BC Hydro
Power smart

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

2022 Annual Report

Prepared in accordance with the Agricultural Monitoring and Follow-up Program (December 22, 2015)
2022 Annual Report Submission Date: July 21, 2022

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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 has a projected in-service date of 2025. 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 of 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]) • 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 between Fall 2023 and Spring 2024 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 2022 AMAFP Annual Report covers the time period from April 1, 2021 to March 31, 2022 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.

One of the key tasks from the reporting year was to continue with the camera trapping and seasonal grazing exclusion plans. In total, 65 passive, unbaited camera traps were installed along benchmark field boundaries and 36 temporary grazing exclusion cages were installed on perennial forage benchmark fields.

During the 2021 growing season 34 benchmark sites were selected from the agriculture fields identified to be subject to higher wildlife pressures both pre- and post-inundation. Of this, 12 were used for annual crop production while 22 site contained a perennial forage stand.

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

2022 Annual Report
Site C Clean Energy Project

Crop Damage Monitoring Program


Prepared for:

BC Hydro and Power Authority

June 30, 2022

Technical Report – Rev. 0

Project No.: 22002

Blackbird Environmental Ltd.
10, 10421 100 Street | Fort St. John, BC | V1J 3Z3

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Table of Revisions

Revision No.	Date	Reason/Type of Revision
R0	June 30, 2022	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 has a projected in-service date of 2025 (BC Hydro 2022).

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.

Environmental Impact Statement 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."*

The Environmental Assessment Certificate (EAC) 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 and Power Authority (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.

Specifically, 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."*

1.3 Scope

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 patterns and trends.

As part of BC Hydro's annual reporting requirements, this report outlines Project activities completed in relation to the CDMP component between **April 1, 2021** and **March 31, 2022**.

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 developed and implemented a comprehensive agricultural producer outreach and engagement program for the CDMP. Blackbird continues to engage with landowners within the Project boundary on an ongoing basis throughout the growing season.

For all producers that expressed interest in the CDMP during initial engagement efforts in 2019, an in-person interview was conducted to gather project-relevant background information, including:

- farm/ranch operational and production information,
- historic wildlife damage patterns on temporal and spatial scales, and
- wildlife-related crop damage mitigation measures employed.

Producers participating in the CDMP were updated on project activities on their holdings during the spring of 2021, throughout the growing season, and a post-season interview program was implemented to gather information on observations and perceptions with regards to the 2021 growing season and wildlife-related crop damage in the 2021 crop.

Blackbird's team prepared a pre-recorded CDMP annual update presentation summarizing program activities during the 2021 growing season, assessment outcomes, challenges, and learnings during the spring of 2022. BC Hydro invited representatives from regional producer associations and provincial government representatives, specifically:

- River Forage Association of BC,
- BC Grain Producers Association,
- Peace River Cattlemen's Association,
- Peace River Forage Seed Association, and
- BC Ministry of Agriculture and Food.

This group was asked to review the virtual presentation and submit questions or comments, which will be responded to jointly by Blackbird and BC Hydro by the end of June 2022.

2.2 Crop Damage Monitoring

Blackbird's team researched, developed, and implemented 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 included:

- wildlife-related 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 (i.e., proximity of escape or wintering habitat).

During the 2021 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 were monitored during the growing season and assessed for wildlife related damage patterns prior to harvest.

Assessment procedures include remote sensing techniques (i.e., satellite, RPAS) and on-the-ground evaluations of crop health, yields, and wildlife-related damage patterns. Assessment methodologies were based on published standards, where publicly 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 and pellet counts.

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

The 2021 growing season marked Blackbird's third season maintaining camera traps and collecting passively collected wildlife distribution and use frequency data on benchmark fields. Additionally, 2021 was the second year in which grazing exclusion cages were used to quantify wildlife-caused damage to perennial forage crops during the dormant season.

2.3.1 Camera Traps

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

Camera trap data is retrieved during the growing season, formatted, and saved in compliance with provincial standards (BC ECCS & FLNRORD 2019). The data is then analysed using a combination of machine learning technology and manual classification (Greenberg et al. 2019, Schneider et al. 2020, Norouzzadeh et al. 2021, Fennell et al. 2022). Classification results are analysed in R (Niedballa et al. 2016, Hongo et al. 2021).

2.3.2 Grazing Exclusion Cages

In the fall of 2021, Blackbird's team installed a total of 36 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, ground, and live plant coverage, plant height, alfalfa crown development, grazing patterns). Following the assessments, 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 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 were originally engaged through direct means (i.e., phone or email) 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 annual crop (i.e., grain, oilseed, or pulse) during the 2021 growing season, with the remaining 5,900 ha used for perennial forage production.

Throughout the 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, 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).

Program 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 have been observed 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 of the field or pasture on the landscape,
- ongoing nearby construction activities,
- seasonal wildlife migration patterns,
- annual weather patterns, and
- the time of year when the damage occurred.

Throughout the 2021 growing season, field methodologies and techniques, including loss assessments as well as remote sensing and on-the-ground crop health evaluations, were utilized based on past learnings and further refined to fit program information requirements.

3.3 Wildlife Habitat Utilization Monitoring

Camera trap maintenance and data retrieval is completed during crop health and wildlife damage assessment work throughout the growing season to minimize private land access requirements.

The camera trap network was active for a total of 22,238 camera trap days during the reporting period, with a total of 252,557 images collected. A preliminary classification indicates that the collected image data comprise:

- 69.3 % false trigger events (i.e., images collected when a camera trap is triggered but no animal, human, or vehicle is traversing its detection area),
- 22.7 % wildlife,
- 6.3 % domestic animals (primarily cows, bison, and horses), and
- 1.7 % humans or vehicles.

The most dominant wildlife species recorded to date is Rocky Mountain elk, which represents 15.6 % of the trigger events, with mule and white-tailed deer as the second numerous species group (5.6 %). Other target species for this program include black bear (1.5 % of all images) and moose (0.1 %).

Green-up assessments were completed in late spring of 2021 to assess dormant season damage to perennial forage crops within the project area. Plant health assessments were completed within the exclusion cages (i.e., unaffected by potential wildlife), to areas immediately adjacent to the cages. Several benchmark fields displayed signs of high wildlife pressure on perennial crops, with the majority damage caused specifically by elk utilizing these fields in early spring.

4 Recommendations

In compliance with EAC Condition No. 31, field surveys and producer engagement efforts will resume during the 2022 growing season 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 2021 growing season, including producer engagement and the implementation of the field program.

1. Continue to complete RPAS assessments of benchmark sites through the 2022 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 further standardize and verify yield estimates and allow for an accurate characterizations of wildlife-related crop losses to growing stands. Implement non-destructive sampling approaches (e.g., rising plate meters, multispectral estimation methods) to further refine field methodologies for perennial forage assessments.

3. 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 Blackbird's team at your convenience by email at info@blackbird.ca.

6 References

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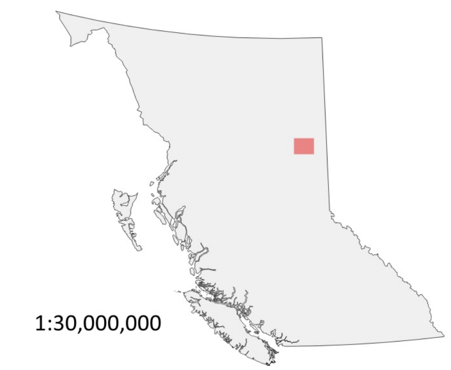
Appendix A Project Area Overview

BC Hydro and Power Authority

Crop Damage 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

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

Disclaimer

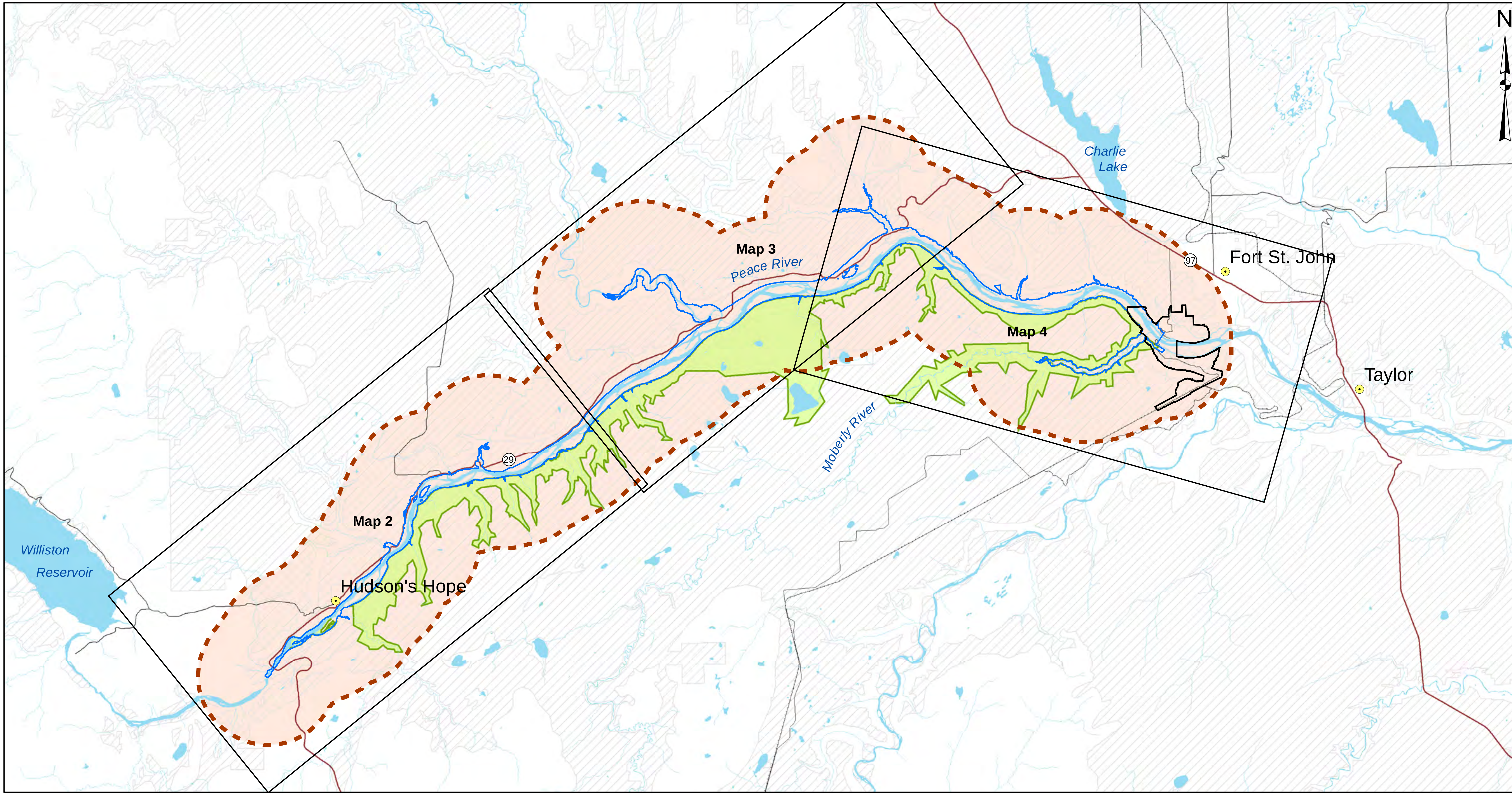
UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

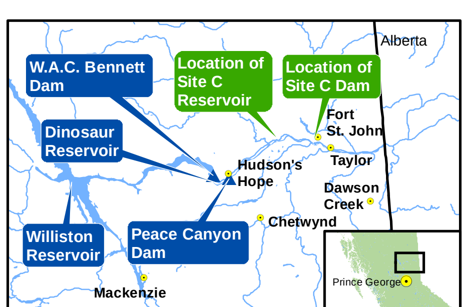
Our File:	21006	Gov. File #:	n/a	Revision #:	0
Client File:	n/a	GIS:	ML	Date:	June 12, 2021

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

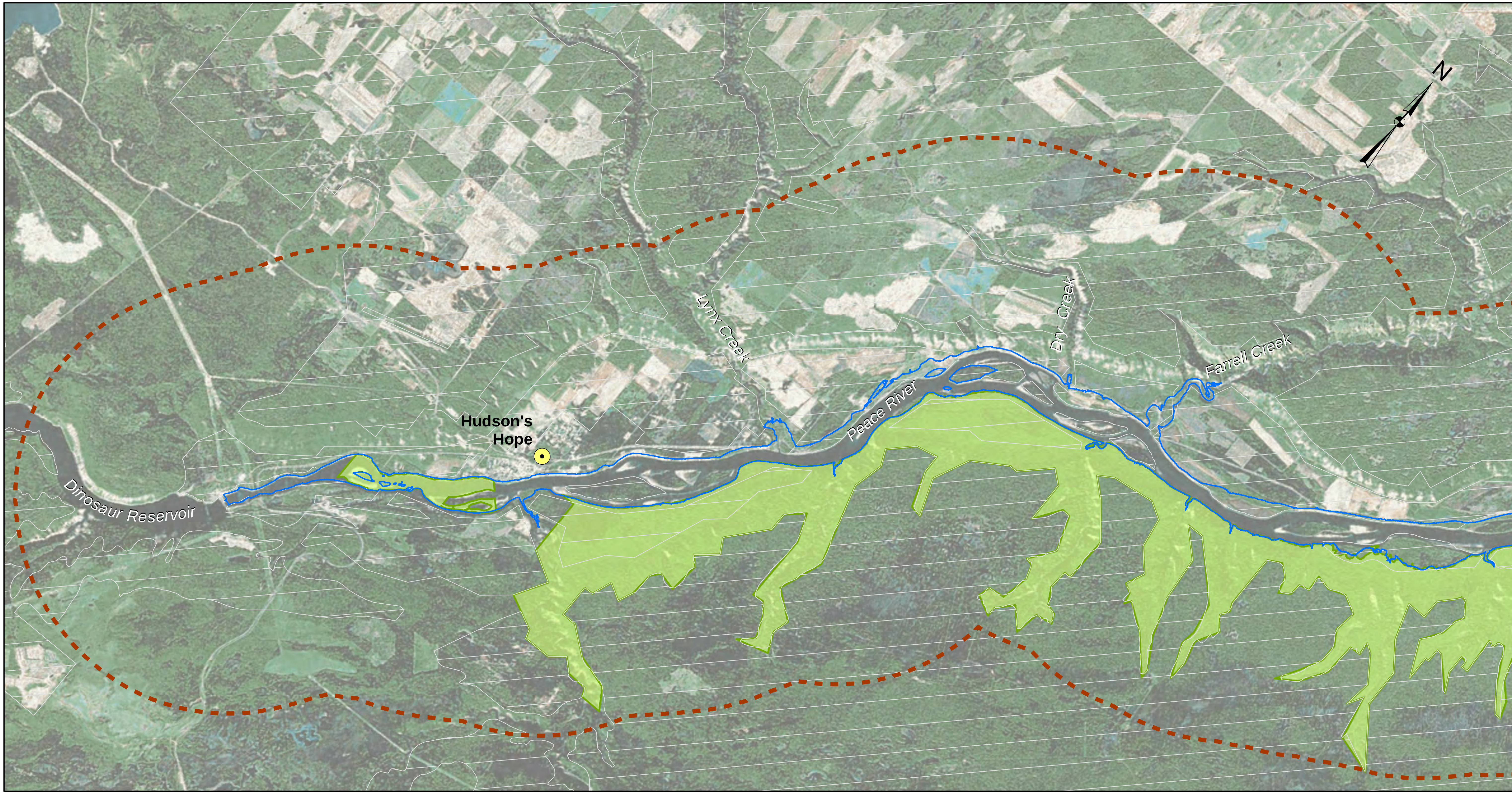
BC Hydro

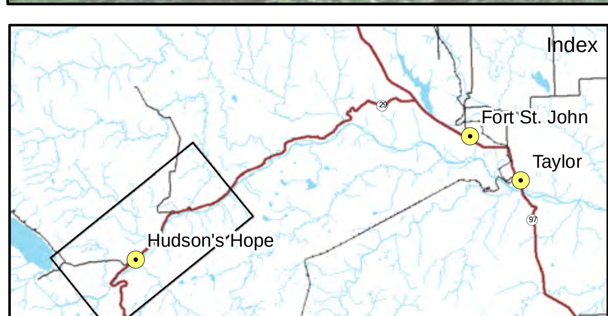
Wildlife Habitat Utilization Monitoring Area Identification - Overview Map 1 of 4

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.

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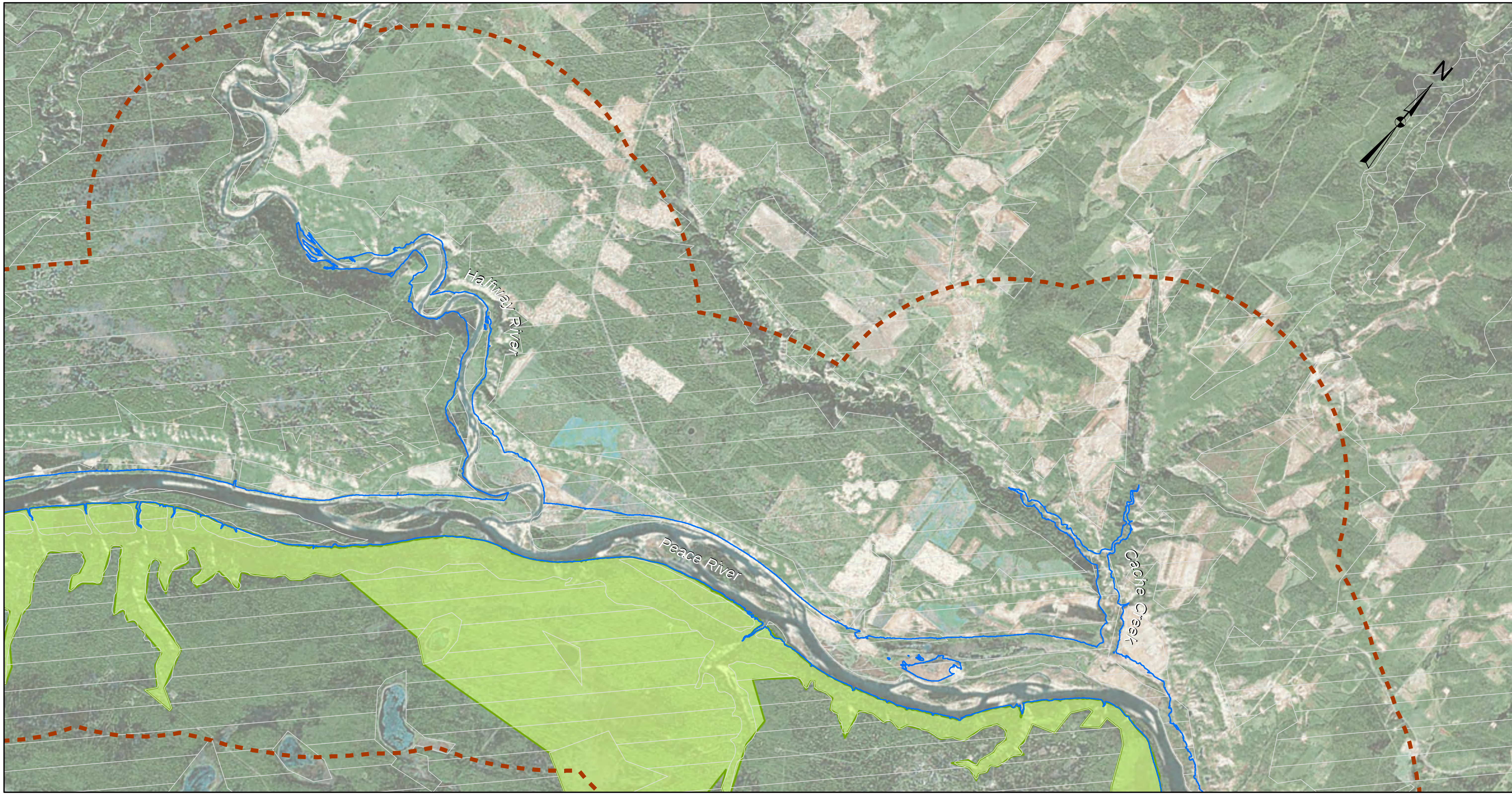

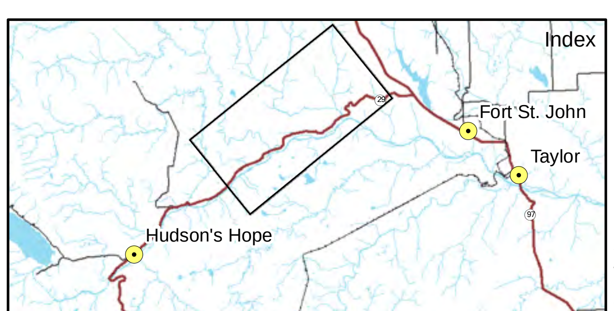

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos provided by ESRI
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

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 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.

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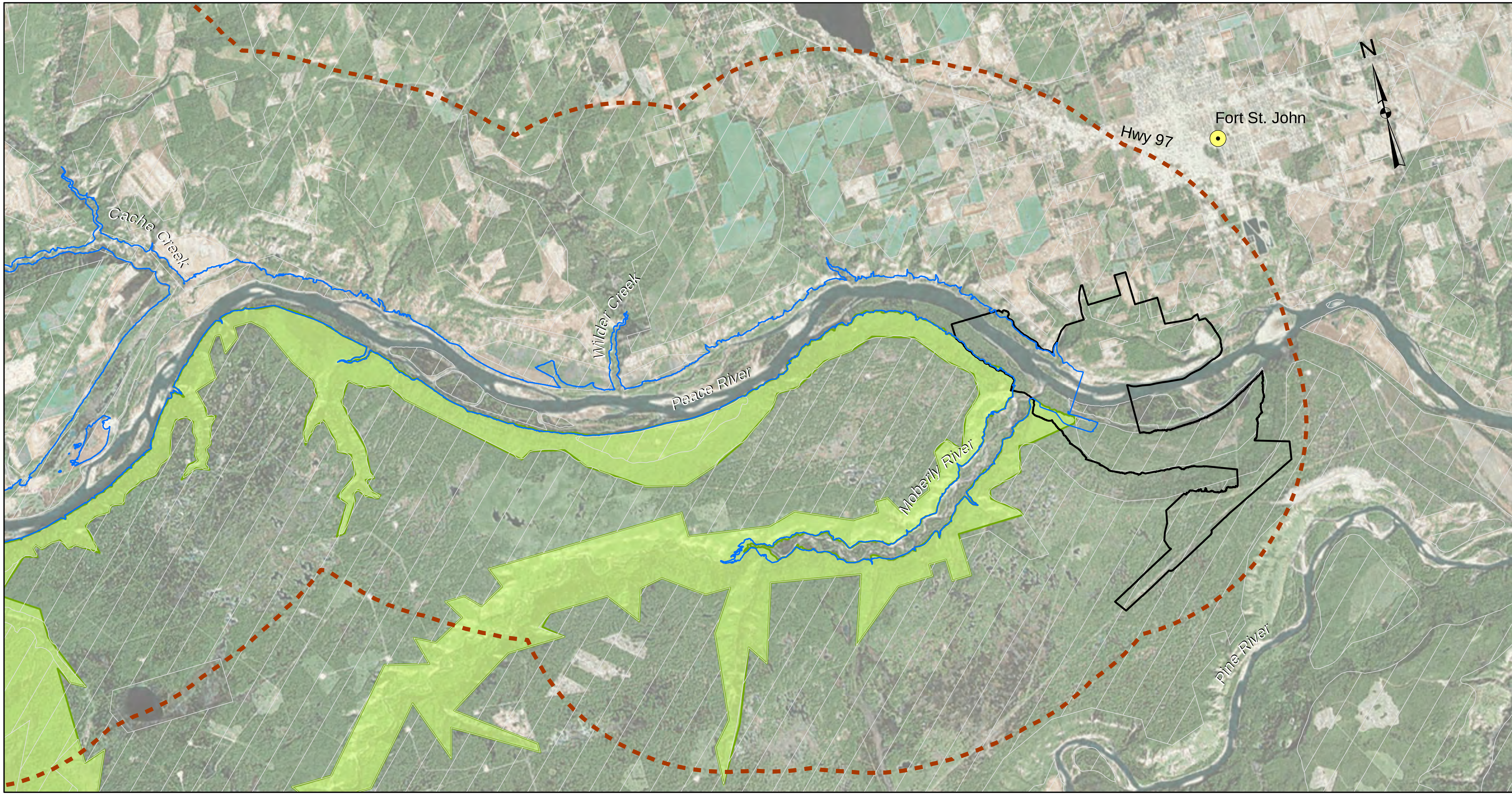

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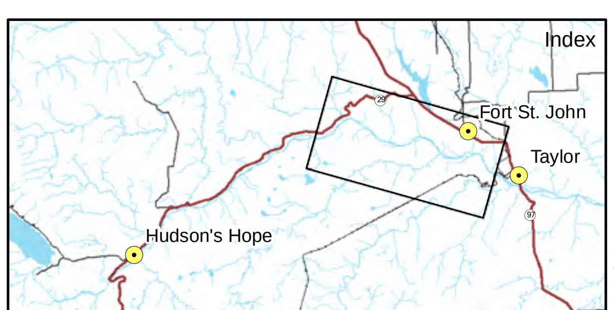
0 2 km



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

BC Hydro

Wildlife Habitat Utilization Monitoring Area Identification - Map 4 of 4

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

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

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

Appendix B – Crop Drying and Humidity Monitoring Program Report

REPORT

SITE C AGRICULTURAL CLIMATE REPORT

FORT ST. JOHN, BC

2021 ANNUAL REPORT

RWDI # 2002353

July 20, 2022

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 99% for both EC stations, and the daily collection of half-hour computed fluxes and climate data resulted in a 100% data representation for 2021. Main line power outages were the only cause for data loss.

Climatologically, 2021 was dry and very warm, experiencing a record-breaking heat dome between June 25th and July 1st. 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). On average June was the driest GS month, and August was the wettest due to an intense rain event early in that month. Station 4 received the least precipitation during the GS, while it maintained a high volumetric water content.

The EC measured and Priestley and Taylor (PT) modelled cumulative evapotranspiration (ET) was greatest at Station 4, reaching 347 mm compared to 331 mm at Station 1 with a difference of 16 mm, prior to energy balance closure (EBC). The annual EBC values were 0.69 and 0.75 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of ET increases their values to 435 and 433 mm, respectively. This eliminates the difference in annual cumulative ET between the two stations to within uncertainties.

The PT proportionality constant α was used to estimate actual ET from Potential Evapotranspiration (PET) estimates 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 α for Stations 1 and 4 was closer to 1.24 and 0.95, 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 1.09 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 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 11 had the highest CMD (286 mm) 26 mm above the average (260 mm) by the end of the GS. The stations in decreasing order of CMD are 11, 1, 3, 6, 7, 4, and10. During the GS, all stations experience moisture deficit because ET > Effective Precipitation (EP). Stations 11, 7, and 4 had the highest annual *ET* of 337 mm, 319 mm, and 315 mm, respectively. The low EP at Station 11 (51 mm) and high ET contributed to it having he largest CMD.

Output from the CDM was used to compute the cumulative Good Drying Days (GDD) for each month and station. Based on this output, June had the highest number of GDD averaged across stations. In line with the CMD results, Station 11 had the highest number of GDD recorded. The high drying rate and low rain rewetting recorded for that Station account for this similarity where CMD results were the balance between low EP and high ET. In contrast to the CMD results, Station 10 had equally high CDM as Station 11 with 136 total. This is likely due to the difference in calculations for effective precipitation and rain rewetting between the CMD and CDM. Also in contrast with the CMD results, Station 1 had the lowest number of GDD and second highest CMD recorded. This was the result of accounting for dew formation and rewetting at that Station in the CDM.

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VERSION HISTORY

Index	Date	Pages	Authors
1	July 19, 2022	All	Iain Hawthorne, Ph.D. 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
GDD	Good Drying Days
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 of Dunne Zaa, Cree and Tse'khene cultural descent.

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 to evaluate associated effects on the calculated Climate Moisture Deficit (CMD) and Crop Drying Model (CDM) within the area. Monitoring includes 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 2021. 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 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 Figure A-1 (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	Canola and 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 2021, the ground cover was observed to be;

- Station 1 – Canola and grasses. The unmanaged wild grass portion of the field was tilled in August. The Canola portion of the field was harvested in October.
- Station 3 – wheat and grasses. Similarly to Station 1, this field was harvested in October.
- Station 4 – alfalfa/clover/grasses/wildflower cover crop that grew undisturbed throughout the year.
- Station 6 – grasses/wildflower/small shrubs comprised the dominant ground cover on this unmanaged pasture .
- Station 7B – grasses/wildflower/small shrubs comprised the dominant ground cover on this mostly unmanaged field
- Station 10 – alfalfa/clover forage crop that was harvested in September.
- Station 11 – grasses/wildflower/small shrubs comprised the dominant ground cover on this unmanaged pasture

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 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.

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

where ρ_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 2021 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});
λE = 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;
γ 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
α 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 α. 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 α. A growing season (GS) assessment of the PT proportionality constant (α) 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:

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

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

A value of γ = 0.062 was used for the psychrometric constant in Equation 2 (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:

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

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:

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

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

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

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

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 when 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:

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

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 GDD (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. Time periods when the IRGA/sonic anemometer are malfunctioning or the system experiences a power outage can contribute to data loss. At other times (e.g., CF card failure) the 30-minute fluxes that are downloaded daily can be carefully assessed for use.

The 2021 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. The utilization of a spare IRGA allowed annual calibrations to occur with no associated data loss. 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 2021.

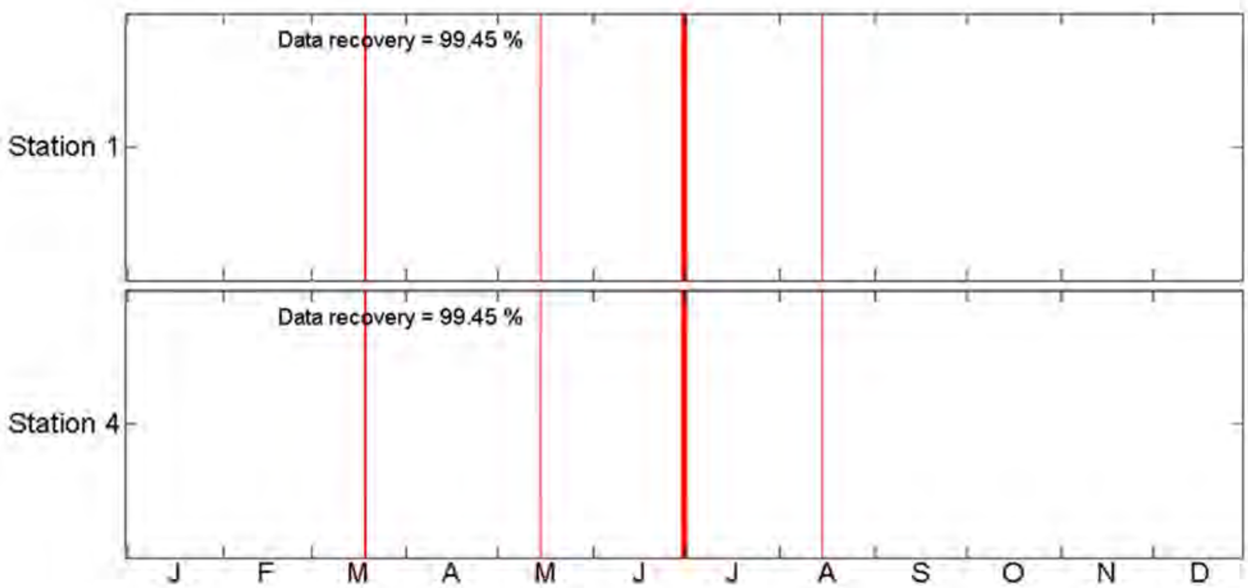

Figure 2-1: System High Frequency Performance in 2021.

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 produce 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 (λE) 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 λE 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 λE 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 (λE). 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 λE 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, these gaps were filled using the standard Food Climate Research Network (FCRN) gap filling approach as modified by Brown et al. (2010). 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 λE 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: 2021 Annual Report where necessary (RWDI, 2022). This is followed in section 3.2 by a more specific presentation of EC λE measurements and EBC estimates at those stations. Next, ET measurements are presented and compared to modelled ET, and the *PT* α 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: 2021 Annual Report (RWDI, 2022). 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 2021 was a very warm and dry year (RWDI, 2022).

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 and 6 have high G values early in the GS; this difference is likely early melting of snow cover at these locations as indicated by increasing soil moisture content (Figure 3-1). 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 inconsistently during summer months of June, July, and August (Figure 3-1).

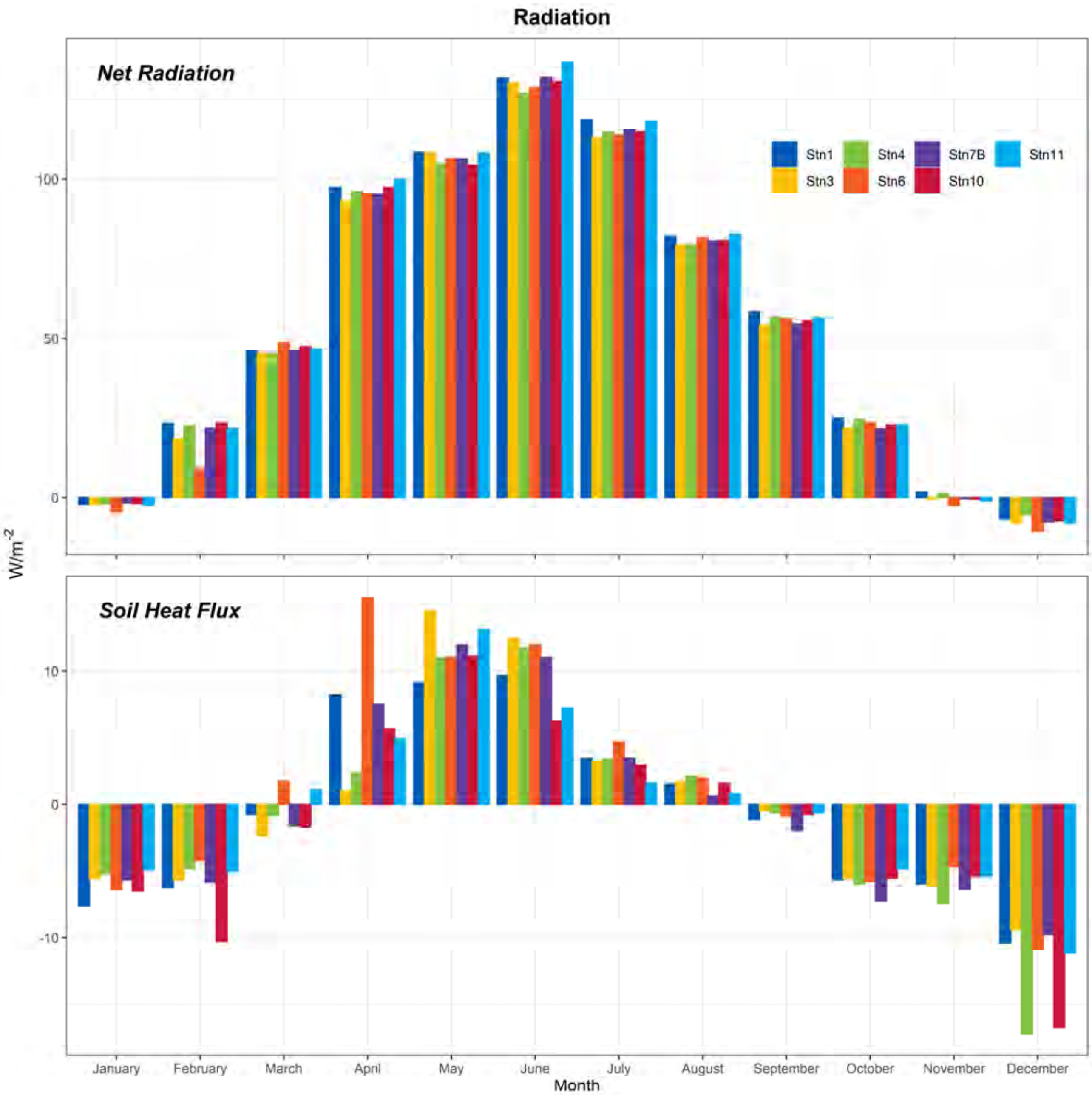

Figure 3-1: Mean monthly daytime net radiation and mean monthly soil heat flux at all climate stations in 2021.

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 early in the GS and Stations 7B throughout 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). Annual temperatures were above average in 2021.
- Relative humidity (Figure 3-3) was highest at Stations 1 and 11 (low 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 November (75 – 85%).
- There was very little precipitation during the spring melt in April, while precipitation measurements during the GS were highest in August. Annual total precipitation was low for all stations compared to other years and this is expressed later in effective precipitation total volumes calculated for the GS.
- The soil volumetric water content (VWC) was greatest at Stations 7B and 11 early in the growing season. In May and June, it was greatest at Station 4 and 10, likely in part due to the specific soil types at that location. This suggests less limitation to ET, and rates should be high at these stations. While there was a large and intense rain event in early August, VWC was low at all stations in July and August. Station 3 VWC sensor was determined dysfunctional from January onwards (due to rodent damage) and removed for repair in April (after snow melt) and reinstalled in October when field access was granted after harvest.

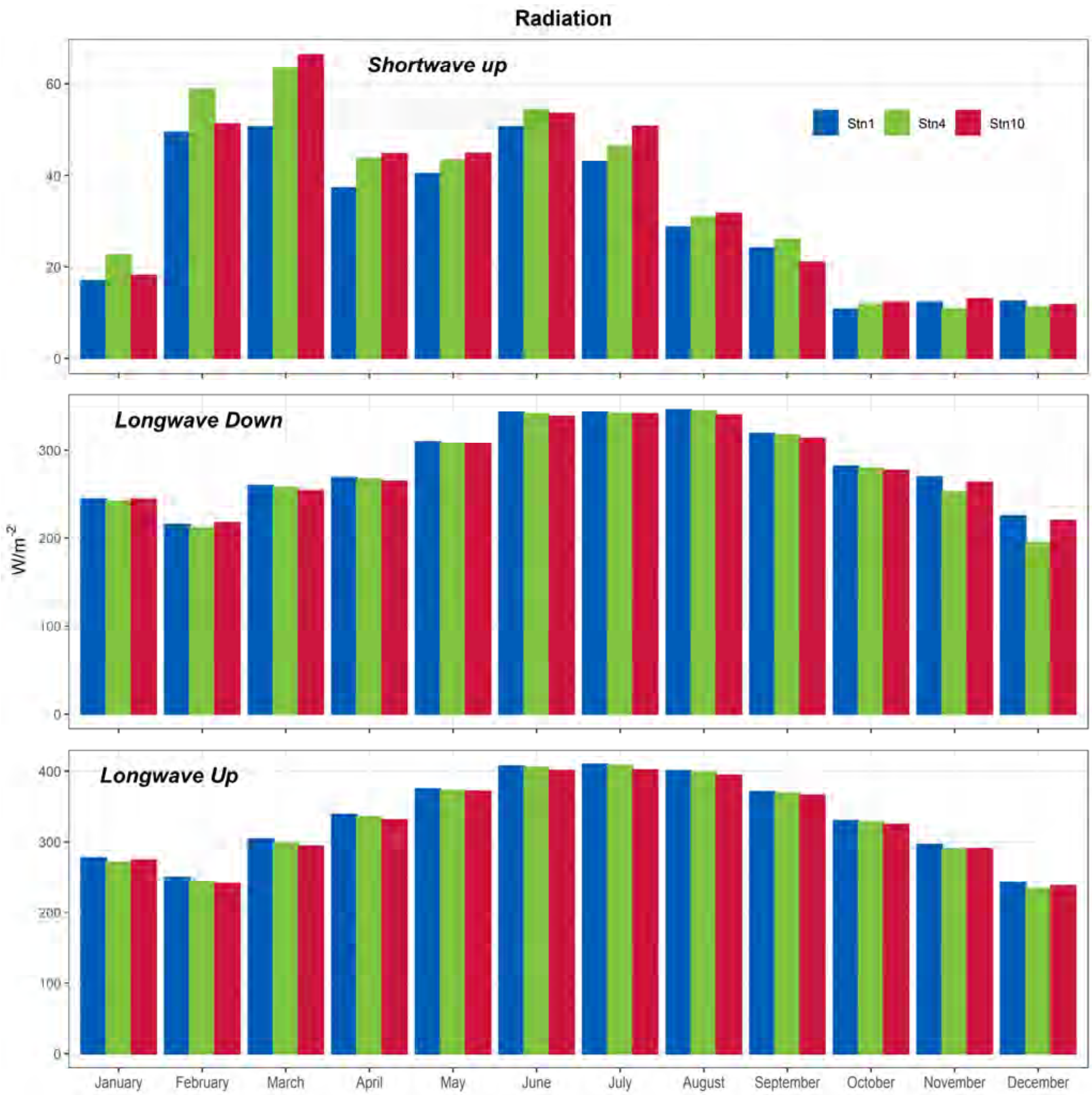

Figure 3-2: Mean monthly radiation balance components measured at EC Stations 1 and 4 and climate Station 10 in 2021.

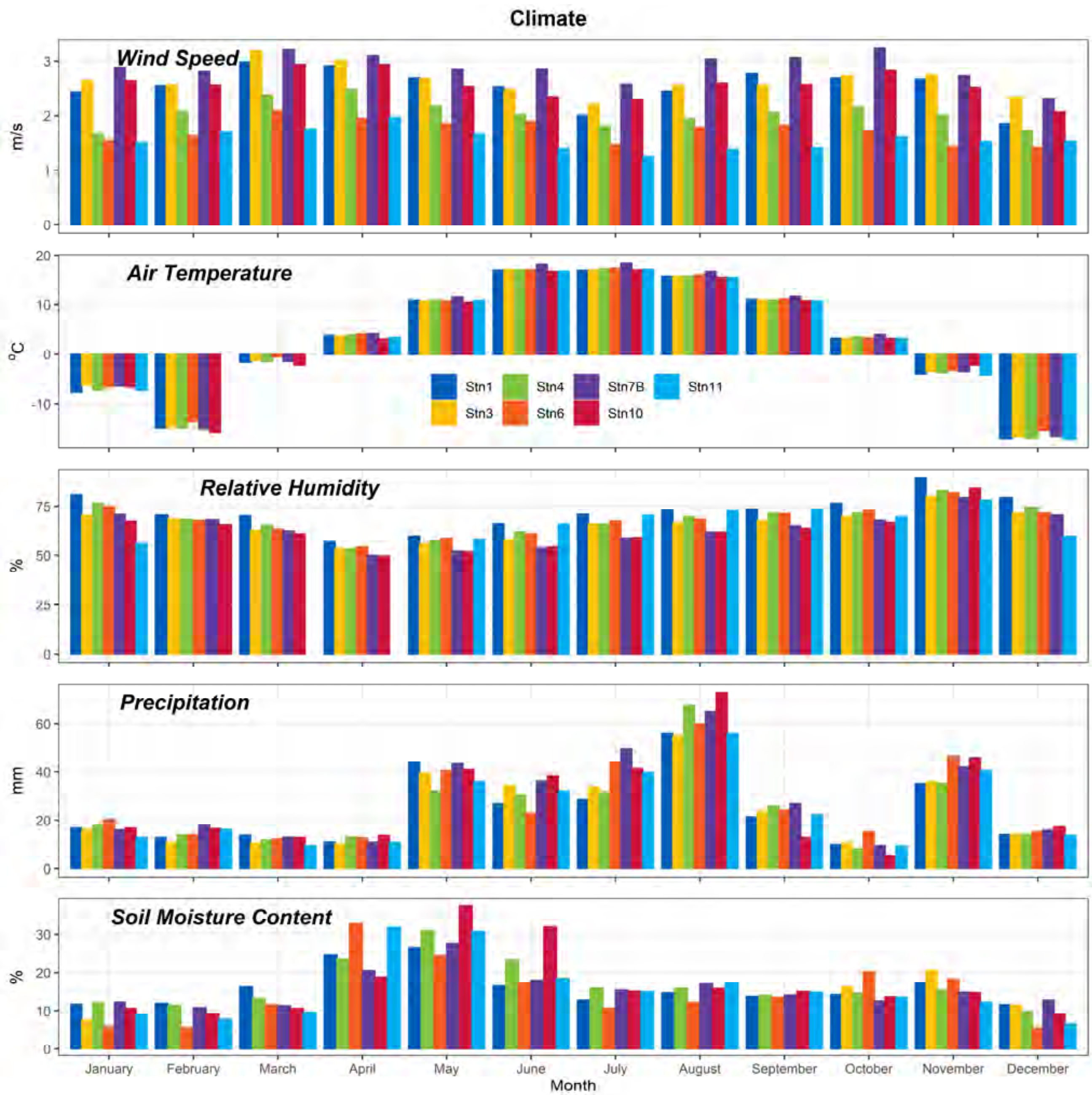

Figure 3-3: Mean monthly wind speed, air temperature, relative humidity, total monthly precipitation, and volumetric soil moisture content measured at all climate stations in 2021.

3.2 Energy Balance Measurements and Evapotranspiration

Energy balance components at both EC stations followed similar trends throughout 2021 (Figure 3-4). Sensible heat flux (*H)* and soil heat flux (*G*) increased in April after the snow melted through March, while latent heat flux (*λE* denoted as *LE* in figures) and net radiation (R_n) followed an approximately sinusoidal trend throughout the year. Net radiation R_n was similar at Station 1 than 4 during the GS. 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 347 mm compared to 331 mm at Station 1 with a difference of 16 mm, prior to energy balance closure (EBC) correction. The annual EBC values were 0.69 and 0.75 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of ET increases their values to 435 and 433 mm, respectively. This eliminates the difference in annual cumulative ET between the two stations to within uncertainties. Figure 3-5 indicates that this has little impact on the seasonal trends and monthly differences.

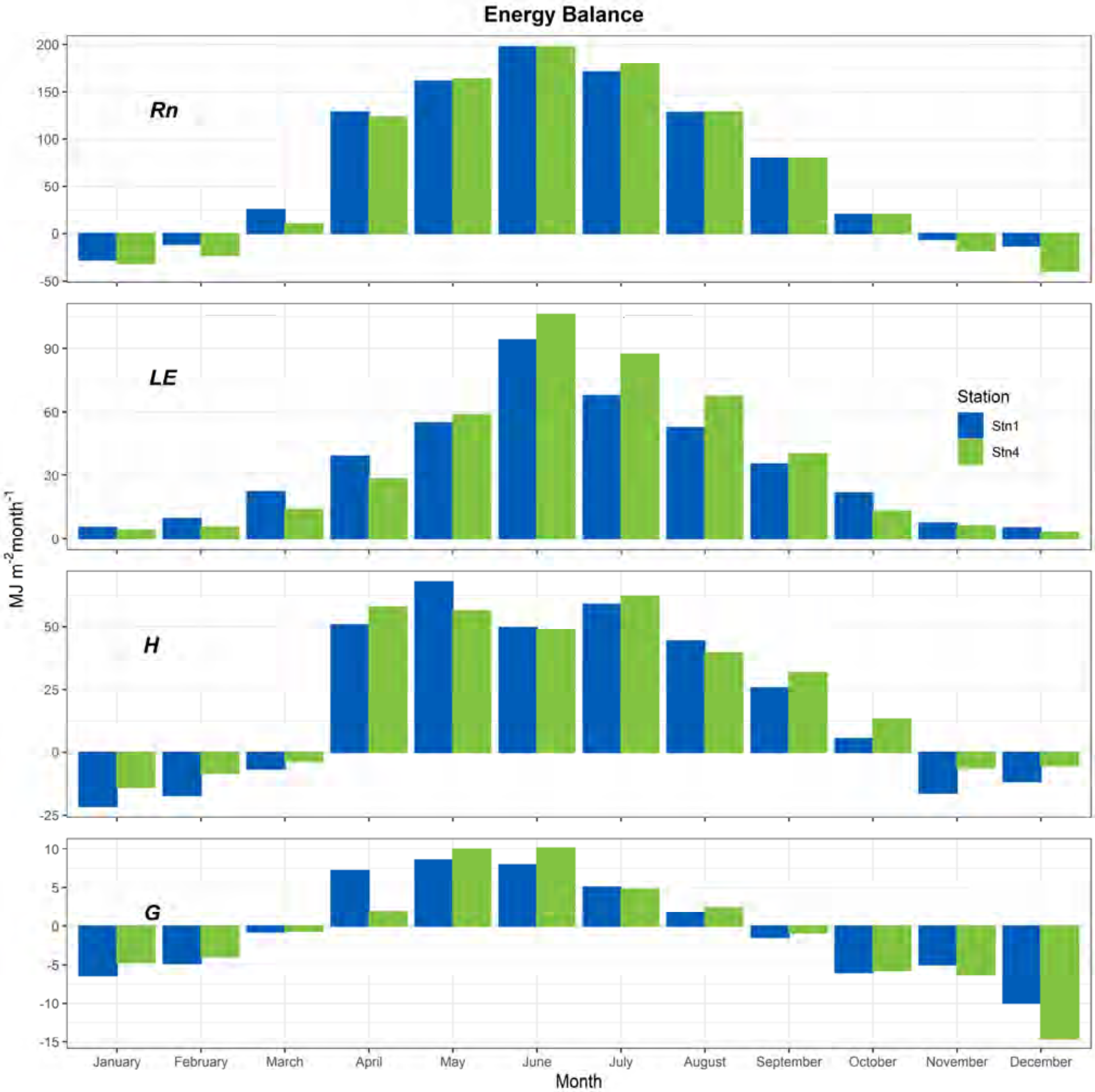

Figure 3-4: Cumulative monthly energy balance components measured at EC Stations 1 and 4 in 2021: net radiation (*Rn*), latent heat (*LE*), sensible heat (*H*), and soil heat flux (*G*).

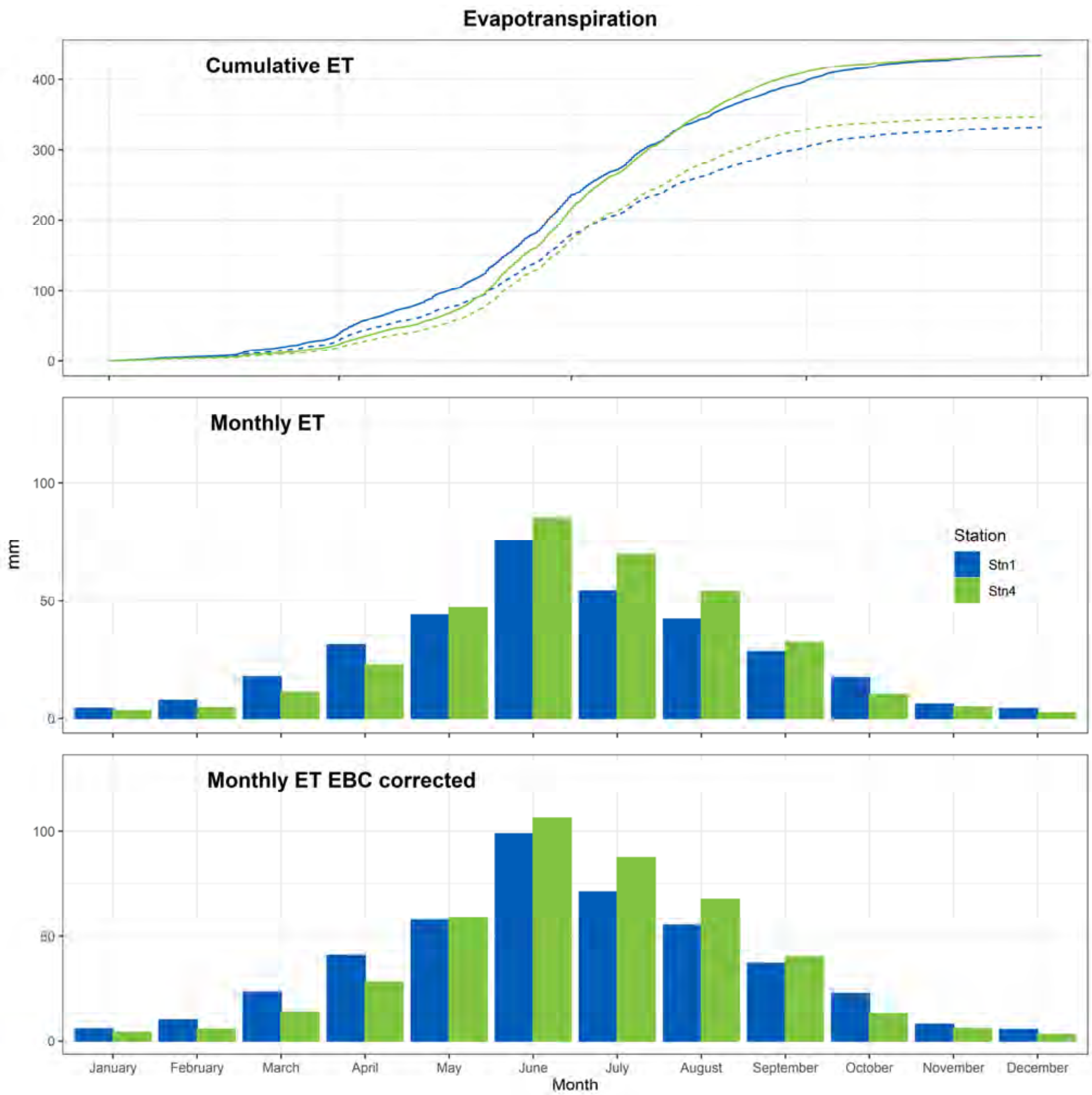

Figure 3-5: Cumulative annual and monthly ET from EC measurements available at Stations 1 and 4 in 2021. Solid lines in Cumulative ET indicate energy balance closure applied.

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 109 and 91 W/m^2 over measured values at Stations 1 and 4, respectively, without EBC applied. The EBC correction reduced the differences to 93 and 79 W/m^2, respectively.

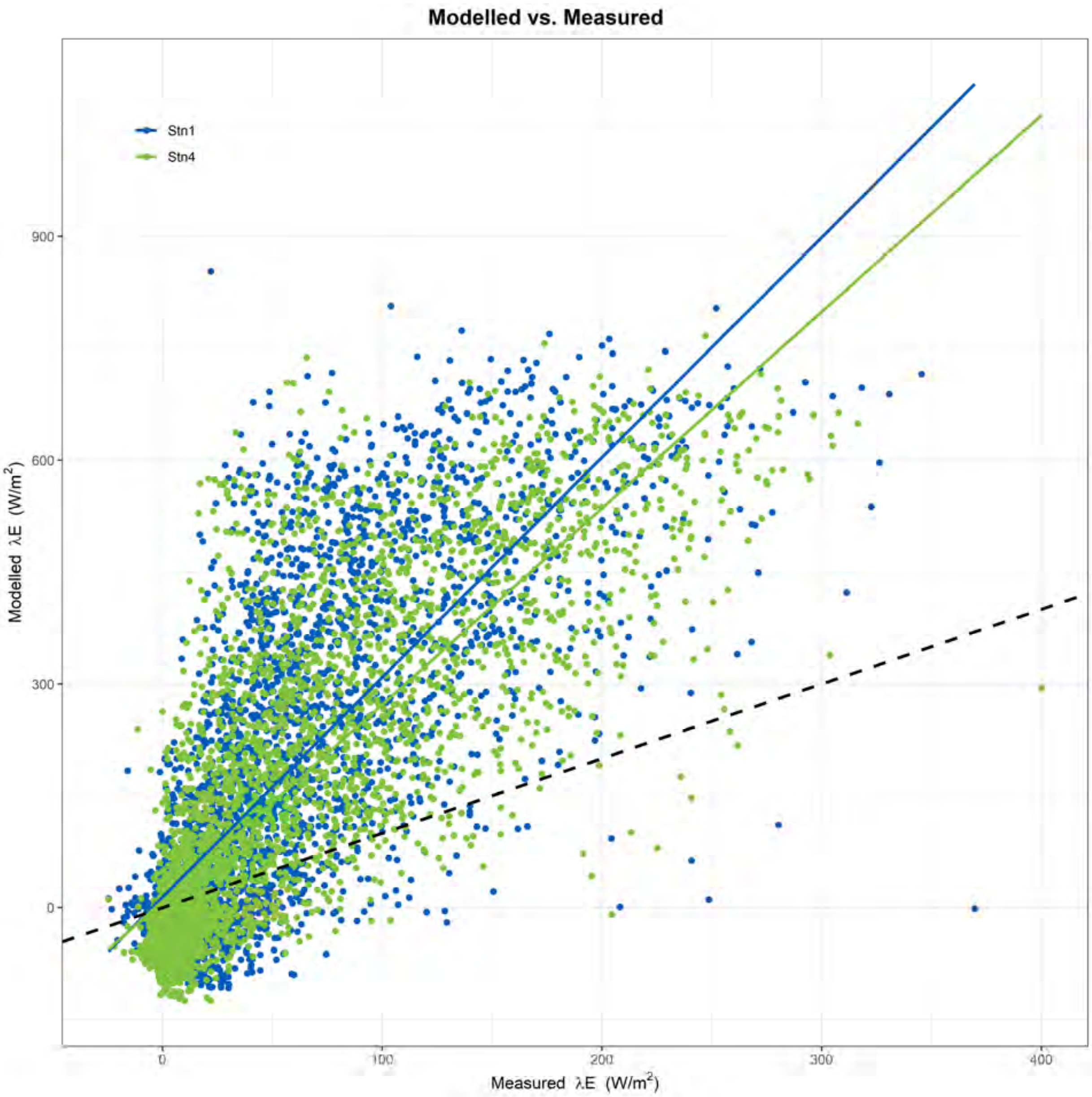

Figure 3-6: Hourly measured λE vs. PT modelled λE in 2021. No EBC correction was applied. PT α value of 1.26 was used. The black dotted line is the 1:1 linear regression. Modelled values are consistently overestimated.

Table 3-1 illustrates the differences in the two stations linear regression equations when comparing modelled vs. measured. 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 0.15 and 0.12 mm/h for Stations 1 and 4, respectively. After the EBC correction was applied, this difference was reduced to 0.13 and 0.10 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 *λE* linear regression output for 2021.

Station	α	*y*	EBC	Intercept	Slope	R^2	DF	*P*
1	1.26	0.062	1	13.89	2.95	0.60	3752	<2.2e-16
4	1.26	0.062	1	8.83	2.63	0.65	4049	<2.2e-16
1	1.26	0.062	1.31	13.89	2.25	0.60	3752	<2.2e-16
4	1.26	0.062	1.25	8.82	2.11	0.65	4049	<2.2e-16
1	1.23	0.062	1.31	13.64	2.21	0.60	3752	<2.2e-16
4	0.95	0.062	1.25	6.62	1.58	0.5	4049	<2.2e-16

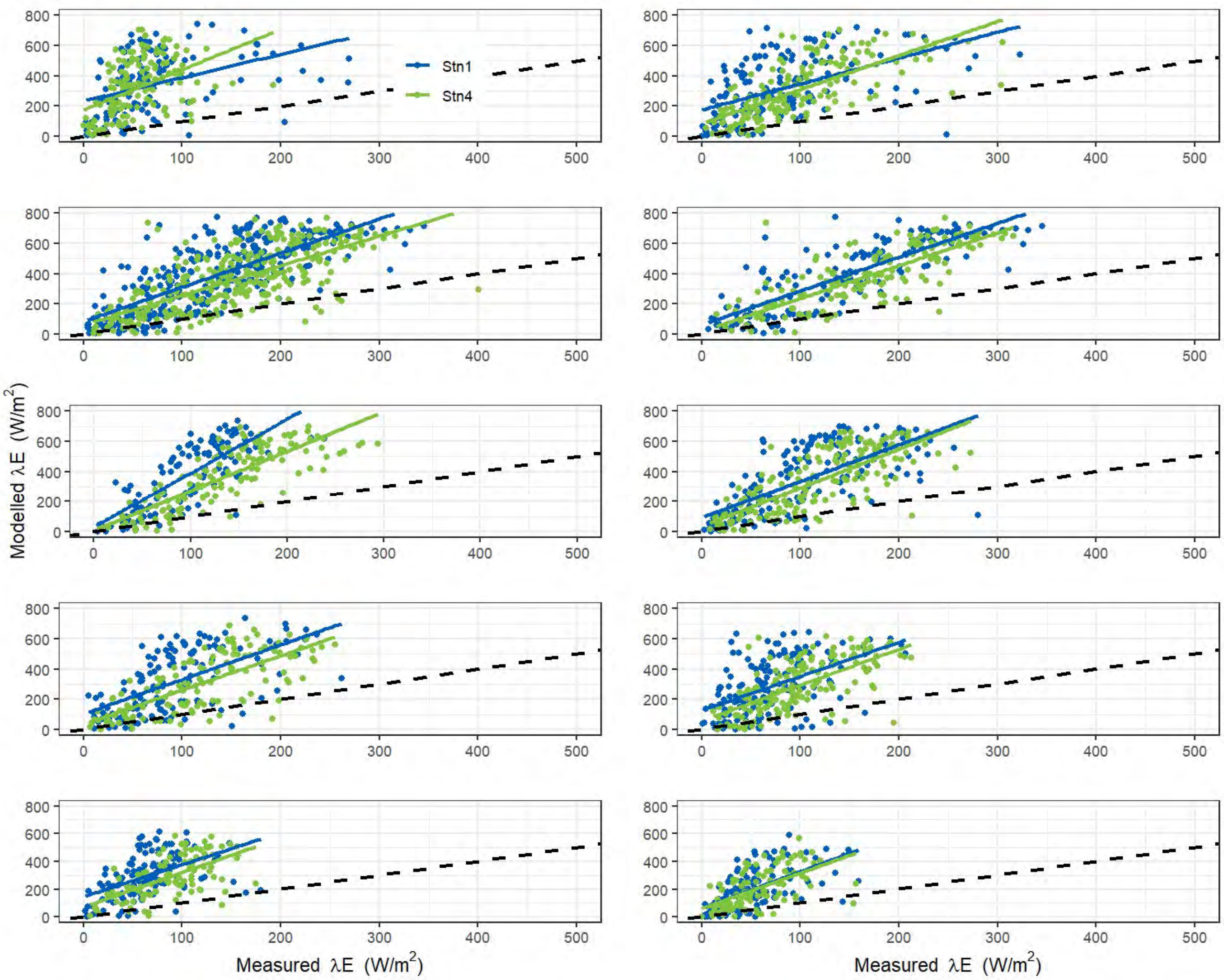

Figure 3-7: Biweekly May through September 2021 (top left to bottom right panel) modelled vs measured latent heat flux (LE) linear relationship. The black dotted line is the 1:1 linear regression. Modelled values are consistently overestimated and less so during June and July.

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 latent relative to sensible heat flux (H/LE <0.3). From measurements during the GS, it was determined that PT α for Stations 1 and 4 were likely close to 1.24 and 0.95, 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 0.06 mm/h and 0.09 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 parameter α 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 during 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 ±11% of the mean values (Table 3-2). Station 11 had the highest CMD with 27 mm above the average by the end of the GS (286 mm). This was largely the result of Station 11 having higher ET and lower EP later in the growing season. The stations in decreasing order of CMD are 11, 1, 3, 6, 7, 4, and 10. Station 10 had the highest EP while Station 3 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 11 and 4, with Station 11 estimated to be 21 mm above average and station 4 10 mm below the average. Station 11 ET increased in August, when VWC was higher than other stations (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 11 (51 mm) and highest 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 2021.

Station	Percentage Data Cover	*Rn* (W/m^2)	*Ta* (°C)	*EP* (mm)	*ET* (mm)	CMD (mm)
1	99.0	100.2	14.3	46	314	268
3	100	97.0	14.3	46	313	266
4	99.4	96.8	14.4	56	306	250
6	100	97.4	14.5	55	315	260
7	100	97.8	15.3	69	319	250
10	100	97.3	14.1	72	309	237
11	100	100.5	14.2	51	337	286
Average	**99.8**	**98.1**	**14.4**	**57**	**316**	**260**

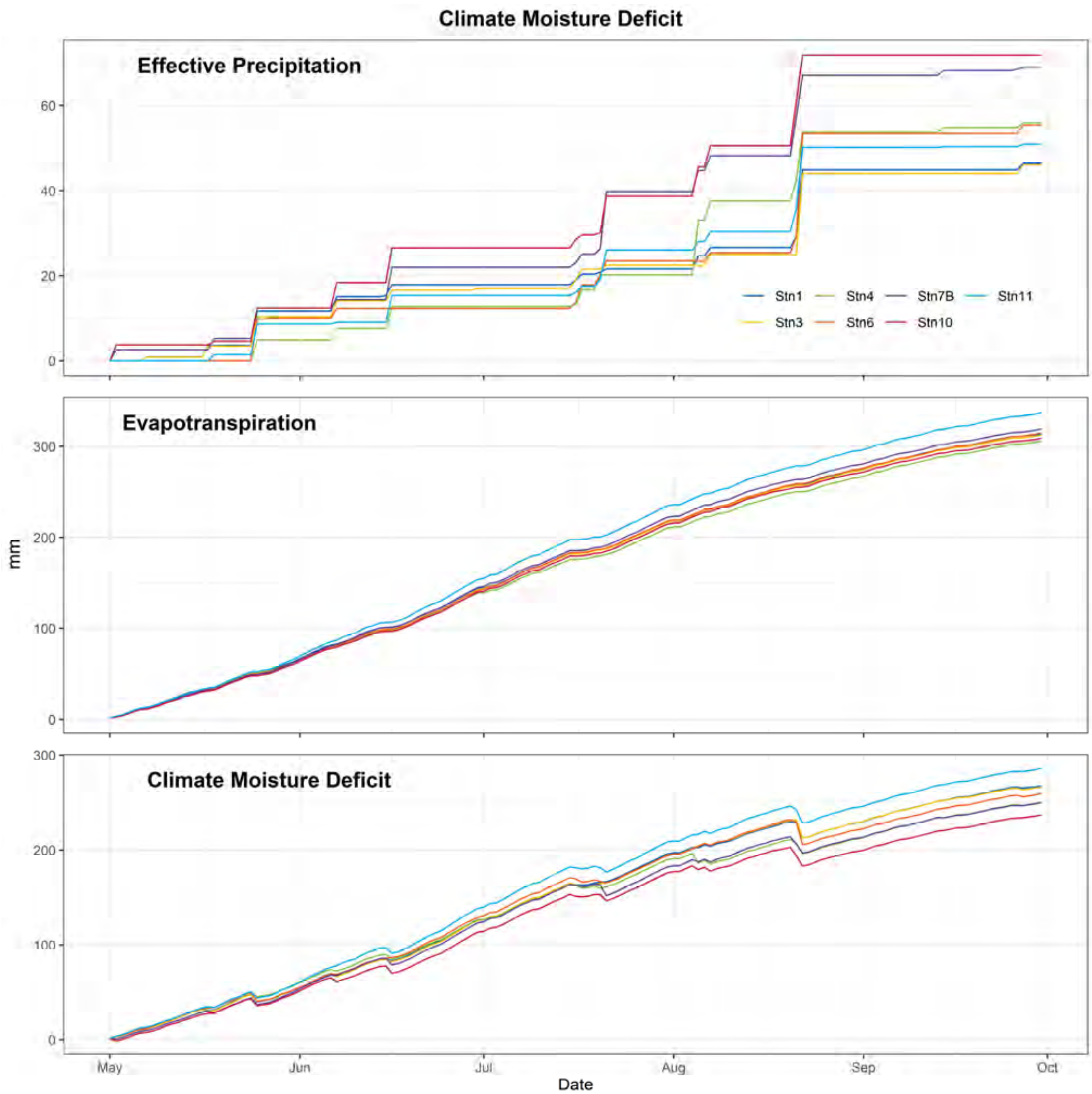

Figure 3-8: Modelled cumulative EP, ET, and CMD for all climate stations in 2021.

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 parameter 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 GDD (drying rate > wetting rate) was calculated for each station (Table 3-3). Figure 3-9 through Figure 3-13 show the computed inputs and CDM output for each month. Monthly GDD were similar across the GS with the highest number recorded during May, June and August of 27. July and September recorded the lower GDD with 26. The order of stations with increasing cumulative annual GDD is 1and 7 each with 130 and 133 GDD, followed by Stations 3, 4, and 6 each having 134 GDD, and finally, Stations 10 and 11 each with 136 GDD in 2021.

Table 3-3: Growing season good drying days in 2021.

Station	May	Jun	Jul	Aug	Sep	GS Total
1	26	26	26	27	25	**130**
3	27	27	27	27	26	**134**
4	27	27	27	27	26	**134**
6	26	28	26	27	27	**134**
7	26	27	27	27	26	**133**
10	27	28	26	27	28	**136**
11	28	28	26	28	26	**136**
Averages	**27**	**27**	**26**	**27**	**26**	**134**

Additional notes on Figure 3-9:

- The month of May had on average 27 GDD.
- Station 11 had the most GDD in May (28).
- Stations 1, 6, and 7 had the fewest GDD (26).
- Stations 11 maintained the fastest drying rate with the crop moisture content being reduced below 20% on 2021-05-10 followed by Stations 1, 3, 4, and 6 on the same day.
- Stations 7B and 10 passed the 20% crop moisture mark the following day on 2021-05-10 largely due to them having slower drying rates and a greater rain rewetting earlier in the month.
- The drying rate at Stations 1, 6, and 7 were lower than at other stations and Stations 1 and 7 experienced increased rewetting during the first rain event of the month.
- Only Station 1 experienced rewetting from dew formation in May.

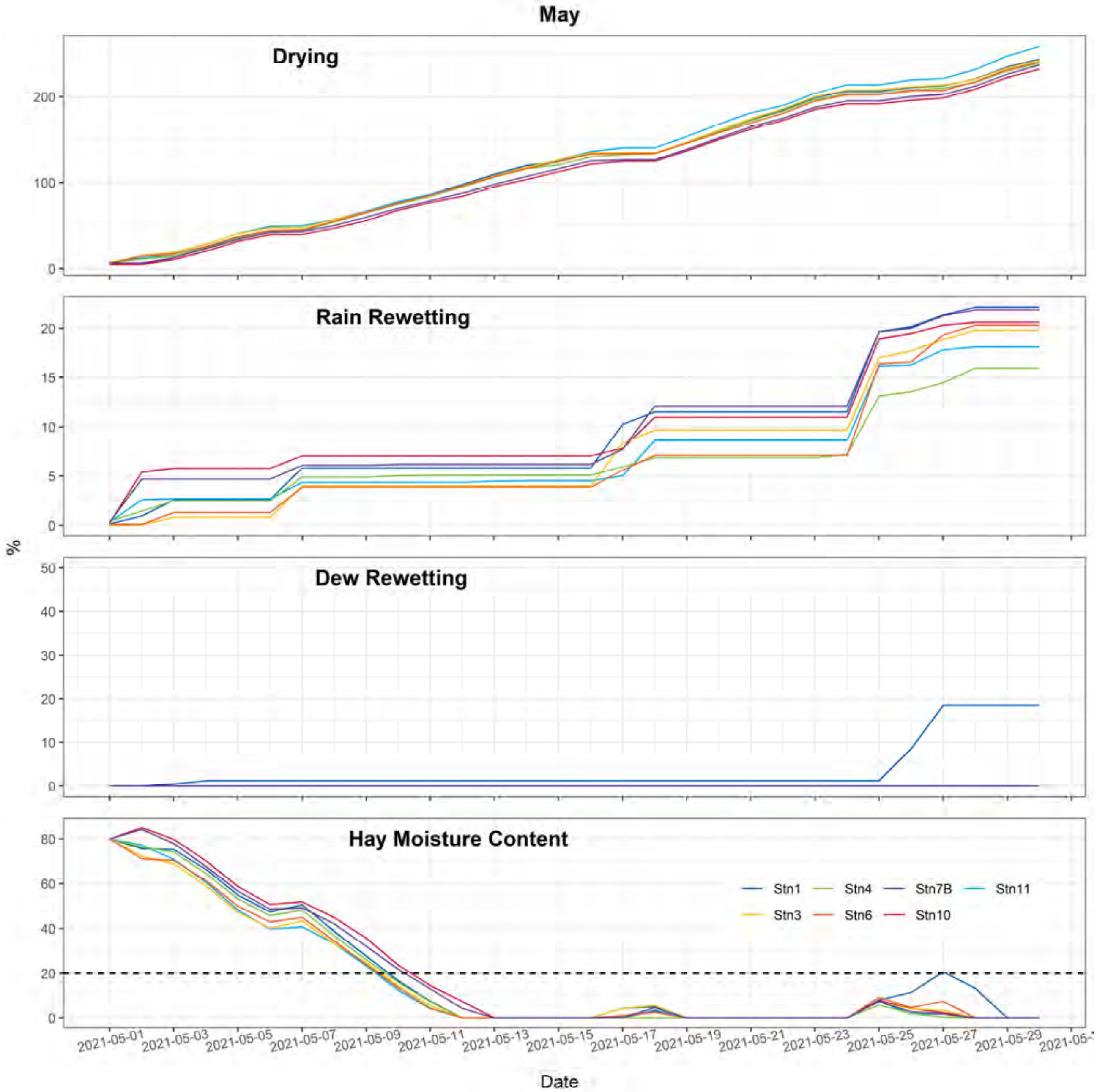

Figure 3-9: CDM components for May 2021.

Figure 3-10 shows CDM components for the June 2021 with the following observations:

- The month of June had the highest average of 27 GDD.
- Stations 6,10, and 11 had the highest number of GDD with 28 each.
- Station 11 maintained the fastest drying rate and was the first station where crop moisture content was reduced below 20% on 2021-06-05, two days before all other stations.
- Stations 1 had the lowest number of GDD in June with 26 because of dew rewetting towards the middle of the month.

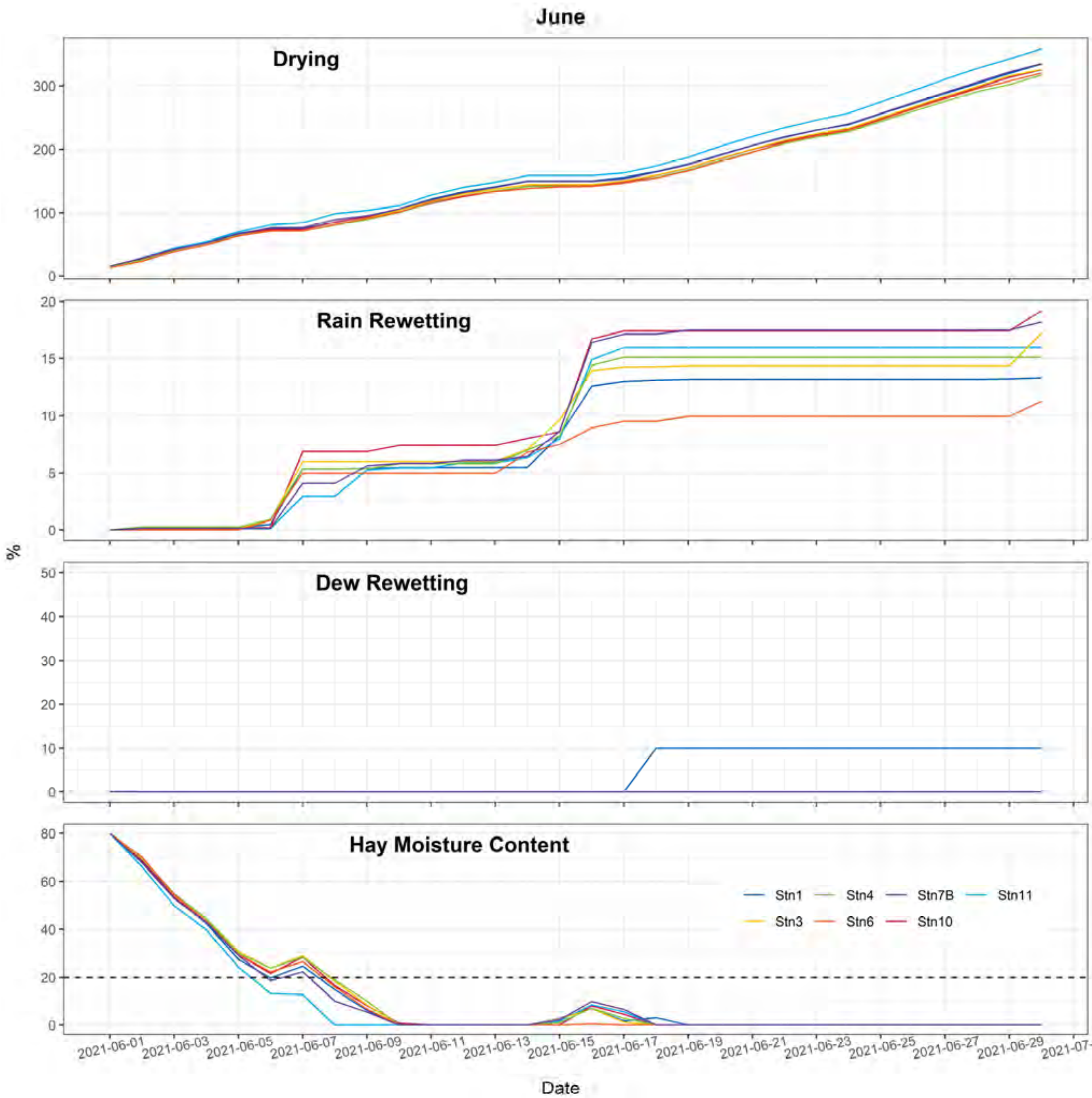

Figure 3-10: CDM components for June 2021.

The CDM components in July 2021 (Figure 3-11) display the following characteristics:

- July had below average GDD (26.4). This was largely due to large rain rewetting events in the second half of the month.
- Stations 3, 4, and 7 had the highest number of GDD with 27 each.
- Station 11 crossed below the 20% hay moisture content on 2021-07-05, one day ahead of all other stations.

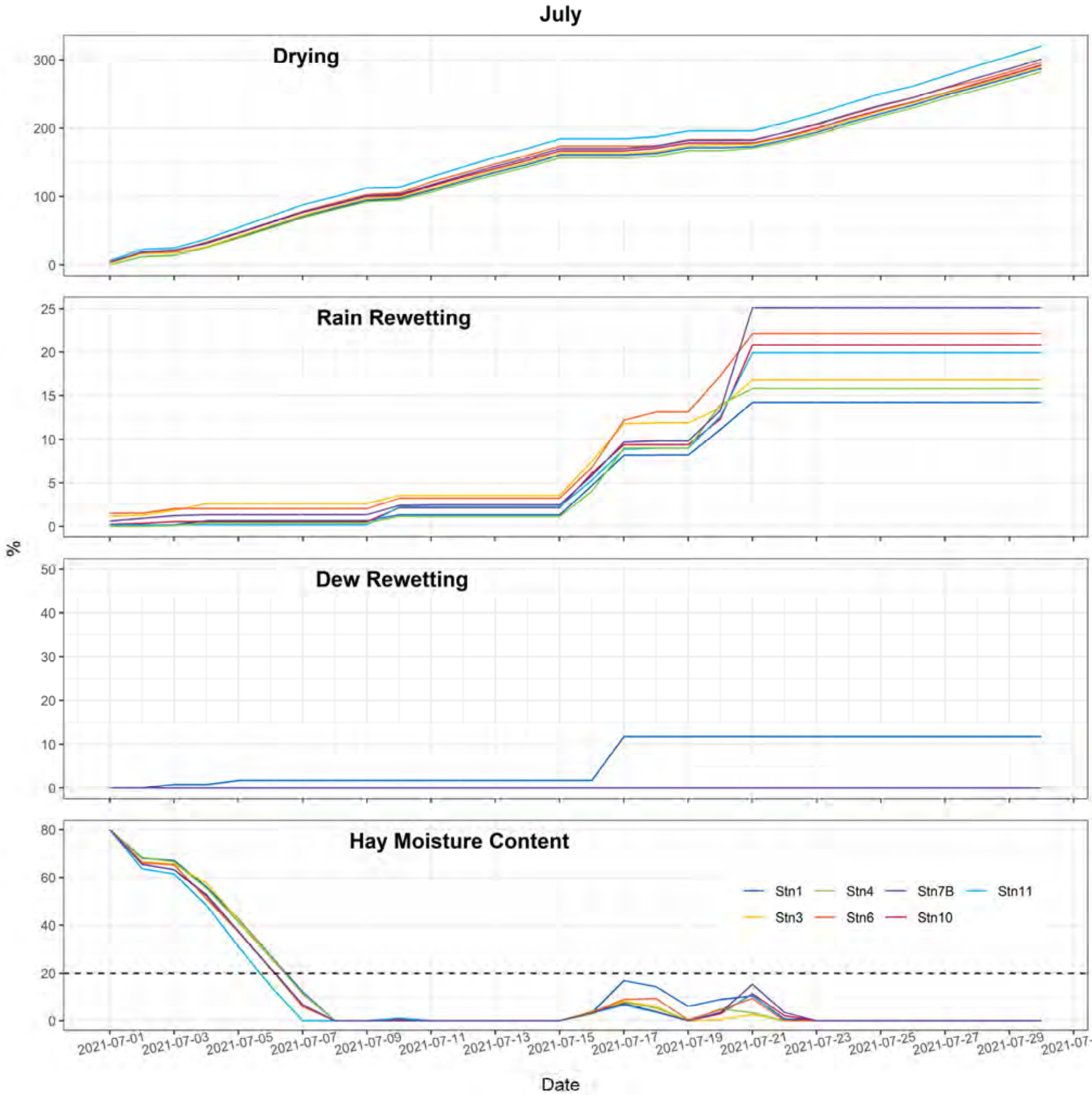

Figure 3-11: CDM components for July 2021.

The following characteristics are noted for the CDM component in August 2021 (Figure 3-12):

- The month of August had on average 27GDD.
- During August, Station 11 had the highest number of GDD with 28.
- All other stations had 27 GDD.
- Station 6 was the first station where crop moisture content was reduced below 20% on 2021-08-08.
- Stations 3 and 11 crop moisture content was reduced below 20% on 2021-08-09 followed by Stations 1, 7, and 10 on 2021-08-10 and lastly Station 4 on 2021-08-11.
- Station 4 was the last station where crop moisture content was reduced to below 20% due to it having the lowest drying rate and highest rewetting rate early in August.

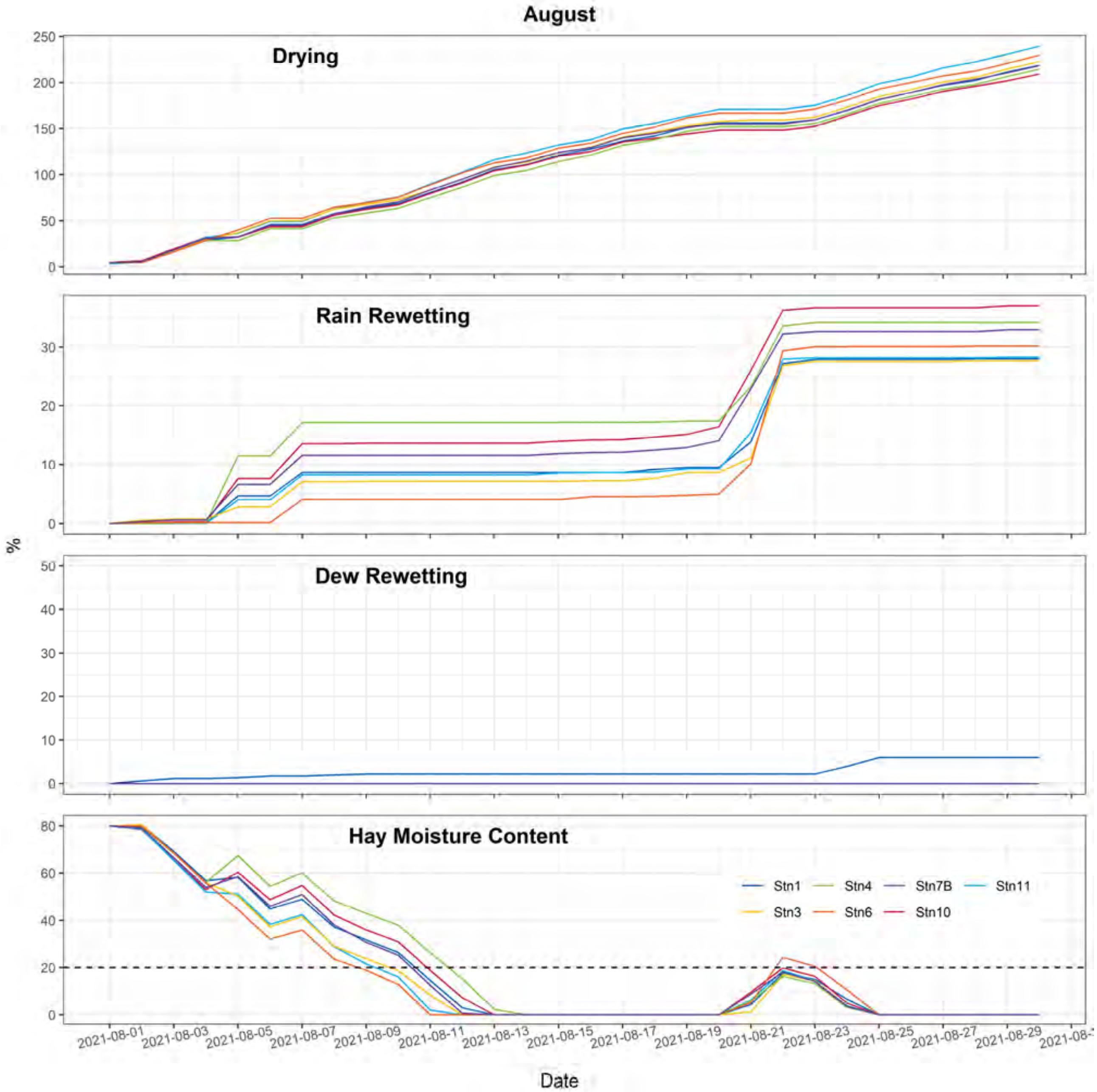

Figure 3-12: CDM components for August 2021.

Finally, for the month of September 2021, the following is noted (Figure 3-13):

- September had on average 26.3 GDD.
- Station 10 had the highest number of GDD with 28 followed by Station 6 with 27, Stations 3, 4, 7B, and 11 with 26, and lastly, Station 1 with 25.
- Station 1, 3, 4, and 11 maintained the fastest drying rate early in September and were the first stations where crop moisture content was reduced to below 20% on 2021-09-09, followed by Stations 6, 7B, and 10 on 2021-09-10.
- Station 1 had the fewest GDD on record with only 25 in September because of significant dew rewetting during that month.

In line with the CMD results, Station 11 had the highest number of GDD recorded. The high drying rate and low rain rewetting recorded for that station account for this similarity where CMD results were the balance between low EP and high ET. In contrast to the CMD results, Station 10 had equally high CDM as Station 11 with 136 total. This is likely due to the difference in calculations for effective precipitation and rain rewetting between the CMD and CDM. Also, in contrast with the CMD results, Station 1 had the lowest number of GDD and second highest CMD recorded. This was the result of accounting for dew formation and rewetting at that Station in the CDM.

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.

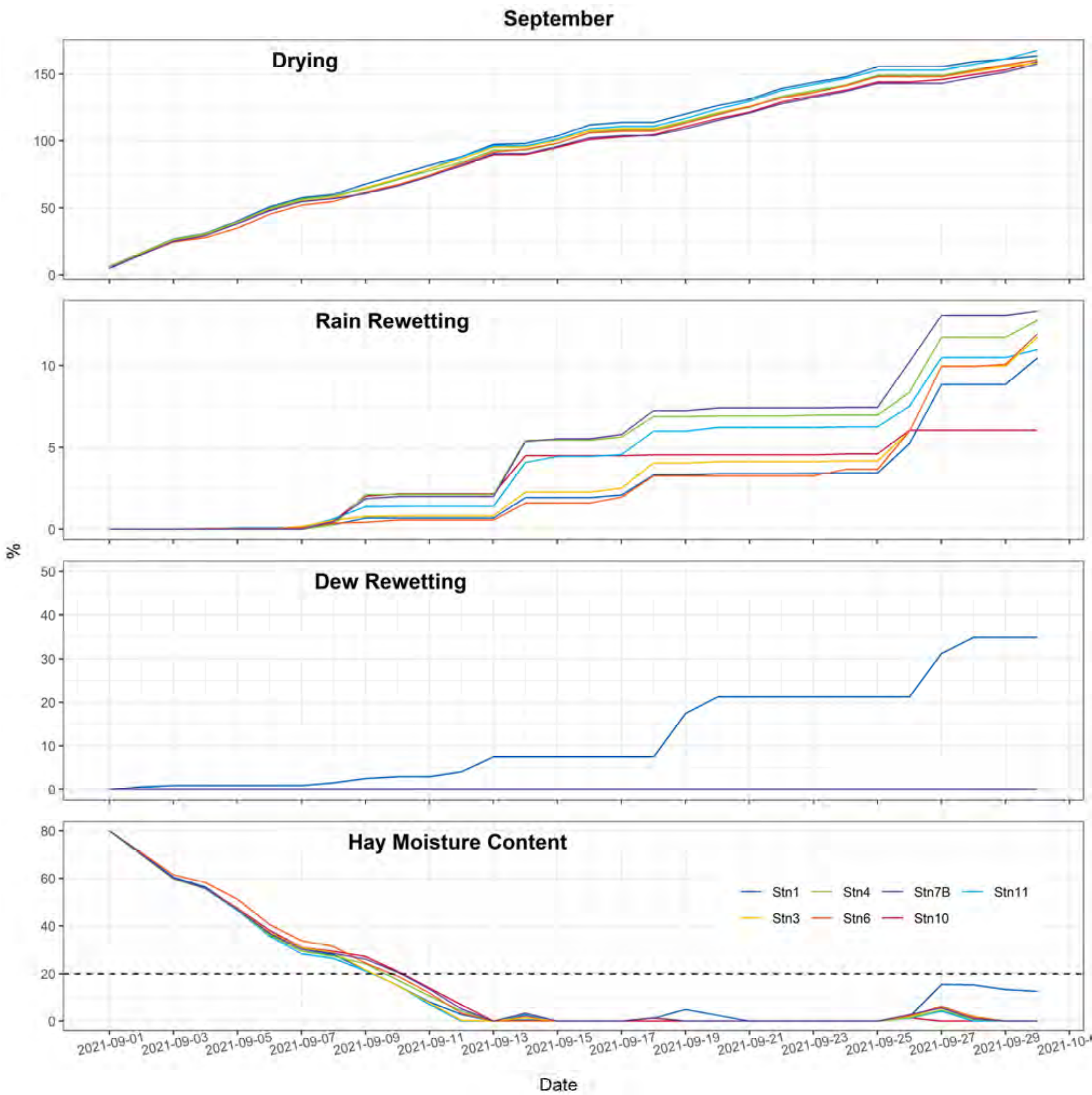

Figure 3-13: CDM components for September 2021.

4 SUMMARY OF RESULTS

The EC system performance for collected high frequency data was over 99% for both EC stations, and the daily collection of half-hour computed fluxes and climate data resulted in a 100% data representation for 2021. Main line power outages were the only cause for data loss.

Climatologically, 2021 was dry and very warm, experiencing a record-breaking heat dome between June 25th and July 1st. 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. On average June was the driest GS month, and August was the wettest due to an intense rain event early in that month. 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 347 mm compared to 331 mm at Station 1 with a difference of 16 mm, prior to EBC. The annual EBC values were 0.69 and 0.75 for Stations 1 and 4, respectively. Applying the corrections to the annual estimates of ET increases their values to 435 and 433 mm, respectively. This eliminates the difference in annual cumulative ET between the two stations to within uncertainties.

The PT proportionality constant α was used to estimate actual ET from PET estimates 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 *α* for Stations 1 and 4 was closer to 1.24 and 0.95, 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 1.09 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 11 had the highest CMD (286 mm), 26 mm above the average (260 mm) by the end of the GS. The stations in decreasing order of CMD are 11, 1, 3, 6, 7, 4, and 10. During the GS, all stations experience moisture deficit because ET > EP. Stations 11, 7, and 4 had the highest annual ET of 337 mm, 319 mm, and 315 mm, respectively. The low EP at Station 11 (51 mm) and high ET contributed to it having he largest CMD.

Output from the CDM was used to compute the cumulative GDD for each month and station. Based on this output, June had the highest number of GDD averaged across stations. In line with the CMD results, Station 11 had the highest number of GDD recorded. The high drying rate and low rain rewetting recorded for that Station account for this similarity where CMD results were the balance between low EP and high ET. In contrast to the CMD results, Station 10 had equally high CDM as Station 11 with 136 total. This is likely due to the difference in calculations for effective precipitation and rain rewetting between the CMD and CDM. Also, in contrast with the CMD results, Station 1 had the lowest number of GDD and second highest CMD recorded. This was the result of accounting for dew formation and rewetting at that Station in the CDM.

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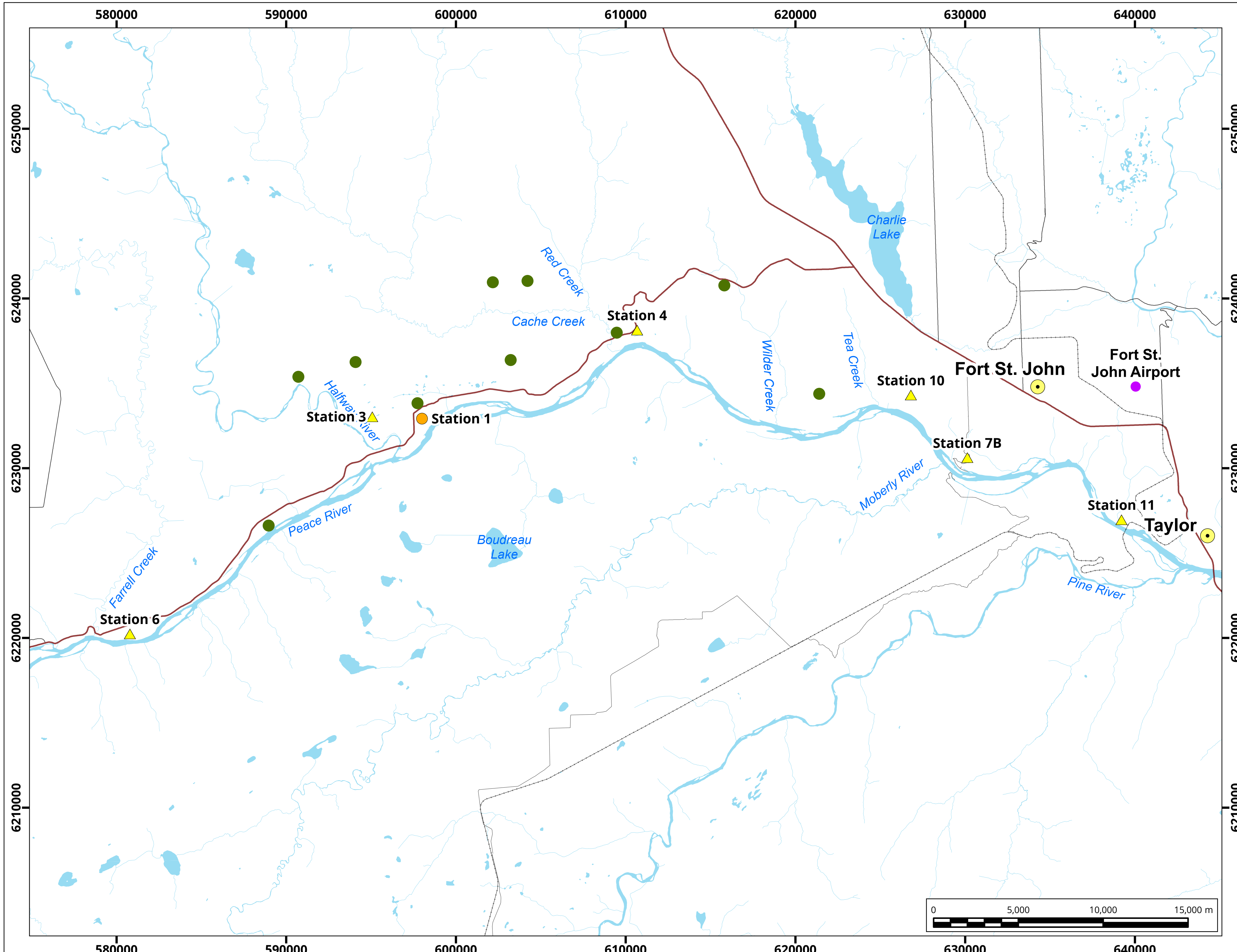
APPENDIX A

STATION LOCATION MAP AND 2021 ANNUAL RESULTS

The 2021 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 drying days (GDD). The results are displayed beside the station location and can be compared to the 2021 regional average computed using all stations (top left corner). Red indicates values that were greater than the 2021 regional average and blue indicates values that were below that amount.



Legend

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

- EP = Effective Precipitation
- ET = Evapotranspiration
- GDD = Good Drying Days
- Red indicates values greater than the 2021 regional average
- Blue indicates values below the 2021 regional average

Station Number	Station Name	EP	ET	CMD	GDD
1	Attachie Flat Upper Terrace	46	314	268	130
3	Attachie Plateau	46	313	266	134
4	Bear Flat	56	306	250	134
6	Farrell Creek	55	315	260	134
7B	Site C North Camp	69	319	250	133
10	Tea Creek	72	309	237	136
11	Taylor	51	337	286	136
	Average	**57**	**316**	**260**	**134**

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

2021 Annual Climate Moisture Deficit (CMD) and Crop Drying Model (CDM) Results at Climate Stations

Map Projection: NAD 1983 UTM Zone 10N

True North

Project #: 2102352

Drawn by:	DJH	Figure:	1
Approx. Scale:	1:250,000		
Date Revised:	Jul 14, 2022		

APPENDIX B

SITE PICTURES

Station 1 March through October shows the leafing out and dieback experienced across the region. Short growing season observed in May, June, and July with harvesting of the Canola crop occurring in August.

Station 3 September

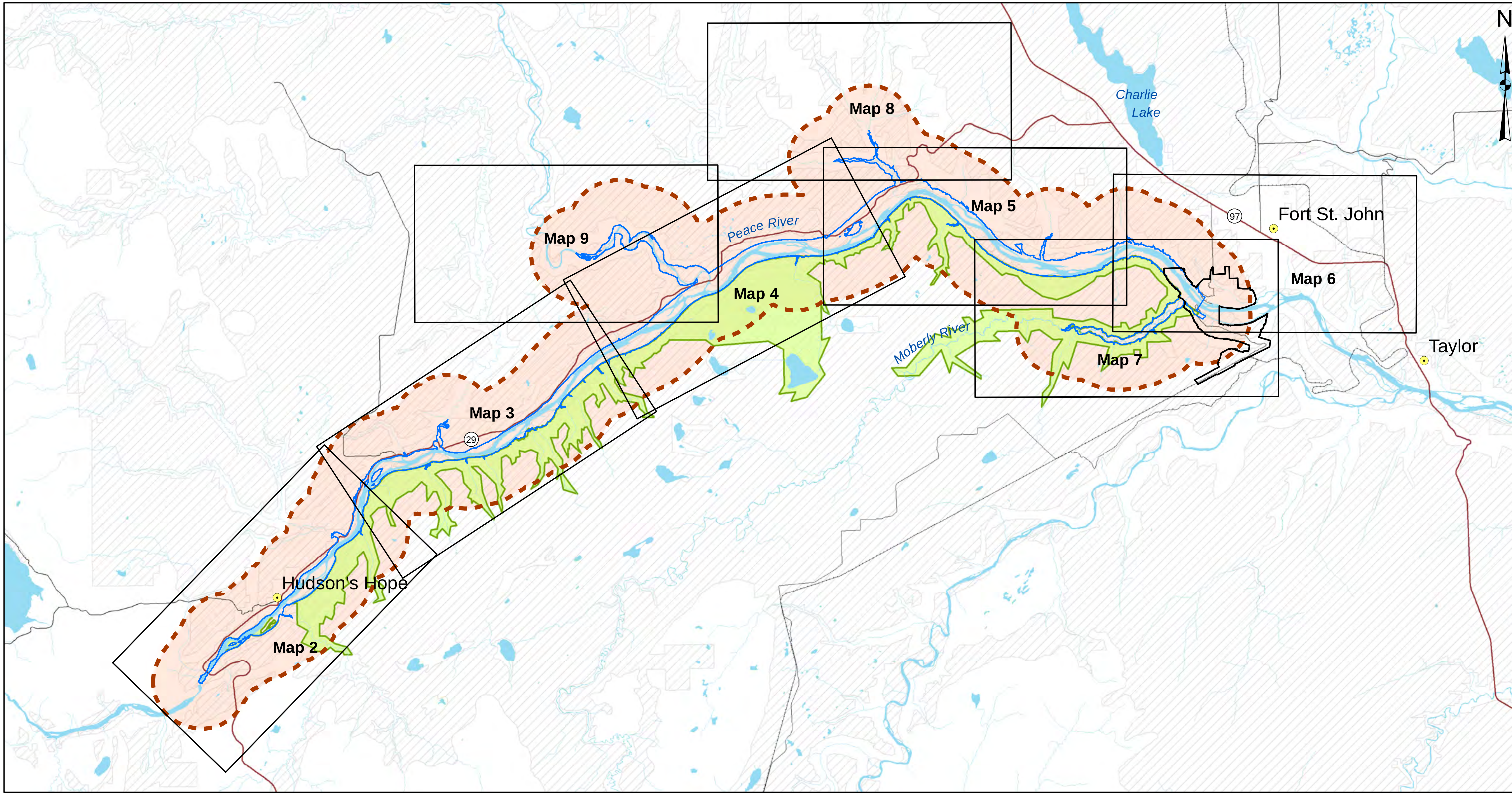
Station 4 in August and September

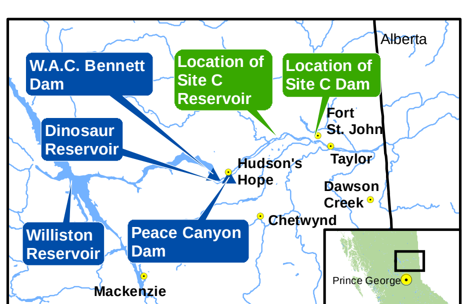
Station 6 in October

Station 7 in August

Station 10 in May

Station 11 in 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.

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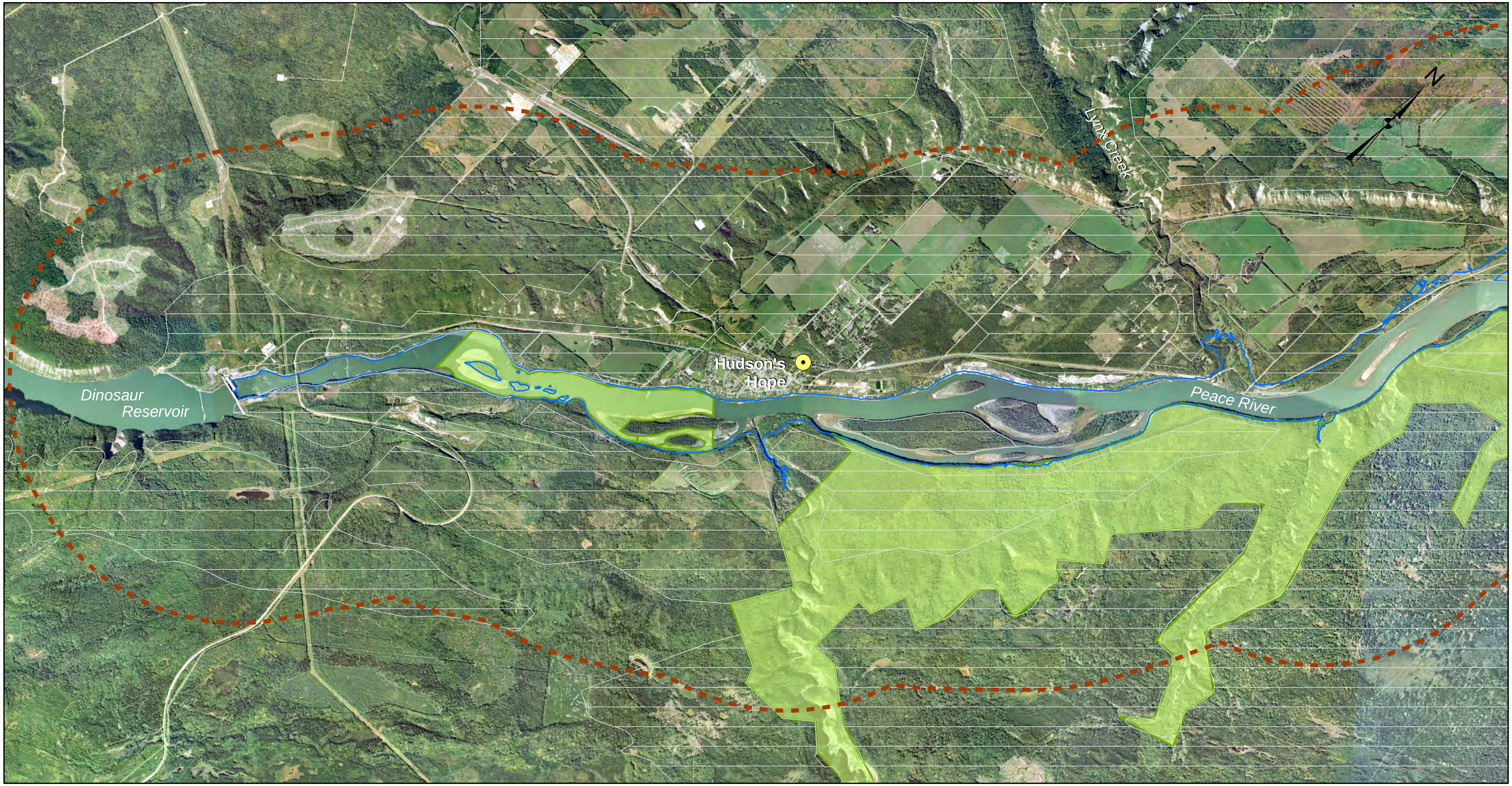

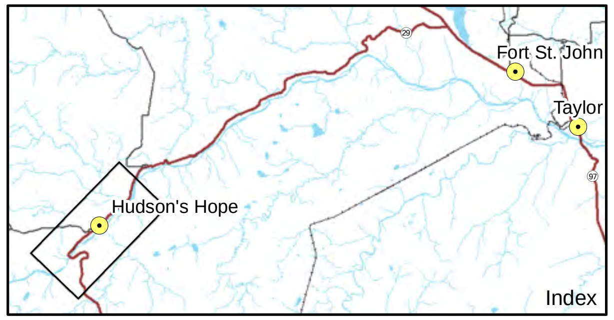

Map Notes:
1. Datum: NAD83
2. Projection: UTM Zone 10N
3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August,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

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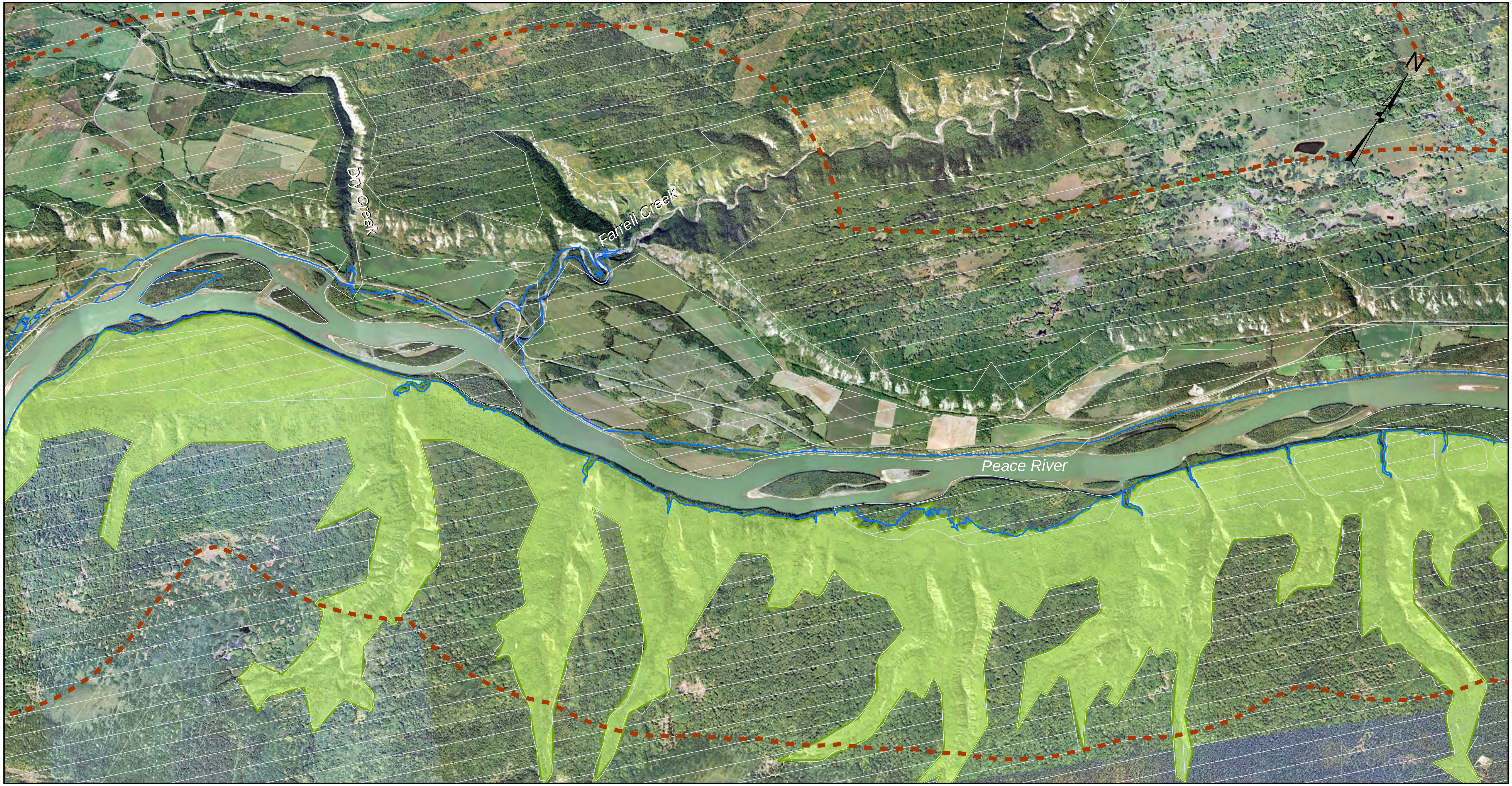

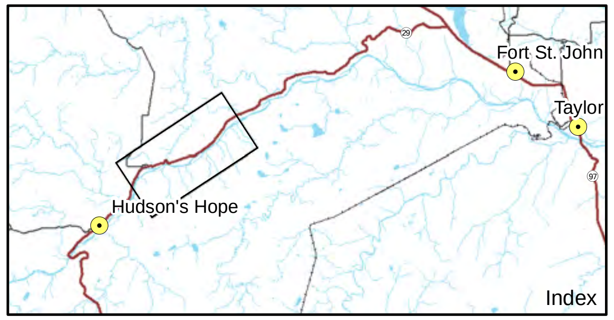

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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August,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

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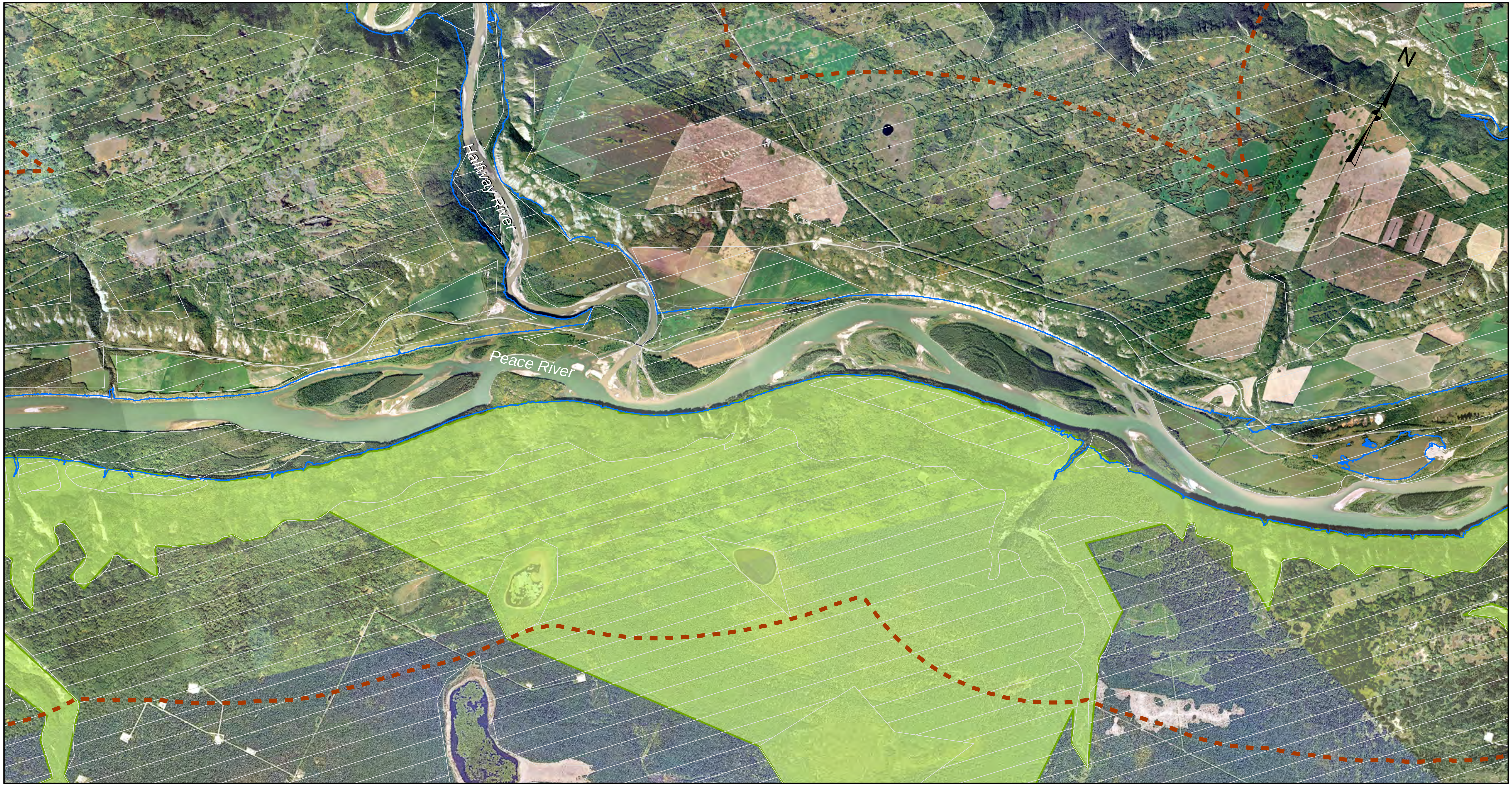

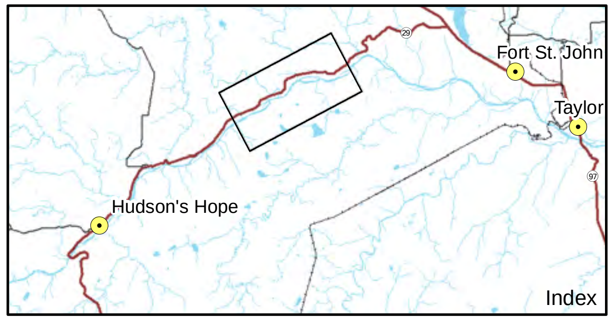

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4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
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Legend

- 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.

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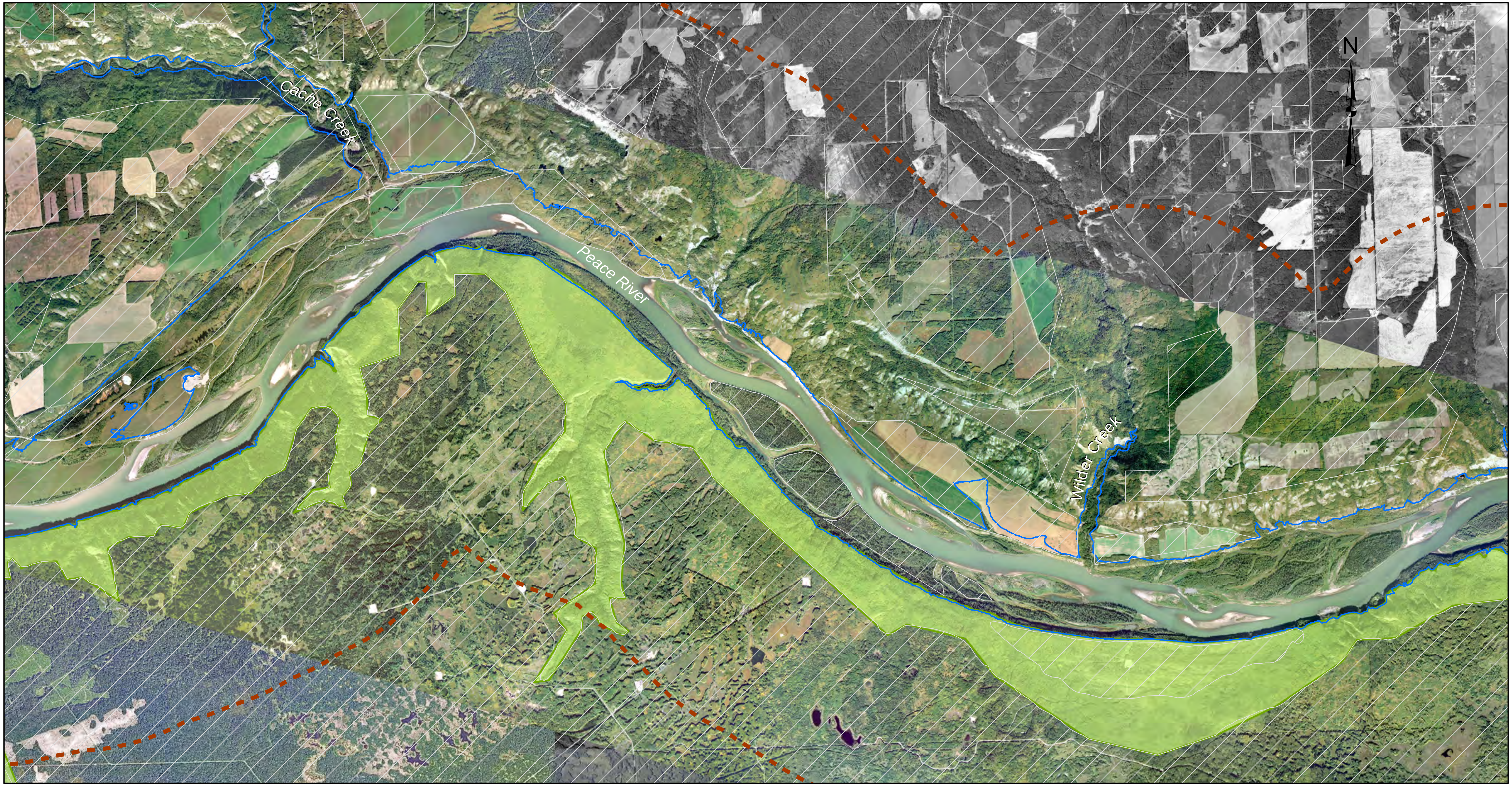

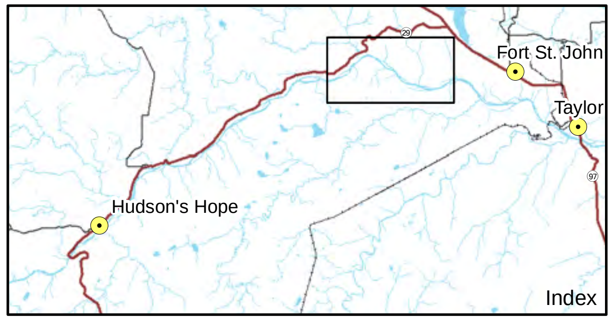

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Legend

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- 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.

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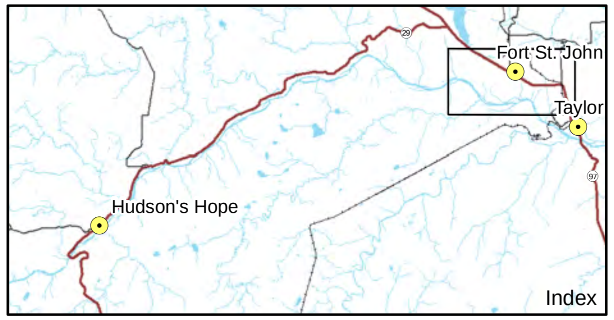
1:50,000

0 2 km



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3. Base Data: Province of B.C.
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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

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.

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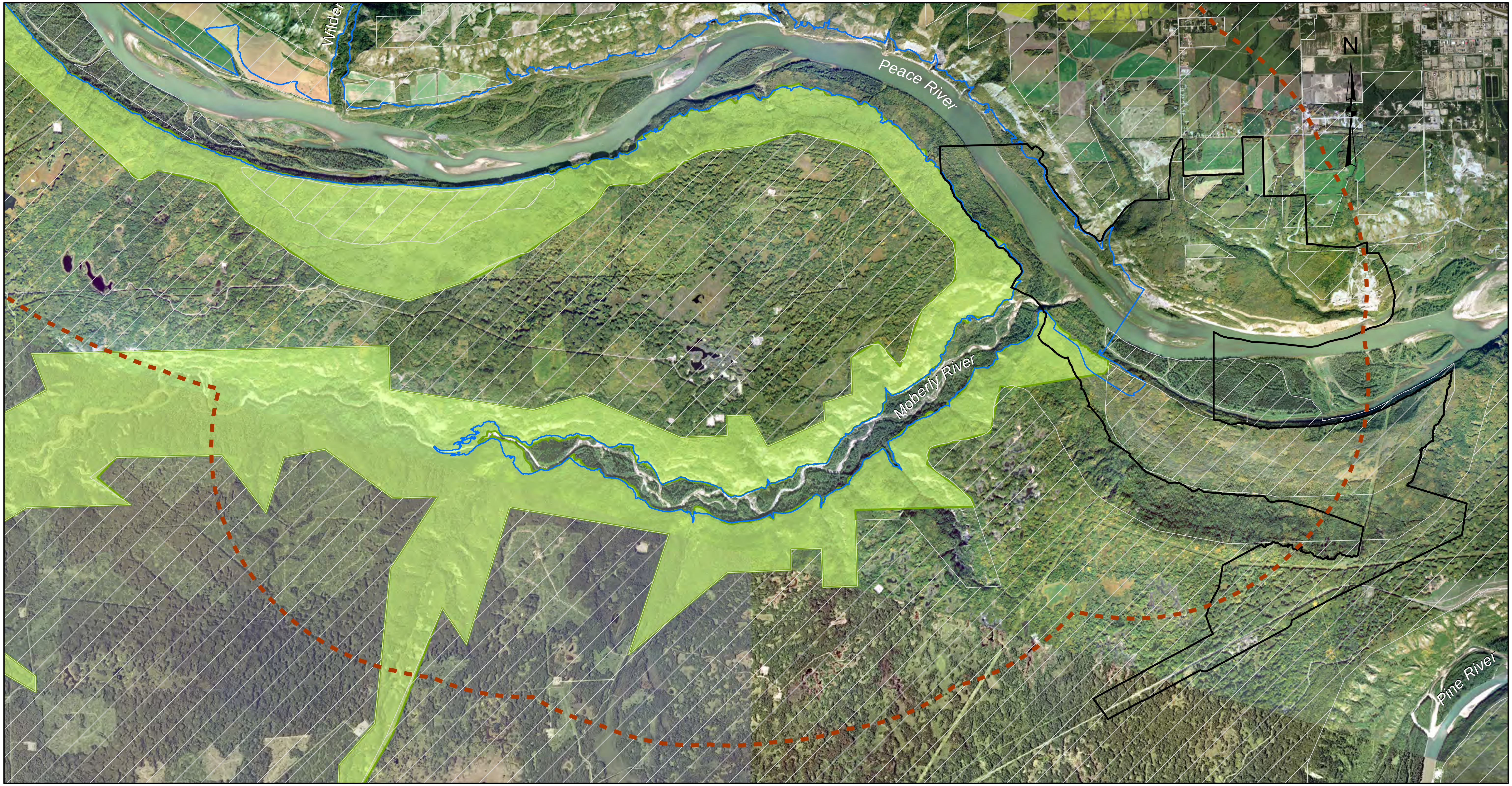

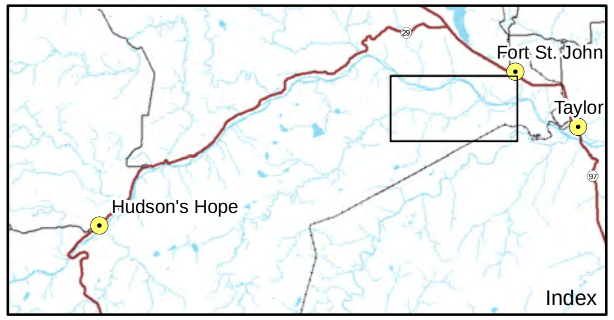

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Legend

- 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.

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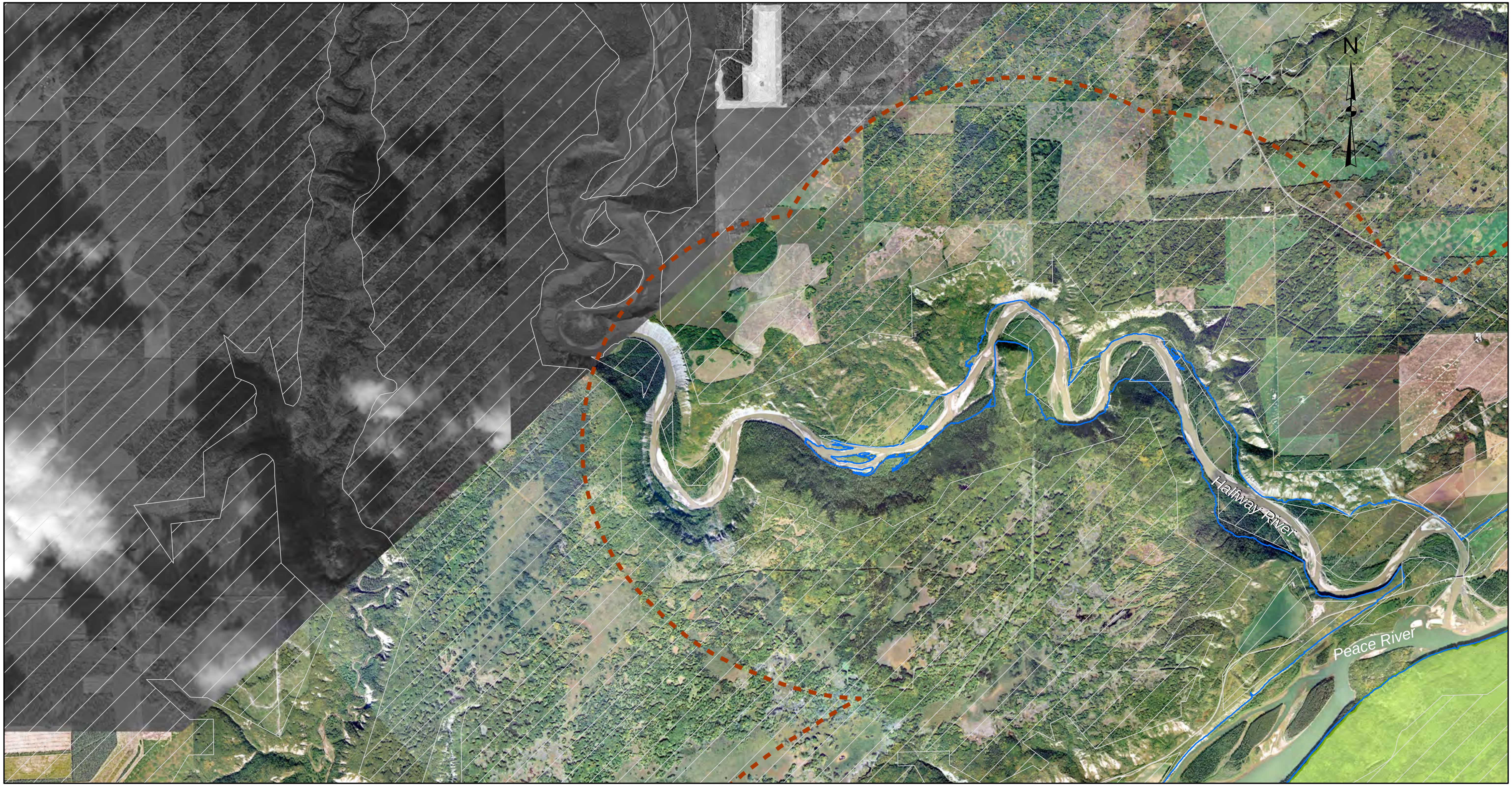

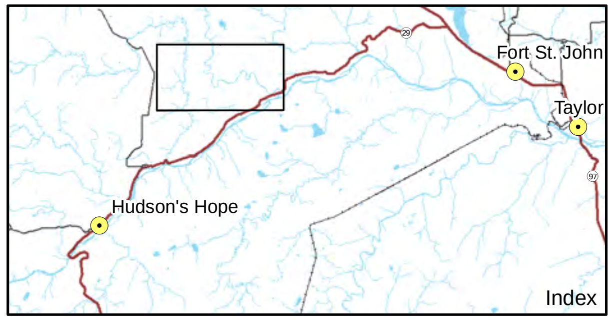

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5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

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.

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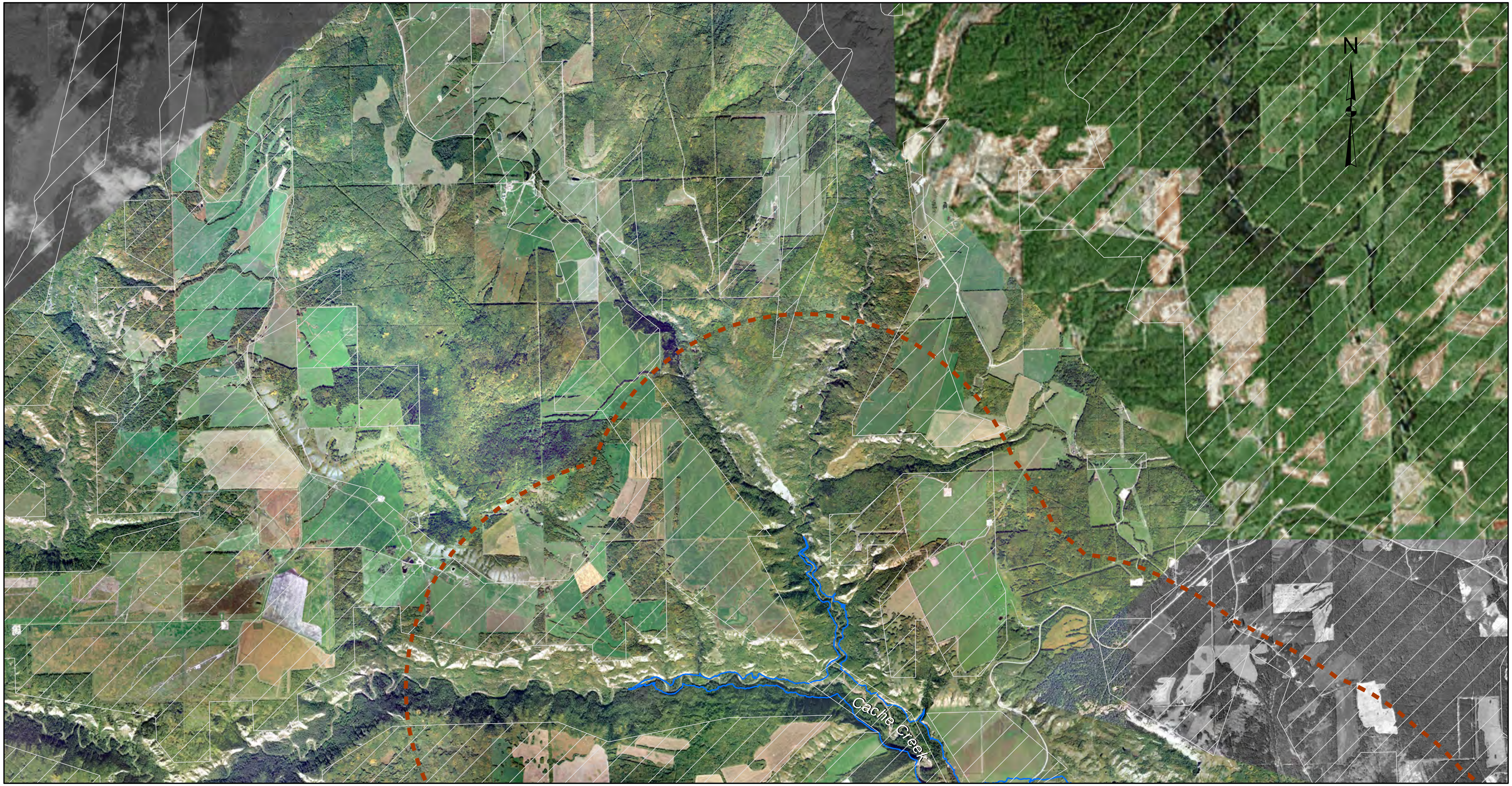

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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August,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

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Appendix C – Crop Productivity and Groundwater Monitoring Program Report

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

Blackbird File: 21006
June 30, 2022

RE: Crop Productivity and Groundwater Monitoring Program
Site C Clean Energy Project
2022 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 British Columbia (BC). Construction started in July 2015 and has a projected in-service date of 2025 (BC Hydro 2022).

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*."

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.

Specifically, 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."*

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, 2021,** and **March 31, 2022**.

2 Project Activities

Groundwater monitoring under this program is being conducted through a variety of methods and technologies including a network of soil moisture sensors, crop health and development monitoring, as well as cooperation with BC Hydro's hydrology specialists and contractor 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 has 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 is used to monitor actual groundwater levels in the immediate vicinity of the identified monitoring sites. In early 2019, Blackbird's team reviewed the current groundwater monitoring network in relation to the previously identified focus areas and determined a requirement for additional shallow groundwater monitoring infrastructure. One additional shallow groundwater monitoring well was installed in the Bear Flat area in late 2019.

Blackbird's team monitored crop development during the 2021 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 agriculture producers, agricultural associations, producer groups, and government agencies that may have data or local knowledge related to this morning plan.

The following recommendations are based on the finding of project activities during the 2021 growing season, including producer engagement, research on available hydrological, 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

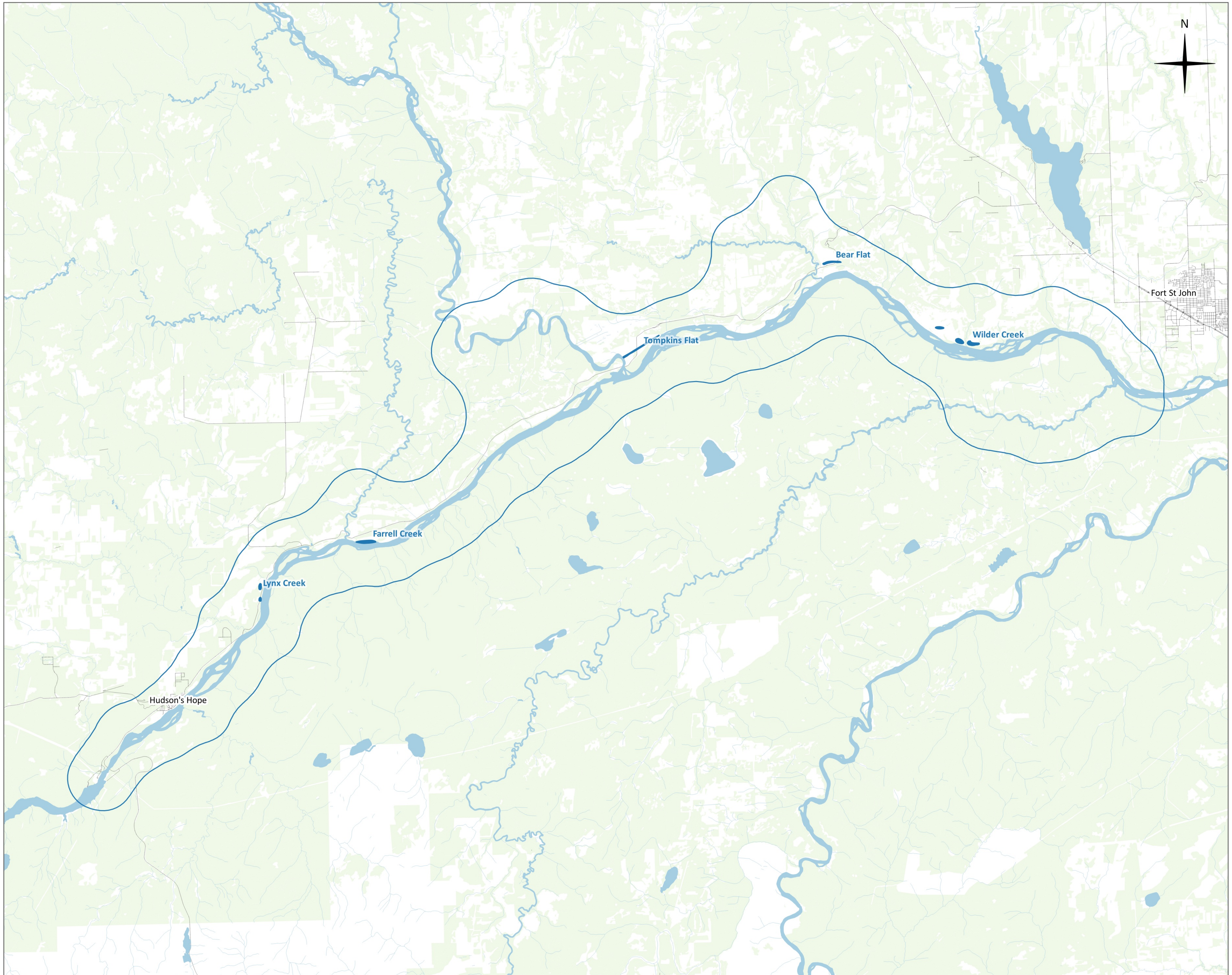
Services provided by Blackbird for this memorandum have been conducted in a manner consistent with the level of skill, care, and competence ordinarily exercised by registered members of the profession of agrology and biology currently practicing under similar conditions and like circumstances in the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

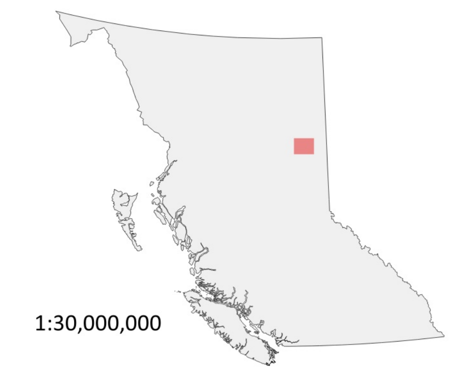
If you have questions with regards to this memorandum, feel free to contact Blackbird's team at your convenience by email at info@blackbird.ca.

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

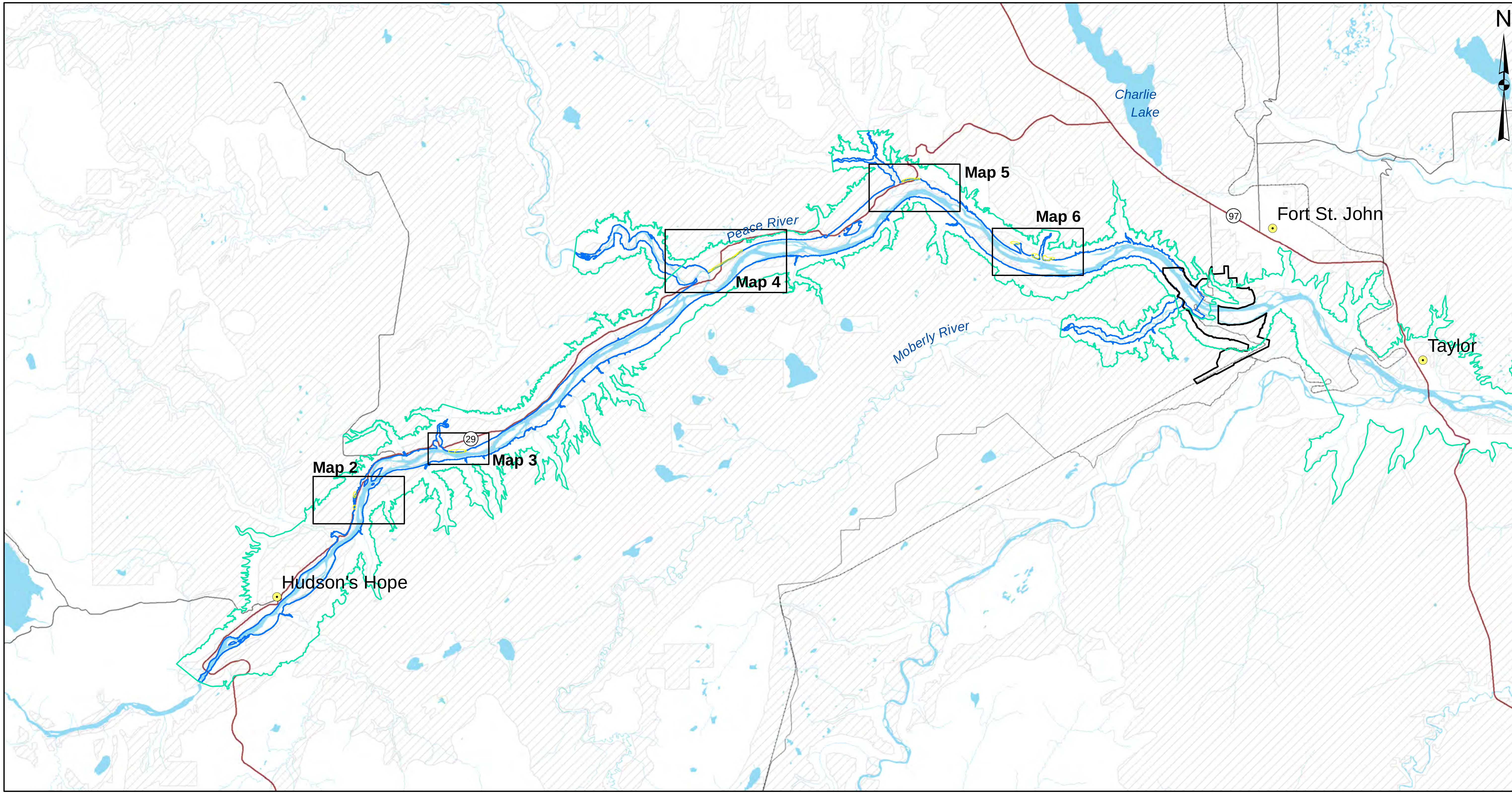
UTM Zone 10, NAD 83
Date of data acquisition: n/a
Data Credit: Blackbird Environmental Ltd., BC Geodata Warehouse
For representational purposes only, all locations are approximate.

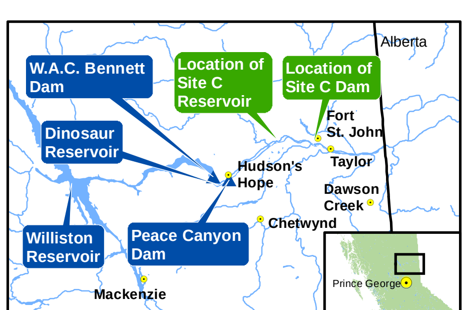
Our File:	21006	Gov. File #:	n/a	Revision #:	2
Client File:	n/a	GIS:	ML	Date:	June 5, 2021

Blackbird Environmental

blackbird.ca
Fort St. John, BC
250.793.7262

Figure 1





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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

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

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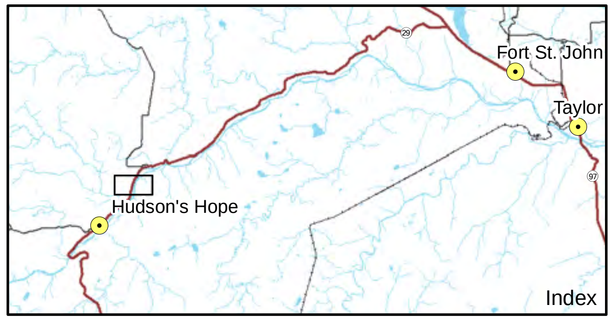

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3. Base Data: Province of B.C.
4. Orthophotos created from 1:40,000 photos taken Sept. 10th 2007, TRIM.
5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August,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

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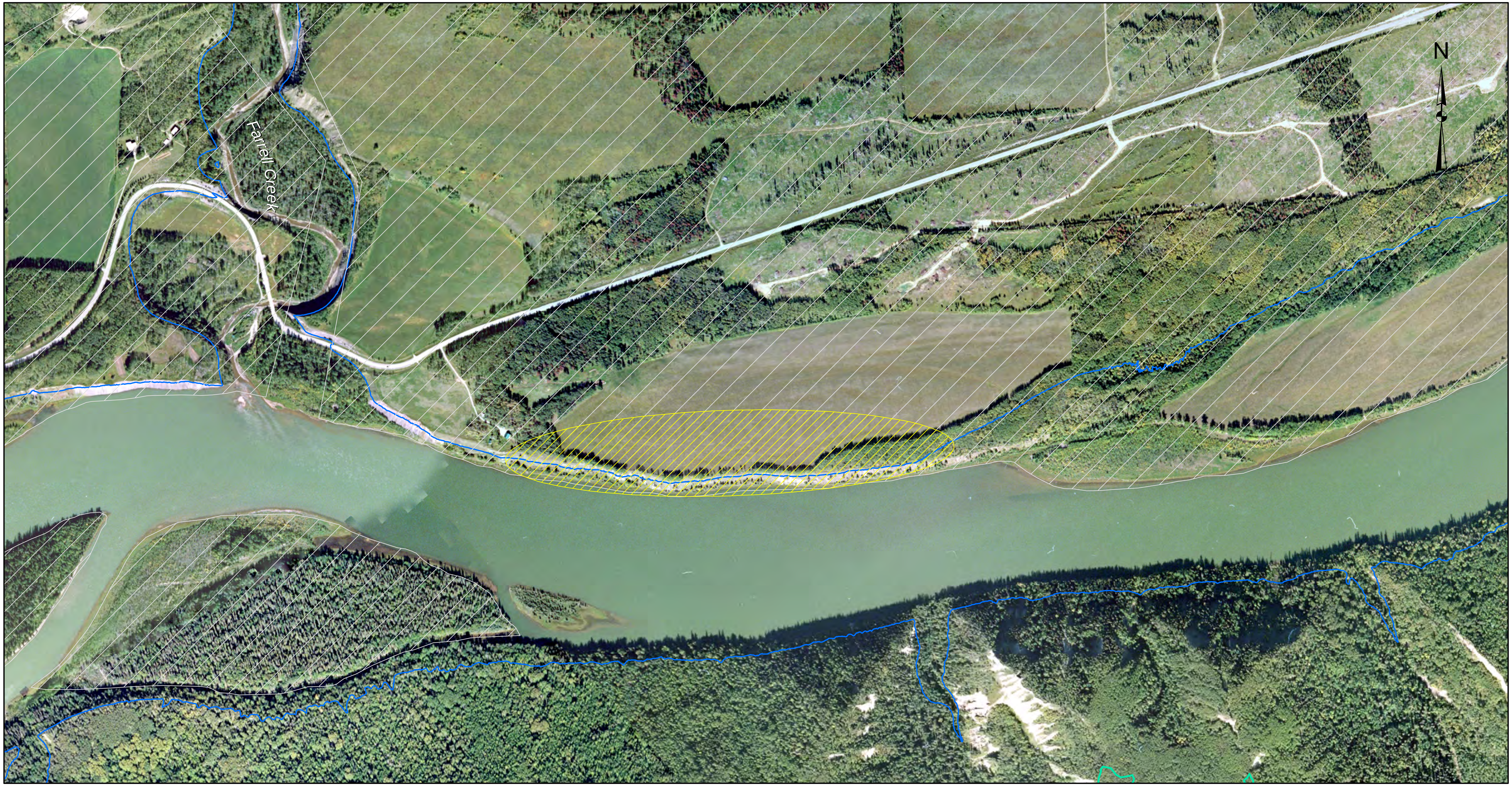

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Legend

- 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

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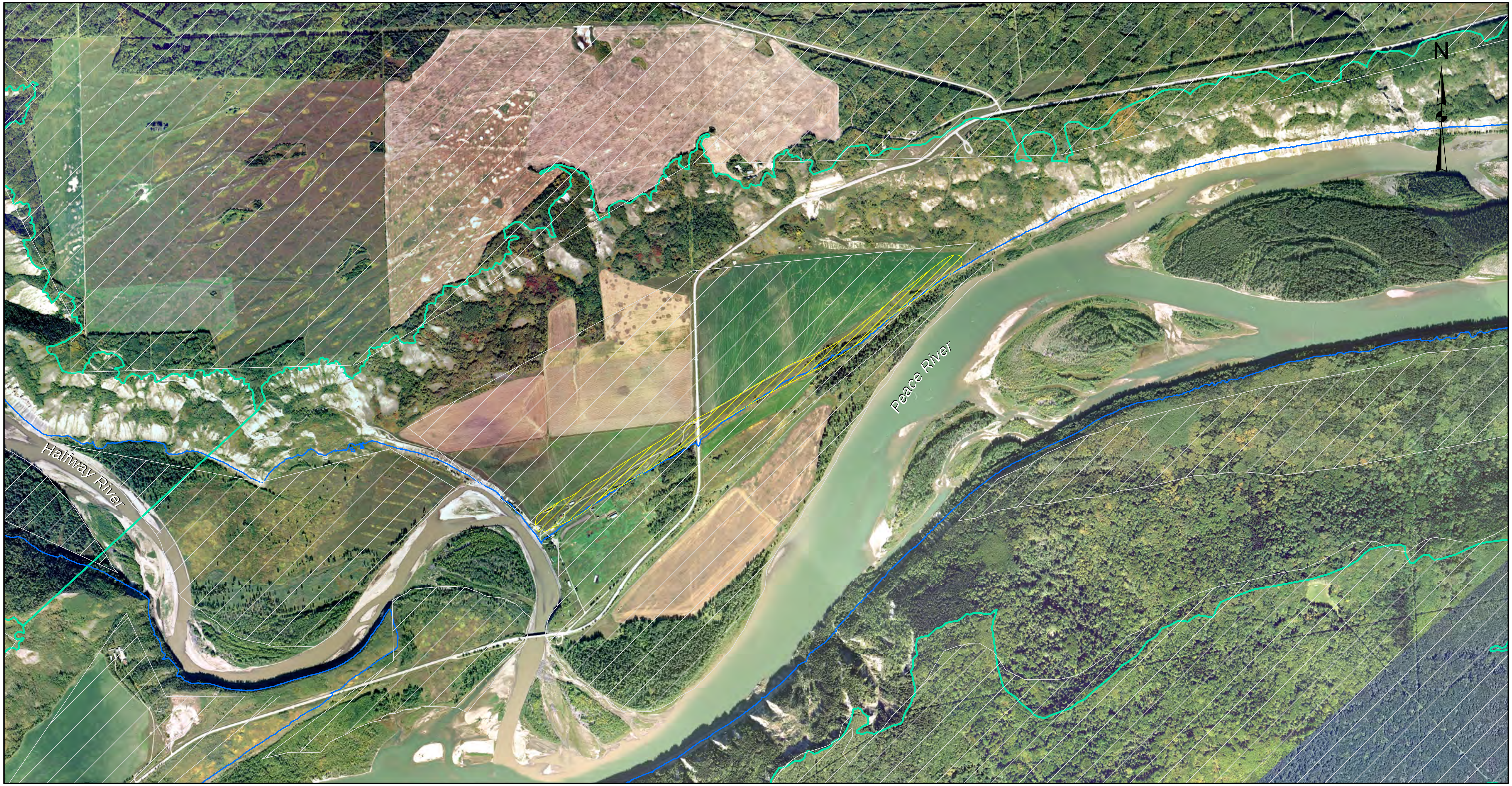

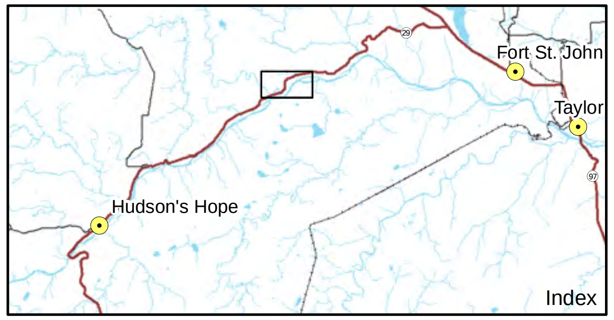

Legend

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

Map Notes:
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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.
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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.

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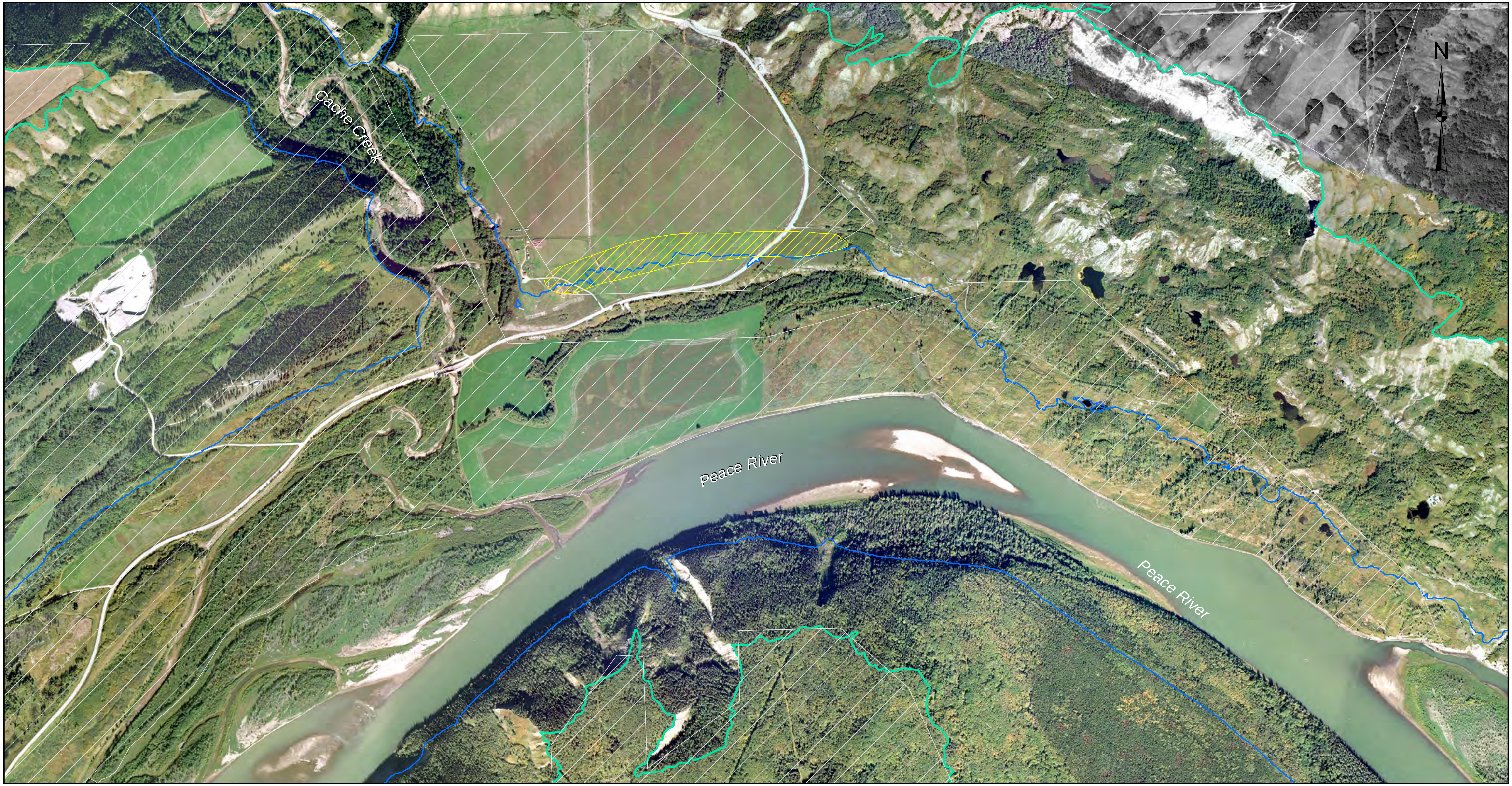

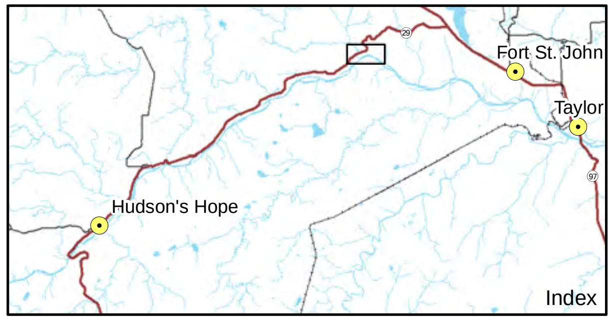

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5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

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.

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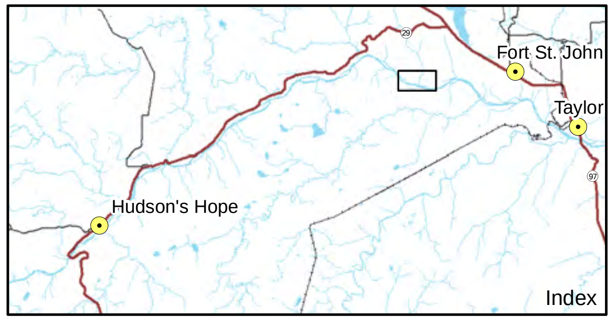

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5. Proposed reservoir area (461.8m maximum normal elevation) from Digital Elevation Models (DEM) generated from LiDAR data acquired July/August, 2006.

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

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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

<u>Study Location</u>: The study areas are agricultural operations within 3 km of the reservoir. The plan relies on climate station installation, maintenance, and data collection tasks carried out in the Appendix B: Monitoring Potential Effects on Crop Drying Plan.

<u>Activities</u>: Activities have included coordination of data needs with Appendix B: Monitoring Potential Effects on Crop Drying Plan, mapping, baseline data collection, 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 2021 *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.

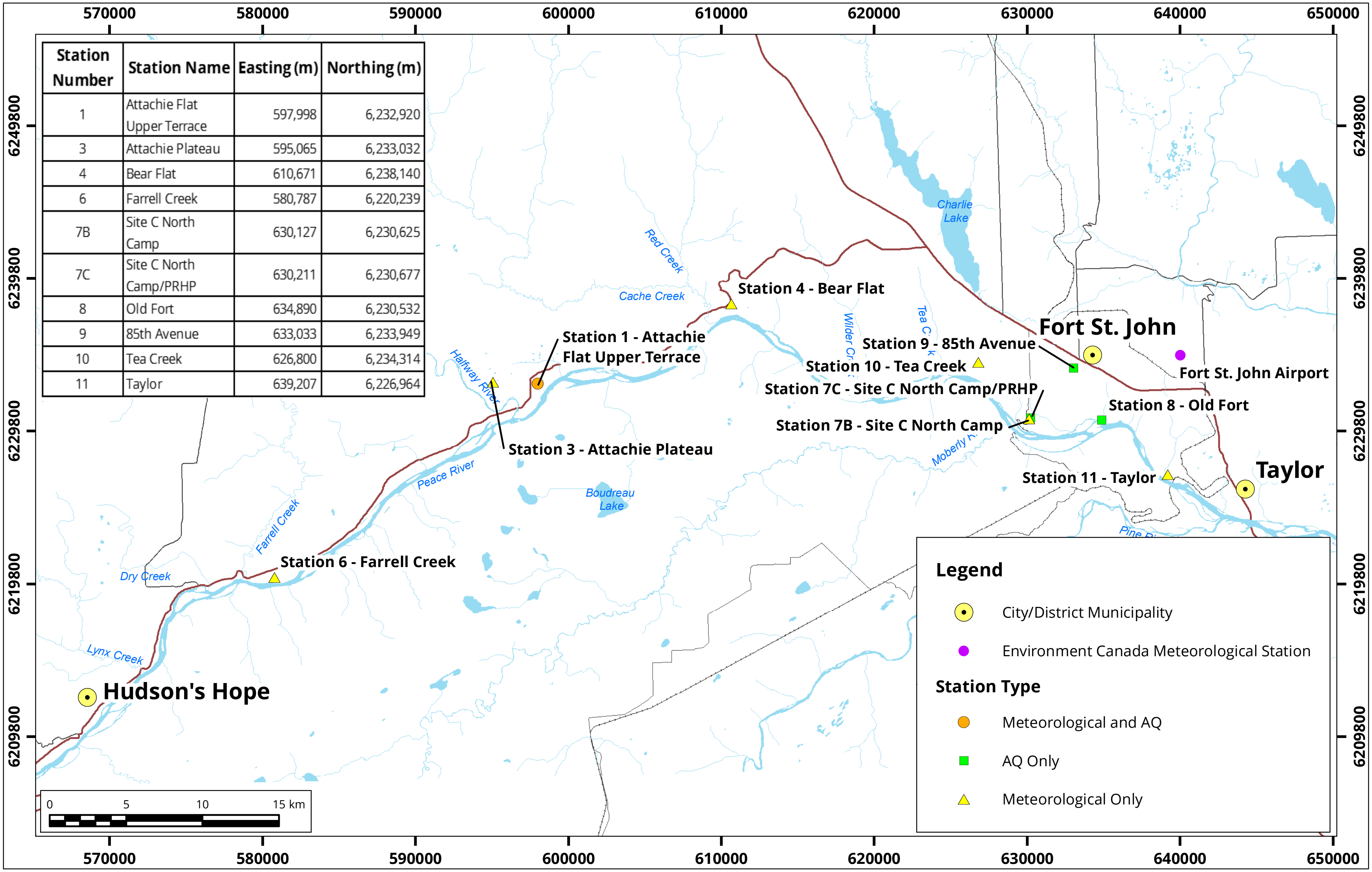
RWDI Inc. (2019), Site C Climate & Air Quality Monitoring Annual Report 2018, Final. February 22, 2019.

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.

RWDI Inc. (2022), Site C Climate & Air Quality Monitoring Annual Report 2021, Final. March 8, 2022.

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

Project #: 1601625

Map Projection: NAD 1983 UTM Zone 10N

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