-0.329**	**0.750**	**0.697**	**0.684**
Annual Fuel Cost ($million)						
Forecast LTA Diesel (GWh)			10.0	10.5	14.1	14.5
% New	Diesel (new)		50%	50%	50%	50%
	LNG		15.0%	90%	90%	90%
Fuel Cost	Diesel (new)		2.200	2.121	3.356	3.435
	LNG		2.297	1.946	2.228	2.280
Difference (LNG-Diesel)			**0.097**	**-0.175**	**-1.128**	**-1.155**
Net Ratepayer Impact ($million)						
	Diesel (new)		4.182	4.647	5.700	5.739
	LNG		3.950	5.223	5.268	5.268
Difference (LNG-Diesel)			**-0.232**	**0.575**	**-0.432**	**-0.471**

Notes:

1. Updated capital costs as of 2017-18 GRA ($0.553 million with LNG for decommissioining Mirrlees units is now assumed after 2018). All capital costs (excluding decommissioning) depreciated over 40 years; return on mid-year rate base at 5.45%/year prior to 2017, and 5.00% thereafter.
2. Diesel fuel costs vary by year: for 2015 average Oct-Dec at 20.3 c/kWh new diesel (WH), 23.7 c/kWh existing diesel (grid average), $0.867 per litre; for 2016 average at Whitehorse Jan-Dec at 18.6 c/kWh new diesel (WH), 21.8 c/kWh other diesel, $0.798 per litre; for 2017 and 2018, as per GRA, Whitehorse diesel price at $0.9163 per litre and 22.0 c/kW.h for new diesel and 25.45 c/kW.h for existing diesel at Whitehorse. In 2015 and 2016, assume 4.28 kW.h/l for new diesel and 3.66 kW.h/l average for existing diesel; in 2017 and 2018, GRA assumption of 3.60 kW.h for existing Whitehorse diesel and 4.17 kW.h/litre for new diesel (39% efficiency).
3. LNG delivered fuel costs vary by year: for 2015, at 18.83 c/kWh (DCF Filing) based on May-Dec actual delivered fuel cost of $20.92/GJ and assumed (per DCF filing) 40.0% unit efficiency at 2.683 kWh/litre of LNG and 24.15 GJ/m^3 of LNG; for 2016, at 18.17c/kW.h actual average cost from inventory based on DCF Annual Report filing; for 2017 and 2018, 14.67 c/kW.h per the GRA forecast (cost of $0.3767 per litre, Sept. to Dec. average for deliveries from Ferus with assumed energy content of 0.02369 GJ per litre, efficiency of 2.57 kW.h litre (39%)).
4. Updated LTA Default Diesel (GW.h) as per Table 2.2 of 2017-18 GRA: actual for 2015 and 2016 LTA as reported in DCF filing; 2017 and 2018 LTA as per GRA.
5. Percent of LTA thermal supplied by LNG as per DCF filing for 2015 (partial year impact) and 90% thereafter (per 2017-18 GRA assessments). Percent of LTA thermal supplied by new diesel at 50% based on capacity limits and assumed insufficient incentive to use for enhanced hydro storage during drought.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-26 LNG third generator

QUESTION:

a) Since the LNG plant was designed for three 4.4 MW generators, please explain why each of the proposed option review, preliminary engineering, development of equipment specifications, grid impact, and detailed engineering studies are required?

b) Why is it not just a matter of specifying and ordering equipment identical to the equipment specified, purchased, and brought into service just over 2 years ago?

c) Once the third generator is installed, what will be the dependable annual energy capability of the LNG plant?

ANSWER:

(a)

From Phase 1 (when 2 engines were installed) there were some key lessons learned and to translate these lessons into technical requirements, YEC performed preliminary engineering and specification development. In addition, the utility is required to complete grid impact and detailed engineering each time a new project is initiated to ensure successful implementation and integration of new equipment into the YEC grid.

(b)

There are two reasons to revisit the specification and design: first, the original selection process was executed over 2012/13, about five years ago. It is prudent for YEC to re-visit the market to ensure the selection is still in the best interests of the utility; this includes market pricing as well as potential technology changes. Secondly, it is logical to review the selection criteria for knowledge gained during construction and operation of Phase I of this project.

(c)

Assuming a capacity factor of 95%, firm annual energy capability for 13.2 MW of LNG generation is approximately 110 GWh.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-29 lines 6-8

QUESTION:

a) If the subject work extends the life of the WAF lines, is there a corresponding reduced depreciation cost? If not why not?

ANSWER:

(a)

Replacement of components of the transmission system contribute to life extension, however, this does not translate necessarily into lower depreciation expense. One important countervailing effect is the vintage of the investment; that is, when a component is replaced today, rate base is inflated at today's dollars, replacing dollars that were spent up to 40-50 years ago. This effect alone will have significant upward pressure on depreciation.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-32 to 5-33 Stewart Crossing - Keno City Transmission Line

QUESTION:

a) Detailed line design and substation design work was expected to be complete in Q1 2017, now that we are in Q3 is this work complete? Please provide an update.

b) The last paragraph on this topic on page 5-33 suggests that the project could be staged with the first stage being the removal and replacement of end of life infrastructure. Is this not in effect what has been happening over the past 20 or more years?

c) Could Victoria Gold's requirements be met with the present 69 kV line for at least a period of time? Or for an indeterminate time?

ANSWER:

(a)

Detailed line design was completed in Q1 2017. The design for a new substation required by Victoria Gold will be completed in Q3 2017.

(b)

Over the past 20 years, line structures have typically been repaired when needed but not replaced. In addition, maintenance has been deferred whenever feasible in anticipation of replacing the line. A key element of this project is the replacement of the conductor, which cannot be completed as a maintenance activity.

(c)

Based on the current forecasted mine load, the existing line could meet full loads in year 1. As noted YCS-YEC-1-76 and YCS-YEC-1-17, the 69 kV line from Mayo to the Keno region was constructed in the 1950's, is end-of-life, and needs to be replaced as soon as feasible.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Pages 5-34 to 36 Battery project

QUESTION:

a) Around early August there were a series of quite extensive outages.
   i. What was the cost to YEC to restore the grid from these outages (labour, diesel fuel, lost sales etc.)?
   ii. What was the estimated cost to AEY?
   iii. What is the cost of each outage to each of Yukon businesses, industry, and governments?

b) Did the analysis of potential benefits of a BESS include the reduction of cost impacts to customers from fewer outages as a result of a more resilient grid from the provision of additional spinning reserve from the battery?

c) If the hydro grid currently provides the spinning reserve would the grid's hydro resources be better utilized (e.g. more energy available in winter) if a BESS could / would provide at least some portion of the necessary spinning reserve? If so please estimate the potential benefits.

d) Is the difference in cost between the two options listed ($5.7 million) a matter of the difference in the cost of capacity only, or is there a difference in energy storage capability or other features between the two battery options as well?

e) What is the incremental cost of capacity for each of the two battery types?

ANSWER:

(a)

(i)

YEC is unable to respond to this request at this time because final cost impacts are not yet known.

(ii)

YEC does not have access to the information necessary to respond to this request.

(iii)

YEC does not have access to the information necessary to respond to this request.

(b) and **(c)**

The TransGrid Solutions Inc. study focused on thermal displacement as primary use for the energy storage system (ESS). The planned system studies for 2017 and 2018 will look at ancillary benefits such as frequency control, blackstart and spinning reserve.

(d)

The cost included in the Application refer to the 4MW/40MWh Lead-acid ESS ($21.7 million) and the 8MW/40MWh Lithium-ion ESS ($27.4 million). Details regarding the basis of the estimates can be found in the Appendix 5.19 of the 2016 Resource Plan at the link below.

http://resourceplan.yukonenergy.ca/media/site_documents/Appendix_5.19_Evaluation_of_Energy_Storage_Technologies_(Transgrid_Solutions_2016).pdf

(e)

Please see Table 5-107 (2016 Resource Plan, Section 5.2.10, PDF page 273) for a comparison of levelized cost of capacity for all energy storage options.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Pages 5-36 to 5-39 New thermal plant

QUESTION:

a) Is YEC considering an option of installing two new diesel generators in the existing Whitehorse diesel plant effectively replacing the retired Mirrlees generators? If not why not?

b) On what grounds does YEC think that a third party can supply gas to an LNG plant more cheaply than they can supply it themselves?

c) Would the new thermal plant be designed so that it could "firm-up" new intermittent renewable energy supplies (such as the potential Mt. Sumanik wind farm) whether developed by YEC or IPPs?

ANSWER:

(a)

As part of the planned 2017-2018 activities for the New Thermal Plant project, YEC will further study the option of removing the three Mirrlees engines in its existing Whitehorse thermal plant, two of which are already out of service and one of which is approaching end of life, and replacing them with new, efficient dual-fuel engines. The new dual fuel units would allow YEC to decrease its operating costs as it would benefit from the low cost LNG fuel to generate power. Since the original BBA study (2013) excluded certain aspects of the plant retrofit, the new study aims at updating and building upon the work completed in 2013 to reduce remaining uncertainties.

Please see also response to YUB-YEC-79(b).

(b)

Please see response to YUB-YEC-79(b) regarding the potential option of a third party providing an LNG depot in Whitehorse.

(c)

The portfolio analysis completed as part of the 2016 Resource Plan showed thermal assets would be relied upon to primarily meet capacity under the single (N-1) contingency criterion. To a lesser extent, they would be used to support system energy requirements until such time as new renewable resource options could be brought online that would offer least cost solutions (2016 Resource Plan, Chapter 8, Section 8.2.7, PDF page 369).

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-41 DSM

QUESTION:

a) The development of capacity focused DSM programming is expected to take 2 years, why so long especially since peak load growth has been apparent for some time and some capacity programming was considered in the previous CPR study?

ANSWER:

(a)

The DSM program planning process is outlined in the response to YUB-YEC-1-80(g).

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-50 Time of Use Rate Structure and Smart Grid study

QUESTION:

a) Please discuss this item in light of the YUB's decision to not to approve AEY's proposed contribution of $100,000. How does this affect YEC's cost?

b) Along the same lines as secondary sales, is YEC considering other rate or rate structure measures that would encourage summer season use of energy when hydro is often in surplus supply while conserving winter supplies (e.g. seasonal rates, or summer farm or irrigation rates that would support other Yukon government initiatives in food self-sufficiency)? Please explain.

ANSWER:

(a)

YEC believes this is a legitimate utility project. The key conclusion from the Resource Plan Update is the challenge the utility faces with growing peaks and lack of generation capacity to meet these peaks. The primary goal of time-of-use rates is to shift peaks, either daily or seasonally, to mitigate this challenge. In addition, smart meters are critical infrastructure to properly implement time-of-use rate programs. We intend to continue our dialogue with AEY regarding possible partnership in this study, and we will be looking at potential government funding support; we do not know today if these options will or will not materialize or how this could affect the scope of YEC's plans.

(b)

No other rate or rate structures are being considered at this time.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5-50 Detailed Line Inspection

QUESTION:

a) Is this work a repeat of similar work carried out about 15 years ago? Please explain.

ANSWER:

(a)

Yes, similar work was carried out in the past and is required to be regularly updated in order to assess the constantly changing condition of transmission assets.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.3-4 Whitehorse Wind 1 Decommission

QUESTION:

a) Has YEC tried to sell this asset “as is where is” to minimize ratepayer costs?

b) Should the cost not come from a net salvage value account? If not why not?

ANSWER:

(a)

YEC is currently exploring the option of selling the asset to a third-party.

(b)

Any cost to decommission the asset will be charged to the Reserve for Site Restoration fund.

TOPIC: **Page 5.3-9 Building Condition Report**

REFERENCE:

QUESTION:

a) Please provide a copy of this report.

b) Is it YEC's intention to bring all of its buildings into full compliance with all of the most recent building codes? Please explain.

c) Can this work and cost be spread out over a longer period of time?

ANSWER:

(a)

Please see the report provided as John Maissan-YEC-1-37 Attachment 1.

(b) and **(c)**

YEC will bring buildings into compliance with building codes where there is a health and safety or environmental risk, an impact on operations, or a positive cost benefit in doing so. Portions of the work are being deferred to future years and scheduled based on report recommendations combined with internal YEC priority assessment.

John Maissan-YEC-1-37 Attachment 1

(Large attachment – please see 2017/2018 General Rate Application Round 1 Interrogatory Responses Appendix A)

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.3-10 Mayo B exterior overhead crane

QUESTION:

a) How was this deficiency in the recently built Mayo B plant overlooked? Why shouldn't the contractor be responsible for correcting this deficiency?

b) How often is this crane inspected and serviced?

c) What is the cost of renting the boom hoist?

d) Can this project be deferred?

ANSWER:

(a)

YEC did not anticipate the complications or costs involved in accessing the crane equipment for inspections. As the access door was not specified in the plant design, it is not considered a project deficiency.

(b)

The crane is inspected annually and serviced as determined by the inspections.

(c)

The cost of renting a boom hoist to service or inspect the crane is approximately $600 per day plus transportation to Mayo at $175 per hour.

(d)

Deferral of this project may result in ongoing additional costs as well as the potential for a significant period of time without access to the crane if it were to suffer a mechanical failure in the middle of the span.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.3-10 Stewart-Minto Local SCADA

QUESTION:

a) How did such an important design features get overlooked in these recently built facilities?

b) Was it to minimize capital costs in their original construction?

c) Can this project be deferred?

ANSWER:

(a) and **(b)**

At the time of construction of Carmacks-Stewart Transmission Project Stage 2, it was not normal practice for YEC to retrieve fault data from substations for detailed analysis. In recent years, in an effort to improve grid reliability, this type of analysis has become common practice. As a result, YEC did not anticipate the frequency of required site visits and consequent cost and the significant benefits of remote diagnostic capability and SCADA control. Although there were some cost savings realized in the original installation, this was not the primary driver of the decision.

(c)

With any significant load growth in the Mayo region, the frequency of issues and events could be expected to increase; enhanced remote SCADA access to these sites will become increasingly beneficial and allow YEC to accomplish more work without increasing staff levels.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.4-2 Aishihik and Mayo Hydro Climate Change Study

QUESTION:

a) Please provide the scope of work and any other documentation YEC possesses on these studies.

b) What portion of the overall study cost is YEC covering?

c) At over $441,000 these studies are very costly to YEC and ratepayers. Since predictions of future water flows can only be general in nature at best, please justify this cost to ratepayers at a time of significant rate increases.

ANSWER:

(a)

The objective of the Aishihik and Mayo Climate Change Study is to develop and implement a distributed hydrological modeling system on Aishihik and Mayo watersheds YEC uses for power generation. This modelling system will be used for short (up to 2 weeks) and long (seasonal, annual) term inflow forecasting into Mayo and Aishihik lakes.

The short-term model will enable YEC to more efficiently plan short term energy generation, while the long-term model will enable YEC to forecast impacts of climate change on long-term inflow availability, inflow timing and extreme events, and, consequently, power generation. As such, the model outputs will be used as inputs to both operations planning and integrated resource planning.

The study scope is presented in terms of milestones and description of activities in Table 1.

Table1: Scope of the Aishihik and Mayo Hydro Climate Change Study

Milestone (WP - Work Package)	Descriptioin of activities
WP1 - Forecasting System - First Version	Database design, model calibration implementation of the forecasting procedure, development and implementation of the GUI
WP2 - Permafrost & Snow Permafrost Module	Integration of an analytical model, permafrost surveying and validation of the model
Technical group meetings	Twice-a-year in-person technical meetings
Technology transfer meetings	Once-a-year in-person technology transfer meetings
WP2 - Permafrost & Snow Multilayer Snow Module	Development of the model, Validation of the model and Snow surveying
WP5 - Hydroclimatic assessment	Simulations, Frequency analysis, and Change signal analysis
WP5 - Hydroclimatic assessment	Selection of CMIP5 simulations
WP5 -Ocean-Atmosphere circulation & hydrology	Selection of CMIP5 simulations, Data preprocessing, Design of observed data databases, Development of computational procedure, Identification of large-scale circulations, and Large-scale circulations & hydrology
WP1 - Forecasting System - Final Version	Updating w/r to WP2 and WP3, & integration of the data assimilation techniques, training

(b)

YEC is covering 50% of the study costs.

(c)

Please see response to part (a). Any measurable improvement in YEC operation of its facilities on these key watersheds will yield long-term savings in thermal generation costs.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.4-3 Mt. Sumanik Wind Study

QUESTION:

a) At the end of 2018 will there be a completed wind farm feasibility for Mt. Sumanik?

b) Will this study be made public?

ANSWER:

(a)

YEC had initiated collection of wind data at Mt Sumanik. The Mt. Sumanik project goal is the wind data collection and interpretation. Part of the project scope includes removal of monitoring equipment from the site once the data collection is completed. The completion of the study will depend on the quality of data collected. If warranted, the study might be extended beyond 2018.

(b)

At this time, YEC cannot commit to make public a study that is in progress. Typically, YEC strives to make its studies public, subject to normal restrictions on privacy, proprietary rights and commercial value.

TOPIC: **Section 5 Capital Projects**

REFERENCE: Page 5.4-3 Northern Diesel Plant Relocation Study

QUESTION:

a) Would it be YEC's intention to sell the land on which these plants are currently located if it is decided to move them?

ANSWER:

(a)

YEC has not yet studied options or taken a position with respect to land disposition.

TOPIC: **Other issues**

REFERENCE: **Very high levels of studies and capital projects**

QUESTION:

a) YEC's rate base seems to be growing rapidly because of high numbers of studies and a high number of smaller capital projects. They give the impression of everyone's wish list being included. Given the requested rate increases it would seem that this must be an unsustainable level of activity from a ratepayer point of view, even if no other. Please discuss what YEC anticipates in the five years following the test years – will the level of activity and costs forecasted in smaller projects for the test years continue? Please explain.

b) Does YEC have a plan or target for reducing these costs to reduce future rate increases? Will projects be selected more carefully in future, and will costs be pared down to bare essentials in future? Please explain why or why not.

ANSWER:

(a) and **(b)**

YEC takes exception to the suggestion that capital planning is done based on a "wish list" approach or that projects are not selected carefully.

The utility has been clear during this and previous proceedings that the approach to allocation of capital spending involves a thorough vetting of options with the impact to ratepayers who depend upon reliable service at front of mind at all times. This approach is explained in CW-YEC-1-34. Many of YEC assets are approaching end-of-life. While options to extend life are always reviewed, at some point this is not a viable strategy and replacement is required. Even with a like-for-like replacement, rate base and therefore rates will be increased as assets originally capitalized in the 50's, 60's and 70's are being replaced with current dollars.

YEC further disagrees with the assertion that this level of spending is "unsustainable"; YEC has a duty to provide reliable service to customers as a condition of its franchise under the *Public Utilities Act*.

YEC continually updates future capital plans; it is unreasonable at this time to speculate on levels of activity in future years outside of the test years. That being said, based on the age of the existing asset portfolio, as well as increasing demands on energy and capacity generation, it appears unlikely that investment levels will decline over time.