EVALUATION OF RECLAMATION PRACTICES ON PEATLAND WELLSITES – RESEARCH PROGRAM

SITE SELECTION, RE-EVALUATION OF OBJECTIVES AND SAMPLING METHODOLOGY

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EXECUTIVE SUMMARY

In 2018, the Petroleum Technology Alliance Canada (PTAC) initiated a multi-stage project on the reclamation certification process for sites that were constructed using imported mineral soil pads in peatlands (padded sites). Stage 1 of the project was completed in 2019 and identified knowledge gaps for making decisions to accept or reject requests for a change in land use for padded sites during the reclamation certification process. Stage 2 concluded in 2022 and included the publication of a decision framework and support tools to make decisions related to reclamation certification of padded sites. Stage 2, also re-iterated the knowledge gaps from Stage 1 as well as additional knowledge gaps. Stage 3 is the field research component of the project with four research objectives that addressed the knowledge gaps:

1. Determine factors that result in sustainable forest ecosystem development on padded sites, including access roads, in peatlands
2. Develop a mechanism for detecting and evaluating the effects of pads off-site
3. Determine factors that result in padded sites impacting surrounding peatland ecosystems in the long term and the extent and severity of these impacts
4. Evaluate the effectiveness of partial reclamation activities for alleviating off-site impacts resulting from pads left in place in peatlands

Initial site selection and a pilot study in 2021 to 2022, provided a padded site inventory and preliminary data for the first research objective. Prior to completing the full research project, research objectives were re-evaluated, site selection was completed, and a sampling methodology was developed. These components of the project are described in this document and summarized below.

Based on the availability of sites for Stage 3 and learnings from the pilot study, it was determined that Objectives 1 to 3 could be addressed with minor revisions, while objective 4 likely cannot be addressed with the current pool of sites and may need to be deferred.

To select sites for Stage 3, the padded site inventory was analyzed and site characteristics assigned. A total of 63 sites were randomly selected from a narrowed down pool of 260 suitable sites. The 260 sites were compatible with the research objectives (e.g., abandoned prior to 2003, reclamation certified, not re-disturbed, padded and located in wetland), and characterized based on research variables (e.g., on-site vegetation cover, off-site wetland type, off-site impacts).

The sampling methodology developed allows for the collection of data for multiple research objectives at each site. Field measurements of vegetation, soil, hydrology, and water quality will be taken as one-time measurements at plots located on the pad and off-site wetland areas and trends may be evaluated using remote sensing.

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1.0 INTRODUCTION

1.1 Project Overview

In 2018, the Petroleum Technology Alliance of Canada (PTAC) initiated a multi-stage project on the reclamation certification process for sites that were constructed using imported mineral soil pads in peatlands, and upland sites with vegetation on a trajectory to approximate natural forest vegetation but with one or more reclamation deficiencies according to the applicable wellsite criteria. These sites cannot receive a reclamation certificate without additional scrutiny and professional justification under current regulatory criteria and policies. The goal of the project is to ensure that decisions made during the reclamation certification process result in the best possible ecological outcome (i.e., net environmental benefit) for these sites and surrounding region.

1.2 Stage 1 Literature Review & Identification of Knowledge Gaps

Stage 1 of the project was completed in 2019. It identified that there was limited guidance on how decisions were being made to accept or reject requests for a change in land use for sites constructed using imported mineral soil pads in peatlands (Tokay et al., 2019). Stage 1 also identified key factors to consider when assessing the ecological implications of a change in land use request. These factors include hydrology, cumulative effects and regional considerations, upland function, status of the borrow pit, site location, and land use considerations. Knowledge gaps related to these key factors were identified as priority areas to address in subsequent activities to improve decision support guidance.

1.3 Stage 2 Draft Wellsite Certification Guidance Documents

Stage 2 of the project was completed in 2022 and resulted in the publication of two decision framework and support tools:

- *Preparing Variance Justifications for Reclamation Certification of Wellsites and Associated Facilities on Forested Land* (Tokay et al., 2022) and
- *Certification of Mineral Soil Pads in the Boreal Region – Decision Framework and Support Tools* (Powter et al., 2022).

1.4 Stage 3 Research Program

Stage 3 of the project is on-going. The overall goal of Stage 3 is to **address key priority areas for research** identified in Stages 1 and 2 related to mineral soil pads. A summary of these knowledge gaps is provided in Appendix A.

Based on the priority areas for research, the following research objectives were developed:

1. Determine factors that result in sustainable forest ecosystem development on padded sites, including access roads, in peatlands
2. Develop a mechanism for detecting and evaluating the effects of pads off-site
3. Determine factors that result in padded sites impacting surrounding peatland ecosystems in the long term and the extent and severity of these impacts

4. Evaluate the effectiveness of partial reclamation activities for alleviating off-site impacts resulting from pads left in place in peatlands

Other areas of research that **were not included as objectives** for this research program include:

- Likelihood of success for peatland recovery if the pad is removed and the factors that influence success (being addressed by the Northern Alberta Institute of Technology (NAIT))
- Cumulative effects threshold based on scientific and geographical approaches to allow a proportion of wetlands in a given area to be "lost" without significant degradation of function in the region

Specific research questions and the experimental approach associated with each research objective are provided in Appendix B.

1.4.1 *Inventory of Padded Sites*

To inform research objectives and knowledge gaps, a mapping initiative began in 2021 and was completed in 2022. The initiative differentiated padded sites and non-padded sites in peatlands at a provincial scale and in a cost-effective manner (Caron et al., 2022). High-resolution light detection and ranging (LiDAR) data combined with open-access optical imagery from Sentinel-2 were used to develop a supervised machine learning model that predicted mineral pad presence by exploiting the differences in elevation, texture, vegetation, and moisture characteristics on pads compared to adjacent landscapes. Approximately 7,000 padded sites in Alberta were identified.

1.4.2 *Pilot Study*

A pilot study began in 2021 and was completed in 2022, to provided preliminary data for the first research objective; as well to:

- verify that the methods used are appropriate for answering the research question,
- provide preliminary results, and
- identify efficiencies that can be applied to a large-scale study.

Preliminary results from the pilot study indicated that vegetation which approximates a natural forest can establish on pads. Characteristics that influence pad vegetation composition and productivity are predominately pad moisture conditions, cation concentrations in the pad material, and pad dimensions. The pilot study validated the research questions, sampling design, measurement and data analysis methods developed for a large-scale study, with some minor amendments. The results from this study also supported the need for a large-scale study and approaches that address the other research objectives (Renkema et al., 2022).

1.4.3 *Site Selection, Re-evaluation of Objectives and Sampling Methodology*

In anticipation of a full field study for Stage 3, current work that was completed and is summarized in this document includes re-evaluation of research objectives (Section 2.0), site selection, (Section 3.0), and

development of a sampling methodology (Section 4.0). Site selection and re-evaluation of objectives were completed concurrently and the order of these items in this document does not imply that one was completed prior to the other.

2.0 RE-EVALUATION OF OBJECTIVES

The research objectives were re-evaluated based on results of the pilot study and in conjunction with site selection completed in Section 3.0. The original objectives in their entirety are included as Appendix B.

2.1 Determine Factors that Result in Sustainable Forest Ecosystem Development of Padded Sites in Peatlands

The first research objective was to investigate or determine factors that result in sustainable forest ecosystem development of padded sites in peatlands. The specific questions associated with this research objective were:

- Do sustainable forest ecosystem develop on pads?
- What factors result in sustainable forest ecosystem development on pads?

These research objectives were examined in the pilot study (Renkema et al., 2022), and resulted in a recommendation to adjust the objectives and questions to the following:

> *Which pad characteristics result in a vegetation composition and tree growth performance that meet expected thresholds for a forest ecosystem.*

This revised objective removes the need to define a sustainable forest ecosystem and assumes that meeting the peatland or forested criteria is sufficient. Itis recommended that this revision is adopted as the first research objective.

Overall, based on the number of sites identified during site selection with a range of on-site vegetation cover (Section 3.0), this revised research objective can be addressed. One challenge associated with this objective may be identifying undocumented disturbances to the site (follow-up reclamation, third-party or others), post well-abandonment, that may influence vegetation composition and tree growth performance on the selected sites. Obtaining high resolution historical imagery at regular and frequent time intervals may be needed to address this challenge.

2.2 Develop a Mechanism for Detecting and Evaluating the Effects of Pads Off-Site

The second research objective was to develop methods for detecting and evaluating any effects pads may have off-site to the surrounding wetland. The specific questions associated with this research objective were:

- What is the effectiveness of remote sensing as a method to detect impacts of pads left in place in peatlands and can remote sensing accurately detect different kinds of impacts?
- Are measurements of water chemistry, water levels or sedimentation required to detect impacts or are impacts to water chemistry or water levels reflected in the vegetation?

- When should impacts be detected or evaluated (i.e., how many years after pad construction or reclamation does it take for impacts reach their maximum or steady-state, if they reach a steady-state)?

No pilot study was completed on this objective, but the objective and research questions remain relevant. It is recommended that this objective is evaluated through post-hoc analysis of the field data collected for objective three along with additional remote sensing – sites were not specifically selected to address this research objective (Section 3.0).

2.3 DETERMINE FACTORS THAT RESULT IN PADDED SITES IMPACTING SURROUNDING PEATLAND ECOSYSTEMS IN THE LONG TERM AND THE EXTENT AND SEVERITY OF THESE IMPACTS

The third research objective was to determine factors that result in padded sites changing or impacting the peatlands surrounding the pad and the extent and severity of these impacts. The specific questions associated with this research objective were:

- What characteristics of pads result in impacts to the long-term health and function of the surrounding peatland ecosystem?
- What characteristics of peatland ecosystems and the location and orientation of the wellpad/access road within a peatland result in the pad having a long-term impact on the ecosystem?

No pilot study was completed on this objective. Based on site selection and additional review of the research objectives and questions, further clarification could be added to the research objective and questions to enable a well-scoped project and achievable outcomes. Proposed clarifications include:

- Evaluation of impacts from a single padded wellsite and associated access road (which may or may not be padded).
- Evaluation of impacts for padded wellsites and associated access roads in peatlands (bog and fens, excludes marshes, swamps and open water wetlands)
- Measurements of hydrology, soil and vegetation characteristics that can be used to infer function. These characteristics could be measured from areas near the pad and compared to reference areas.
- Impact refers to differences in hydrology, soil and vegetation characteristics near the pad compared to reference areas

The objective also includes determining the extent of the impacts, this is not always easily achieved through field data collecting and could be completed using remote sensing, building-off of the outcomes from the second research objective.

Overall, based on the number of sites identified during site selection with a range of off-site impacts (Section 3.0), this research objective can be addressed, with the aforementioned clarifications. Completion of this project may identify areas where additional data is needed to provide conclusive outcomes. Challenges that remain include:

- Differentiating changes caused by a pad versus those caused by other natural and anthropogenic influences; and
- comparing pads with different lengths or lack of padded access roads.

2.4 Evaluate the effectiveness of partial reclamation activities for alleviating off-site impacts resulting from pads left in place in peatlands

The fourth research objective was to evaluate if, in the long-term, partial reclamation activities were effective for lessening or alleviating off-site impacts pad reclaimed in place in peatlands. Partial reclamation activities include:

- Partial removal of pad material to create drainage channels (e.g., swales), allowing water flow across/through the padded feature; and/or,
- partial removal of pad material from a vertical perspective to reduce the thickness of the pad and lower the elevation of the pad surface to match the surrounding peatland (on all or portions of the site).

The specific questions associated with this research objective were:

- Are partial reclamation methods effective in reducing off-site impacts caused by pads left in place in peatlands?
- What characteristics of the pads affect the success of partial reclamation?
- What characteristics of peatland ecosystems and the location and orientation of the pads within a peatland affect the success of partial reclamation?

The selection methods utilized in Section 3.0 were not specific enough to identify if partial reclamation had been completed to pads. No sites were selected specifically for this objective. Field data collection can include recording instances of partial reclamation, where identifiable, and if partial reclamation has been completed on a sufficient number of pads selected for research objective three, post-hoc analysis of this data could be completed to evaluate this research objective. It is expected that this objective will be deferred because of limitations in sites visited. However, collection of data on sites with partial reclamation can be started to inform future research.

3.0 SITE SELECTION

A rigorous site selection exercise was completed for a full field study to optimize field resources, ensure non-biased (random) selection of sites and allow for evaluation of research objectives (Section 2.0). The following were the desired outcomes for site selection:

- Identification of a minimum of 40 primary sites and 20 back-up sites;
- stratification of the sites based on characteristics (variables) relevant to the research questions (Appendix B, Section 3.2.2); and,
- review of the stratified sites to determine the range of characteristics available and number of sites with each characteristic.

3.1 METHODS

3.1.1 *Filtering*

To select sites for the large-scale research project, the approximately 7,000 sites from the Inventory of Padded Sites were used as a starting point. Based on the previous stages of this project, sites for the research project must meet the following criteria:

- Located in a peatland;
- padded – mineral soils placed over top of organic soil;
- well abandoned and wellsite reclaimed; and,
- Is representative of a typical upstream oil and gas wellsite (approx. dimensions of 120 x 120 m or less)

To refine the site list, the following filters were applied (the number of sites remaining after each filtering step is summarized in Table 1 and a Map of the sites is included as Appendix C).

- Restriction to reclaimed sites and sites where long-term outcomes could be measured, only sites abandoned prior to 2003 and those that were reclamation certified or reclamation exempt were included. This cut-off date was arbitrarily chosen, but 20 years represents a relatively long-term outcome in typical reclamation monitoring activities in Alberta. Abandonment and reclamation status was based on wellsite databases (Abacus Datagraphics Ltd., 2022 and Alberta Energy Regulator, 2022).
- Removal of sites that were potentially not padded or not located in a peatland. Sites with an elevation on-site that was >0.15 m lower than off-site were excluded as well as sites with an elevation on-site that was >3.25 m higher than off-site as these sites were typically not padded (the *Inventory of Padded Sites* had an accuracy of approximately 70% site, so this step helped improve accuracy). Also, if the off-site elevation varied by more than 3 m, these sites were also excluded as these sites were located on sides of steep slopes and not in peatlands. Elevation data was sourced from the *Inventory of Padded Sites* dataset which was based on high-resolution LiDAR data.

- Removal of sites where overlapping activities had impacted on-site and off-site vegetation, soils or hydrology, as well as, sites that were flooded/underwater. This filter was based on manual review of satellite imagery captured within the past 5 years (imagery from ESRI and Google Earth).

Figure 1. Examples of Sites with Overlapping Activities

Figure 2. Examples of Sites Underwater

- A final filtering step included reviewing current and historical aerial or satellite imagery from ESRI and Google Earth to verify the presence of a pad on the wellsite. Sites were classified as padded, not padded or inconclusive (i.e., could not be confidently classified as padded or not padded based on imagery). To avoid bias towards clearly padded sites, only not padded sites were excluded, while inconclusive sites were retained.

Table 1. Filtering Steps and Number of Sites.

Filter	Sites Remaining
Inventory of Padded Sites (unfiltered)	7,077
Abandoned prior to 2003	4,285
Reclamation certified or exempt	3,070
Elevation on-site that was (a) <0.15 m lower than off-site and (b) <3.25 m higher than off-site	2,235
Off-site elevation varied by <3 m	1,362
No overlapping activities impacting on-site and off-site vegetation, soils or hydrology	1,175
Not underwater	1,137
Manually verified pad (padded or inconclusive)	669 (406 Padded + 263 Inconclusive)

3.1.2 *Stratification*

Stratification of 669 sites based on on-site vegetation cover, off-site wetland type, and off-site impact characteristics was completed. These were the main characteristics (variables) associated with the research objectives and/or were the characteristics for which current remotely sensed data to support classification was available. Stratification was completed to allow for re-evaluation of research objectives and to select sites that represent a range of conditions in order to meet multiple research objectives. Additional information about the access road pad, location of the borrow area, off-site activity, and surrounding peatland size was also documented to aid in final site selection.

As per the fourth research objective (Section 2.4), attempts were made to identify if partial reclamation techniques were applied to the pads; however, it was not possible using available data.

3.1.2.1 On-site Vegetation Cover

On-site vegetation cover was classified to address the first research objective. Each site was assigned one of the following vegetation cover ratings:

- >50% tree/shrub cover

Figure 3. Examples of Sites with 50% Tree/Shrub Cover

- 25 to 50% tree/shrub cover

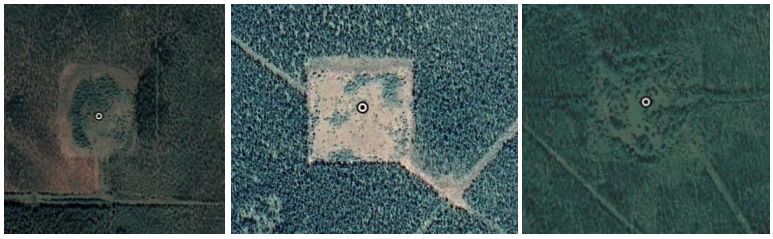

Figure 4. Examples of Sites with 25 to 50% Tree/Shrub Cover

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- <25% tree/shrub cover

Figure 5. Examples of Sites with <25% Tree/Shrub Cover

Vegetation cover was classified using a simple image classification function in Google Earth Engine. Sentinel-2 imagery with a resolution of 10 m captured between 2019 and 2022 was utilized. Vegetation cover was classified in a 35 m radius around well centre. The classifier was trained using 47 manually classified sites out of the 669 sites. No detailed statistics were completed on classification accuracy, but results of the image classification compared to manual classification suggest an accuracy of approximately 85%. Vegetation cover was rated on the wellsite, but not on associated access roads due to relatively-low resolution of remotely sensed data. Based on observations during the pilot study, it could be assumed that the access road would have similar or higher tree canopy cover than the wellsite.

Of the 669 sites:

- 222 sites had >50% tree/shrub cover;
- 307 sites had 25 to 50% tree/shrub cover; and,
- 140 sites had <25% tree/shrub cover.

3.1.2.2 Off-site Wetland Type

Off-site wetland or forest type was classified to address all research objectives. Wetland or forest type was classified around the wellsite but not along the access roads due to lack of readily accessible data on access road locations. Classifications were simplified from the Reclamation Criteria for *Wellsites and Associated Facilities for Peatlands* (Alberta Environment and Parks, 2017), *Field Guide to Ecosites of Northern Alberta* (Beckingham and Archibald, 1996) and the *Alberta Wetland Classification System* (Alberta Environment and Sustainable Resource Development, 2015).

Classifications included:

- Bog (may also include coniferous swamps)
- Poor fen (acid fen and may also include coniferous swamps)
- Rich fen (moderate/extreme-rich/circumneutral/saline fen and may also include deciduous swamps and marshes)
- Transitional (forested; pad is located on or near edge of peatland)

Combinations of these types were also classified (e.g., bog-poor fen). Where more than two peatland types were present around a site, it was classified as a "peatland complex". Classifications were later simplified into larger groups that combined poor fens with either bogs or rich fens to reduce the number of classification types.

Classification was completed using a simple image classification function in Google Earth Engine. Sentinel-2 imagery with a resolution of 10 m captured between 2020 and 2022 was utilized. The classifier was trained using 197 manually classified points. Wetland type was classified in a 250 m buffer around the wellsite. Dominant wetland types in the buffer were utilized to assign a wetland type. No detailed statistics were completed on classification accuracy, but results of the image classification compared to manual classification suggest an accuracy of approximately 70%.

The distribution of sites among wetland types is summarized in Table 2.

Table 2. Distribution of Padded Sites Between Wetland Types

Wetland Type	Number of Sites
Bog	34
Bog-poor fen	85
Bog-poor fen-transitional	35
Bog-rich fen	20
Bog-rich fen-transitional	11
Bog-transitional	43
Peatland complex	31
Peatland complex-transitional	10
Poor fen	32
Poor fen-transitional	60
Poor-rich fen	97
Poor-rich fen-transitional	68
Rich fen	81
Rich fen-transitional	62

3.1.2.3 Off-site Impacts

Off-site impacts were classified to address the second, third and fourth research objectives. Off-site impacts were classified around the wellsite and approximately 300 m length of the access road nearest the wellsite (if an access road was associated with the site). Each site was assigned a single off-site impact rating even if there were areas of impacts and no impacts. Ratings included the following:

- Impact (readily observable)

- Slight Impact (not readily observable or uncertain)

- No Impact

Impact ratings were assigned by manually reviewing current and historical aerial or satellite imagery from ESRI and Google Earth (An automated process is currently being developed but was not available for use at this time).

Of the 669 sites:

- 104 sites had an impact;
- 196 sites had a slight impact; and
- 369 sites had no impact.

3.1.3 *Additional Site Information*

Classification of the presence of a pad on the access road, location of the borrow area, and off-site activity was completed to aid in site selection. These factors were primarily utilized to aid in site selection to support the third and fourth research objectives.

- Presence of a pad on the access road was not a main factor in selecting or stratifying sites but was still considered to avoid selecting all sites with or without padded access roads. Access roads were classified as padded, not padded or inconclusive. Padding was assessed by manually reviewing current and historical aerial or satellite imagery. Of the 669 sites:
    - 225 roads were padded;
    - 160 roads were not padded;
    - 220 roads had inconclusive observations; and
    - 64 sites did not appear to have associated access roads or had access roads located solely in forested (upland) areas.
- Location of the borrow area was not a main factor in selection or stratifying site for the first research objective but was important for the third research objective as the borrow could have an influence on the area surrounding the pad. Borrows, if present within 250 m of the well centre, were classified based on their location within a peatland or forested area. Borrows beyond 250 m were not classified as they are less likely to have an influence. Location of the borrow was assessed by manually reviewing current and historical aerial or satellite imagery. Of the 669 sites:
    - 58 sites had a borrow area located within 250 m of well centre and in a peatland;
    - 163 sites had a borrow area located within 250 m of well centre and in a forested area;
    - 106 sites had a borrow area located greater than 250 m from well centre; and,
    - 315 sites had no identifiable borrow area.
- Off-site activity (or features) was not a main factor in selection or stratifying site for the first research objective but was important for the third research objective as the activity could have an influence on the area surrounding the pad. Activity within 250 m of the well centre was classified. Activity classifications included: roads (includes frequently travelled trails, padded roads, gravel or dirt roads and paved roads; and excludes the associated access road and infrequently travelled trails that are vegetated and not padded, dirt, gravel or paved), industrial site (wells, etc. but excludes associated borrow areas), pipelines, beaver flooding, fire/burnt, open water (pond, lake, stream). Multiple activities may have been occurring around a site; however, only one activity was identified per site. Classifications were assigned in the order listed above which was considered to represent the degree of severity. Off-site activity was assessed by manually reviewing current and historical aerial or satellite imagery. Of the 669 sites:
    - 65 sites were located near roads;
    - 51 sites were located near industrial sites;

- 31 sites were located near pipelines;
- 20 sites were located near beaver flooding;
- 22 sites were located near in areas that had been burnt;
- 90 sites were located near in areas that had open water; and
- 390 sites had no noted off-site activity.

A complete summary of sites by the combination of stratification units is included as Appendix D.

3.1.4 *Selection*

To select the 40 sites and 20 backup sites, an additional filtering step was applied to reduce the geographical area. A reduced geographical area was utilized for the following reasons:

- To reduce variability/variables that would need to be accounted for in the sampling design (a larger geographical area would likely require more than 40 sites); and,
- to improve efficiency during fieldwork through reduced travel time.

The geographical area selected was the Central Mixedwood Natural Subregion (Natural Regions Committee, 2006) but bounded to the east by Highway 63, to the west approximately by Highway 35 and south by approximately Highway 18 and 33. The area encompasses Slave Lake, Red Earth and Wabasca. This area was selected as it encompasses approximately 50% of all the abandoned padded sites in Alberta. Of the 669 sites obtained through the filtering described in Section 2.1.2, 361 of them were located in this area. Additional filtering was completed to eliminate sites with off-site activities (roads, pipeline powerlines, borrows and other industrial sites). This additional filtering may have introduced bias towards a certain type of site and this site list may need to be used with caution; however, it allows multiple research objectives to be addressed at each site. The additional filtering reduced the sites available to 260.

Controlled variables (characteristics) for the first research objective was on-site vegetation cover and for the third research objective were off-site impacts and wetland types. While other variables could be controlled, these were considered the most important. Sites were first selected to meet the needs of the first research objective. Twenty-one sites were randomly selected from each of the three on-site vegetation cover stratifications by assigning a random number to each site and then selecting the sites numbered 1 to 21 (13 as primary sites and seven as backup sites, and one additional site to balance designs across each of the three treatments for a total of 63 sites)

The sites selected to meet the requirements of the first research objective, were evaluated for suitability for the third research objective. This approach will allow for multiple research objectives to be addressed at the same site (selection for research objectives 2 and 4 was not completed - refer to Section 2.0). As this approach initially resulted in an unbalanced number of sites for each variable associated with the third research objective, sites with the highest random numbers were eliminated from variables that had a greater number of sites, and the next site, in the order the random number was added. This process was iterated until a nearly balanced design was achieved. A breakdown of the sites by stratification is included in Table 3 and a list of these sites and a map of their locations are included in Appendix E.

Table 3. Site Breakdown for Site Selection (Primary Sites)

On-Site Vegetation	Off-Site Impact	Wetland Type						Grand Total
		Bog-Poor Fen	Bog-Poor Fen-Transitional	Peatland Complex	Peatland Complex-Transitional	Poor-Rich Fen	Poor-Rich Fen-Transitional	
<25% tree/shrub	None	1				1		2
	Slight	1	1	1		1	2	6
	Impact		1			2	2	5
Total		**2**	**2**	**1**		**4**	**4**	**13**
25 to 50% tree/shrub	None	1	1			2	1	5
	Slight	3					1	4
	Impact	2				1	2	5
Total		**6**	**1**			**3**	**4**	**14**
>50% tree/shrub	None	1	2		1		2	6
	Slight		1			2		3
	Impact	1	1	1	1			4
Total		**2**	**4**	**1**	**2**	**2**	**2**	**13**
Grand Total		**10**	**7**	**2**	**2**	**9**	**10**	**40**

After selection, it was noted that for primary and backup sites:

- Eleven of the 21 sites with no off-site impacts may not have a padded access road and all 20 sites with impacts likely have a padded access road;
- 14 of the 63 sites may have natural off-site disturbances that may complicate off-site data collection (beaver activity, fire, open water bodies); and,
- 15 of the 63 sites had inconclusive results for the visual interpretation of a pad from aerial/satellite imagery.

Further filtering could be completed to remove sites without padded access, natural disturbances and inconclusive for visual interpretation of pad, and there may still be a sufficient number of sites for each

stratification category. However, doing this may introduce additional bias into the sites selected, and it was not completed at this time.

4.0 SAMPLING METHODOLOGY

This sampling methodology is for field data collection. It assumes that data collection for both research objective 1 and 3 is completed at each site. The sampling design incorporates learnings from the pilot study.

4.1 VERIFICATION OF SITE CHARACTERISTICS

Site characteristics (variables) determined from the site selection exercise will be verified in the field prior to commencing sampling. If field verification findings contradict the site selection characteristics, a backup site may need to be utilized. Field verification could be completed during sampling or during a reconnaissance trip. The following table provides a preliminary decision tree; however, final decisions will be made by the project manager.

Table 5. Field Verification Steps

Parameter/Variable	Decision
1. Wellsite is at least 75% padded and the pad is located within a peatland (bog or fen)	If no, exclude site
2. Wellsite has evidence of disturbance within the past 20 years	If yes, exclude site from research objective 1
3. There is anthropogenic activity in the same peatland as the site and within 250 m of the wellsite. The anthropogenic activity has resulted in clearing of lines greater than 5 m in width or any soil disturbance	If yes, exclude site from research objective 3
4. On-site vegetation cover is not as expected	Discuss with project manager
5. Off-site impact is not as expected	Discuss with project manager
6. Off-site wetland type is not as expected	Discuss with project manager

Additionally, documentation of any other characteristics that may aid in data interpretation will be completed and information on any partial reclamation activities that may have occurred will be noted.

4.2 PLOT LAYOUT

Sample areas will be located at the centre of the wellsite, padded areas of the access road, and in the wetland (peatland) surrounding each site (off-site). The off-site areas in a 100 m buffer around the wellsite and padded portions of the access road (if there is an associated padded access road) will be stratified into zones of visual impact, slight visual impact, and no visual impact by wetland type (i.e., each impact zone will only encompass a single wetland type – different wetland types will be a different stratification zone). The position of the sample areas will be as follows:

- On the wellsite, four sample areas 10 m from the centre of the pad (generally well centre) in each of the cardinal directions. To avoid trails and/or cutlines, the sample areas can also be rotated 45^{o}. Sampling targets only the centre of pad based on a recommendation from the pilot study to focus on the pad centre as it represents the most limiting portion of the pad.
- On the padded portions of the access road, corresponding to each of the stratified zones and spaced a minimum of 100 m apart along the access road. If there are fewer than four stratified

zones, additional sample areas will be added, up to a maximum of four; however, each sample area must be spaced 100 m apart.

- In the peatland surrounding each site and located in each of the stratification zones. The sample should include an upstream, downstream and reference area:
    - **Upstream** - located 10 m from the access road/wellsite clearing (may be greater than 10 m from the edge of the pad) and in the middle of the stratification zone
    - **Downstream** - located 10 m from the access road/wellsite clearing (may be greater than 10 m from the edge of the pad)
    - **Reference** – located either upstream or downstream at least 100 m from the access road/wellsite, outside the area of visual impact and in the same wetland type as the upstream and downstream locations. Note: reference areas may be shared for different stratification units at the same site if they are located in the same wetland type. Also, additional reference areas may be sampled to better capture natural variability

For the wellsite, each sample area from the same wellsite will be treated as a subsample. For the access road, as not all wellsites may have a padded access road and conditions may vary along access roads, to ensure sufficient replication, each sample area will be treated as its own experimental unit. Spacing of the sample areas by 100 m will create some independence between sample areas but the correlation between sample areas on a single access road will still need to be accounted for during data analysis.

Preliminary sample areas will be pre-plotted prior to field data collection, and they can be adjusted in the field. Example sample area layouts are included as Appendix F.

4.3 MEASUREMENTS

4.3.1 *On-site Vegetation*

On-site measurements of vegetation will be used primarily for the first research objective. Based on recommendations from the pilot study, vegetation will be assessed in a 10 m^2 circular plot at each of the sample areas. On access roads the plot shape will be adjusted to ensure that it fits within the padded width of the access road and excludes a 1 m buffer area from the edge of the padded area (i.e., a rectangular plot could be used). The following will be measured in the plot:

- Canopy cover by vegetation strata (tree and shrub, native forbs and prostrate shrubs, native graminoids, agronomic species and weeds, nonvascular, total vegetation cover, bare ground, litter, and standing water)
- List of vegetation species and a rating of their abundance by cover class (1 = <1%, 2 = 1-5%, 3=5-10%, 4=10-20%, 5 = 20-50%, 6, >50%)
- Tree stem count by height class (<1.3 m, 1.3 m to 3.0 m, >3.0 m) and species
- Height, diameter at breast height (DBH) and an estimate of tree age for up to three “site” trees of each species (largest trees by DBH)

4.3.2 *Pad Characterization*

Pad characterization will be used for the first and third research objectives. Pad material will be characterized at each of the on-site sample areas, by hand-digging and hand-auguring sample pits/test holes. Based on recommendations from the pilot study, characteristics documented will include:

- Pad thickness
- Thickness of peat below pad
- Elevation of pad above the surrounding peatland surface
- Pad material texture and coarse fragment content in 30 cm increments
- Depth to water
- Depth to gleying and/or mottling
- Rooting restrictions

Two bulk density samples at a depth of approximately 15 cm and 35 cm will be collected and analyzed. Additionally, samples of the pad material will be collected from a 0-30 cm interval and a composite from a depth of 30 cm to maximum thickness of pad.

The samples will be submitted for laboratory analysis of:

- pH
- electrical conductivity (EC)
- sodium adsorption ratio (SAR)
- percent saturation
- concentrations of
    - calcium
    - magnesium
    - potassium
    - sodium

The 0-30 cm interval will also be analyzed for organic carbon, total nitrogen and available nitrogen, phosphorus, potassium, and sulfur.

For the pad, pad size, location within the landscape and historical construction and reclamation practices will be documented in the field and verified with aerial and satellite imagery and other available remote sensing data.

4.3.3 *Off-site Vegetation*

Off-site vegetation measurements will be used primarily for the third research objective. Vegetation will be characterized at each sample area with the same methods used for on-site vegetation measurements (4.3.1) with the addition of classification of the wetland class, form and type as per the *Alberta Wetland Classification System* (Alberta Environment and Sustainable Resource Development, 2015). Classification will require measurement of peat depth, pH and electrical conductivity, which is included in off-site soil and hydrology measurements (Section 4.3.4). Classification will include current wetland type and, if the area is impacted, an estimate of the pre-impact wetland type.

4.3.4 *Off-site Soil and Hydrology*

Off-site soil and hydrology measurements will be used primarily for the third research objective. Soil and hydrology will be characterized at each sample area. Characteristics documented will include:

- Peat thickness
- Texture of substrate underlying peat
- Presence of any sediment originating from the pad
- Depth to water
- Degree of decomposition for the profile (von Post)
- Field measurements of pH and electrical conductivity

Samples of the pore water will be collected and submitted for laboratory analysis of:

- Routine water chemistry
- Select samples will be analyzed for total metals and nutrients to support the second research objective

Note: If there are no off-site sample areas located within 50 m of the wellsite, wetland type and depth to water will be classified in an upstream and downstream location 10 m from the wellsite clearing.

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APPENDIX A: SUMMARY OF KNOWLEDGE GAPS

	Knowledge Gaps
Local and Regional Impacts	Relationship between peatland type (e.g., bog vs. fen), feature type (e.g., pad vs. road) and direction of water flow relative to the feature on the occurrence of off-site impacts
	Impacts of pads and roads left in place on groundwater, wildlife habitat, wildlife movement and use of the landscape
	Methods that can be used to measure the occurrence and extent of current pad impacts to hydrology, as well as the potential for future impacts
	Cumulative impacts of multiple pads and roads on local and regional peatland hydrology, chemistry, vegetation and greenhouse gas fluxes and the threshold at which cumulative impacts degrade overall ecological function of the region
	Magnitude of carbon emissions released during pad removal (including site access) and associated net environmental "benefit" associated with pad removal vs. leaving the pad in place
	Success rate of pad removal in achieving peatland ecosystem function, ecological land classification and the factors and reclamation practices that contribute to success or failure. Specifically: • Extent of peat compression under the pad, and impact of overall thickness and weight of the pad • Extent of peat rebound after pad removal and impact from duration of pad being in place and thickness/weight of the pad • Potential for and risk of minimal peat rebound and the creation of an open water body instead of a site on a trajectory to a functional peatland • Impacts to underlying peat chemistry resulting from the pad material, and how those changes may impact a developing plant community after pad removal
	Cumulative effect threshold based on scientific and geographical approaches to allow a proportion of wetland in a given area to be "lost" without significant degradation of function of the region
Site Specific Considerations	Factors that result in padded sites impacting the surrounding peatland ecosystems in the long term and affect the extent and severity of these impacts
	Effectiveness of partial reclamation activities for alleviating impacts resulting from pads (wellsite and/or access roads) in peatlands
	Likelihood of success for peatland recovery if the pad is removed
	Success rate of pads left in place that achieve and maintain upland ecosystem function and ELC in the long term. Specifically: • Relative importance of factors that influence successful reforestation of pads (e.g., soil quality, topsoil depth, compaction, dispersal vectors, historical revegetation efforts, time, surrounding peatland type, water quality and levels, etc.) • Potential for water table to rise into the root zone over time • Resiliency of upland ecosystems developed on pads left in place
	Factors that result in sustainable forest ecosystem development on padded sites

APPENDIX B: RESEARCH OBJECTIVES, QUESTIONS AND EXPERIMENTAL APPROACHES

Objective 1) <u>Investigate the factors that result in sustainable forest ecosystem development on padded sites in peatlands</u>

Rationale

One factor in the decision to leave a pad in place in a peatland is the sustainability of the ecosystem that has developed on the pad; this must be demonstrated to justify/approve reclamation certification. Additional understanding of the factors that encourage the development of sustainable forest ecosystems on padded sites is required to optimize reclamation practices to achieve this goal.

Research Questions

Objective 1 will specifically focus on the following research questions:

- Does the vegetation community on pads meet expected thresholds for composition and tree growth performance of forest ecosystems?
- Which pad characteristics result in a vegetation composition and tree growth performance that meet expected thresholds for a forest ecosystem?

Experimental Approach

To determine if sustainable forest ecosystems develop on pads and what factors result in development of sustainable forest ecosystems, reclaimed pads with different vegetation compositions will be selected. Sites will be stratified into groups or treatment levels based on their vegetation composition:

- Closed or nearly closed tree and shrub canopy
- Open canopy of trees and shrubs
- No/minimal tree and shrub canopy.

Differences between the pad characteristics and local surroundings of pads of the treatment levels will be used to determine which factors affect development of a sustainable forest ecosystem on pads. To determine if pads support sustainable forest ecosystem, a fourth treatment level will be upland (forested) wellsites that have met the natural recovery or planted requirements of the Forested Reclamation Criteria and have received a reclamation certificate. These upland wellsites will be compared to pads with closed or nearly close tree and shrub canopy.

Effect of time will be controlled by selection sites that have been reclaimed between 15 and 20 years previous (this age range may change depending on availability of sites).

Factors that will be measured to compare pads in the different treatment groups and determine what contributes to sustainable forest ecosystem development on pads will include:

- Reclamation practices: none, deep ripping, mounding, application of amendments (or salvaged topsoil), fertilization (depending on the availability of sites)
- Pad thickness and size
- Presence, type and depth of liner (e.g., corduroy, geotextile)

- Physical and chemical properties of the pad material
- Water level within the pad material (i.e., pad water table; depth to water below the surface of the pad)
- Surrounding peatland size and proximity of the pad to off-site seed sources for upland or mineral wetland ecosystems
- Surrounding peatland type: bog, poor fen, moderate-rich fen, extreme-rich fen

Measurements that will be used to compare forest ecosystems on pads to upland wellsites will include:

- Vegetation cover, composition and structure
- Tree density, height, diameter at breast height, age, mean annual increment
- Litter accumulation and decomposition
- Density and diversity of propagules in the soil seedbank

Application

Results from this objective will be used to refine the site-specific decision support tool in the Decision Framework and Support Tool. It will provide measurable characteristics that can be used to determine if a sustainable forest ecosystem is likely to develop on the pad and the pad could be left in place or if the pad should be removed.

Objective 2) Develop a mechanism for detecting and evaluating the effects of pads off-site

Rationale

To make decisions about leaving a pad in place in a peatland, or to justify/approve reclamation certification for a pad left in place in a peatland, appropriate metrics, and an accurate methodology to assess the metrics, are needed to verify that there are acceptable to the surrounding peatlands. There are many options for metrics and methodologies that could be used to indicate that pads left in place are not having impacts on the surrounding peatland. The value of these different methods needs to be evaluated to ensure that we are using the appropriate measurements to have certainty about the occurrence of impacts within the peatland ecosystem overall, while also avoiding measuring unnecessary parameters that do not provide additional benefits in terms of decision making.

Research Questions

Objective 2 will focus specifically on the following research questions:

- What is the effectiveness of remote sensing as a method to detect impacts of pads left in place in peatlands and can remote sensing accurately detect different kinds of impacts?
- Are measurements of water chemistry, water levels or sedimentation required to detect impacts or are impacts to water chemistry or water levels reflected in the vegetation?
- When should impacts be detected or evaluated (I.e. how many years after pad construction or reclamation does it take for impacts reach their maximum or steady-state, if they reach a steady-state)?

Identifying ecological thresholds that define an impact was identified as an important question for this objective; however, determining thresholds needs to consider various factors include land uses, ecological role/function and risk tolerance of regulatory bodies and land users and would be beyond the scope of this research proposal. For this research objective, impact[1] will be defined as a statistical difference, at an alpha value of 0.05, between the peatland surrounding the site and an appropriate reference area(s).

Experimental Approach

To answer the research questions, sites will be stratified into groups based on visual indicators of off-site impacts:

- No visual impact
- Visual impact – difference in vegetation or ponded water as observed on an aerial image

Sites will also be stratified by time since construction of the pad:

- 5 to 10 years since construction
- 10 to 20 years since construction
- >20 years since construction

Field measurements of water levels, water chemistry, sedimentation and vegetation composition, cover and density of the peatland adjacent to the pad will be taken and compared to an appropriate reference area. Similarly, remote sensing will be utilized to characterize the peatland adjacent to the pad and the remote sensing data will be compared to an appropriate reference area.

Data will be analyzed as follows:

1. To determine if remote sensing can be used to identify impacts, outcomes of field-based measurements (impact or no-impact based on differences between peatland adjacent to the pad and a reference area) will be compared to remote-sensing based outcomes to determine if there is a correlation. The effectiveness of remote sensing to identify vegetation impacts compared to water and sedimentation impacts as well as the ability to detect less severe impacts will be evaluated.
2. To determine if water chemistry, water levels or sedimentation measurements are needed to identify impacts or just vegetation measurements, measurements will be compared to reference areas, if there is a difference in water chemistry, water levels or sedimentation but not vegetation, it could suggest that vegetation measurements are not sufficient. However, if vegetation, water chemistry, water levels and sedimentation are all different, vegetation measurements may suffice. These outcomes may be related to time since construction of pad as vegetation may take longer to respond than the other parameters. Hence, including different ages of pads in the comparison may determine when (years since pad construction/reclamation) vegetation measurements alone can

[1] *The definition for impact is subject to change based on site selection.*

be used to identify impacts and when water chemistry, water levels or sedimentation measurements also required to identify impacts.

3. To determine when impacts should be detected or evaluated and when they reach their maximum or steady state will utilize remote sensing. Historical remote sensing data will be utilized and learnings from analysis 1 and 2 will be incorporated. Changes in impacts will be tracked over time to determine when a maximum or steady-state has been achieved. The field measurements and outcomes from analysis 2 will also be used to verify the results.

Application

Results from this objective will be used to develop standardized methods for measuring site impacts which can be used to guide decisions in the local and regional impacts decision support tool.

Objective 3) Investigate the factors that result in padded sites having off-site impacts to their surrounding peatland ecosystems in the long-term and affect the extent and severity of these impacts

Rationale

The occurrence, or the potential for the occurrence, of impacts to the surrounding peatland as a result of a pad left in place is a major factor in justifying/approving reclamation certification for pads left in place in peatlands. Current and short-term off-site impacts can be directly measured (through work to address Objective 1), but prediction of future impacts is also a critical component of the decision. In the absence of long-term monitoring, there is a need to understand the factors that result in off-site impacts, to use these as predictors of long-term impacts.

Research Questions

Objective 3 will focus specifically on pads, including both padded wellsites and access roads, that have been reclaimed for 20 years or greater and the following research questions:

- What characteristics of pads result in impacts to the long-term health and function of the surrounding peatland ecosystem?
- What characteristics of peatland ecosystems and the location and orientation of the wellpad/access road within a peatland result in the pad having a long-term impact on the ecosystem?

Experimental Approach

To answer the research questions, sites will be stratified into groups based on visual indicators of off-site impacts:

- No visual impact
- Visual impact – difference in vegetation or ponded water as observed on an aerial image

Post data analysis, sites may be reclassified as impacted and not impacted based on the definition of impacts; however, this will ensure that sites with and without impacts are included.

Sites will also be stratified by peatland type:

- Bog
- Fen
- Marsh

Effect of time will be controlled by selection sites that have been reclaimed >20 years previous (this age range may change depending on availability of sites and assuming that impacts have reached a steady state). As explanatory factors for pad impacts, measurements of the following characteristics will be made in the field and using remote sensing data/aerial imagery. Data collected from Objective 1 and 2 will be utilized:

- Facility type: padded wellsite without a padded access road, padded wellsite with a padded access road, padded access road only
- Pad size
- Pad thickness
- Physical and chemical properties of the pad material.
- Location of the pad within the peatland
- Erosion and run-off potential of the pad; inferred from vegetation cover, slope and evidence of past erosion
- Peat thickness
- Texture of the substrate below the peat.
- Size of the peatland
- Heterogeneity of the peatland

To determine the characteristics of pads and peatlands that result in impacts to the long-term health and function of the surrounding peatland ecosystem, pads with impacts in the surrounding peatland will be compared to pads without impacts to determine if there are certain characteristics associated with pads with or without impacts. If there are associated characteristics, these characteristics can be used as predictions for impacts.

Application
Results from this objective will be used to refine the local and regional impacts decision support tool in the Decision Framework and Support Tool. It will provide measurable characteristics that can be used to determine if a pad could be left in place or if the pad should be removed.

Objective 4) Evaluate the effectiveness of partial reclamation activities for alleviating off-site impacts resulting from pads left in place in peatlands

Rationale
Instead of complete pad removal, alleviating adverse effects to surrounding peatlands caused by pads left in place may be achieved through partial reclamation. Whether or not partial reclamation activities are successful at alleviating these off-site impacts is one of several factors that is considered in justifying/approving reclamation certification for pads left in place in peatlands.

For the purposes of this project, the partial reclamation options that will be studied are those that mitigate off-site impacts and may include:

- Partial removal of pad material to create drainage channels (e.g., swales), allowing water flow across/through the padded feature
- Partial removal of pad material from a vertical perspective to reduce the thickness of the pad and lower the elevation of the pad surface to match the surrounding peatland (on all or portions of the site)

Installation of culverts was not included as a potential partial reclamation option that will be studied because culverts cannot be left in place for reclamation certification. Partial reclamation options targeted at alleviating or improving soil conditions on the pad itself (e.g., deep ripping) are also not included in the project.

Research Questions

This project will specifically focus on the following research questions:

- Are partial reclamation methods effective in reducing off-site impacts caused by pads left in place in peatlands?
- What characteristics of the pads affect the success of partial reclamation?
- What characteristics of peatland ecosystems and the location and orientation of the pads within a peatland affect the success of partial reclamation?

Experimental Approach

Objective 4 will not include application of partial reclamation treatments to unreclaimed sites, instead sites where partial pad removal has already been conducted will be located and these pads will be utilized to answer the research questions. Sites will be stratified into groups or treatment levels based on reclamation treatment:

- Partial pad removal: swales
- Partial pad removal: vertical
- No pad removal
- Full pad removal

Sites will also be stratified by facility type:

- Access Road
- Wellsite

And sites will be stratified by peatland type:

- Bog
- Fen
- Marsh

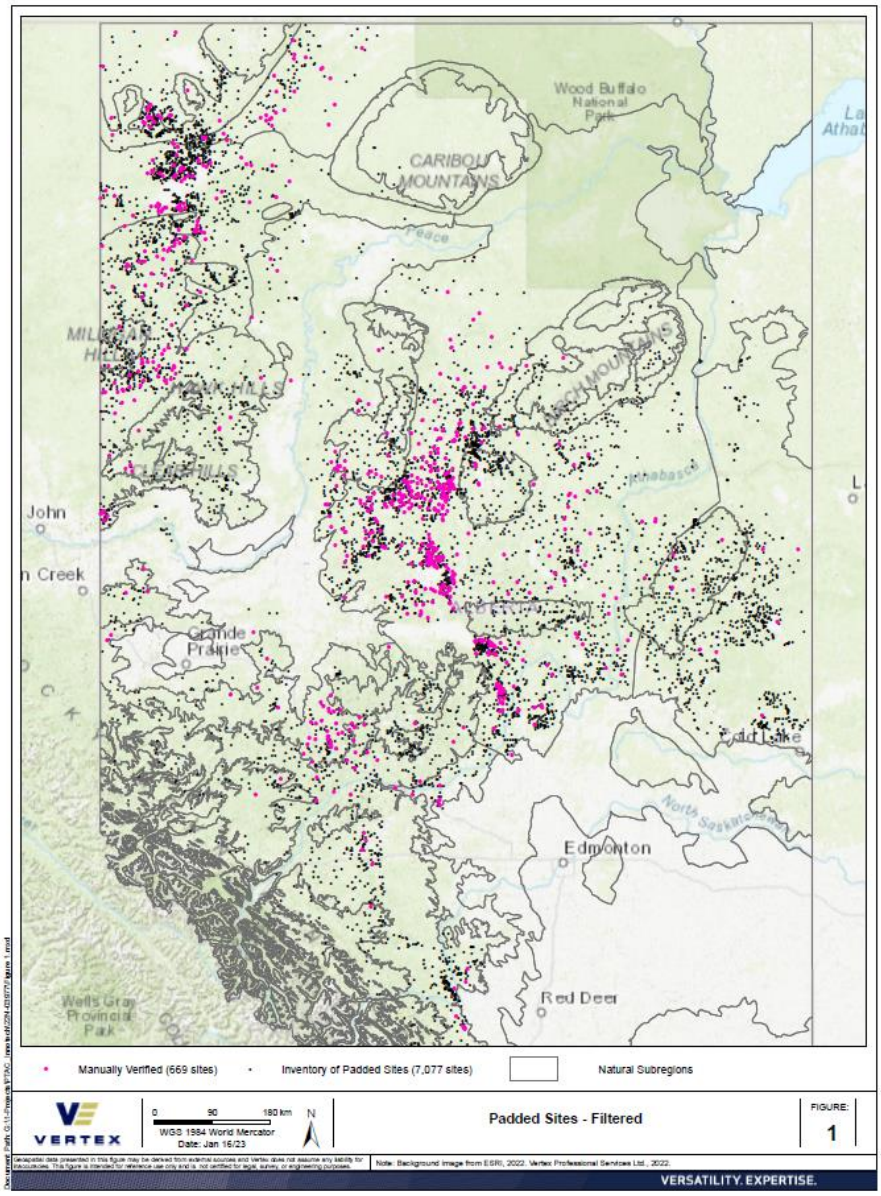
Remote sensing will be utilized (incorporating the learnings from the use of remote sensing in Objective 2), to evaluate historical impacts in the peatlands surrounding the pads prior to application of the

reclamation treatment. This will be compared to conditions of the peatland after application of the reclamation treatment and over several years (if possible) to determine how the peatland changes due to the partial reclamation. Field measurements of water levels, quality and vegetation composition and cover of the surrounding peatland will also be taken and compared to an appropriate reference area to verify the presence or absence of impacts.
In addition to the treatments, the following field measurements will also be taken on pads with partial reclamation to determine where partial reclamation is successful:

- Pad size and shape
- Pad thickness and size
- Physical and chemical properties of the pad road material
- Length of time the pad road has been present
- Location of the pad road within the peatland and distance to edge of the peatland
- Peat depth
- Permeability of the substrate below the peat
- Peatland size
- Peatland heterogeneity
- Peatland water level and hydrology

Application
Results from this objective will be used to help determine when partial reclamation can be applied to alleviate off-site impacts.

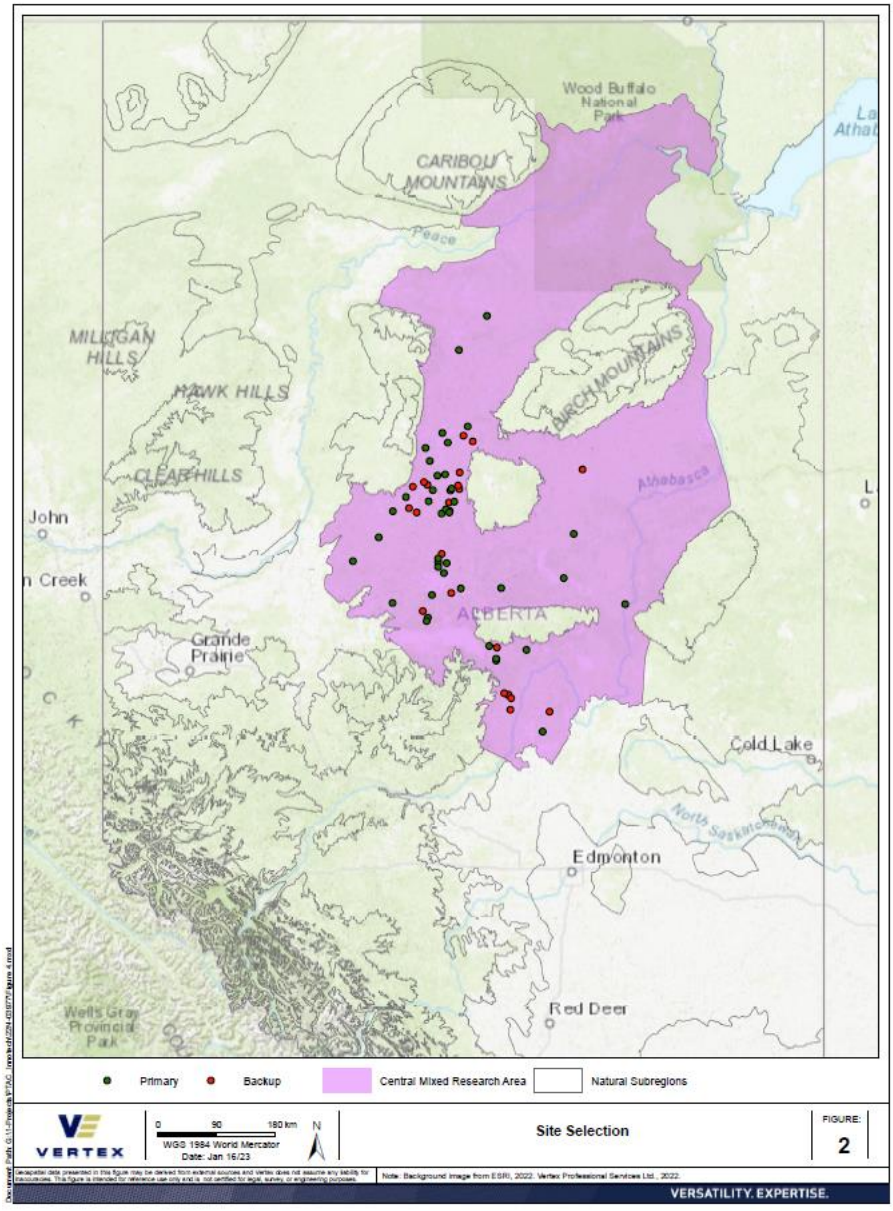
APPENDIX C: PADDED SITES MAP



APPENDIX D: ALL STRATIFIED SITES

On-Site Vegetation Cover	Off-Site Impact	Wetland Type (Number of Sites)						
		Bog-Poor Fen	Bog-Poor Fen-Transitional	Poor-Rich Fen	Poor-Rich Fen-Transitional	Peatland Complex	Peatland Complex-Transitional	**Total**
<25% tree/shrub cover	None	16	13	17	14	6	3	69
	Slight	10	10	12	9	6	1	48
	Impact	3	4	8	5	3		23
Total		**29**	**27**	**37**	**28**	**15**	**4**	**140**
25 to 50% tree/shrub cover	None	40	38	40	24	11	9	162
	Slight	30	20	21	14	5	4	94
	Impact	7	8	19	12	5		51
Total		**77**	**66**	**80**	**50**	**21**	**13**	**307**
>50% tree/shrub cover	None	32	34	34	28	8	2	138
	Slight	8	8	15	20	2	1	54
	Impact	5	3	12	4	5	1	30
Total		**45**	**45**	**61**	**52**	**15**	**4**	**222**

APPENDIX E: SITE SELECTION

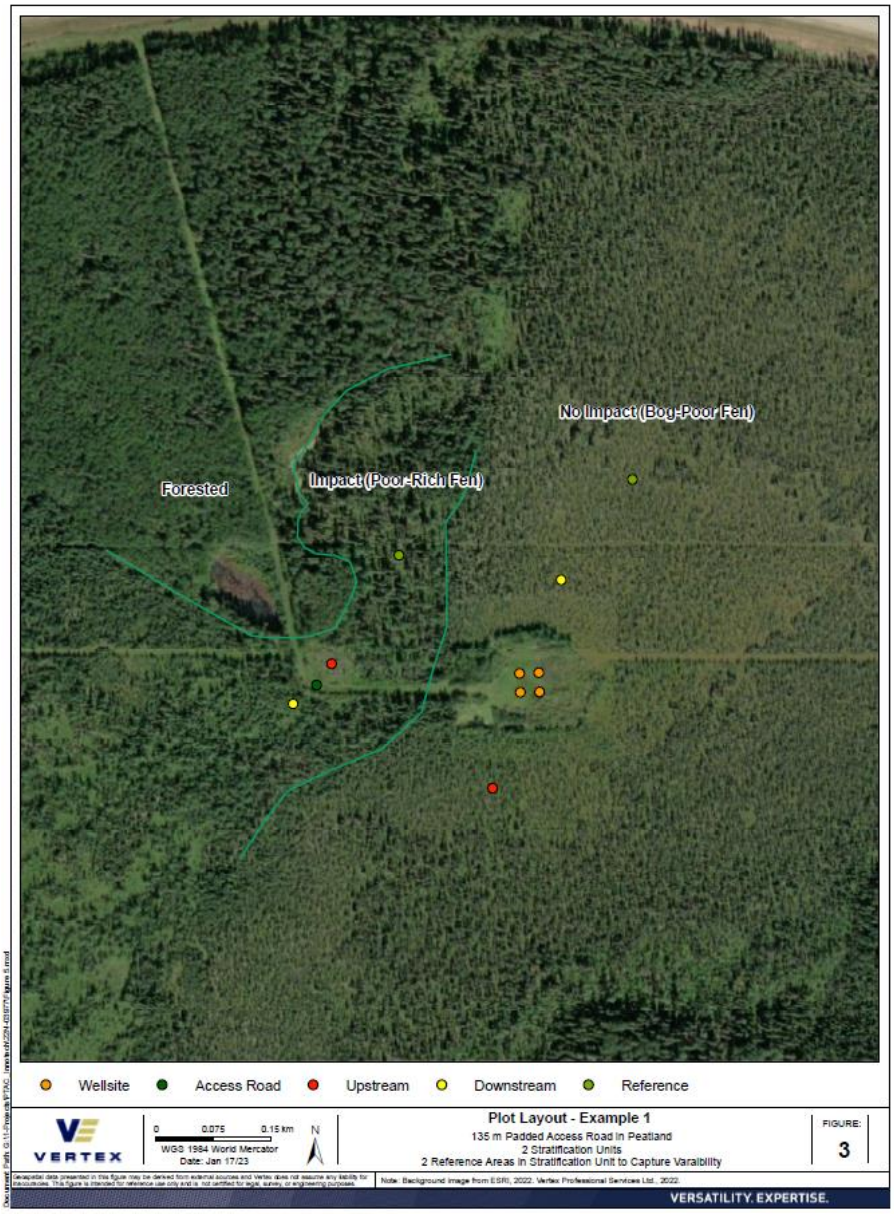


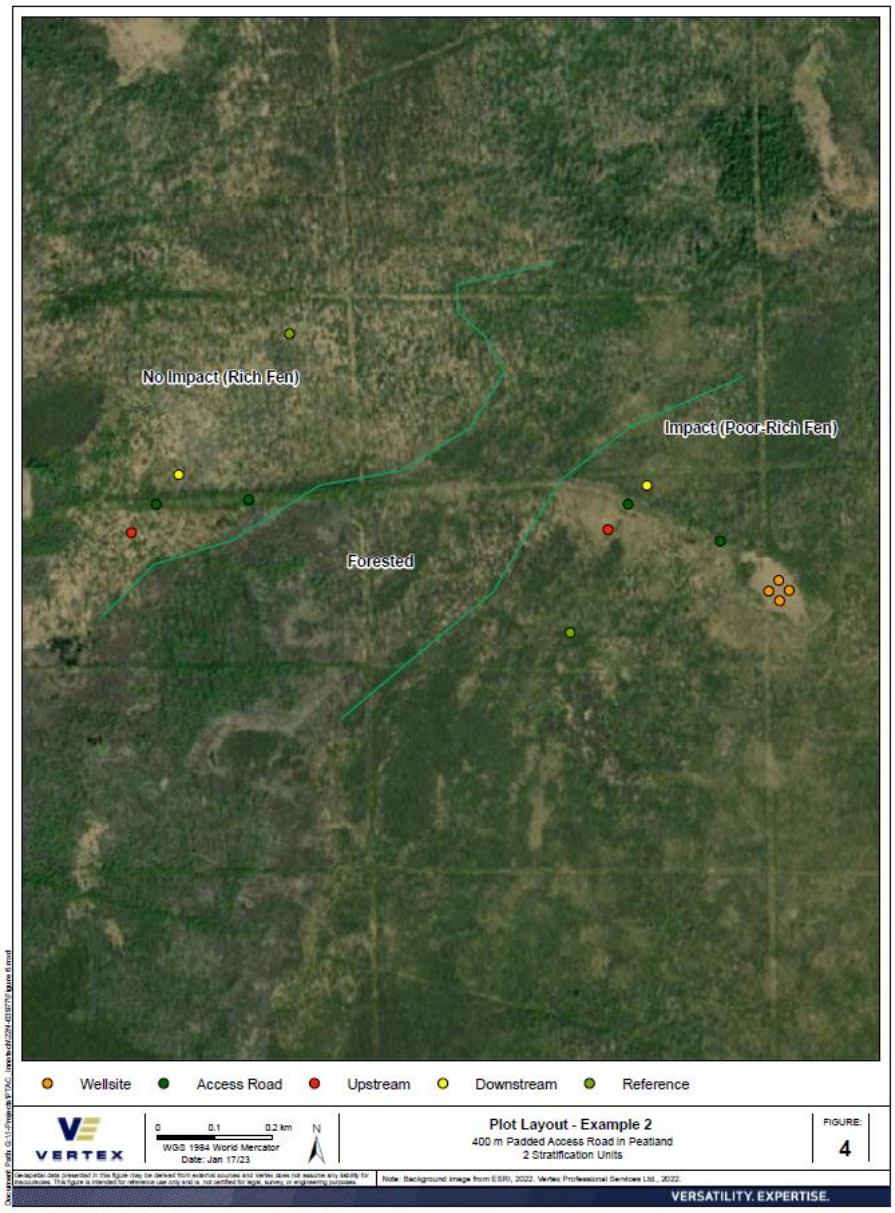
Well	On-Site Vegetation	Wetland Type	Off-Site Impacts	Presence of Pad on Site	Presence of Pad on Access Road	Location of Borrow	Off-site Activity	Primary/ Backup
100 / 02-28-072-04 W5 / 0	<25% tree/shrub	Poor-Rich Fen	Impact	Padded	Padded	Not Identified	None	Primary
100 / 02-33-072-04 W5 / 0	<25% tree/shrub	Bog-Poor Fen	Slight Impact	Padded	Inconclusive	Not Identified	None	Primary
100 / 02-34-087-08 W5 / 0	<25% tree/shrub	Poor-Rich Fen-Transitional	Impact	Padded	Padded	Forested within 250 m	None	Primary
100 / 04-21-081-09 W5 / 0	<25% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 07-04-092-08 W5 / 0	<25% tree/shrub	Bog-Poor Fen-Transitional	Slight Impact	Padded	Inconclusive	>250 from Wellsite	None	Primary
100 / 08-04-086-13 W5 / 0	<25% tree/shrub	Peatland Complex	Slight Impact	Padded	Padded	Forested within 250 m	None	Primary
100 / 08-36-092-09 W5 / 0	<25% tree/shrub	Poor-Rich Fen-Transitional	Slight Impact	Inconclusive	Not Padded	Not Identified	Beaver Flooding	Primary
100 / 09-07-089-08 W5 / 0	<25% tree/shrub	Poor-Rich Fen	No Impact	Padded	Not Padded	Not Identified	None	Primary
100 / 09-18-093-06 W5 / 0	<25% tree/shrub	Bog-Poor Fen-Transitional	Impact	Padded	Padded	Not Identified	None	Primary
100 / 10-14-090-10 W5 / 0	<25% tree/shrub	Poor-Rich Fen	Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 10-34-086-10 W5 / 0	<25% tree/shrub	Poor-Rich Fen-Transitional	Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 12-22-091-10 W5 / 0	<25% tree/shrub	Poor-Rich Fen-Transitional	Slight Impact	Padded	None/Upland	>250 from Wellsite	None	Primary
100 / 16-23-081-17 W5 / 0	<25% tree/shrub	Bog-Poor Fen	No Impact	Padded	Inconclusive	>250 from Wellsite	Open Water	Primary
100 / 01-09-089-09 W5 / 0	>50% tree/shrub	Poor-Rich Fen-Transitional	No Impact	Padded	Inconclusive	Forested within 250 m	None	Primary
100 / 03-02-088-08 W5 / 0	>50% tree/shrub	Bog-Poor Fen-Transitional	Impact	Padded	Padded	Forested within 250 m	None	Primary
100 / 04-03-100-07 W5 / 0	>50% tree/shrub	Bog-Poor Fen-Transitional	No Impact	Inconclusive	Not Padded	Not Identified	None	Primary
100 / 04-33-081-09 W5 / 0	>50% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	Forested within 250 m	Beaver Flooding	Primary
100 / 05-36-086-08 W5 / 0	>50% tree/shrub	Poor-Rich Fen-Transitional	No Impact	Padded	Not Padded	Not Identified	None	Primary
100 / 06-06-084-22 W4 / 0	>50% tree/shrub	Bog-Poor Fen-Transitional	Slight Impact	Inconclusive	None/Upland	Not Identified	None	Primary
100 / 06-08-066-26 W4 / 0	>50% tree/shrub	Poor-Rich Fen	Slight Impact	Inconclusive	Inconclusive	Forested within 250 m	None	Primary
100 / 06-36-102-05 W5 / 0	>50% tree/shrub	Bog-Poor Fen-Transitional	No Impact	Inconclusive	Not Padded	Not Identified	None	Primary
100 / 07-07-086-08 W5 / 0	>50% tree/shrub	Peatland Complex-Transitional	Impact	Inconclusive	None/Upland	Forested within 250 m	None	Primary
100 / 10-08-076-10 W5 / 0	>50% tree/shrub	Bog-Poor Fen	No Impact	Inconclusive	Not Padded	Not Identified	None	Primary
100 / 10-18-081-08 W5 / 0	>50% tree/shrub	Bog-Poor Fen	Impact	Padded	Padded	Not Identified	Burnt	Primary
100 / 11-21-076-10 W5 / 0	>50% tree/shrub	Peatland Complex-Transitional	No Impact	Padded	Inconclusive	Not Identified	None	Primary
100 / 12-04-081-09 W5 / 0	>50% tree/shrub	Peatland Complex	Impact	Padded	Padded	Not Identified	None	Primary
100 / 01-02-074-05 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen	Impact	Padded	Padded	Not Identified	None	Primary
100 / 02-35-085-09 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen-Transitional	Impact	Inconclusive	Padded	Forested within 250 m	None	Primary

100 / 03-32-077-13 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen	Slight Impact	Padded	Inconclusive	Not Identified	None	Primary
100 / 04-09-079-07 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 04-29-073-01 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	No Impact	Inconclusive	Not Padded	Not Identified	Open Water	Primary
100 / 06-24-080-09 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen-Transitional	Slight Impact	Inconclusive	Inconclusive	Forested within 250 m	None	Primary
100 / 06-29-083-14 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen-Transitional	No Impact	Padded	Padded	Forested within 250 m	None	Primary
100 / 06-31-087-09 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen	No Impact	Padded	Not Padded	Not Identified	None	Primary
100 / 07-12-079-04 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	No Impact	Inconclusive	Not Padded	Not Identified	None	Primary
100 / 10-29-077-18 W4 / 0	25 to 50% tree/shrub	Bog-Poor Fen	Slight Impact	Padded	Not Padded	>250 from Wellsite	None	Primary
100 / 10-33-085-08 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen-Transitional	Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 11-23-078-10 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen-Transitional	No Impact	Padded	Padded	>250 from Wellsite	Open Water	Primary
100 / 14-11-087-12 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen	Impact	Padded	Padded	>250 from Wellsite	None	Primary
100 / 16-01-080-24 W4 / 0	25 to 50% tree/shrub	Bog-Poor Fen	Slight Impact	Padded	Padded	Forested within 250 m	None	Primary
100 / 01-08-088-11 W5 / 0	<25% tree/shrub	Poor-Rich Fen	No Impact	Padded	Not Padded	Not Identified	Open Water	Backup
100 / 02-15-088-10 W5 / 0	<25% tree/shrub	Poor-Rich Fen-Transitional	Slight Impact	Padded	Padded	Forested within 250 m	Open Water	Backup
100 / 05-30-089-21 W4 / 0	<25% tree/shrub	Bog-Poor Fen	No Impact	Padded	Inconclusive	Not Identified	Open Water	Backup
100 / 06-06-068-25 W4 / 0	<25% tree/shrub	Poor-Rich Fen	No Impact	Inconclusive	None/Upland	Not Identified	Open Water	Backup
100 / 08-21-069-03 W5 / 0	<25% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	Forested within 250 m	None	Backup
100 / 14-33-087-07 W5 / 0	<25% tree/shrub	Poor-Rich Fen	Impact	Padded	Padded	Not Identified	None	Backup
100 / 15-08-088-07 W5 / 0	<25% tree/shrub	Bog-Poor Fen	Impact	Padded	Padded	>250 from Wellsite	None	Backup
100 / 06-11-068-03 W5 / 0	>50% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Inconclusive	Not Identified	None	Backup
100 / 08-04-086-08 W5 / 0	>50% tree/shrub	Poor-Rich Fen-Transitional	Slight Impact	Padded	Padded	Forested within 250 m	None	Backup
100 / 10-28-078-08 W5 / 0	>50% tree/shrub	Poor-Rich Fen	Impact	Inconclusive	Padded	Not Identified	None	Backup
100 / 11-34-085-11 W5 / 0	>50% tree/shrub	Poor-Rich Fen-Transitional	No Impact	Padded	None/Upland	>250 from Wellsite	Open Water	Backup
100 / 12-11-082-09 W5 / 0	>50% tree/shrub	Poor-Rich Fen	No Impact	Padded	Padded	Not Identified	Burnt	Backup
100 / 14-12-086-12 W5 / 0	>50% tree/shrub	Poor-Rich Fen	Slight Impact	Inconclusive	Inconclusive	Not Identified	None	Backup
100 / 15-01-077-11 W5 / 0	>50% tree/shrub	Bog-Poor Fen	No Impact	Padded	Not Padded	Not Identified	None	Backup
102 / 04-34-073-04 W5 / 0	>50% tree/shrub	Poor-Rich Fen	Impact	Inconclusive	Padded	>250 from Wellsite	None	Backup
100 / 06-22-069-03 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	>250 from Wellsite	None	Backup
100 / 08-30-069-03 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	Forested within 250 m	None	Backup

100 / 09-20-088-10 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	No Impact	Padded	Not Padded	Not Identified	Beaver Flooding	Backup
100 / 10-11-069-03 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	Slight Impact	Padded	Padded	Not Identified	None	Backup
100 / 11-16-089-07 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen-Transitional	Impact	Padded	Padded	Not Identified	Beaver Flooding	Backup
100 / 14-03-092-06 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	No Impact	Padded	Padded	Not Identified	None	Backup
100 / 14-28-086-08 W5 / 0	25 to 50% tree/shrub	Bog-Poor Fen-Transitional	Impact	Padded	Padded	Not Identified	None	Backup
100 / 16-23-092-07 W5 / 0	25 to 50% tree/shrub	Poor-Rich Fen	Impact	Padded	Padded	Not Identified	None	Backup

APPENDIX F: PLOT LAYOUT EXAMPLES




No Impact (Rich Fen)
Impact (Poor-Rich Fen)
Forested
Wellsite
Access Road
Upstream
Downstream
Reference
0 0.1 0.2 km
WGS 1984 World Mercator
Date: Jan 17/23
N
Plot Layout - Example 2
400 m Padded Access Road in Peatland
2 Stratification Units
FIGURE:
4
Geospatial data presented in this figure may be derived from external sources and Vertex does not assume any liability for inaccuracies. This figure is intended for reference use only and is not certified for legal, survey, or engineering purposes.
Note: Background image from ESRI, 2022. Vertex Professional Services Ltd., 2022.
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