BC Hydro
Power smart

# Site C Clean Energy Project Agriculture Monitoring and Follow-up Program

## 2021 Annual Report

*Prepared in accordance with the Agricultural Monitoring and Follow-up Program (December 22, 2015)*
*2021 Annual Report Submission Date: July 21, 2021*

## Table of Contents

# 1.0 Background

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction in northeast B.C. Construction started in July 2015 and will be in service in 2024. The Project will help meet future electricity needs by providing 1,100 megawatts of dependable capacity, and producing about 5,100 gigawatt hours of energy each year — enough to power the equivalent of 450,000 homes per year. Once built, the Project will be a source of clean, reliable and cost-effective electricity in B.C. for more than 100 years.

The key components of the Project are:

- Access roads and a temporary construction bridge across the river, at the dam site.
- Worker accommodation at the dam site.
- Upgrades to 240, 269, 271 and Old Fort roads.
- The realignment of six segments of Highway 29.
- Two temporary cofferdams across the river to allow for construction of the earthfill dam.
- Two new 500 kilovolt transmission lines connecting Site C to the Peace Canyon Substation, within an existing right-of-way.
- Shoreline protection at Hudson's Hope, including upgrades to DA Thomas Road.
- An 800-metre roller-compacted-concrete buttress to enhance seismic protection.
- An earthfill dam, approximately 1,050 metres long and 60 metres high above the riverbed.
- A generating station with six 183 MW generating units.
- An 83-kilometre-long reservoir that will be, on average, two to three times the width of the current river.

# 2.0 Environmental Assessment Certificate Conditions

Condition 31 of the Environmental Assessment Certificate (EAC) requires the following:

> *"The Agriculture Monitoring and Follow-up Program must include at least the following:*
>
> *Monitoring for Project-induced changes in wildlife habitat utilization, and evaluation of associated crop or feed storage damage for, agricultural operations within 5 km of the reservoir, to assess if there is an increase in wildlife-related crop depredation due to Project-related habitat losses. Monitoring must include pre- and post- reservoir filling field surveys, wildlife monitoring, farm operator interviews, and analysis of relevant records related to wildlife-related crop depredation.*
>
> *Monitoring for Project-induced changes to humidity within 3 km of the reservoir, and evaluate associated effects on crop drying within this area. Monitoring must include collection and analysis of climate data, calculation of crop drying indices, and farm operator interviews.*
>
> *Monitoring for Project-induced changes to groundwater elevations within 2 km of the reservoir (the area potentially influenced by groundwater elevation changes), and evaluate*

*associated effects on crop productivity. Monitoring must include field surveys and farm operator interviews.*

*Monitoring for climatic factors to estimate moisture deficits and to estimate irrigation water requirements in the vicinity of the reservoir to provide information for potential future irrigation projects. Data collection will be undertaken before reservoir filling, and in the 5 years after reservoir filling, and data will be reviewed as required for proposed irrigation projects.*

*The Agriculture Monitoring and Follow-up Program reports must be provided annually during the monitoring and follow-up period to affected agricultural land owners and tenure holders, and Ministry of Agriculture.*

*The results of the Agriculture Monitoring and Follow-up Program must inform the Farm Mitigation Plans.*

*Reporting must begin 180 days after the commencement of the monitoring and follow-up program that is to begin 180 days after commencement of construction.*

*The EAC Holder must provide this draft Agriculture Monitoring and Follow-up Program to the Ministry of Agriculture, Peace River Regional District and the District of Hudson's Hope for review within 90 days after the commencement of construction. The EAC Holder must file the final Agriculture Monitoring and Follow-up Program with EAO, Ministry of Agriculture, Peace River Regional District and the District of Hudson's Hope within 150 days of commencement of construction.*

*The EAC Holder must develop, implement and adhere to the final Agriculture Monitoring and Follow-up Program, and any amendments, to the satisfaction of EAO."*

# 3.0 Agriculture Monitoring and Follow-up Program Overview

BC Hydro described the approach required by the above condition in the Agriculture Monitoring and Follow-up Program ("AMAFP"), submitted as final on December 22, 2015. The AMAFP was developed and has been implemented in accordance with Condition 31 of EAC #14-02, dated 14 October 2014, which was issued in respect of the Project.

Regarding the schedule presented in the AMAFP and those presented in this report (and previous Annual Reports), the discrepancy is due to the change to reservoir filling schedule that occurred in 2017. The most current project schedule dated February 2020 can be found on the Site C Project website here:

https://www.sitecproject.com/sites/default/files/construction-schedule-202002.pdf

The Project's Environmental Assessment assessed how the creation of the reservoir may result in site-specific changes that may affect agricultural operations on individual farm operations, and where Project effects on agricultural operations are not already addressed under agreements with BC Hydro. The monitoring programs, included as described in EAC Condition 31 and the AMAFP, will be used to determine if a Project-induced change has occurred as it relates to the following:

A. Effects on crops and stored feed as a results of changes in wildlife habitat utilization,
B. Effects on crop drying due to changes in humidity, and
C. Effects on crop productivity as a result in changes to groundwater elevations.

Upon completion for the above monitoring programs, the collected data will be evaluated and used to inform Individual Farm Mitigation Plans (where applicable) or on other mitigation measures.

Additional monitoring will occur for climatic factors to:

D. Estimate moisture deficits and irrigation water requirements.

The resulting estimations will be used in supporting future potential decisions regarding irrigation improvements, including support for projects that may be proposed under the Agricultural Mitigation and Compensation Plan.

The AMAFP states that monitoring, analysis and reporting will be undertaken in accordance with the following schedule:

| **Phase Description** | **Timeline**[1] |
|---|---|
| Historical data review, baseline data collection[2], climate station siting and installation, preparation for field survey, consultation and interviews. | • January 2016 – December 2018 |
| Data collection, field surveys, interviews, consultation, and data analysis. | • Five Years Prior to Reservoir Filling (December 2018 - December 2023[3])<br>• Five Year Post Reservoir Filling (January 2024 - January 2029) |
| Annual and Final Reporting | • July 2016 – July 2029 |

[1] Updated timeline as per 2017 schedule change

[2] Baseline data refers to the continued collection of data from existing climate stations and monitoring sites. As new stations and sites are added, and additional parameters are included at existing stations, this data will be incorporated into reporting as it becomes available.

[3] The reservoir fill date is Fall 2023 at the time of this report.

The AMAFP stated that annual reports on the implementation of the AMAFP will be submitted beginning on July 21, 2016 (360 days after commencement of construction). These reports will include a summary of monitoring plan implementation activities. The annual reports will be posted on BC Hydro’s website and notifications sent to affected agricultural land owners and tenure holders, and the Ministry of Agriculture.

# 4.0 Annual Report Time Period and Format

The 2021 AMAFP Annual Report covers the time period from April 1, 2020 to March 31, 2021 and includes separate updates for each of the monitoring programs:

- Program A – Crop Damage Monitoring Program
- Program B – Crop Drying and Humidity Monitoring Program
- Program C – Groundwater and Crop Productivity Monitoring Program
- Program D – Irrigation Water Requirement Program

Program reporting, included in the appendices as a report or a memo, all employ a similar format:

- Introduction,
- Methods (i.e., study area and program activities),
- Results and analysis,
- Next steps, and
- References

# 5.0 Summary of Activities

Each of the programs are in the monitoring phase and a summary of each program for the reporting year is provided below.

## 5.1 Crop Damage Monitoring Program

BC Hydro's Crop Damage Monitoring Program (CDMP) contractor is Blackbird Environmental Ltd. (Blackbird), who developed and implemented activities to monitor for project-induced wildlife habitat utilization, while also evaluating the associated crop and feed storage damage.

During the reporting year, BC Hydro and the project team continued activities associated with the agricultural monitoring program in partnership with participating agricultural producers, which included field activities on their holdings beginning with the 2019 growing season and for the 10-year duration of the monitoring program. In total, 49 producers are participating in the program, representing approximately 9,200 hectares or 88% of the land currently utilized for agriculture production in the project area.

Additional activities during the reporting year would typically include:

- Engagement with
  - Ministry of Agriculture (AGRI),
    - Regional Agrologist
    - Agriculture Wildlife Program (AWP) Manager
  - Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) wildlife biologists, and
  - Regional agricultural producer groups.
- Historical data review of

- AGRI's AWP data,
- Ministry of Transportation and Infrastructure wildlife-vehicle collision reports, and
- FLNRORD wildlife inventory surveys.

One of the key tasks from the reporting year was to implement the camera trapping and seasonal grazing exclusion plans. In total, 65 passive, unbaited camera traps were installed along benchmark field boundaries and 40 temporary grazing exclusion cages were installed on perennial forage benchmark fields. Note that 34 benchmark sites were selected from the agriculture fields identified to be subject to higher wildlife pressures both pre- and post-inundation.

## 5.2 Crop Drying and Humidity Monitoring Program

The Crop Drying and Humidity Monitoring Program (CDHMP) scope was assessed and developed in coordination with RWDI; the BC Hydro contractor responsible for climate station operation and management. Program scope was to monitor project-induced changes to humidity and evaluate associated effects within the area.

The climate stations currently available (as of the date of this report) were determined to be appropriate and sufficient for the purposes of the program. These stations monitor climate parameters on an ongoing basis to evaluate if changes occur and how these changes may affect crop drying indices.

## 5.3 Crop Productivity and Groundwater Monitoring Program

BC Hydro's Crop Productivity and Groundwater Monitoring Program (CPGMP) contractor is Blackbird, who developed and implemented activities to monitor and assess groundwater levels and related change to agricultural crops.

During the reporting year, BC Hydro and the project team oversaw activities associated with the program in order to meet the monitoring requirements as described in Condition 31. It was determined that the groundwater monitoring wells in the existing BC Hydro network could be employed within the CPGMP in place of installing all new wells. Only one (1) new well was required and installed in the reporting year (October 2019) in Bear Flats; identified to be a data collection gap area.

Blackbird will monitor in-season crop development through remote sensing, supplemented with field visits to assess crop variability in relation to soil moisture factors. Field methodology is being refined based on project experience.

## 5.4 Irrigation Water Requirements Program

The Irrigation Water Requirements Program (IWRP) was assessed and developed in coordination with RDWI.

The climate stations currently available (as of the date of this report) were determined to be appropriate and sufficient for the purposes of the program. These stations monitor climate parameters on an ongoing basis which will be available, when required, to support future proposed irrigation projects.

# Appendix A – Crop Damage Monitoring Program Report

# 2021 Annual Report
# Site C Clean Energy Project
# Crop Damage Monitoring Program

## BC Hydro and Power Authority

**Blackbird Environmental Ltd.**

July 5, 2021

Final Report – Rev. 0
Blackbird File No.: 21006

**Table of Contents**



**Table of Revisions**

| Revision No. | Date | Reason/Type of Revision |
|---|---|---|
| R0 | July 5, 2021 | Original Report issued |

# 1 Introduction

## 1.1 Project Background

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction along the Peace River in northeast British Columbia (BC). Construction started in July 2015 and the project is anticipated to be in service in 2025 (BC Hydro 2021).

## 1.2 Regulatory Context

During the joint federal-provincial environmental assessment process, the Project's Environmental Impact Statement (EIS; BC Hydro 2013) noted a potential for increased wildlife-related crop damage.

EIS Section 20.7.2.1 (page 20-53, lines 12 to 14) states: "*The loss of wildlife habitat in the reservoir may lead to an increase in wildlife in agricultural areas near the reservoir, which could lead to wildlife damage to crops and stored livestock feed for farm operations*."

EAC Condition No. 31 states: "*the Agriculture Monitoring and Follow-up Program must include monitoring for Project-induced changes in wildlife habitat utilization, and evaluation of associated crop or feed storage damage for, agricultural operations within 5 km of the reservoir, to assess if there is an increase in wildlife related crop depredation due to Project-related habitat losses. Monitoring must include pre- and post-reservoir filling field surveys, wildlife monitoring, farm operator interview, and analysis of relevant records related to wildlife-related crop depredation*."

As a result, the Environmental Assessment Certificate for the Project (EAC # E14-02, issued October 14, 2014) contains a condition to develop an Agricultural Monitoring and Follow-Up Plan (AMAFP), which requires BC Hydro to monitor and assess wildlife habitat use and related damage to agricultural crops for a 10-year period including five years prior to reservoir filling and the first five years of operation.

## 1.3 Scope

BC Hydro and Power Authority (BC Hydro) retained Blackbird Environmental Ltd. (Blackbird) in 2019 to implement the Crop Damage Monitoring Program (CDMP) component of the AMAFP for the Project. Blackbird's scope includes the development and implementation of field methodologies to monitor for Project-induced changes in wildlife habitat utilization and the evaluation of associated crop and feed storage damage.

As part of BC Hydro's annual reporting requirements, this report outlines Project activities completed in relation to the CDMP component between **April 1, 2020,** and **March 31, 2021.**

As per the requirements of EAC Condition No. 31, the CDMP focuses on parcels with agricultural production within a five-kilometre buffer around the future Project reservoir (project area).

# 2 Methods

## 2.1 Ongoing Stakeholder Consultation & Producer Engagement

Blackbird's team has developed and implemented a comprehensive agricultural producer outreach and engagement program for the CDMP. Blackbird continues to engage with landowners who have benchmark fields within the Project boundary on an ongoing basis throughout the growing season.

For all producers that expressed interest in the CDMP in 2019, initial phone or email conversations were followed up on with an in-person interview to gather current project relevant background information, including farm/ranch operational and production information, historic wildlife damage patterns on temporal and spatial scales, as well as wildlife-related crop damage mitigation measures employed.

Producers participating in the CDMP were updated on project activities on their holdings during the spring of 2020, throughout the growing season, and a post-season interview program was implemented to gather information on observations and perceptions with regards to the 2020 growing season and wildlife-related crop damage in the 2020 crop.

BC Hydro invited representatives from regional producer associations (i.e., Peace River Forage Association of BC, BC Grain Producers Association, Peace River Cattlemen's Association, Peace River Forage Seed Association) and provincial government representatives (i.e., BC Ministry of Agriculture, Food, and Fisheries) to participate in a virtual CDMP agricultural forum hosted in Fort St. John to receive updates on the crop damage monitoring work completed during the 2020 growing season. The virtual agricultural forum for the 2020 growing season was held on April 15, 2021.

## 2.2 Crop Damage Monitoring

Blackbird's team has been working to research, develop, and implement scientifically sound and defensible methodologies to assess and measure wildlife-related crop damaged in both annual and perennial crops in the CDMP project area. Throughout the growing season, field methodologies and techniques include wildlife crop loss assessments, crop development and health monitoring, and remotely piloted aircraft system (RPAS) data acquisition.

Blackbird's team, in consultation with participating producers and BC Hydro project management, selected a total of 34 benchmark sites within the project area based on the outcome of initial engagement efforts, the review of available historic information, and a geospatial review of factors related to wildlife occurrence in the project area (e.g., proximity of escape or wintering habitat).

During the 2020 growing season, 12 of the selected benchmark sites were used for annual crop production while 22 sites contained a perennial forage stand. The field crops at all benchmark locations was monitored during the growing season and assessed for wildlife-related crop damage prior to harvest.

Assessment procedures include remote sensing techniques and on-the-ground evaluations of crop health, yields, and wildlife-related damage patterns. Assessment methodologies were based on published standards, where available, and included clipping and drying of forage samples, enumerative evaluations of plants, tillers, heads, pods, and seeds, as well as area-based estimates of wildlife impacts.

Yield estimates from both annual and perennial crops were reconciled with yield information provided by the participating producers following harvest, where available.

## 2.3 Wildlife Habitat Utilization Monitoring

During 2020, Blackbird implemented two additional methods for monitoring wildlife habitat use of agricultural fields within the project boundary: camera trapping and seasonal grazing exclusion.

### 2.3.1 Camera Traps

A total of 65 passive, unbaited camera traps were installed along benchmark field boundaries throughout the CDMP focus area to monitor wildlife use patterns and frequencies (Kolowski & Forrester 2017, McIntyre et al. 2020, Moll et al. 2020, Gilbert et al. 2021, Kolowski & McShea 2021).

The benchmark-based deployment approach includes sites considered likely to be subject to higher wildlife pressures (both during the baseline survey period and following the creation of the reservoir) and sites that are believed to have experienced lower historic wildlife pressures. The benchmark approach makes efficient use of resources, while providing adequate spatial coverage of the agriculturally used private land base that is part of the CDMP.

### 2.3.2 Grazing Exclusion Cages

In the fall of 2020, Blackbird's team installed a total of 40 temporary grazing exclusion cages on perennial forage benchmark fields within the project area. Exclusion cages allow for an objective evaluation of dormant season impacts to forage stand composition and yields (Richer et al. 2005, Drewry et al. 2008, Medina-Roldán et al. 2012, Corgatelli et al. 2019).

Green-up assessments compare a plot within the exclusion cage to a plot adjacent to the cage location during spring green-up, and include pellet counts as well as plot health factors (e.g., species distribution, litter and live plant coverage, plant height, alfalfa crown development, grazing patterns). Following assessment, the cages are removed to enable forage use during the growing season.

# 3 Results and Analysis

## 3.1 Ongoing Stakeholder Consultation & Producer Engagement

Blackbird's team has identified approximately 10,400 ha of land within the CDMP project area that is currently supporting agriculture production (not including Crown land under range tenures).

Fifty-four producers within the project area have been engaged through direct means to provide information about the CDMP and offer interested producers an opportunity to participate in the program. As a result of this engagement, 49 of the producers expressed a general interest in participating in the CDMP.

These 49 producers operate on approximately 9,200 ha (88 %) of the land currently utilized for agricultural production within the project area. Of those 9,200 ha of agricultural land (partitioned into 203 fields and pastures), approximately 3,300 ha were used to produce an annual crop (i.e., grain, oilseed, or pulse) within the 2020 growing season, with the remaining 5,900 ha used for perennial forage production.

Throughout initial and ongoing producer engagements, producers consistently state that agricultural production within the CDMP project areas is subject to significant wildlife pressures. Primary species causing wildlife-related crop losses are perceived to be elk, mule deer, and black bears. For perennial forage crops, most quantitative and qualitative crop losses are believed to occur during the dormant season, particularly in the spring. Wildlife-related crop losses to annual crops are perceived to occur throughout the growing season, with heavier losses associated with weather-induced harvest delays and a lack of available alternative foraging habitat, particularly during drought years.

## 3.2 Crop Damage Monitoring

Agricultural enterprises in the CDMP area operate in an environment with historically high ungulate and bear populations which exert significant pressures on most crop types (Thiessen 2009, Bridger 2016, Bridger 2018, Gagne-Delorme 2018, WARS 2019).

Initial assessment results indicate that perennial forage crops are subject to slightly lower crop losses during the growing season than annual crops. However, perennial crops in several of the benchmark fields are believed to experience significant suppression losses during the dormant season. The absolute levels of yield losses in the monitored field crops are a function of, at a minimum, the crop type, the location on the landscape, ongoing nearby construction activities, seasonal migration patterns, annual weather patterns, and the time of year when the damage occurred.

Throughout the 2020 growing season, field methodologies and techniques, including loss assessments as well as remote sensing and on-the-ground crop health evaluations, were tested, evaluated, and adapted to fit program requirements.

### 3.3 Wildlife Habitat Utilization Monitoring

Camera trap maintenance and data retrieval will be completed during crop health and wildlife damage assessment work in the 2021 growing season to minimize private land access requirements. Initial results for the camera trap program will be available following the growing season of 2021 and will be included in the 2021/2022 annual report.

Similarly, initial results, learnings, and potential methodology adjustments for the dormant season 2020/2021 deployment of the grazing exclusion cages will be available following the green-up assessments in late spring of 2021 and will be included in the 2021/2022 annual report.

## 4 Recommendations

In accordance with EAC Condition No. 31, field surveys and interviews will continue to be completed with the goal of continuing monitoring until five years after reservoir filling. Similarly, the Blackbird's team will continue to work closely with agricultural producers, agricultural associations, producer groups, and government agencies that may have data or local knowledge related to this monitoring plan.

The following recommendations are based on the findings of project activities during the 2020 growing season, including producer engagement and the implementation of the field program.

1. Complete RPAS assessments of benchmark sites through the 2021 growing season to document crop development, delineate crop health patterns, estimate forage yields, and objectively record wildlife impacts to field crops.

2. Continue destructive sampling of forage crops on benchmark fields during the growing season to reinforce yield estimates and allow for an accurate characterization of wildlife-related crop losses to growing stands. Evaluate non-destructive sampling approaches (e.g., rising plate meters, multispectral estimation methods) to further refine field methodologies for perennial forage assessments.

3. Similar to the previous year, install exclusion cages on benchmark fields to allow for an objective evaluation of dormant season impacts to forage stand composition and yield.

4. Maintain the camera trap network and analyse retrieved information to facilitate an initial baseline assessment of site use frequencies and patterns at benchmark field sites.

# 5 Closure

Services provided by Blackbird for this technical report have been conducted in a manner consistent with the level of skill, care, and competence ordinarily exercised by registered members of the profession of agrology and biology currently practicing under similar conditions and like circumstances in the same jurisdiction in which the services were provided.

The conclusions of this report are based in part on information provided by others. Blackbird believes this information to be accurate but cannot guarantee or warrant its accuracy or completeness.

The information presented in this report was acquired, compiled, and interpreted exclusively for BC Hydro for the purposes described in this report.

If you have questions with regards to this report, feel free to contact the lead author at your convenience by email at matthias@blackbird.ca.

## 6 References

Blackbird Environmental Ltd. (Blackbird). 2020. Analysis of Available Records for Wildlife-related Crop Depredation. Technical Report, Fort St. John, BC.

BC Hydro. 2021. Site C Construction Schedule February 2020. Available at: https://www.sitecproject.com/sites/default/files/construction-schedule-202002.pdf (Accessed May 27, 2021)

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013.

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013. Volume 3, Section 20 Agriculture. Subsection 20.3 Mitigation Measures.

Bridger, M. 2016. 2016 Winter Moose Survey: MU 7-34. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

Bridger, M. 2018. 2018 Winter Moose Survey: MU 7-32. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

Corgatelli, G., Mattiello, S., Colombini, S. and Crovetto, G.M. 2019. Impact of red deer (Cervus elaphus) on forage crops in a protected area. Agricultural Systems, 169, pp.41-48.

Drewry, J.J., Cameron, K.C. and Buchan, G.D. 2008. Pasture yield and soil physical property responses to soil compaction from treading and grazing—a review. Soil Research, 46(3), pp.237-256.

Gagne-Delorme, A. 2018. 2018 Elk Survey in 7-20A. BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, Fort St. John, BC.

Gilbert, N.A., Clare, J.D., Stenglein, J.L. and Zuckerberg, B. 2021. Abundance estimation of unmarked animals based on camera-trap data. Conservation Biology, 35(1), pp.88-100.

Kolowski, J.M. and Forrester, T.D. 2017. Camera trap placement and the potential for bias due to trails and other features. *PLoS One*, *12*(10), p.e0186679.

Kolowski, J.M., Oley, J. and McShea, W.J. 2021. High-density camera trap grid reveals lack of consistency in detection and capture rates across space and time. Ecosphere, 12(2), p.e03350.

McIntyre, T., Majelantle, T.L., Slip, D.J. and Harcourt, R.G. 2020. Quantifying imperfect camera-trap detection probabilities: implications for density modelling. Wildlife Research, 47(2), pp.177-185.

Medina-Roldán, E., Paz-Ferreiro, J., and R.D. Bardgett RD. 2012. Grazing exclusion affects soil and plant communities, but has no impact on soil carbon storage in an upland grassland. Agriculture, Ecosystems & Environment. 149:118-23.

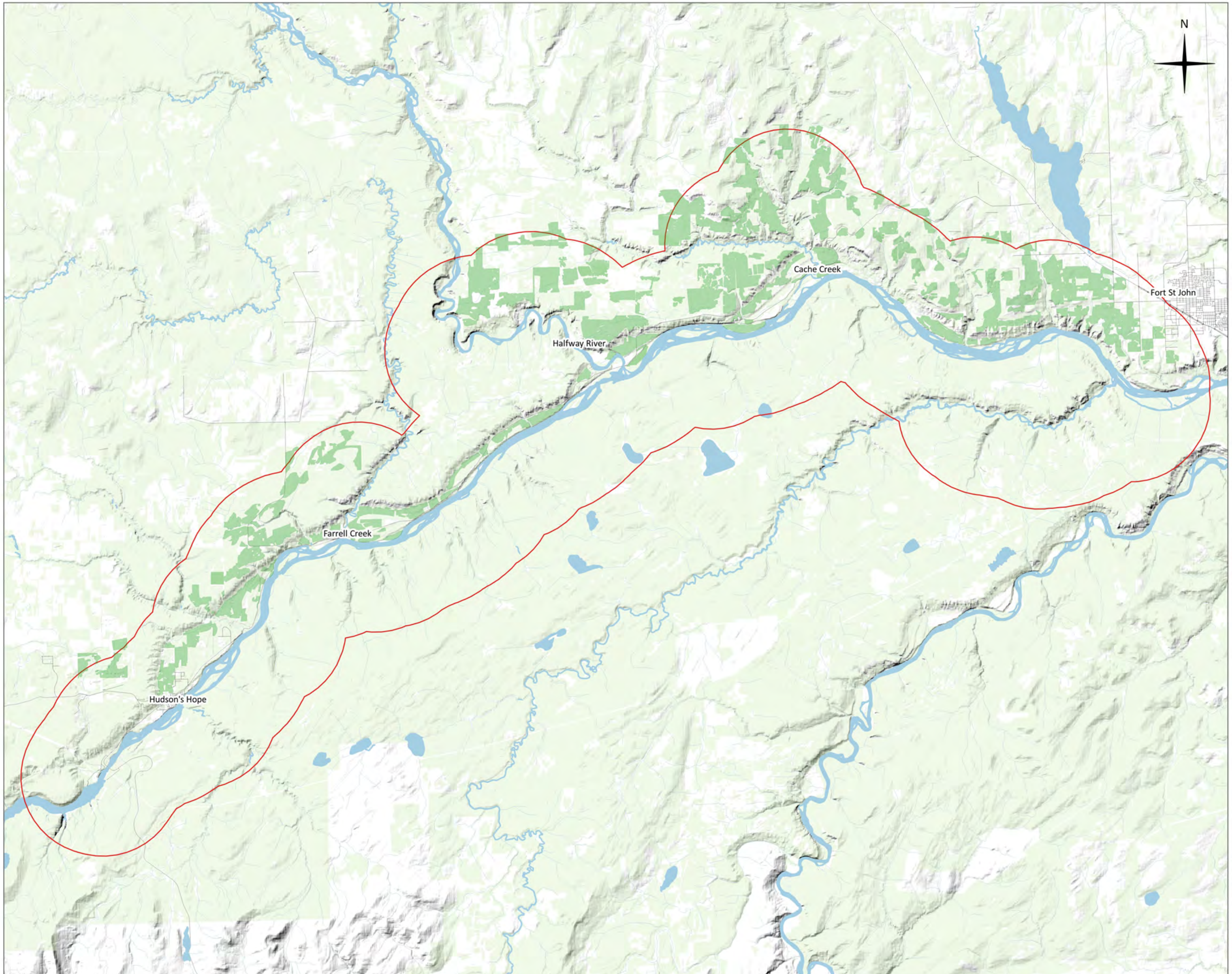
Moll, R.J., Ortiz-Calo, W., Cepek, J.D., Lorch, P.D., Dennis, P.M., Robison, T. and Montgomery, R.A. 2020. The effect of camera-trap viewshed obstruction on wildlife detection: implications for inference. Wildlife Research, 47(2), pp.158-165.

Richer, M.C., Ouellet, J.P., Lapointe, L., Crête, M. and Huot, J. 2005. Impacts of white-tailed deer grazing in hay fields of southern Québec. Wildlife Society Bulletin, 33(4), pp.1274-1281.

Thiessen, C. 2009. Agriculture Zone Elk Inventory 2007/2008. Ministry of Environment, Fort St. John, BC.

Wildlife Accident and Reporting System (WARS). 2019. Highway 29: Fort St. John to Hudson’s Hope. Ministry of Transport and Infrastructure, Victoria, BC.

# Appendix A: Project Area Overview




# BC Hydro and Power Authority

**Crop Damage Monitoring Program**
**Project Area Overview**

1:30,000,000

Horizontal Scale 1:250,000

0 2 4 6 8 10 km

Map to scale when plotted on a page 280 mm x 432 mm (Tabloid)

## Legend

- CDMP Project Area
- Agricultural Fields and Pastures
- Lakes & Rivers
- Road Network

## Disclaimer

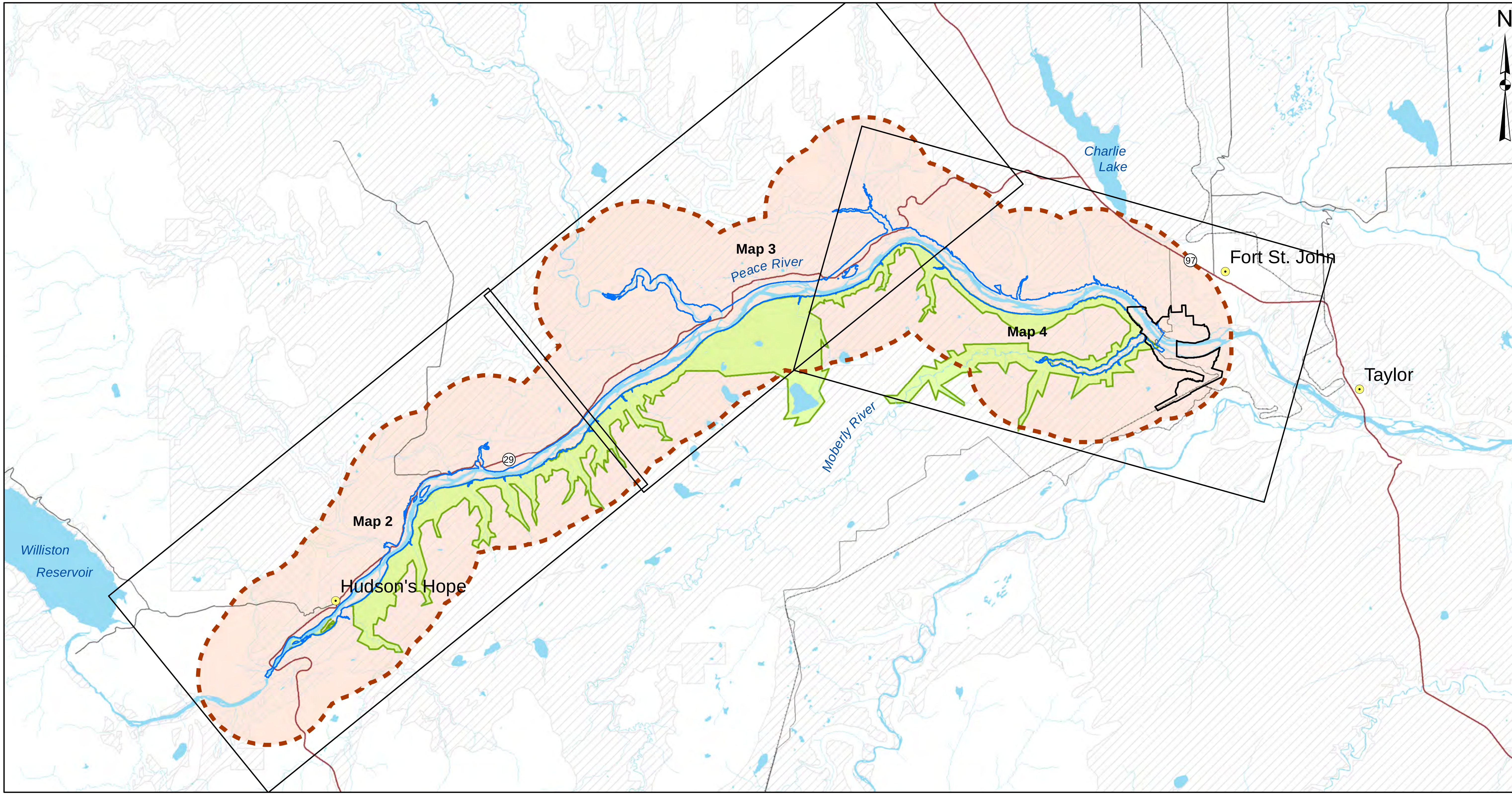
UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

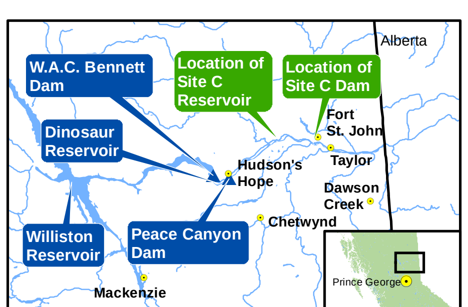
| | | | | | |
|---|---|---|---|---|---|
| Our File: | 21006 | Gov. File #: | n/a | Revision #: | 0 |
| Client File: | n/a | GIS: | ML | Date: | June 12, 2021 |

Blackbird Environmental

blackbird.ca
Fort St. John, BC
250.793.7262

**Figure 1**




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area
- Town
- Road
- Highway
- Railway

1:280,000

0 5 km

BC Hydro

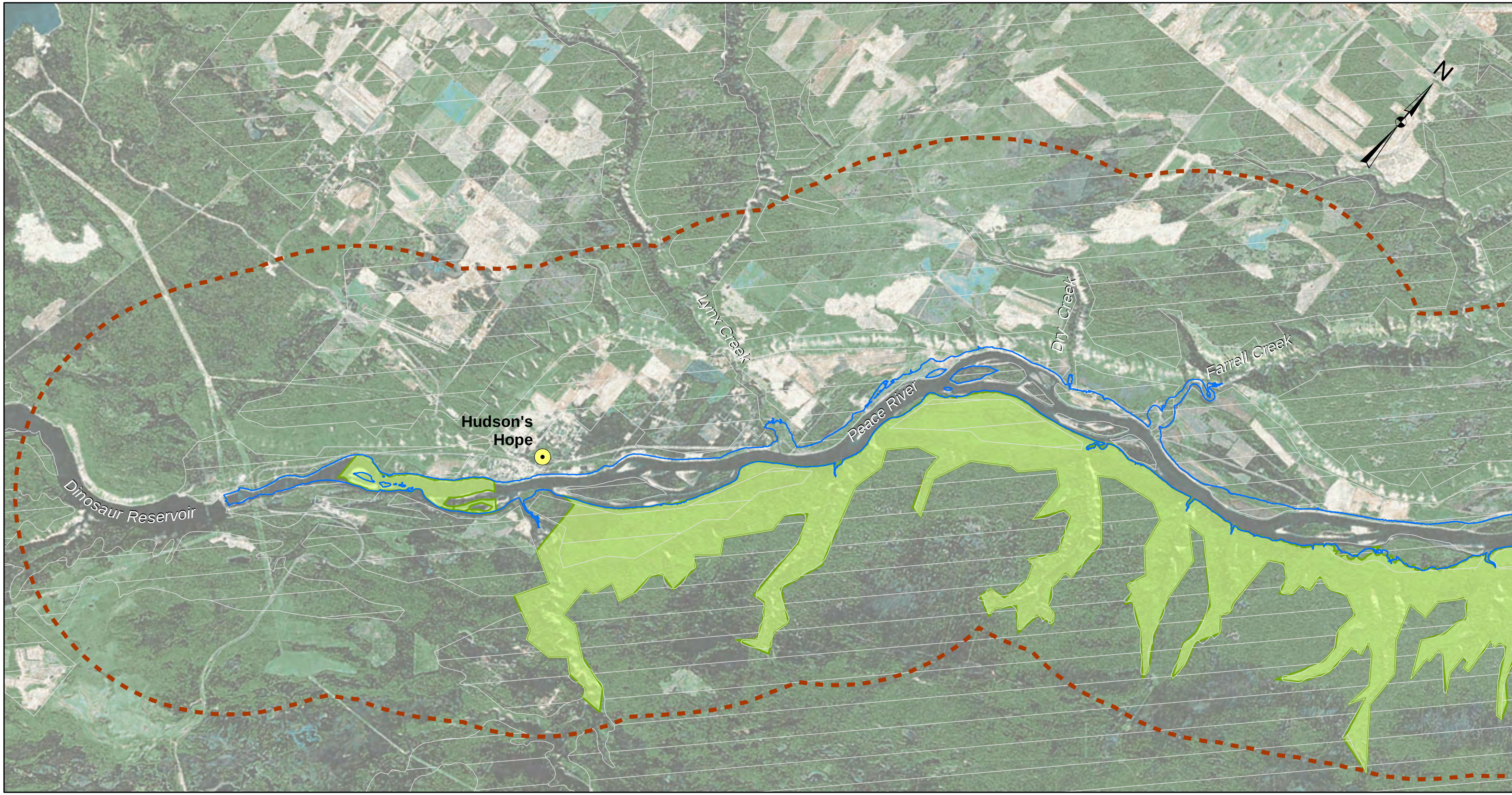
**Wildlife Habitat Utilization Monitoring Area Identification - Overview**
**Map 1 of 4**

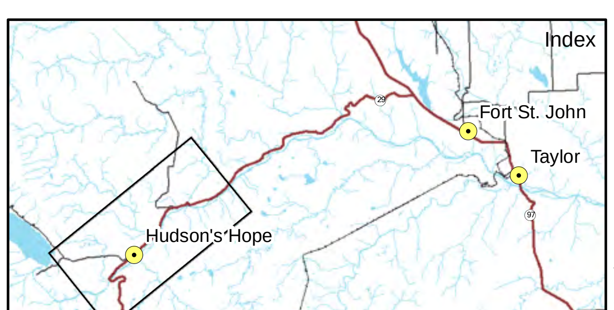
| Date | July 14, 2016 | DWG NO | 1016-C14-07343-1 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_5kmReservoirBoundary_Overview_1016_C14_07343-1.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:90,000

0 2 km

BC Hydro

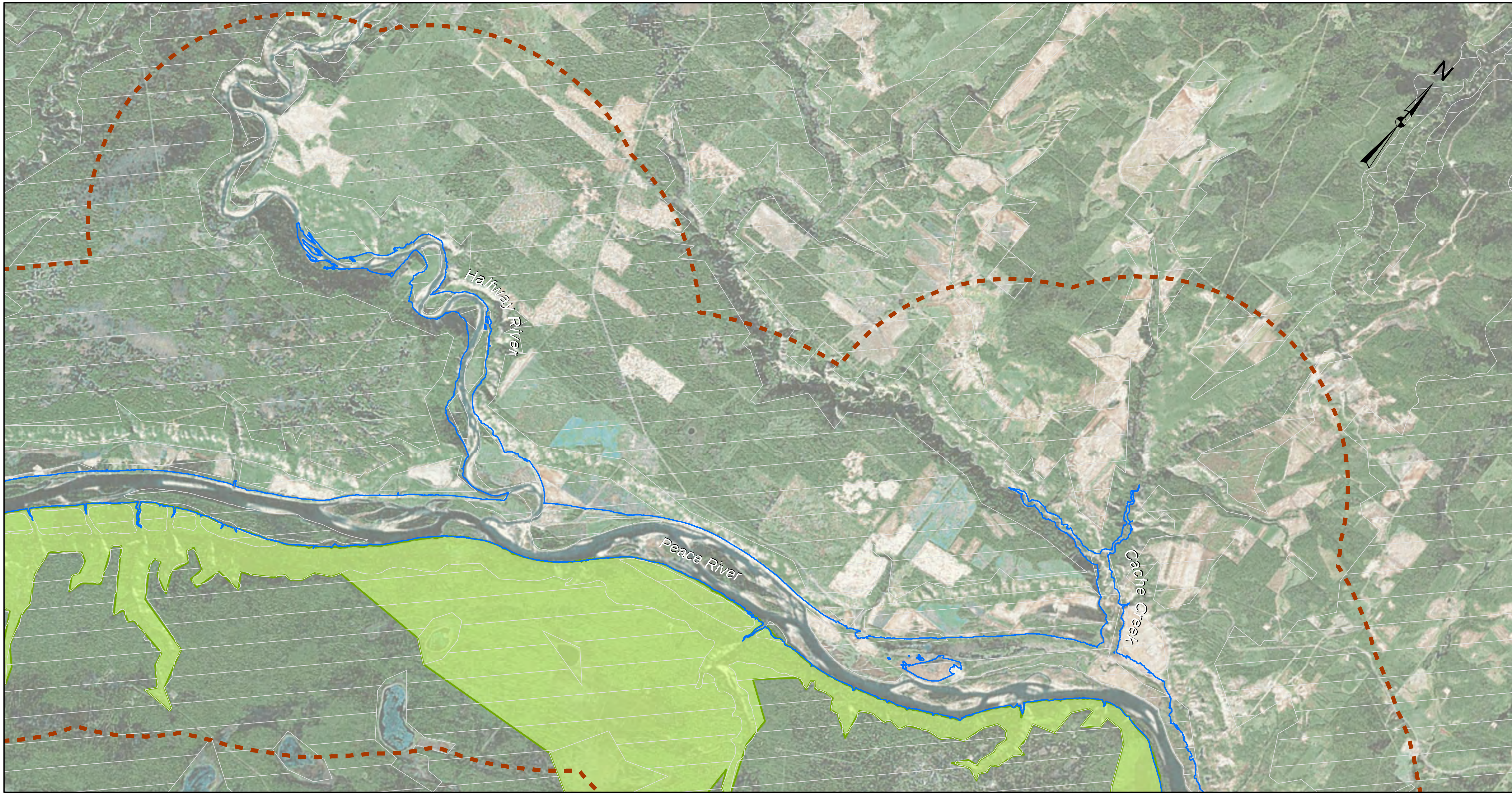
**Wildlife Habitat Utilization Monitoring Area Identification - Map 2 of 4**

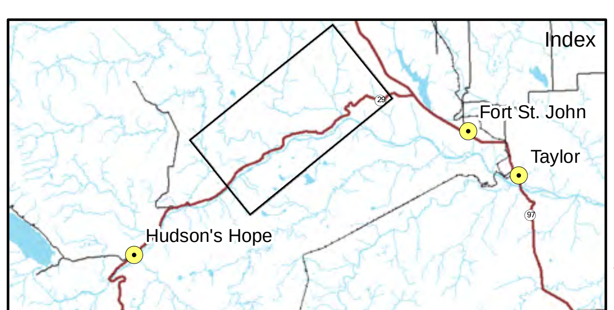
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-2 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGIS\Projects\Environment\Agriculture\Ag_5kmReservoirBoundary_1016_C14_07343-2-4.mxd




1:90,000

0 2 km

## Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

BC Hydro

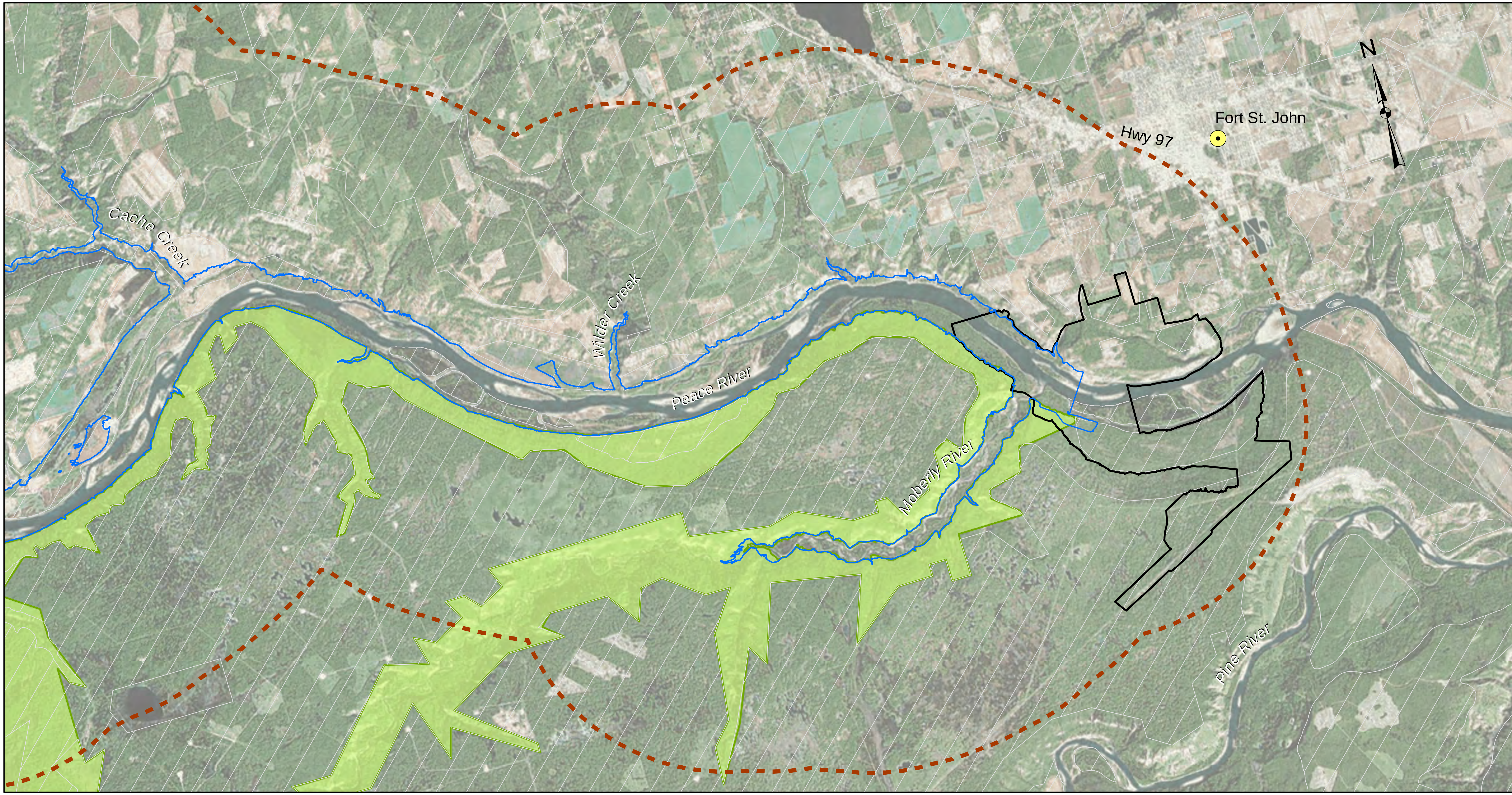
**Wildlife Habitat Utilization Monitoring Area Identification - Map 3 of 4**

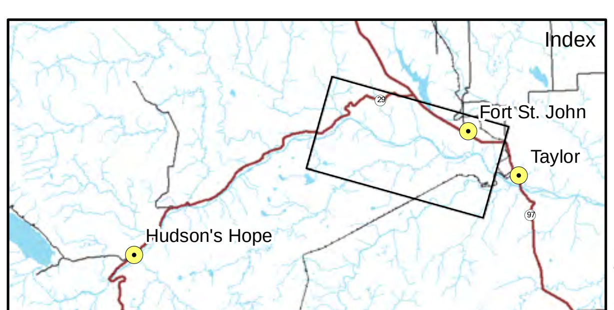
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-3 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGIS\Projects\Environment\Agriculture\Ag_5kmReservoirBoundary_1016_C14_07343-2-4.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for wildlife habitat utilization monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:90,000

0 2 km

BC Hydro

**Wildlife Habitat Utilization Monitoring Area Identification - Map 4 of 4**

| Date | July 14, 2016 | DWG NO | 1016-C14-07342-4 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_5kmReservoirBoundary_1016_C14_07343-2-4.mxd

# Appendix B – Crop Drying and Humidity Monitoring Program Report

REPORT

# SITE C AGRICULTURAL CLIMATE REPORT

FORT ST. JOHN, BC

**2020 ANNUAL REPORT**

RWDI # 2002353

July 13, 2021

## SUBMITTED TO


**Ben Rauscher, P.Ag.**
Project Manager, Community and Social Mitigation (Site C)
Ben.Rauscher@bchydro.com

**BC Hydro**
Site C Consultation Office
Fort St. John, BC


## SUBMITTED BY


**Laura Dailyde, P. Eng., PMP**
Senior Project Manager / Associate
Laura.Dailyde@rwdi.com

**Christian Reuten, Ph.D., ACM**
Technical Director / Associate
Christian.Reuten@rwdi.com

**Iain Hawthorne, Ph.D.**
Senior Field Specialist
Iain.Hawthorne@rwdi.com

**RWDI**
Suite 280 – 1385 West 8th Avenue,
Vancouver, Canada, V6H 3V9
T: 604.730.5688
F: 519.823.1316

# EXECUTIVE SUMMARY

The eddy covariance (EC) system performance for collected high frequency data was over 75% for both EC stations, and the daily collection of half-hour computed fluxes and climate data resulted in a 100% data representation for 2020. Main line power outages were the only cause for data loss.

Climatologically, 2020 was wet and warm. Climate differences between all study stations are the result of differences in elevation, aspect, exposure, vegetation cover, and soil type. Stations at higher elevations recorded higher wind speeds. Station 11 had consistently high monthly net radiation throughout the growing season (GS) and was higher in July and August than other stations. Station 4 received the least precipitation during the GS, while it maintained a high volumetric water content.

The EC measured and Priestley-Taylor (PT) modelled cumulative evapotranspiration (*ET*) was greatest at Station 4, reaching 440 mm compared to 352mm at Station 1 with a difference of 88 mm, prior to energy balance closure (EBC). The annual EBC values were 0.69 and 0.86 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of *ET* increases their values to 461 and 502 mm, respectively. This decreases the difference in annual cumulative *ET* between the stations for 2020 to 41 mm.

The PT proportionality constant (α) was used to provide an estimate of actual *ET* from potential evapotranspiration (PET) estimates made using the PT radiation-based approach. A common value recommended for this constant is 1.26. From measurements during the GS, it was determined that PT $\alpha$ for Stations 1 and 4 were closer to 0.81 and 1.13, respectively. Linear regression analysis showed that while the correlation of the relationship between measured vs. modelled values did not change, using this new α reduced the slope of the relationship and further improved the accuracy of the model output. An average value of 0.965 was selected to improve the accuracy of modelled *ET* at all climate stations where EC measurements were not available. Testing both the PET and the actual *ET* estimates for each climate station in the network, it was possible to compute drying indices that were used as an input for the climate moisture deficit (CMD) and crop drying model (CDM) for each location.

A spatial summary of CMD results is presented along with the station location map in Appendix A. Station 4 had the highest CMD with more than 32 mm above the average by the end of the GS (299.6 mm). The stations in decreasing order of CMD are 4, 11, 7, 3, 10, 1, and 6. During the GS, all stations experience moisture deficit because evapotranspiration exceeds effective precipitation (*ET* > *EP*). Stations 11, 3, and 4 had the highest annual *ET* of 418.6 mm, 410.1 mm, and 401.3 mm, respectively. The low *EP* at Station 4 (106.7 mm) contributed to it having he largest CMD.

Output from the CDM was used to compute the cumulative good crop drying days for each month and station. Based on this output, August had the highest number of good drying days averaged across stations. June had the lowest average cumulative good drying days with 25.6 because of an extended rainfall event early in the month. In line with the CMD results, Station 11 had the fastest drying rates, while Station 4 recorded less precipitation in May, June, and July.

# TABLE OF CONTENTS



# LIST OF TABLES

# LIST OF FIGURES



# LIST OF APPENDICES

# VERSION HISTORY

| Index | Date | Pages | Authors |
|---|---|---|---|
| 1 | July 13, 2021 | All | Iain Hawthorne, Ph.D.<br>Christian Reuten, Ph.D, ACM |

# ACRONYMS

| | |
|---|---|
| BC MECCS | British Columbia Ministry of the Environment and Climate Change Strategy |
| CDM | Crop Drying Model |
| CMD | Climate Moisture Deficit |
| CDI | Crop Drying Index |
| DM | Dry Matter (content) |
| DR | Drying Rate |
| EBC | Energy Balance Closure |
| EC | Eddy Covariance |
| EP | Effective Precipitation |
| *ET* | Evapotranspiration |
| FCRN | Food Climate Research Network |
| FHAYD | Field Hay Drying Model |
| GS | Growing Season |
| HF | High Frequency |
| Hz | Hertz |
| IRGA | Infrared Gas Analyzer (Open Path) |
| PET | Potential Evapotranspiration |
| PT | Priestley and Taylor |
| RWD | Rewetting through Dew Formation |
| RWP | Wetting Rate from Precipitation |
| SDM | Synchronous Device for Measurement |
| VWC | Volumetric Water Content (soil) |

# 1 INTRODUCTION

BC Hydro's Site C Clean Energy Project (the Project) in British Columbia's Peace region will create a new hydroelectric dam and generating station on the Peace River in the vicinity of the City of Fort St. John. To characterize the microclimate and to provide a baseline to assess future changes caused by the Project, BC Hydro installed a network of climate monitoring stations in the Peace River Valley. This network has been active since 2011, through the preparation and submission of the Project's Environmental Impact Statement, and throughout Project construction to date, which began in mid-2015.

We acknowledge this work is being conducted on the traditional territory of Treaty 8 First Nations. We also acknowledge the history of the Dunne Zaa people in the Fort St. John area, and the original Fort St. John Beaver Band who are now the Blueberry River First Nations and Doig River First Nation.

The Site C Clean Energy Environmental Impact Statement (EIS) (BC Hydro, 2013) identified reservoir induced changes to microclimate on adjacent agricultural operations as a key indicator (EIS Section 10, Table 20.3). Effect on crop drying is one reservoir-induced change which may occur. EIS Section 20.3.6 (page 20-50, lines 27 to 36) states: "Predicting the effect that the reservoir might have on crop drying is made difficult by the complexity of the effect of the reservoir on several climatic parameters that drive both drying and wetting effects. Generally, the RWDI model predicts increases in humidity up to 15% for stations located closely adjacent to the reservoir during the summer and fall months. the model predicts the effect on humidity during the summer and fall not to be statistically significant for locations not directly adjacent to the reservoir. The RWDI report predicts that effects on fog formation from the reservoir are in the order of 0.5% or less over the year. However, due to increased humidity, the reservoir could potentially have a small effect on crop drying during summer and early fall in the Peace River valley in areas adjacent to the reservoir."

As a result of these general conclusions, a commitment was made to monitor project-induced changes to humidity within 3 km of the reservoir; and evaluate associated effects on the calculated Climate Moisture Deficit (CMD) and Crop Drying Model (CDM) within the area. Monitoring will include continued collection and analysis of climate data from the BC Hydro monitoring network, calculation of the CMD and a Crop Drying Index (CDI) (Dyer and Brown, 1977), and farm operator interviews.

This report summarizes the results of the eddy covariance (EC) component of the baseline environmental measurement program for 2020. This technique provides a direct measurement of evapotranspiration (*ET*) that is then used to facilitate the computation of the CMD at each of seven climate stations available for this study. The CMD for each station is then used as an input to a CDM to be computed for each location.

# 2 METHODS

The seven climate stations available for this study are listed in Table 2-1. As part of the collection of baseline environmental data for the Site C project area, EC systems continue to be operated at two meteorological stations: Station 1 (Attachie Flat Upper Terrace, installed on January 13, 2011) and Station 4 (Bear Flat, installed on December 2, 2010). Station locations are shown in Appendix A, station pictures can be found in Appendix B.

### Table 2-1: Available Climate Stations

| Station Name | Latitude, Longitude (decimal degrees) | Elevation (m) | Dominant Ground Cover | Distance (m)[1] |
|---|---|---|---|---|
| **Station 1 – Attachie Flat Upper Terrace** | 56.23N, -121.42W | 479 | Wheat and other wild grasses | 209 |
| **Station 3 – Attachie Plateau** | 56.23N, -121.46W | 645 | Wheat and other wild grasses | 522 |
| **Station 4 – Bear Flat** | 56.27N, -121.21W | 474 | Pasture (Grasses/wildflower/clover/alfalfa) | 73 |
| **Station 6 – Farrell Creek** | 56.12N, -121.70W | 471 | Pasture (Grasses/wildflower/small shrubs) | 70 |
| **Station 7B – Site C North Camp** | 56.20 N, -120.90W | 581 | Pasture (Grasses/wildflower/small shrubs) | 573 |
| **Station 10 – Tea Creek** | 56.24 N, -120.95W | 653 | Forage (alfalfa/clover) | 812 |
| **Station 11 – Taylor** | 56.17N, -120.76W | 411 | Pasture (Grasses/wildflower/small shrubs) | 9744 |

Notes: 1. Approximate distance from the reservoir high water mark.

Land use and ground cover vary between locations. Broadly, in 2020 it was observed that the abundant ground cover at ;

- Station 1 was wheat and other grasses. The unmanaged wild grass portion of the field was tilled in August. The wheat portion of the field was harvested in October.
- Station 3, there was wheat and other grasses and like Station 1 this was harvested in October.
- Station 4, there was an Alfalfa/clover/grasses/wildflower cover crop that grew undisturbed throughout the year.
- Station 6, there was unmanaged pasture that had a dominant ground cover of mostly grasses/wildflower/small shrubs.
- The ground cover at Station 7B was mostly unmanaged and consisted of grasses/wildflower/small shrubs.
- At Station 10, there was Alfalfa/clover forage crop that was harvested in September.
- Station 11 there was unmanaged pasture that had a dominant ground cover of mostly grasses/wildflower/small shrubs.

One of the requirements of this monitoring program is to monitor climate variables to be used in the calculation of CMD and CDM within a 3 km distance of the reservoir. Efforts are being made to better characterize differences between locations with the potential for feedback during farmer interviews. Table 2-1 shows that the climate stations provide spatial coverage up to 812 m from the reservoir edge. The inclusion of Station 11, a station approximately 9.7 km from the reservoir edge and outside the 3-km study area, will be helpful in monitoring downstream climate effects on agriculture after reservoir filling.

## 2.1 Eddy Covariance Measurements

The EC technique has become the standard method for measuring sensible heat flux (*H*) and latent heat flux (λ*E*) over footprints of ≤ 1 $km^2$ (Baldocchi, 2003). Knowledge of the partitioning of available energy ($R_n$ – *G*, or net radiation minus soil heat flux) between sensible and latent heat fluxes is critical for understanding the interaction of the measured ecosystem with the overall water cycle, atmospheric boundary layer development, weather, and climate (Wilson et al. 2002).

Since the installation, continuous 10 Hz measurements of the three components of the wind vector and air temperature have been made using a 3-dimensional ultrasonic anemometer (model CSAT3, Campbell Scientific Inc. (CSI), Logan, Utah), while 20 Hz turbulent fluctuations of $CO_2$ and $H_2O$ have been measured using an open-path infrared gas analyzer (IRGA) (model LI-7500A, LI-COR, Inc., Lincoln, Nebraska). Signals were measured with a data logger (CSI, model CR1000) with a synchronous-device-for-measurement (SDM) connection. High frequency (HF) data were stored on a compact flash card that was replaced every 2-3 weeks. Half-hourly covariances and other statistics were calculated on the data logger (to provide near-real time diagnostics), and as well from the raw HF data using in-house MATLAB processing code. The fluxes *H* and λ*E* were calculated as the half-hourly covariances of the sonic air temperature and $H_2O$ mixing ratio with the vertical wind velocity (*w*). Further details of the flux calculations can be found in Brown et al. (2010). Latent heat flux *λE* is calculated using Equation 1 below.

$$\boldsymbol{\lambda E = \lambda \rho_a \overline{w' s_v'}} \qquad \text{Equation 1}$$

where $\rho_a$ is the dry air density, *w* is the vertical wind velocity, $s_v$ is the $H_2O$ mixing ratio, λ is the latent heat of vaporization, and the primes indicate fluctuations from the half-hourly mean value and the overbar indicates the time average. The calculation is a 30-minute block average with no detrending applied.

## 2.2 Climate Moisture Deficit Calculations

Daily potential evapotranspiration (PET) from May to September 2020 was calculated for each of the seven BC Hydro climatological stations, for which air temperature ($T_a$), net radiation ($R_n$), and precipitation (*P*) data were collected, using the PT energy balance formulation (Priestley & Taylor, 1972) in Equation 2 below. This approach has been shown to accurately estimate PET ($LE_0$) from a forage crop in the Peace River region of British Columbia (Davis & Davies, 1981; Davis, 1978).

$$\boldsymbol{LE_0 = \frac{1}{L}\alpha\frac{s}{s+\gamma}(R_n - G)} \text{ or } \boldsymbol{\lambda E = \alpha\frac{s}{s+\gamma}(R_n - G)} \qquad \text{Equation 2}$$

where:

$LE_0 = \frac{\lambda E}{L}$ = potential evapotranspiration (mm $day^{-1}$),
λ*E* = latent heat flux (W $m^{-2}$ $day^{-1}$)

$L$ = volumetric latent heat of evaporation for water (W m$^{-2}$ day);
$s$ slope of the saturation vapour pressure-temperature curve;
$\gamma$ psychrometric constant;
$R_n$ net radiation flux at the surface (W m$^{-2}$ day$^{-1}$);
$G$ soil heat flux (W m$^{-2}$ day$^{-1}$); and
$\alpha$ the PT proportionality constant (shown to have a value close to 1.26 in studies in the Peace River region (Davis & Davies, 1981) and elsewhere.

By making direct measurements of *ET* using EC, the PT equation can be re-arranged to provide an estimate of $\alpha$. For consistency in the computations and comparisons, to correct for difference in instrumentation between the climate stations, the $R_n$ values used were estimated from:

**0.559 * Incoming Shortwave Radiation - 17.9 W m$^{-2}$** ( BC Hydro, 2013)

Actual *ET* is given by providing location specific $\alpha$. A growing season (GS) assessment of the PT proportionality constant ($\alpha$) was performed by comparing modelled $LE_0$ estimates to EC measured $LE_0$ on occasions when incoming energy and water were not limiting to plant growth. In this way, an improved parametrization of the PT energy balance model was possible.

The slope of the saturation vapour pressure-temperature curve (s), shown below in Equation 3, was calculated following Eq. 13 in the Food and Agriculture 0rganisation Crop Evapotranspiration Guidelines (FAO, 1998) as follows:

$$s = (4098\ (0.6108 \exp((17.27 * T_a) / (T_a + 237.3))) / (T_a + 237.3)^2 \qquad \text{Equation 3}$$

where: $T_a$ = air temperature (°C) at two meters height.

A value of $\gamma$ = 0.062 was used for the psychrometric constant (Table 2.2 in the FAO Guidelines lists values for different altitudes above sea level).

Site specific CMD was computed daily by subtracting the effective precipitation (*EP*) from the cumulative daily $LE_0$ as shown in Equation 4, for each station:

$$\boldsymbol{CMD = Cumulative\ Daily\ LE_o - \left((Cumulative\ Daily\ P - 5) * 0.75\right)} \qquad \text{Equation 4}$$

The values accumulate over the course of the GS for each station to a GS maximum by the end of September.

## 2.3 Crop Drying Model Calculations Steps

The CDM follows closely the Field Hay Drying Model (FHAYD) described by Dyer and Brown (1977), with improvements where measured data are now available. The main computational steps are described here. On a daily time step, a CDI is first calculated using Equation 5:

$$\boldsymbol{CDI = Cumulative\ Daily\ LE_o - (Cumulative\ Daily\ P * 0.2)} \qquad \text{Equation 5}$$

The drying rate (*DR*) and wetting rate from precipitation (*RWP*) is calculated, using empirical constants provided in Dyer and Brown (1977), as shown in Equations 6 and 7:

$$DR = CDI \times 4.3 \quad \text{Equation 6}$$

$$RWP = 0.5 \times P \times 1.03 \quad \text{Equation 7}$$

The last wetting rate calculation accounts for rewetting through dew formation (*RWD*) only occurring on specific nights when RH > 90% and the calculated dew point temperature was above air temperature. The total amount of moisture added to the hay was computed from the average number of hours where dew was formed ($X_{ave}$) and could not be larger than 10%. This was multiplied by the ratio of the dry matter content (*DM*) of the crop (90%) and the day's prior moisture ($M_{n-1}$) content as shown in Equation 8:

$$RWD = \frac{DM}{M_{n-1}} \times \frac{0.1}{X_{ave}} \quad \text{Equation 8}$$

It was assumed that the starting moisture content by wet weight of the crop material was 80% at the start of each month for all stations and the total number of days until dry (<20 % moisture content) was estimated. Additionally, the total number of "good drying days" (DR>(RWP+RWD)) within each month was calculated.

## 2.4 System uptime/data loss

System uptime describes when the EC system was operating and HF data card collection was successful. Only time periods when the IRGA/sonic anemometer are malfunctioning or there is no system in place (e.g., calibration time period for Station 4) contribute to data loss and require gap filling through modelling. At other times (e.g., CF card failure) the 30 min fluxes that are downloaded daily can be carefully assessed for use.

The 2020 system performance was over 99% complete at both stations (Figure 2-1). Data loss was exclusively due to local power outages on the local main power line. Data card storage failures resulted in the loss of high-frequency data at both stations. The utilization of a spare IRGA allowed annual calibrations starting in December to occur with no associated data loss. During all data periods when HF EC data were missing, half-hourly EC computed values had been collected daily and were used to gap-fill. Additionally, instrumentation at the climate stations was collecting data that could be used to gap-fill through modelling (described in Section 2.6) for any periods without computed 30-minute fluxes. These steps resulted in a 100% data representation for the year of 2020.

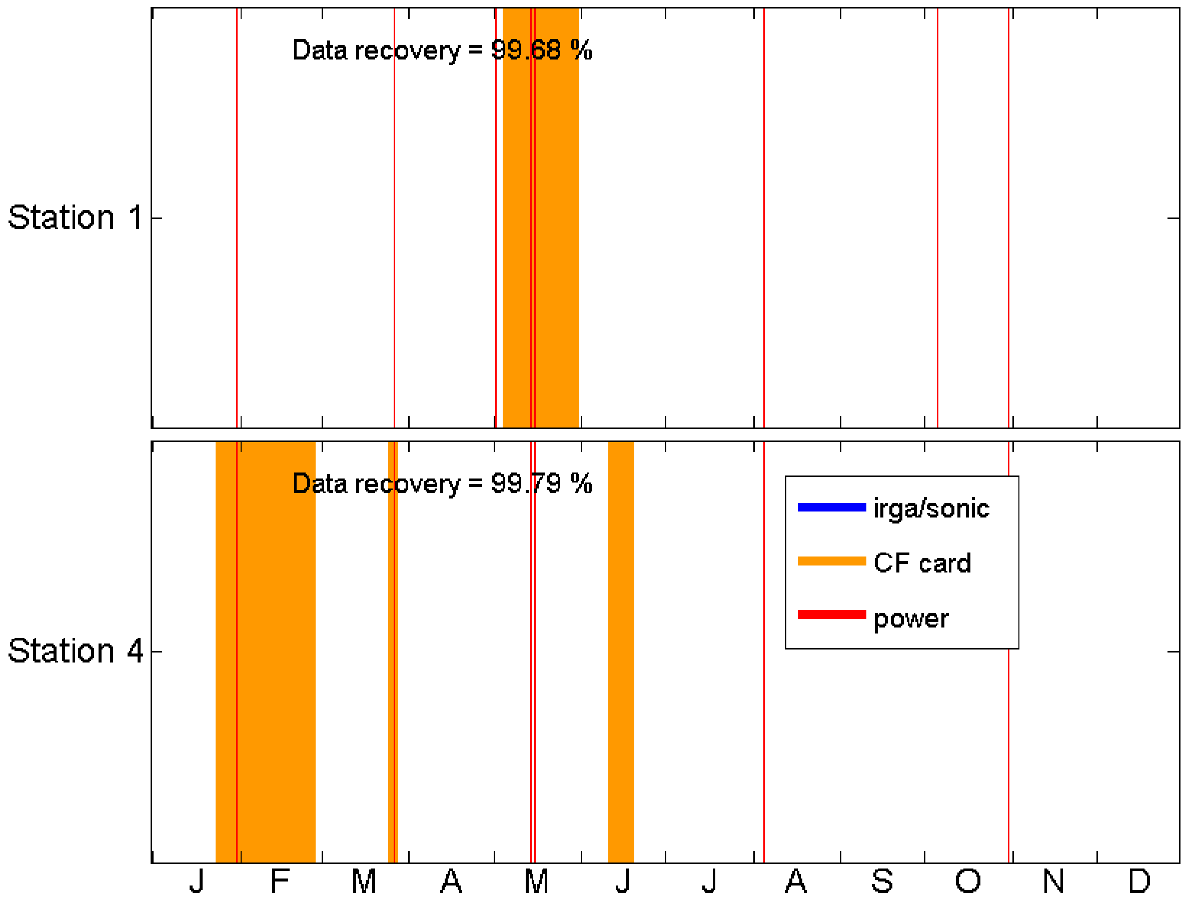



**Figure 2-1: System High Frequency Performance in 2020.**

## 2.5 Quality Assurance and Quality Control Measures

Data from the Site C climate stations and half-hour computed fluxes are remotely downloaded on a regular basis to RWDI computers using Campbell Scientific Loggernet software over cellular and satellite modem connections. In addition, HF data collected for the EC calculations is collected monthly from data cards. Stations with AC power (Station 1) have more frequent collection intervals of 1 hour, whereas solar powered stations (Stations 3, 6, 7, 10, and 11) have their data collected on a daily interval to preserve battery power at the stations. Station 4 is connected to AC power but also uses a satellite modem connection. Downloads from Station 4 are daily to reduce connection charges.

Data QA procedures are in line with those used by regulatory agencies such as the BC MECCS. QA is carried out at least weekly. This involves running R-scripts to plot the data over the recent period to allow for a visual inspection so the operator can detect anomalous trends or data outliers. This allows rapid detection and repair of any instrumental breakdown.

A second QA/QC operation is conducted monthly to remove or flag any anomalous data points. Corrections are also applied to the data where appropriate such as setting precipitation to 0 mm when a large value is recorded on the same hour that maintenance was performed on the precipitation gauge in question, for example.

The EC measurements are manually downloaded monthly on site by RWDI. The QA of these data includes:

- Plausibility checking for each variable from the IRGA and sonic anemometer (i.e. checking measurement from the EC equipment against plausible thresholds so that, for example, unreasonable wind speeds of 500 km/h or $CO_2$ concentrations of 20,000 ppm for the atmospheric background are discarded).
- Removal of spikes in the data.
- Flagging measurements using the diagnostic flags output by each instrument. For example, neither the sonic anemometer nor the IRGA produces reliable data during rain and snow which is indicated by a diagnostic flag, i.e., the IRGA starts reporting that its optical path is being obstructed due to water on the optical windows. Precipitation data from the climate stations are used to help confirm that the data from the IRGA and sonic anemometer can indeed be discarded during these periods.
- Checking the energy balance closure (EBC). A CNR4 4-way radiometer and soil heat flux plates are operated at the EC sites. Because of conservation of energy, the net radiation ($R_n$) as measured by the CNR4 minus the soil heat flux ($G$) as measured by the soil heat flux plates should equal the sum of the sensible heat flux ($H$) and latent heat (water vapour) flux ($\lambda E$) measured by the EC equipment. Any difference is checked and reported to show the degree to which the EC method is capturing all turbulent fluxes.
- Redundant measurements are used to check the EC instrumentation such as air temperature (obtained from the sonic anemometer) and humidity (from the IRGA).

All QA/QC tasks have both automated and manual components. Every EC trace is inspected after the data is collected, so as not to rely completely on automation.

In a natural forest or grassland ecosystem, filling data gaps in the $\lambda E$ fluxes would typically be accomplished using protocols slightly modified from those used in the Fluxnet Canada Research Network and the Canadian Carbon Program (Barr et al. 2004, Brown et al., 2010). This approach is best suited to natural ecosystems where the response of the local vegetation is largely the result of the integration of the phenological response of the individual species of plants and trees and environmental variables such as light, air and soil temperatures, and moisture.

In the agricultural settings in which the Site C EC stations are situated, the biological response is affected by human factors, as the farmer is the one controlling the timing of sowing and planting. Gap-filling of $\lambda E$ was accomplished using the EBC model approach (Amiro et al., 2006) with no additional uncertainty as $H$ continued to be measured throughout the IRGA calibration period.

## 2.6 Uncertainty Analysis

Uncertainties associated with calculating annual totals of *ET* from the half-hour EC fluxes were determined using techniques detailed extensively elsewhere (Brown et al. 2010, Krishnan et al. 2006, Morgenstern et al. 2004). Random error was assessed using propagation of errors following Morgenstern et al. (2004), in which up to a 20% error is randomly assigned to each half-hourly measured flux ($\lambda E$). The uncertainty due to the gap filling algorithms was estimated using Monte Carlo simulation following the procedure of Krishnan et al. (2006). Briefly, gaps were created in annual $\lambda E$ ranging from a half-hour to ten days in length, and a uniformly distributed random number generator was applied to day- and night-time readings separately to approximate the typical diurnal distribution of data gaps in the annual dataset for each site. For each iteration, the standard Food Climate Research Network (FCRN) gap filling approach as modified by Brown et al. (2010) was used to fill the gaps generated. This procedure was then repeated 1,000 times, and the simulated annual values of *ET* were then sorted to determine the 95% confidence intervals. For the Site C EC stations, the combined random and systemic error introduced from the gap filling procedure amounted to ~10 mm for the annual *ET*.

Finally, as was standard Fluxnet protocol, the annual totals for *ET* reported have not initially been corrected for EBC. However, analysis discussed later in this report indicated that performing this correction on $\lambda E$ was important prior to use in the CMD and CDM models, and so this was done to provide the most accurate estimate of *ET*.

# 3 RESULTS

The measured climate variables used as inputs to the CMD and CDM models are presented to characterize any differences between the stations and potential influences on *ET*. To aid a better understanding of seasonal climate impacts on model output, additional climate variables which control *ET* are also included. Reference is made to the Site C Climate & Air Quality Monitoring: 2020 Annual Report where necessary (RWDI, 2021). This is followed in section 3.2 by a more specific presentation of EC $\lambda E$ measurements and EBC estimates at those stations. Next, *ET* measurements are presented and compared to modelled *ET*, and the *PT* $\alpha$ parameter is discussed (section 3.3). In section 3.4, the daily CMD components and estimate are presented, and annual budgets are provided for the GS (May – September). Lastly in section 3.5, the daily CDM components and estimates are presented monthly for the GS.

## 3.1 Model Input Climate Variables

A detailed review of BCH Site C climate station data is available in the Site C Climate and Air Quality Monitoring: 2020 Annual Report (RWDI, 2021). Here the focus is on measurements made during the GS that were input variables or of interest to the computation of the CMD and CDM. The station data compared to the 30-year normal recorded at Fort St. John Airport indicate that 2020 was a warm and wet year (RWDI, 2021).

In Figure 3-1, *G* is an order of magnitude lower than the other energy balance components that are measured at all stations. Stations 1, 6, and 11 have high *G* values early in the GS; this difference is likely due to similarities in ground cover (unmanaged pasture dominated by grasses and small shrubs) and soil types (i.e., likely fluvial soils as both stations are close to the Peace River) inside their compounds. All stations display an approximately sinusoidal trend in radiation balance components that is controlled by the suns seasonal cycle. The $R_n$ values indicate that $R_n$ was similar at all stations with Station 11 being on average higher than other stations and in particular higher in summer months of July and August (Figure 3-1).

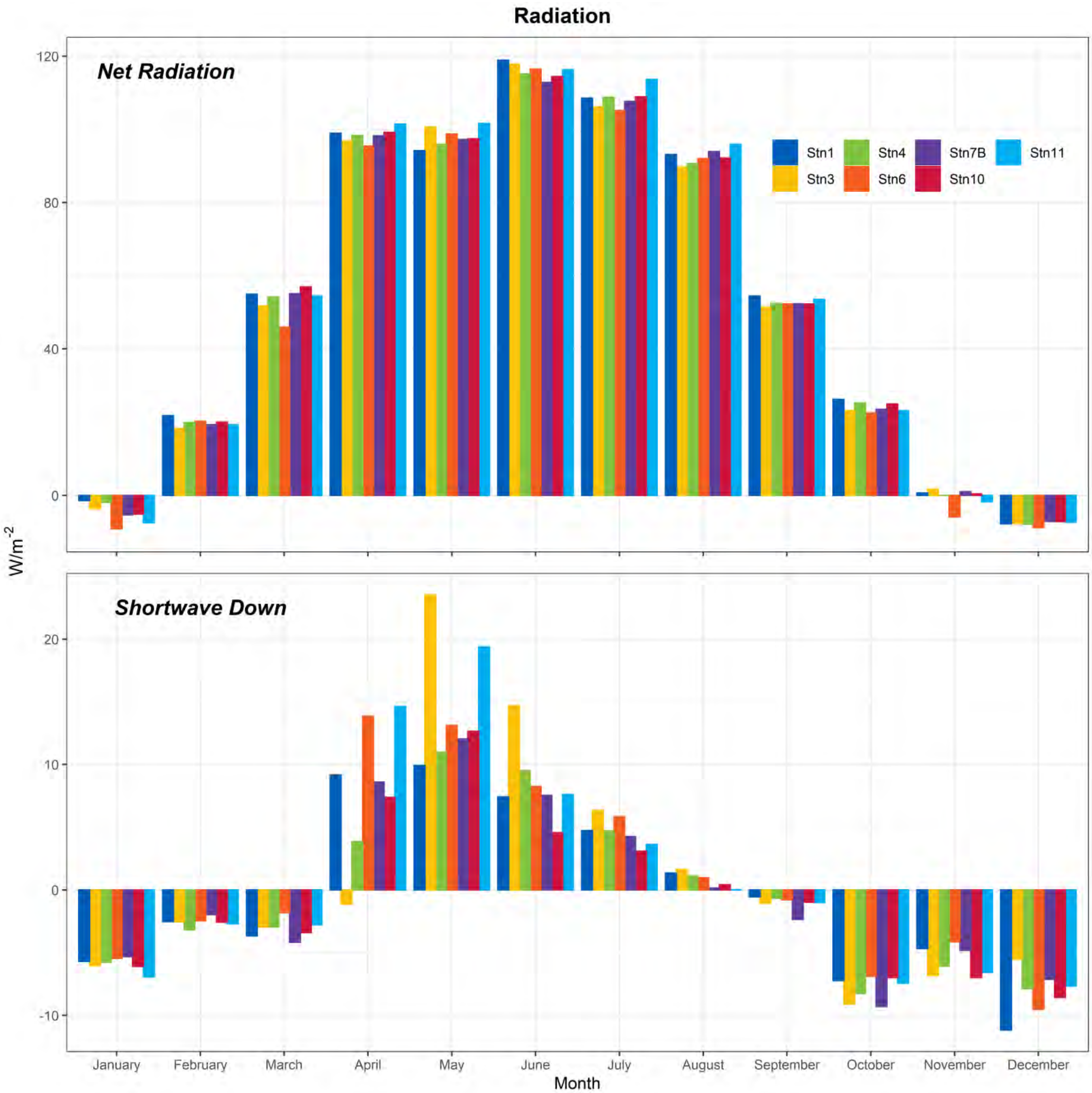



**Figure 3-1: Mean monthly net radiation and soil heat flux at all climate stations in 2020.**

Net-radiation components (incoming and outgoing short and longwave radiation) are only measured at Stations 1, 4, and 10, and differences are small between the Stations (Figure 3-2). One would expect incoming longwave radiation to be similar (likely controlled by regional weather patterns for the day). Differences in $R_n$ are likely due to differences in the surface absorption of long or shortwave radiation: where $R_n$ is higher, either of these outgoing components is lower. Increasing absorption of these components over vegetated land surfaces indicates that there is increasing biomass. Increasing live biomass results in faster rates of photosynthesis and more *ET*, assuming all other things remain the same.

- Wind speeds were highest at Stations 1, 3, 7, and 10. These stations are in more exposed locations and at higher elevations than the other stations. Higher wind speeds increase *ET* by moving moist air away from surfaces and increasing the moisture gradient.
- Mean monthly $T_a$ was highest at Stations 7B and 11 during the GS (Figure 3-3). These two stations are at the most southeasterly edge of the monitored area and close to the urban areas of Fort St. John and Taylor (Appendix A). Air temperature in May at Station 3 were very high because of multiple days of vegetation burning in preparation for planting after crops were left on the land likely due to high soil water and plant content in fall of 2019.
- Relative humidity (Figure 3-3) was highest at Station 11 (lowest elevation, close to Peace River) throughout the entire year, steadily increasing at all stations from a seasonal low in April (approximately 55%) to a high in December (75 – 85%).
- There was very little precipitation during the spring melt in March and April, while precipitation measurements during the GS were highest in June and July. The highest precipitation (Figure 3-3) at all stations was measured in June. Station 4 measured noticeably less than other stations, which is likely a reflection of the difference in localized rainfall capture during spatially variable high intensity rainfall associated with thunderstorms.
- The soil volumetric water content (VWC) throughout the GS was greatest at Station 4 and 10, likely in part due to the specific soil types at that location. This suggest that there would be less of a limitation to *ET*, and rates should be high at these stations. The VWC measurements at Station 3 were disconnected partway through May due to damage resulting from the stubble burning to prepare the land for planting.

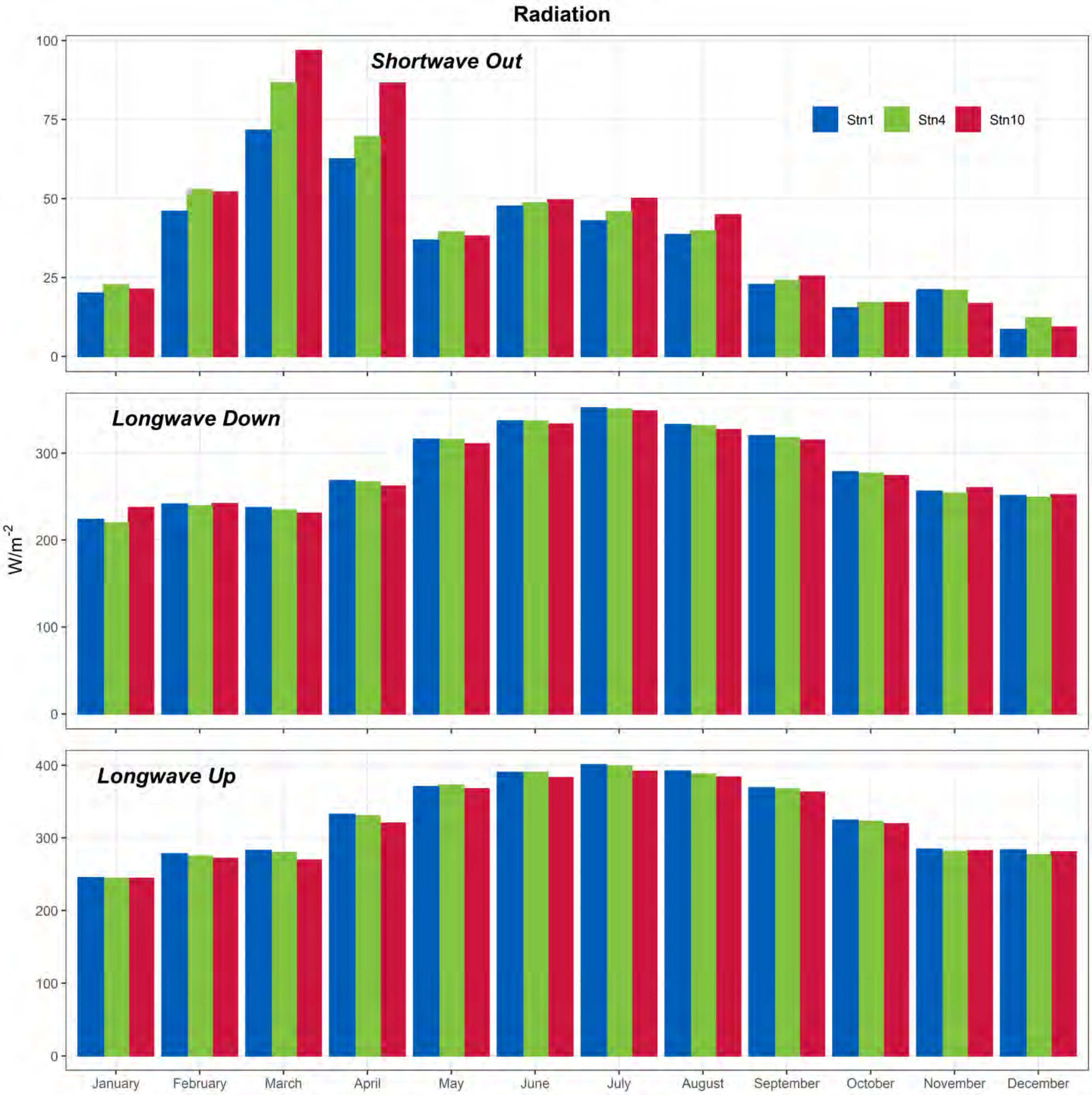



**Figure 3-2: Mean monthly radiation balance components measured at EC Stations 1 and 4 and climate Station 10 in 2020.**

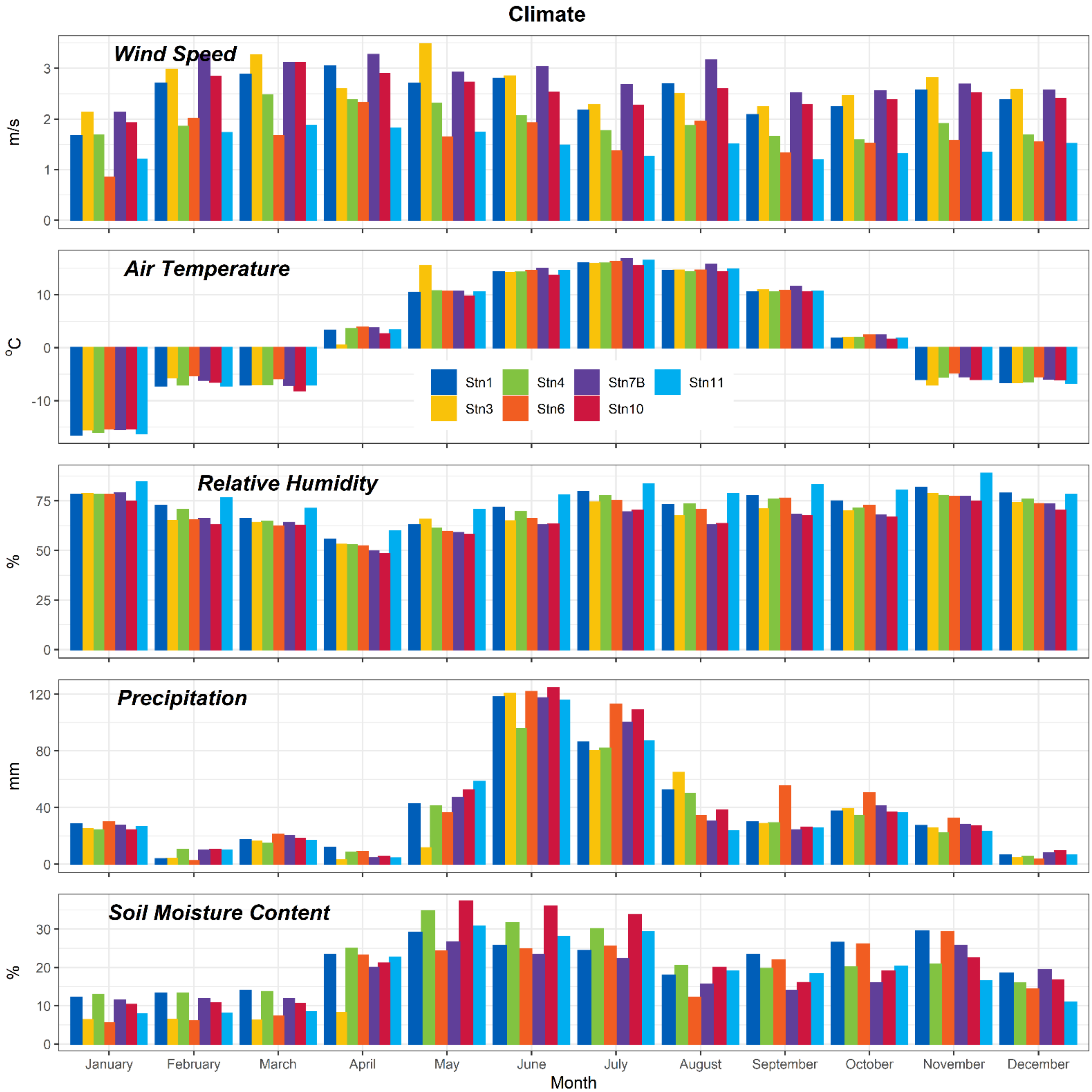



**Figure 3-3: Mean monthly wind speed, air temperature, relative humidity, cumulative monthly precipitation, and volumetric soil moisture content measured at all climate stations in 2020.**

## 3.2 Energy Balance Measurements and Evapotranspiration

Energy balance components at both EC stations followed similar trends throughout 2020 (Figure 3-4). The sensible heat flux (*H)* and soil heat flux (*G*) increased in April after the snow melted through March, while latent heat flux ($\lambda E$ denoted as *LE* in figures) and net radiation ($R_n$) followed an approximately sinusoidal trend throughout the year. Net radiation $R_n$ was on average greater at Station 1 than 4. Latent heat flux *LE* based on eddy covariance measurements was generally higher at Station 4 (Figure 3-5). These differences are likely due to differences in vegetation cover and soil type. It can be seen clearly in the monthly cumulative values (Figure 3-4) and from the annual cumulative values (Figure 3-5) that Station 4 maintains a more pronounced difference in *LE* towards the end of the GS. Cumulative evapotranspiration (*ET*) was greatest at Station 4, reaching 440 mm compared to 352mm at Station 1 with a difference of 88 mm, prior to energy balance closure (EBC) correction. The annual EBC values were 0.69 and 0.86 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of *ET* increases their values to 461 and 502 mm, respectively. This decreases the difference in annual cumulative *ET* between the two stations for 2020 to 41 mm. Figure 3-5 indicates that this has little impact on the seasonal trends and monthly differences.

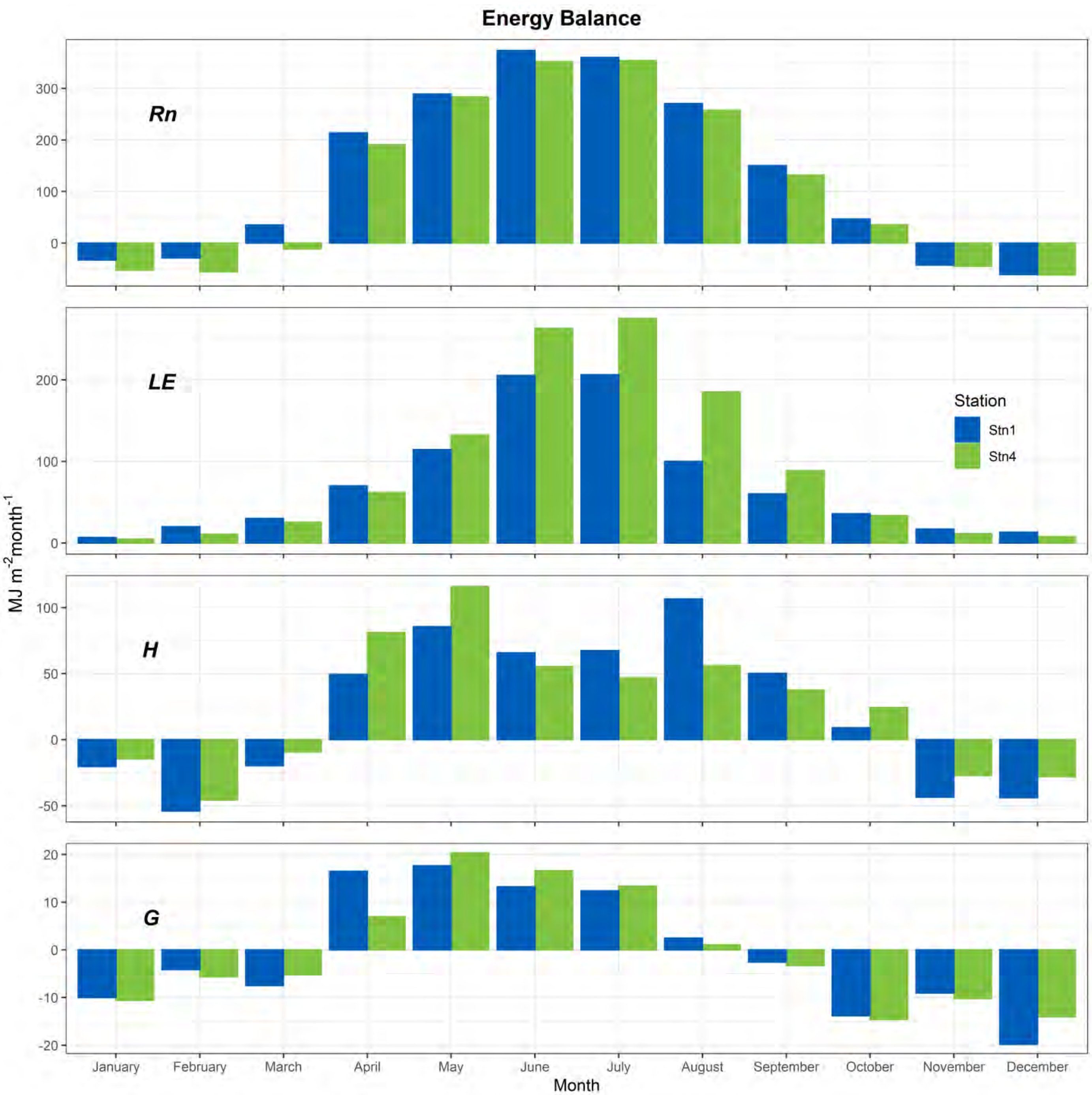



**Figure 3-4: Cumulative monthly energy balance components measured at EC Stations 1 and 4 in 2020.**

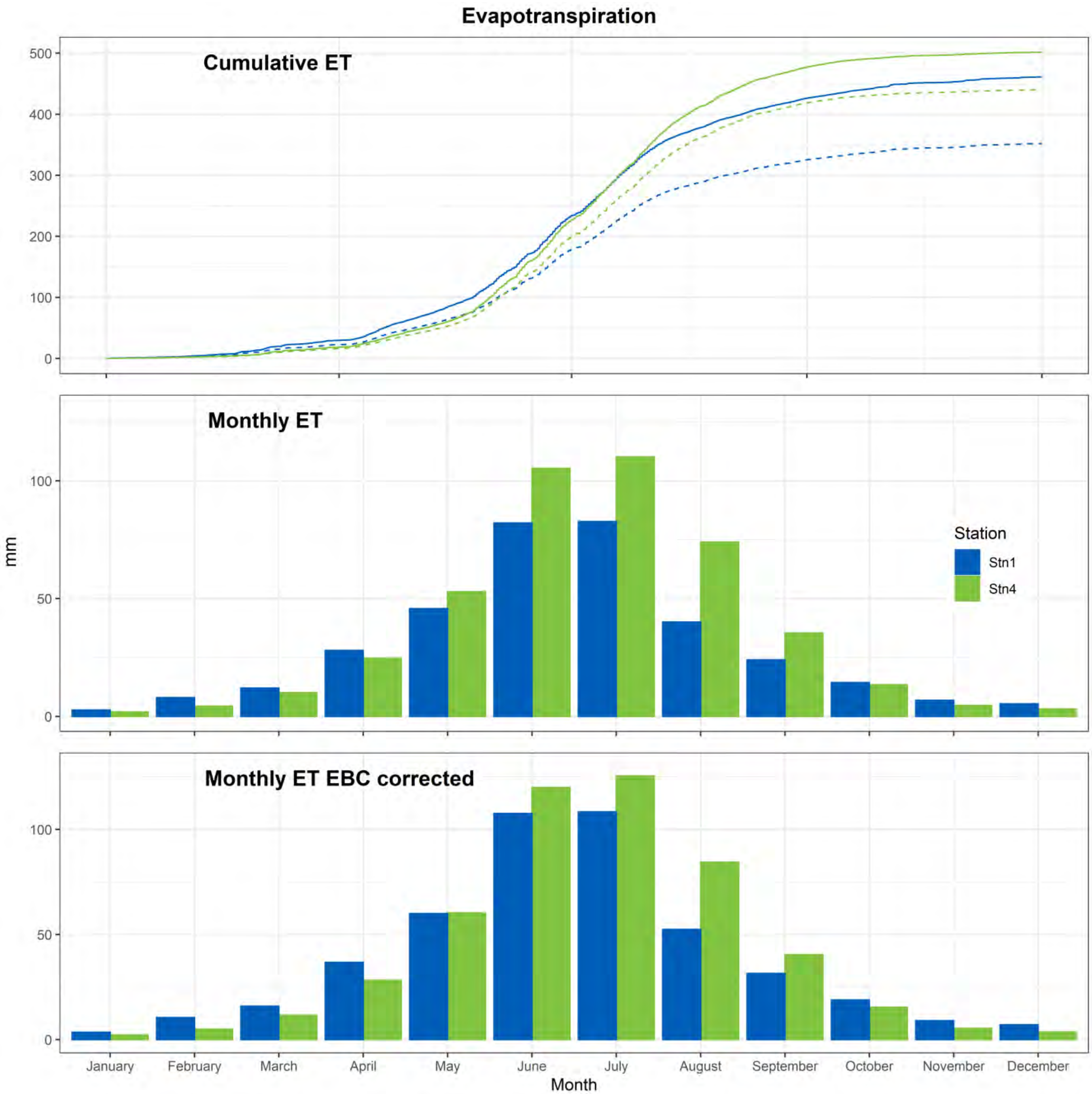



**Figure 3-5: Cumulative annual and monthly ET from EC measurements available at Stations 1 and 4 in 2020. Solid lines in Cumulative ET indicate energy balance closure applied.**

# 3.3 Modelled Evapotranspiration

The linear relationship between modelled *λE* (using the PT energy balance formulation, Section 2.2) and measured *λE* (using eddy covariance measurements, Section 2.1) is illustrated in Figure 3-6 for Stations 1 and 4, where EC measurements for *λE* were available. The PT model consistently over estimated *λE* on average by 95 and 85 W/m$^2$ over measured values at Stations 1 and 4, respectively, without EBC applied. The EBC correction reduced the differences to 79 and 75 W/m$^2$, respectively.

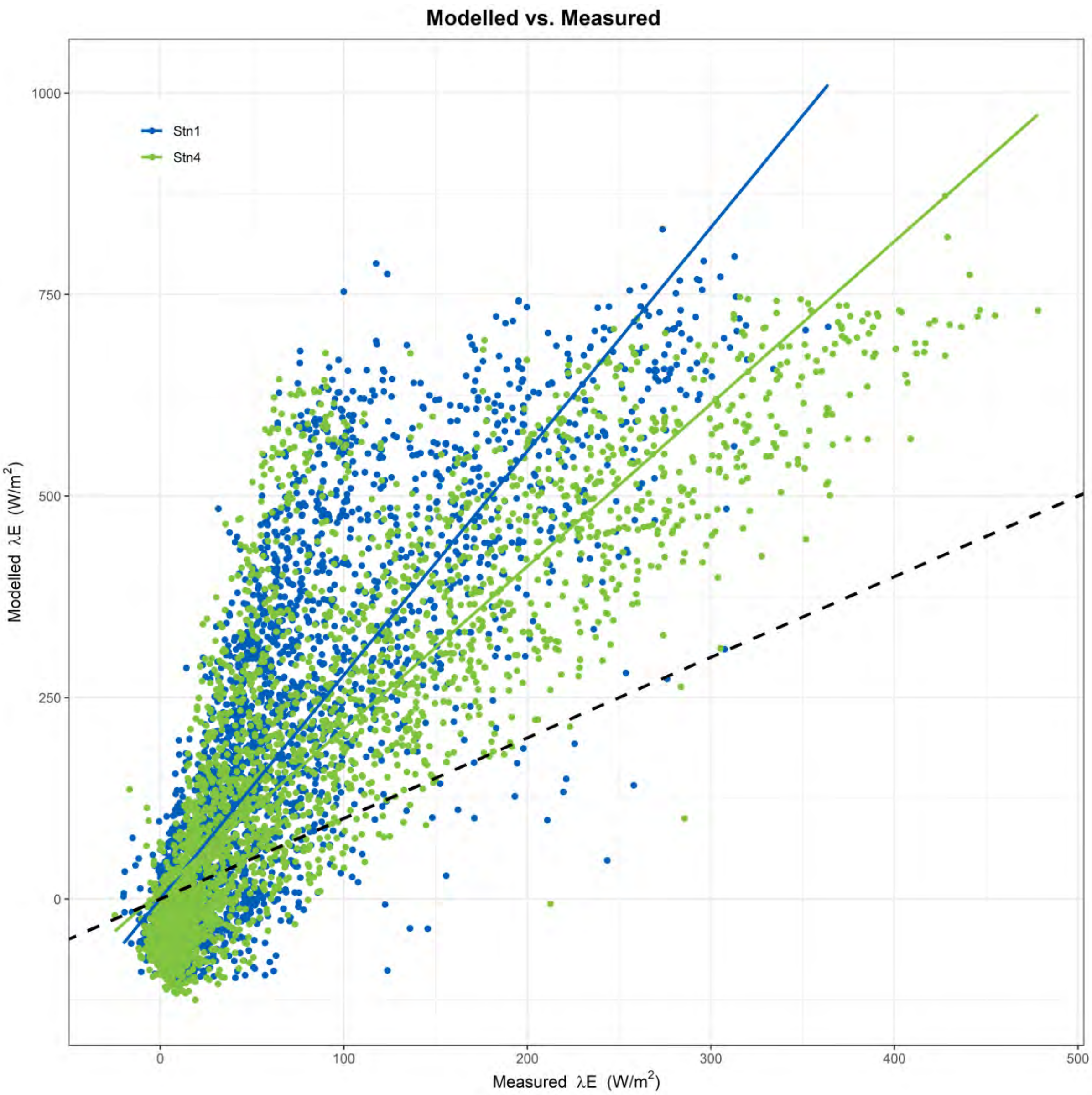



**Figure 3-6: Hourly measured *λE* vs. PT modelled *λE* in 2020. No EBC correction was applied. PT α value of 1.26 was used. The black dotted line is the 1:1 linear regression. Modelled values are consistently overestimated.**

Table 3-1 illustrates the differences in the two stations linear regression equations when comparing measured vs. modelled. The correlation coefficient remains the same regardless of EBC, while the slope is shown to be reduced with the correction applied. Prior to any corrections, the mean difference between modelled and measured estimated values of *ET* were 0.13 and 0.09 mm/h for Stations 1 and 4, respectively. After the EBC correction was applied, this difference was reduced to 0.11 and 0.08 mm/h at Stations 1 and 4, respectively. This reflects an improvement in the accuracy of the modelled estimate. Improvements in the correlation coefficient can be observed when the data is reduced to shorter intervals of time and indicate that the relationship between model parameters and the output changes over time. Figure 3-7 illustrates the differences when the GS months are split into 15-day intervals.

**Table 3-1: Modelled vs. measured $\lambda E$ linear regression output for 2020.**

| Station | α | γ | EBC | Intercept | Slope | $R^2$ | DF | *P* |
|---|---|---|---|---|---|---|---|---|
| **1** | 1.26 | 0.062 | 1 | 57.02 | 2.43 | 0.63 | 2440 | <2.2e-16 |
| **4** | 1.26 | 0.062 | 1 | 71.46 | 1.75 | 0.67 | 2268 | <2.2e-16 |
| **1** | 1.26 | 0.062 | 1.31 | 57.01 | 1.85 | 0.63 | 2440 | <2.2e-16 |
| **4** | 1.26 | 0.062 | 1.14 | 71.46 | 1.53 | 0.67 | 2268 | <2.2e-16 |
| **1** | 0.80 | 0.062 | 1.31 | 36.2 | 1.17 | 0.63 | 2440 | <2.2e-16 |
| **4** | 1.13 | 0.062 | 114 | 64.1 | 1.37 | 0.67 | 2268 | <2.2e-16 |

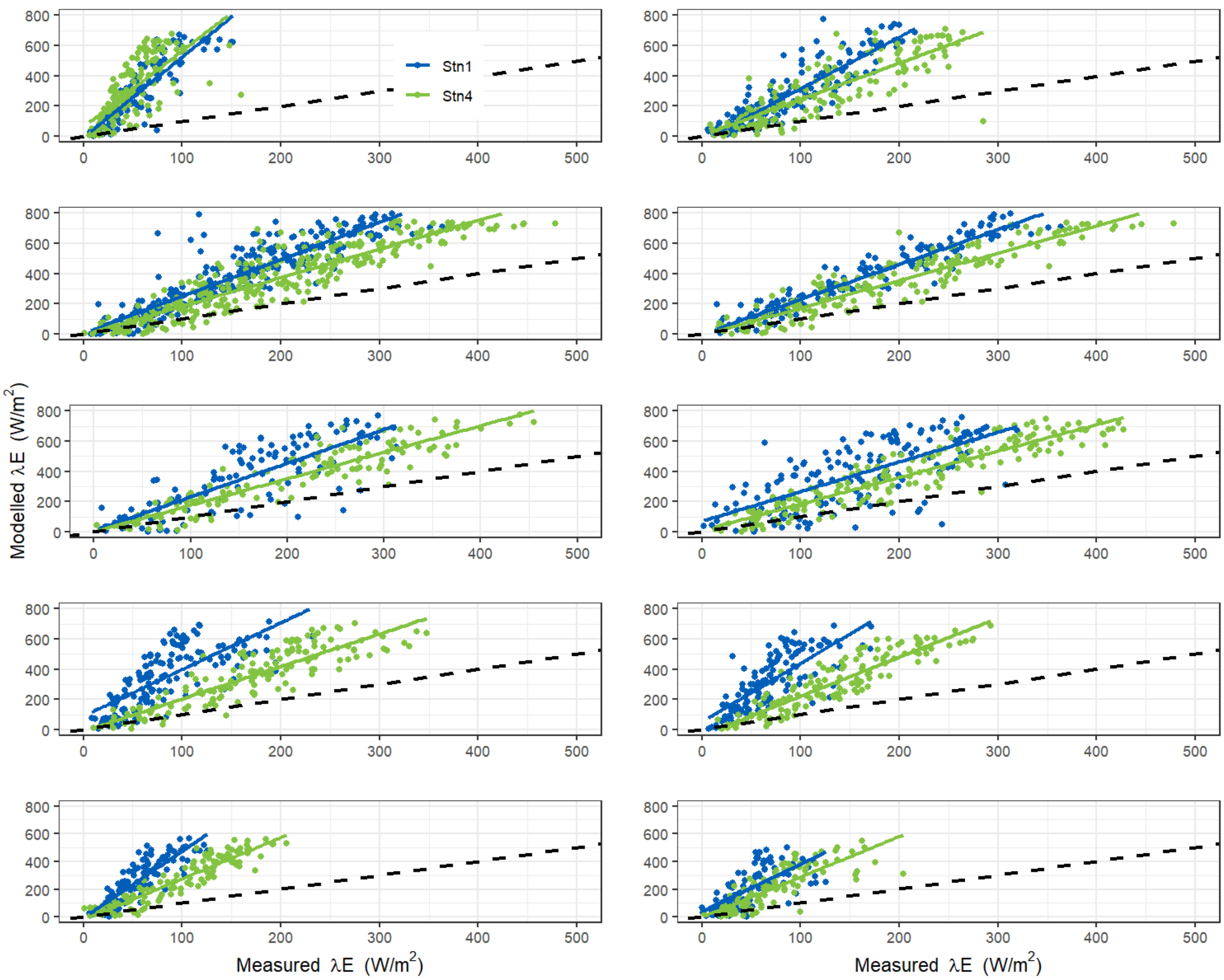



**Figure 3-7: Biweekly May through September 2020 (top left to bottom right panel) modelled vs measured LE linear relationship. The black dotted line is the 1:1 linear regression. Modelled values are consistently overestimated and less so during June and July**

PET calculated here is converted to actual *ET* using the PT α obtained from the EC systems. For this report, investigation of the PT α parameter was based on measured $LE_o$ during periods when soil moisture was well above field capacity, incoming energy was not limiting for plant growth, and the computed Bowen ratio indicated high LE relative to H (H/LE <0.3). From measurements during the GS, it was determined that PT α for Stations 1 and 4 were likely close to 0.80 and 1.13, respectively. These are lower than the literature-provided value of 1.26 (Davis & Davies, 1981), reflecting the difference in actual vs potential evapotranspiration. Using these new PT α values further reduces the difference in the modelled and measured estimate of *ET* for each station to a GS mean difference of 0.03 mm/h and 0.06 mm/h. This change can be seen to also reduce the slope and the intercept of the linear regression equations (Table 3-1). For this report, the mean α value of was used to model *ET* for all climate stations.

Adjustments to the PT α parameter remain to be investigated further as more data is accumulated. Furthermore, efforts are underway to provide a moving average computation of this parameter to better represent the phenological changes in the vegetation cover across the GS.

## 3.4 Climate Moisture Deficit

The hourly cumulative estimates of components and resulting CMD are presented in Figure 3-8. All estimates of *ET* and CMD are within ±10% of the mean values (Table 3-2). Station 4 had the highest CMD with more than 32 mm above the average by the end of the GS (299.6 mm). This was largely the result of Station 4 not receiving as much effective precipitation (*EP*) in June. The stations in decreasing order of CMD are 4, 11, 7, 3, 10, 1, and 6. Station 6 had the highest *EP* while Station 4 had the lowest (Table 3-2). At all stations, the *ET* values were larger than the *EP* values reported, and as such, there was a moisture deficit throughout the GS. The largest difference in *ET* was between Stations 1 and 11, with Station 1 estimated to be 14.2 mm below average and station 11 15.3 mm above the average. Station 11 *ET* picked up in July, when $T_a$ was high and $R_n$ was greatest at this station (Figure 3-1). The periodic influence of *EP* on CMD can be seen by the saw-toothed increase, whereas *ET* had a diminishing rate through the GS (Figure 3-8). The low *EP* at Station 4 (139.6 mm) and above average *ET* throughout the GS resulted in that station having the largest CMD.

**Table 3-2: Cumulative GS CMD and climate controls and mean air temperature in 2020.**

| Station | Percentage Data Cover | *Rn* | *Ta* | *EP* | *ET* | CMD |
|---|---|---|---|---|---|---|
| **1** | 98.4 | 93.9 | 13.2 | 139.6 | 389.1 | **249.5** |
| **3** | 99.75 | 94.4 | 13.1 | 146.8 | 410.1 | **263.4** |
| **4** | 99.9 | 92.7 | 13.1 | 106.7 | 406.2 | **299.6** |
| **6** | 100 | 93 | 13.4 | 153.1 | 393.5 | **240.9** |
| **7** | 100 | 93 | 13.9 | 131.3 | 403.7 | **272.3** |
| **10** | 100 | 93.2 | 12.7 | 149.7 | 402.2 | **252.5** |
| **11** | 100 | 96.4 | 13.4 | 121.8 | 418.6 | **296.8** |
| **Average** | **99.7** | **93.8** | **13.3** | **134.1** | **403.3** | **267.9** |

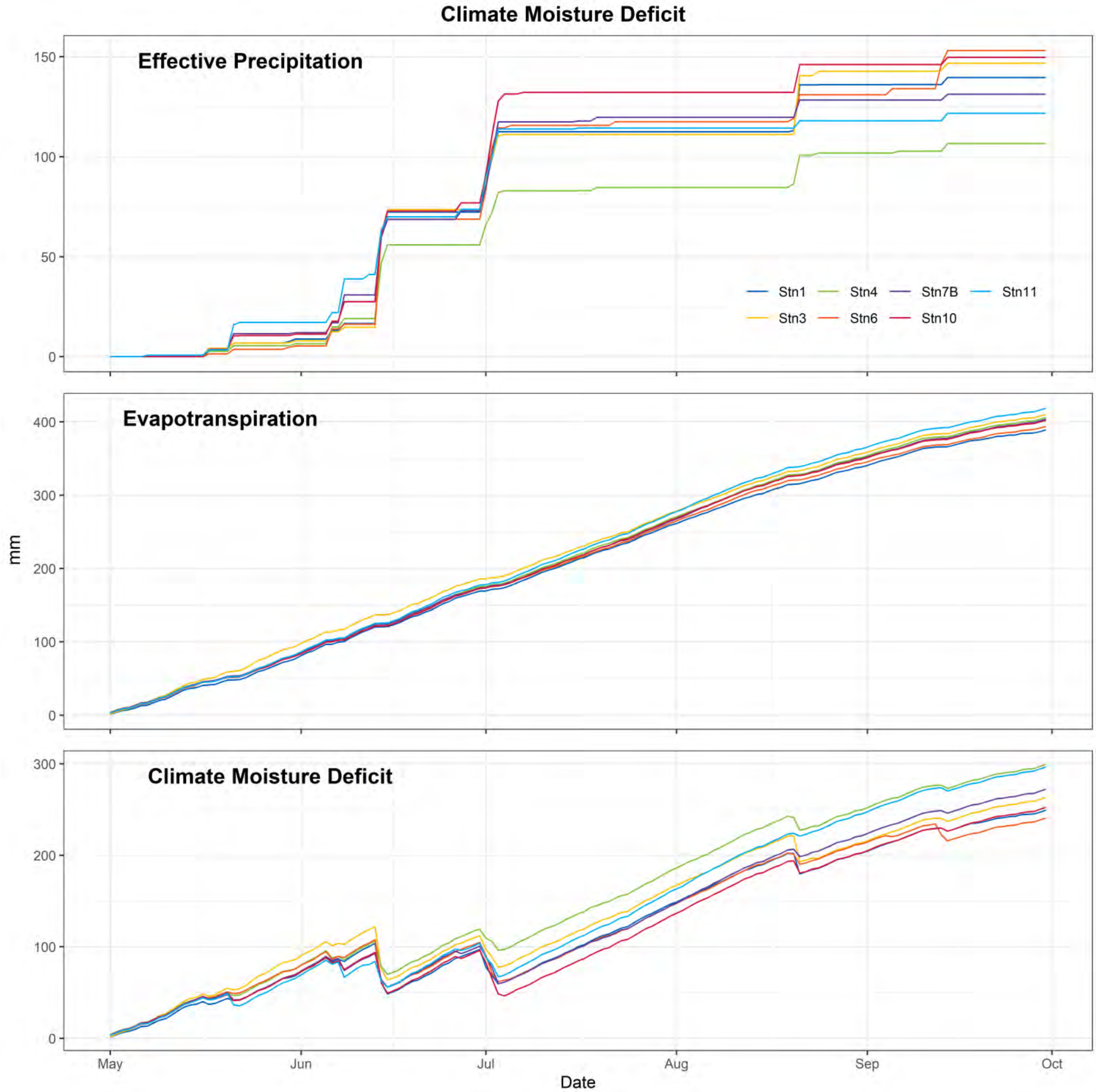



**Figure 3-8: Modelled daily EP, ET and the CMD for all climate stations in 2020.**

During the GS, the CMD can be calculated monthly or on request to inform interested parties on potential water deficit and the need for irrigation in the region. As more data becomes available, statistical analysis of the different controlling variables and PT model parameters (α) on CMD will be possible. A retro-active analysis of previous years of data already collected is an option.

## 3.5 Crop Drying Model

The CDM was run for each month of the GS and the total number of good drying days (drying rate > wetting rate) was calculated (Table 3-3) for each station. Figure 3-9 through Figure 3-13 show the computed inputs and CDM output for each month. Monthly good drying days were similar across the growing season with the highest average recorded during the warm and dry month of August. June recorded the lowest good drying days likely because of the wet start to that month at all stations. The order of stations with increasing cumulative annual good drying days is 1, 6, 7B, 10, 3, 11, and 4, with Station 4 having 6 more additional good drying days compared to Station 1.

**Table 3-3: Growing season good drying days in 2020.**

| Station | May | Jun | Jul | Aug | Sep | GS Total |
|---|---|---|---|---|---|---|
| **1** | 25 | 26 | 27 | 27 | 24 | **129** |
| **3** | 27 | 25 | 26 | 28 | 28 | **134** |
| **4** | 26 | 25 | 27 | 28 | 29 | **135** |
| **6** | 26 | 26 | 26 | 27 | 27 | **132** |
| **7B** | 27 | 26 | 26 | 27 | 26 | **132** |
| **10** | 25 | 26 | 27 | 28 | 26 | **132** |
| **11** | 27 | 25 | 26 | 28 | 28 | **134** |
| **Averages** | **26.1** | **25.6** | **26.4** | **27.6** | **26.9** | **132.6** |

Stations 3, 7, and 11 had the most good drying days in May (27), and Station 3 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-9). Stations 1 and 10 had the fewest good drying days in May with only 25 each. The drying rate at Station 1 started off slowly in May, while at Station 10 the drying rate dropped off late in the month, and Station 3 received more of the last precipitation event in the month. Station 1 was the last station where crop moisture content was reduced below 20%.

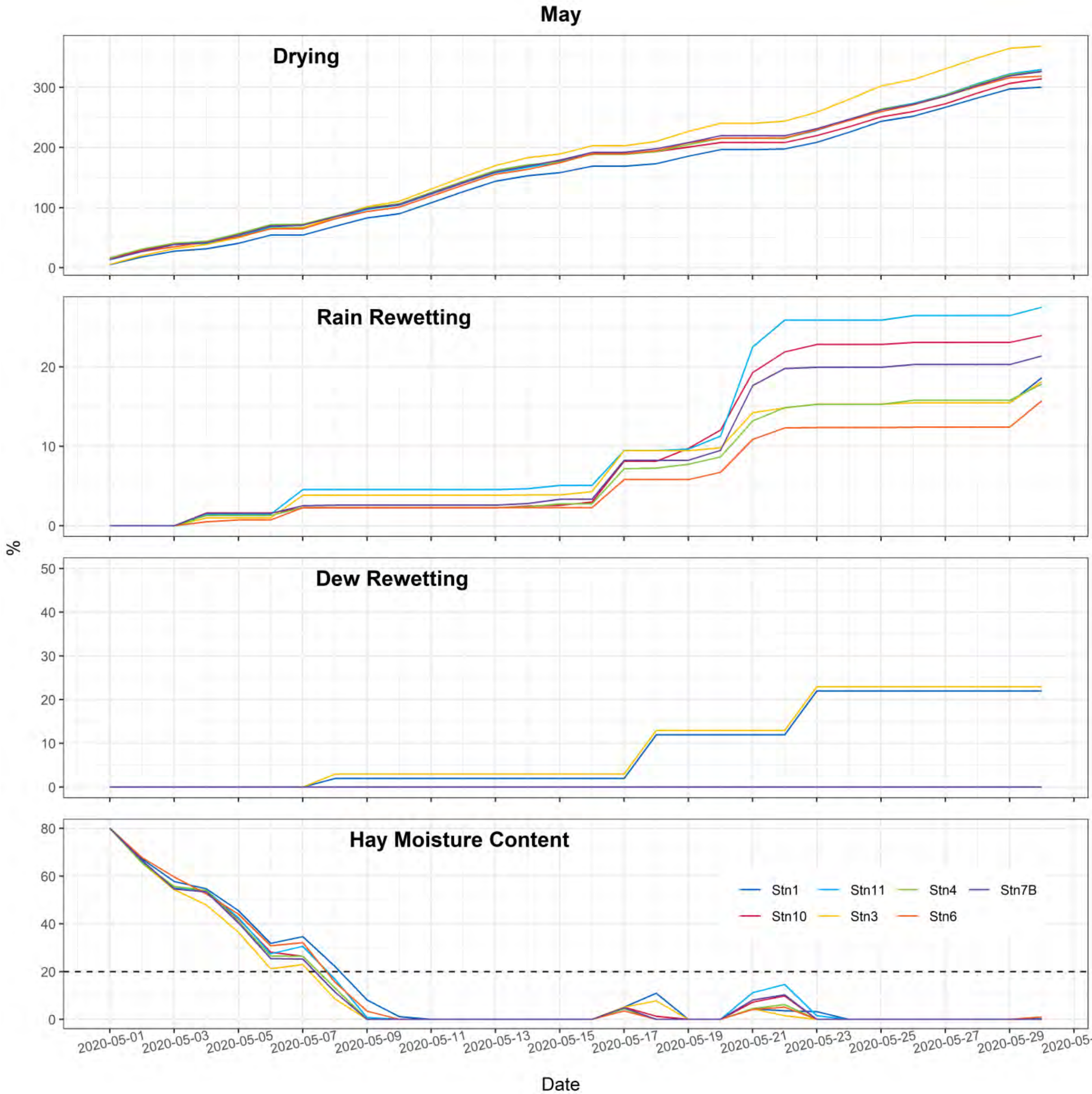



**Figure 3-9: CDM components for May 2020.**

The month of June had on average of 25.6 good drying days. Stations 1, 6, 7, and 10 had the highest number of good drying days with 26 each, while Station 4 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-10). Stations 3, 4, and 11 had below average numbers of good drying days. Stations 10 and 11 were the last stations where crop moisture content was reduced to below 20%, likely due to the lower drying rate at Station 10 and the higher rain and dew rewetting at Station 11.

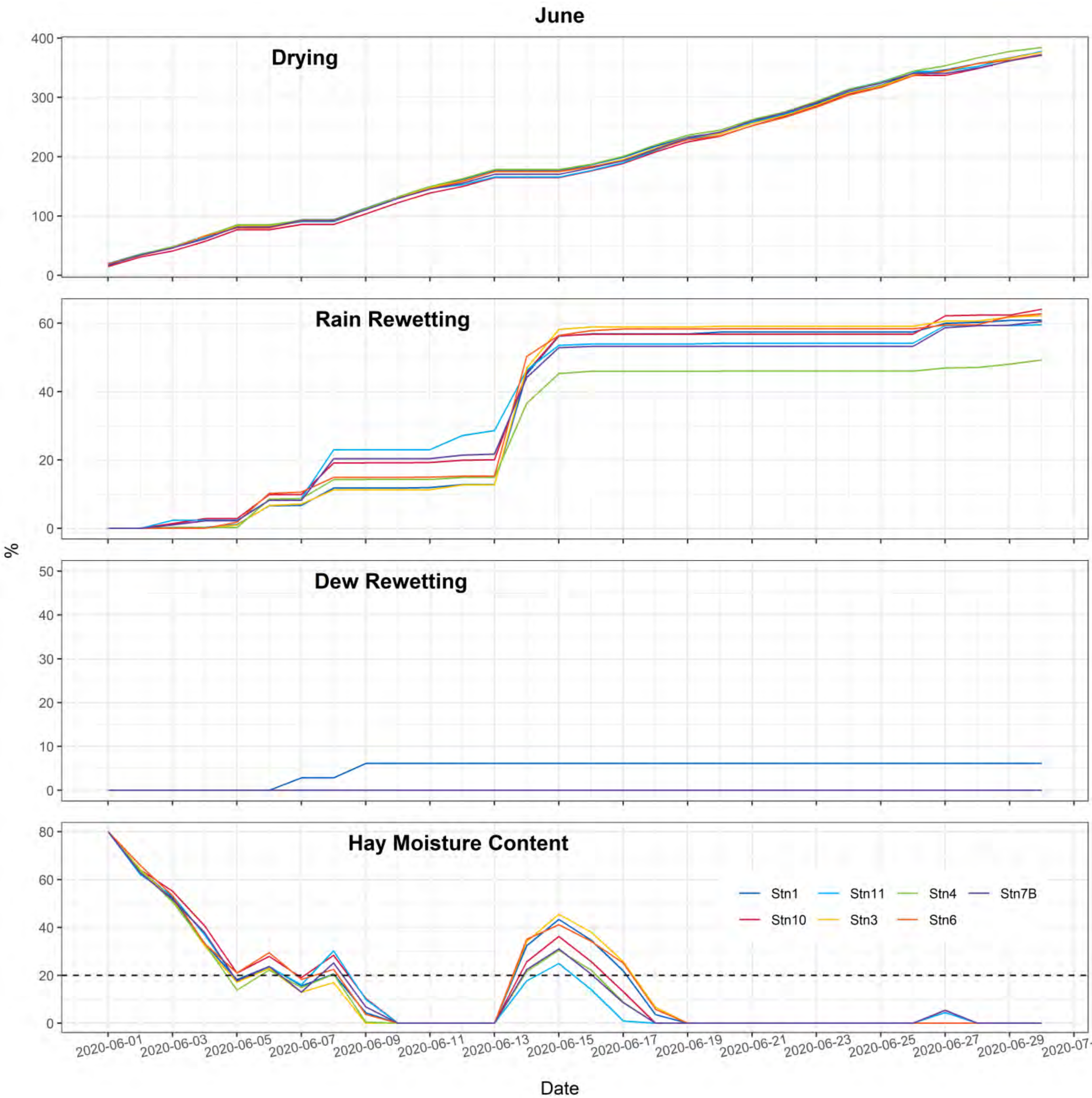



**Figure 3-10: CDM components for June 2020.**

July had on average 26.4 good drying days. Stations 1, 10, and 4 had the highest number of good drying days with 27 each, while Station 11 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-11). Stations 3, 6, 7, and 11 had 26 good drying days. Station 6 recorded the lowest drying rate and greatest wetting rate and was the last station where crop moisture content was reduced to below 20%.

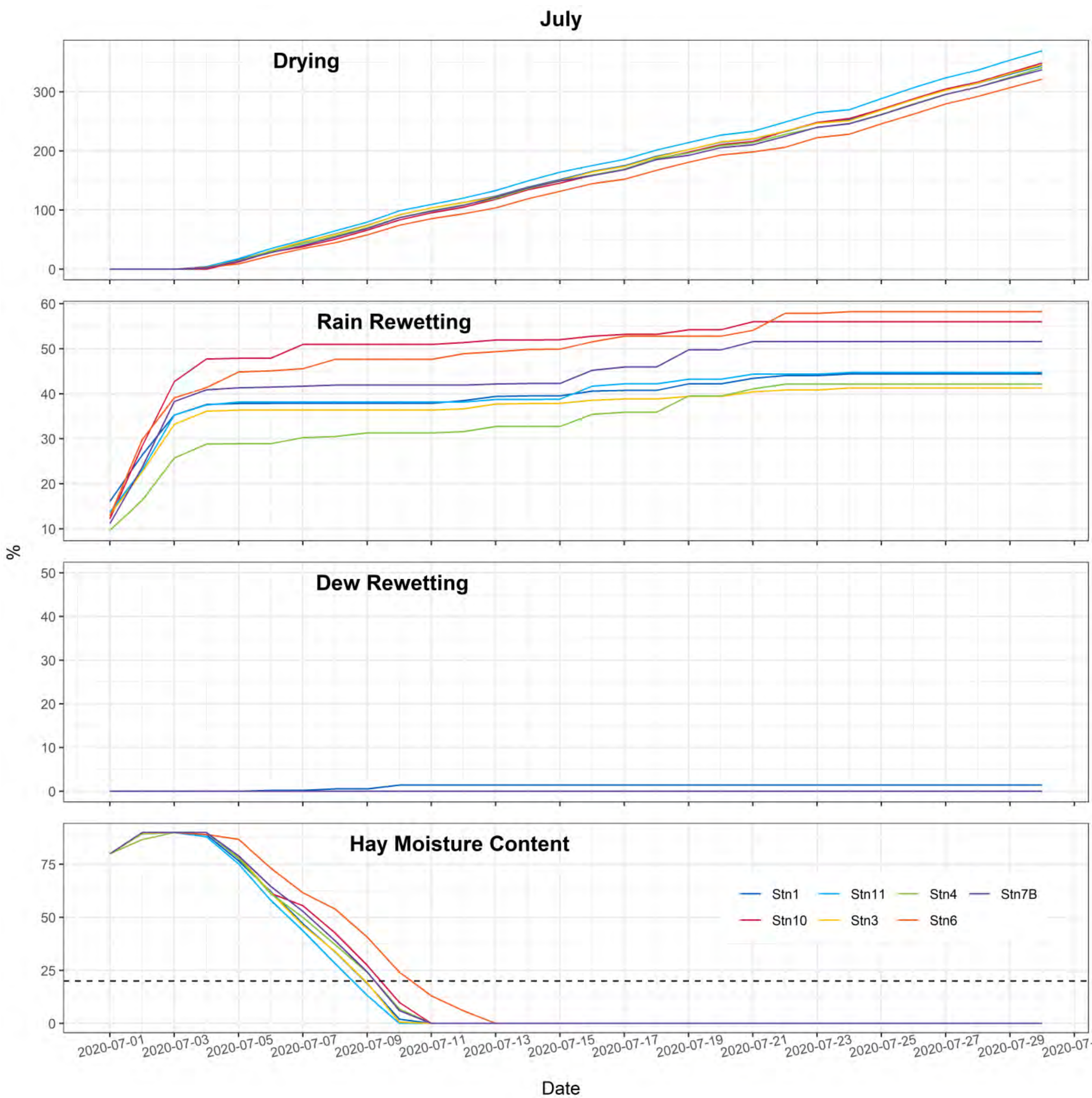



**Figure 3-11: CDM components for July 2020.**

The month of August had on average 27.6 good drying days. During August Stations 3, 4, 10, and 11 had the highest number of good drying days with 28 each, and Station 11 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% (Figure 3-12). Stations 1, 6, and 7 had the fewest good drying days with 27 each. Stations 3 and 4 were the last stations where crop moisture content was reduced to below 20%.

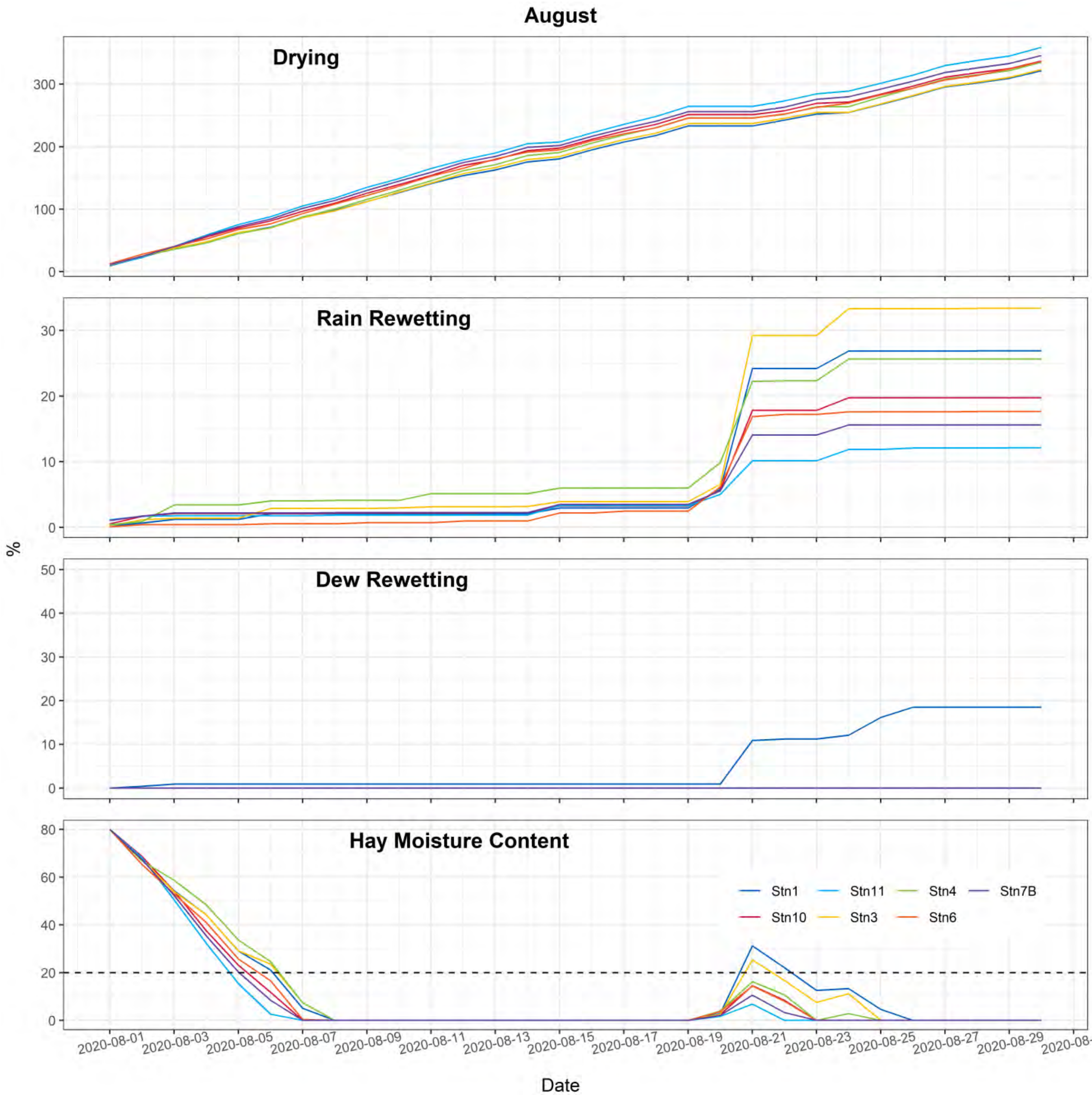



**Figure 3-12: CDM components for August 2020.**

September had on average 26.9 good drying days. Station 4 had the highest number of good drying days with 29 followed by Stations 3 and 11 with 28 good drying days each. Station 11 maintained the fastest drying rate and was the first station where crop moisture content was reduced to below 20% (Figure 3-13). Station 1 had the fewest good drying days on record with only 24 in September because of significant dew rewetting during that month. Station 6 recorded the lowest drying rate and greatest wetting rate and as a result was the last station where crop moisture content was reduced to below 20%.

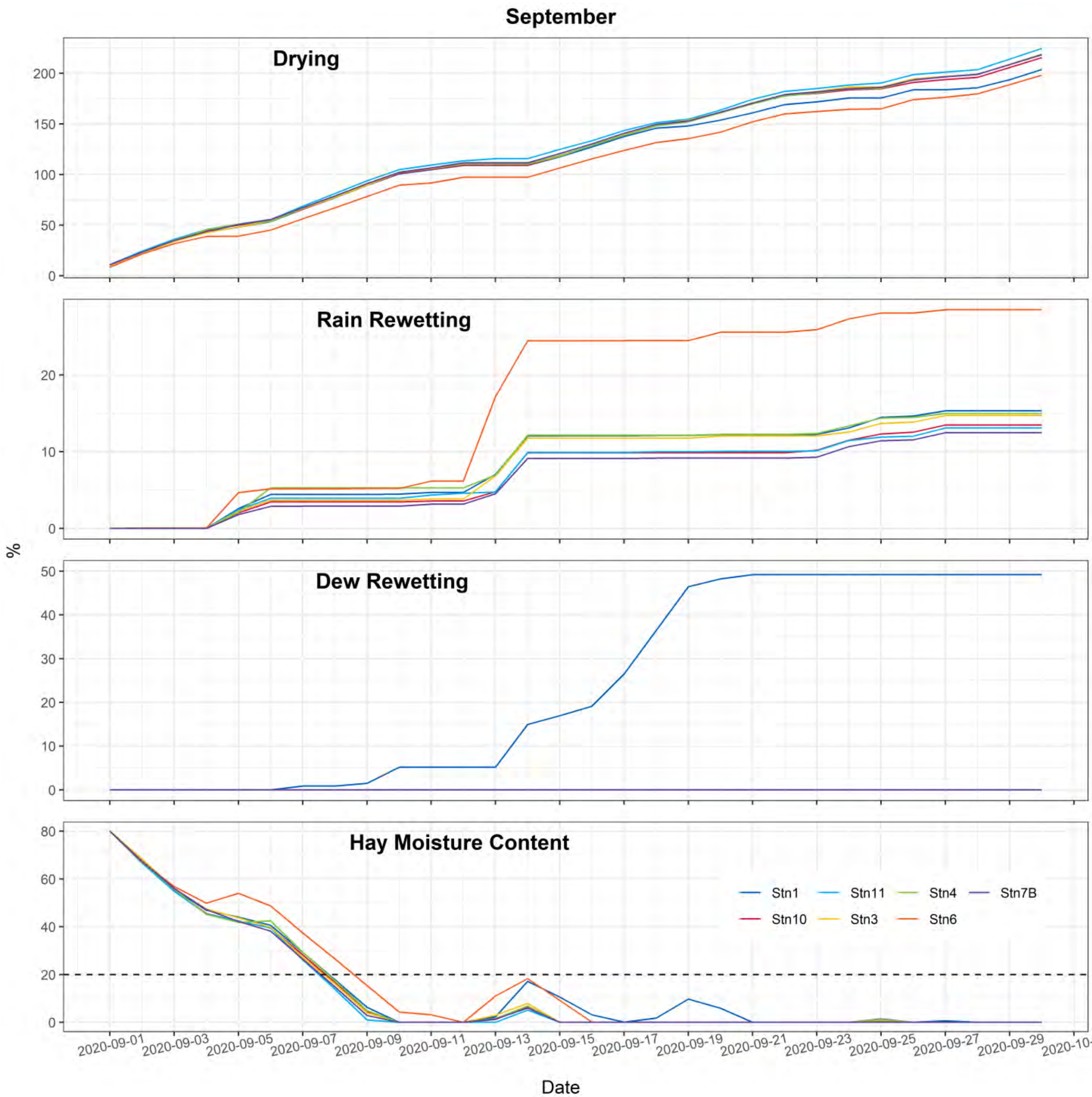



**Figure 3-13: CDM components for September 2020.**

Comparatively to the CMD results, Stations 4 and 11 had the highest number of good drying days recorded. Station 4 consistently had low to mid-range rain rewetting and a moderate to high drying rate in all months. Station 11 had low to moderate rain rewetting rate and the highest drying rate.

The monthly plots shown above are helpful in illustrating the drying trends within that month and can be provided monthly after data QA/QC has been completed. With harvest timing input from farmers along with an estimate of the starting wet weight moisture content of the crop, drying computations can be created and used to provide input on crop drying conditions in the region. A retro-active analysis of previous years of data already collected is also an option.

# 4 SUMMARY OF RESULTS

The EC system performance for collected high frequency data was over 75% for both EC stations, and the daily collection of half-hour computed fluxes and climate data resulted in a 100% data representation for 2020. Main line power outages were the only cause for data loss.

Climatologically, 2020 was wet and warm. Climate differences between all study stations are the result of differences in elevation, aspect, exposure, vegetation cover, and soil type. Stations at higher elevations recorded higher wind speeds. Station 11 had consistently high monthly net radiation throughout the GS and was higher in July and August than other stations. Station 4 received the least precipitation during the GS, while it maintained a high volumetric water content.

The EC measured and PT modelled cumulative *ET* was greatest at Station 4, reaching 440 mm compared to 352mm at Station 1 with a difference of 88 mm, prior to EBC. The annual EBC values were 0.69 and 0.86 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of *ET* increases their values to 461 and 502 mm, respectively. This decreases the difference in annual cumulative *ET* between the stations for 2020 to 41 mm.

The PT proportionality constant (α) was used to provide an estimate of actual *ET* from PET estimates made using the PT radiation-based approach. A common value recommended for this constant is 1.26. From measurements during the GS, it was determined that PT $\alpha$ for Stations 1 and 4 were closer to 0.81 and 1.13, respectively. Linear regression analysis showed that while the correlation of the relationship between measured vs. modelled values did not change, using this new α reduced the slope of the relationship and further improved the accuracy of the model output. An average value of 0.965 was selected to improve the accuracy of modelled *ET* at all climate stations where EC measurements were not available. Testing both the PET and the actual *ET* estimates for each climate station in the network, it was possible to compute drying indices as input for the CMD and CDM for each location.

A spatial summary of CMD results is presented along with the station location map in Appendix A. Station 4 had the highest CMD with more than 32 mm above the average by the end of the GS (299.6 mm). The stations in decreasing order of CMD are 4, 11, 7, 3, 10, 1, and 6. During the GS, all stations experience moisture deficit because *ET* > *EP*. Stations 11, 3, and 4 had the highest annual *ET* of 418.6 mm, 410.1 mm, and 401.3 mm, respectively. The low *EP* at Station 4 (106.7 mm) contributed to it having he largest CMD.

Output from the CDM was used to compute the cumulative good crop drying days for each month and station. Based on this output, August had the highest number of good drying days averaged across stations. June had the lowest average cumulative good drying days with 25.6 because of an extended rainfall event early in the month. In line with the CMD results, Station 11 had the fastest drying rates, while Station 4 recorded less precipitation in May, June, and July.

# 5 REFERENCES

Amiro, B.D., Barr A.G., Black T.A., Iwashitad H., Kljun N., McCaughey J.H., Morgenstern K., Murayama S., Nesic Z., Orchansky A.L., and Saigusa N. 2006. Carbon, energy and water fluxes at mature and disturbed forest sites, Saskatchewan, Canada. Agricultural and Forest Meteorology: 136, 237–251.

Baldocchi, D.D. 2003. Assessing the eddy covariance technique for evaluating carbon dioxide exchange rates of ecosystems: past, present and future. Global Change Biology: 9, 479–492.

Barr, A.G., Black, T.A., Hogg, E.H., Kljun, N., Morgenstern, and Nesic. 2004. Inter-annual variability in the leaf area index of a boreal aspen-hazelnut forest in relation to net ecosystem production. Agricultural and Forest Meteorology: 126, 237–255.

Barry Tompkins. 2019. Landowner. Telephone conversation September 6, 2019.

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013.

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013. Volume 3, Appendix D Agricultural Assessment, Supporting Documentation. Appendix A. Climatic Moisture Deficit MD Calculations.

Brown M., Black T.A., Nesic Z., Foord V.N., Spittlehouse D.L., Fredeen A.L., Grant N.J., Burton P.J., Trofymow J.A. 2010. Impact of mountain pine beetle on the net ecosystem production of Lodgepole pine stands in British Columbia. Agricultural and Forest Meteorology: 150, 254-264.

Davis, R. and J. Davies. 1981. Potential evapotranspiration in the Peace River Region of British Columbia. Atmosphere-Ocean 19: 251-260.

Dyer, J.A. and D.M. Brown (1977). A climatic simulator for field-drying hay. Agricultural Meteorology, 18:37-48.

Krishnan, P., Black, T.A., Grant, N.J., Barr, A.G., Hogg, E.H. Jassal, R.S., and Morgenstern, K, 2006. Impact of changing soil moisture distribution on net ecosystem productivity of a boreal aspen forest during and following drought. Agricultural and Forest Meteorology: 139, 208–223.

Morgenstern, K., Black, T.A., Humphreys, E.R., Griffis, T.J, Drewitt, G.B., Cai, T., Nesic, Z., Spittlehouse, D.L., and Livingston, N.J. 2004. Sensitivity and uncertainty of the carbon balance of a pacific northwest Douglas-fir forest during an el Niño/La Niña cycle. Agricultural and Forest Meteorology: 123, 201–219.

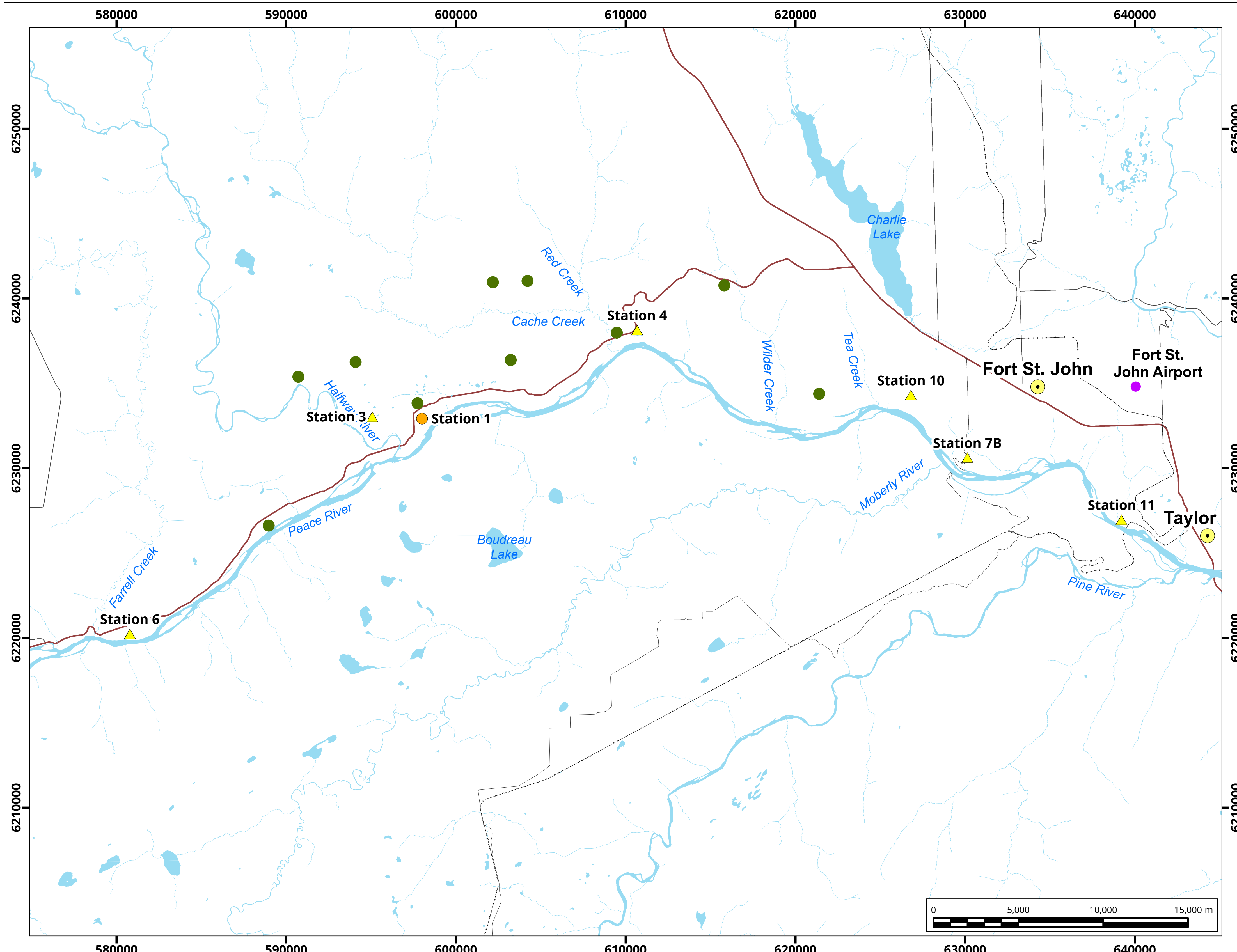
Priestley, C. and R. Taylor. 1972. On assessment of surface heat flux and evaporation using large-scale parameters. Monthly Weather Review 100: 81-92.

RWDI AIR Inc. 2020. Site C Climate and Air Quality Monitoring: 2019 Annual Report. RWDI Project Number 1601625.

Wilson K, et al. 2002. Energy balance closure at FLUXNET sites. Agricultural and Forest Meteorology: 113:223-243.

# APPENDIX A

The 2020 GS CMD and its components EP and *ET* are presented in units of mm in Figure A-1. Also presented are the CDM results shown as the cumulative good growing days (GGD). The results are displayed beside the station location and can be compared to the 2020 regional average computed using all stations (top left corner). Red indicates values that were greater than the 2020 regional average and blue indicates values that were below that amount.




## Legend

- Farm Interview Homes
- Meteorological and AQ
- Meteorological Only
- Environment Canada Meteorological Sta
- City/District Municipality

| Station Number | Station Name | EP | ET | CMD | GDD |
|---|---|---|---|---|---|
| 1 | Attachie Flat Upper Terrace | 139.6 | 389.1 | 249.5 | 129 |
| 3 | Attachie Plateau | 146.8 | 410.1 | 263.4 | 134 |
| 4 | Bear Flat | 106.7 | 406.2 | 299.6 | 135 |
| 6 | Farrell Creek | 153.1 | 393.5 | 240.9 | 132 |
| 7B | Site C North Camp | 131.3 | 403.7 | 272.3 | 132 |
| 10 | Tea Creek | 149.7 | 402.2 | 252.5 | 132 |
| 11 | Taylor | 121.8 | 418.6 | 296.8 | 135 |
| | **Average** | **134.1** | **403.3** | **267.9** | **132.6** |

Service Layer Credits: Hydrological and transportation data retrieved from Geogratis, 2021.

**Station and Farm Interview Home Locations**

Map Projection: NAD 1983 UTM Zone 10N

True North

Project #: 2102352

Drawn by: DJH | Figure: A-1

Approx. Scale: 1:250,000

Date Revised: Jul 9, 2021

# APPENDIX B

**Station 1. May through August. Grasses tilled in August. Crop harvested in October 1st.**

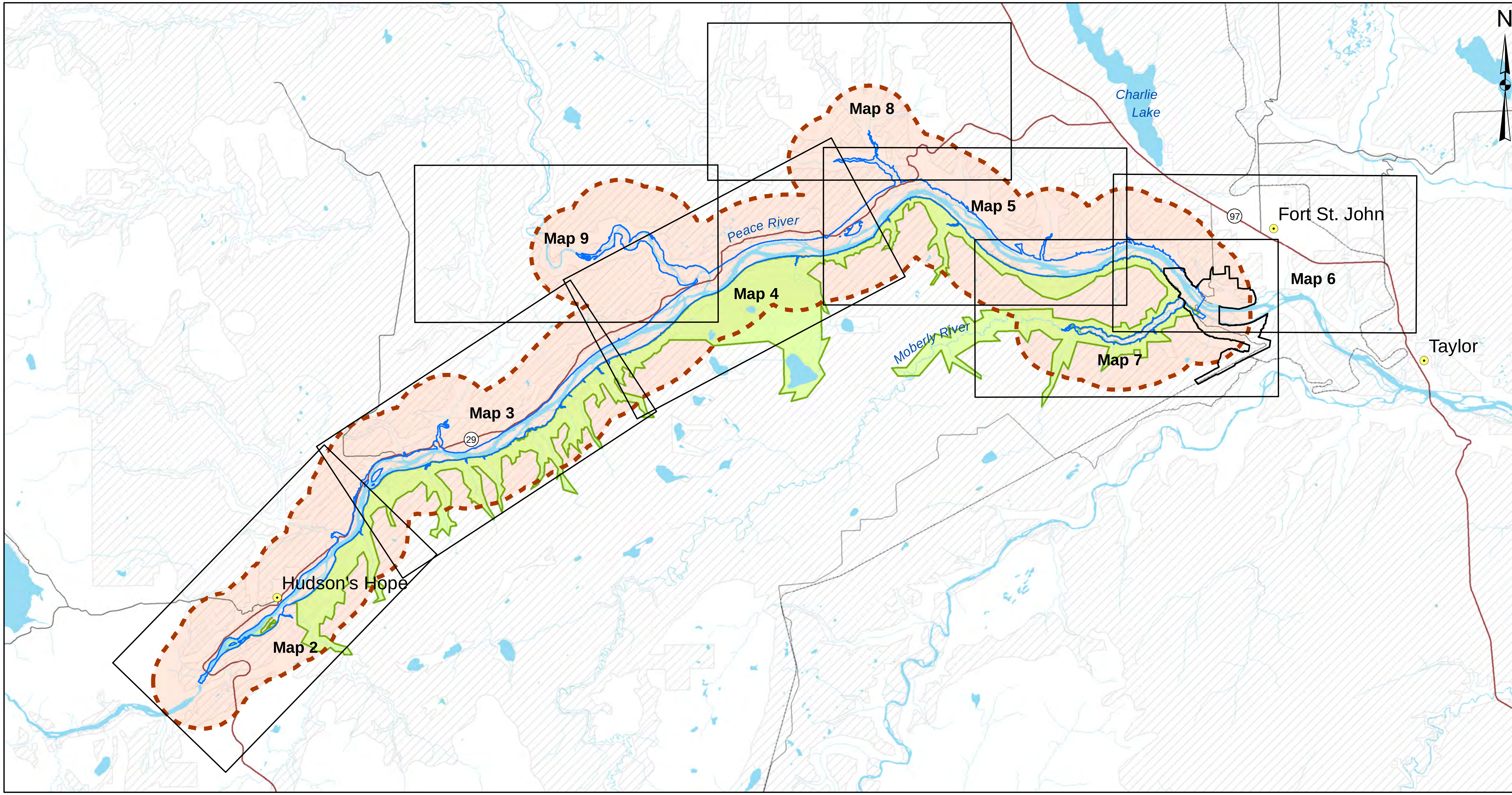
**Station 3. May, June.**

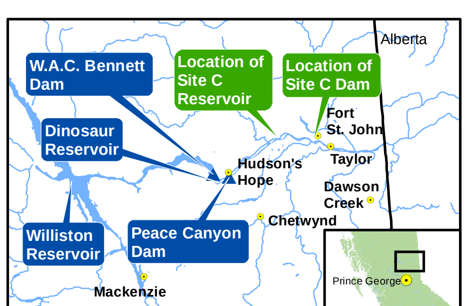
**Station 4. May, June, July**

**Station 6. June, July**

**Station 10. No station visits during the 2020 GS. Image from July 2019. Field management the same in 2020.**

**Station 11. August**




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area
- Town
- Road
- Highway
- Railway

1:250,000

0 5 km

BC Hydro

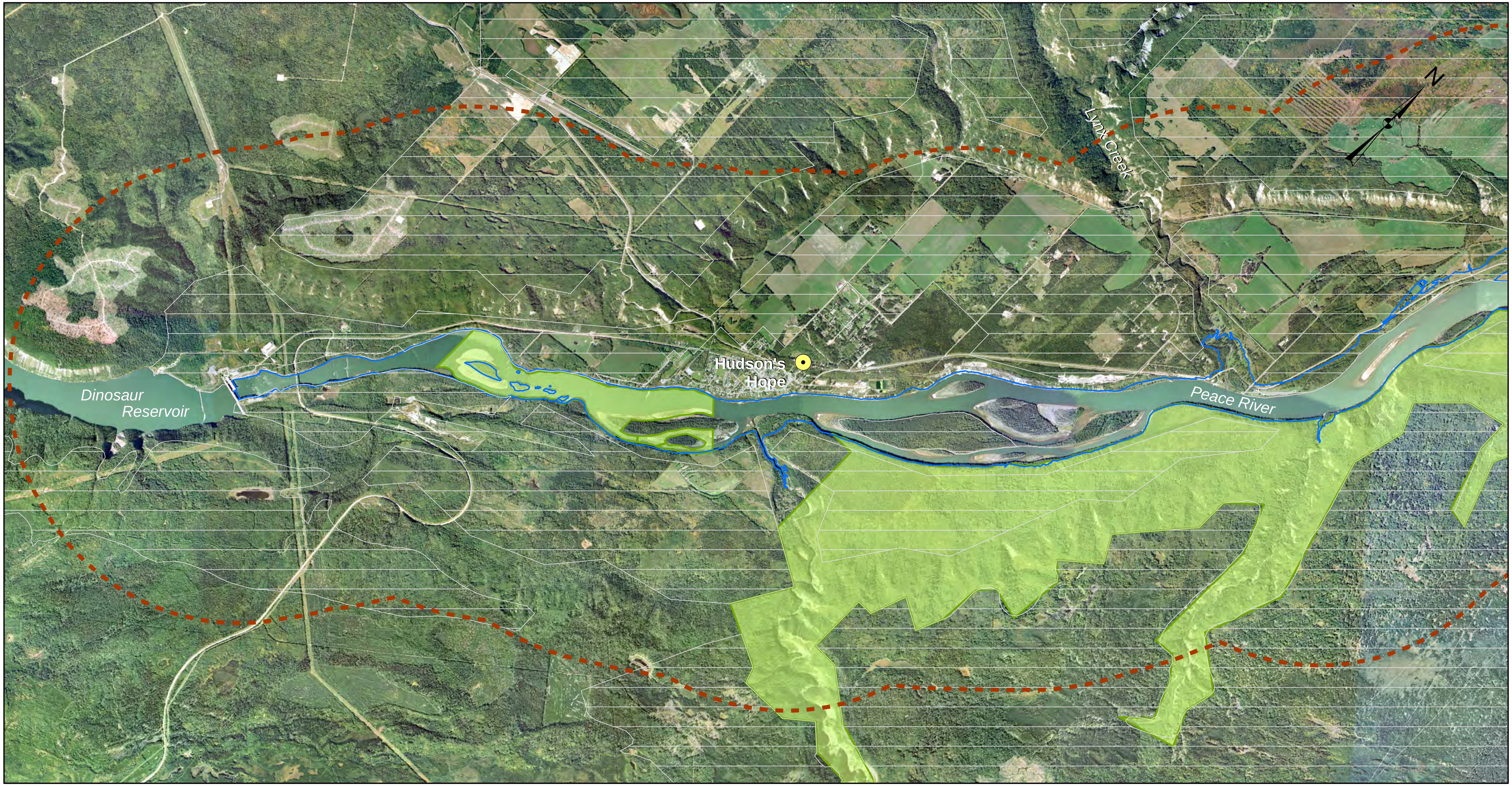
**Crop Drying Monitoring Area Identification - Overview Map 1 of 9**

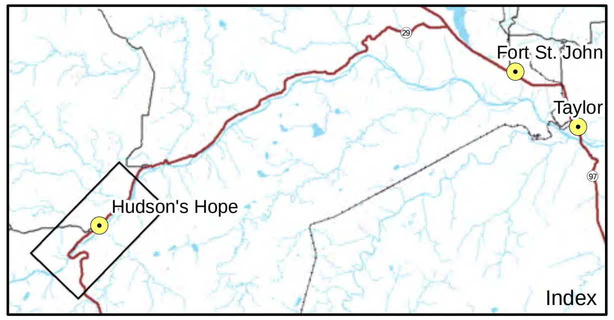
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-1 | R 0 |
|---|---|---|---|---|



Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_Overview_1016_C14_07342-1.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 — 2 km

BC Hydro

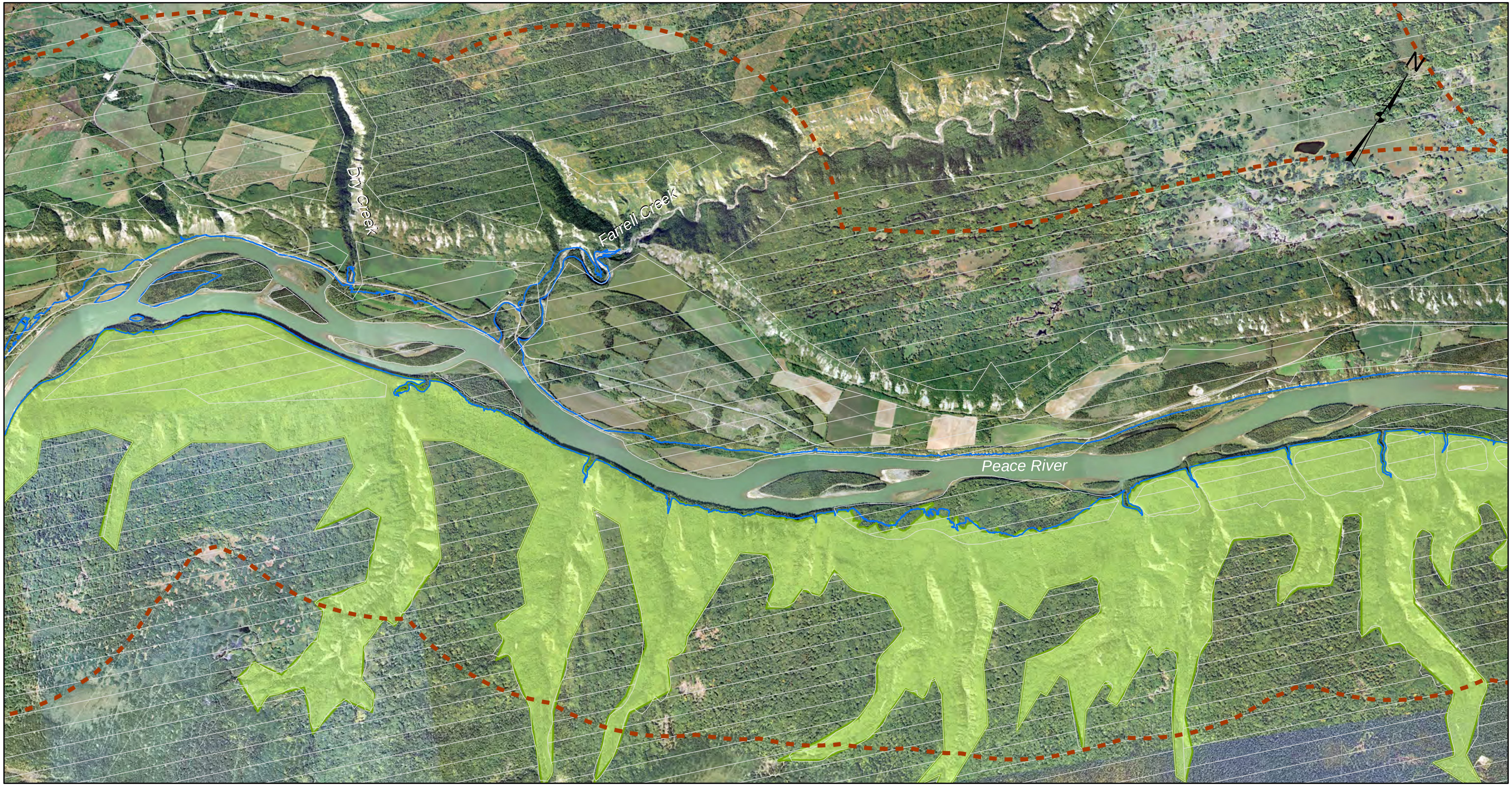
**Crop Drying Monitoring - Area Identification Map 2 of 9**

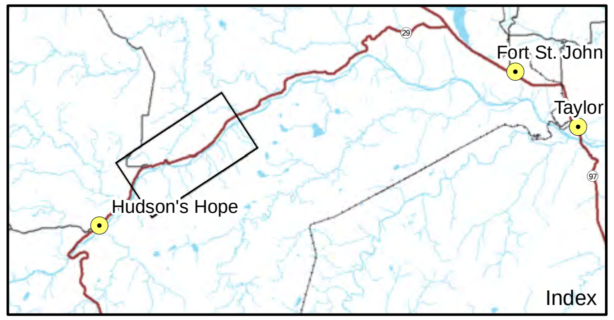
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-2 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGIS\Projects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

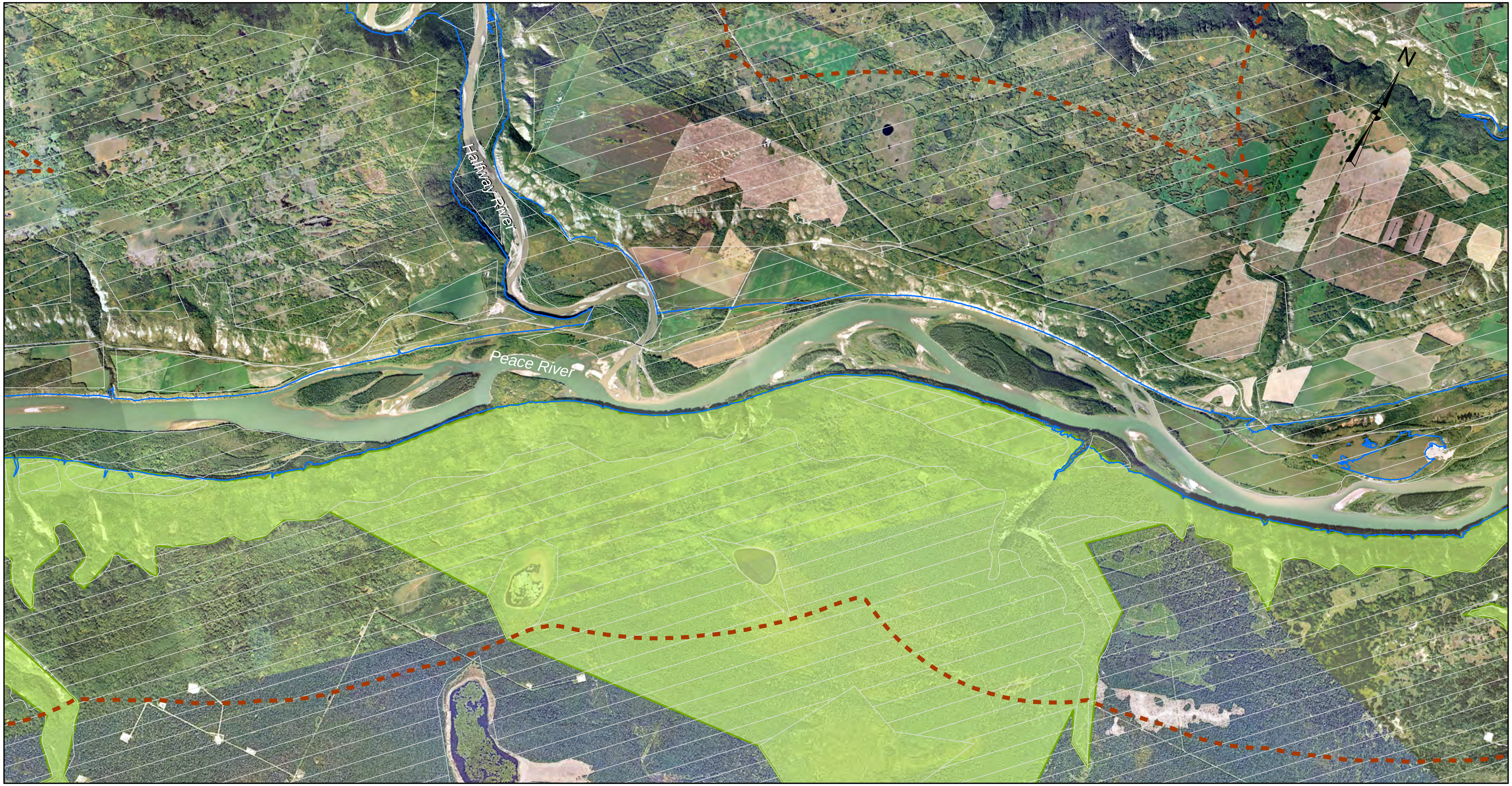
BC Hydro

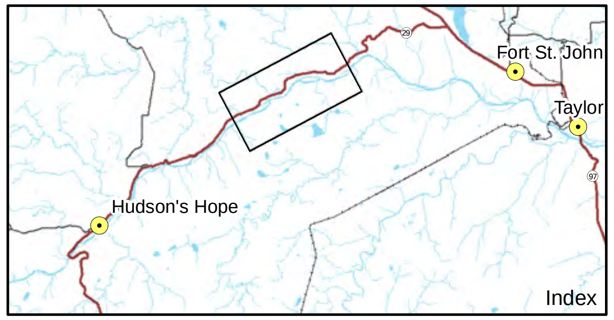
**Crop Drying Monitoring - Area Identification Map 3 of 9**

| Date | July 14, 2016 | DWG NO | 1016-C14-07342-3 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGIS\Projects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

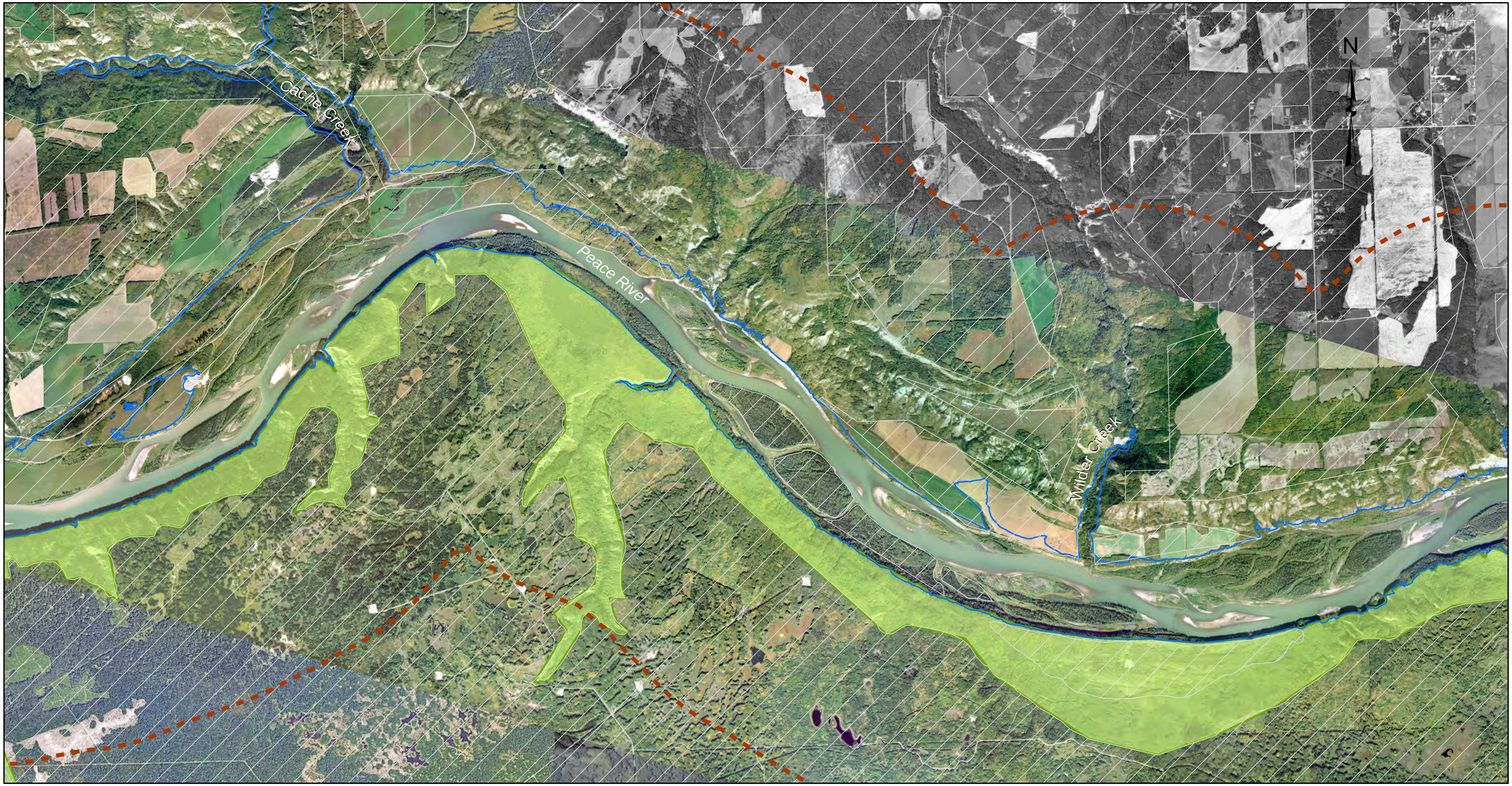
**Crop Drying Monitoring - Area Identification Map 4 of 9**

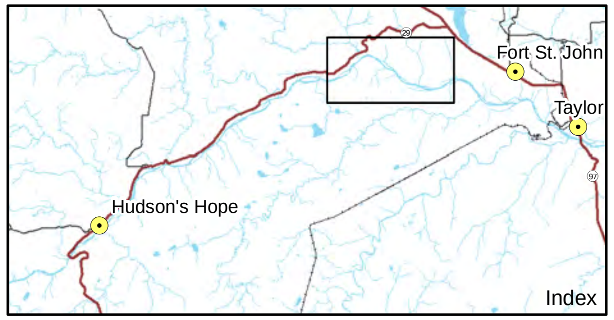
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-4 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

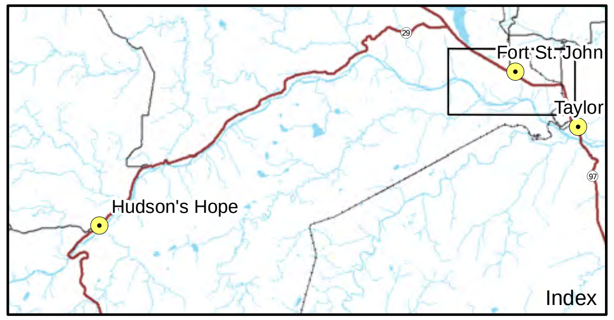
BC Hydro

**Crop Drying Monitoring - Area Identification Map 5 of 9**

| Date | July 14, 2016 | DWG NO | 1016-C14-07342-5 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd


Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

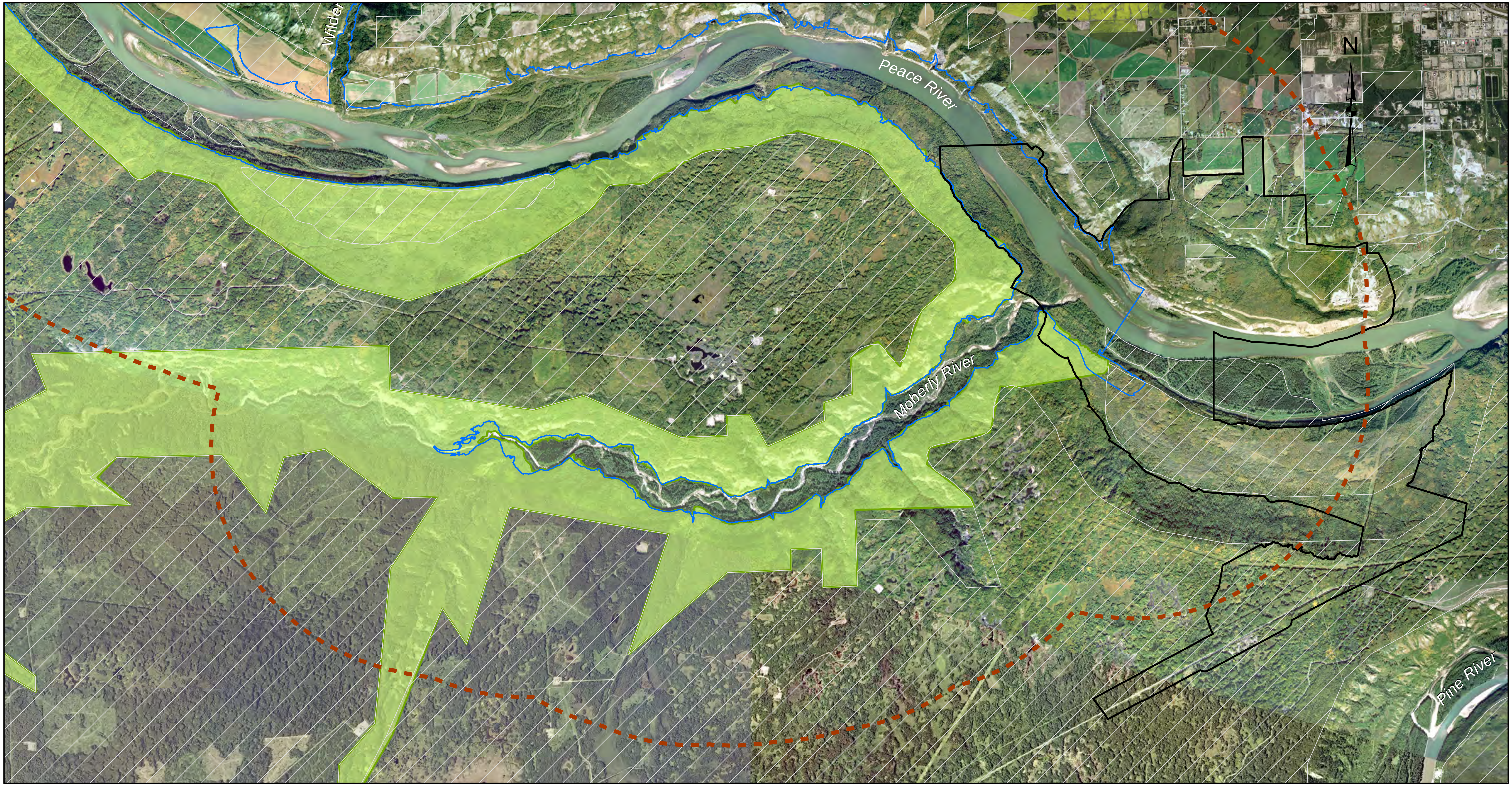
**Crop Drying Monitoring - Area Identification Map 6 of 9**

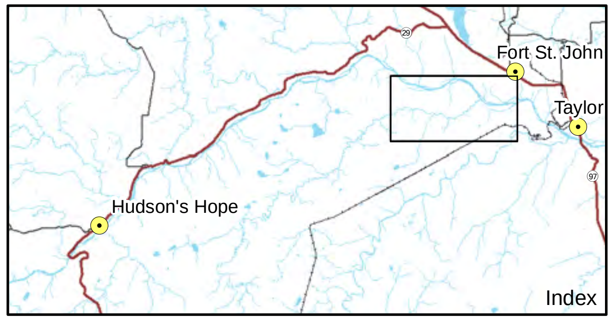
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-6 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

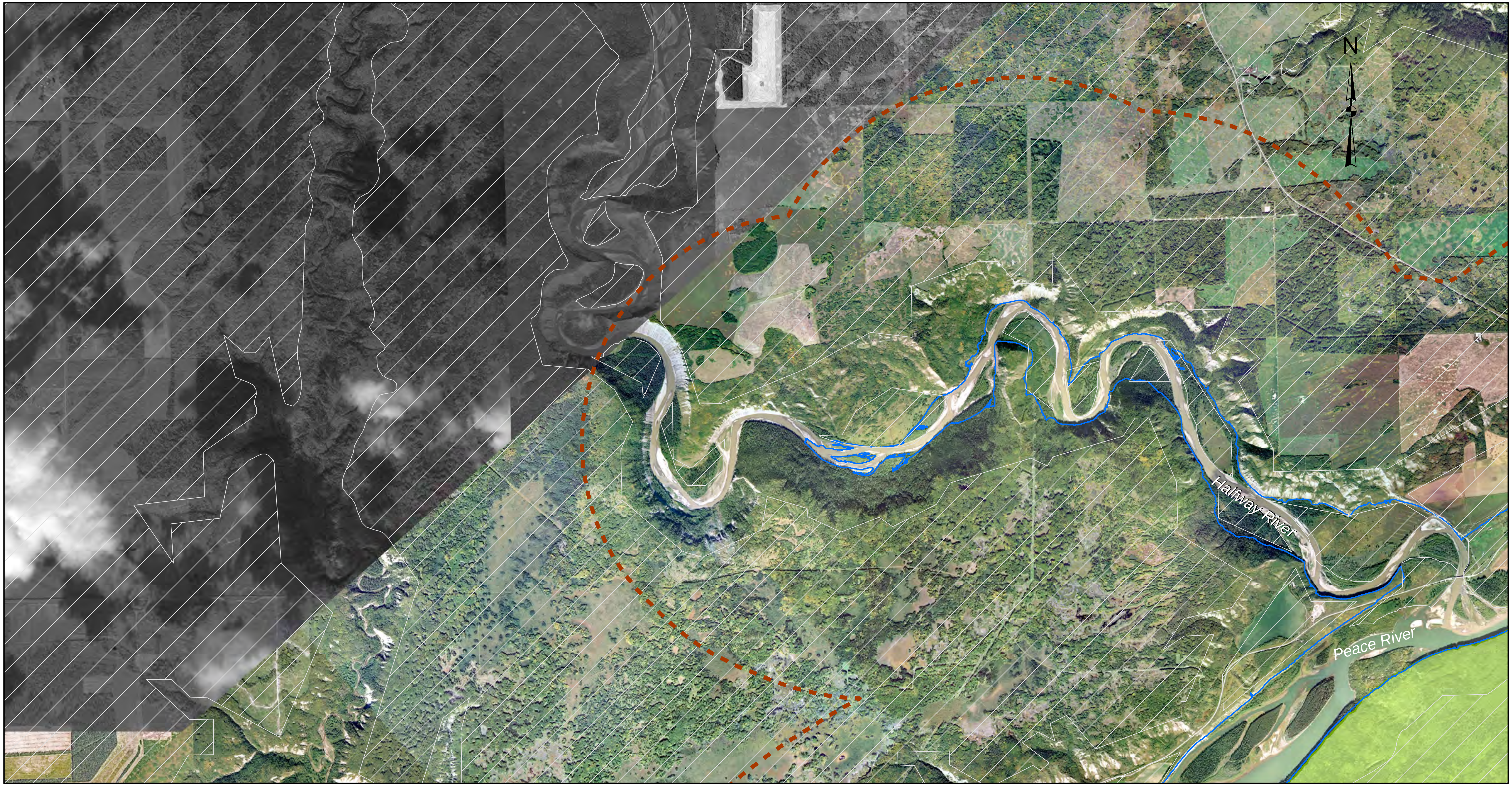
**Crop Drying Monitoring - Area Identification Map 7 of 9**

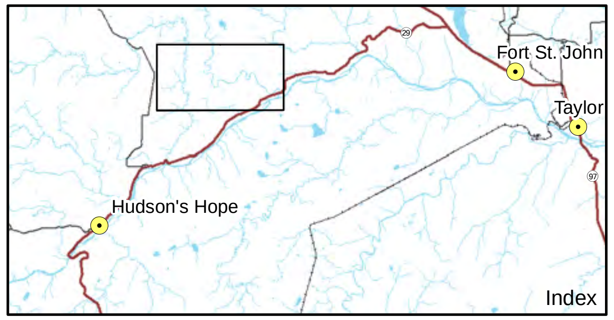
| Date | July 14, 2016 | DWG NO | 1016-C14-07342-7 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

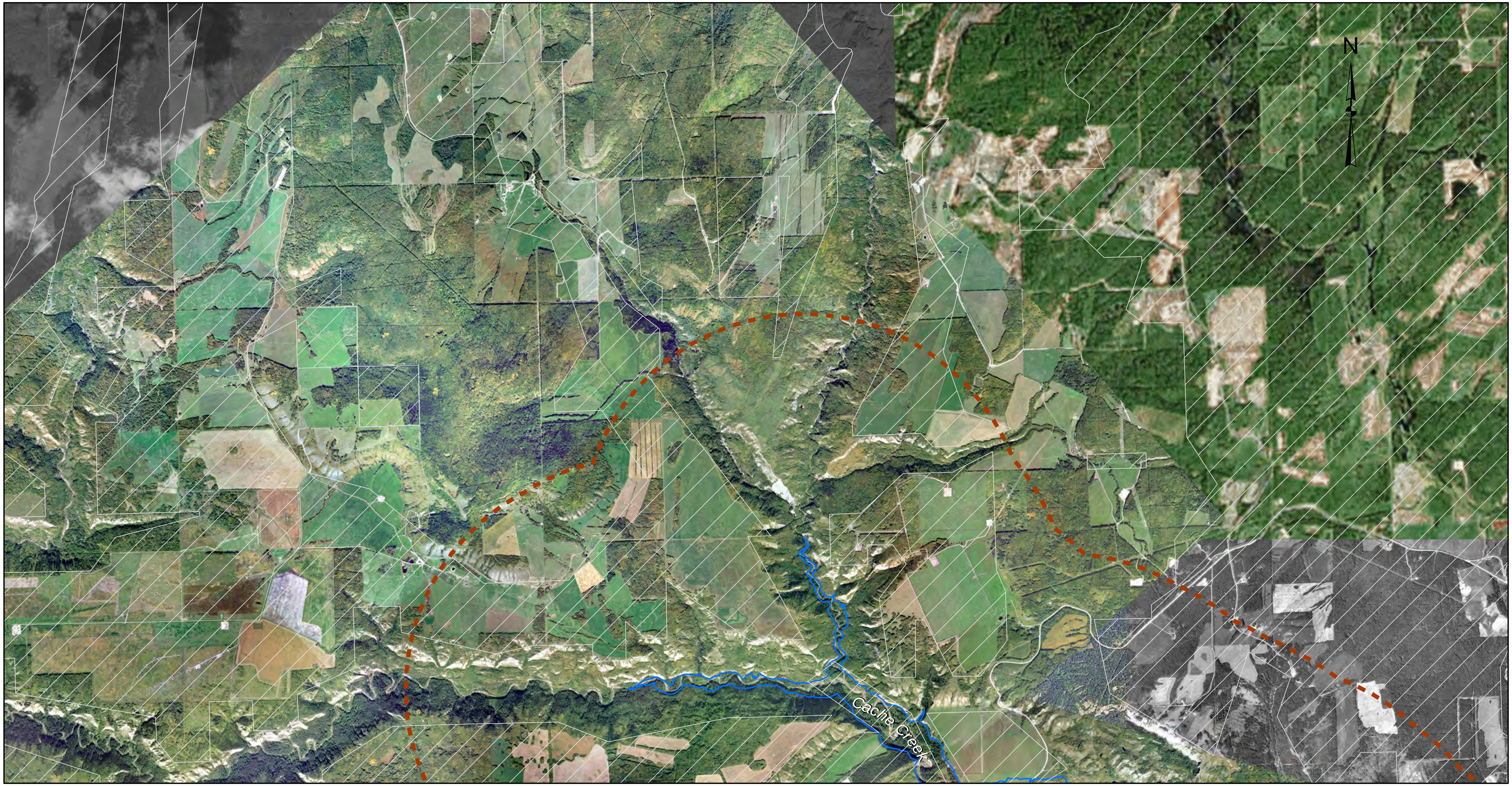
**Crop Drying Monitoring - Area Identification Map 8 of 9**

| Date | July 14, 2016 | DWG NO | 1016-C14-07342-8 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Area to be considered for crop drying monitoring
- Agricultural Land Reserve
- Proposed Reservoir
- Proposed Peace Boudreau Protected Area
- Dam Site Area

1:50,000

0 2 km

BC Hydro

**Crop Drying Monitoring - Area Identification Map 9 of 9**

| Date | July 14, 2016 | DWG NO | 1016-C14-07342-9 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Agriculture\Ag_3kmReservoirBoundary_1016_C14_07342-2-9.mxd

# Appendix C – Crop Productivity and Groundwater Monitoring Program Report

BC Hydro and Power Authority
333 Dunsmuir Street
Vancouver, BC V6B 5R3

Blackbird File: 21006
July 5, 2021

**RE: Crop Productivity and Groundwater Monitoring Program**
**Site C Clean Energy Project**
**2021 Annual Report**

**1. Project Background and Scope**

The Site C Clean Energy Project (the Project) is a hydroelectric dam and generating station under construction along the Peace River in northeast BC. Construction started in July 2015 and the project is planned to be in service in 2025 (BC Hydro 2021).

During the joint federal-provincial environmental assessment process, the Project's Environmental Impact Statement (EIS; BC Hydro 2013) noted a potential for the elevation of groundwater to rise in the vicinity of the reservoir and identified changes to local hydrology and groundwater as a key indicator (Table 20.3).

EIS Section 20.3.2.2 (page 20-34, lines 7 to 9) states: *"The reservoir would result in rises in the groundwater elevation in areas near the reservoir and may affect agricultural land where the water table is anticipated to rise within 1 m of surface. Yields or the range of suitable crops may be affected on agricultural properties located on low terraces and banks near the proposed reservoir. However, since the majority of the cultivated lands within the local assessment area are located topographically above the proposed reservoir levels by greater than 1 meter and in most cases by greater than 10 m, only limited effects related to water table rise are anticipated*."

EAC Condition No. 31 states: *"The Agriculture Monitoring and Follow-up Program must include monitoring for Project-induced changes to groundwater elevations within 2 km of the reservoir (the area potentially influenced by groundwater elevation changes), and evaluate associated effects on crop productivity. Monitoring must include field surveys and farm operator interviews."*

As a result, the Environmental Assessment Certificate for the Project (EAC # E14-02, issued Oct. 14, 2014) contains a condition to develop an Agricultural Monitoring and Follow-Up Plan (AMAFP), which requires BC Hydro to monitor and assess groundwater level and related damage to agricultural crops for a 10-year period which includes the five years prior to reservoir filling and the first five years of operation.

BC Hydro and Power Authority (BC Hydro) has retained Blackbird Environmental Ltd. (Blackbird) to implement the Crop Productivity and Groundwater Monitoring Program (CPGMP) component of the AMAFP. Blackbird's scope includes the development and implementation of a desktop and field program to monitor for project-related changes in groundwater and soil moisture levels specifically focused on areas used for agricultural production within a two-kilometre buffer around the future Project reservoir.

As part of BC Hydro's annual reporting requirements, this report outlines Project activities completed in relation to the CPGMP component of the AMAFP between **April 1, 2020,** and **March 31, 2021**.

## 2. Project Activities

Groundwater monitoring under this program will be conducted through a variety of methods and technologies including the deployment and maintenance of a network of soil moisture sensors, crop health and development monitoring, as well as cooperation with BC Hydro's hydrology specialists to access data derived from the existing well network in the project area.

The AMAFP identifies several sites for groundwater monitoring and potential crop impacts within 2 km of the reservoir, which defined the focus of the CPGMP. At these locations, Blackbird deployed soil probes at depths of 10, 30, and 100 cm to log moisture, temperature, and electric conductivity data at one-hour intervals throughout the year. Soil moisture monitoring benchmarks are located on land currently owned by BC Hydro in landscape/field positions that reduce the potential of an impact on agricultural operations to a minimum.

BC Hydro's existing groundwater monitoring network within the Peace River valley will be used to monitor actual groundwater levels in the immediate vicinity of the identified monitoring sites. Blackbird's team reviewed the current groundwater monitoring infrastructure in relation to the previously identified focus areas and determined a requirement for additional shallow groundwater monitoring infrastructure. One well was installed in the Bear Flat area in late 2019.

Blackbird's team monitored crop development during the 2020 growing season through remote-sensing techniques to minimize the disturbance caused by field inspections whenever feasible. Field inspections were completed at the monitoring locations in early spring and in mid- to late July to assess crop variability in relation to soil moisture factors.

## 3. Recommendations

In accordance with EAC Condition No. 31, field surveys and producer interviews will continue to be completed with the goal of continuing monitoring until five years after reservoir filling. Similarly, Blackbird's team will continue to work closely with agricultural producers, agricultural associations, producer groups, and government agencies that may have data or local knowledge related to this monitoring plan.

The following recommendations are based on the findings of project activities during the 2020 growing season, including producer engagement, research on available hydrological information, and the installation of monitoring instrumentation.

1. Continue to monitor crop development at the monitoring sites through remote sensing technologies and field surveys throughout the growing season.

## 4. Closure

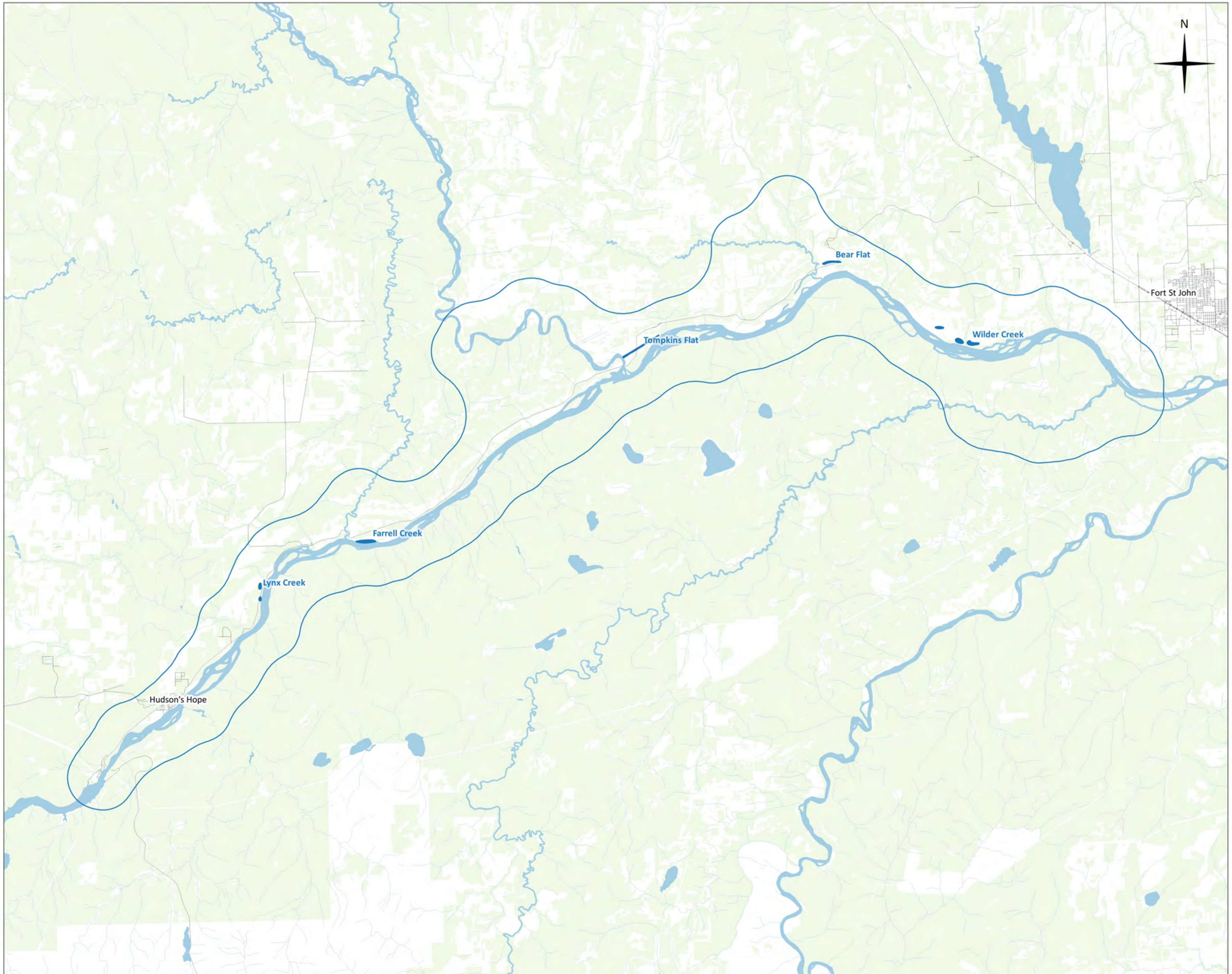
Services provided by Blackbird for this memorandum have been conducted in a manner consistent with the level of skill, care, and competence ordinarily exercised by registered members of the profession of agrology and biology currently practicing under similar conditions and like circumstances in the same jurisdiction in which the services were provided.

The conclusions of this memorandum are based in part on information provided by others. Blackbird believes this information to be accurate but cannot guarantee or warrant its accuracy or completeness.

The information presented in this memorandum was acquired, compiled, and interpreted exclusively for BC Hydro for the purposes described in this report.

If you have questions with regards to this memorandum, feel free to contact the lead author at your convenience by email at matthias@blackbird.ca.

Attachments: Figure 1 – CPGMP Project Area Overview




# BC Hydro and Power Authority

**Crop Productivity and Groundwater Monitoring Program**
**Project Area Overview**


Horizontal Scale 1:250,000

0 2 4 6 8 10 km

Map to scale when plotted on a page 280 mm x 432 mm (Tabloid)

## Legend

- CPGMP Project Area
- Lakes & Rivers
- Crop Productivity and Groundwater Monitoring Areas
- Road Network

## Disclaimer

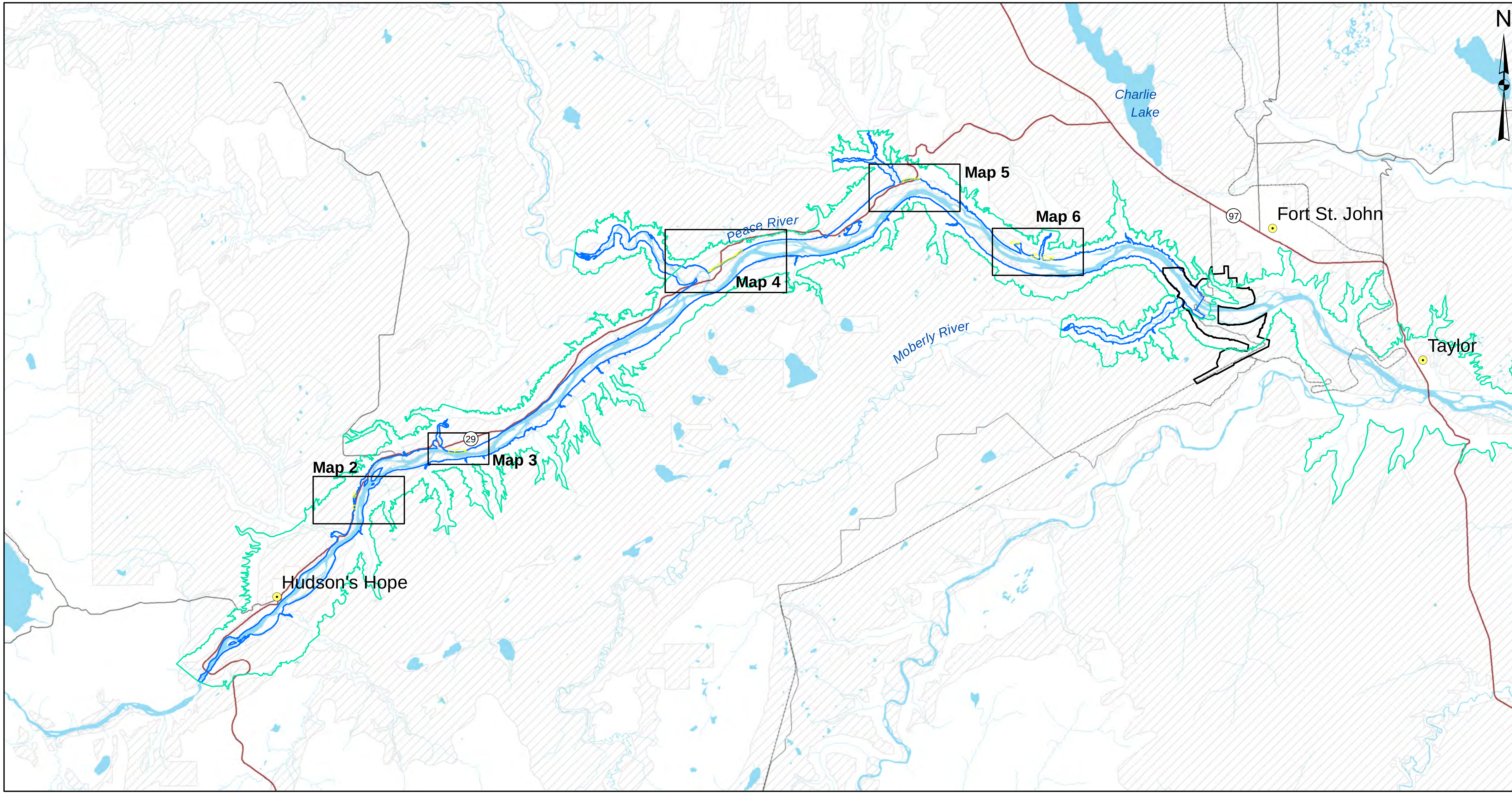
UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

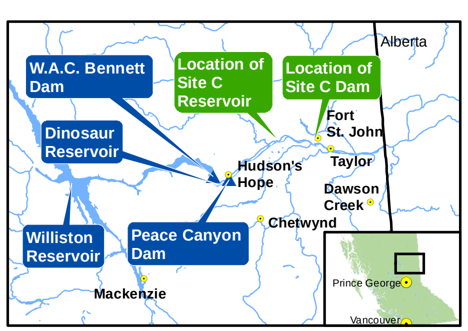
| | | | | | |
|---|---|---|---|---|---|
| Our File: | 21006 | Gov. File #: | n/a | Revision #: | 2 |
| Client File: | n/a | GIS: | ML | Date: | June 5, 2021 |

Blackbird Environmental

blackbird.ca
Fort St. John, BC
250.793.7262

**Figure 1**




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve
- Town
- Road
- Highway
- Railway

1:250,000

0 5 km

BC Hydro

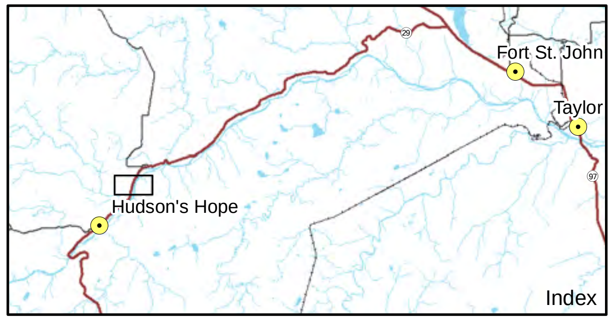
**Groundwater Monitoring Areas Overview Map 1 of 6**

| Date | July 14, 2016 | DWG NO | 1016-C14-07345-1 | R 0 |
|---|---|---|---|---|

Path: X:\ArcGISProjects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_Overview_1016_C14_07345-1.mxd



Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.


Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 — 0 — 0.5 km

BC Hydro

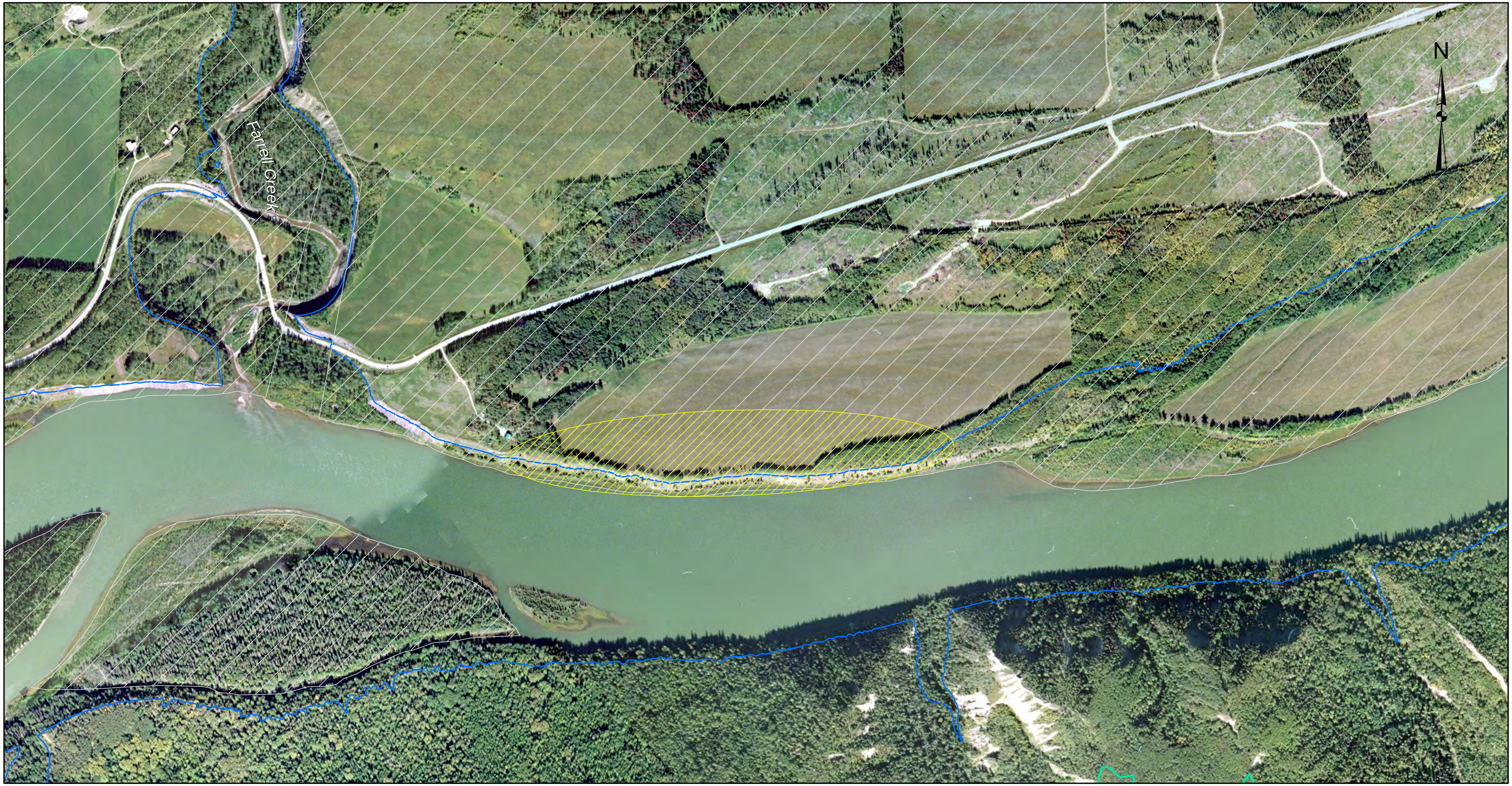
**Groundwater Monitoring Areas**
**Map 2 of 6**

| Date | July 14, 2016 | DWG NO | 1016-C14-07345-2 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_1016_C14_07345-2-6.mxd





Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:10,000 0 0.5 km

BC Hydro

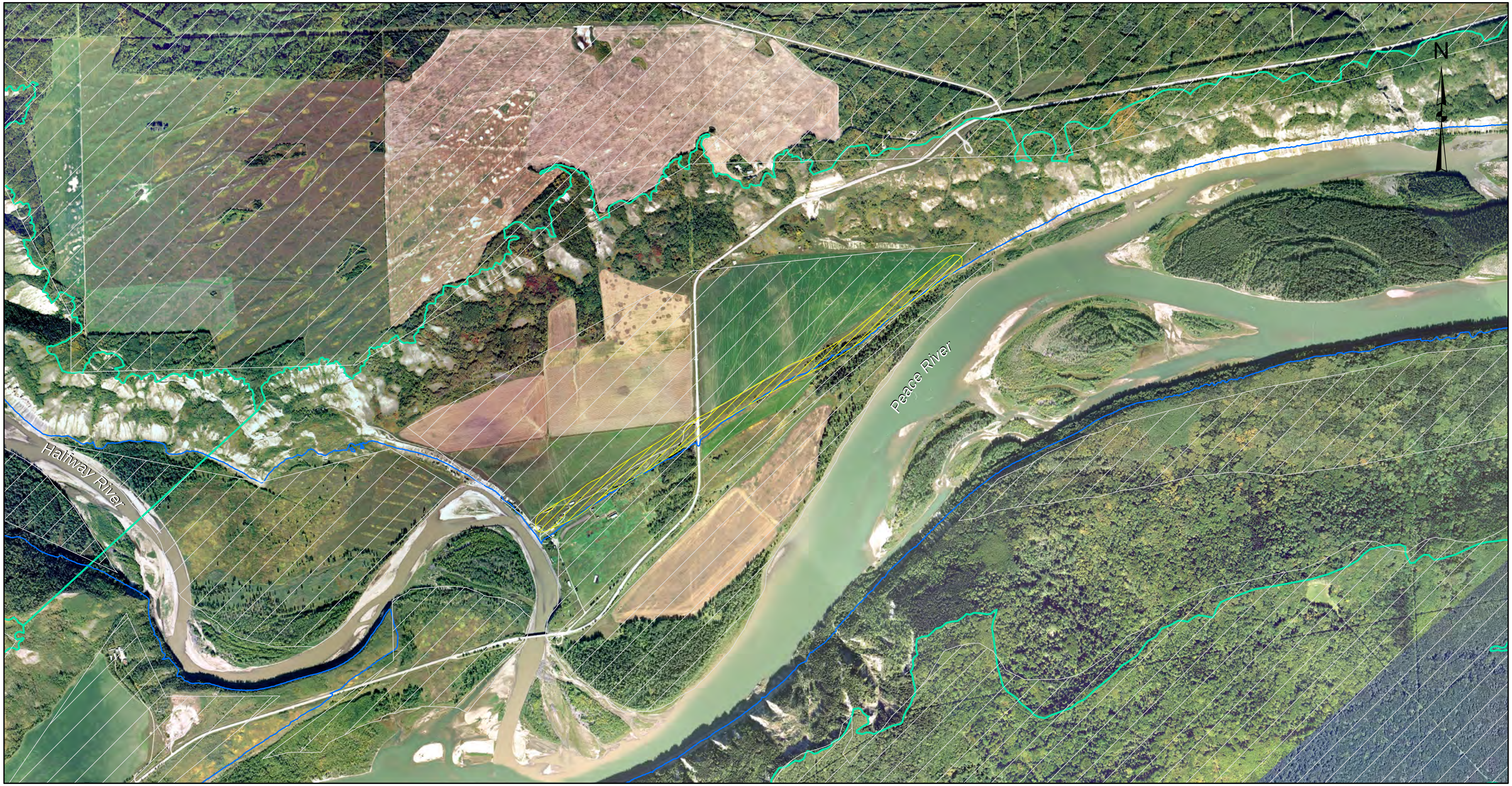
**Groundwater Monitoring Areas**
**Map 3 of 6**

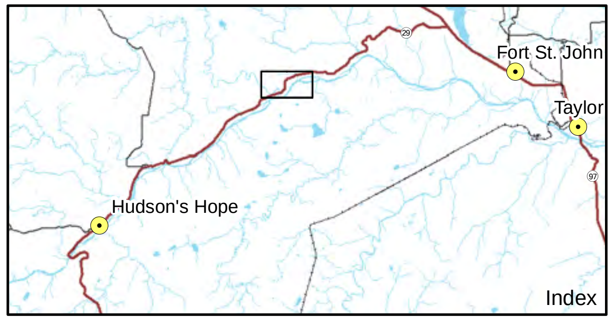
| Date | July 14, 2016 | DWG NO | 1016-C14-07345-3 | R 0 |
|---|---|---|---|---|



Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGIS\Projects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_1016_C14_07345-2-6.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:20,000 0 0.5 km

BC Hydro

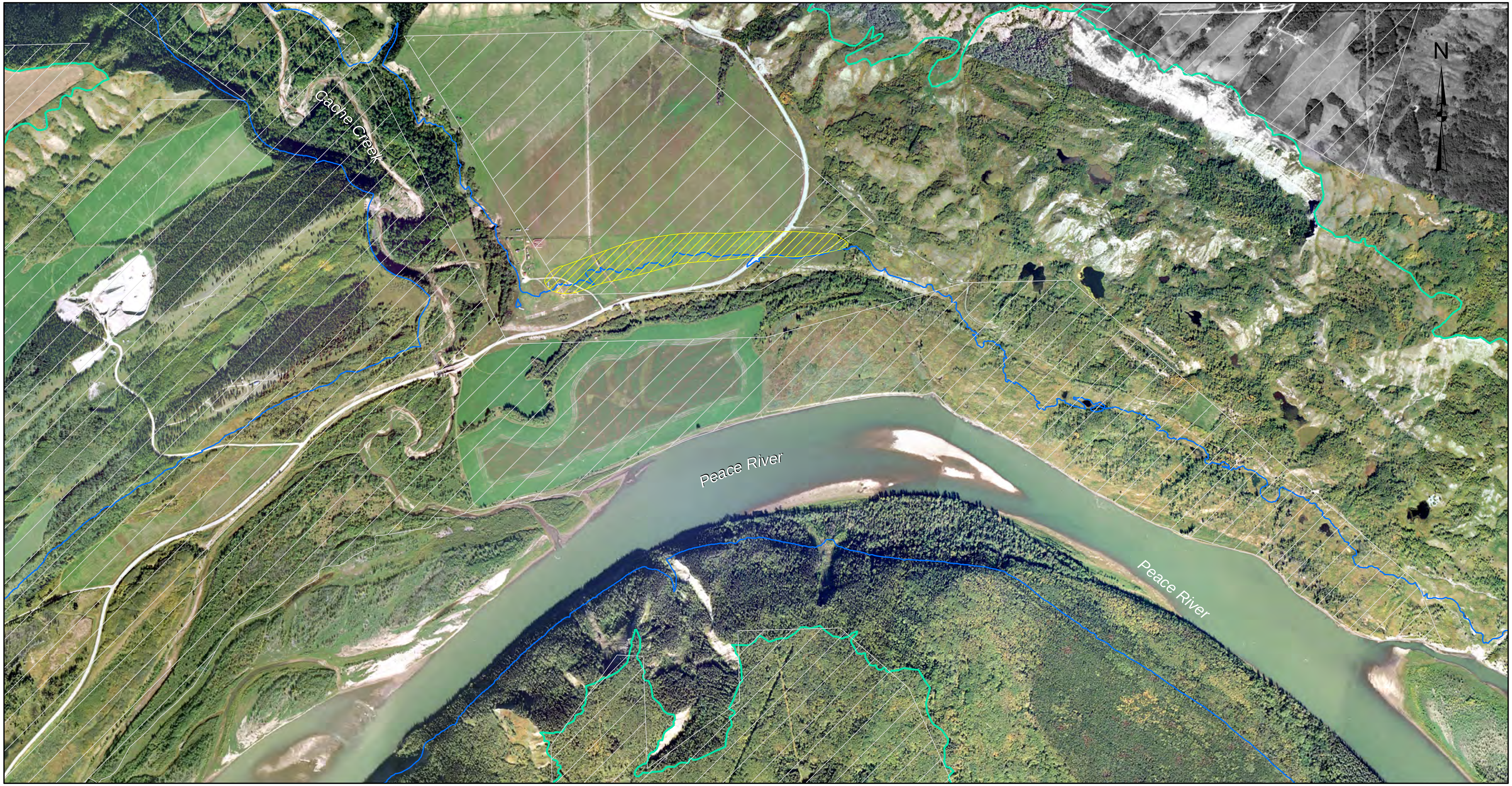
**Groundwater Monitoring Areas**
**Map 4 of 6**

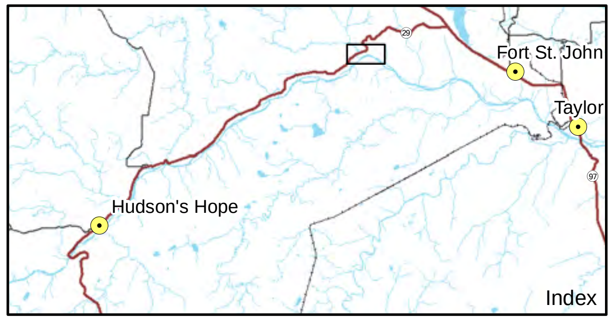
| Date | July 14, 2016 | DWG NO | 1016-C14-07345-4 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.



Path: X:\ArcGISProjects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_1016_C14_07345-2-6.mxd




Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 0 0.5 km

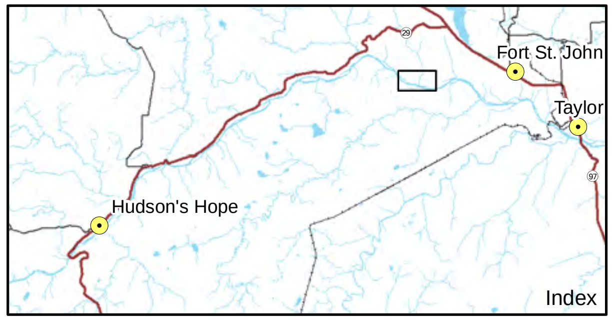
BC Hydro

**Groundwater Monitoring Areas**
**Map 5 of 6**

| Date | July 14, 2016 | DWG NO | 1016-C14-07345-5 | R 0 |
|---|---|---|---|---|

Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

Path: X:\ArcGIS\Projects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_1016_C14_07345-2-6.mxd


Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

## Legend

- Groundwater Monitoring Area
- Peace River and Tributary Valleys Definition
- Proposed Reservoir
- Dam Site Area
- Agricultural Land Reserve

1:15,000 0 0.5 km

BC Hydro

**Groundwater Monitoring Areas**
**Map 6 of 6**

| Date | July 14, 2016 | DWG NO | 1016-C14-07345-6 | R 0 |
|---|---|---|---|---|

Path: X:\ArcGISProjects\Environment\Physical_Environment\Ground_Water\Groundwater_Monitoring_1016_C14_07345-2-6.mxd



Construction of the Site C Clean Energy Project is subject to required regulatory and permitting approvals.

# Appendix D – Irrigation Water Requirements Program Report

## Introduction

The Site C Clean Energy Project's Environmental Impact Statement (BC Hydro. 2013) ("EIS") Section 20.3.4.1.2 identifies irrigation improvements as a potential mitigation measure for the permanent loss of agricultural land. Lines 25 to 27, page 20-42, of this section state: "Irrigation research, demonstration projects, and funding assistance for irrigation water supply infrastructure will be considered within the proposed agricultural compensation fund."

EAC Condition 31 states: "The Agriculture Monitoring and Follow-up Program must include monitoring for climatic factors to estimate moisture deficits and to estimate irrigation water requirements in the vicinity of the reservoir to provide information for potential future irrigation projects. Data collection will be undertaken before reservoir filling, and in the 5 years after reservoir filling, and data will be reviewed as required for proposed irrigation projects."

In accordance with EAC Condition 31, this study will monitor climate data and estimate irrigation water requirements. The objective of this monitoring program is to collect and analyze climate data to generate estimates of irrigation water requirements.

## Methods

The plan will rely on climate station installation, maintenance, and data collection tasks carried out in the *Appendix B: Monitoring Potential Effects on Crop Drying Plan*. Both plans are carried out in the same study area, which is comprised of agricultural operations within 3 km of the reservoir.

Activities include coordination of data needs with *Appendix B: Monitoring Potential Effects on Crop Drying Plan*, including mapping, collection of baseline data, climate station siting, and consideration of consultation input.

- Maps supporting this program are included in *Appendix B: Monitoring Potential Effects on Crop Drying Plan*.
- To ensure that all parameters required for the successful completion of this program, coordination with the Crop Drying and Humidity Monitoring Program is required for future climate station siting and any necessary network upgrades.
- Irrigation was discussed during the consultation process and included numerous submissions by regional agricultural producers and associations for the Framework of the Agricultural Mitigation and Compensation Plan. Content relevant to irrigation was considered and will be retained for future use in this program.

## Results and Analysis

During the program establishment phase there are limited results or analysis required. The climate stations are collecting information that will provide baseline information to support future analysis.

**Next Steps**

In the five years pre- and post-reservoir filling, complete summaries of the collected data from the new and existing BC Hydro climate stations will be analyzed annually to estimate irrigation water demand (as required). It should be noted that:

- The existing climate station network was upgraded and expanded between January 2016 and December 2017 and that data collected will be the baseline for any future irrigation project.
- Efforts will be made to collaborate with associations, producer groups and government agencies that may have data or local knowledge related to this monitoring program. Examples may include the BC Grain Producers Association which has funded the following study; *Evaluation of Irrigation Potential in the BC Peace Region*.

## References

BC Grain Producers Association (2015) "Peace – Evaluation of Irrigation Potential in the BC Peace Region" Available at: http://www.bcgrain.com/Current_Projects.html. Accessed: December 2015.

FAO. (1998). Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements. Rome: Food and Agriculture Organization of the United Nations – Paper 56.

BC Hydro. 2013. Site C Clean Energy Project Environmental Impact Statement. Dated January 25, 2013; Amended August 2, 2013.

# Appendix E – Climate Stations Information

The following tables show information specific to the BC Hydro's existing climate station network.

**Table 1 - Periods of Operation for Climate Stations Supporting the AMAFP**

| Monitoring Station | Period of Operation |
|---|---|
| Attachie Flat Upper Terrace | 2011 - Present |
| Attachie Flat Lower Terrace[1] | 2010 - 2017 |
| Attachie Plateau | 2010 - Present |
| Bear Flat | 2010 - Present |
| Farrell Creek | 2009 - Present |
| Site C Dam[2] | 2010 - 2016 |
| Site C North Camp[3] | 2016 - Present |
| Old Fort | 2011 - Present |
| 85th Avenue | 2013 - Present |
| Tea Creek | 2017 – Present |
| Taylor | 2017 – Present |
| Fort St. John Airport[4] | 1942 – Present |

[1] Attachie Flat Lower Terrace was closed in 2017 due to the location being inside the Site C reservoir

[2] Site C Dam Station was relocated in 2016 to an area adjacent to the camp and offices. It is now the Site C North Camp Station

[3] Site C North Camp Climate Station has instruments in two areas located near the Site C offices

[4] Fort St. John Airport is operated by Environment Canada

**Table 2 - Locations & Elevations of Current Climate Stations Supporting the AMAFP**

| Monitoring Station | UTM NAD 83 (m) | Latitude and Longitude (decimal degrees) | Elevation (m) |
|---|---|---|---|
| Attachie Flat Upper Terrace | 597983 E, 6232938 N | 56.23N, -121.41W | 479 |
| Attachie Plateau | 595065 E, 6233032 N | 56.23N, -121.46W | 645 |
| Bear Flat | 610669 E,6238135 N | 56.27N, -121.21W | 474 |
| Farrell Creek | 580779 E, 6220238 N | 56.12N, -121.70W | 471 |
| Site C North Camp[1] | 630127 E, 6230625 N | 56.20N, -120.90W | 581 |
| Old Fort | 634,890 E, 6,230,532 N | 56.20N, -120.83W | 421 |

| | | | |
|---|---|---|---|
| 85th Avenue | 633,033 E, 6,233,949 N | 56.23N, -120.85W | 686 |
| Tea Creek | 626812 E, 6234340 N | 56.24N, -120.95W | 653 |
| Taylor | 639212 E, 6226929 N | 56.17N, -120.76W | 411 |
| Fort St. John Airport | 640053 E, 6234872 N | 56.24N, -120.74W | 695 |

[1] The “Site C Dam” meteorological station was decommissioned from its original location on April 13, 2016 due to excavation at that location. It was relocated to a new location, “Site C North Camp”, on July 7, 2016.

Full reports including tabular summaries of the agricultural monitoring parameters are included in the 2014 through to 2020 *Site Climate and Air Quality Monitoring Annual Reports*. These parameters include:

- air temperature,
- humidity,
- precipitation,
- solar radiation,
- wind speed,
- wind direction,
- barometric pressure,
- net radiation,
- soil temperature,
- soil heat flux,
- soil water content, and
- relative humidity.

**References:**

RWDI Inc. (2015), Site C Climate & Air Quality Monitoring Annual Report 2014, Final. August 26, 2015.

RWDI Inc. (2016), Site C Climate & Air Quality Monitoring Annual Report 2015, Final. June 9, 2016.

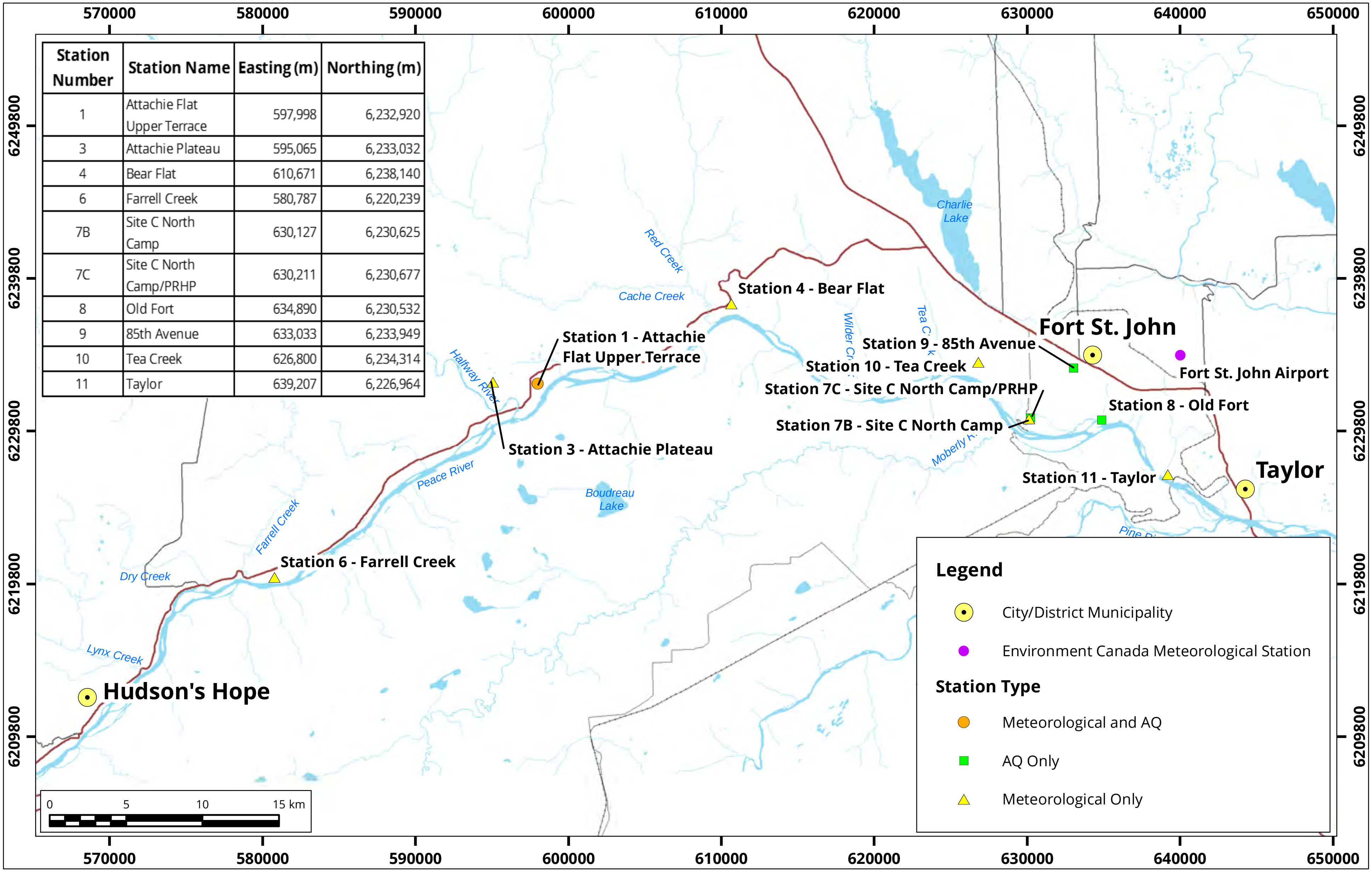
RWDI Inc. (2017), Site C Climate & Air Quality Monitoring Annual Report 2016, Rev. 1. June 14, 2017.

RWDI Inc. (2018), Site C Climate & Air Quality Monitoring Annual Report 2017, Final. March 12, 2018.

RWDI Inc. (2019), Site C Climate & Air Quality Monitoring Annual Report 2018, Final. February 22, 2019.

RWDI Inc. (2020), Site C Climate & Air Quality Monitoring Annual Report 2019, Final. March 31, 2020.

RWDI Inc. (2021), Site C Climate & Air Quality Monitoring Annual Report 2020, Final. March 19, 2021.




| Station Number | Station Name | Easting (m) | Northing (m) |
|---|---|---|---|
| 1 | Attachie Flat Upper Terrace | 597,998 | 6,232,920 |
| 3 | Attachie Plateau | 595,065 | 6,233,032 |
| 4 | Bear Flat | 610,671 | 6,238,140 |
| 6 | Farrell Creek | 580,787 | 6,220,239 |
| 7B | Site C North Camp | 630,127 | 6,230,625 |
| 7C | Site C North Camp/PRHP | 630,211 | 6,230,677 |
| 8 | Old Fort | 634,890 | 6,230,532 |
| 9 | 85th Avenue | 633,033 | 6,233,949 |
| 10 | Tea Creek | 626,800 | 6,234,314 |
| 11 | Taylor | 639,207 | 6,226,964 |

# BC Hydro - Site C Meteorological and Air Quality Stations

True North

| Drawn by: DJH | Figure: 2-1 |
|---|---|
| Approx. Scale: 1:350,000 | |
| Date Revised: Sep 18, 2017 | |

Map Projection: NAD 1983 UTM Zone 10N

Project #: 1601625

Map Document: C:\Users\djh\Desktop\GIS Temp\1601625\1601625 - Confidential BC Hydro Climate_Monitoring Locations_Figure_2-1_Sep2017.mxd