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MANITOBA INFRASTRUCTURE REMOTE ROAD OPERATIONS

Greenhouse Gas Follow-Up Assessment

East Side Lake Winnipeg

August 2017 – 16-3689

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East Side Lake Winnipeg Greenhouse Gas Follow-Up Assessment – Final Report

Dillon Consulting Limited (Dillon) is pleased to present the methodology and results for the East Side Lake Winnipeg Greenhouse Gas (GHG) Follow-Up Assessment. Desktop GHG calculations for the proposed RRO all-season road construction projects (P1 P2, P3a, P3b, P3c, P4, P5, P6, P7, and P7a) are summarised in this report. The results of the assessment are based on available data and a winter road traffic count conducted in February 2017.

Sincerely,

DILLON CONSULTING LIMITED

Ravi Mahabir, P.Eng., CRM
Project Manager

Our file: 16-3689

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1.0 Introduction

1.1 Background

Manitoba Infrastructure Remote Road Operations (RRO), formerly the East Side Road Authority (ESRA), is responsible for the design and construction of new all-season road (ASR) projects on the east side of Lake Winnipeg. Currently, communities in the area are serviced only by airplane, ferry, and seasonal winter/ice roads. The design and construction of ASRs will improve accessibility to the remote communities in this area.

Projects under RRO's mandate are under different phases of development; such as planning, Environmental Assessment process, functional design, detailed design, and construction.

Climate change and greenhouse gas (GHG) considerations must be incorporated into the Environmental Assessment (EA) process as per federal guidelines and as part of the provincial Environment Act licensing. A GHG Assessment for the Project 1 (P1) ASR was conducted by Dillon Consulting Limited (Dillon) in 2010 and was incorporated into the Environmental Assessment (EA) for P1. In that assessment, future values such as fuel consumption, equipment use, and traffic volumes were estimated based on the best available information. Now that construction activities have begun on P1, data related to fuel consumption, construction equipment, air travel, vehicle travel, and ferry travel has been collected over the past five years, and may be more accurate than the estimated values used in the 2010 P1 GHG Assessment. In addition, a winter road traffic count was conducted in February of 2017 throughout the East Side Lake project area. The recently collected data is relevant to all of the proposed ASR projects, and therefore this report provides an update of the 2010 P1 estimates based on current data methodologies, available data on the new projects, and data collected from P1 which would be representative of other projects.

The Canadian Environmental Assessment Agency (CEAA) provided a letter to the RRO/ESRA highlighting specific requirements for the GHG considerations within the Project 4 (P4) ASR EA on February 11, 2016. The requirements include:

- An estimate of the direct GHG emissions associated with all phases of the project. This information is to be presented by individual pollutant and should also be summarized in carbon dioxide equivalents (CO_2e) per year. Individual GHGs include CO_2, methane (CH_4) nitrous oxide (N_2O), perflurocarbons (PFCs), hydroflurorcarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluroide (NF_3).
- An analysis of cumulative GHG emissions of current (e.g. facilities in operation) and reasonably foreseeable (e.g. proposed) projects should also be included in the cumulative effects assessment.

These comments have been taken into consideration in the development of this study, to the extent possible. CEAA comments related to identification of GHG mitigation measures applicable to each individual project are outside of the scope of this report.

1.2 Greenhouse Gas Considerations

The ASR projects involve the construction and operation of the ASR in the region east of Lake Winnipeg. Ongoing and proposed ASR projects will have GHG emissions associated with both the construction and operational phases.

The projects vary in scale and anticipated construction timelines, as described in further detail in Section 2.2. The existing and planned RRO ASR projects total approximately 1,100 km, and will replace approximately 1,250 km of winter roads. Manitoba Infrastructure maintains approximately 19,000km of all-season roads and constructs 2,200 km of winter roads yearly (MI, 2016). The projects will contribute to a minor increase in the total length of roadway in Manitoba, and primarily replaces winter roads with all-season roads.

Environment and Climate Change Canada (ECCC, 2016) provides annual national and provincial GHG emissions per sector, from 1990 to 2014. The most recent GHG inventory year of 2014 indicated that for construction activities in Manitoba, approximately 0.111 megatonnes CO_2e were emitted in 2014, the total emissions for road transportation in the province was approximately 6.29 megatonnes CO_2e. Since 1990, the annual GHG emissions from construction in Manitoba have increased by approximately 75% and GHG emissions due to road transportation in Manitoba have increased by approximately 62%.

Nationally, GHG emissions from the construction sector in 2014 was estimated to be approximately 1.29 megatonnes CO_2e, and for the road transportation sector it was estimated to be approximately 140 megatonnes CO_2e (ECCC, 2016). The emissions due to construction decreased in 2014 by 31% from 1990 levels and for the road transportation sector there was an increase of approximately 41%. Manitoba contributed less than 9% to the national GHG emissions due to construction and less than 5% to the national road transportation GHG emissions in 2014.

In order to determine the magnitude of the GHG emissions associated with the ASR projects, this GHG assessment is being conducted.

1.3 Assessment Outline

An overview of the RRO ASR projects can be found in Section 2. A description of the assessment methodology is detailed in Section 3, and a summary of the estimated GHG emissions associated with each ASR project can be found in Section 4.

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2.0 The Projects

The RRO ASR projects located along the eastern shoreline of Lake Winnipeg area shown in Figure 1. The study area encompasses First Nations traditional lands and the limits extend from the:

- South - Hollow Water First Nation traditional land;
- North - Bunibonibee Cree Nation;
- East - Pauingassi First Nation, Little Grand Rapids First Nation, and Red Sucker Lake First Nation; and
- West - Poplar River First Nation and Norway House Cree Nation.

2.1 Existing Conditions

The area to the north and east of Lake Winnipeg is not currently served by ASRs, with the exception of some sections of the P1 ASR where construction is complete. The remoteness of communities in the area, their size and lack of economic development has resulted in a costly and limited transportation system. These communities included the Southeast Resource Development Council (SRDC) communities of Poplar River, Berens River, Bloodvein, Little Grand Rapids, and Pauingassi; the Island Lake Tribal Council (ILTC) communities of St. Theresa Point, Wasagamack, Garden Hill, and Red Sucker Lake; and the Keewatin Tribal Council (KTC) communities of Oxford House (Bunibonibee), Gods Lake Narrows, and Gods River (Manto Sipi).

The transportation system for the East Side Lake Winnipeg project area relies on air service, seasonal ferry service during the non-winter months, and seasonal winter/ice roads. The northern portion of the seasonal road network is connected to Provincial Trunk Highway (PTH) 6 and Provincial Road (PR) 373. The southern portion of the seasonal road network is connected to PR 304, which is a paved provincial trunk road and connects to Winnipeg via Highway 59. In addition, a ferry, M.V. Edgar Wood, serviced Bloodvein via Islandview prior to the recent development of the P1 ASR project. Lastly, scheduled and charter flights provide service to the East Side Lake Winnipeg project area.

The study area is covered by boreal forest, wetlands, small rivers and lakes. The predominant forest cover is Black Spruce and Jack Pine within the Boreal Shield ecozone.

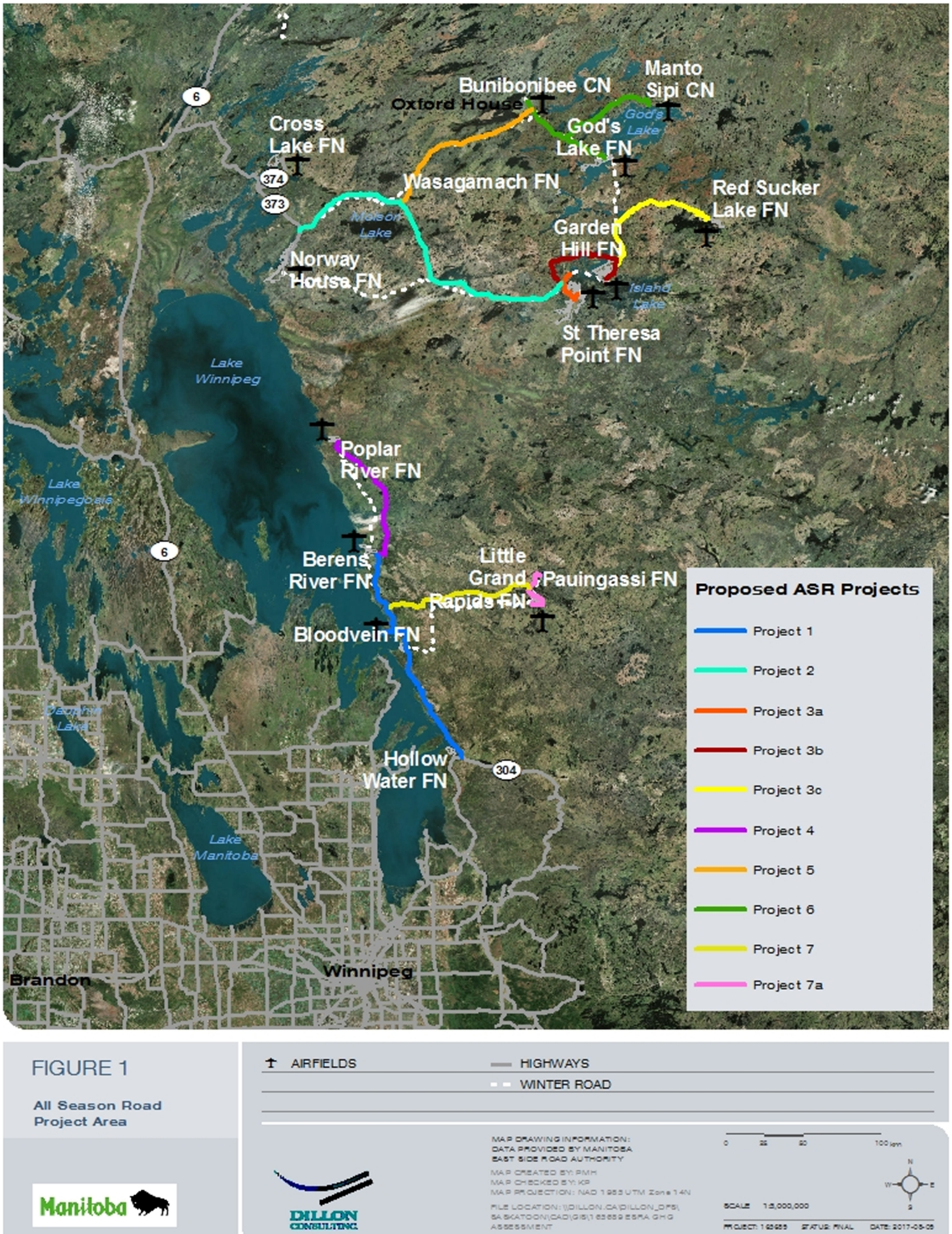

Figure 1– Study Area

2.2 Project Description

The RRO ASR projects are detailed in Table 2.1.

The proposed ASRs will be gravel, 10 m in width, with two 3.7 m wide lanes, 1.0 m shoulders and a 0.3 m shoulder rounding allowance. The roadway will be centred within a 100 m right of way (ROW) and the cleared limit of the roadway will be 60 m within this ROW. Further clearing will be on as required basis to maintain line of sight. In an effort to minimise clearing, where applicable, the alignment will follow the existing seasonal winter/ice road and Manitoba Hydro distribution line ROW. The proposed ASRs will also entail the construction of a number of bridges (both permanent and modular) in order to cross water courses.

The construction of each proposed ASR is anticipated to be completed within 4-8 years, depending on the project. Borrow and quarry areas near the proposed ASRs will be required to support construction, operations, and maintenance needs.

Table 2.1 – RRO ASR Projects and Phases

Project	Length[1] (km)	Alternative Modes of Transportation	Number of Proposed Bridges[2/6]	Phase/ Status	Assumed Construction Dates[3]	Assumed Years of Construction[4]
Project 1 (P1)	167.8	· Air Travel · Ferry · PR 304/Highway 59 to Seasonal Road	Modular - 0 Permanent - 9	Construction	2012-2019	8
Project 2 (P2)	225.9	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 0 Permanent - 2	Planning	2030-2037	8
Project 3a (P3a)	28.2	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 0 Permanent - 3	Construction	2016-2021	5
Project 3b (P3b)	79.6	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 0 Permanent - 7	Planning	2030-2036	7
Project 3c (P3c)[5]	114.6	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 1 Permanent - 2	Planning	2030-2036	7
Project 4 (P4)	94.4	· Air Travel · PR 304/Highway 59 to Seasonal Road	Modular - 0 Permanent - 4	Environmental Assessment	2018-2025	8
Project 5 (P5)	113.6	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 3 Permanent - 0	Planning	2030-2037	8
Project 6 (P6)	137.3	· Air Travel · PTH 6/ PR 373 to Seasonal Road	Modular - 0 Permanent - 2	Environmental Assessment	2030-2037	8

Project	Length[1] (km)	Alternative Modes of Transportation	Number of Proposed Bridges[2/6]	Phase/ Status	Assumed Construction Dates[3]	Assumed Years of Construction[4]
Project 7 (P7)	102.4	· Air Travel · PR 304/Highway 59 to Seasonal Road	Modular - 0 Permanent - 6	Planning	2020-2027	8
Project 7a (P7a)	41.2	· Air Travel · PR 304/Highway 59 to Seasonal Road	Modular - 0 Permanent - 2	Environmental Assessment	2016-2020	5

1 – Proposed ASR lengths based on geographic information systems (GIS) shapefiles provided by RRO staff on June 10, 2016.
2 – Proposed number of bridges per project based on GIS shapefiles provided by RRO staff.
3/4 – Anticipated construction dates estimated for P2, P3a, P3b, P3c, P5, and P6 were assumed based on limited data and confirmed with RRO staff. These dates are subject to change.
5 – The proposed P3c road alignment and associated bridge requirements have not been determined. The stated information, therefore, follows existing winter road alignment and estimates the number of bridges based on similar proposed ASR projects in the area.
6 – A detailed examination of the topography needs to be completed before routing and crossings can be finalized.

3.0 GHG Emissions Assessment Methodology

The GHG Assessment is based on comparing the estimated annual GHG emissions for the Baseline Scenario (without the project) to the Project Scenario (with the project). In both scenarios, the timeframe of the annual GHG emissions is projected for the anticipated length of Project Scenario construction of the ASR followed by up to 30 years of operation. The natural ecosystem sources and sinks are also included to demonstrate their contribution to the overall GHG implications of the Baseline and Project Scenarios. Section 3.1 describes the Baseline Scenario calculation methodology, and Section 3.2 describes the Project Scenario calculation methodology.

Calculations associated with both the Baseline Scenario and Project Scenario are included in Appendix A.

3.1 Baseline Scenario

The Baseline Scenario assumes that existing conditions are to continue into the future. The timeline begins at the proposed start date for each ASR project, and is projected for the length of time equal to the total construction period of the proposed ASR plus up to 30 years of operation. The scenario further assumes that the existing climatic conditions will be maintained, as the impacts of climate change to the study region cannot be exactly predicted and is beyond the scope of this GHG assessment. The changes in climate are expected to impact the transportation patterns of the study region due to a shortened winter road season, and increased frequency of extreme weather events.

The Baseline Scenario GHG emissions and sinks / removals and the resulting cumulative GHG emissions are estimated by the following equation:

Annual Baseline GHG Emissions (tonnes CO_2e/yr)
= *- Carbon sequestration due to forest carbon sequestration along the proposed ASR (tonnes CO_2e/yr)*
+ Net GHG emissions due to wetlands and soil along the proposed ASR (tonnes CO_2e/yr)
+ GHG emissions due to air travel to/from relevant communities (tonnes CO_2e/yr)
+ GHG emissions due to ferry crossings to/from relevant communities (tonnes CO_2e/yr)
+ GHG emissions due to vehicular travel on seasonal winter/ice roads (tonnes CO_2e/yr)
+ GHG emissions due to the construction and maintenance of seasonal roads (tonnes CO_2e/yr).

Estimated emissions for specific GHGs were also calculated, based on the above equation (including CO_2, CH_4, and N_2O). Detailed results can be found in Appendix B.

Details on the above sources and sinks / removals are given in the following sections.

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3.1.1 Carbon Sequestration of Forest

Canada's National Forest Inventory (NFI, 2016a) has classified the ecozone, within which the study area is located, as Boreal Shield. For the study area, the NFI plot statistics indicated that the predominant tree species in the study area is Black Spruce followed by Jack Pine based on the most recent forest inventory maps.

Trees serve as a carbon sink by sequestering carbon emissions (in the form of CO_2) from the air. In order to estimate the carbon sequestration rate of the forest cover, the total carbon stock of the forest cover along the proposed ASR was calculated, and was attributed to the estimated average age of the forest cover in each project area. The methodology used in estimating the total carbon stock was based on the Tree Canada (2015) protocol for calculating the above and below ground carbon stock of the forest cover.

The aboveground carbon (C) stock is estimated using the following relationship:

Above Ground C-stock (tonnes CO_2)
= above ground tree density (tonnes tree/ha)
× project area (ha)
× specific gravity of tree dry weight to green tree weight (unitless)
× conversion to aboveground dry tree biomass to tree biomass C (tonne C/ tonnes dry tree biomass)
× C-CO_2 conversion (tonne CO_2/tonne C).

The below ground C-stock is estimated by:

Below Ground C-stock (tonnes CO_2)
= root-shoot ratio
× Aboveground C-stock (tonnes CO_2).

The rate of carbon sequestration is estimated by:

Forest Sequestration Rate (tonnes CO_2/year)
= Aboveground C-stock (tonnes CO_2) + Belowground C-stock (tonnes CO_2)
x Average age of forest (years).

Parameters pertaining to the above equation (C-CO_2 conversion, and root shoot ratio) are retrieved from the Tree Canada (2015) methodology for broadleaf, coniferous, and mixed wood forests in Manitoba's boreal shield. NFI (2016b) statistics for the Manitoba boreal shield west forest provide the tree density of the forest cover.

The age of the forest stand in the area is estimated based on an analysis of Natural Resource Canada's Wildland Fire Information System GIS maps (NRCan, 2016a). The GIS maps provide forest fire perimeters in the province of Manitoba from the year 1928 to 2014. Historic forest fire activity influences the overall age of the forest stand which in turn informs the biomass density and volume parameters described above. The weighted average age of forest within each project area was determined based on historical fire areas and dates. Where no fires occurred within the GIS data, it was assumed that the maximum tree age was 100 years.

The aboveground tree biomass and density represents green biomass, where water content is included in the tree weight. The average moisture content of wood as a percentage of green wood by weight is 36% for North American spruce tree species and 43% for pine tree species (Miles and Smith, 2009). As such, an average dry weight biomass to green tree biomass of 40% is applied to the aboveground green tree biomass.

Spatial coverage of hardwood, softwood, and other land uses along the ROW of the proposed ASR was determined for the proposed RRO ASR project in question. A 60 m width along the length of the proposed ASR was considered as the project area. The land cover statistics along the ROW for the length of the ASR were determined through publically available land use GIS data (NRCan, 2000).

3.1.2 Net GHG Emissions from the Land Cover

The route of the proposed ASR traverses both wetlands and forested areas. Boreal wetlands and uplands (forested areas) are known natural sources and sinks of CH_4 (e.g., Bubier et al., 2005, and Potter et al., 2001) and CO_2 (Potter et al., 2001, and Trumbore et al., 1999).

The following methodology was used in estimating the net GHG emissions from the wetlands impacted by the ASR:

Net GHG emissions due to land cover along the proposed ASR (tonnes CO_2e/yr)
= Methane flux from forest soils (tonnes CO_2e/ha) × forest area (ha)
+ Methane flux from wetlands (tonnes CO_2e/ha) × wetland area (ha)
+ Carbon dioxide flux from forest soils (tonnes C/ha) × forest area (ha)
+ Carbon dioxide flux from wetlands (tonnes C/ha) × wetland area (ha)
× C-CO_2 conversion (tonne CO_2/tonne C).

Several academic studies pertaining to methane and carbon flux (net ecosystem production) have been conducted in the boreal wetland and old black spruce upland near Thompson, Manitoba. These studies include: Potter et al. (2001a), Potter et al. (2001b), Bubier et al. (2005), Yuan et al. (2008), and Trumbore et al. (1999). The studies provided ranges of measured or modelled emission flux values. An average of the ranges provided in all five studies was taken to estimate both the methane and carbon flux from forest soils and wetlands, respectively. Each study is described below, and the overall flux value used for the purposes of this study is presented in Table 3.1.

Using a process model, Potter et al. (2001a) estimated the carbon sink ranging from -10.7 to -11.8 g C/m^2/yr for wetland (fen) area and -49.1 to -25.8 g C/m^2/yr for an old black spruce upland area. Methane (CH_4) emissions were estimated to range from 4.0 to 5.3 mg CH_4/m^2/day in wetland areas, and -0.79 to -0.86 mg CH_4/m^2/day in old black spruce uplands.

A study by Potter et al. (2001b) compared the results of net ecosystem production from nine models considering the same study area near Thompson, Manitoba. Results of the comparison demonstrated a range of -11 to 61 g C/m^2/yr with an average carbon source of 24 g C/m^2/yr for the forest stand.

Bubier et al. (2005) measured that methane (CH_4) emissions over the growing season from wetlands ranged from 12 to 250 mg CH_4/m^2/day and sinks (removals) from black spruce upland soils that ranged from -0.1 to 0.1 mg CH_4/m^2/day. The wetland consisted of fens, bogs, and small ponds. The forested areas were mature forests 60 years or more in age (since the last burn). These emissions and removals would occur over the growing season of the study area which was estimated to be from April to October.

Another study by Yuan et al. (2008) observed net ecosystem production of 81 g C/m^2/yr in the Thompson, Manitoba black spruce study area.

Trumbore et al. (1999) measured and estimated the annual carbon sink from four differing wetlands and using three different estimation methods that ranged from - 180 to 2.65 g C/m^2/yr. The negative value indicates that the wetland was a carbon source during the study period.

Table 3.1 – Average Carbon and Methane Fluxes in Forest Uplands and Wetlands

Land Cover	CH_4 Emission Average* (g CH_4/m^2/year)	C Emission Average (g C/m^2/year)	Net GHG Emission Average (g $C0_2e/m^2$/year)
Forest (Uplands)	-0.145	7.53	24.0
Wetland	16.9	-59.3	206

* CH_4 emissions are assumed to occur over the growing season only, estimated to be from April to October.

The land cover statistics along the ROW for the length of the ASR were determined through publically available land use GIS data (NRCan, 2000). The data provides the land areas considered forest and wetland within the project ROW. Net GHG emissions (emissions minus removals) are estimated from the wetland and forested area data. The methane emissions and removals occur over the growing season of the study area which was estimated to be from April to October. The carbon emissions and removals occur over the course of the entire year. As presented in Table 3.1 above, both forest (uplands) and wetlands areas serve as a net GHG source.

It should be noted that CO_2 and CH_4 emissions and removals (i.e., flux) are highly variable, intermittent and are dependent on environmental temperature (growing season), moisture and precipitation. Thompson, Manitoba, where the studies above were conducted, is approximately 150-400 km north of the study area and, therefore, has lower annual environmental temperatures and rainfall than the study area. It is, therefore, expected that the net CO_2 and CH_4 flux may be slightly higher for the study area than the calculated approximations from these research studies. The above process for the estimation of net CO_2 and CH_4 emissions from wetlands and forest soil for the study area should, therefore, be considered as an approximation.

3.1.3 GHG Emissions of Air Travel

Air travel by airplane and helicopter is the primary mode of transit in and out of the communities in the project areas in the Baseline Scenario. The GHG emissions based on air travel was estimated from the routes of flights (based on schedules), flight distances, and the total average annual passenger kilometers projected up to 30 years after the proposed project is constructed. Helicopter flights to connect isolated communities to airports were also considered. Fuel burned in air travel emits CO_2, CH_4, and N_2O.

The annual GHG emissions due to the air traffic can be calculated from:

Annual Air Travel GHG Emissions (tonnes CO_2e/yr)

$$= \Sigma_{Airport}\{\text{Passenger-kilometers (km)} \times EF_{air}\ (\text{kg } CO_2\text{e/passenger kilometer}) \times 10^{-3}\ \text{tonnes/kg}\}$$

$$= \Sigma_{Airport}\{\text{Annual use (hours)} \times \text{Fuel Efficiency}_{helicopter}\ (\text{L/hr}) \times EF_{helicopter}\ (\text{kg } CO_2\text{e/L fuel})\}.$$

Where:

Airport refers to the airport in the relevant communities;

Passenger-kilometers is the annual summation of kilometers travelled by all passengers;

EF_{air} = the emission factor short-haul flights; and

$EF_{helicopter}$ = the emission factor for helicopters.

Airplane Travel

Nearly every community in the study area is supported by a remote airstrip; however, the following communities are serviced by airports with commercial/scheduled airline service:

- Berens River
- Bloodvein;
- Cross Lake;
- Garden Hill (Island Lake);
- Gods Lake;
- Gods River (Manto Sipi);
- Little Grand Rapids;
- Norway House;

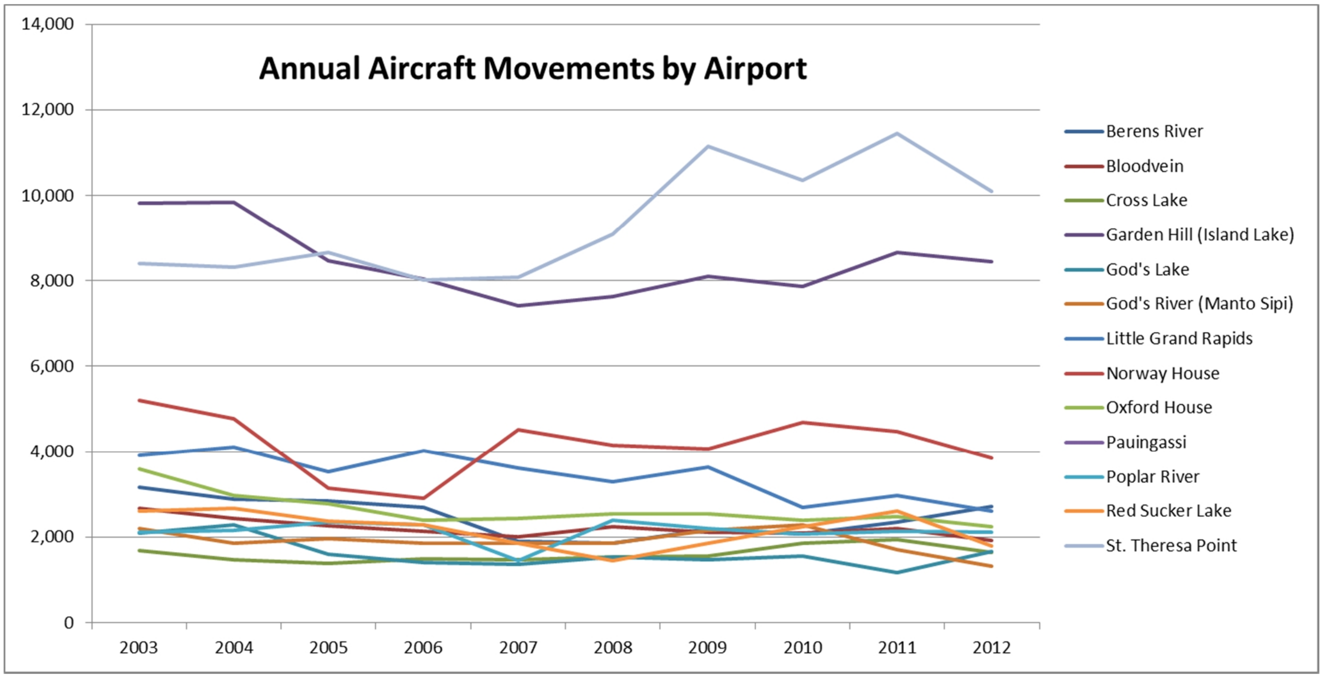
- Oxford House;
- Poplar River;
- Red Sucker Lake; and
- St. Theresa Point.

Data on the number of air movements at the relevant airports was sourced from Manitoba Infrastructure (MI, 2016b) and is presented in Table 3.2. The average air traffic movements from 2003 – 2012 was used to estimate air travel from each relevant airport, as this time period represents the most recent available 10 year data set (MI, 2016b). As demonstrated in the graph in Figure 2 below, no distinguishable trends in air traffic increases or decreases can be reasonably confirmed, and as such it was assumed that aircraft movements will remain consistent (with the 10 year average) in future years for the purposes of this assessment.

Table 3.2 – Total Air Movements in the Study Area from 2003 to 2012

Airport	Number of Air Craft Movements										
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
Berens River	3,175	2,881	2,838	2,686	1,902	1,860	2,176	2,070	2,347	2,706	2,464
Bloodvein	2,668	2,429	2,272	2,144	1,997	2,233	2,112	2,092	2,207	1,928	2,208
Cross Lake	1,677	1,463	1,382	1,484	1,480	1,537	1,554	1,853	1,946	1,645	1,602
Garden Hill (Island Lake)	9,812	9,835	8,465	8,027	7,417	7,621	8,102	7,873	8,653	8,453	8,426
God's Lake	2,091	2,275	1,598	1,400	1,354	1,526	1,467	1,553	1,159	1,655	1,608
God's River (Manto Sipi)	2,196	1,861	1,966	1,851	1,863	1,866	2,150	2,290	1,714	1,321	1,908
Little Grand Rapids	3,910	4,115	3,531	4,025	3,626	3,290	3,637	2,695	2,982	2,606	3,442
Norway House	5,213	4,777	3,134	2,901	4,510	4,147	4,072	4,697	4,473	3,841	4,177
Oxford House	3,593	2,970	2,770	2,402	2,434	2,538	2,534	2,398	2,482	2,234	2,636
Poplar River	2,108	2,151	2,356	2,296	1,458	2,400	2,205	2,066	2,144	2,118	2,130
Red Sucker Lake	2,603	2,682	2,380	2,285	1,860	1,440	1,861	2,246	2,612	1,782	2,175
St. Theresa Point	8,390	8,323	8,668	8,020	8,078	9,092	11,142	10,348	11,458	10,104	9,362

Figure 2 – Annual Aircraft Movements by Airport (2003-2013)



Based on an analysis of scheduled flights from commercial airlines, the airport to airport air movement fraction was determined. Airline schedule data was obtained through airline websites (Northway Aviation, 2016a; Perimeter Aviation, 2016a). The airport movement fraction ratios were applied to the passenger traffic values presented in Table 3.3 (which encompasses both scheduled and chartered flights) to estimate the annual passenger traffic for each airport by destination. These values were multiplied by the airport to airport distance (in kilometers) to determine the overall passenger kilometers travelled by airport and year.

It should be noted, however, that actual air movements are suspected to be higher than those officially recorded as aircraft arrive and depart from the airports outside of official hours. Therefore, when estimating the GHG emissions associated with air traffic movement, the reported air movements given in Table 3.2 and reported passenger traffic given in Table 3.3 were increased by 25% to account for the unrecorded air movements, based on feedback from RRO. This assumption was also made in the 2010 P1 GHG assessment, as was deemed reasonable. A sensitivity analysis has demonstrated that the assumed 25% assumed increase in recorded passenger traffic values does not affect the results of the assessment. The air movement and passenger traffic analysis is presented in full in Appendix C.

Table 3.3 – Total Passenger Airplane Traffic in the Study Area from 2000 to 2012

Airport	Passenger Traffic										
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Average
Berens River	7,853	7,697	6,553	6,456	4,418	4,892	5,581	5,644	6,790	8,648	6,453
Bloodvein	3,851	3,434	3,153	3,353	2,377	1,264	1,264	3,928	1,264	4,715	2,860
Cross Lake	5,205	4,615	3,392	4,055	3,523	3,993	4,076	5,548	5,770	5,019	4,520
Garden Hill (Island Lake)	34,238	35,302	37,175	39,030	34,577	38,221	40,716	36,341	50,567	54,615	40,078
God's Lake	7,825	6,880	10,786	14,391	11,231	14,755	13,852	13,682	11,890	14,820	12,011
God's River (Manto Sipi)	4,717	4,087	4,710	4,936	4,452	5,386	5,300	5,458	4,933	4,283	4,826
Little Grand Rapids	7,688	8,630	7,917	9,505	7,376	7,702	8,788	6,712	6,313	5,124	7,576
Norway House	13,652	12,985	8,339	4,415	3,999	7,201	8,515	8,657	6,690	6,226	8,068
Oxford House	13,335	10,743	10,598	10,261	9,665	10,282	10,956	10,385	14,590	11,866	11,268
Poplar River	5,473	6,072	6,733	6,209	4,327	7,486	8,426	8218	7728	7676	6,835
Red Sucker Lake	4,867	5,538	6,010	4,933	5,135	4,770	5,710	5,612	4,845	4,010	5,143
St. Theresa Point	25,951	26,028	31,000	31,398	31,699	39,273	35,126	32,544	39,759	45,962	33,874

The air service providers and types of aircraft operating within the study area are presented in Table 3.4. Aircraft fleet data is obtained through Transport Canada's Civil Aircraft Registry (Transport Canada, 2016). In general, turbo prop short-haul aircraft are used in the project area.

Table 3.4 – Air Service Providers and Aircraft Types

Service Provider	Airports Serviced	Aircraft Make and Model	Quantity
Perimeter Aviation	Berens River St. Theresa Point Wasagamack Island Lake / Garden Hill God's Lake Red Sucker Lake Manto Sipi/ God's River Oxford Lake/ Bunibonibee Cross Lake	Fairchild SA227-AC	8
		Swearingen SA226-TC	15
		Beech E95	1
		Beech 95-B55	2
		Dehavilland DHC-8-106	2
		Dehavilland DHC-8-314	2
		Dehavilland DHC-8-102	1
Northway Aviation	Berens River Bloodvein Pauingassi Poplar Hill Little Grand Rapids	Pilatus PC-12	1
		Cessna 208	2
		Cessna 208B	4
Amik Airlines	Pauingassi Little Grand Rapids Bloodvein	Cessna 208	2
		Cessna 208B	1
		Cessna A185F	1

An emission factor, EF_{air}, for domestic flights from the United Kingdom (UK) Department for Business, Energy, and Industrial Strategy (2016) was used based on passenger kilometers travelled (0.2787 kg

CO_2e/passenger-km). This emission factor includes an 8% uplift factor, an adjustment recommended by the Intergovernmental Panel on Climate Change (IPCC) to account for discrepancies in geographical distance and actual flight distance, circling, and routing of take-off/landing. A multiplier (of 1.9) was applied to the CO_2 emission factor to account for uncertainty surrounding non-CO_2 climate change effects of aviation, as recommended by the methodology (UK Department for Business, Energy, and Industrial Strategy, 2016). Speciated emission factors, EF_{air} in units of kg/passenger kilometer were applied for CO_2, CH_4, and N_2O emissions from the same source.

Helicopter Travel

Helicopter travel is required in the Little Grand Rapids, Pauingassi and Island Lake communities to shuttle persons to the nearest airport for approximately three months per year during spring break up and winter freeze up, when both winter roads and ferry travel are not available. This situation is not the case for all communities. Annual helicopter usage was provided by RRO staff and obtained from helicopter service providers. The fuel efficiency is assumed to be 114L/hr, as per the Bell Jet Ranger helicopter statistics (Delta Helicopters, 2016), which are the most commonly used helicopters in the area.

Emission factors, $EF_{helicopter}$, were sourced from the ECCC speciated emission factors (NIR, 2016) in units of kg/L fuel for CO_2, CH_4, and N_2O emissions.

3.1.4 GHG Emissions of Ferry Crossing

Manitoba Infrastructure operated the one ferry in the study area, M.C. Edgar Wood. The ferry service provided a vital link for the connected communities in the Baseline Scenario. According to RRO staff, a private ferry operation also historically operated in the same region as the M.C. Edgar Wood.

Ferry operations emit CO_2, CH_4, and N_2O emissions associated with burning fossil fuels. The GHG emission estimates are based on the total number of round trip ferry crossings per year, the total distance of each trip, and the projected number of such trips forecasted up to 30 years past construction completion.

The annual GHG emissions due to the ferry crossings can be calculated as follows:

$$\begin{aligned} &\textit{Annual Ferry Crossing GHG Emissions (tonnes } CO_2e/yr) \\ &\quad = \textit{Average annual passenger traffic (unitless)} \\ &\quad \times \textit{Distance per trip (km)} \\ &\quad \times \textit{Fuel consumption}_{ferry} \textit{ (L/passenger-100 km)} \\ &\quad \times EF_{ferry} \textit{ (kg } CO_2e/L) \times 10^{-3} \textit{ (tonnes/kg).} \end{aligned}$$

Historically, ferry and barge service to Bloodvein occurred from April / May to October, inclusive, from Islandview and Pine Dock harbours. Ferry services in the existing scenario are presented in Table 3.5

below. The M.C. Edgar Wood ferry closed in late 2015, but it will be considered in the Baseline Scenario since its closure was due largely to the availability of the partially completed P1 ASR. Manitoba Infrastructure (MI, 2016c) provided data on the ferry service which is used to estimate the existing and the potential future annual number of trips conducted by the ferry service, details of which are highlighted in the table below.

Table 3.5 – Ferry Information – Baseline Scenario

Ferry Name	Connecting Communities	Projects Impacted	Operating Schedule	Trip Distance (km)	Average Annual Passenger Traffic (2000-2010)
M.V. Edgar Wood	Bloodvein Princess Harbour Islandview	P1	May 25- October 26	45	2,393

For the purposes of this study, it is assumed that the ferry season is from the beginning of May to the end of October. An emission factor (EF_{ferry} =5.1 L diesel/ passenger-100km) and fuel consumption rate (EF_{ferry} = 2.914 kg CO_2e/L diesel) for ferries from the B.C. Ministry of Environment (2016) is used based on passenger kilometers travelled. A speciated emission factor for CO_2, CH_4, and N_2O was also used, as provided in B.C. Ministry of Environment (2016) guidelines.

No data is available for the privately operated ferry/barge. Therefore it is assumed that the annual GHG emissions associated with this private operation was approximately 50% of the emissions due to the M.V. Edgar Wood ferry.

It should also be noted that in addition to ferry services in Bloodvein, there is also water taxi services on Island Lake in the open water season. Water taxi services were not included in calculations as it is assumed that this type of travel will remain relatively consistent between both the Baseline Scenario and Project Scenario, and there is limited data availability.

3.1.5 GHG Emissions of Vehicular Travel

For the Baseline Scenario, vehicular travel results from transporting community supplies during the winter/ice road season, and travel to ferry access. As such, the annual GHG emission due to vehicles travelling both on existing highways and seasonal roads was estimated using the following formulae:

Annual GHG due to Vehicular Travel (tonnes CO_2e/yr)
= Travel on Existing Seasonal (Winter and Ice) Roads (tonnes CO_2e/yr)
+Travel on Existing Highways to Ferry Terminal (tonnes CO_2e/yr).

Where:

Annual GHG Emissions of Travel on Existing Seasonal Roads (tonnes CO_2e/yr)

= $\Sigma_{seasonal\ road\ segment}$ $\Sigma_{vehicle\ category}$ {Vehicle Category Number of Trips (trips/yr) X Trip Distance (km/trip) X Fuel Use (L/100km) X $EF_{vehicle\ category}$ (g CO_2e/L) × 10^{-6} (tonnes/g)}.

And:

Annual GHG Emission Travel on Existing Highways to Ferry Terminals (tonnes CO_2e/yr)

= $\Sigma_{vehicle\ category\{}$ $\Sigma_{vehicle\ category}$ {Vehicle Category Number of Trips (trips/yr) X Trip Distance (km/trip) X Fuel Use (L/100km) X $EF_{vehicle\ category}$ (g CO_2e/L) × 10^{-6} (tonnes/g)}.

Emission factors were retrieved from ECCC (NIR, 2016). Specifically, the emission factor is 2,462 g CO_2e/L for cars (light duty vehicles or LDV), 2,495 g CO_2e/L fuel for pickup trucks (light duty truck or LDT), 2,718 g CO_2e/L fuel for heavy trucks (heavy duty or HD), and 2,992 for off-road vehicles. Light duty vehicle cars, light duty trucks, and off-road vehicles were assumed to be gasoline-fueled with moderate controls, as gasoline was observed to be the most widely available fuel in the area. Heavy duty (transport) trucks were assumed to be diesel. Speciated emission factors in units of kg/L fuel for CO_2, CH_4, and N_2O emissions (NIR, 2016) were also used in the calculations.

The fuel consumption rate of 9.2 L/100 km for a typical car (LDV), 12.3 L/100 km for a typical pickup truck (LDT) or off-road vehicle travelling on asphalt road surface was conservatively assumed to represent the fuel economy (B.C. Ministry of Environment, 2016). For the heavy truck category, a fuel consumption rate of 39.5 L/100 km for a typical heavy truck (HD) travelling on asphalt road surface was assumed (NRCan, 2016b).

However, gravel road and winter road surfaces lower fuel efficiency as compared to asphalt road surfaces. Due to the poorer road surface conditions that a gravel road present in comparison to a paved road surface, the US EPA (2006) has estimated that fuel efficiency on gravel roads are 83.9% of paved roadways. This deterioration in fuel economy is applied to travel on gravel roadways such as PR 234 which connects Winnipeg to ferry services in Pine Dock. Winter and ice road surfaces also lower fuel efficiency as compared to asphalt roads. NRCan (2016c) estimates that the fuel economy degrades by 1.5-3.0% due to temperature, and 7%-35% due to poor road conditions, both of which are present during winter road travel. As such, it is assumed that fuel economy is decreased for travel on snowy gravel roads in comparison to dry paved (asphalt) roads by an average of the two above ranges (approximately 23%).

Travel on Seasonal (Winter/Ice) Roads

Vehicular traffic volumes on the winter and ice roads were estimated for the projects based on a winter road traffic count that was conducted over several days at a variety of locations in the East Side Lake Winnipeg project area in February 2017. Results of the winter road traffic assessment are found in Appendix D.

The traffic count was conducted at eight locations in the project area over the course of a two-week period during the winter road season for a total of 24 - 74 hours per location. Traffic counting shifts occurred between 4am and 10pm. The winter and ice roads are estimated to be operational for two months from approximately January 1st to March 1st (i.e., approximately 60 days), and as such results of the traffic count were extrapolated to a 60 day seasonal (ice/winter) road season. This assumption provides an estimate on the total number of trips per vehicle category for the season (i.e., year) on a given road segment (ice road or winter road). It was assumed that each vehicle counted was headed to the next community in order to estimate approximate kilometerage for each project area.

Table 3.6 summarises the traffic volumes on winter roads associated with each ASR project. It should be noted that these volumes are an approximation and that traffic volumes are dependent on a variety of factors such as weather, road conditions, bulk shipment schedules, special community events, development activities, and other factors.

Table 3.6 – Estimated Winter and Ice Road Travel Distances

Project	Winter Road Vehicle Travel Distance per 60 Days (km)			
	ATV/ Snowmobile (Off-Road)	Car (LDV)	Truck /Van / SUV (LDT)	Transport Truck (HD)
P1	0	27,691	1,542,412	274,145
P2	13,072	0	309,377	392,168
P3a	0	0	20,507	34,862
P3b	2,164	0	62,742	29,568
P3c	9,720	0	345,053	35,794
P4	1,962	3,924	280,536	19,618
P5	43,872	0	1,144,664	414,791
P6	23,999	0	581,768	183,710
P7	0	4,517	309,421	60,981
P7a	0	547	37,503	7,391

Estimated Annual Volume of Vehicles based on Ferry Travel

Multi-modal travel to the study area may involve vehicular travel in conjunction with ferry. As such, travel from Winnipeg to Pine Dock/Islandview Harbour to access the ferry terminal is included in the Baseline Scenario. For the purpose of this study, it was conservatively assumed that all travel originated or terminated from or in Winnipeg. Estimating the travel distances and patterns from other communities along the highways, and other travel patterns that would flow into these roadways was considered beyond the scope of this study. Access to the ferry from Winnipeg is via PR 234 (80 km) and PTH 8 (140 km). PTH 8 is asphalt and PR 234 from PHT 8 to Islandview / Pine Dock is a gravel road.

The annual total number of cars and pickup trucks, and heavy trucks travelling between Winnipeg and Pine Dock/Islandview Harbour was estimated from the ferry passenger and freight data, received from

Manitoba Infrastructure staff (MI, 2010). Publically available data (MI, 2016d) on the number of passengers, volumes of vehicles and the vehicle classes that used the ferry to cross to and from Pine Dock/ Islandview Harbour and Bloodvein were also used in the calculation. Note that the cars and pickup truck category include vehicles up to ¾ -ton trucks and miscellaneous vehicles (motorcycles and all terrain personal vehicles). The heavy truck category included trucks with single and dual axle over ¾-ton, semi-trailers, buses, graders and loaders.

No data on vehicular volumes and types were available for the privately operated ferry/barge. Therefore it was assumed that the additional traffic going to this ferry/barge was 50% of the traffic reported for the M.V. Edgar Wood.

3.1.6 GHG Emissions of Seasonal Road Construction and Maintenance

Seasonal roads (i.e., winter roads and ice roads) currently serve communities throughout the project area. It was assumed that the seasonal roads are constructed and operated annually for a two month period between January and March. The GHG emissions are due to the mobile equipment used to construct the winter roads and ice roads, and the emissions associated with the equipment used in the general maintenance of the seasonal roads as demonstrated in the equation below.

$$\text{Annual GHG Emissions Construction and Maintenance of Seasonal Roads (tonnes } CO_2e/yr) = \Sigma_{\text{equipment type}} \{\text{Equipment Use (hr/km)} \times \text{Length (km)} \times EF_{\text{equipment type}} (g\ CO_2e/hr) \times 10^{-6} \text{ (tonnes/g)}\}.$$

The type and quantity of road construction equipment assumed to be used in the construction of the seasonal roads is given in Table 3.7. It was assumed that the construction and maintenance of seasonal roads would employ all of the equipment listed in the table. Average annual equipment use per kilometer was based on average contractor equipment usage for the construction and maintenance of the 2014/2015 and 2015/2016 winter roads.

The aggregated GHG emission factors for each type of equipment ($EF_{equipment}$) are also listed in Table 3.7. The CO_2 emission factors are based on US EPA NONROAD 2008 emission factors for non-highway mobile equipment (US EPA, 2006). Net power for each piece of equipment is required in calculating $EF_{equipment}$ and was retrieved from manufacturers' specifications. Speciated GHG emissions are not currently available from ECCC for specific types of construction equipment based on hourly use. As such, the ratios between speciated emission factors from ECCC's speciated emission factor (NIR, 2016) in units of kg/L fuel for heavy duty, moderate control vehicles were used as the basis for determining emission factors for CH_4 and N_20 in kg/hr.

Table 3.7 – Equipment Type and Utilization for the Construction of Winter/Ice Roads

Equipment Type	Average Use (hrs/km)	Emission Factor (kg CO_2e/hr)
Bobcat (50-75 HP)	0.54	36
Bulldozer (75-100 HP)	3.43	53
Equipment (25-50 HP)	0.14	15
Front-End Loader (100-175 HP)	2.77	95
Grader (100-175 HP)	1.68	68
Grader (175-300 HP)	1.40	109
Snowmobile (50-75 HP)	3.00	45
Truck (300-600 HP)	4.18	181

3.2 Project Scenario

The Project Scenario estimated the GHG emissions associated with years of construction of the ASR in addition to projecting up to 30 years of emissions associated with the operation of the ASR. As with the Baseline Scenario, the Project Scenario assumes that the existing climatic conditions will be maintained into the future and the impact of climate change is not incorporated into the assessment. The Project Scenario also does not assume any growth in the communities. Such growth may potentially impact the traffic volumes on the ASR predicted for the purposes of this GHG assessment and is beyond the scope of this study.

It should be noted that Baseline Scenario conditions would persist during the initial construction period and gradually change, as defined in each of the following sections. The Project Scenario estimated the GHG emissions and sinks / removals and the resulting cumulative GHG emissions by:

Annual Project GHG Emissions (tonnes CO_2e/yr)
= - Carbon sequestration due to forest carbon sequestration along the proposed ASR (tonnes CO_2e/yr)
+ Net GHG emissions due to wetlands and soil along the proposed ASR (tonnes CO_2e/yr)
+ GHG emissions due to air travel to/from relevant communities (tonnes CO_2e/yr)
+ GHG emissions due to ferry crossings to/from relevant communities (tonnes CO_2e/yr)
+ GHG emissions due to vehicular travel on existing highways and ASR (tonnes CO_2e/yr)
+ GHG emissions due to the construction and maintenance of seasonal roads (tonnes CO_2e/yr)
+ GHG emissions due to land clearing along the proposed ASR (tonnes CO_2e/yr)
+ GHG emissions due to construction of the proposed ASR (tonnes CO_2e/yr).

Estimated GHG emissions for specific GHGs were also calculated, based on the above equation (including CO_2, CH_4, and N_2O). Details on the above sources and sinks / removals are given in the following sections. Detailed results can be found in Appendix B.

DILLON CONSULTING

3.2.1 Carbon Sequestration of Disturbed Land and Reforested Area

In order to mitigate the environmental impacts and GHG emissions associated with the ASR, it is estimated that approximately 15% of the land cleared along the ASR route will be allowed to reforest naturally. The carbon sequestered by the reforestation will occur over a multi-decadal time period. However, for the purposes of this assessment, it was assumed that the carbon sequestered over the time period to establish a mature forest can be distributed linearly over time.

The annual carbon sequestration rate (tonnes CO_2e/year-ha forest) of the project-specific study area was used, as determined in Section 3.1.1. It is assumed that the land clearing and reforestation associated with construction occurs gradually over the course of the construction phase.

3.2.2 Net GHG Emissions from Land Cover

The proposed ASR is anticipated to cover approximately 27% of the land cleared for each project. This estimate was based on the width of the road of 10 m and the assumption that there is an additional 3 m on each side of the road that will be disturbed and cover the existing land surface. Therefore, it is estimated that the net annual GHG emissions under the Baseline Scenario would be reduced by 27% due to the coverage of the ASR.

The methodology for calculating net GHG emissions from land cover was described in Section 3.1.2. It is assumed that the changes in GHG emissions related to land cover associated with road construction occurs gradually over the course of the construction phase.

3.2.3 GHG Emissions of Air Travel

It is assumed that air travel to and from relevant communities would remain the same as the Baseline Scenario during the construction phase. In the first year of ASR operation, it was assumed that air traffic would decline to 80% of the Baseline Scenario for roads in the south (P1, P4, P7, and P7a), and to 90% for roads in the north (P2, P3a, P3b, P5, and P6). The decline in air travel is expected since the lower priced mode of transportation (road based) would be favoured. The lower reduction in the north is due to the fact that community members in the north will still have to drive around Lake Winnipeg (west side) to access roads in to Winnipeg. Therefore, it was assumed that there would be a lower modal shift (air to passenger vehicle) for communities in the North.

It is important to note that some of the air traffic serviced routes between communities, and for the northern communities it was found that variations in the percentage of modal shift did not affect the results of the assessment. The relatively short distances between communities in the north (compared to the distance to driving to Winnipeg) led to insignificant impacts on the GHG profile of the project scenario when changes in model shift for inter-community air travel was assumed.

Helicopter travel would cease after the construction period, as the primary purpose of helicopter travel was to shuttle persons to the nearest airport for approximately three months per year during spring break up and winter freeze up, when both winter roads and ferry travel are not available. In the Project Scenario, the ASR would replace the need for the helicopter travel.

The methodology used in estimating the annual GHG emissions due to air travel described in Section 3.1.3 was applied with the above assumptions.

3.2.4 GHG Emissions of Ferry Crossing

As with air travel, it was assumed that ferry traffic to and from relevant communities would remain the same as the Baseline Scenario during the construction phase. In the first year of ASR operation, it is assumed that ferry/barge services would cease to operate.

The methodology used in estimating the annual GHG emissions due to ferry crossing described in Section 3.1.4 was applied with the above assumptions.

3.2.5 GHG Emissions of Vehicular Travel

In the Project Scenario, there are three components which would define vehicular traffic as described in the formula below:

Annual Vehicular Travel GHG Emissions (tonnes CO_2e/yr)
= GHG Emissions from Shift from Winter/Ice Road to ASR (tonnes CO_2e/yr)
+ GHG Emissions from Modal Shift from Air Travel to ASR (tonnes CO_2e/yr)
+ GHG Emissions from Modal Shift from Ferry Travel to ASR (tonnes CO_2e/yr).

The emission factors used in estimating the annual Project Scenario GHG emissions due to vehicular travel described in Section 3.1.5 were used, along with the methodology described below.

Seasonal (Winter/Ice) Road to ASR Shift

As the ASRs become operational, travel on seasonal roads will shift to travel on ASRs. Traffic levels estimated based on the 2017 winter road traffic assessment (Appendix D) have been assumed to remain consistent; however, fuel efficiency will improve from driving on winter roads to ASR travel as discussed in Section 3.1.5. In addition, road lengths vary slightly when between seasonal (winter/ice) roads and ASRs. For the purpose of this study, it was conservatively assumed that all travel is to the nearest community.

Air Travel Modal Shift

Air travel is expected to decline upon completion of the ASR, as the passengers shift to vehicular travel. As described in Section 3.2.3, it is estimated that 20% of the Baseline Scenario passenger air traffic estimates, are shifted from air travel to ASR travel for communities in the south. For those in the north, 10% shift was assumed as described in Section 3.2.3.

It is assumed that air travel to and from relevant communities would remain the same as the Baseline Scenario during the construction phase. In the first year of ASR operation, it was assumed that air traffic would decline. The decline in air travel is expected as the potentially cheaper mode of road transportation would be favoured. For the purpose of this study, it was assumed that all travel originated or terminated from or in Winnipeg. In addition, it was assumed that the modal shift from air travel to vehicular travel on the ASRs occurred in vehicles with two occupants (i.e. two persons per vehicle when driving on an ASR rather than flying).

Air passenger traffic volumes were retrieved from Manitoba Infrastructure (2016). The breakdown of air passenger traffic volumes by departure and destination community were analyzed based on commercial airline schedules, and airport movement fraction ratios applied to the passenger traffic. This methodology and associated emission factors are described in Section 3.1.3 and Section 3.1.5.

Ferry Travel Modal Shift

Ferry travel is expected to cease upon completion of the ASR, as the passengers shift to ASR travel. The Baseline Scenario ferry passenger traffic estimates, described in Section 3.1.4, were shifted from ferry/ seasonal road travel to ASR travel. The percentage of cars and pickup trucks (LDT) versus heavy trucks (HD) using the ferry in the Baseline Scenario was also applied to the Project Scenario.

It is assumed that travel using the ferry/barge service would continue during the years of construction to allow for commuting between communities along existing highways between Winnipeg and ferry service communities. It is assumed that ferries in the project area will cease in the first year of ASR operation due to their redundancy. For the purpose of this study, it was conservatively assumed that all travel originated or terminated from or in Winnipeg.

3.2.6 GHG Emissions of Seasonal Road Construction and Maintenance

The operation of winter roads will continue throughout the ASR construction phase. Emissions associated with the construction and maintenance of seasonal roads will remain consistent with the Baseline Scenario as described in Section 3.1.6.

Upon completion of the ASR construction phase, the winter road construction and maintenance (and associated emissions will cease.

3.2.7 GHG Emissions Due to Land Clearing

GHG emissions associated with land clearing in preparation of the construction of the proposed ASR include the assumed burning of slash and shrubs and the use of land clearing and construction equipment in the harvesting of the wood and clearing of the land.
Total annual GHG emissions are calculated by:

Annual GHG Emissions due to Land Clearing (tonnes CO_2e/yr)

= GHG Emissions from Tree and Shrub Slash and Burn (tonnes CO_2e/yr)
+ GHG Emissions Land Clearing Equipment (tonnes CO_2e/yr).

Tree and Shrub Slash and Burn

The proposed ASR projects have a 100 m ROW with approximately 60 m of cleared land. The land cover statistics along the ROW for the length of the ASR were determined through publically available land use GIS data (NRCan, 2000). The data provides the land areas considered forest and shrub covered land in the right-of-way of the proposed ASR. Total net GHG emissions were then estimated from the wetland and forested area data. The emission factors and methodology from the IPCC 2006 Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) were used to calculate GHG emissions from the treed biomass and shrub biomass cleared for the ASR construction.

While there may be efforts to have some of the harvested tree biomass converted into durable products, it was conservatively assumed that 100% of the biomass was to be burnt.

The IPCC (2006) methodology was used in estimating the GHG emissions due to slash burning:

GHG Emissions from Slash Burning (tonnes CO_2e/yr)
= Area of Burn (ha)
× Density of Available Fuel (tonnes/ha)
× C_f
× Specific gravity of tree dry weight to green tree weight (unitless)
× EF_{slash} (g/kg dry biomass burnt).

Where C_f is the combustion factor and is considered to be 0.33 for boreal forest post logging slash burn, and EF_{slash} = 1748 g CO_2e/kg fuel for extra tropical forests (i.e., temperate, boreal).
The Mass of Available Fuel is the sum of the tree biomass available for slash burning and the total shrub biomass cleared for the ASR. The GHG emission due to slash burning was assumed to occur linearly over the years of construction of the proposed ASR project.

Land Clearing

The GHG emissions associated with the clearing of the land in preparation of the proposed ASR was estimated by:

Annual GHG Emissions Land Clearing (tonnes CO_2e/yr)
= Σequipment types {Number of Equipment Type × Rate of Use (hr/km) × Distance (km) x $EF_{equipment}$ (kg CO_2e/hr) × 10^{-4} (tonnes/kg)}.

The hourly use, type, and quantity of earth moving, land clearing, and general mobile equipment used in the clearing and mulching operation was provided by Dillon (2016) in daily and weekly inspection reports associated with P1 land clearing. This data was analyzed to determine the rate of use (hr/km) of each piece of equipment.

The emission factors are based on equipment make/model from actual construction activities data, and the cumulative GHG emission factors, $EF_{equipment}$, for each type of equipment are listed in Table 3.8. The CO_2 emission factors are based on US EPA NONROAD 2008 emission factors for non-highway mobile equipment (US EPA, 2006). Net power for each piece of equipment is required in calculating $EF_{equipment}$ and was retrieved from manufacturer specification documentation. Speciated GHG emissions are not currently available from ECCC for specific types of construction equipment in hourly units. As such, the ratios between speciated emission factors from ECCC's speciated emission factor (NIR, 2016) in units of kg/L fuel for heavy duty, moderate control vehicles were used as the basis for determining emission factors for CH_4 and N_20 in kg/hr.

Table 3.8 – Equipment Used in Land Clearing – Rate of Use and GHG Emission Factors

Equipment	Net Power (HP)	Rate of Use (hrs/km)	$EF_{equipment}$ ($kgCO_2e/hr$)
Backhoe	215	221.5	136
Backhoe with Mulcher	182	48.9	115
Bulldozer	191	149.7	103
Front-End Loader	305	0.1	193
Rock Truck	359	75.8	227
Tandem Truck	500	20.1	271
Timberjack Skidder	200	0.8	126

3.2.8 GHG Emissions Due to Construction of the ASR

Construction of the ASR involves the construction of the roadway and bridges (both permanent and modular bridges). The following was used to estimate the GHG emissions associated with the construction:

Annual GHG Emissions Due to Construction (tonnes CO_2e/yr)

$$= \Sigma ASR_{equipment} \{Number\ of\ Equipment \times Rate\ of\ Use\ (hr/km) \times Distance\ (km)\ x\ EF_{equipment}\ (kg\ CO_2e/hr) \times 10^{-4}\ (tonnes/kg)\}$$

$$+ \Sigma Bridge_{equipment} \{Number\ of\ Equipment \times Rate\ of\ Use\ (hr/km) \times Distance\ (km)\ x\ EF_{equipment}\ (kg\ CO_2e/hr) \times 10^{-4}\ (tonnes/kg)\}$$

Dillon (2016) provided data on the list of equipment used in the construction of the ASR and bridges, and the total number of hours of operation for each type of equipment based on P1 construction administration reporting. This data was analysed to determine the rate of use (hr/km) of each piece of equipment for ASRs and the use (hr) for bridges.

The emission factors are based on equipment make/model from actual construction activities data, and the cumulative GHG emission factors, $EF_{equipment}$ and usage for each type of equipment are listed in Table 3.9 (ASR), Table 3.10 (Permanent Bridges), and Table 3.11 (Modular Bridges). The $EF_{equipment}$ may vary since the actual equipment net horsepower and rate of use for P1 projects was used to calculate the emission factor. The CO_2 emission factors are based on US EPA NONROAD 2008 emission factors for non-highway mobile equipment (US EPA, 2006). Net power for each piece of equipment is required in calculating $EF_{equipment}$ and was retrieved from manufacturers' specifications. Speciated GHG emissions are not currently available from ECCC for specific types of construction equipment in hourly units. As such, the ratios between speciated emission factors from ECCC's speciated emission factor (NIR, 2016) in units of kg/L fuel for heavy duty, moderate control vehicles were used as the basis for determining emission factors for CH_4 and N_20 in kg/hr.

Table 3.9 – Equipment Used in Construction of ASR – Rate of Use and GHG Emission Factors

Equipment	Net Power (hp)	Rate of Use (hrs/km)	$EF_{equipment}$ (kg CO_2e/hr)
Backhoe	228	497.5	144
Bulldozer	211	299.7	114
Crusher	240	196.0	130
Front-End Loader	380	416.3	240
Grader	240	20.4	130
Rock Drill	225	421.8	120
Rock Truck	362	1188.7	229
Semi and Trailer	503	338.2	272
Smooth Drum Roller	104	64.7	56
Tandem Truck	500	88.3	271
Truck	334	46.7	181
Water Truck	275	10.4	149

Table 3.10 – Equipment Used in Construction of Permanent Bridges – Use and GHG Emission Factors

Equipment	Net Power (hp)	Use per Bridge (hrs)	$EF_{equipment}$ (kg CO_2e/hr)
Backhoe	228	102	144
Bobcat	53	310	37
Bulldozer	211	480	114
Compactor	208	110	111
Concrete Truck	363	72	229
Crane	329	82	176
Crusher	240	110	130
Equipment General	100	100	60

Equipment	Net Power (hp)	Use per Bridge (hrs)	$EF_{equipment}$ (kg CO_2e/hr)
Forklift	70	30	42
Front-End Loader	380	1290	240
Excavator	100	1195	54
Grader	240	50	130
Packer	39	30	23
Pump Truck	2050	71	1,110
Rock Drill	225	160	120
Rock Truck	362	321	229
Semi and Trailer	503	60	272
Smooth Drum Roller	104	50	56
Tandem Truck	500	197	271
Truck	334	384	181
Zoom Boom	112	930	61

Table 3.11 – Equipment Used in Construction of Modular Bridges – Use and GHG Emission Factors

Equipment	Net Power (hp)	Use per Bridge (hrs)	$EF_{equipment}$ (kg CO_2e/hr)
Bobcat	69	556	48
Bulldozer	103	580	56
Concrete Truck	106	40	57
Conveyor	35	35	21
Crane	130	167	70
Excavator	189	1055	161
Generator	25	3168	102
Grader	185	177	15
Front-End Loader	198	603	100
Mechanic Truck	255	320	125
Ranger All-Terrain	44	303	138
Rock Drill	300	190	26
Rock Truck	285	961	153
Semi and Trailer	500	518	271
Tandem Truck	303	553	164
Tractor	500	20	271
Truck	385	2268	208

4.0 Project Specific Calculations

Table 4.1 presents a summary of the Baseline Scenario and Project Scenario GHG emissions for each project, speciated into GHG emission estimates such as CO_2, CH_4, and N_2O, as well as in CO_2e during a 10 year operation time period. Table 4.2 presents the same data for a 30 year operation time period. Table 4.3 presents a summary of the Baseline Scenario and Project Scenario GHG emissions for each project and by GHG source/sink category for a 10 year time period. Table 4.4 presents the same data for a 30 year operation time period. Detailed calculations are presented in Appendix A and a summary of annual results are in Appendix B.

Note that the results below represent an estimate of GHG emissions based on the assumptions described in Section 3. Table 4.5 presents the key input parameters associated with the GHG calculations for each project.

Perflurocarbons (PFCs), hydroflurorcarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluroide (NF_3) are not expected to be a significant source of emissions from this project.

4.1 Discussion

Results of the analysis estimate that *construction* of the ASR and land clearing drive an increase in GHG emissions over the course of the ASR construction phase and are above Baseline Scenario emissions. These are temporary increases related to the construction phase.

However, in general, estimated GHG emissions associated with the *operational* phase of the ASR in the Project Scenario are comparable to or lower than the estimated GHG emissions in the operational phase of the Baseline Scenario.

Cases where Project Scenario operational emission estimates are higher than the Baseline Scenario operational emissions include communities with high traffic airports associated with an individual project (ASR) such as Island Lake and Saint Theresa Point. The assumed displacement of some air traffic by passenger vehicle traffic (10% shift of air traffic) leads to a significant increase in vehicular emissions because of the significant distance associated with this vehicular travel. If a reduced level of modal shift is assumed (e.g., 5%) the overall results show that the Baseline Scenario would potentially have higher emissions than the Project Scenario. For the purposes of this study, the more conservative assumption (10%) has been used.

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Table 4.1 – GHG Emission Estimate by Project – 10 Years of Operation – Speciated (tonnes CO_2, tonnes CH_4, tonnes N_2O)

Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
P1	Baseline – During ASR Construction Period	Year 1 – Year 8	6,649	548	1	20,789
	Baseline – During ASR Operational Period	Year 9 – Year 18	8,311	685	2	25,986
	Baseline – Total	Year 1 – Year 18	14,960	1,233	3	46,775
	Project – During ASR Construction Period	Year 1 – Year 8	154,710	506	7	169,589
	Project – During ASR Operational Period	Year 9 – Year 18	11,808	502	2	24,915
	Project – Total	Year 1 – Year 18	166,518	1,009	9	194,504
P2	Baseline – During ASR Construction Period	Year 1 – Year 8	37,069	442	1	48,433
	Baseline – During ASR Operational Period	Year 9 – Year 18	46,336	552	1	60,542
	Baseline – Total	Year 1 – Year 18	83,405	993	2	108,975
	Project – During ASR Construction Period	Year 1 – Year 8	224,632	424	9	237,790
	Project – During ASR Operational Period	Year 9 – Year 18	51,553	405	2	62,212
	Project – Total	Year 1 – Year 18	276,185	830	10	300,003
P3a	Baseline – During ASR Construction Period	Year 1 – Year 5	27,416	5	0	27,682
	Baseline – During ASR Operational Period	Year 6 – Year 15	45,693	8	1	46,136
	Baseline – Total	Year 1 – Year 15	73,109	13	1	73,818
	Project – During ASR Construction Period	Year 1 – Year 5	53,292	11	2	54,005
	Project – During ASR Operational Period	Year 6 – Year 15	53,231	7	1	53,826
	Project – Total	Year 1 – Year 15	106,523	17	3	107,830
P3b	Baseline – During ASR Construction Period	Year 1 – Year 7	34,161	35	1	35,243
	Baseline – During ASR Operational Period	Year 8 – Year 17	48,802	50	1	50,347
	Baseline – Total	Year 1 – Year 17	82,963	86	2	85,590
	Project – During ASR Construction Period	Year 1 – Year 7	106,961	50	4	109,305

Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
	Project – During ASR Operational Period	Year 8 – Year 17	53,585	38	2	55,076
	Project – Total	Year 1 – Year 17	160,546	88	5	164,381
P3c	Baseline – During ASR Construction Period	Year 1 – Year 7	3,828	279	0	10,905
	Baseline – During ASR Operational Period	Year 8 – Year 17	5,469	398	1	15,579
	Baseline – Total	Year 1 – Year 17	9,297	677	1	26,485
	Project – During ASR Construction Period	Year 1 – Year 7	100,871	260	4	108,628
	Project – During ASR Operational Period	Year 8 – Year 17	6,430	292	1	13,904
	Project – Total	Year 1 – Year 17	107,301	552	5	122,532
P4	Baseline – During ASR Construction Period	Year 1 – Year 8	3,861	260	0	10,479
	Baseline – During ASR Operational Period	Year 9 – Year 18	4,827	326	0	13,099
	Baseline – Total	Year 1 – Year 18	8,688	586	1	23,579
	Project – During ASR Construction Period	Year 1 – Year 8	86,523	245	4	93,762
	Project – During ASR Operational Period	Year 9 – Year 18	6,167	239	1	12,318
	Project – Total	Year 1 – Year 18	92,690	484	4	106,079
P5	Baseline – During ASR Construction Period	Year 1 – Year 8	17,277	189	1	22,384
	Baseline – During ASR Operational Period	Year 9 – Year 18	21,596	237	2	27,980
	Baseline – Total	Year 1 – Year 18	38,873	426	3	50,364
	Project – During ASR Construction Period	Year 1 – Year 8	114,956	187	5	121,174
	Project – During ASR Operational Period	Year 9 – Year 18	21,993	174	2	26,810
	Project – Total	Year 1 – Year 18	136,950	361	7	147,983
P6	Baseline – During ASR Construction Period	Year 1 – Year 8	15,625	159	1	19,851
	Baseline – During ASR Operational Period	Year 9 – Year 18	19,532	199	1	24,814
	Baseline – Total	Year 1 – Year 18	35,157	358	2	44,665

Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
	Project – During ASR Construction Period	Year 1 – Year 8	132,381	170	6	138,300
	Project – During ASR Operational Period	Year 9 – Year 18	19,750	146	1	23,690
	Project – Total	Year 1 – Year 18	152,130	316	7	161,990
P7	Baseline – During ASR Construction Period	Year 1 – Year 8	7,113	238	0	13,203
P7	Baseline – During ASR Operational Period	Year 9 – Year 18	8,891	298	1	16,504
P7	Baseline – Total	Year 1 – Year 18	16,005	536	1	29,707
P7	Project – During ASR Construction Period	Year 1 – Year 8	97,556	227	4	104,438
P7	Project – During ASR Operational Period	Year 9 – Year 18	6,061	218	1	11,688
P7	Project – Total	Year 1 – Year 18	103,616	445	5	116,126
P7a	Baseline – During ASR Construction Period	Year 1 – Year 5	4,661	40	0	5,692
P7a	Baseline – During ASR Operational Period	Year 6 – Year 15	9,323	79	0	11,385
P7a	Baseline – Total	Year 1 – Year 15	13,984	119	0	17,077
P7a	Project – During ASR Construction Period	Year 1 – Year 5	40,383	43	2	41,921
P7a	Project – During ASR Operational Period	Year 6 – Year 15	7,102	58	0	8,692
P7a	Project – Total	Year 1 – Year 15	47,485	101	2	50,613

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Table 4.2 – GHG Emission Estimate by Project – 30 Years of Operation – Speciated (tonnes CO_2, tonnes CH_4, tonnes N_2O)

Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
P1	Baseline – During ASR Construction Period	Year 1 – Year 8	6,649	548	1	20,789
	Baseline – During ASR Operational Period	Year 9 – Year 38	24,934	2,054	6	77,959
	Baseline – Total	Year 1 – Year 38	31,583	2,602	7	98,748
	Project – During ASR Construction Period	Year 1 – Year 8	154,710	506	7	169,589
	Project – During ASR Operational Period	Year 9 – Year 38	35,424	1,507	6	74,746
	Project – Total	Year 1 – Year 38	190,134	2,013	13	244,335
P2	Baseline – During ASR Construction Period	Year 1 – Year 8	37,069	442	1	48,433
	Baseline – During ASR Operational Period	Year 9 – Year 38	139,008	1,656	4	181,625
	Baseline – Total	Year 1 – Year 38	176,076	2,097	5	230,058
	Project – During ASR Construction Period	Year 1 – Year 8	224,632	424	9	237,790
	Project – During ASR Operational Period	Year 9 – Year 38	154,660	1,216	5	186,637
	Project – Total	Year 1 – Year 38	379,292	1,640	14	424,427
P3a	Baseline – During ASR Construction Period	Year 1 – Year 5	27,416	5	0	27,682
	Baseline – During ASR Operational Period	Year 6 – Year 35	137,079	24	2	138,409
	Baseline – Total	Year 1 – Year 35	164,495	29	3	166,090
	Project – During ASR Construction Period	Year 1 – Year 5	53,292	11	2	54,005
	Project – During ASR Operational Period	Year 6 – Year 35	159,692	20	4	161,477
	Project – Total	Year 1 – Year 35	212,984	30	6	215,481
P3b	Baseline – During ASR Construction Period	Year 1 – Year 7	34,161	35	1	35,243
	Baseline – During ASR Operational Period	Year 8 – Year 37	146,406	151	3	151,041
	Baseline – Total	Year 1 – Year 37	180,567	186	4	186,283
	Project – During ASR Construction Period	Year 1 – Year 7	106,961	50	4	109,305

Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
	Project – During ASR Operational Period	Year 8 – Year 37	160,756	113	6	165,227
	Project – Total	Year 1 – Year 37	267,717	163	9	274,532
P3c	Baseline – During ASR Construction Period	Year 1 – Year 7	3,828	279	0	10,905
	Baseline – During ASR Operational Period	Year 8 – Year 37	16,407	1,194	2	46,737
	Baseline – Total	Year 1 – Year 37	20,235	1,473	2	57,643
	Project – During ASR Construction Period	Year 1 – Year 7	100,871	260	4	108,628
	Project – During ASR Operational Period	Year 8 – Year 37	19,289	876	2	41,713
	Project – Total	Year 1 – Year 37	120,160	1,136	6	150,340
P4	Baseline – During ASR Construction Period	Year 1 – Year 8	3,861	260	0	10,479
	Baseline – During ASR Operational Period	Year 9 – Year 38	14,480	977	1	39,298
	Baseline – Total	Year 1 – Year 38	18,341	1,237	2	49,777
	Project – During ASR Construction Period	Year 1 – Year 8	86,523	245	4	93,762
	Project – During ASR Operational Period	Year 9 – Year 38	18,501	717	2	36,953
	Project – Total	Year 1 – Year 38	105,024	962	6	130,715
P5	Baseline – During ASR Construction Period	Year 1 – Year 8	17,277	189	1	22,384
	Baseline – During ASR Operational Period	Year 9 – Year 38	64,789	711	5	83,939
	Baseline – Total	Year 1 – Year 38	82,066	900	6	106,323
	Project – During ASR Construction Period	Year 1 – Year 8	114,956	187	5	121,174
	Project – During ASR Operational Period	Year 9 – Year 38	65,980	522	5	80,429
	Project – Total	Year 1 – Year 38	180,936	709	10	201,602
P6	Baseline – During ASR Construction Period	Year 1 – Year 8	15,625	159	1	19,851
	Baseline – During ASR Operational Period	Year 9 – Year 38	58,596	597	3	74,442
	Baseline – Total	Year 1 – Year 38	74,221	757	4	94,294

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Project	Scenario	Year Range	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
	Project – During ASR Construction Period	Year 1 – Year 8	132,381	170	6	138,300
	Project – During ASR Operational Period	Year 9 – Year 38	59,249	438	3	71,069
	Project – Total	Year 1 – Year 38	191,630	608	9	209,369
P7	Baseline – During ASR Construction Period	Year 1 – Year 8	7,113	238	0	13,203
	Baseline – During ASR Operational Period	Year 9 – Year 38	26,674	893	2	49,512
	Baseline – Total	Year 1 – Year 38	33,788	1,131	2	62,716
	Project – During ASR Construction Period	Year 1 – Year 8	97,556	227	4	104,438
	Project – During ASR Operational Period	Year 9 – Year 38	18,182	655	2	35,064
	Project – Total	Year 1 – Year 38	115,737	881	6	139,502
P7a	Baseline – During ASR Construction Period	Year 1 – Year 5	4,661	40	0	5,692
	Baseline – During ASR Operational Period	Year 6 – Year 35	27,968	238	1	34,155
	Baseline – Total	Year 1 – Year 35	32,630	278	1	39,847
	Project – During ASR Construction Period	Year 1 – Year 5	40,383	43	2	41,921
	Project – During ASR Operational Period	Year 6 – Year 35	21,306	175	1	26,076
	Project – Total	Year 1 – Year 35	61,689	218	3	67,997

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Table 4.3 –GHG Emission Estimate by Project and by Activity – 10 Years of Operation (tonnes CO_2e)

Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
			Forest Sequest-ration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction	Land Clearing	ASR Construc-tion	Total
P1	Baseline – During ASR Construction Period	Year 1 – Year 8	-3,649	7,839	5,078	192	9,149	2,179	-	-	20,789
	Baseline – During ASR Operational Period	Year 9 – Year 18	-4,561	9,799	6,348	240	11,437	2,724	-	-	25,986
	Baseline – Total	Year 1 – Year 18	-8,210	17,639	11,426	432	20,586	4,902	-	-	46,775
	Project – During ASR Construction Period	Year 1 – Year 8	-1,904	6,664	5,078	192	9,149	2,179	25,026	123,205	169,589
	Project – During ASR Operational Period	Year 9 – Year 18	-684	7,186	5,078	0	13,335	0	0	0	24,915
	Project – Total	Year 1 – Year 18	-2,588	13,850	10,156	192	22,484	2,179	25,026	123,205	194,504
P2	Baseline – During ASR Construction Period	Year 1 – Year 8	-3,847	6,650	36,563	0	5,135	3,932	-	-	48,433
	Baseline – During ASR Operational Period	Year 9 – Year 18	-4,809	8,313	45,704	0	6,419	4,915	-	-	60,542
	Baseline – Total	Year 1 – Year 18	-8,655	14,963	82,267	0	11,553	8,847	-	-	108,975
	Project – During ASR Construction Period	Year 1 – Year 8	-2,008	5,653	36,563	0	5,135	3,932	31,727	156,789	237,790
	Project – During ASR Operational Period	Year 9 – Year 18	-721	6,096	41,134	0	15,704	0	0	0	62,212
	Project – Total	Year 1 – Year 18	-2,729	11,749	77,697	0	20,839	3,932	31,727	156,789	300,003
P3a	Baseline – During ASR Construction Period	Year 1 – Year 5	-588	251	27,422	0	323	273	-	-	27,682
	Baseline – During ASR Operational Period	Year 6 – Year 15	-979	419	45,704	0	539	454	-	-	46,136
	Baseline – Total	Year 1 – Year 15	-1,567	670	73,126	0	862	727	-	-	73,818
	Project – During ASR Construction Period	Year 1 – Year 5	-296	212	27,422	0	323	273	4,031	22,040	54,005
	Project – During ASR Operational Period	Year 6 – Year 15	-147	307	41,134	0	12,532	0	0	0	53,826
	Project – Total	Year 1 – Year 15	-443	519	68,556	0	12,855	273	4,031	22,040	107,830
P3b	Baseline – During ASR Construction Period	Year 1 – Year 7	-2,176	1,158	35,202	0	447	613	-	-	35,243
	Baseline – During ASR Operational Period	Year 8 – Year 17	-3,109	1,654	50,288	0	638	876	-	-	50,347

Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
	Baseline – Total	Year 1 – Year 17	-5,286	2,812	85,489	0	1,085	1,489	-	-	85,590
	Project – During ASR Construction Period	Year 1 – Year 7	-1,119	981	35,202	0	447	613	12,287	60,895	109,305
	Project – During ASR Operational Period	Year 8 – Year 17	-466	1,213	44,067	0	10,262	0	0	0	55,076
	Project – Total	Year 1 – Year 17	-1,586	2,194	79,269	0	10,709	613	12,287	60,895	164,381
P3c	Baseline – During ASR Construction Period	Year 1 – Year 7	-1,681	3,946	5,874	0	1,276	1,490	-	-	10,905
	Baseline – During ASR Operational Period	Year 8 – Year 17	-2,401	5,638	8,392	0	1,823	2,128	-	-	15,579
	Baseline – Total	Year 1 – Year 17	-4,082	9,584	14,266	0	3,099	3,618	-	-	26,485
	Project – During ASR Construction Period	Year 1 – Year 7	-864	3,345	5,874	0	1,276	1,490	15,823	81,684	108,628
	Project – During ASR Operational Period	Year 8 – Year 17	-360	4,134	7,552	0	2,578	0	0	0	13,904
	Project – Total	Year 1 – Year 17	-1,225	7,479	13,427	0	3,854	1,490	15,823	81,684	122,532
P4	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,315	3,938	6,611	0	1,072	1,173	-	-	10,479
	Baseline – During ASR Operational Period	Year 9 – Year 18	-2,893	4,922	8,263	0	1,340	1,466	-	-	13,099
	Baseline – Total	Year 1 – Year 18	-5,208	8,860	14,874	0	2,413	2,640	-	-	23,579
	Project – During ASR Construction Period	Year 1 – Year 8	-1,208	3,347	6,611	0	1,072	1,173	14,408	68,358	93,762
	Project – During ASR Operational Period	Year 9 – Year 18	-434	3,610	6,611	0	2,531	0	0	0	12,318
	Project – Total	Year 1 – Year 18	-1,642	6,957	13,221	0	3,604	1,173	14,408	68,358	106,079
P5	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,218	3,041	12,015	0	8,013	1,533	-	-	22,384
	Baseline – During ASR Operational Period	Year 9 – Year 18	-2,772	3,801	15,019	0	10,017	1,916	-	-	27,980
	Baseline – Total	Year 1 – Year 18	-4,990	6,841	27,034	0	18,030	3,448	-	-	50,364
	Project – During ASR Construction Period	Year 1 – Year 8	-1,157	2,585	12,015	0	8,013	1,533	16,461	81,725	121,174
	Project – During ASR Operational Period	Year 9 – Year 18	-416	2,787	13,517	0	10,921	0	0	0	26,810
	Project – Total	Year 1 – Year 18	-1,573	5,372	25,532	0	18,935	1,533	16,461	81,725	147,983
P6	Baseline – During ASR Construction Period	Year 1 – Year 8	-4,122	3,327	14,242	0	3,792	2,612	-	-	19,851
	Baseline – During ASR Operational Period	Year 9 – Year 18	-5,153	4,159	17,802	0	4,740	3,265	-	-	24,814

Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
	Baseline – Total	Year 1 – Year 18	-9,275	7,487	32,044	0	8,532	5,878	-	-	44,665
	Project – During ASR Construction Period	Year 1 – Year 8	-2,151	2,828	14,242	0	3,792	2,612	20,979	95,998	138,300
	Project – During ASR Operational Period	Year 9 – Year 18	-773	3,050	16,022	0	5,390	0	0	0	23,690
	Project – Total	Year 1 – Year 18	-2,924	5,878	30,264	0	9,182	2,612	20,979	95,998	161,990
P7	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,278	3,664	8,544	0	1,592	1,682	-	-	13,203
P7	Baseline – During ASR Operational Period	Year 9 – Year 18	-2,848	4,580	10,680	0	1,990	2,102	-	-	16,504
P7	Baseline – Total	Year 1 – Year 18	-5,126	8,244	19,224	0	3,582	3,784	-	-	29,707
P7	Project – During ASR Construction Period	Year 1 – Year 8	-1,189	3,115	8,544	0	1,592	1,682	15,053	75,641	104,438
P7	Project – During ASR Operational Period	Year 9 – Year 18	-427	3,359	5,553	0	3,203	0	0	0	11,688
P7	Project – Total	Year 1 – Year 18	-1,616	6,473	14,097	0	4,795	1,682	15,053	75,641	116,126
P7a	Baseline – During ASR Construction Period	Year 1 – Year 5	-567	673	5,340	0	121	127	-	-	5,692
P7a	Baseline – During ASR Operational Period	Year 6 – Year 15	-1,135	1,346	10,680	0	241	253	-	-	11,385
P7a	Baseline – Total	Year 1 – Year 15	-1,702	2,018	16,020	0	362	380	-	-	17,077
P7a	Project – During ASR Construction Period	Year 1 – Year 5	-278	565	5,340	0	121	127	5,985	30,062	41,921
P7a	Project – During ASR Operational Period	Year 6 – Year 15	-170	987	5,553	0	2,322	0	0	0	8,692
P7a	Project – Total	Year 1 – Year 15	-448	1,552	10,893	0	2,443	127	5,985	30,062	50,613

Table 4.4 – GHG Emission Estimate by Project and by Activity – 30 Years of Operation (tonnes CO_2e)

Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
			Forest Sequest-ration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction	Land Clearing	ASR Construc-tion	Total
P1	Baseline – During ASR Construction Period	Year 1 – Year 8	-3,649	7,839	5,078	192	9,149	2,179	-	-	20,789
	Baseline – During ASR Operational Period	Year 9 – Year 38	-13,683	29,398	19,043	720	34,310	8,171	-	-	77,959
	Baseline – Total	Year 1 – Year 38	-17,331	37,237	24,121	912	43,459	10,350	-	-	98,748
	Project – During ASR Construction Period	Year 1 – Year 8	-1,904	6,664	5,078	192	9,149	2,179	25,026	123,205	169,589
	Project – During ASR Operational Period	Year 9 – Year 38	-2,052	21,559	15,234	0	40,005	0	0	0	74,746
	Project – Total	Year 1 – Year 38	-3,957	28,222	20,313	192	49,154	2,179	25,026	123,205	244,335
P2	Baseline – During ASR Construction Period	Year 1 – Year 8	-3,847	6,650	36,563	0	5,135	3,932	-	-	48,433
	Baseline – During ASR Operational Period	Year 9 – Year 38	-14,426	24,938	137,112	0	19,256	14,745	-	-	181,625
	Baseline – Total	Year 1 – Year 38	-18,273	31,588	173,675	0	24,390	18,677	-	-	230,058
	Project – During ASR Construction Period	Year 1 – Year 8	-2,008	5,653	36,563	0	5,135	3,932	31,727	156,789	237,790
	Project – During ASR Operational Period	Year 9 – Year 38	-2,164	18,288	123,401	0	47,112	0	0	0	186,637
	Project – Total	Year 1 – Year 38	-4,171	23,941	159,964	0	52,247	3,932	31,727	156,789	424,427
P3a	Baseline – During ASR Construction Period	Year 1 – Year 5	-588	251	27,422	0	323	273	-	-	27,682
	Baseline – During ASR Operational Period	Year 6 – Year 35	-2,938	1,256	137,112	0	1,617	1,363	-	-	138,409
	Baseline – Total	Year 1 – Year 35	-3,526	1,507	164,534	0	1,940	1,635	-	-	166,090
	Project – During ASR Construction Period	Year 1 – Year 5	-296	212	27,422	0	323	273	4,031	22,040	54,005
	Project – During ASR Operational Period	Year 6 – Year 35	-441	921	123,401	0	37,596	0	0	0	161,477
	Project – Total	Year 1 – Year 35	-737	1,133	150,823	0	37,919	273	4,031	22,040	215,481
P3b	Baseline – During ASR Construction Period	Year 1 – Year 7	-2,176	1,158	35,202	0	447	613	-	-	35,243
	Baseline – During ASR Operational Period	Year 8 – Year 37	-9,328	4,962	150,864	0	1,915	2,628	-	-	151,041

Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
	Baseline – Total	Year 1 – Year 37	-11,504	6,120	186,065	0	2,362	3,241	-	-	186,283
	Project – During ASR Construction Period	Year 1 – Year 7	-1,119	981	35,202	0	447	613	12,287	60,895	109,305
	Project – During ASR Operational Period	Year 8 – Year 37	-1,399	3,639	132,201	0	30,787	0	0	0	165,227
	Project – Total	Year 1 – Year 37	-2,519	4,620	167,403	0	31,233	613	12,287	60,895	274,532
P3c	Baseline – During ASR Construction Period	Year 1 – Year 7	-1,681	3,946	5,874	0	1,276	1,490	-	-	10,905
P3c	Baseline – During ASR Operational Period	Year 8 – Year 37	-7,203	16,913	25,175	0	5,468	6,385	-	-	46,737
P3c	Baseline – Total	Year 1 – Year 37	-8,884	20,859	31,049	0	6,744	7,874	-	-	57,643
P3c	Project – During ASR Construction Period	Year 1 – Year 7	-864	3,345	5,874	0	1,276	1,490	15,823	81,684	108,628
P3c	Project – During ASR Operational Period	Year 8 – Year 37	-1,080	12,403	22,657	0	7,733	0	0	0	41,713
P3c	Project – Total	Year 1 – Year 37	-1,945	15,748	28,531	0	9,009	1,490	15,823	81,684	150,340
P4	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,315	3,938	6,611	0	1,072	1,173	-	-	10,479
P4	Baseline – During ASR Operational Period	Year 9 – Year 38	-8,680	14,767	24,790	0	4,021	4,399	-	-	39,298
P4	Baseline – Total	Year 1 – Year 38	-10,994	18,705	31,401	0	5,094	5,572	-	-	49,777
P4	Project – During ASR Construction Period	Year 1 – Year 8	-1,208	3,347	6,611	0	1,072	1,173	14,408	68,358	93,762
P4	Project – During ASR Operational Period	Year 9 – Year 38	-1,302	10,829	19,832	0	7,594	0	0	0	36,953
P4	Project – Total	Year 1 – Year 38	-2,510	14,176	26,443	0	8,666	1,173	14,408	68,358	130,715
P5	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,218	3,041	12,015	0	8,013	1,533	-	-	22,384
P5	Baseline – During ASR Operational Period	Year 9 – Year 38	-8,317	11,402	45,057	0	30,050	5,747	-	-	83,939
P5	Baseline – Total	Year 1 – Year 38	-10,535	14,443	57,072	0	38,064	7,280	-	-	106,323
P5	Project – During ASR Construction Period	Year 1 – Year 8	-1,157	2,585	12,015	0	8,013	1,533	16,461	81,725	121,174
P5	Project – During ASR Operational Period	Year 9 – Year 38	-1,248	8,362	40,551	0	32,763	0	0	0	80,429
P5	Project – Total	Year 1 – Year 38	-2,405	10,946	52,566	0	40,777	1,533	16,461	81,725	201,602
P6	Baseline – During ASR Construction Period	Year 1 – Year 8	-4,122	3,327	14,242	0	3,792	2,612	-	-	19,851
P6	Baseline – During ASR Operational Period	Year 9 – Year 38	-15,458	12,478	53,407	0	14,220	9,796	-	-	74,442

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Project	Scenario	Year Range	GHG Estimate (tonnes CO_2e)								
	Baseline – Total	Year 1 – Year 38	-19,580	15,805	67,648	0	18,012	12,408	-	-	94,294
	Project – During ASR Construction Period	Year 1 – Year 8	-2,151	2,828	14,242	0	3,792	2,612	20,979	95,998	138,300
	Project – During ASR Operational Period	Year 9 – Year 38	-2,319	9,150	48,066	0	16,171	0	0	0	71,069
	Project – Total	Year 1 – Year 38	-4,470	11,979	62,308	0	19,963	2,612	20,979	95,998	209,369
P7	Baseline – During ASR Construction Period	Year 1 – Year 8	-2,278	3,664	8,544	0	1,592	1,682	-	-	13,203
	Baseline – During ASR Operational Period	Year 9 – Year 38	-8,544	13,741	32,040	0	5,969	6,307	-	-	49,512
	Baseline – Total	Year 1 – Year 38	-10,822	17,405	40,583	0	7,561	7,989	-	-	62,716
	Project – During ASR Construction Period	Year 1 – Year 8	-1,189	3,115	8,544	0	1,592	1,682	15,053	75,641	104,438
	Project – During ASR Operational Period	Year 9 – Year 38	-1,282	10,076	16,660	0	9,609	0	0	0	35,064
	Project – Total	Year 1 – Year 38	-2,471	13,191	25,204	0	11,201	1,682	15,053	75,641	139,502
P7a	Baseline – During ASR Construction Period	Year 1 – Year 5	-567	673	5,340	0	121	127	-	-	5,692
	Baseline – During ASR Operational Period	Year 6 – Year 35	-3,404	4,037	32,040	0	723	759	-	-	34,155
	Baseline – Total	Year 1 – Year 35	-3,971	4,709	37,379	0	844	886	-	-	39,847
	Project – During ASR Construction Period	Year 1 – Year 5	-278	565	5,340	0	121	127	5,985	30,062	41,921
	Project – During ASR Operational Period	Year 6 – Year 35	-511	2,960	16,660	0	6,966	0	0	0	26,076
	Project – Total	Year 1 – Year 35	-789	3,525	22,000	0	7,087	127	5,985	30,062	67,997

Table 4.5 – Key Input Parameters by Project

Project	Assumed Construction Start Year	Assumed Operation Start Year	ASR Length (km)	Number of Permanent Bridges	Number of Modular Bridges	Existing Winter Road Length (km)	Total Project Area (ha)
P1	2012	2020	167.8	9	0	167.9	1,007.4
P2	2030	2038	225.9	2	0	303.0	1,355.8
P3a	2016	2022	28.2	3	0	28.0	170.0
P3b	2030	2037	79.6	7	0	54.0	478.0
P3c	2030	2037	114.6	2	1	131.2	687.8
P4	2018	2026	94.4	4	0	90.4	566.6
P5	2030	2038	113.6	0	3	118.1	682.0
P6	2030	2038	137.3	2	0	201.3	824.1
P7	2020	2028	102.4	6	0	129.6	614.7
P7a	2016	2021	41.2	2	0	15.6	248.2

Appendix A

Calculations for Baseline Scenario and Project Scenario GHG Emission Estimations

Emission Intensities (100 Year GWPs)

GHG	100 Year GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous Oxide (N_2O)	298

Source - 2016 National Inventory Report (1990-2014), Environment Canada, Table 1-1

C-CO_2 Conversion	3.666666667	tonne CO_2/tonne C

Source - Table 11 of Tree Canada Forest and Urban Tree Carbon Project Protocol (2009)

Clearing/ Burning

EF_{slash} (g CO_2/kg dry biomass fuel burnt)	1569
EF_{slash} (g CH_4/kg dry biomass fuel burnt)	4.7
EF_{slash} (g N_2O/kg dry biomass fuel burnt)	0.26
EF_{slash} (g CO_2e/kg dry biomass fuel burnt)	1764

Source - Extra Tropical Forest/ Other Forest in Table 2.5 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2

Air Travel - Airplane

EF_{air} (kg CO_2/passenger-km)	0.2772
EF_{air} (kg CH_4/passenger-km)	0.000004
EF_{air} (kg N_2O/passenger-km)	0.000005
EF_{air} (kg CO_2e/passenger-km)	0.2787

Source - Table 34 (Domestic Flights) of the UK Department for Business, Energy and Industrial Strategy 2016 GHG Conversion Factors for Company Reporting:Methodology Paper for Emission Factors

Includes an 8% uplift factor (for CO_2, CH_4, N_2O) and a 1.9 multiplier for non-CO_2 radiative forcing impacts (for CO_2 only) as prescribed in the methodology.

Air Travel - Helicopter

Fuel Efficiency $_{helicopter}$ (L/hr)	114

Source - Delta Helicopter Specifications For Bell Jet Ranger Helicopter <http://www.deltahelicopters.com/bell206b.html>

$EF_{helicopter}$ (kg CO_2/L fuel)	2.560
$EF_{helicopter}$ (kg CH4/L fuel)	0.000029
$EF_{helicopter}$ (kg N2O/L fuel)	0.000071

Source - 2016 National Inventory Report (1990-2014), Environment Canada, Table A6-12 for aviation turbo fuel

$EF_{helicopter}$ (kg CO_2e/L fuel)	2.582

Calculated based on GWPs

Ferry Travel

Fuel Efficiency $_{ferry}$ (L diesel/ passenger-100km)	5.1
EF_{ferry} (kg CO_2e/L diesel)	2.914
EF_{ferry} (kg CO_2/L diesel)	2.582
EF_{ferry} (kg CH_4/L diesel)	0.00015
EF_{ferry} (kg N_2O/L diesel)	0.0011

Source- "2016/2017 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions", Table 10

Road Vehicle Transportation

Vehicle Class	Emission Factor (g CO_2e/L fuel) CO_2	CH_4	N_2O	CO_2e
Light Duty Gasoline Vehicle (2004-2013)	2316	0.14	0.022	2326.1
Light Duty Gasoline Vehicle (1994-2003)	2316	0.23	0.47	2461.8
Light Duty Gasoline Vehicle (1980-1995)	2316	0.32	0.66	2520.7
Light Duty Gasoline Truck (2004-2013)	2316	0.14	0.022	2326.1
Light Duty Gasoline Truck (1994-2003)	2316	0.24	0.58	2494.8
Light Duty Gasoline Truck (1980-1995)	2316	0.21	0.66	2517.9
Heavy Duty Gasoline Vehicle Controlled	2316	0.29	0.047	2337.3
Heavy Duty Gasoline Vehicle Uncontrolled	2316	0.49	0.084	2353.3
Light Duty Diesel Vehicle Moderate Control	2690	0.068	0.21	2754.3
Light Duty Diesel Truck Moderate Control	2690	0.068	0.21	2754.3
Heavy Duty Diesel Vehicle Moderate Control	2690	0.14	0.082	2717.9
Off-Road Diesel	2316	2.7	0.05	2398.4
Off-Road Gasoline	2690	0.15	1.0	2991.8

Source - 2016 National Inventory Report (1990-2014), Environment Canada, Table A6-12

Vehicle Class	Average Fuel Efficiency (L fuel/100km)	Emission Factor (kg CO_2e/L)
Light Duty Gasoline Vehicle	9.2	
Light Duty Diesel Vehicle	7.2	
Light Duty Gasoline Truck	12.3	
Light Duty Diesel Truck	10.8	
Heavy Duty Gasoline		2.262
Heavy Duty Diesel		2.63
Off Road Vehicle Equipment Gasoline		2.283
Off Road Vehicle Equipment Gasoline		2.914

Source - 2016/2017 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions, Table 7 and Table 10

1- In units of L/passenger-100km

Vehicle Class	Average Fuel Efficiency (L fuel/100km)
Heavy Duty Trailer Truck	39.5

Source- Natural Resources Canada, 2016, "Fuel Efficiency Benchmarking in Canada's Trucking Industry. From <http://www.nrcan.gc.ca/energy/efficiency/transportation/commercial-vehicles/reports/7607>

Construction & Maintenance Equipment

Source- Calculations and EFs based on US EPA NONROAD 2008 Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling Compression-Ignition (2010)

**CH_4 and N_2O emission rates are based on the ratio of CO_2 : CH_4 and CO_2 :N_2O from 2016 National Inventory Report (1990-2014), Environment Canada, Table A6-12 for Heavy Duty diesel vehicles with moderate control*

		EF_{ss}		TAF		DF		Ef_{adj}		CO_2	CO_2	CH_4 *	N_2O*	CO_2e
Equipment Type	HP	BSFC	HC	BSFC	HC	BSFC	HC	BSFC	HC	(g/hp-hr)	(kg CO_2/hr)	(kg CH_4/hr)	(kg N_2O/hr)	(kg CO_2/hr)
ASR Construction Equipment														
Backhoe (175-300 HP)	228	0.367	0.3384	1.18	2.29	-	1.017	0.4331	0.78811	624.1	142.3	0.007	0.004	144
Bulldozer (175-300 HP)	211	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	112.9	0.006	0.003	114
Crusher (175-300 HP)	240	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	128.4	0.007	0.004	130
Front-End Loader (300-600 HP)	380	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	237.6	0.012	0.007	240
Grader (175-300 HP)	240	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	128.4	0.007	0.004	130
Rock Drill (175-300 HP)	225	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	119.2	0.006	0.004	120
Rock Truck (300-600 HP)	362	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	226.4	0.012	0.007	229
Semi & Trailer (300-600 HP)	503	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	269.5	0.014	0.008	272
Smooth Drum Roller (100- 175 HP)	104	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	55.7	0.003	0.002	56
Tandem Truck (300-600 HP)	500	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	267.9	0.014	0.008	271
Truck (300-600 HP)	334	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	179.0	0.009	0.005	181
Water Truck (175-300 HP)	275	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	147.2	0.008	0.004	149
Bridge (Permanent) Construction Equipment														
Backhoe (175-300 HP)	228	0.367	0.3384	1.18	2.29	-	1.017	0.4331	0.78811	624.1	142.3	0.007	0.004	144
Bobcat (50-75 HP)	53	0.408	0.3672	1.18	2.29	-	1.017	0.4814	0.855183	693.9	36.8	0.002	0.001	37
Bulldozer (175-300 HP)	211	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	112.9	0.006	0.003	114
Compactor (175-300 HP)	208	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	110.2	0.006	0.003	111
Concrete Truck (300-600 HP)	363	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	227.0	0.012	0.007	229
Crane (300-600 HP)	329	0.367	0.1669	1.00	1.00	-	1.017	0.3670	0.169737	530.5	174.5	0.009	0.005	176
Crusher (175-300 HP)	240	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	128.4	0.007	0.004	130
Equipment (75-100 HP)	100	0.408	0.3672	1.01	1.05	-	1.017	0.4121	0.392115	595.0	59.5	0.003	0.002	60
Forklift (50-75 HP)	70	0.408	0.3672	1.01	1.05	-	1.017	0.4121	0.392115	595.0	41.7	0.002	0.001	42
Front-End Loader (300-600 HP)	380	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	237.6	0.012	0.007	240
Excavator (100-175 HP)	100	0.367	0.1836	1.01	1.05	-	1.017	0.3707	0.196057	535.7	53.6	0.003	0.002	54
Grader (175-300 HP)	240	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	128.4	0.007	0.004	130
Packer (25-50 HP)	39	0.408	0.2789	1.00	1.00	-	1.017	0.4080	0.283641	589.5	23.0	0.001	0.001	23
Pump Truck (>1200 HP)	2050	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	1098.4	0.057	0.033	1110
Rock Drill (175-300 HP)	225	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	119.2	0.006	0.004	120
Rock Truck (300-600 HP)	362	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	226.4	0.012	0.007	229
Semi & Trailer (300-600 HP)	503	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	269.5	0.014	0.008	272
Smooth Drum Roller (100- 175 HP)	104	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	55.7	0.003	0.002	56
Tandem Truck (300-600 HP)	500	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	267.9	0.014	0.008	271
Truck (300-600 HP)	334	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	179.0	0.009	0.005	181
Zoom Boom (100-175 HP)	112	0.367	0.1836	1.01	1.05	-	1.017	0.3707	0.196057	535.7	60.0	0.003	0.002	61

Bridge (ACROW) Construction Equipment														
Bobcat (50-75 HP)	69	0.408	0.3672	1.18	2.29	-	1.017	0.4814	0.855183	693.9	47.9	0.002	0.001	48
Bulldozer (100-175 HP)	103	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	55.1	0.003	0.002	56
Concrete Truck (100-175 HP)	106	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	56.2	0.003	0.002	57
Conveyor (25- 50 HP)	35	0.408	0.3389	1.01	1.05	-	1.017	0.4121	0.361894	595.1	20.8	0.001	0.001	21
Crane (100-175 HP)	130	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	68.9	0.004	0.002	70
Rock Drill (175-300 HP)	300	0.367	0.3085	1.00	1.00	-	1.017	0.3670	0.313745	530.0	159.0	0.008	0.005	161
Excavator (175-300 HP)	189	0.367	0.3085	1.01	1.05	-	1.017	0.3707	0.329432	535.3	101.2	0.005	0.003	102
Generator (16-25 HP)	25	0.408	0.4380	1.01	1.05	-	1.017	0.4121	0.467718	594.8	14.9	0.001	0.000	15
Grader (175-300 HP)	185	0.367	0.3085	1.01	1.05	-	1.017	0.3707	0.329432	535.3	99.0	0.005	0.003	100
Front-End Loader (175-300 HP)	198	0.367	0.3085	1.18	2.29	-	1.017	0.4331	0.718475	624.3	123.6	0.006	0.004	125
Mechanic Truck (175-300 HP)	255	0.367	0.3085	1.01	1.05	-	1.017	0.3707	0.329432	535.3	136.5	0.007	0.004	138
Ranger All- Terrain (25- 50 HP)	44	0.408	0.3389	1.00	1.00	-	1.017	0.4080	0.344661	589.3	25.9	0.001	0.001	26
Rock Truck (175-300 HP)	285	0.367	0.3384	1.00	1.00	-	1.017	0.3670	0.344153	529.9	151.0	0.008	0.005	153
Semi & Trailer (300-600 HP)	500	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	267.9	0.014	0.008	271
Tandem Truck (300-600 HP)	303	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	162.3	0.008	0.005	164
Tractor (300-600 HP)	500	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	267.9	0.014	0.008	271
Truck (300-600 HP)	385	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	206.3	0.011	0.006	208
Land Clearing Equipment														
Backhoe (175-300 HP)	215	0.367	0.3384	1.18	2.29	-	1.017	0.4331	0.78811	624.1	134.2	0.007	0.004	136
Backhoe with Mulcher (175-300 HP)	182	0.367	0.3384	1.18	2.29	-	1.017	0.4331	0.78811	624.1	113.6	0.006	0.003	115
Bulldozer (175-300 HP)	191	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	102.2	0.005	0.003	103
Front-End Loader (300-600 HP)	305	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	190.7	0.010	0.006	193
Rock Truck (300-600 HP)	359	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	224.5	0.012	0.007	227
Tandem Truck (300-600 HP)	500	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	267.9	0.014	0.008	271
Timberjack Skidder (175-300 HP)	200	0.367	0.1669	1.18	2.29	-	1.017	0.4331	0.388698	625.4	125.1	0.007	0.004	126
Winter Road Construction Equipment														
Bobcat (50-75 HP)	51	0.408	0.3672	1.18	2.29	-	1.017	0.4814	0.855183	693.9	35.4	0.002	0.001	36
Bulldozer (75-100 HP)	88	0.408	0.3672	1.01	1.05	-	1.017	0.4121	0.392115	595.0	52.4	0.003	0.002	53
Equipment (25-50 HP)	25	0.408	0.2789	1.01	1.05	-	1.017	0.4121	0.297823	595.3	14.9	0.001	0.000	15
Front-End Loader (100-175 HP)	151	0.367	0.3384	1.18	2.29	-	1.017	0.4331	0.78811	624.1	94.2	0.005	0.003	95
Grader (100-175 HP)	125	0.367	0.3384	1.01	1.05	-	1.017	0.3707	0.36136	535.2	66.9	0.003	0.002	68
Grader (175-300 HP)	201	0.367	0.3085	1.01	1.05	-	1.017	0.3707	0.329432	535.3	107.6	0.006	0.003	109
Snowmobile (50-75 HP)	75	0.408	0.3672	1.00	1.00	-	1.017	0.4080	0.373442	589.2	44.2	0.002	0.001	45
Truck (300-600 HP)	334	0.367	0.1669	1.01	1.05	-	1.017	0.3707	0.178224	535.8	179.0	0.009	0.005	181

From Table A4 — For Tier 2

From Table A5

From Table A6 — Assumes half of useful life is expended

$$CO_2 = (BSFC * 453.6 - HC) * 0.87 * (44/12)$$ [Equation 6]

where

CO_2 is in g/hp-hr
BSFC is the in-use adjusted fuel consumption in lb/hp-hr
453.6 is the conversion factor from pounds to grams
HC is the in-use adjusted hydrocarbon emissions in g/hp-hr
0.87 is the carbon mass fraction of diesel
44/12 is the ratio of CO_2 mass to carbon mass

$$EF_{adj\,(HC,CO,NOx)} = EF_{ss} \times TAF \times DF$$ [Equation 1]

where:
EF_{adj} = final emission factor used in model, after adjustments to account for transient operation and deterioration (g/hp-hr)
EF_{ss} = zero-hour, steady-state emission factor (g/hp-hr)
TAF = transient adjustment factor (unitless)
DF = deterioration factor (unitless)

East Side Road GHG Assessment
Project P6
Project Information

Project Name

P6

Proposed ASR Length

137.3	km

Retrieved from ESRA GIS shapefiles

Project Area within 60m of ROW

8,240,940	m^2
824.094	ha

Retrieved from ESRA GIS shapefiles

Project Timeline

Construction Start Year=	2030	Years of Construction=	8
Construction End Year =	2037		
Operation Start Year=	2038		

Number of Bridges to be Constructed in Project Area

2	Permanent Bridges
0	ACROW Modular Bridges

Existing Winter/ Ice Road Length

201.3	km

Retrieved from ESRA GIS shapefiles

Approximate Age of Tree Stand in Project Area

100	years

Based on an analysis of Natural Resource Canada's Wildland Fire Information System GIS maps within 60m ROW of project

Landcover Classification Within 60m of ROW

Land Use Type	GIS Code (COVTYPE)	Area (m^2)	Area (ha)	Percent
Water	20	19,467	1.9466886	0%
Barren	30	0	0	0%
Exposed Land	33	280,028	28.00282	3%
Developed	34	0	0	0%
Shrubland	50	0	0	0%
Shrub Tall	51	0	0	0%
Shrub Low	52	0	0	0%
Wetland	80	0	0	0%
Wetland Treed	81	94,940	9.4940163	1%
Wetland Shrub	82	1,082,854	108.28543	13%
Wetland Herb	83	51,420	5.1419998	1%
Grassland	110	0	0	0%
Cultivated Agricultural	120	0	0	0%
Annual Crops	121	0	0	0%
Perennial Crops Pasture	122	0	0	0%
Forest Treed	200	0	0	0%
Coniferous	210	0	0	0%
Coniferous Dense	211	3,058,130	305.81299	37%
Coniferous Open	212	2,529,154	252.91535	31%
Coniferous Sparse	213	1,030,428	103.04283	12%
Broadleaf	220	0	0	0%
Broadleaf Dense	221	64,058	6.405762	1%
Broadleaf Open	222	0	0	0%
Broadleaf Sparse	223	0	0	0%
Mixedwood	230	0	0	0%
Mixedwood Dense	231	16,346	1.634619	0%
Mixedwood Open	232	0	0	0%
Mixedwood Sparse	233	0	0	0%
Other (Cloud, Shadow)	0,10,11,12	24,191	2.41914	0%
TOTAL		8251016.54	825.10165	

Retrieved from GIS analysis within 60m of the ROW
Landcover data from GeoBase shapefiles - Land Cover, circa 2000-Vector (LCC2000-V)
<http://ftp2.cits.rncan.gc.ca/pub/geobase/official/lcc2000v_csc2000v/shp_en/>

Total Tree Cover =	679	ha	82%

Total Broadleaf Tree Cover =	6	ha	1%
Total Coniferous Tree Cover =	662	ha	80%
Total Mixed Tree Cover =	11	ha	1%

Total Soft Wood Tree Cover =	671	ha	81%
Total Hard Wood Tree Cover =	8	ha	1%

Total Wetland Cover=	123	ha	15%

Total Shrub Cover=	113	ha	14%

Above Ground C-stock (tonnes CO_2) [1]

= above ground tree density (tonnes/ha)
× project area (ha)
× specific gravity of tree dry weight to green tree weight (unitless)
× conversion to aboveground dry tree biomass to tree biomass C (tonne C/ tonnes dry tree biomass)
× C-CO_2 conversion (tonne CO_2/tonne C)

Below Ground C-stock (tonnes CO_2) [1]

= root-shoot ratio
× Aboveground C-stock

Methodology and parameters based on Tree Canada's Tree Canada Afforestation and Reforestation Protocol, Version 2.0 (April 2015)

Approximate age of tree stand in project area= 100 years

(based on an analysis of Natural Resource Canada's Wildland Fire Information System GIS maps within 60m ROW of project)

Aboveground tree density=	106.5	tonnes tree/ha	broadleaf
	77.3	tonnes tree/ha	coniferous
	81.3	tonnes tree/ha	mixed wood
	77.7	tonnes tree/ha	weighted average

(based on Canada's National Forest Inventory tables for boreal shield - see table to right)

Area,Gross Total Volume,Total Above-Ground Biomass by Forest/Non-forest,Forest Type

Terrestrial Ecozone	Forest/Non-forest	Forest Type	Area (1000 ha)	Tree Volume (million m3)	Tree Biomass (million t)
Boreal Shield	Non-forest land	Unreported	32751.08	153.11	390.87
Boreal Shield	Forest land	Broadleaf	12903	2076.43	1374.1
Boreal Shield	Forest land	Coniferous	78878.98	9378.45	6099.2
Boreal Shield	Forest land	Mixedwood	30789.26	4014.03	2503.02
Boreal Shield	Forest land	Non-treed	8703.49	1.34	64.9
Boreal Shield	Water	Unreported	28081.47	0	0
			192107.28	15623.36	10432.09

Generated: 11/21/2016
Source: Canada's National Forest Inventory, ***revised 2006 baseline***

Area=	6	ha	broadleaf
	662	ha	coniferous
	11	ha	mixed wood

Average Dry Weight to Green Tree Specific Gravity = 40 %

(based on Table 5 of P. Miles/ W.Smit/ US Department of Agriculture Forest Service - Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America)

Conversion to tree biomass C= 0.5 tonne C/ tonnes dry tree biomass

(based on Table 4 of Tree Canada (2015) protocol)

C-CO_2 conversion = 3.67 tonne CO_2/tonne C

(based on Table 4 of Tree Canada (2015) protocol)

Root shoot ratio=	0.10	hardwood (broadleaf, mixed wood)
	0.20	softwood (coniferous- pine and spruce)
	0.20	weighted average

(based on Table D2 of Tree Canada (2015) protocol)

Aboveground dry biomass =	273	tonnes	broadleaf
	20,468	tonnes	coniferous
	362	tonnes	mixed wood
Belowground biomass =	27	tonnes	broadleaf
	4,094	tonnes	coniferous
	71	tonnes	mixed wood
Aboveground C-Stock =	500	tonnes CO_2	broadleaf
	37,525	tonnes CO_2	coniferous
	663	tonnes CO_2	mixed wood
	38,689	tonnes CO_2	
	-387	tonnes CO_2/year	
Belowground C-Stock =	50	tonnes CO_2	broadleaf
	7,505	tonnes CO_2	coniferous
	131	tonnes CO_2	mixed wood
	7,686	tonnes CO_2	
	-77	tonnes CO_2/year	
Total C-Stock=	46,375	tonnes CO_2	Total

Forest Sequestration Rate =	-515.3	tonnes CO_2/year
	0.00	tonnes CH_4/year
	0.00	tonnes N_2O/year
	-515.3	tonnes CO_2e/year

Net GHG emissions due to land cover along the proposed ASR (tonnes CO_2 e/yr)
= Methane flux from forest soils (tonnes CO_2 e/ha) × forest area (ha)
+ Methane flux from wetlands (tonnes CO_2 e/ha) × wetland area (ha)
+ Carbon dioxide flux from forest soils (tonnes C/ha) × wetland area (ha)
+ Carbon dioxide flux from wetlands (tonnes C/ha) × wetland area (ha)
× C-CO_2 conversion (tonne CO_2 /tonne C).

C-CO_2 conversion = 3.67 tonne CO_2/tonne C

		Study				
Land Cover		Potter et al. (2001a)	Potter et al. (2001b)	Bubier et al. (2005)	Yuan et al. (2008)	Trumbore et al. (1999)
Forest (Upland)	Methane Emissions (mg CH_4/m^2/day)	-0.79		-0.1		
		-0.86		-1.0		
				-0.1		
				-1.3		
	Carbon Emissions (g C/m^2/year)	-49.1	24		81	
		-25.8				
Forest (Wetland)	Methane Emissions (mg CH_4/m^2/day)	4.0		12		
		5.2		44		
				133		
				70		
				45		
				148		
				12		
				70		
				250		
				120		
				45		
				171		

Forest (Wetland)	-10.7	2.65
	-11.8	-111.19
		-164.15
		-15.24
		-23
Carbon Emissions (g C/m^2/year)		-180
		-180
		-25
		-3
		-65
		-31
		-13

Land Cover	CH_4 Emission Average (mg CH_4/m^2/day)	CH_4 Emission Average (g CH_4/m^2/year)	C Emission Average (g C/m^2/year)	Net GHG Emission Average (g CO_2e/m^2/year)	Land Cover area (ha)
Forest (Uplands)	-0.69	-0.145	7.53	23.96	679
Wetland	80.66	16.94	-59.32	205.96	123

Methane flux from forest upland areas- growing season (Apr-Oct)=	-0.99	tonnes CH_4/year	-25	tonnes CO_2e/year
Methane flux from wetland areas- growing season (Apr-Oct)=	20.8	tonnes CH_4/year	521	tonnes CO_2e/year
Carbon dioxide flux from forest upland areas =	187	tonnes CO_2/year	187	tonnes CO_2e/year
Carbon dioxide flux from wetlands areas=	-267	tonnes CO_2/year	-267	tonnes CO_2e/year

Net GHG Emissions from Wetlands =	-79.9	tonnes CO_2/year
	19.8	tonnes CH_4/year
	0	tonnes N_2O/year
	415.9	tonnes CO_2e/year

East Side Road GHG Assessment
Project P6
Baseline Scenario: AirTravel

Annual Air Travel GHG Emissions (tonnes CO_2e/yr)

= Plane travel (kg CO_2e) + helicopter travel(kg CO_2e)

= $\Sigma_{Airport}$ {Passenger-kilometers x EF_{air} (kg CO_2e/passenger-km)}

+ $\Sigma_{Airport}$ {Annual use (hours) x Fuel Efficiency $_{helicopter}$ (L/hr) x $EF_{helicopter}$ (kg CO2e/L fuel)}

Airplane Travel

% Unrecorded air movements = 25% 0.25

Applicable to Project (0=no, 1=yes)	From Airport	Passenger Kilometers[1] (passenger-km)	Increased Passenger Kilometers[2] (passenger-km)	EF_{air} (kg CO_2/ passenger-km)	EF_{air} (kg CH_4/ passenger-km)	EF_{air} (kg N_2O/ passenger-km)	EF_{air} (kg CO_2e/ passenger-km)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
0	Berens River	1,347,981	1,684,977	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Bloodvein	473,856	592,320	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Cross Lake	1,264,666	1,580,833	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Garden Hill (Island Lake)	14,052,914	17,566,143	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
1	God's Lake	2,971,824	3,714,780	0.2772	0.0000043	0.0000047	0.2787	1029.83	0.0160	0.0175	1,035.45
1	God's River (Manto Sipi)	2,137,568	2,671,960	0.2772	0.0000043	0.0000047	0.2787	740.73	0.0115	0.0126	744.77
0	Little Grand Rapids	1,992,357	2,490,446	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Norway House	2,643,582	3,304,477	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Oxford House	4,310,560	5,388,201	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Poplar River	2,371,676	2,964,595	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	Red Sucker Lake	2,408,456	3,010,570	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00
0	St. Theresa Point	13,117,414	16,396,768	0.2772	0.0000043	0.0000047	0.2787	0.00	0.0000	0.0000	0.00

1- Analysis conducted in a separate spreadsheet, based on publically-available MIT Data and commercial airline flight schedules.

2- Assume a 25% increase in air traffic to account for periods when flights are not recorded.

	1770.57	tonnes CO_2/year
	0.0276	tonnes CH_4/year
	0.0301	tonnes N_2O/year
GHG Emissions from Airplane Travel =	1,780.2	tonnes CO_2e/year

Helicopter Travel

Required to shuttle persons to airports for approximately 3 months per year (during spring breakup and winter freezeup) when both winter roads and ferry travel is not available.

Annual Helicopter Usage estimates provided by ESRA staff

Applicable to Project? (0=no, 1=yes)	To Airport	Annual Use (hrs)	Fuel Efficiency (L/hr)	EF_{air} (kg CO_2/L fuel)	EF_{air} (kg CH_4/L fuel)	EF_{air} (kg N_2O/L fuel)	EF_{air}[1] (kg CO_2e/L fuel)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
0	Island Lake	450	114	2.560	0.000029	0.000071	2.582	0	0.00000	0	0.0
0	Little Grand Rapids	1,270	114	2.560	0.000029	0.000071	2.582	0.00	0	0	0.0

1- From 2016 National Inventory Report (1990-2014), Environment Canada, Table A6-12 for aviation turbo fuel

	0	tonnes CO_2/year
	0.00000	tonnes CH_4/year
	0	tonnes N_2O/year
GHG Emissions from Helicopter Travel =	0.0	tonnes CO_2e/year

GHG Emissions from Air Travel =	1,770.57	tonnes CO_2/year
	0.03	tonnes CH_4/year
	0.03	tonnes N_2O/year
	1,780.2	tonnes CO_2e/year

East Side Road GHG Assessment
Project P6
Baseline Scenario: Ferry Travel

Annual Ferry Crossing GHG Emissions (tonnes CO_2 e/yr)
= Average annual passenger traffic (unitless)
× Distance per Trip (km)
× Fuel consumption $_{ferry}$ (L/passenger-km)
× EF $_{ferry}$ (kg CO_2 e/L) x 10-3 (tonnes/kg)

Applicable to Project (0=no, 1=yes)	Ferry Name	Locations	Average Annual Passenger Traffic (2000-2010)	Average Annual Vehicular Traffic (2000-2010)	Distance per Trip (km)	Fuel Consumption[2] (L diesel/ passenger-100km)	EF_{ferry} (kg CO_2/L diesel)	EF_{ferry} (kg CH_4/L diesel)	EF_{ferry} (kg N_2O/L diesel)	EF_{ferry} (kg CO_2e/L diesel)	GHG Emissions (tonnes CO_2e)
0	M.V. Edgar Wood	Island View - Bloodvein -	2,393	1,129	45	5.1	2.582	0.00015	0.0011	2.914	0.00
0	Private[1]	Princess Harbour	-	-	-	-	-	-			0.00

1 - Assumed that the private ferry services 50% of the M.V. Edgar Wood ferry traffic/emissions

GHG Emissions from Ferry Travel =	0.00	tonnes CO_2/year
	0.0000	tonnes CH_4/year
	0.0000	tonnes N_2O/year
	0.0	tonnes CO_2e/year

Annual GHG due to Vehicular Travel (tonnes CO_2e/yr)
= Travel on Seasonal (Winter and Ice) Roads
+ Travel on Existing Highways to Ferry Terminals

Travel on Seasonal (Winter and Ice) Roads (tonnes CO_2e/yr)
= Σ seasonal road segment Σ vehicle category {Vehicle Category Number of Trips (Trips/yr) X Trip Duration (hr/Trip)
X Fuel Use (L/hr) X $EF_{vehicle\ category}$ (g CO_2e/L) × 10-6 (tonnes/g)}

Travel on Existing Highways to Ferry Terminals (tonnes CO_2e/yr)
= Σ vehicle category {Vehicle Category Number of Trips (Trips/yr) X Trip Duration (hr/Trip)
X Fuel Use (L/hr) X $EF_{vehicle}$ category (g CO_2e/L) × 10^{-6} (tonnes/g)}

Travel on Winter Roads (based on winter road traffic count)

Vehicle Distance Travel Per 60 Days on Winter Road (km)

	ATV/ Snowmobile	Car	Truck/ Van/ SUV	Transport Truck
Distance Travelled[1] (km)=	23,999	0	581,768	183,710

1- Analysis conducted in a separate spreadsheet, based on a winter road traffic count conducted in February 2017

Class=	Off-Road	LDV	LDT	HD	
Fuel Consumption[2] (L/100km) =	15.2	11.3	15.2	48.7	
EF (gCO_2/L fuel)=	2,690.0	2,316.0	2,316.0	2,690.0	
EF (gCH_4/L fuel)=	0.15	0.23	0.24	0.14	
EF (gN_2O/L fuel)=	1.00	0.47	0.58	0.08	
EF (gCO_2e/L fuel)=	2,991.8	2,461.8	2,494.8	2,717.9	
	9.8	0.0	204.3	240.6	tonnes CO_2/year
	0.0	0.0	0.0	0.0	tonnes CH_4/year
	0.0	0.0	0.1	0.0	tonnes N_2O/year
	10.9	0.0	220.0	243.1	tonnes CO_2e/year

2- Fuel is seasonally adjusted at the pump. A liter of winter gas has 1.5% -3.0% less energy than a liter of summer gas due to temperature adjustments. Fuel consumption can increase 7-35% due to poor road conditions (such as heavy snow, slush, etc).
Source- NRCan Cold Weather Effects on Fuel Efficiency <http://www.nrcan.gc.ca/energy/efficiency/transportation/cars-light-trucks/buying/16748>

	454.6	tonnes CO_2/year
	0.034	tonnes CH_4/year
	0.062	tonnes N_2O/year
GHG Emissions due to Vehicular Traffic =	474.0	tonnes CO_2e/year

Travel on Existing Highways (Based on Ferry Travel)

Applicable only to P1

Average Annual Traffic (2000-2010)[1]

Applicable to Project (0=no, 1=yes)	Ferry	Passengers	Car/ Truck	Heavy Duty Truck	Semi-Trailer	Bus	Loader	Grader	Miscellaneous	Total Vehicles
0	M.V. Edgar Wood	2395	710	144	56	8	7	4	200	1129
0	Private[3]	1198	355	72	28	4	4	2	100	565

1- Data provided by Lauri Blair, Government of Manitoba in 2010 P1 GHG Assessment. Older data used to account for changes in traffic due to the construction of P1.

2- Assume 2 passengers per vehicle on average

3- Assume the number of vehicles in increased by 50% to account for private barge/ferry

Travel to Ferry on Paved Road (PTH 8)

Paved Road Speed Limit =	100	km/hr
Estimated Vehicle Speed=	80	km/hr
Paved Road Trip Distance=	140	km
Total Annual Distance (HD)=	0	km
Total Annual Distance (LDT)=	0	km
Paved Road Trip Duration=	1.75	hr
Total Annual Duration (HD)=	0	hr
Total Annual Duration (LDT)=	0	hr
Fuel Consumption HD =	39.5	L/100 km
Fuel Consumption LDT =	12.3	L/100 km
EF_{HD} =	2718	g CO_2e/L fuel
EF_{LDT} =	2754	g CO_2e/L fuel

Travel to Ferry on Gravel Road (PR 234)

Gravel Road Speed Limit =	90	km/hr
Estimated Vehicle Speed=	75	km/hr
Paved Road Trip Distance=	80	km
Total Annual Distance (HD)=	0	km
Total Annual Distance (LDT)=	0	km
Paved Road Trip Duration=	1.07	hr
Total Annual Duration (HD)=	0	hr
Total Annual Duration (LDT)=	0	hr
Fuel Consumption HD[1] =	45.9	L/100 km
Fuel Consumption LDT[1] =	14.3	L/100 km
EF_{HD} =	2718	g CO_2e/L fuel
EF_{LDT} =	2754	g CO_2e/L fuel

1- Fuel efficiency on gravel roads is reduced to 83.9% on average as per US EPA, 2006, "Final Technical Support Document:Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates"

	0.0	tonnes CO_2/year
	0.000	tonnes CH_4/year
	0.000	tonnes N_2O/year
GHG Emissions due to Vehicular Traffic (based on ferry travel data) =	0.0	tonnes CO_2e/year

GHG Emissions due to Vehicular Traffic =	454.6	tonnes CO_2/year
	0.034	tonnes CH_4/year
	0.062	tonnes N_2O/year
	474.0	tonnes CO_2e/year

East Side Road GHG Assessment
Project P6
Baseline Scenario: Construction and Maintenance of Winter and Ice Roads

Annual GHG Emissions Construction and Maintenance of Seasonal Roads (tonnes CO_2 e/yr)
= Σ equipment type {Equipment Use (hr/km) X Length (km)
X $EF_{equipment\ type}$ (g CO_2 e/hr) × 10-6 (tonnes/g)}

Construction

Equipment Type	Average Annual Use[1] (hrs/km)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	Winter/Ice Road Length in Project Area[2]	Hours Required	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Bobcat (50-75 HP)	0.54	35.39	0.0018	0.0011	35.76	201.3	109	3.85	0.0002	0.0001	3.89
Bulldozer (75-100 HP)	3.43	52.36	0.0027	0.0016	52.91		690	36.15	0.0019	0.0011	36.53
Equipment (25-50 HP)	0.14	14.88	0.0008	0.0005	15.04		28	0.42	0.0000	0.0000	0.42
Front-End Loader (100-175 HP)	2.77	94.24	0.0049	0.0029	95.22		558	52.55	0.0027	0.0016	53.09
Grader (100-175 HP)	1.68	66.90	0.0035	0.0020	67.59		338	22.62	0.0012	0.0007	22.86
Grader (175-300 HP)	1.40	107.60	0.0056	0.0033	108.71		282	30.32	0.0016	0.0009	30.64
Snowmobile (50-75 HP)	3.00	44.19	0.0023	0.0013	44.65		604	26.69	0.0014	0.0008	26.96
Truck (300-600 HP)	4.18	178.95	0.0093	0.0055	180.81		841	150.58	0.0078	0.0046	152.14

1-Average annual equipment use per kilometer based on 2014/2015 and 2015/2016 contractor equipment use data received by ESRA. Analysis conducted in a separate spreadsheet.
2-Ice/Winter Road Length in Project Area determined through ESRA GIS files

	323.18	tonnes CO_2/year
	0.0168	tonnes CH_4/year
	0.0099	tonnes N_2O/year
GHG Emissions from Winter and Ice Road Construction & Maintenance =	326.5	tonnes CO_2e/year

East Side Road GHG Assessment
Project P6
Project Scenario: Forest Land Cover

GHG Emissions from Forest Sequestration (tonnes CO_2 e/yr)
= ∑ year (GHG Emissions from Tree Sequestration in Baseline Scenario (tonnes CO_2 e/ha) X Proportion of Tree Cover Remaining (ha))
+ ∑year(GHG Emissions from Tree Sequestration in Baseline Scenario (tonnes CO_2 e/ha) X Reforested Area (ha))

Forest sequestration rate = -515.3 tonnes CO_2e/year
Total tree cover area in project area = 679 ha
Estimated carbon sequestration rate of reforested land = -0.76 tonnes CO_2e/year-ha forest
Reforested land= 101.9 ha
Assumed that 15% of total forested cleared area is reforested.
Years of Construction = 8

	Year								
	1	2	3	4	5	6	7	8	
Forested Area Land Cover Sequestration - During Construction =	-461	-406	-351	-296	-242	-186.8	-132	-77.29	tonnes CO_2/year
Land clearing assumed to be distributed linearly over years of construction (ie. forest removed gradually over the course of construction period). Reforestation is also assumed to occur linearly.	0	0	0	0	0	0	0	0	tonnes CH_4/year
	0	0	0	0	0	0	0	0	tonnes N_2O/year
	-461	-406	-351	-296	-242	-186.8	-132	-77.29	tonnes CO_2e/year

Reforested Area Land Cover Sequestration - During Operation =	-77	tonnes CO_2/year
Assumed to be distributed linearly over 90 years	0	tonnes CH_4/year
	0	tonnes N_2O/year
	-77	tonnes CO_2e/year

East Side Road GHG Assessment
Project P6
Project Scenario: Land Cover

Net GHG emissions due to land cover along the proposed ASR (tonnes CO_2 e/yr)
= ∑year(GHG Emissions from Wetlands in Baseline Scenario (tonnes CO_2 e/yr)
X Proportion of Landcover Remaining)

Width of road =	10	m
Road Shoulder =	3	m
Total ROW =	60	m

Proportion of area covered by road and road shoulder = 27%

Years of Construction = 8

	Year								
	1	2	3	4	5	6	7	8	
Wetland GHG Emissions - During Construction =	-77	-75	-72	-69	-67	-64	-61	-59	tonnes CO_2/year
Construction (road coverage) assumed to be distributed linearly over years of construction (ie. Wetlands covered gradually over the course of construction period).	19	19	18	17	17	16	15	15	tonnes CH_4/year
	0	0	0	0	0	0	0	0	tonnes N_2O/year
	402	388	374	360	347	333	319	305	tonnes CO_2e/year

Wetland GHG Emissions - During Operation =	-59	tonnes CO_2/year
Assumed to be distributed linearly over 90 years	15	tonnes CH_4/year
	0	tonnes N_2O/year
	305	tonnes CO_2e/year

Annual Air Travel GHG Emissions (tonnes CO_2e/yr)

= GHG Emissions from Air Travel in Baseline Scenario (tonnes CO_2e/yr)

X Proportion of Air Travel Remaining

GHG Emissions from Air Travel During Construction=	1,770.57	tonnes CO_2/year
Assumed that air travel will remains consistent during construction.	0.028	tonnes CH_4/year
	0.030	tonnes N_2O/year
	1,780.2	tonnes CO_2e/year
GHG Emissions from Air Travel During Operation=	1,593.51	tonnes CO_2/year
Assumed that air travel will reduce to 80% in first two years of operation and helicopter travel to airport will cease.	0.02	tonnes CH_4/year
	0.03	tonnes N_2O/year
	1,602.2	tonnes CO_2e/year

Annual Ferry Travel GHG Emissions (tonnes CO_2e/yr)
= GHG Emissions from Ferry Travel in Baseline Scenario (tonnes CO_2e/yr)
X Proportion of Ferry Travel Remaining

GHG Emissions from Ferry Travel During Construction=	0.00	tonnes CO_2/year
Assumed that ferry travel will remain consistent during construction	0.00	tonnes CH_4/year
	0.00	tonnes N_2O/year
	0.0	tonnes CO_2e/year
GHG Emissions from FerryTravel During Operation=	0.00	tonnes CO_2/year
Assumed that ferry travel will cease after operation begins	0.00	tonnes CH_4/year
	0.00	tonnes N_2O/year
	0.0	tonnes CO_2e/year

Annual Vehicular Travel GHG Emissions (tonnes CO_2e/yr)

= GHG Emissions from Vehicular Travel in Baseline Scenario based on Modal Shift from Winter Road to ASR Travel (tonnes CO_2e/yr)

+ GHG Emissions from Vehicular Travel in Baseline Scenario X Proportional Increase from Modal Shift from Air Travel (tonnes CO_2e/yr)

+ GHG Emissions from Vehicular Travel in Baseline Scenario X Proportional Increase from Modal Shift from Ferry Travel (tonnes CO_2e/yr)

Modal Shift from Winter Road to ASR (Based on tonnage requirements per community)

Assume remains consistent; baseline scenario winter road traffic moves to gravel ASR once constructed

Vehicle Distance Travel Per 60 Days on Winter Road (km)

	ATV/ Snowmobile	Car	Truck/ Van/ SUV	Transport Truck
Distance Travelled[1] (km)=	16,369	0	396,804	125,302

1- Analysis conducted in a separate spreadsheet, based on a winter road traffic count conducted in February 2017, prorated to convert winter road length to ASR length

Class=	Off-Road	LDV	LDT	HD	
Fuel Consumption[2] (L/100km) =	14.3	10.7	14.3	45.9	
EF (gCO_2/L fuel)=	2,690.0	2,316.0	2,316.0	2,690.0	
EF (gCH_4/L fuel)=	0.2	0.2	0.2	0.1	
EF (gN_2O/L fuel)=	1.0	0.5	0.6	0.1	
EF (gCO_2e/L fuel)=	2,991.8	2,461.8	2,494.8	2,717.9	
	6.3	0.0	131.2	154.6	tonnes CO_2/year
	0.0	0.0	0.0	0.0	tonnes CH_4/year
	0.0	0.0	0.0	0.0	tonnes N_2O/year
	7.0	0.0	141.4	156.2	tonnes CO_2e/year

2 - Fuel efficiency on gravel roads is reduced to 83.9% on average as per US EPA, 2006, "Final Technical Support Deocument:Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates"

	292.1	tonnes CO_2/year
	0.022	tonnes CH_4/year
	0.040	tonnes N_2O/year
GHG Emissions due to Vehicular Traffic shifting from winter road to ASR =	304.5	tonnes CO_2e/year

Increase due to Travel Modal Switch (Air Travel)

Assume 20% of air travel moves to vehicular travel

Baseline Scenario Air Passenger Traffic

Estimated Annual Passenger Traffic - Return

Applicable to Project (0=no, 1=yes)	From Airport	To Airport: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
0	Berens River	4,425	-	2,028	-	-	-	-	-	-	-	-	6,453
0	Bloodvein	1,907	953	-	-	-	-	-	-	-	-	-	2,860
0	Cross Lake	2,054	-	-	-	-	-	-	-	2,465	-	-	4,519
0	Garden Hill (Island Lake)	29,068	-	-	-	-	-	-	-	-	2,202	8,808	40,078
1	God's Lake	4,425	-	-	-	-	-	1,580	6,006	-	-	-	12,011
1	God's River (Manto Sipi)	3,510	-	-	-	-	731	-	292	-	292	-	4,825
0	Little Grand Rapids	7,576	-	-	-	-	-	-	-	-	-	-	7,576
0	Norway House	5,379	-	-	2,689	-	-	-	-	-	-	-	8,068
0	Oxford House	6,966	-	-	-	-	3,893	410	-	-	-	-	11,269
0	Poplar River	6,835	-	-	-	-	-	-	-	-	-	-	6,835
0	Red Sucker Lake	4,377	-	-	-	547	-	219	-	-	-	-	5,143
0	St. Theresa Point	28,034	-	-	-	5,840	-	-	-	-	-	-	33,874

Project Scenario Vehicle Trips (20% of air traffic, 2 persons per car)

Estimated Annual Traffic Diverted from Air Travel to Vehicular Travel

Applicable to Project (0=no, 1=yes)	From Airport	To Airport: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
0	Berens River	221	0	101	0	0	0	0	0	0	0	0	323
0	Bloodvein	95	48	0	0	0	0	0	0	0	0	0	143
0	Cross Lake	103	0	0	0	0	0	0	0	123	0	0	226
0	Garden Hill (Island Lake)	1,453	0	0	0	0	0	0	0	0	110	440	2,004
1	God's Lake	221	0	0	0	0	0	79	300	0	0	0	601
1	God's River (Manto Sipi)	176	0	0	0	0	37	0	15	0	15	0	241
0	Little Grand Rapids	379	0	0	0	0	0	0	0	0	0	0	379
0	Norway House	269	0	0	134	0	0	0	0	0	0	0	403
0	Oxford House	348	0	0	0	0	195	21	0	0	0	0	563
0	Poplar River	342	0	0	0	0	0	0	0	0	0	0	342
0	Red Sucker Lake	219	0	0	0	27	0	11	0	0	0	0	257
0	St. Theresa Point	1,402	0	0	0	292	0	0	0	0	0	0	1,694

Distance by Vehicle (km) - Paved Roads (Highways)

Applicable to Project (0=no, 1=yes)	From Location	To Location: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point
0	Berens River	195										
0	Bloodvein	195										
0	Cross Lake	765								115		
0	Garden Hill (Island Lake)	765										
1	God's Lake	765										
1	God's River (Manto Sipi)	765										
0	Little Grand Rapids	195										
0	Norway House	805			115							
0	Oxford House	765										
0	Poplar River	195										
0	Red Sucker Lake	765										
0	St. Theresa Point	765										

Distance by Vehicle (km) - Gravel Roads (ASR)

Applicable to Project (0=no, 1=yes)	From Location	To Location: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point
0	Berens River	167.8		73								
0	Bloodvein	88.8	73									
0	Cross Lake	0										
0	Garden Hill (Island Lake)	305.5									115	108
1	God's Lake	257.3						101	66			
1	God's River (Manto Sipi)	298.2					101		107		524	
0	Little Grand Rapids	286.7										
0	Norway House	0										
0	Oxford House	190.9					66	107				
0	Poplar River	262.2										
0	Red Sucker Lake	420.1				115		524				
0	St. Theresa Point	254.1				108						

Paved Road (Highway) Segment			*ASR Road (Gravel) Segment*		
Percent HD Vehicles=	24%		Percent HD Vehicles=	24%	
Percent LDT Vehicles=	76%		Percent LDT Vehicles=	76%	
Percent LDV Vehicles=	0%		Percent LDV Vehicles=	0%	
Total Distance (Paved/Highway Road)=	303,514	km	Total Distance (Gravel/ASR Road)=	150,057.43	km
Total Annual Distance (HD)=	72,841	km	Total Annual Distance (HD)=	36,013	km
Total Annual Distance (LDT)=	230,672	km	Total Annual Distance (LDT)=	114,045	km
Total Annual Distance (LDV)=	0	km	Total Annual Distance (LDV)=	0	km
Fuel Consumption $_{HD}$ =	39.5	L/100km	Fuel Consumption $_{HD}$ =	45.9	L/100km
Fuel Consumption $_{LDT}$ =	12.3	L/100km	Fuel Consumption $_{LDT}$ =	14.3	L/100km
Fuel Consumption $_{LDV}$ =	9.2	L/100km	Fuel Consumption $_{LDV}$ =	10.7	L/100km

Fuel efficiency on gravel roads is reduced to 83.9% on average as per US EPA, 2006, "Final Technical Support Deocument:Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates"

	HD	LDT	LDV
EF (gCO_2/L fuel)=	2,690.0	2,316.0	2316.0
EF (gCH_4/L fuel)=	0.1	0.2	0.2
EF (gN_2O/L fuel)=	0.1	0.6	0.5
EF (gCO_2e/L fuel)=	2,717.9	2,494.8	2461.8

Paved Road (Highway) Segment		ASR Road (Gravel) Segment	
143.1	tonnes CO_2/year	82.1	tonnes CO_2/year
0.0	tonnes CH_4/year	0.0	tonnes CH_4/year
0.0	tonnes N_2O/year	0.0	tonnes N_2O/year
149.0	tonnes CO_2e/year	85.5	tonnes CO_2e/year

225.3 tonnes CO_2/year

0.017 tonnes CH_4/year

0.030 tonnes N_2O/year

GHG Emissions due to Modal Switch (Air to Vehicular Traffic) = 234.5 tonnes CO_2e/year

Increase due to Travel Modal Switch (Ferry Travel)

Applicable only to P1 -M.V. Edgar Wood

Assume all ferry traffic is diverted to ASR after in the first year of operation

Assume two passengers per vehicle

Applicable to project (0=no, 1=yes)	0
Average passenger traffic (2000-2010)=	3,590
Assumes private ferry services 50% of the M.V. Edgar Wood ferry	
Percent HD Vehicles=	24%
Percent LDT Vehicles=	76%

Paved Road (Highway) Segment

Paved Road Speed Limit =	90	km/hr
Estimated Vehicle Speed=	80	km/hr
Fuel Consumption HD =	39.5	L/100 km
Fuel Consumption LDT =	12.3	L/100 km
EF_{HD} =	2718	g CO_2e/L fuel
EF_{LDT} =	2754	g CO_2e/L fuel

ASR Road (Gravel) Segment

Gravel Road Speed Limit =	60	km/hr
Estimated Vehicle Speed=	50	km/hr
Fuel Consumption HD[1] =	45.9	L/100 km
Fuel Consumption LDT[1] =	14.3	L/100 km
EF_{HD} =	2718	g CO_2e/L fuel
EF_{LDT} =	2754	g CO_2e/L fuel

1- Fuel efficiency on gravel roads is reduced to 83.9% on average as per US EPA, 2006, "Final Technical Support Deocument:Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates"

	Distance (km)				Trip Duration from Winnipeg (hr)		Total Annual Duration from Winnipeg (hr)		Total Annual Distance from Winnipeg (km)	
Destination	Paved Roads	ASR Gravel Road	% Breakdown[1]	Number of Vehicle Trips	Paved Roads	ASR Gravel Road	Paved Roads	ASR Gravel Road	Paved Roads	ASR Gravel Road
Bloodvein	195	88.8	17%	299	2.44	1.78	727.9	530.3	58,229	26,517
Berens River	195	168	33%	600	2.44	3.36	1463.2	2017.0	117,059	100,851
Poplar River	195	258.7	20%	365	2.44	5.17	890.7	1890.7	71,256	94,533
Little Grand Rapids	195	218.4	20%	362	2.44	4.37	882.4	1581.3	70,596	79,067
Pauingassi	195	218.4	9%	168	2.4375	4.37	410.5	735.5	32,837	36,777

1- Proportion based on population size

	0	tonnes CO_2/year
	0.0000	tonnes CH_4/year
	0.0000	tonnes N_2O/year
GHG Emissions due to Modal Switch (Ferry to Vehicular Traffic) - operation=	0.0	tonnes CO_2e/year

GHG Emissions from VehicularTravel During Construction=	454.6	tonnes CO_2/year
Assumed that vehicular travel will remain consistent during construction.	0.03	tonnes CH_4/year
	0.06	tonnes N_2O/year
	474.0	tonnes CO_2e/year
GHG Emissions from Vehicular Travel During Operation=	517.4	tonnes CO_2/year
Assumed modal shift from winter road/ ferry/ air travel to ASR. Assumed that ferry travel will cease once operating and will be diverted to ASR traffic.	0.0	tonnes CH_4/year
	0.1	tonnes N_2O/year
	539.0	tonnes CO_2e/year

Annual GHG Emissions Construction and Maintenance of Seasonal Roads (tonnes CO_2e/yr)
= Σ equipment type {Equipment Use (hr/km) X Length (km)
X $EF_{equipment\ type}$ (g CO_2e/hr) × 10-6 (tonnes/g)}

Construction

Equipment Type	Average Annual Use[1] (hrs/km)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	Winter/Ice Road Length in Project Area[2]	Hours Required	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Bobcat (50-75 HP)	0.54	35.39	0.0018	0.0011	35.76	201.3	109	3.85	0.0002	0.0001	3.89
Bulldozer (75-100 HP)	3.43	52.36	0.0027	0.0016	52.91		690	36.15	0.0019	0.0011	36.53
Equipment (25-50 HP)	0.14	14.88	0.0008	0.0005	15.04		28	0.42	0.0000	0.0000	0.42
Front-End Loader (100-175 HP)	2.77	94.24	0.0049	0.0029	95.22		558	52.55	0.0027	0.0016	53.09
Grader (100-175 HP)	1.68	66.90	0.0035	0.0020	67.59		338	22.62	0.0012	0.0007	22.86
Grader (175-300 HP)	1.40	107.60	0.0056	0.0033	108.71		282	30.32	0.0016	0.0009	30.64
Snowmobile (50-75 HP)	3.00	44.19	0.0023	0.0013	44.65		604	26.69	0.0014	0.0008	26.96
Truck (300-600 HP)	4.18	178.95	0.0093	0.0055	180.81		841	150.58	0.0078	0.0046	152.14

1-Average annual equipment use per kilometer based on 2014/2015 and 2015/2016 contractor equipment use data received by ESRA. Analysis conducted in a separate spreadsheet.

2-Ice/Winter Road Length in Project Area determined through ESRA GIS files

	323.18	tonnes CO_2/year
	0.0168	tonnes CH_4/year
	0.0099	tonnes N_2O/year
GHG Emissions from Winter and Ice Road Construction & Maintenance =	326.5	tonnes CO_2e/year

Annual GHG Emissions due to Land Clearing (tonnes CO_2 e/yr)
= GHG Emissions from Slash and Shrub Burning (tonnes CO_2 e/yr)
+ GHG Emissions Land Clearing Equipment (tonnes CO_2 e/yr)

GHG Emissions from Slash Burning (tonnes CO_2 e/yr) [1]
= Area of Burn (ha)
× Density of Available Fuel (Wood Biomass) (tonnes/ha)
× C_f
× specific gravity of tree dry weight to green tree weight (unitless)
× EF_{slash} (g/kg dry biomass burnt)

GHG Emissions Land Clearing Equipment (tonnes CO_2 e/yr)
= Σ equipment types {Number of Equipment Type × Distance (km) x Rate of Use (hr/year) × $EF_{equipment\ type}$ (kg CO_2 e/L) × 10-4 (tonnes/kg)}

1 - Methodology and parameters based on IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2, Equation 2.27
2 - Methodology and parameters retrieved from Tree Canada Forest and Urban Tree Carbon Project Protocol, V.1.1 (2009)

Slash Burning
Trees

Total tree covered area cleared =	679	ha	
Percent slash burned =		80%	
Percent remaining in ground=		20%	
Percent recovered (firewood, construction materials)=		0%	
		100%	*(must sum to 100%)*
Density of fuel (wood biomass) =	77.7	tonnes fuel/ha	
Combustion Factor (C_f) =	0.33		

(based on post-logging slash burn in boreal forest in Table 2.6 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2)

EF_{slash} =	1569	g CO_2/kg dry biomass fuel burnt
EF_{slash} =	4.7	g CH_4/kg dry biomass fuel burnt
EF_{slash} =	0.26	g N_2O/kg dry biomass fuel burnt
EF_{slash} =	1764.0	g CO_2e/kg dry biomass fuel burnt

(based on Extra Tropical Forest/ Other Forest in Table 2.5 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2)

Average Dry Weight to Green Tree Specific Gravity = 40%

(based on Table 5 of P. Miles/ W.Smit/ US Department of Agriculture Forest Service - Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America)

	8,769.380	tonnes CO_2	1,096.2	tonnes CO_2/year
	26.269	tonnes CH_4	3.28	tonnes CH_4/year
	1.453	tonnes N_2O	0.18	tonnes N_2O/year
GHG Emissions from slash burning (trees) =	9,859.153	tonnes CO_2e	1,232.4	tonnes CO_2e/year

Shrubs

Total shrub covered area cleared =	113.4274339	ha
Density of fuel (wood biomass) =	37	tonnes fuel/ha

(based on willow/alder/shrub average biomass for Manitoba Boreal Shield in Landscape Management Network, 2007, Canada's Forest Biomass Resources)

Combustion Factor (C_f) = 0.33

(based on post-logging slash burn in boreal forest in Table 2.6 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2)

EF_{slash} =	1569	g CO_2/kg dry biomass fuel burnt
EF_{slash} =	4.7	g CH_4/kg dry biomass fuel burnt
EF_{slash} =	0.26	g N_2O/kg dry biomass fuel burnt
EF_{slash} =	1764	g CO_2e/kg dry biomass fuel burnt

(based on Extra Tropical Forest/ Other Forest in Table 2.5 of IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Volume 4, Chapter 2)

Average Dry Weight to Green Tree Specific Gravity = 40%

(based on Table 5 of P. Miles/ W.Smit/ US Department of Agriculture Forest Service - Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America)

	869.19 tonnes CO_2	108.6 tonnes CO_2/year
	2.60 tonnes CH_4	0.3 tonnes CH_4/year
	0.14 tonnes N_2O	0.0 tonnes N_2O/year
GHG Emissions from slash burning (shrubs) =	977.2 tonnes CO_2e	122.2 tonnes CO_2e/year

Equipment

Equipment	Rate of Use (hrs/km)	Total Use (hrs)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Backhoe	221.5	30,417	134.19	0.0070	0.0041	135.5786	4081.54	0.2124	0.1244	4124
Backhoe with Mulcher	48.9	6,710	113.59	0.0059	0.0035	114.7689	762.20	0.0397	0.0232	770
Bulldozer	149.7	20,553	102.22	0.0053	0.0031	103.2850	2100.97	0.1093	0.0640	2123
Front-End Loader	0.1	14	190.74	0.0099	0.0058	192.7251	2.69	0.0001	0.0001	3
Rock Truck	75.8	10,414	224.52	0.0117	0.0068	226.8470	2338.03	0.1217	0.0713	2362
Tandem Truck	20.1	2,760	267.89	0.0139	0.0082	270.6746	739.41	0.0385	0.0225	747
Timber Jack Skidder	0.8	106	125.08	0.0065	0.0038	126.3771	13.21	0.0007	0.0004	13

	10038.04 tonnes CO_2	1,254.75 tonnes CO_2/year
	0.5224 tonnes CH_4	0.065 tonnes CH_4/year
	0.3060 tonnes N_2O	0.038 tonnes N_2O/year
Total GHG Emissions from land clearing equipment =	10,142.3 tonnes CO_2e	1,267.8 tonnes CO_2e/year

GHG Emissions from land clearing -construction=	2,459.6 tonnes CO_2/year
	3.7 tonnes CH_4/year
	0.2 tonnes N_2O/year
	2,622.3 tonnes CO_2e/year

Annual GHG Emissions Due to Construction (tonnes CO_2 e/yr)

= Σ ASR equipment {ASR Length (km) x Rate of Use (hr/km) × $EF_{equipment}$ (kg CO_2 e/hr) × 10-4 (tonnes/kg)}

+ Σ bridge equipment {Number of bridges x Rate of Use (hr/bridge) × $EF_{equipment}$ (kg CO_2 e/hr) × 10-4 (tonnes/kg)}

ASR Construction

Distance of Project ASR to be Constructed = 137.3 km

Equipment	Use (hrs/km)	Total Use (hrs)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Backhoe (175-300 HP)	497.5	68,312	142.30	0.0074	0.0043	143.78	9721	0.506	0.296	9822
Bulldozer (175-300 HP)	299.7	41,155	112.93	0.0059	0.0034	114.10	4648	0.242	0.142	4696
Crusher (175-300 HP)	196.0	26,911	128.45	0.0067	0.0039	129.78	3457	0.180	0.105	3493
Front-End Loader (300-600 HP)	416.3	57,159	237.65	0.0124	0.0072	240.12	13584	0.707	0.414	13725
Grader (175-300 HP)	20.4	2,802	128.45	0.0067	0.0039	129.78	360	0.019	0.011	364
Rock Drill (175-300 HP)	421.8	57,912	119.24	0.0062	0.0036	120.48	6905	0.359	0.210	6977
Rock Truck (300-600 HP)	1188.7	163,211	226.39	0.0118	0.0069	228.74	36950	1.923	1.126	37333
Semi & Trailer (300-600 HP)	338.2	46,436	269.50	0.0140	0.0082	272.30	12514	0.651	0.381	12644
Smooth Drum Roller (100- 175 HP)	64.7	8,886	55.66	0.0029	0.0017	56.24	495	0.026	0.015	500
Tandem Truck (300-600 HP)	88.3	12,118	267.89	0.0139	0.0082	270.67	3246	0.169	0.099	3280
Truck (300-600 HP)	46.7	6,414	178.95	0.0093	0.0055	180.81	1148	0.060	0.035	1160
Water Truck (175-300 HP)	10.4	1,422	147.18	0.0077	0.0045	148.71	209	0.011	0.006	212

	93,236 tonnes CO_2	11,654 tonnes CO_2/year
	4.85 tonnes CH_4	0.61 tonnes CH_4/year
	2.84 tonnes N_2O	0.36 tonnes N_2O/year
Total GHG Emissions from ASR construction equipment =	94,204.1 tonnes CO_2e	11,775.5 tonnes CO_2e/year

Bridge Construction

Permanent Bridges

Number of Permanent Bridges to be Constructed along ASR= 2

Equipment	Total Use (hrs/bridge)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Backhoe (175-300 HP)	102	142.30	0.0074	0.0043	143.78	29.0	0.0015	0.0009	29.3
Bobcat	310	36.78	0.0019	0.0011	37.16	22.8	0.0012	0.0007	23.0
Bulldozer (175-300 HP)	480	112.93	0.0059	0.0034	114.10	108.4	0.0056	0.0033	109.5
Compactor	110	110.23	0.0057	0.0034	111.37	24.3	0.0013	0.0007	24.5
Concrete Truck	72	227.02	0.0118	0.0069	229.37	32.7	0.0017	0.0010	33.0
Crane	82	174.54	0.0091	0.0053	176.35	28.6	0.0015	0.0009	28.9
Crusher (175-300 HP)	110	128.45	0.0067	0.0039	129.78	28.3	0.0015	0.0009	28.6
Equipment	100	59.50	0.0031	0.0018	60.12	11.9	0.0006	0.0004	12.0

Forklift	30	41.65	0.0022	0.0013	42.08	2.5	0.0001	0.0001	2.5
Front-End Loader (300-600 HP)	1290	237.65	0.0124	0.0072	240.12	613.1	0.0319	0.0187	619.5
Excavator	1195	53.57	0.0028	0.0016	54.13	128.0	0.0067	0.0039	129.4
Grader (175-300 HP)	50	128.45	0.0067	0.0039	129.78	12.8	0.0007	0.0004	13.0
Packer	30	22.99	0.0012	0.0007	23.23	1.4	0.0001	0.0000	1.4
Pump Truck	71	1098.36	0.0572	0.0335	1109.77	156.0	0.0081	0.0048	157.6
Rock Drill (175-300 HP)	160	119.24	0.0062	0.0036	120.48	38.2	0.0020	0.0012	38.6
Rock Truck (300-600 HP)	321	226.39	0.0118	0.0069	228.74	145.3	0.0076	0.0044	146.9
Semi & Trailer (300-600 HP)	60	269.50	0.0140	0.0082	272.30	32.3	0.0017	0.0010	32.7
Smooth Drum Roller (100- 175 HP)	50	55.66	0.0029	0.0017	56.24	5.6	0.0003	0.0002	5.6
Tandem Truck (300-600 HP)	197	267.89	0.0139	0.0082	270.67	105.5	0.0055	0.0032	106.6
Truck (300-600 HP)	384	178.95	0.0093	0.0055	180.81	137.4	0.0072	0.0042	138.9
Zoom Boom	930	60.00	0.0031	0.0018	60.62	111.6	0.0058	0.0034	112.8

ACROW Modular Bridges

Number of ACROW Bridges to be Constructed along ASR= 0

Equipment	Total Use (hrs/bridge)	EF_{equip} (kg CO_2/hr)	EF_{equip} (kg CH_4/hr)	EF_{equip} (kg N_2O/hr)	EF_{equip} (kg CO_2e/hr)	GHG Emissions (tonnes CO_2)	GHG Emissions (tonnes CH_4)	GHG Emissions (tonnes N_2O)	GHG Emissions (tonnes CO_2e)
Bobcat	556	47.88	0.00249	0.00146	48.38	0.0	0.0000	0.0000	0.0
Bulldozer (100-175 HP)	580	55.13	0.00287	0.00168	55.70	0.0	0.0000	0.0000	0.0
Concrete Truck (100-175 HP)	40	56.17	0.00292	0.00171	56.76	0.0	0.0000	0.0000	0.0
Conveyor	35	20.83	0.00108	0.00063	21.05	0.0	0.0000	0.0000	0.0
Crane (100-175 HP)	167	68.89	0.00359	0.00210	69.61	0.0	0.0000	0.0000	0.0
Rock Drill	190	159.01	0.00828	0.00485	160.66	0.0	0.0000	0.0000	0.0
Excavator	1055	101.17	0.00527	0.00308	102.22	0.0	0.0000	0.0000	0.0
Generator	3168	14.87	0.00077	0.00045	15.02	0.0	0.0000	0.0000	0.0
Grader	177	99.03	0.00515	0.00302	100.06	0.0	0.0000	0.0000	0.0
Front-End Loader	603	123.62	0.00643	0.00377	124.90	0.0	0.0000	0.0000	0.0
Mechanic Truck	320	136.50	0.00710	0.00416	137.92	0.0	0.0000	0.0000	0.0
Ranger	303	25.93	0.00135	0.00079	26.20	0.0	0.0000	0.0000	0.0
Rock Truck	961	151.03	0.00786	0.00460	152.60	0.0	0.0000	0.0000	0.0
Semi Trailer	518	267.89	0.01394	0.00817	270.67	0.0	0.0000	0.0000	0.0
Tandem Truck	553	162.34	0.00845	0.00495	164.03	0.0	0.0000	0.0000	0.0
Tractor	20	267.89	0.01394	0.00817	270.67	0.0	0.0000	0.0000	0.0
Truck	2268	206.28	0.01074	0.00629	208.42	0.0	0.0000	0.0000	0.0

	1,775.82 tonnes CO_2	222 tonnes CO_2/year
	0.092 tonnes CH_4	0.01 tonnes CH_4/year
	0.054 tonnes N_2O	0.01 tonnes N_2O/year
Total GHG Emissions from bridge construction equipment =	1,794 tonnes CO_2e	224.3 tonnes CO_2e/year

GHG Emissions from ASR and bridge construction=	11,876 tonnes CO_2/year
	0.618 tonnes CH_4/year

0.362	tonnes N_2O/year
11,999.8	tonnes CO_2e/year

Appendix B

Detailed GHG Emission Estimates

DILLON
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East Side Road GHG Assessment
Project P6
GHG Summary

Total GHGs

CO_2e

Baseline Scenario
GHG Estimate (tonnes CO_2e)

Phase		Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	TOTAL	
Construction									
	2030	-515	416	1,780	0	474	327	2,481	
	2031	-515	416	1,780	0	474	327	2,481	
	2032	-515	416	1,780	0	474	327	2,481	
	2033	-515	416	1,780	0	474	327	2,481	
	2034	-515	416	1,780	0	474	327	2,481	
	2035	-515	416	1,780	0	474	327	2,481	
	2036	-515	416	1,780	0	474	327	2,481	
	2037	-515	416	1,780	0	474	327	2,481	
Operation									
	2038	-515	416	1,780	0	474	327	2,481	
	2039	-515	416	1,780	0	474	327	2,481	
	2040	-515	416	1,780	0	474	327	2,481	
	2041	-515	416	1,780	0	474	327	2,481	
	2042	-515	416	1,780	0	474	327	2,481	
	2043	-515	416	1,780	0	474	327	2,481	
	2044	-515	416	1,780	0	474	327	2,481	
	2045	-515	416	1,780	0	474	327	2,481	
	2046	-515	416	1,780	0	474	327	2,481	
	2047	-515	416	1,780	0	474	327	2,481	
	2048	-515	416	1,780	0	474	327	2,481	
	2049	-515	416	1,780	0	474	327	2,481	
	2050	-515	416	1,780	0	474	327	2,481	
	2051	-515	416	1,780	0	474	327	2,481	
	2052	-515	416	1,780	0	474	327	2,481	
	2053	-515	416	1,780	0	474	327	2,481	
	2054	-515	416	1,780	0	474	327	2,481	
	2055	-515	416	1,780	0	474	327	2,481	
	2056	-515	416	1,780	0	474	327	2,481	
	2057	-515	416	1,780	0	474	327	2,481	
	2058	-515	416	1,780	0	474	327	2,481	
	2059	-515	416	1,780	0	474	327	2,481	
	2060	-515	416	1,780	0	474	327	2,481	
	2061	-515	416	1,780	0	474	327	2,481	
	2062	-515	416	1,780	0	474	327	2,481	
	2063	-515	416	1,780	0	474	327	2,481	
	2064	-515	416	1,780	0	474	327	2,481	
	2065	-515	416	1,780	0	474	327	2,481	
	2066	-515	416	1,780	0	474	327	2,481	
	2067	-515	416	1,780	0	474	327	2,481	
Total Construction		-4,122	3,327	14,242	0	3,792	2,612	19,851	CO_2e
Total Operation (10 Years)		-5,153	4,159	17,802	0	4,740	3,265	24,814	CO_2e
Total Operation (30 Years)		-15,458	12,478	53,407	0	14,220	9,796	74,442	CO_2e
TOTAL 10 Year		-9,275	7,487	32,044	0	8,532	5,878	44,665	CO_2e
TOTAL 30 Year		-19,580	15,805	67,648	0	18,012	12,408	94,294	CO_2e

East Side Road GHG Assessment
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GHG Summary

Total GHGs

CO_2e

Phase		Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	Land Clearing	ASR Construction	TOTAL	
		Project Scenario GHG Estimate (tonnes CO_2e)									
Construction											
	2030	-461	402	1,780	0	474	327	2,622	12,000	17,144	
	2031	-406	388	1,780	0	474	327	2,622	12,000	17,185	
	2032	-351	374	1,780	0	474	327	2,622	12,000	17,226	
	2033	-296	360	1,780	0	474	327	2,622	12,000	17,267	
	2034	-242	347	1,780	0	474	327	2,622	12,000	17,308	
	2035	-187	333	1,780	0	474	327	2,622	12,000	17,349	
	2036	-132	319	1,780	0	474	327	2,622	12,000	17,390	
	2037	-77	305	1,780	0	474	327	2,622	12,000	17,431	
Operation											
	2038	-77	305	1,602	0	539	0	0	0	2,369	
	2039	-77	305	1,602	0	539	0	0	0	2,369	
	2040	-77	305	1,602	0	539	0	0	0	2,369	
	2041	-77	305	1,602	0	539	0	0	0	2,369	
	2042	-77	305	1,602	0	539	0	0	0	2,369	
	2043	-77	305	1,602	0	539	0	0	0	2,369	
	2044	-77	305	1,602	0	539	0	0	0	2,369	
	2045	-77	305	1,602	0	539	0	0	0	2,369	
	2046	-77	305	1,602	0	539	0	0	0	2,369	
	2047	-77	305	1,602	0	539	0	0	0	2,369	
	2048	-77	305	1,602	0	539	0	0	0	2,369	
	2049	-77	305	1,602	0	539	0	0	0	2,369	
	2050	-77	305	1,602	0	539	0	0	0	2,369	
	2051	-77	305	1,602	0	539	0	0	0	2,369	
	2052	-77	305	1,602	0	539	0	0	0	2,369	
	2053	-77	305	1,602	0	539	0	0	0	2,369	
	2054	-77	305	1,602	0	539	0	0	0	2,369	
	2055	-77	305	1,602	0	539	0	0	0	2,369	
	2056	-77	305	1,602	0	539	0	0	0	2,369	
	2057	-77	305	1,602	0	539	0	0	0	2,369	
	2058	-77	305	1,602	0	539	0	0	0	2,369	
	2059	-77	305	1,602	0	539	0	0	0	2,369	
	2060	-77	305	1,602	0	539	0	0	0	2,369	
	2061	-77	305	1,602	0	539	0	0	0	2,369	
	2062	-77	305	1,602	0	539	0	0	0	2,369	
	2063	-77	305	1,602	0	539	0	0	0	2,369	
	2064	-77	305	1,602	0	539	0	0	0	2,369	
	2065	-77	305	1,602	0	539	0	0	0	2,369	
	2066	-77	305	1,602	0	539	0	0	0	2,369	
	2067	-77	305	1,602	0	539	0	0	0	2,369	
Total Construction		-2,151	2,828	14,242	0	3,792	2,612	20,979	95,998	138,300	CO_2e
Total Operation (10 Years)		-773	3,050	16,022	0	5,390	0	0	0	23,690	CO_2e
Total Operation (30 Years)		-2,319	9,150	48,066	0	16,171	0	0	0	71,069	CO_2e
TOTAL 10 Year		-2,924	5,878	30,264	0	9,182	2,612	20,979	95,998	161,990	CO_2e
TOTAL 30 Year		-4,470	11,979	62,308	0	19,963	2,612	20,979	95,998	209,369	CO_2e

East Side Road GHG Assessment
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GHG Summary - Speciated

Speciated GHGs

CO_2

Baseline Scenario
GHG Estimate (tonnes CO_2)

Phase		Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	TOTAL	
Construction									
	2030	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2031	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2032	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2033	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2034	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2035	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2036	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2037	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
Operation									
	2038	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2039	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2040	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2041	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2042	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2043	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2044	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2045	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2046	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2047	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2048	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2049	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2050	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2051	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2052	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2053	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2054	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2055	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2056	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2057	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2058	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2059	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2060	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2061	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2062	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2063	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2064	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2065	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2066	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
	2067	-515.3	-79.9	1,770.6	0.0	454.6	323.2	1,953	
Total Construction		-4,122	-639	14,165	0	3,637	2,585	15,625	CO_2
Total Operation (10 Years)		-5,153	-799	17,706	0	4,546	3,232	19,532	CO_2
Total Operation (30 Years)		-15,458	-2,397	53,117	0	13,639	9,695	58,596	CO_2
TOTAL 10 Year		-9,275	-1,438	31,870	0	8,183	5,817	35,157	CO_2
TOTAL 30 Year		-19,580	-3,037	67,281	0	17,276	12,281	74,221	CO_2

East Side Road GHG Assessment
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GHG Summary - Speciated

Speciated GHGs

CO_2

Project Scenario
GHG Estimate (tonnes CO_2)

Phase		Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	Land Clearing	ASR Construction	TOTAL	
Construction											
	2030	-461	-77.3	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,347	
	2031	-406	-74.6	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,404	
	2032	-351	-71.9	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,461	
	2033	-296	-69.3	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,519	
	2034	-242	-66.6	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,576	
	2035	-187	-63.9	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,634	
	2036	-132	-61.3	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,691	
	2037	-77	-58.6	1,770.6	0.0	454.6	323.2	2,459.6	11,876.5	16,749	
Operation											
	2038	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2039	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2040	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2041	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2042	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2043	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2044	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2045	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2046	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2047	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2048	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2049	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2050	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2051	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2052	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2053	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2054	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2055	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2056	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2057	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2058	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2059	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2060	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2061	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2062	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2063	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2064	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2065	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2066	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
	2067	-77.3	-58.6	1593.5	0.0	517.4	0.0	0.0	0.0	1,975	
Total Construction		-2151	-543	14165	0	3637	2585	19677	95012	132,381	CO_2
Total Operation (10 Years)		-773	-586	15935	0	5174	0	0	0	19,750	CO_2
Total Operation (30 Years)		-2319	-1758	47805	0	15521	0	0	0	59,249	CO_2
TOTAL 10 Year		-2,924	-1,129	30,100	0	8,811	2,585	19,677	95,012	152,130	CO_2
TOTAL 30 Year		-4,470	-2,302	61,970	0	19,158	2,585	19,677	95,012	191,630	CO_2

Speciated GHGs

CH_4

Phase	Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	TOTAL	
	Baseline Scenario GHG Estimate (tonnes CH_4)							
Construction								
2030	0.000	19.834	0.028	0.000	0.034	0.017	20	
2031	0.000	19.834	0.028	0.000	0.034	0.017	20	
2032	0.000	19.834	0.028	0.000	0.034	0.017	20	
2033	0.000	19.834	0.028	0.000	0.034	0.017	20	
2034	0.000	19.834	0.028	0.000	0.034	0.017	20	
2035	0.000	19.834	0.028	0.000	0.034	0.017	20	
2036	0.000	19.834	0.028	0.000	0.034	0.017	20	
2037	0.000	19.834	0.028	0.000	0.034	0.017	20	
Operation								
2038	0.000	19.834	0.028	0.000	0.034	0.017	20	
2039	0.000	19.834	0.028	0.000	0.034	0.017	20	
2040	0.000	19.834	0.028	0.000	0.034	0.017	20	
2041	0.000	19.834	0.028	0.000	0.034	0.017	20	
2042	0.000	19.834	0.028	0.000	0.034	0.017	20	
2043	0.000	19.834	0.028	0.000	0.034	0.017	20	
2044	0.000	19.834	0.028	0.000	0.034	0.017	20	
2045	0.000	19.834	0.028	0.000	0.034	0.017	20	
2046	0.000	19.834	0.028	0.000	0.034	0.017	20	
2047	0.000	19.834	0.028	0.000	0.034	0.017	20	
2048	0.000	19.834	0.028	0.000	0.034	0.017	20	
2049	0.000	19.834	0.028	0.000	0.034	0.017	20	
2050	0.000	19.834	0.028	0.000	0.034	0.017	20	
2051	0.000	19.834	0.028	0.000	0.034	0.017	20	
2052	0.000	19.834	0.028	0.000	0.034	0.017	20	
2053	0.000	19.834	0.028	0.000	0.034	0.017	20	
2054	0.000	19.834	0.028	0.000	0.034	0.017	20	
2055	0.000	19.834	0.028	0.000	0.034	0.017	20	
2056	0.000	19.834	0.028	0.000	0.034	0.017	20	
2057	0.000	19.834	0.028	0.000	0.034	0.017	20	
2058	0.000	19.834	0.028	0.000	0.034	0.017	20	
2059	0.000	19.834	0.028	0.000	0.034	0.017	20	
2060	0.000	19.834	0.028	0.000	0.034	0.017	20	
2061	0.000	19.834	0.028	0.000	0.034	0.017	20	
2062	0.000	19.834	0.028	0.000	0.034	0.017	20	
2063	0.000	19.834	0.028	0.000	0.034	0.017	20	
2064	0.000	19.834	0.028	0.000	0.034	0.017	20	
2065	0.000	19.834	0.028	0.000	0.034	0.017	20	
2066	0.000	19.834	0.028	0.000	0.034	0.017	20	
2067	0.000	19.834	0.028	0.000	0.034	0.017	20	
Total Construction	0.000	158.670	0.221	0.000	0.274	0.135	159	CH_4
Total Operation (10 Years)	0.000	198.337	0.276	0.000	0.342	0.168	199	CH_4
Total Operation (30 Years)	0.000	595.012	0.828	0.000	1.027	0.505	597	CH_4
TOTAL 10 Year	0.00	357.01	0.50	0.00	0.62	0.30	358	CH_4
30 Year	0.00	753.68	1.05	0.00	1.30	0.64	757	CH_4

Speciated GHGs

CH_4

Project Scenario

GHG Estimate (tonnes CH_4)

Phase	Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	Land Clearing	ASR Construction	TOTAL	
Construction										
2030	0	19.173	0.028	0.000	0.034	0.017	3.674	0.618	24	
2031	0	18.511	0.028	0.000	0.034	0.017	3.674	0.618	23	
2032	0	17.850	0.028	0.000	0.034	0.017	3.674	0.618	22	
2033	0	17.189	0.028	0.000	0.034	0.017	3.674	0.618	22	
2034	0	16.528	0.028	0.000	0.034	0.017	3.674	0.618	21	
2035	0	15.867	0.028	0.000	0.034	0.017	3.674	0.618	20	
2036	0	15.206	0.028	0.000	0.034	0.017	3.674	0.618	20	
2037	0	14.545	0.028	0.000	0.034	0.017	3.674	0.618	19	
Operation										
2038	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2039	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2040	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2041	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2042	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2043	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2044	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2045	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2046	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2047	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2048	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2049	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2050	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2051	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2052	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2053	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2054	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2055	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2056	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2057	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2058	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2059	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2060	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2061	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2062	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2063	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2064	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2065	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2066	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	
2067	0.0	14.545	0.025	0.000	0.039	0.00	0.000	0.000	15	CH_4
Total Construction	0.000	134.869	0.221	0.000	0.274	0.135	29.395	4.945	170	CH_4
Total Operation (10 Years)	0.000	145.447	0.248	0.000	0.391	0.000	0.000	0.000	146	CH_4
Total Operation (30 Years)	0.000	436.342	0.745	0.000	1.172	0.000	0.000	0.000	438	CH_4
TOTAL 10 Year	0.000	280.317	0.469	0.000	0.664	0.135	29.395	4.945	316	CH_4
30 Year	0.000	571.212	0.966	0.000	1.445	0.135	29.395	4.945	608	

Speciated GHGs

N_2O

Phase	Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	TOTAL	
	Baseline Scenario GHG Estimate (tonnes N_2O)							
Construction								
2030	0.000	0.000	0.030	0.000	0.062	0.010	0	
2031	0.000	0.000	0.030	0.000	0.062	0.010	0	
2032	0.000	0.000	0.030	0.000	0.062	0.010	0	
2033	0.000	0.000	0.030	0.000	0.062	0.010	0	
2034	0.000	0.000	0.030	0.000	0.062	0.010	0	
2035	0.000	0.000	0.030	0.000	0.062	0.010	0	
2036	0.000	0.000	0.030	0.000	0.062	0.010	0	
2037	0.000	0.000	0.030	0.000	0.062	0.010	0	
Operation								
2038	0.000	0.000	0.030	0.000	0.062	0.010	0	
2039	0.000	0.000	0.030	0.000	0.062	0.010	0	
2040	0.000	0.000	0.030	0.000	0.062	0.010	0	
2041	0.000	0.000	0.030	0.000	0.062	0.010	0	
2042	0.000	0.000	0.030	0.000	0.062	0.010	0	
2043	0.000	0.000	0.030	0.000	0.062	0.010	0	
2044	0.000	0.000	0.030	0.000	0.062	0.010	0	
2045	0.000	0.000	0.030	0.000	0.062	0.010	0	
2046	0.000	0.000	0.030	0.000	0.062	0.010	0	
2047	0.000	0.000	0.030	0.000	0.062	0.010	0	
2048	0.000	0.000	0.030	0.000	0.062	0.010	0	
2049	0.000	0.000	0.030	0.000	0.062	0.010	0	
2050	0.000	0.000	0.030	0.000	0.062	0.010	0	
2051	0.000	0.000	0.030	0.000	0.062	0.010	0	
2052	0.000	0.000	0.030	0.000	0.062	0.010	0	
2053	0.000	0.000	0.030	0.000	0.062	0.010	0	
2054	0.000	0.000	0.030	0.000	0.062	0.010	0	
2055	0.000	0.000	0.030	0.000	0.062	0.010	0	
2056	0.000	0.000	0.030	0.000	0.062	0.010	0	
2057	0.000	0.000	0.030	0.000	0.062	0.010	0	
2058	0.000	0.000	0.030	0.000	0.062	0.010	0	
2059	0.000	0.000	0.030	0.000	0.062	0.010	0	
2060	0.000	0.000	0.030	0.000	0.062	0.010	0	
2061	0.000	0.000	0.030	0.000	0.062	0.010	0	
2062	0.000	0.000	0.030	0.000	0.062	0.010	0	
2063	0.000	0.000	0.030	0.000	0.062	0.010	0	
2064	0.000	0.000	0.030	0.000	0.062	0.010	0	
2065	0.000	0.000	0.030	0.000	0.062	0.010	0	
2066	0.000	0.000	0.030	0.000	0.062	0.010	0	
2067	0.000	0.000	0.030	0.000	0.062	0.010	0	
Total Construction	0.000	0.000	0.241	0.000	0.497	0.079	1	N_2O
Total Operation (10 Years)	0.000	0.000	0.301	0.000	0.621	0.099	1	N_2O
Total Operation (30 Years)	0.000	0.000	0.903	0.000	1.864	0.296	3	N_2O
TOTAL 10 Year	0.00	0.00	0.54	0.00	1.12	0.18	2	N_2O
TOTAL 30 Year	0.00	0.00	1.14	0.00	2.36	0.37	4	N_2O

Speciated GHGs

N_2O

Phase	Forest Sequestration	Land Cover	Air Travel	Ferry Travel	Vehicular Travel	Winter Road Construction & Maintenance	Land Clearing	ASR Construction	TOTAL	
	Project Scenario GHG Estimate (tonnes N_2O)									
Construction										
2030	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2031	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2032	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2033	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2034	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2035	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2036	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
2037	0.000	0.000	0.030	0.000	0.062	0.010	0.238	0.362	1	
Operation										
2038	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2039	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2040	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2041	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2042	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2043	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2044	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2045	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2046	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2047	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2048	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2049	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2050	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2051	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2052	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2053	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2054	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2055	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2056	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2057	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2058	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2059	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2060	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2061	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2062	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2063	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2064	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2065	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2066	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
2067	0.000	0.000	0.027	0.000	0.070	0.0	0.000	0.000	0	
Total Construction	0.000	0.000	0.241	0.000	0.497	0.079	1.903	2.896	6	N_2O
Total Operation (10 Years)	0.000	0.000	0.271	0.000	0.695	0.000	0.000	0.000	1	N_2O
Total Operation (30 Years)	0.000	0.000	0.812	0.000	2.086	0.000	0.000	0.000	3	N_2O
TOTAL 10 Year	0.000	0.000	0.512	0.000	1.192	0.079	1.903	2.896	7	N_2O
TOTAL 30 Year	0.000	0.000	1.053	0.000	2.583	0.079	1.903	2.896	9	N_2O

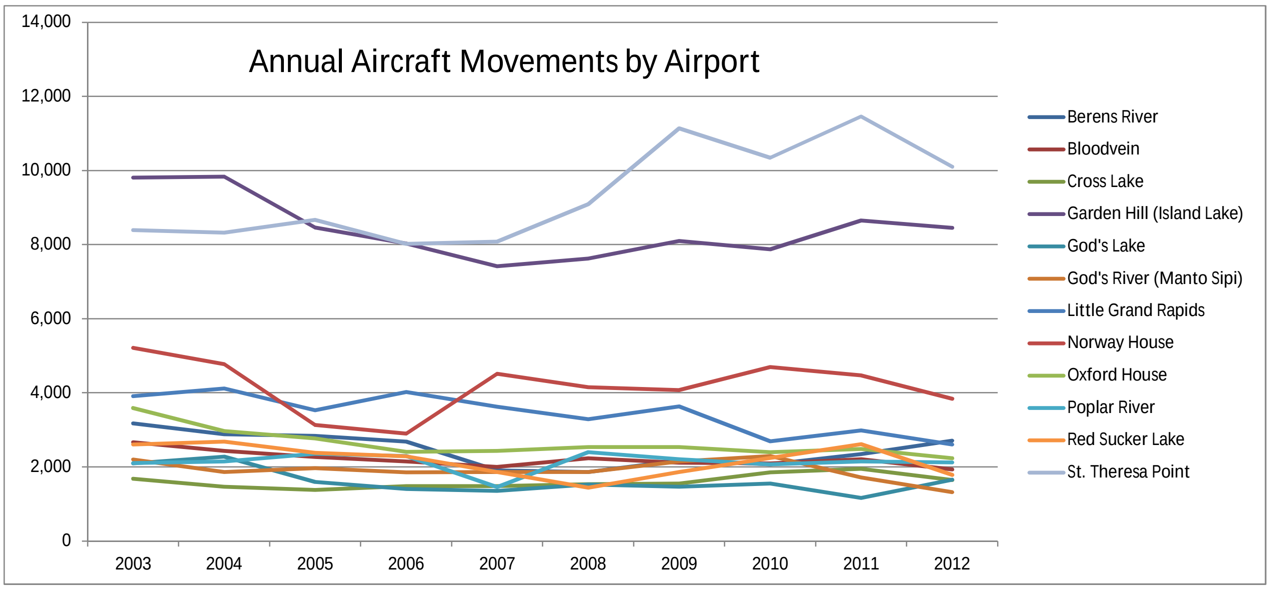
Appendix C

Aircraft Movement and Passenger Traffic Analysis

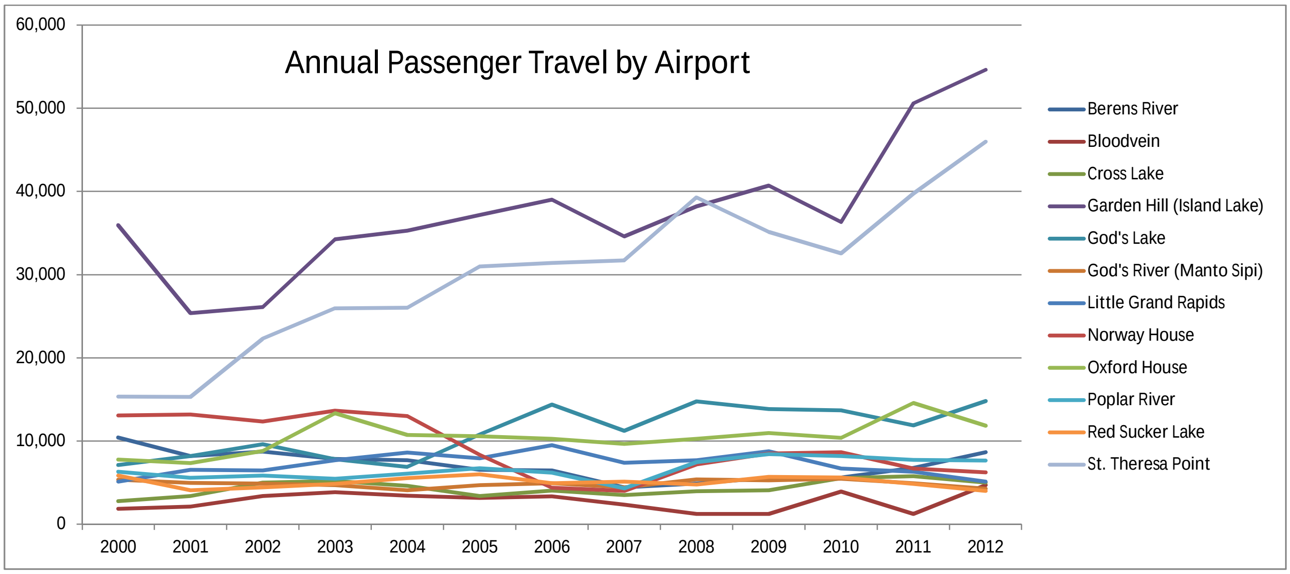
DILLON CONSULTING

Air Traffic Analysis
Raw Air Movement Data

Aircraft Movements														
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Average (2003-2012)**
Berens River	4,392	3,394	3,153	3,175	2,881	2,838	2,686	1,902	1,860	2,176	2,070	2,347	2,706	**2,464**
Bloodvein	1,319	1,491	2,361	2,668	2,429	2,272	2,144	1,997	2,233	2,112	2,092	2,207	1,928	**2,208**
Cross Lake	1,564	1,537	1,686	1,677	1,463	1,382	1,484	1,480	1,537	1,554	1,853	1,946	1,645	**1,602**
Garden Hill (Island Lake)	9,971	9,113	8,059	9,812	9,835	8,465	8,027	7,417	7,621	8,102	7,873	8,653	8,453	**8,426**
God's Lake	2,497	2,795	2,687	2,091	2,275	1,598	1,400	1,354	1,526	1,467	1,553	1,159	1,655	**1,608**
God's River (Manto Sipi)	2,346	2,231	2,423	2,196	1,861	1,966	1,851	1,863	1,866	2,150	2,290	1,714	1,321	**1,908**
Little Grand Rapids	3,086	3,591	3,619	3,910	4,115	3,531	4,025	3,626	3,290	3,637	2,695	2,982	2,606	**3,442**
Norway House	5,589	5,263	5,141	5,213	4,777	3,134	2,901	4,510	4,147	4,072	4,697	4,473	3,841	**4,177**
Oxford House	2,236	2,071	2,558	3,593	2,970	2,770	2,402	2,434	2,538	2,534	2,398	2,482	2,234	**2,636**
Poplar River	2,204	2,191	2,528	2,108	2,151	2,356	2,296	1,458	2,400	2,205	2,066	2,144	2,118	**2,130**
Red Sucker Lake	1,817	1,710	1,891	2,603	2,682	2,380	2,285	1,860	1,440	1,861	2,246	2,612	1,782	**2,175**
St. Theresa Point	7,652	6,916	7,720	8,390	8,323	8,668	8,020	8,078	9,092	11,142	10,348	11,458	10,104	**9,362**



Passenger Traffic														
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**Average (2003-2012)**
Berens River	10,440	8,214	8,752	7,853	7,697	6,553	6,456	4,418	4,892	5,581	5,644	6,790	8,648	**6,453**
Bloodvein	1,880	2,140	3,395	3,851	3,434	3,153	3,353	2,377	1,264	1,264	3,928	1,264	4,715	**2,860**
Cross Lake	2,795	3,398	5,007	5,205	4,615	3,392	4,055	3,523	3,993	4,076	5,548	5,770	5,019	**4,520**
Garden Hill (Island Lake)	35,945	25,386	26,118	34,238	35,302	37,175	39,030	34,577	38,221	40,716	36,341	50,567	54,615	**40,078**
God's Lake	7,111	8,214	9,617	7,825	6,880	10,786	14,391	11,231	14,755	13,852	13,682	11,890	14,820	**12,011**
God's River (Manto Sipi)	5,347	4,980	4,913	4,717	4,087	4,710	4,936	4,452	5,386	5,300	5,458	4,933	4,283	**4,826**
Little Grand Rapids	5,143	6,537	6,488	7,688	8,630	7,917	9,505	7,376	7,702	8,788	6,712	6,313	5,124	**7,576**
Norway House	13,063	13,203	12,349	13,652	12,985	8,339	4,415	3,999	7,201	8,515	8,657	6,690	6,226	**8,068**
Oxford House	7,780	7,366	8,823	13,335	10,743	10,598	10,261	9,665	10,282	10,956	10,385	14,590	11,866	**11,268**
Poplar River	6,336	5,584	5871	5,473	6,072	6,733	6,209	4,327	7,486	8,426	8218	7728	7676	**6,835**
Red Sucker Lake	5,862	4,093	4,436	4,867	5,538	6,010	4,933	5,135	4,770	5,710	5,612	4,845	4,010	**5,143**
St. Theresa Point	15,332	15,293	22,288	25,951	26,028	31,000	31,398	31,699	39,273	35,126	32,544	39,759	45,962	**33,874**



Based on the data above, assume that air traffic levels will remain consistent. The 10 year average will be taken to estimate future travel.

Data Sources (June 2016):

Manitoba Infrastructure, Northern Airports and Marine Operations, Aircraft Movements: http://www.gov.mb.ca/mit/namo/air/movement.html

Manitoba Infrastructure, Northern Airports and Marine Operations, Passenger Traffic: http://www.gov.mb.ca/mit/namo/air/passenger.html

Air Traffic Analysis
Scheduled Flight Data

Weekly Commercial Flights (Two-Way)

Flight #	To	From	Quantity per Week	Airline	Distance (km)	Total Distance (km)
113/114	Berens River	Winnipeg	12	Perimeter	273	3276
117/118	Cross Lake	Winnipeg	10	Perimeter	528	5280
106/105,115/116	Cross Lake via Norway House	Winnipeg	24	Perimeter	567	13608
107/108, 109/110, 612	Garden Hill (Island Lake)	Winnipeg	33	Perimeter	473	15609
107/108	Garden Hill via Red Sucker Lake	Winnipeg	5	Perimeter	603	3015
639,611	Garden Hill via St. Theresa Point	Winnipeg	10	Perimeter	479	4790
203/204	God's Lake	Winnipeg	7	Perimeter	567	3969
203/204, 209/210	God's Lake via Oxford House	Winnipeg	17	Perimeter	639	10863
203	God's Lake	Oxford House	2	Perimeter	66	132
407/408	God's Lake	God's River (Manto Sipi)	5	Perimeter	25	125
207,218,219	God's River (Manto Sipi) via Red Sucker Lake	Winnipeg	2	Perimeter	615	1230
219,201/202,207,214/213	God's River (Manto Sipi)	Winnipeg	12	Perimeter	588	7056
403/404	God's River (Manto Sipi)	Oxford House	2	Perimeter	78	156
205/206, 211/212, 207/208	Red Sucker Lake	Winnipeg	13	Perimeter	533	6929
639,621/622,610/609	St. Theresa Point	Winnipeg	33	Perimeter	465	15345
612	St. Theresa Point via Garden Hill	Winnipeg	5	Perimeter	488	2440
639	Garden Hill	St. Theresa Point	5	Perimeter	14	70
	Berens River via Bloodvein	Winnipeg	11	Northway Aviation	273	3003
	Little Grand Rapids / Pauingassi	Winnipeg	27	Northway Aviation	263	7101
	Poplar Hill via Deer Lake	Winnipeg	6	Northway Aviation	347	2082

Total Number of Flights 315

106,079 km weekly
5,516,108 km annually

Data Sources (June 2016):
Perimeter Airlines: https://www.perimeter.ca/passengers/destinations-map
Northway Aviation :http://www.northwayav.com/index.php/flight-schedule

Number of Air Movements per Week for Scheduled Flights

	From Airport											
To Airport	Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	12	-	6	-	-	-	-	-	-	-	-	18
Bloodvein	11	6	-	-	-	-	-	-	-	-	-	17
Cross Lake	10	-	-	-	-	-	-	-	12	-	-	22
Garden Hill (Island Lake)	33	-	-	-	-	-	-	-	-	3	10	46
God's Lake	7	-	-	-	-	-	3	10	-	-	-	19
God's River (Manto Sipi)	12	-	-	-	-	3	-	1	-	1	-	17
Little Grand Rapids	27	-	-	-	-	-	-	-	-	-	-	27
Norway House	24	-	-	12	-	-	-	-	-	-	-	36
Oxford House	17	-	-	-	-	10	1	-	-	-	-	28
Poplar River	6	-	-	-	-	-	-	-	-	-	-	6
Red Sucker Lake	20	-	-	-	3	-	1	-	-	-	-	24
St. Theresa Point	48	-	-	-	10	-	-	-	-	-	-	58
												315

Air Movements Fractions

	From Airport											
To Airport	Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	69%	-	31%	-	-	-	-	-	-	-	-	100%
Bloodvein	67%	33%	-	-	-	-	-	-	-	-	-	100%
Cross Lake	45%	-	-	-	-	-	-	-	55%	-	-	100%
Garden Hill (Island Lake)	73%	-	-	-	-	-	-	-	-	5%	22%	100%
God's Lake	37%	-	-	-	-	-	13%	50%	-	-	-	100%
God's River (Manto Sipi)	73%	-	-	-	-	15%	-	6%	-	6%	-	100%
Little Grand Rapids	100%	-	-	-	-	-	-	-	-	-	-	100%
Norway House	67%	-	-	33%	-	-	-	-	-	-	-	100%
Oxford House	62%	-	-	-	-	35%	4%	-	-	-	-	100%
Poplar River	100%	-	-	-	-	-	-	-	-	-	-	100%
Red Sucker Lake	85%	-	-	-	11%	-	4%	-	-	-	-	100%
St. Theresa Point	83%	-	-	-	17%	-	-	-	-	-	-	100%

Estimated Annual Air Movements

From Airport

To Airport	Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	1,690	-	774	-	-	-	-	-	-	-	-	2,464
Bloodvein	1,472	736	-	-	-	-	-	-	-	-	-	2,208
Cross Lake	728	-	-	-	-	-	-	-	874	-	-	1,602
Garden Hill (Island Lake)	6,111	-	-	-	-	-	-	-	-	463	1,852	8,426
God's Lake	592	-	-	-	-	-	212	804	-	-	-	1,608
God's River (Manto Sipi)	1,387	-	-	-	-	289	-	116	-	116	-	1,908
Little Grand Rapids	3,442	-	-	-	-	-	-	-	-	-	-	3,442
Norway House	2,784	-	-	1,392	-	-	-	-	-	-	-	4,177
Oxford House	1,629	-	-	-	-	910	96	-	-	-	-	2,636
Poplar River	2,130	-	-	-	-	-	-	-	-	-	-	2,130
Red Sucker Lake	1,851	-	-	-	231	-	93	-	-	-	-	2,175
St. Theresa Point	7,748	-	-	-	1,614	-	-	-	-	-	-	9,362

Estimated Annual Passenger Traffic

From Airport

To Airport	Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	4,425	-	2,028	-	-	-	-	-	-	-	-	6,453
Bloodvein	1,907	953	-	-	-	-	-	-	-	-	-	2,860
Cross Lake	2,054	-	-	-	-	-	-	-	2,465	-	-	4,520
Garden Hill (Island Lake)	29,068	-	-	-	-	-	-	-	-	2,202	8,808	40,078
God's Lake	4,425	-	-	-	-	-	1,580	6,006	-	-	-	12,011
God's River (Manto Sipi)	3,510	-	-	-	-	731	-	292	-	292	-	4,826
Little Grand Rapids	7,576	-	-	-	-	-	-	-	-	-	-	7,576
Norway House	5,379	-	-	2,689	-	-	-	-	-	-	-	8,068
Oxford House	6,966	-	-	-	-	3,893	410	-	-	-	-	11,268
Poplar River	6,835	-	-	-	-	-	-	-	-	-	-	6,835
Red Sucker Lake	4,377	-	-	-	547	-	219	-	-	-	-	5,143
St. Theresa Point	28,034	-	-	-	5,840	-	-	-	-	-	-	33,874

Flight Distance (km)

To Airport	From Airport: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	273	-	69	-	-	-	-	-	-	-	-	342
Bloodvein	214	69	-	-	-	-	-	-	-	-	-	283
Cross Lake	528	-	-	-	-	-	-	-	73	-	-	601
Garden Hill (Island Lake)	473	-	-	-	-	-	-	-	-	82	14	569
God's Lake	567	-	-	-	-	-	42	66	-	-	-	675
God's River (Manto Sipi)	588	-	-	-	-	42	-	67	-	80	-	777
Little Grand Rapids	263	-	-	-	-	-	-	-	-	-	-	263
Norway House	455	-	-	73	-	-	-	-	-	-	-	528
Oxford House	578	-	-	-	-	66	67	-	69	-	-	780
Poplar River	347	-	-	-	-	-	-	-	-	-	-	347
Red Sucker Lake	536	-	-	-	82	-	80	-	-	-	-	698
St. Theresa Point	465	-	-	-	14	-	-	-	-	-	-	479

Total Passenger Kilometers (passenger km)

To Airport	From Airport: Winnipeg	Berens River	Bloodvein	Cross Lake	Garden Hill	God's Lake	God's River	Oxford House	Norway House	Red Sucker Lake	St. Theresa Point	TOTAL
Berens River	1,208,039	-	139,942	-	-	-	-	-	-	-	-	1,347,981
Bloodvein	408,069	65,787	-	-	-	-	-	-	-	-	-	473,856
Cross Lake	1,084,704	-	-	-	-	-	-	-	179,962	-	-	1,264,666
Garden Hill (Island Lake)	13,749,025	-	-	-	-	-	-	-	-	180,572	123,318	14,052,914
God's Lake	2,509,076	-	-	-	-	-	66,378	396,370	-	-	-	2,971,824
God's River (Manto Sipi)	2,063,859	-	-	-	-	30,712	-	19,597	-	23,400	-	2,137,568
Little Grand Rapids	1,992,357	-	-	-	-	-	-	-	-	-	-	1,992,357
Norway House	2,447,263	-	-	196,319	-	-	-	-	-	-	-	2,643,582
Oxford House	4,026,195	-	-	-	-	256,913	27,453	-	-	-	-	4,310,560
Poplar River	2,371,676	-	-	-	-	-	-	-	-	-	-	2,371,676
Red Sucker Lake	2,346,083	-	-	-	44,864	-	17,508	-	-	-	-	2,408,456
St. Theresa Point	13,035,650	-	-	-	81,765	-	-	-	-	-	-	13,117,414

Total Passenger Kilometers by Airport		
Berens River	1,347,981	passenger km
Bloodvein	473,856	passenger km
Cross Lake	1,264,666	passenger km
Garden Hill (Island Lake)	14,052,914	passenger km
God's Lake	2,971,824	passenger km
God's River (Manto Sipi)	2,137,568	passenger km
Little Grand Rapids	1,992,357	passenger km
Norway House	2,643,582	passenger km
Oxford House	4,310,560	passenger km
Poplar River	2,371,676	passenger km
Red Sucker Lake	2,408,456	passenger km
St. Theresa Point	13,117,414	passenger km

Air Traffic Analysis
Overview of Methodology

METHODOLOGY

1. Analyse 'Air Movements' data from publically available MIT website to consider trends at each airport (ie. Are aircraft movements increasing, decreasing, consistent?)
2. Analyse 'Scheduled Flights' to determine the ratio (fractions) of flight passenger traffic to/from each airport based on publically available commercial flight data.
3. Apply Ratio/Fraction to Flight Passenger Traffic (by airport) to determine passenger kilometers (by airport)
4. Consider typical commercial aircraft operating in the project area to determine appropriate emission factors.

Appendix D

Winter Road Traffic Assessment

163689 Greenhouse Gas Followup
P6 Area Traffic Count Analysis

Total Time Traffic Counter on Shift

Intersection	Hours	Days
Oxford	71.1	3.0
GodsRiver	49.7	2.1

Total Traffic Count

		ATV/Snowmobile			Car			Truck/Van/SUV			Transport Truck			Construction Equipment		
Intersection	Direction	Count	Count Per 60 Days	Total Km	Count	Count Per 60 Days	Total Km	Count	Count Per 60 Days	Total Km	Count	Count Per 60 Days	Total Km	Count	Count Per 60 Days	Total Km
GodsRiver	Oxford House/Gods Lake	0	0	0	0	0	0	66	1,337	128,100	61	1,236	118,396	0	0	0
GodsRiver	Gods Lake/Gods River	0	0	0	0	0	0	5	101	10,774	0	0	0	0	0	0
GodsRiver	Gods River/Oxford House	1	20	2,649	0	0	0	2	41	5,299	0	0	0	0	0	0
Oxford	Oxford House/Gods Lake	11	223	21,350	0	0	0	229	4,639	444,469	10	203	19,409	2	41	3,882
Oxford	Gods Lake/Norway House	0	0	0	0	0	0	58	1,175	96,382	94	1,904	156,205	1	20	1,662
Oxford	Norway House/Oxford House	0	0	0	0	0	0	89	1,803	24,845	29	587	8,095	2	41	558

Vehicle Distance Travel Per 60 Days on Winter Road (km)

ATV/ Snowmobile	Car	Truck/ Van/ SUV	Transport Truck	Construction Equipment
23,999	0	581,768	183,710	6,102

Note: Transport Trucks and Pickup Trucks were not inlcuded using the Gods River data to avoid double counting data, Oxford Data was used due to it having the higher 60day traffic volume.

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