PROTOCOLS FOR MONITORING ECOLOGICAL RECOVERY OF RECLAIMED WELL PADS ON GRASSLANDS[1]

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Abstract. We developed a scientifically robust monitoring protocol to enable a consistent assessment of ecological recovery of physical, chemical, and biological indicators at certified reclaimed industrial well pads on grasslands. Using the developed protocols, data can be generated from measurement of soil, vegetation, and landscape indicators at reclaimed well pads and adjacent reference sites. We selected the appropriate vegetation, soil, and habitat indicators for a long-term reclamation monitoring program and have provided sampling protocols for the selected indicators here. The protocols may be used to identify and prioritize indicators of reduced ecosystem health and to track ecological recovery of reclaimed sites over time. The development of these integrated monitoring protocols is a first step towards successful and consistent long-term monitoring to assess ecological recovery of certified reclaimed well pads on grasslands.

Introduction

We developed a scientifically robust and financially sustainable monitoring protocol to enable a consistent assessment of ecological recovery of physical, chemical, and biological indicators at certified reclaimed well pads on Alberta grasslands. Using the developed protocols, reclamation professionals, government agencies and scientists can generate data from measurement of soil, vegetation, and

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landscape indicators at reclaimed well pads and adjacent reference sites. The protocols describe the sampling layout for individual sites, followed by sampling protocols for each ecosystem component, and finally information related to management of personnel and data. These protocols are part of a larger program to establish a long-term monitoring network tracking post-reclamation performance. Similar protocols for forested lands are also available online (McIntosh et al., 2019). Uses for the protocols include the identification and prioritization of ecosystem health indicators and tracking ecological recovery of reclaimed sites over time. Information related to analysis of the data collected in these protocols is beyond the scope of this document. The development of these integrated monitoring protocols is a first step towards successful and consistent long-term monitoring to assess ecological recovery of certified well pads in Alberta. Although the document refers to policy and practices specific to Alberta (e.g., avoidance vs collection of endangered species), the general protocol is useful in any grassland region.

Methods

1. Sampling Design

In this section, we describe the sampling design and layout for individual sites, including detailed information on accessing and laying out individual sampling sites for future measurement. These sampling design and protocols have been updated from the original version, based on feedback from the Ecological Recovery Monitoring of Certified Sites in Alberta Advisory Group and our first pilot of the sampling protocols in the Dry Mixedgrass Region during Summer 2013. We recognize that there are multiple methods of implementation for sampling design and monitoring. The system that we have adopted samples two different areas within a single unit: the wellsite (excluding access roads), and a reference site (i.e., a paired comparison design). Both the on and off wellsite areas are sampled; the area is considered to be one unit that consists of two sites. The wellsite includes the disturbance footprint of the wellsite, and an adjacent reference condition site that does not have a footprint of human disturbance is the control/reference against which we assess ecological recovery. To measure the temporal change in the selected indicators, systematically select sampling points to minimize spatial variability. Ease of use and sampling efficiency make systematic sampling better than random sampling for this monitoring program.

A. Plot Establishment - Setting up Access to Long-term Monitoring/Research Sites. Plot establishment is designed to facilitate field sampling by having predetermined information identified route to site center recorded on an access sheet (note: this may not always be possible depending on what information is available ahead of time and whether a crew has previously scouted the location). Crews will have an estimated timeframe for getting to the site and knowledge of potential access hazards.

Gaining access to terrestrial sites has multiple components:

1. Prior to the first site visit map/GIS and data reconnaissance work in the office that gathers as much data as possible about accessing the site and the site history[3] are needed to assist field crews in their first visit to the site. The wellsite center should be labeled and GPS coordinates from the map/GIS recorded for the wellsite center and four corners. The need for surveying for ground disturbance needs to be established prior to the first visit to the site too[4]. This involves setting up an account on Alberta OneCall (http://www.albertaonecall.com/) and submitting ground disturbance requests a minimum of 3 business days before sampling is going to be conducted. Companies with potential belowground infrastructure will contact you to let you know whether or not there is a conflict and whether marking of lines will be required. Individuals using the protocols outside of Alberta will need to follow their State or Province protocols for surveying. In addition, if you are working on private lands and/or public lands with grazing leases – you need to contact the landowner for permission to access their land. For agricultural lands in Alberta you can get information by going to: https://maps.srd.alberta.ca/RecAccess/default.aspx?Viewer=RecAccess. There will be an identified recreational access that will provide you with information on who has the grazing lease so you can contact them for permission to have access to their site (this is for grazing leases on public lands). Additional information can be accessed using the abandoned well map at: http://portal.aer.ca/portal/site/srp.

[3] Note, footnote numbering starts again with #1. These data could be collected using an approach similar to a Phase 1 Environmental Site Assessment – a lot of information can be obtained using Abadata (http://abadata.ca/) as well as the Environmental Site Assessment Repository website (https://www.alberta.ca/environmental-site-assessmentrepository.aspx).

[4] There are ground disturbance issues with having some of our sampling of soils occur below 30 cm so ground disturbance approval needs to occur prior to site visit – field staff could take a ground disturbance training course to satisfy this requirement.

2. Finally, before going into the field, prepare a site information package with additional maps and descriptions. Use this package to locate sites and to facilitate data collection during future monitoring visits.

3. During the first visit to the site, identify the most efficient route and potential hazards on Access Datasheets (Appendix 4) and supplied maps.

   - Ensure that compass declination is set appropriately for the location. Declination for the region is determined by checking on the GPS and recorded on the Access Sheet.
     Record the accuracy of the GPS used during site establishment on the Access Sheet.

   - Record the GPS locations of turnoffs, corners, significant landmarks, and parking locations. Include detailed direction and distance measures to aid staff in relocating all access points and site center (Appendix 1). This will be most relevant for locations after you have turned off a main road/highway

<u>Field Equipment Needed:</u> ○ *Cellphone for communications* ○ *2-way radios for communications among partners* ○ *Datasheets and clipboard* ○ *Site maps and wellsite information package* ○ *GPS and compass* ○ *9 (1 per 10-m square plot (centre location gets metal marker) – permanent magnetic metal markers per site*

- ○ *81 pigtails to mark the nested 5x5 m, 10x10 m, and 25x25 m plots, quadrant corners, and wellsite center within the wellsite and reference sites. (1 wellsite centre, 13 per quadrant with bryophytes/lichens, 9 pigtails per quadrant without bryophytes/lichens)* ○ *4-50 m tapes, 4-100 m tapes and 4–30 m tapes*
- ○ *Multiple colors of flagging tape (e.g., orange = 25x25 m, pink = 10x10 m, purple=5x5 m)*
- ○ *Fine tipped colored marker (to delineate polygons on human disturbance sketch)* ○ *Pencils for recording data on datasheets* ○ *Pin locator – magnetic metal detector* ○ *Plot layout 'cheatsheet' (see Appendix 5)* ○ *Datasheets #1-4*

<u>B. Laying out the plot for sampling</u>. For level and near-level sites, use the following sampling design (Fig. 1). On sites where there is significant across-slope curvature, it is important that all slope elements are represented. Hence, the sampling squares should encompass all slope positions within the 1 ha site

with one square in each convergent-divergent sequence across the slope and this should be noted on the site disturbance sketch.

Procedures:

- When the field crew arrive onsite, the first step is to identify the wellsite center, which will be the center point for the reclamation wellsite 1 ha plot too. It must be located as precisely as possible using a hand-held GPS with an accuracy of < 7 m (identify GPS coordinates from the maps and GIS investigation prior to the site visit). If due to heavy forest cover or poor satellite coverage accuracy values from the GPS are > 7 m, note this on the site establishment datasheet.
- At wellsite center place a pigtail in the ground and flag it so that you can readily identify the wellsite center. Note that you may have troubles identifying the wellsite centre so you may have to measure the diagonals between the four corners and then identify the wellsite centre as the point where the two diagonal lines intersect. Insert a permanent metal marker at the wellsite center after the soil sampling is complete so that a quick identification of the location can be made during future visits to the site. Also, use permanent markers on private land with approval from the owner. Record the GPS coordinates at the wellsite centre on Datasheet #2.
- The crew will need to lay out four sub-ordinal transects that are oriented to the four corners of the wellsite (e.g., if the wellsite is square in cardinal directions, then the bearings of the 4 transects would be northeast 45°, southeast 135°, southwest 225°, northwest 315°. if not cardinal, then adapt the directions of the four transects to angles so they intersect the four corners of the wellsite). Each quadrant is assigned a letter code (wellsite = B, C, D, E; reference = F, G, H, I – see Fig. 1). Record the Bearings for the Wellsite Corners for B, C, D, E quadrants on Datasheet #2 and record the GPS coordinates for the centre of each 10x10 m plot (i.e., 9 GPS measurements per site including wellsite centre).
- Start by scanning the quadrants to determine whether one looks richer in bryophytes and lichens – this will be your quadrant where you do the bryophyte and lichen sampling. If all quadrants look similar, randomly select which one you are going to do the bryophyte sampling on – this one will have a different plot establishment strategy.
- Establish the first transect for both the wellsite and adjacent reference site – it is most efficient to have both crewmembers establish each transect together and use the plot layout cheatsheet. Carry an extra 100-m tape and 25-m tape and 20 pigtails (* increase to 24 if you are doing 1 bryophyte/lichen

plot, increase to 28 if you are doing 2 bryophyte/lichen plots) with you. Using a 50-m tape attached to the wellsite centre, lay out your tape along the bearing of the sub-ordinal transect. You should flag the different plots with different colors of flagging to help identify them *(e.g., orange = 25x25 m, pink = 10x10m, purple=5x5m). Hint: it is helpful to use 2 people and triangulate with a single tape to complete the final 2 corners for the 5x5 m, 10x10 m, and 25x25 m plots in areas where there aren't trees.*

- When you have laid out 3.5 m of tape, insert a pigtail (this will be the pigtail for the corner of the center 5x5 m plot).
- If you are doing a lichen/bryophyte plot in this quadrant when you have laid out 6.7 m of tape, insert a pigtail (this will be the pigtail for the near diagonal corner of your 25x25 m transect.
- When you have laid out 7.1 m of tape, insert a pigtail (this will be the pigtail for the corner of the centre 10x10 m plot for soil sampling).
- Continue laying out the tape measure until you reach 27.9 m from wellsite centre and insert a pigtail (this will be the near corner of your 10x10 m plot).
- Continue out to 35 m from the wellsite centre and insert a pigtail (this is the center of your 10x10 m plot). Record the GPS coordinates on Datasheet #2.
- Continue to 42.1 m (the diagonal corner for the 10x10 m and 25x25 m plots).
- Insert pigtails for the remaining sides of the 10-m square (and 25-m square plots if appropriate) by measuring 10 m and 25 m (using the 30 m tape), N or S and E or W (depending on the quadrant of the wellsite you are setting up).
- For the quadrant where you are doing the bryophyte/lichen plot, mark the distance 15 m from the corner of the 25x25 m plot that is closest to the wellsite centre that is not part of the 10x10 m plot to create the fourth corner of the 25x15 m bryophyte/lichen plot.
- Add two additional pigtails for the remaining sides of the 5-m square plots by measuring 5 m, N or S and E or W (again will depend on the quadrant, using the 25 m tape).
- Finally continue measuring the tape out from the far end of the 10x10 m plot (located at 42.1 m from the wellsite centre) to the edge of the wellsite or to a distance of 70.1 m (whichever comes first):
  - if the wellsite corner is less than 70.1 m record the distance from wellsite centre and insert pigtail (this will apply if the wellsite is < 1 ha) record on the on Datasheet 2, or

    - if the edge of the wellsite is beyond 70.1 m from the plot centre then place the wellsite quadrant corner pigtail at 70.1 m, but still run the tape out to the edge of the wellsite and record the distance to the edge of the wellsite on Datasheet 2.

- To establish the reference site plots (assuming the reference sites are contiguous with the wellsite), walk to the corner of the wellsite footprint, roll out the 100-m tape and lay out the line transect at the same bearing as the same sub-ordinal quadrant transect.
  - Insert pigtails at 27.9 m, 35 m, and 42.1 m (these 3 pigtails will mark the two diagonal corners and plot center for the 10x10 m reference square plot). Record the GPS coordinates on Datasheet #2 at 35 m (plot center for 10x10 m plot).
  - If you are doing a bryophyte/lichen plot insert pigtail at 63.3 m (this will be the far diagonal corner of the 25x25 m plot).
  - Insert pigtails for the remaining sides of the 10-m square (and 25x25 m if there is a bryophyte/lichen plot) plots by measuring 10 m (or 25 m for the 25x25 m plots), N or S and E or W (depending on the wellsite or reference site quadrant).
  - Add two additional pigtails for the remaining sides of the 5-m square plots by measuring 5 m, N or S and E or W (depending on the quadrant).
  - For the quadrant where you are doing the bryophyte/lichen plot, mark the distance 15 m from the corner of the 25x25 m plot that is closest to the wellsite centre that is not part of the 10x10 m plot to create the fourth corner of the 25x15 m bryophyte/lichen plot.

    See Fig. 1 for diagram of pigtail layout.
  - Insert a pigtail at 70.1 m and then add 2 additional pigtails for the remaining sides of the quadrant (use for the plant census). If the wellsite is < 1 ha (the distance to corner of quadrant is < 70.1 m then adjust the length of the reference transect to the length of the diagonal distance for the wellsite (i.e., the wellsite and reference locations should have the same area sampled for vascular plant surveys)

For the remaining sub-ordinal transects that have not yet been established repeat the procedures described above.

- Note that 25x25 m plots are only required for the quadrants where bryophyte/lichen plots are being measured.

- If you encounter a wellsite that is located in an area that does not have suitable adjacent reference conditions, then the protocols for selection of reference conditions will differ and you should not extend the running of your lines beyond the edge of the wellsite. You will not establish the reference 10x10 m square plots directly adjacent to the wellsite and instead follow the special protocols described below.
- All flagging and pigtails must be removed after each visit, but magnetic metal markers should be inserted along the transect at the plot centre of each 10x10 m plot so the plots can be re-identified in future visits to the site.
- Minimize impact on crops/livestock on private sites. Refer to the Land Access datasheet for site-specific instructions (access, impact on land, etc.).

Special protocols when there is no adjacent reference condition:

When the reference condition is not located directly adjacent to the wellsite then there will have to be an alternative strategy to sample reference conditions. These will require an expert in the field identifying an area as close as possible to the wellsite that is undisturbed and representative of the natural conditions that were likely to be present on the wellsite prior to disturbance. A total reference area that is similar in size to the wellsite (1 ha) should be sampled, following modified protocols that adapt the protocols described throughout the document to the shape of the reference condition site. Mark GPS points for the centers of the 10x10 m plots sampled in the reference sites.

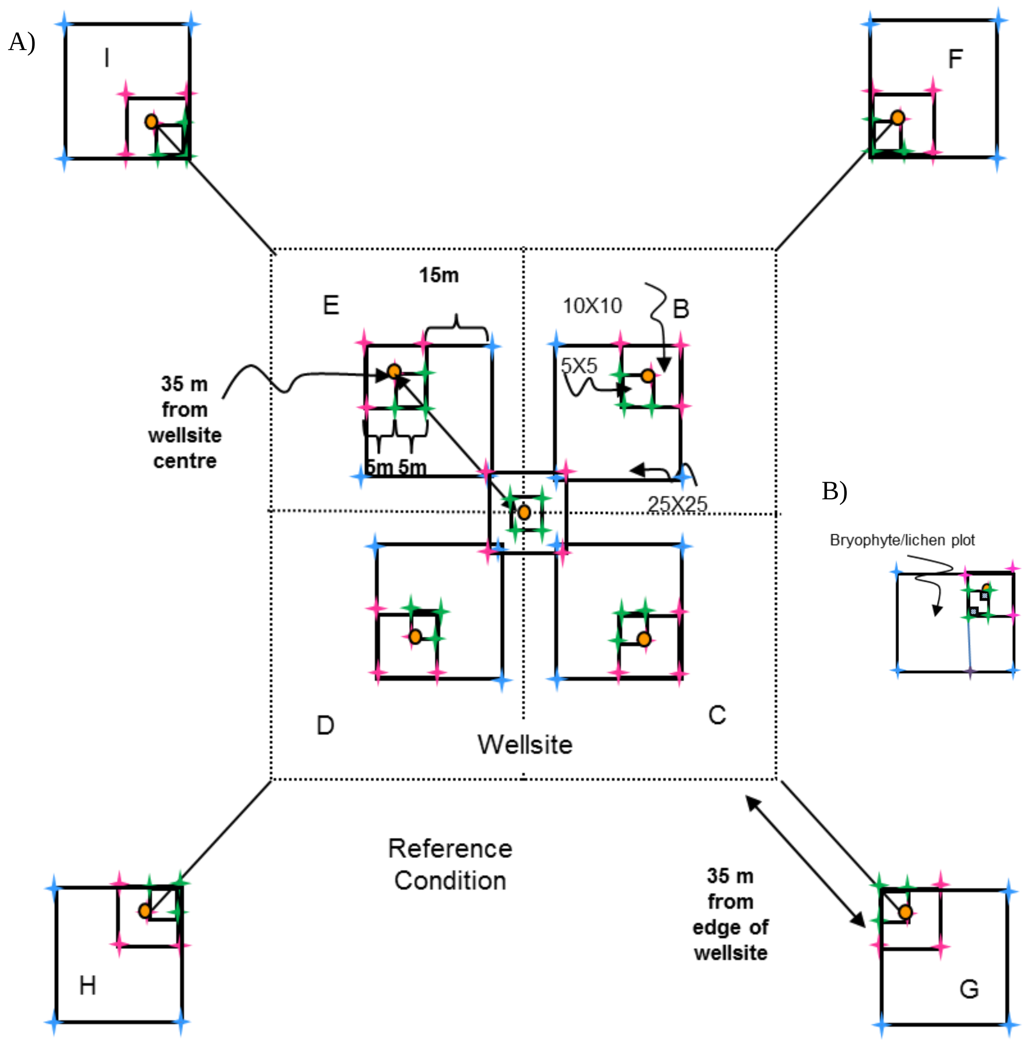

Figure. 1. Sampling layout of wellsites and adjacent reference sites. A) Nested square plots and pigtail placement for the 5x5 m (green), 10x10 m (pink), and 25x25 m (blue) plots, which are located within the four quadrants of the wellsite, wellsite centre (10x10 m plot), and the area surrounding each of the reference condition plots, which are also referred to as a quadrant. B) Pigtail placements for all plots including in the 25x25 m square plot that includes the 25x15 m bryophyte plot are highlighted (in blue) – 13 pigtails are needed per wellsite quadrant and 13 pigtails are needed per reference site quadrant laid out if 25x25 m and 25x15 m plots are established. Note: plots are not drawn to exact scale.

C. Site Sketch – Human Disturbance Field

Equipment Needed: ○ *Datasheets 3A and 3B*

Procedure:

- Disturbances within the wellsite and reference sites are hand drawn based on observation at both sites.

- Use the data sheet provided to complete a map outlining all human disturbance evidence present at the site (e.g., wellhead bore location, roads nearby).
- Write the type of human disturbance in the polygons using the codes described under "Human Disturbance" included on the worksheets.
- Once mapping is completed, review the diagram to ensure that it accurately reflects the true size and shape of the human disturbances.

D. Site Photographs This protocol design provides permanent pictures of the site.

Field Equipment Needed: ○ *Digital camera with extra batteries and charger if appropriate* ○ *Calipers or backpack for scale* ○ *Datasheet 4*

Procedure:

- Use a digital camera with a 35 mm focal length and a quality setting of at least 3 Megapixels. Use "landscape" orientation.
- Take five photographs at each wellsite, and take five photographs of the reference site.
- Include a backpack and/or DBH calipers approximately 5 m from the camera for scale.

For the wellsite:

1. Transect Photos – Standing at wellsite center, take a photograph at eye level in each of the four sub-ordinal directions so that you are pointing towards the transect associated with each Quadrant (B, C, D, E -begin with 'B' quadrant and move clockwise).
2. Representative Site Photo – From anywhere within the 1 ha wellsite take a single photograph that best represents the physical and vegetation characteristics, providing the location and direction of this photo on the site diagram.

Record the photo numbers on Datasheet 4.

For each of the 4 reference site plots:

1. Transect Photos – Standing at the near corner of the 10x10 m plot, take a photograph at eye level at the angle of the transect – facing away from the wellsite.
2. Representative Site Photo – From anywhere within the reference area; take a single photograph that best represents the physical and vegetation characteristics.

Record the photo numbers on Datasheet 4.

*Check the resolution and quality of all photos at the site; re-take if any photos are blurry.

- Back-up and label photo files onto a computer once back at your base camp or in the office. Transect photos are labeled [Region]_[year]_[site]_"W"or"R"_[quadrant].jpg (e.g., DMG _2013_3_W_C.jpg). Representative site photos are labeled with [wellsite] - , if taken on the wellsite - or [reference] if taken in the reference condition - at the end of the label name.
- Copy all photos to an office computer or an external hard drive/flash key and backup regularly.

2. Vegetation Sampling

This section describes the vegetation sampling protocols for native grasslands.

A. Classification of Upland Vegetation Types – (copied from Alberta Environment 2010). Native Grasslands include lands that are permanently vegetated by native herbaceous species. Native grasslands commonly present a mixture of different native grass species, forbs (i.e., flowering/broad-leaved species), shrubs (i.e., woody species) and tree species, whereas tame grasslands (i.e., forage and tame pasture) produce agronomic seeded grass and legume species such as timothy and alfalfa. Grasslands occur primarily in the Grassland Natural Region, and occur in other Natural Regions of Alberta, including the Parkland, Rocky Mountains, and Foothills Natural Regions. Grasslands include range improvement areas, grazing dispositions on public lands (White Zone and Green Zone areas), native prairie and grassland areas. [Special

Areas, the Eastern Irrigation District.] Riparian areas may also occur in Grassland sites. Riparian areas are the moist habitats found along creeks and sloughs, which include wetland grasses, forbs, shrubs, and trees. Assess grasslands that have been cultivated/seeded to agronomic species, and managed as tame forage for hay or pasture, under the Cultivated Land criteria. For those located outside of Alberta, define your vegetation classification system in advance of data collection.

B. Shrubs and 2-Dimensional Cover. This protocol is designed to measure shrubs and vascular plant vegetation at the level of vegetation groups (e.g., shrubs, grasses, forbs), except for shrubs which are measured at the species level.

Field Equipment Needed:

○ *Plant Field Guide (one that is relevant to the area which you are studying* ○

"Cheat sheet" to estimate percent cover ○ *Datasheets 5 and 6* Procedure:

- Ecosite (see Appendix 2) is not recorded for grasslands because by default it will just be "NT"= not treed.
- 2-dimensional cover of the ground layer and shrub layer is measured at each 5 x 5 m plot (n=9 5x5 m plots total, Fig. 2 – shaded boxes highlight the 5x5 m plots). Record on Datasheet 5.
- For the shrub layer estimate 2-dimensional cover (0, <1, and 5% increments) of shrubs and small trees. ○ Shrubs are defined as non-tree woody vascular plants that have woody stems.
    - Small trees are defined as trees <1.3 m in height and are included with shrubs in the estimates
    - Shrub/small tree cover is estimated for three height categories (0-0.5, 0.5-2 m, and 2-5 m high). Note: Each of these estimates cannot be greater than 100%.

  - The estimate for height class 0.5-2 m is recorded as if a photo was taken 2 m above the ground and foliage from all shrubs/trees <0.5 m was excluded.
  - The estimate for height class 2-5 m is recorded as if a photo was taken 5.0 m above the ground and foliage from all shrubs/trees <2 m was excluded.
- For the ground layer (<0.5 m), estimate 2-dimensional cover (0, <1, and 5% increments) as the percentage of the 5 x 5 m plot covered by shrubs/trees, grasses (including sedges/rushes), all "other" vascular plants combined (Herbs/forbs), mosses (includes all bryophytes), lichens, fungi, litter (dead vegetation material plus DWD <2 cm in diameter), wood (live and dead trees >1.3 m tall, plus DWD >2 cm diameter), water, bare ground, rock, and animal matter. These estimates are recorded as if a photo was taken 0.5 m above the ground. Values of all these independent categories must sum to 100%.
- Record percent cover for each individual shrub/tree species rooted within the plot, including which strata (see Table 1) it is located in. Record on Datasheet 6.
- Percent cover is determined by ocular estimation (this requires practice before the start of the data collection to ensure the estimates are precise).

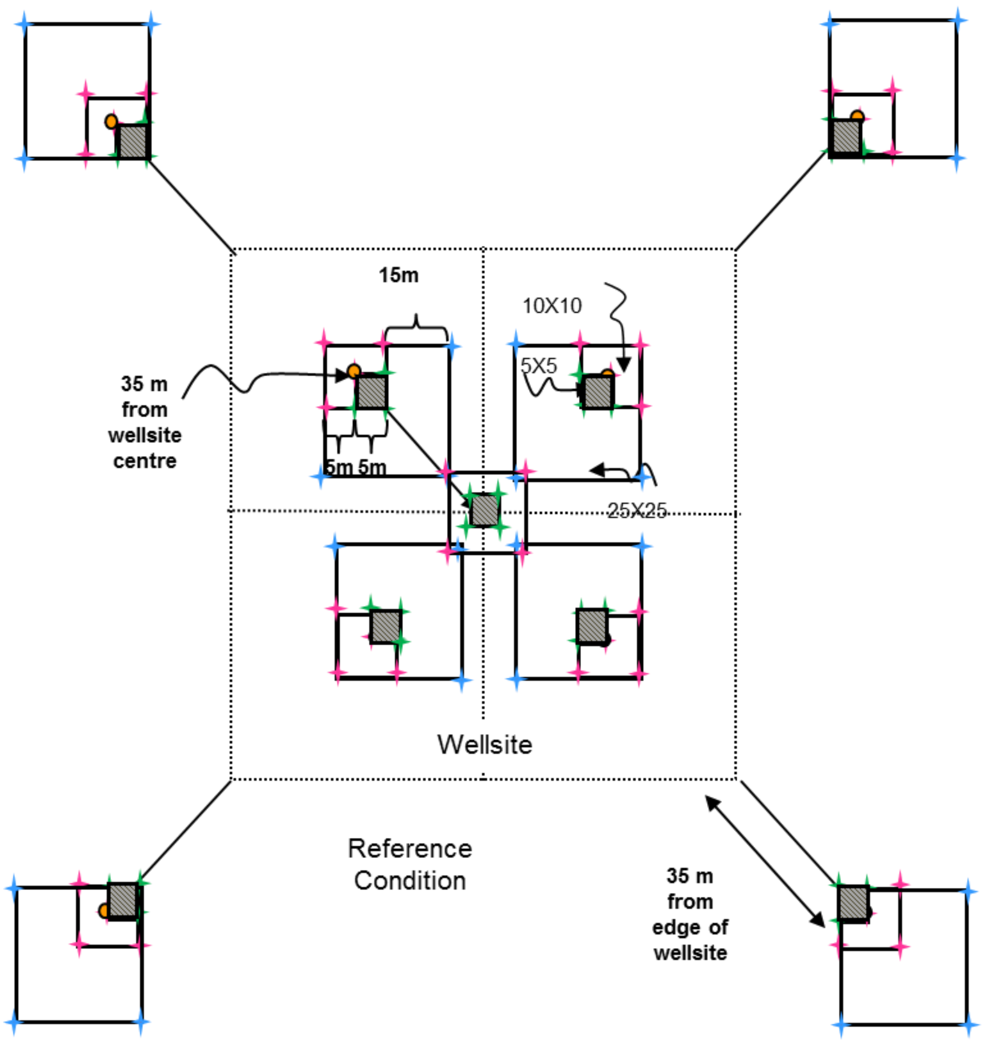

Figure. 2. More detailed scale of 5x5 m, 10x10m, and 25x25m plot sampling. Shrub and 2-D cover are measured in the 5x5 m plots (shaded in grey) identified in the figure.

C. Plant and Lichen Cover by Species (0.25 m^2 plots). This protocol is designed to monitor relative abundance of vascular, non-vascular, and lichen species by height strata.

Field Equipment Needed:

○ Plot frame (0.5 m x 0.5 m) ○ Plant press ○ Vascular plant field guide ○ Datasheets 7A & 7B Procedure:

Ten plant and lichen cover quadrants (0.5x0.5 m = 0.25 m^2) are established in the wellsite, and eight plant and lichen cover quadrants are established in the reference condition site (Fig. 3). For both the wellsite and reference condition sites two 0.5x0.5 m cover quadrants are located in each of the 5x5 m plots at the two diagonal corners of the plot that intersect the subordinal transects (see Fig. 3).

- Record percent cover of individual vascular, non-vascular, and lichen species by strata within each 0.5x0.5 m quadrant. Descriptions of strata are in Table 1. Record on Datasheets 7A and 7B. Use the same order of species list on the reference datasheet at a site as you did for the wellsite – then add additional species not found on the wellsite below this list (this will be super helpful when data are being entered so the species data match up)
- Estimate percent cover (0, <1, and 5% increments) by strata (see Table 1) for each species in each of the 0.5x0.5 m quadrants (Fig. 3).
- In addition, estimate percent cover for rock, bare mineral soil, litter, and water in the quadrant.
- Plants must be rooted within the quadrant to be included in the estimation.
- Due to overlapping of leaves at different heights, percent cover for each species, and all species combined can be greater than 100%.
- Collect voucher specimens of unknown or uncertain specimens from outside the 5x5 m plot if possible. Take the voucher specimens to camp for identification – be sure to label properly so you can match them with your datasheet.

Table 1. Description of vegetation strata as described in the Ecological Land Site Description Manual (ESRD 2003)

Code		Definition
Strata		
T1	Tree (main canopy)	Trees that make up the upper part of the height distribution population and form the general layer of the canopy or foliage
T2	Tree (understory)	Trees and/or shrubs whose crowns extend into the bottom of the general level of the canopy or are located below the main canopy. Trees and/or shrubs must exceed 5 m height

S1	Shrub (tall)	All woody plants between 2-5 m tall (includes regeneration of taller trees)
S2	Shrub (medium)	shrubs and regenerating trees between 0.5-2 m tall
S3	Shrub (low)	All woody plants up to 0.5 m tall
H	Herbs (forbs)	record all forb species regardless of height
G	Grass/graminoid	record graminoids (grasses, sedges, rushes)
M	Moss	record all bryophytes
L	lichen	lichen species growing on dominant substrate (usually mineral or organic soil) included
E	epiphytes	Lichens or mosses growing on other plants, usually trees or shrubs
F	fungi mushrooms	Fungi (excluding lichen) growing on dominant substrate -

- When collecting voucher specimens, record the reclamation site number and a unique reference code (UIS-Site Number- Specimen Number) and collector's name on the field data sheet and on the sheet in the plant press (e.g., the fifth unidentified specimen from site 1 would be: UIS-1-05). Ensure that specimen numbers do not repeat those collected during the vascular plant search.
- For specimens that cannot be identified in the evening, place them in a plant press for temporary storage. Ensure that the information (site number, plot- if applicable, reference code, date, collector's name) on the data sheet matches the information included with the specimen in the plant press.
- Discard any plants identified at camp, cross out the UIS line on the data sheet and the species code indicated beside the row, and add a new row for that species with all of the appropriate information added to the species record.
- At the end of the season, take the press to the laboratory. These unknown specimens will be identified by experts (see Processing of Specimens and Samples in Section 4 Section G).

D. Vascular Plant Searches We designed this protocol to detect as many species of vascular plants as possible during a time-constrained search within the wellsite area along with the reference site. To standardize sampling effort a single person completes all of the vascular plant surveys at a site, in the time specified.

Field Equipment Needed:

- *Datasheet 8*
- *Plant field guide (only for use before or after timed searches)*

Procedure:

Wellsite survey

- The crewmember surveying vascular plants spends an initial 10 minutes populating a species list with the names of vascular plants seen at the wellsite. Conduct this initial listing of plant names so that the subsequent timed searches of the 50x50 m quadrants are spent mainly looking for species, with less time recording plant names/codes. During the initial 10 minutes when species are being recorded, locate the most diverse habitat types within the 1 ha site and spend time in these habitats recording species names. Record on Datasheet 8.

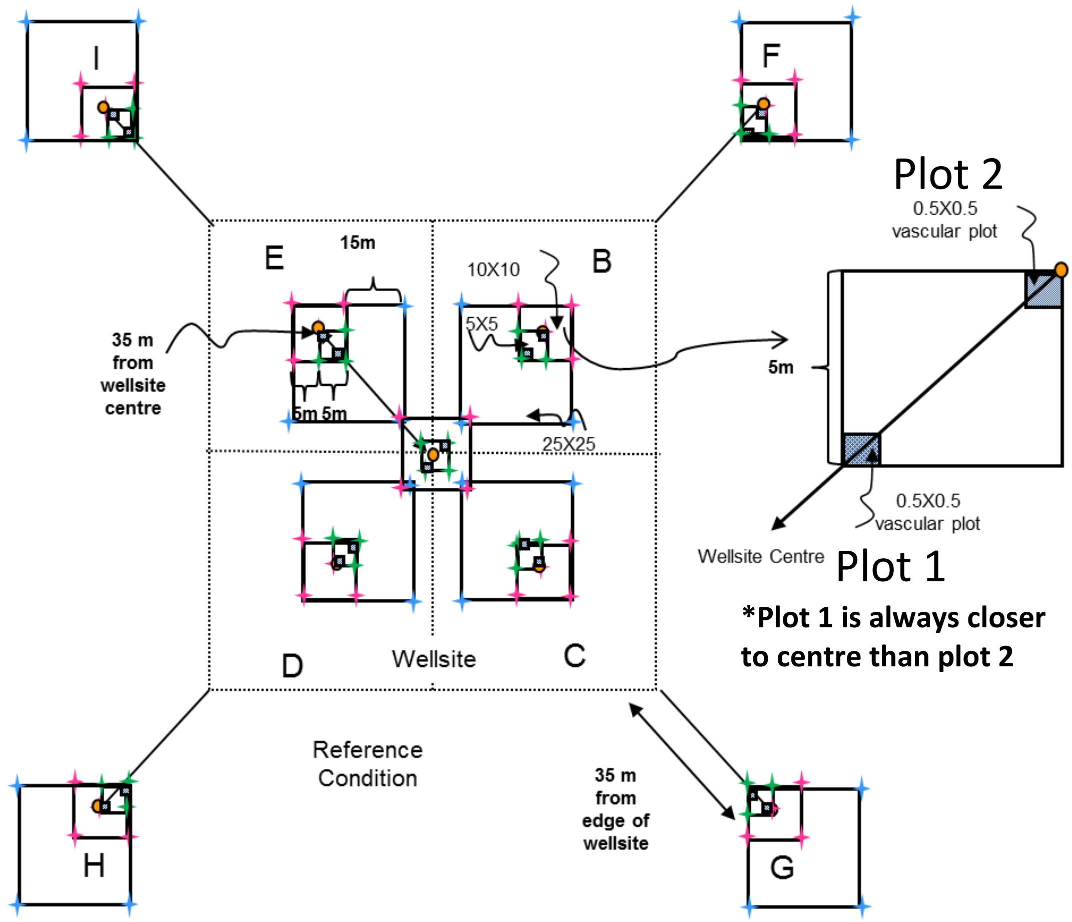

Figure. 3. Locations of the 0.5x0.5 m quadrants where vegetation are sampled at the species x height strata level. Note that for the wellsite centre 0.5x0.5 m plots, they are always in the B and D quadrants.

- The technician then spends 20 minutes in each of the four quadrants (a total of 80 minutes) finding as many species of vascular plants as possible while walking a predetermined path (Fig. 4).

- To maintain consistency among observers, start at the 10x10 m plot center, and then begin heading toward site center, to within 5-10 m. Then head in a clockwise direction around the quadrant staying approximately 5-10 m from the quadrant edge. Stop every four or five steps to examine the plants in the immediate area (see Fig. 4).

- Ensure you have searched all habitat types in the quadrant for vascular plants.
- When you detect a vascular plant species in a quadrant, place a tick mark for that species in that quadrant on Datasheet 8.
- Always start the surveys in the NE quadrant and progress clockwise to the next quadrant (NE, SE, SW and NW).

Reference Condition Site survey

- The crewmember surveying vascular plants spends an initial 10 minutes populating a species list with the names of vascular plants seen at the reference condition site. This initial listing of plant names is conducted so that the subsequent timed searches of the equivalent area (50x50 m = 2500 m^2 – dimensions will vary depending on shape of reference condition polygon) of the reference sites are spent mainly looking for species, with less time recording plant names/codes. During the initial 10 minutes when species names are being recorded, locate the most diverse habitat types within the 1 ha equivalent area of the reference condition (2.5 minutes per reference ‘quadrant’) and spend time in these habitats recording species names. Record on Datasheet 8.
- The technician then spends 20 minutes in each of the four ‘quadrants’ (a total of 80 minutes) finding as many species of vascular plants as possible while walking a predetermined path (Fig. 4).
- To maintain consistency among observers, start at the 10x10 m plot stake, and then begin heading toward the edge of the wellsite, to within 5-10 m. Then head in a clockwise direction around the ‘quadrant’ staying approximately 5-10 m from the quadrant edge. Stop every 4 or 5 steps to examine the plants in the immediate area (Fig. 4). Search all habitat types in the quadrant for vascular plants.
- When you detect a vascular plant species in a reference ‘quadrant’, place a tick mark for that species in that quadrant on Datasheet 8.

For unidentified species:

- Unknown species can be quickly identified after the initial 10-minute search, but if the technician is unable to identify the species quickly, they will collect the specimen from a population of greater than 5 individuals, outside the plot if possible. These samples are assigned a unique specimen number and carried with the technician to avoid multiple collections in each quadrant if possible. Unidentified specimens are named UIS-Site Number-Wellsite/Reference - Specimen Number e.g. UIS-3-W-1.

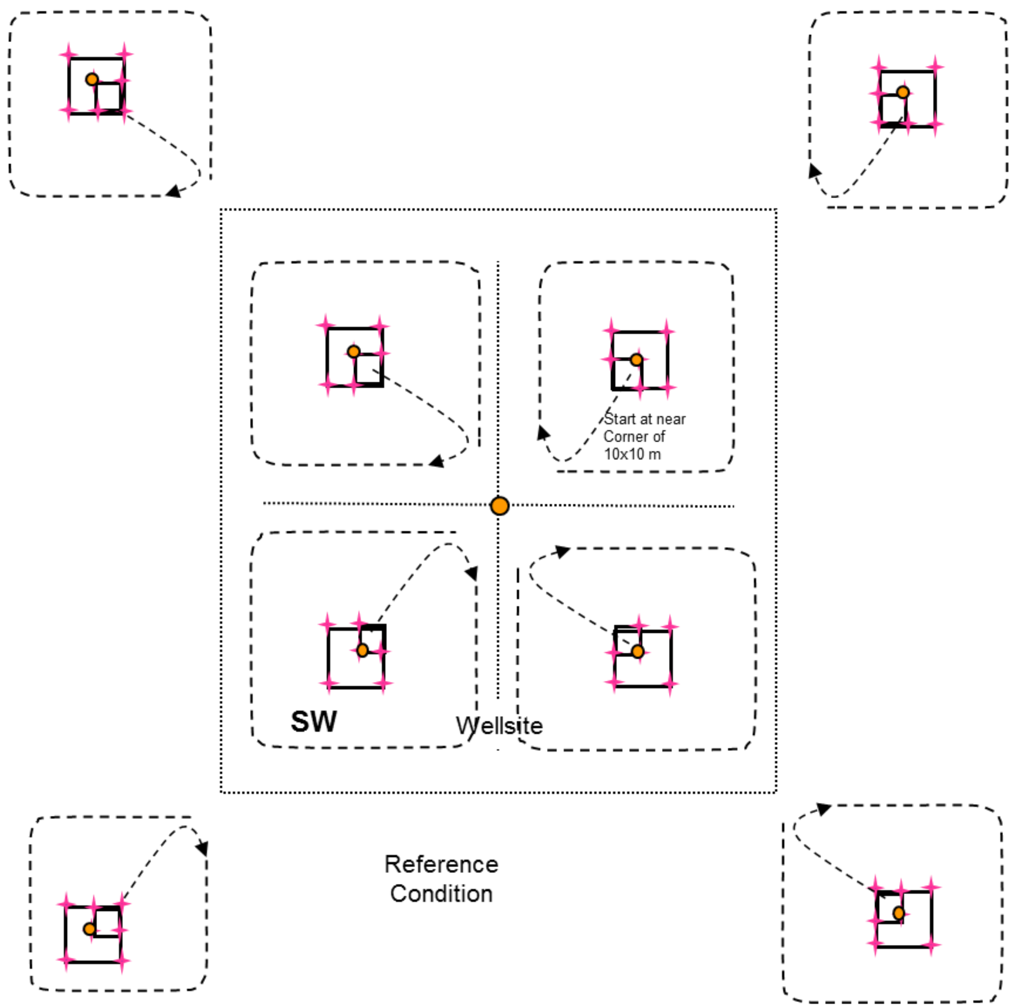

Fig. 4. Layout of survey to identify vascular plant richness within the wellsite and reference sites.

- Field guides should not be used during the 20-minute search time. Collect voucher specimens of unknown or uncertain vascular plant species. After the 20-minute search in a quadrant is complete, attempt to quickly identify the species you have collected using field guides. Place labeled unknown specimens in a plant press and take them to camp for identification during the evening.
- The label on the specimen tag and in the plant press log will be written as UIS-Site Number-Wellsite/Reference - Specimen Number (e.g., the fifth unidentified specimen from site 3 in

the wellsites would be: UIS-3-W-5). Ensure that specimen numbers are not repeated for the site. Be diligent when collecting specimens from the low vegetation and shrub cover plots that specimen numbers are not repeated within site.

- For any vascular plant categorized as S1 or S2 (rare status) by Alberta Conservation Information Management System (ACIMS; https://www.albertaparks.ca/albertaparksca/management-land-use/alberta-conservationinformation-management-system-acims/), collect a specimen so its identity can be confirmed by experts. Collect the specimen from a population of greater than five individuals, outside the plot if possible; otherwise take detailed photographs and notes. For data collected outside Alberta, review your State/Province regulations for rare and protected species.
- Press any ACIMS S1 or S2 plants as well as any unidentified specimens.
- Discard plants identified at camp. Remove the UIS number and replace with the correct species code. Do not forget this step.
- Record any species found after the vascular plant search is complete under incidental species.
- At the end of the field season (or sooner if the plant press is full), plant presses are delivered to the lab. Experts will identify these unknown specimens (see Processing of Specimens and Samples in Section 4 Section G).

E. Methods for Surveying Bryophytes & Lichens

Field Equipment Needed:

○ *Mora knife* ○ *Hand lens* ○ *Toilet paper for fragile specimens* ○ *Squares of paper/small envelopes for small specimens* ○ *20 paper bags (Kraft #8) per site* ○ *1 larger grocery sized paper bag per site (plus additional large bag so that you separate lichens and bryophytes for storage)*

○ *Sharpie* ○ *Water* ○ *Watch* ○ *Datasheets 9A, 9B, 10A, 10B*

Procedure:

- Select the quadrant with the most diversity of microhabitats (or if they all appear similar randomly select one) – only one of the four 25x15 m plots (0.0375 ha) on the wellsite and one of the four reference site 25x15 m plots to survey for bryophytes and lichens (Fig. 5).
  Refer back to Datasheet 2 to determine which quadrants you will be surveying.
- A single person spends up to 35 minutes in each of the two plot quadrants (maximum total 70 minutes) collecting bryophytes. A second person independently completes the protocol for lichens (maximum total 70 minutes), or the first-person samples for lichens but during a separate time period than when sampling for bryophytes; do not try and simultaneously collect both sets of data.
- In each selected quadrant, surveys are divided into two periods:
  - First: sample the strata (microhabitat types) present in the 25x15 m plot.
  - For bryophytes: Search strata #1 logs/ stumps, strata #3 wetlands/peatlands, and strata #4 rocks and cliffs (Table 2).
  - For lichens: Search the strata #1 logs/stumps, strata #2 trees/other structures, and strata #4 rocks and cliffs (Table 2).
  - To help maximize the number of species detected, begin the timed search by surveying one example from each stratum that has the most diverse community of bryophytes/lichens. Complete within a maximum of 5-10 minutes. For example, largediameter soft logs often have the highest diversity of both taxa. Target these logs early in the search when present in the plot.
  - Then search for the three primary strata by zig-zagging through the plot (Fig. 5).
  - Stop every 4 or 5 steps to examine the microhabitat types in the immediate area. Take samples as you encounter examples of the primary strata.
  - Note that if there are no examples of primary strata in the plot, then terminate the search after 5 minutes. Spend a minimum of 5 minutes searching for examples of the primary stratum in each plot as some microhabitats are small and dispersed in space (e.g., rocks).
  - If there are microhabitats (strata) found within the plot, then a minimum of 10 minutes must be spent searching if all examples have been searched (for example, if you are searching for lichens and there is a single tree, no logs, and no rocks/cliffs in the plot then sampling may be terminated after 10 minutes).
  - Plots with all primary strata should take the full 25 minutes to search.

  - Second: the strata (i.e., the microhabitat types) that have less diverse communities are searched in a belt transect following the 2 long sides of the 25x15 m plot (Fig. 5). Walk along the 25x15 m plot boundary and sample within 1 m of either side of the transect. This results in two 25x2 m transects for one each of the wellsite and reference condition quadrants.
  - For bryophytes: Search the strata #2 trees/structures and strata #5 upland soils (Table 2).
  - For lichens: Search the strata #3 wetlands/peatlands and strata #5 upland soils (Table 2).
  - Ensure that examples of both secondary strata are searched if they occur in the transect.
  - Search as many examples (or as much area) of the secondary strata as possible as you encounter them.
- In each stratum in each plot/transect collect examples of all the bryophytes/lichens that appear distinctive.
- When collecting specimens:
  - Select only a small sample (i.e., 4-6 cm^2) so that the vegetation community remains intact.
  - If the specimen is growing on mineral soil, wrap the sample gently with toilet paper so it does not break apart (disintegrate) once the soil dries.
  - If the specimen is growing on a large boulder/rock/cliff, wet it thoroughly to help detach it from the substrate. Place small/fragile specimens in paper packets so they do not get lost.
  - If the sample is very wet (e.g., a moss specimen from a wetland stratum) carefully squeeze out the sample before placing it in the bag. Be mindful to fluff the specimen back out after squeezing.
  - When in doubt about whether a specimen is unique or has been collected already, collect it again.
  - We do not sample crustose lichen; however, when in doubt about whether a specimen is crustose, collect it.
- For each taxon (bryophytes/lichens), place all specimens collected from a stratum as a composite sample in a single bag.
  - It will be easier to pre-label 10 paper bags with the site number and strata.
  - Be diligent; do not collect the same species repeatedly from a stratum as it takes considerable time to sort through duplicates in the lab.
  - If no specimens are found in a stratum of a plot/transect, then indicate "None" on the empty paper bag and on the field data sheet. If no example of a stratum is found in a plot/transect (all

microhabitats are absent), then indicate “VNA” on the bag for that stratum and on the field data sheet. Assume paper bags without either a “None” or a “VNA” contain specimens.

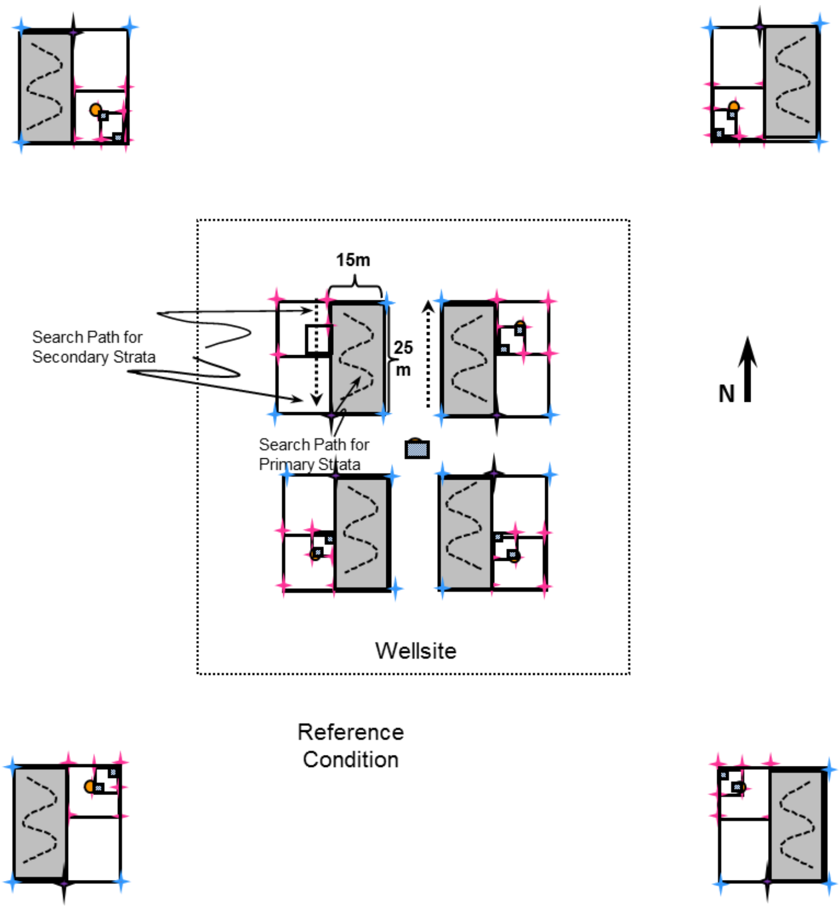

Figure. 5. Description of the plots where bryophytes and lichens are sampled (but only 1 wellsite 25x15 m plot and 1 reference site 25x15 m plot will be sampled).

- If a variety of microhabitats are present in a stratum, then collect specimens from as many of these as possible (e.g., if many different tree species occur, then collect mosses from as many different tree species as possible).
- Use a time-constrained search that is exactly 10 minutes long.

- Once the surveys are completed on a site, ensure there are 10 paper bags for bryophytes and 10 paper bags for lichens.
- Take the collections to camp, and dry them in a well-ventilated space. Place the bags on their side and fluff out the bags for optimal surface area. Be mindful to flip the bags daily and check the dryness of the samples. Most samples are dry within 3 days.

- Once dry, place all bryophyte sample bags into one large paper bag and label it with the site number and “Bryophyte”. Do the same for Lichens.
- At the end of each shift, transfer these samples to the laboratory in the two large bags. Samples collected from the end of the shift will likely have not had time to dry completely. Mark these samples copiously as being wet and staff will attend to them at the lab.

Stratum #1: Logs and Stumps (samples in 1 bag)
LS: Soft stumps & logs (decay classes 3-5) - sample roots and all sides
LH: Hard stumps & logs (decay classes 1-2) - sample roots and all sides
Stratum #2: Trees, Shrubs and Other Vertical Structures (samples in 1 bag)
TD: Deciduous Trees - all sides of the roots, bases, trunks, and branches of both live and dead deciduous trees
TC: Coniferous Trees - all sides of the roots, bases, trunks, and branches of both live and dead coniferous trees
TS: Shrubs - all sides of the roots, bases, stems, and branches of live & dead shrubs
HB: Human Structures - vertical and horizontal parts of the structures (survey from the ground)
Stratum #3: Wetlands and Peatlands (samples in 1 bag)
WMF: Wetlands, marshes, & fens - within the wetland survey both under and away from trees
WSB: Shores/banks of wetlands, ponds, lakes, & streams - survey on organic or mineral soil adjacent water’s edge
WDS: Moist depressions/seasonal wetlands dry at time of survey - sample sides & bottom area influenced by water
WPW: Peatlands with or without standing water - survey both standing water and vegetation hummocks
Stratum #4: Rocks and Cliffs (samples in 1 bag)
BC: Boulders (>50 cm diam.) - survey all surfaces (top, sides, and base) from the soil upwards
RR: Rocks (<50 cm diam.) - survey all surfaces (top, sides, and base) from the soil upwards
CL: Cliffs (steep high rock face) - survey all of the faces, ledges, and crevices that can be accessed safely
Stratum #5: Upland Soils (samples in 1 bag)
UC: Humus soils under trees/shrubs (shaded by canopy) - survey as large a variety as possible
UO: Humus soils without trees/shrubs (open to sunlight) - survey as large a variety as possible
DC: Agriculturally cultivated soils
DM: Mineral soil in upland areas from any causes

Table 2. Strata and microhabitat types used during searches for bryophytes and lichens.

3. Soil Sampling

This section describes the field-based protocols for sampling of soil indicators. Conduct soil sampling on 10x10 m plots only after all other sampling at the sites to minimize the effects of the destructive sampling on the other measured indicators. In these protocols, we do not describe most lab analyses conducted on samples.

A. Number of samples. In a systematic grid sampling design, one composite sample per depth made up of 5 cores from each of the 10m x 10m square is sufficient for each indicator analysis with the exception of bulk density and penetration resistance (Figs. 6 & 7). We suggest compositing samples to reduce analysis cost for measuring SOC, soil EC, and pH. One disadvantage of bulking the samples within the 10m x 10m square is that it does not allow for the calculation of standard deviation or CV values. Carter and Lowe (1986) evaluated the precision of a variable measured by bulking forest floor samples. They compared the mean nutrient contents weighted by depth and bulk densities using 15 sampling points within a plot to the values obtained from analyzing a single composite sample from the 15 sampling points and the values from the composite samples were all within one standard deviation of the mean. Furthermore, they investigated the relationships between the weighted means and the composite sample values across six study plots and found that they were quite strong for most variables, suggesting that bulking samples can provide good estimates of the real population mean.

We do not suggest bulking of samples in the field since it is difficult to determine proper mixing. Preferably, samples should be stored separately and bulking conducted in the laboratory after air-drying and grounding to 2 mm.

For soil bulk density measurements, it was suggested on the first initial sampling interval to collect 5 core samples for the two depths (0-15 cm and 15-30 cm). The penetration resistance measurements will also be done adjacent to the five bulk density sampling points on each of the 10m x 10m squares. On a going forward basis, if the PR measurement correlates well with the bulk density measurements, then collect one bulk density core sample at the center of the 10m x 10m square. On the other hand, if PR does not correlate well with bulk density measurements, do not monitor in subsequent sampling events.

Depth of Sampling

The sample depth combinations were selected based on the indicator chosen. PR is measured at depth intervals of 2.5 cm. Two sample depths are recommended: 0-15 cm (0”-6”) and 15- 30 cm (6”-12”), for soil EC, pH, SOC, and bulk density. Also monitor EC and pH at the 30-60 cm (12”-20”) and 60-100 cm (20”-40”) depths for the center sampling point in each of the 10m x10m square (Fig. 6).

Sampling Frequency

We recommend that the sampling frequency for the soil indicators be between 5 to 10 years depending on the indicator, budget, and number of sites. The sampling frequency has not yet been determined and will be determined in a future version of the protocols. There are 10 different sets of sampling locations identified so that soils can be destructively sampled 10 times within each 10x10 m plot (Fig. 7). Each sampling point will be located a minimum of 1 m apart from the previous sampling location.

B. LFH Depth Organic matter is defined as the LFH layer of the soil horizon. Determining the LFH horizon is usually straight forward in most soil conditions. The organic layer is typically dark in color, coarse, and fibrous (containing rooting systems) whereas the mineral soil is typically lighter in color, finely particulate, and lacking most roots. LFH does not include live vegetation on the surface.

Field Equipment Needed:

- Trowel ○ Ruler (measured to the scale of mm) ○ Datasheet 14A

Procedure:

1. Measure the thickness of the organic layer at each of the five sampling points within each 10x10 m square plot where the soil core is collected from and penetration resistance is recorded.
2. Gently insert the trowel into the organic layer and distinguish the transition between the organic layer and the underlying mineral soil.
3. After distinguishing the transition from LFH to mineral horizon, measure the LFH to the nearest mm.

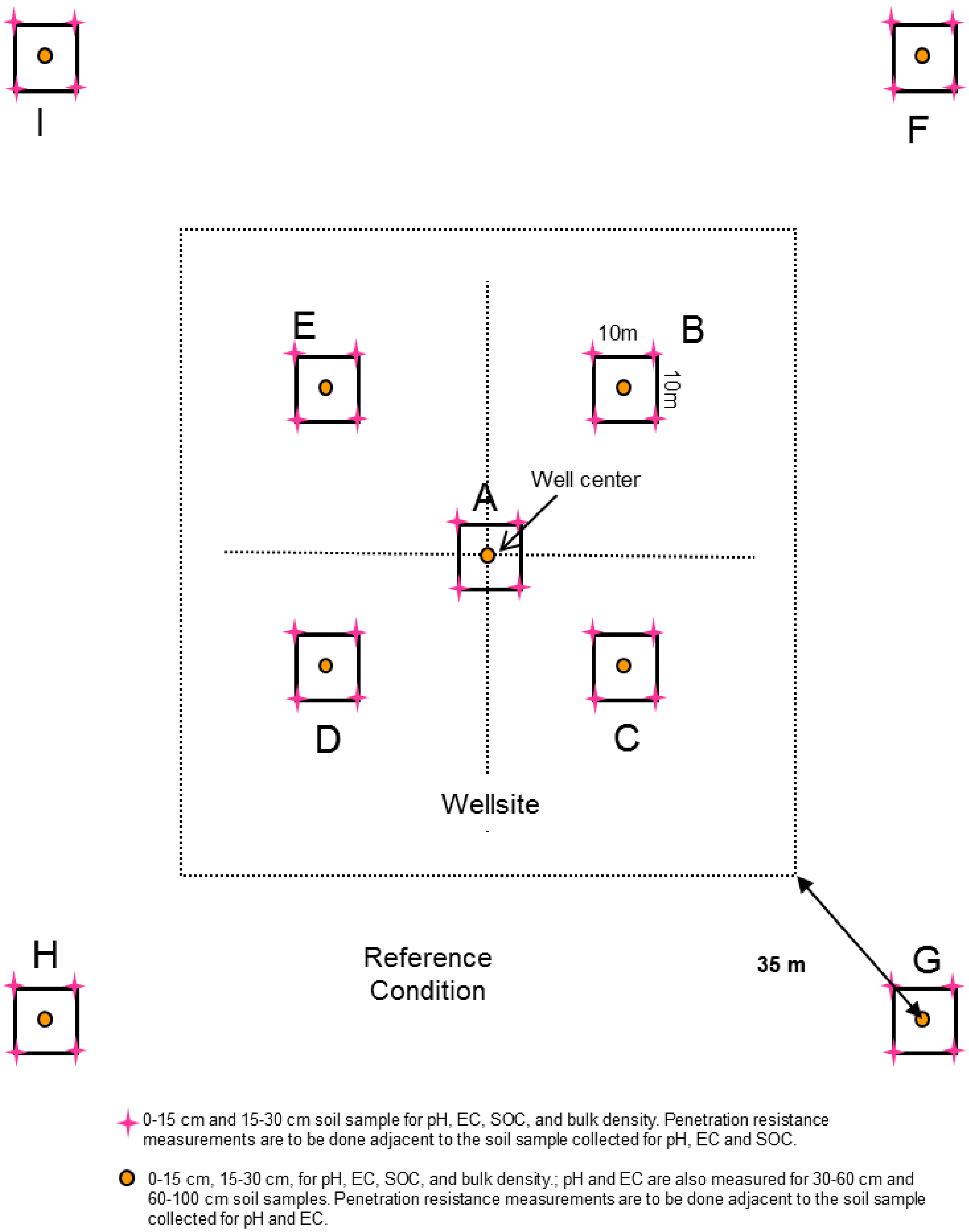

Fig. 6. The soils indicators are sampled within the 10x10 m plots identified in the diagram.

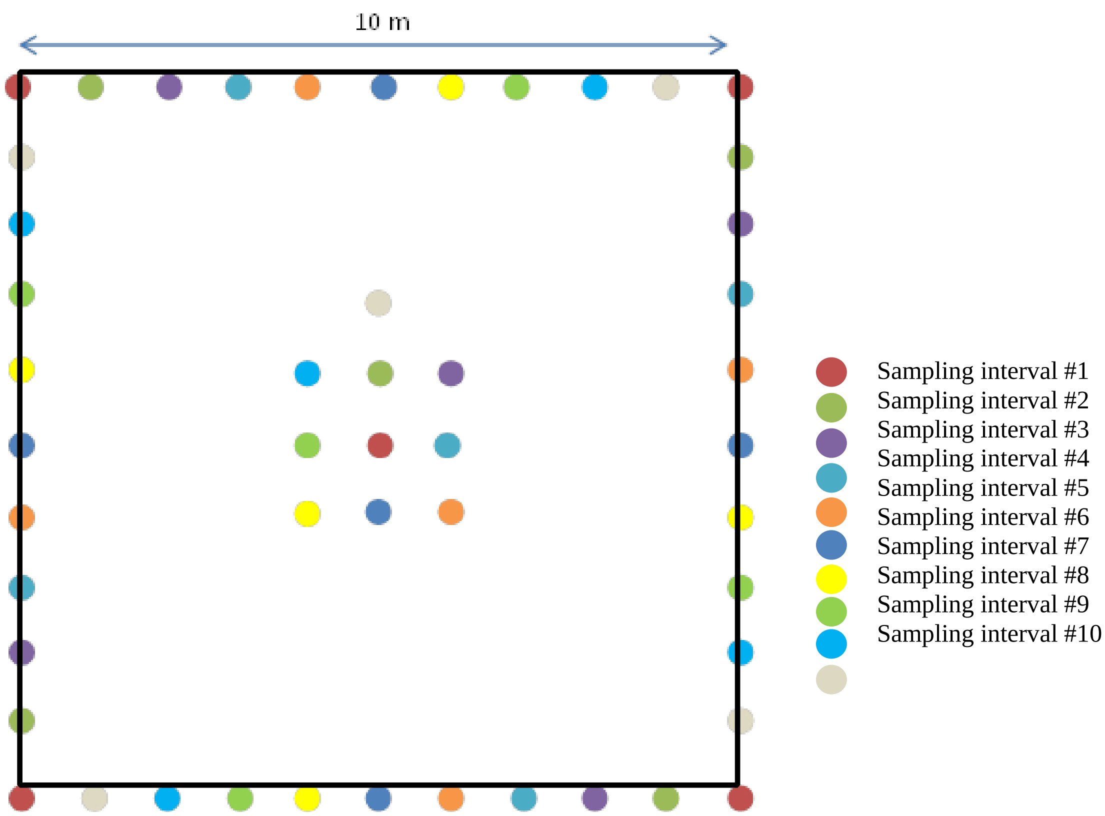

Figure. 7. Sampling layout within each 10x10 m plot on the wellsite and reference sites. Each color represents a different sampling interval, for a total of 10 sampling intervals.

C. Bulk density. There are a variety of soil sampling techniques to assess bulk density; the appropriate sampling method depends largely on the distribution of coarse fragments (particles with diameter > 2 mm) at the given site. The most common method is the core method, and should be used when coarse fragments occupy less than 25% by volume (Maynard, 2006). At forested sites on glacial till of the Precambrian Shield or other rocky soils with lots of coarse fragments and/or tree roots, the core method may be difficult to use and we recommend the excavation method.

Core Method

A double-cylinder, drop-hammer sampler with a liner core is designed to collect an undisturbed soil sample (Fig. 8). The sampler head contains an inner cylinder with a liner and is driven into the soil with blows from a drop hammer. The liner containing an undisturbed soil core can then be removed and trimmed to the end with a knife to yield a core whose volume can easily be calculated from its length and diameter. The weight of this soil core is then determined after drying in an oven at 105°C for 24 hours.

Field Equipment Needed:

- Double-cylinder core sampler. The most common core diameter ranges from 2” to 3” (5.1 cm to 7.6 cm). It is beneficial to have a second core sampler in case of breakage of first sampler
- Two crescent wrenches to tighten the core parts while in the field if they become loose ○ Clean, dry and uniform stainless-steel liners with a known internal diameter and height for volume calculation
- Trowel for excavation method ○ Soil knife or metal spatula ○ Polyethylene plastic bags (2 per sample - 7 pound) ○ Shipping tag labels (pre-labeled) – insert between the two 7 pound plastic bags. ○ Pam cooking spray

Lab Equipment Needed: ○ Analytical balance ○ Drying oven capable of heating up to 105 °C

Fig. 8. AMS Inc. double-cylinder, drop-hammer soil core sampler.

Procedure:

Lab (pre-sampling)

1. Label shipping tags with appropriate label (naming convention is currently the following: Region-Site Number – Wellsite (W) or Reference (R) – Quadrant (A-I) – Starting depth of sample (0,15,30, 60 – e.g., DMG-5-W-C-30) (this can be done in the laboratory before the samples are obtained).

Field

2. Select a smooth and relatively undisturbed surface at the appropriate sampling point. Record the GPS location of the sampling point.

3. Remove the Litter layer if present.
4. Drive or press the core sampler into the soil sufficiently to fill the inner liner without inducing compaction. In frictional or dense soils, lubricant may be required to prevent compaction of the soil and to facilitate emptying the collected core sample from the sampler. Research by Blaylock et al., (1995) found the use of WD-40, PAM cooking oil and Dove dishwashing liquid as lubricants will not affect soil test results other than the case of micronutrients iron, zinc, manganese and copper.
5. Carefully remove the undisturbed soil core and trim the ends flush with the edge of the cylinder. Resample adjacent to the original sampling point if large coarse fragments or roots protrude from the sample. The field staff will record any deviation from the original sampling scheme.
6. Store the sample in polyethylene bags. Store in large durable plastic bag for transport.

Lab (post-sampling):

7. Place the sample in an oven set to 105°C for 24 h. After drying, cool the sample in a desiccator and record the weight of the dry soil.

Excavation method

The excavation method according to Blake and Hartge (1986), Campbell and Henshall (2001), and Grossman and Reinsch (2002) involves digging a small hole, collecting a sample, and then oven drying (at 105°C) and weighing the dried soil sample. Determine the volume of the excavation by lining the hole with plastic film and filling it completely with a measured volume of water (or sand, or silicon beads). Sieve out coarse fragments (diameter > 2 mm) and calculate bulk density as the mass of dry, coarse fragment-free soil per volume of the excavated soil, where volume is also calculated on a coarse fragment-free basis.

D. Penetration Resistance (PR)

Field Equipment Needed:

- Digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter)

Use the digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter) to measure soil resistance (Fig. 9). The digital penetrometer measures soil resistance in kPa through 2.5 cm depth increments and has a cone diameter of 1.28 cm. For each of the 10m x 10m square on site, we recommend doing penetration resistance measurement in five distinct measurement points, adjacent to the area where the bulk density sample is collected. Since you will measure penetration resistance on site, we recommend taking at least three measurements for each discrete measurement point with the digital penetrometer.

Fig. 9. Digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter).

E. Soil Organic Carbon, EC and pH. You can analyze soil organic carbon, EC and pH from the same composite sample. The section below describes the sampling protocol for collecting the core sample in the field as well as the sample handling, processing and compositing/bulking in the lab.

Equipment needed:

- Bucket auger (also known as barrel and core auger) shown in Fig. 10a for dry, coarse textured soil and Dutch auger shown in Fig. 10b for wet, finer textured soil.
- Heavy duty polyethylene bags (see information for bulk density described above) ○ Wire brush ○ Soil knife ○ Perforated drum grinder with 2 mm perforations
- GPS to measure soil sampling locations

a)

b)

Fig.10. a) Dutch auger and b) Bucket auger

Procedure:

1. Before sampling, label bags with sample name, sampling date, location and soil depth.
2. In the field, at each sampling point, drill the auger tip into the ground by turning the handle in a clockwise rotation to the desired depth (30-60 cm and 60-100 cm – as the two shallower depths will be using the same soil cores collected for the bulk density samples). The soil is forced into and retained in the auger. Be prepared to discard cores that are unrepresentative (e.g., excessively compacted during sampling, evidence of rodent activities, and obstructed by rocks). Empty the soil into the labeled bag, avoid any loss of soil. Carefully place the auger in the same hole and repeat the process until it reaches the desired depth. Store the sample in polyethylene bag in a large durable plastic bag for transport. Note that you only need to keep a representative subsample of each depth range – otherwise you will end up with excessive amounts of soil.
3. In the laboratory, remove soil from the polyethylene bags and air dry in lined trays at 37.5 °C. Avoid sample losses during processing and contamination by dust, plant material, and other C-rich contaminants.
4. Once the samples are air dry, crush and grind the samples to pass a 2 mm sieve and screen out any rocks that are > 2mm in diameter.
5. Thoroughly mix the 5 core samples after they have been coarsely ground to < 2mm and then subsample the soil for SOC, EC, and pH analysis.

Soil sample handling and storage requirements are provided in Table 3.

Table 3. Soil sample handling and storage requirements for the selected soil indicators.

Indicator	Sample grinding	Moisture	Storage before analysis	Archival Storage Conditions
Soil Bulk Density	Avoided	Generally reported on an oven-dried basis	Indefinite if refrigerated, may change upon freezing	Indefinite if refrigerated, may change upon freezing
Soil EC & pH	Aggressive grinding acceptable to 2 mm	Generally reported on an oven-dried basis	Short term refrigerated, indefinite if dried	Indefinite if dried
Soil Organic Carbon	Aggressive grinding acceptable to 2 mm	Generally reported on an oven-dried basis	Short term refrigerated, indefinite if dried	Indefinite if dried

4. Managing Personnel, data quality and integrity

This section provides background information related to the number of individuals needed to collect data, required field staff training received prior to data collection, information about datasheets completed in the field, including some metadata for the coding of data, ensuring data quality and completeness, procedures for storage and transfer of field-collected samples, and post-field data entry.

A. Personnel and Sampling These data collection protocols are optimally designed to be implemented by a field crew of two personnel working together, or at times, semi-autonomously. At least one of the field crewmembers needs to have a strong background in identifying vascular plants and one should be familiar with reclamation and reclamation practices and regulations. The sampling should take place during the spring or summer when plants have leafed out so that estimates of plant cover are representative of the maximum site cover. This also ensures relevant comparisons among data collected from multiple sites. We designed these protocols for data collection on a variety of parameters, many of which require expert interpretation. As a result, these protocols include species-level identification of vascular plants in the field setting, and for other species, specimens are collected in the field and later identified by qualified personnel in a laboratory setting. Vascular plant searches are performed by a crewmember that is capable of identifying all common species and >80% of all species encountered. This crewmember must have at least one year of experience surveying vascular plants and/or courses learning plant identification prior to conducting surveys. In addition, the crewmember is required to spend a minimum of two days in the field brushing up on vascular plant identification prior to conducting the monitoring surveys. Due to the excessive time requirements for collecting and pressing vascular plant specimens, field staff that are capable of identifying all common vascular plant species must conduct surveys for vascular plants.

B. Crew Training Prior to Data Collection All field staff are to receive proper and appropriate training so they can operate vehicles and equipment safely. In addition, staff are to receive extensive training (in the classroom and field) prior to the beginning of the field data collection. This protocol training includes learning what to do in the variety of field conditions and how to collect data at test sites. Crewmembers are first required to become familiar with the protocol documents, field manuals, and general field procedures. Then they practice the data collection in the types of habitats where they will be sampling. Trainees should discuss questions that arise during the training with the field supervisors. When possible, provide training by experts in the field (i.e. vascular plant identification, lichen and bryophyte identification, soil sampling, and descriptions). To ensure that data collection remains accurate throughout the field season and to prevent missing data, field crews should review the protocols regularly.

C. Field Preparation Prior to Data Collection Complete the lichen and bryophyte sample-bag labels and label plastic bags for soil sample collection prior to going out in the field. A large paper bag that includes the datasheets and the sampling bags for each site should be organized and ready for collection of samples in the field. See additional sampling sections for additional information.

D. Completing Data Sheets in the Field Crews are responsible for filling information into the data sheets while conducting field protocols (in the future data may be collected using tablets in place of field datasheets, but for now datasheets (rite in the rain) are used). Data sheets must reflect exactly what was found / measured at the site. If options for the data field do not include an appropriate response, instruct field crews to record the most appropriate descriptors and make extensive notes on the data sheets. Technicians do not create new categories or descriptors. All fields on the data sheet must have information recorded – even if it is a "zero," "not applicable," "did not collect" (see below for description of each). If data could not be collected for a specific element, then this must be noted on the data sheet and the crew supervisor advised as soon as possible (note that supervisors must be notified by the end of the day at the latest).

None or 0 – None or "0" is applied to any variable that *was examined* by field crews and found to be absent. Use "None" for text entries and "0" for numerical entries. For example, when field crews examine the canopy and find no "Veteran" trees in the canopy, record as "None." When there is no slope at the site, record as "0." You can use "0" as a code for other variables as well, for example, wind conditions.

Variable Not Applicable (VNA) – Some data are collected in a nested manner. For example, for the variable "Tree Species" a variety of nested conditions could be describing the variable (i.e., Condition, diameter breast height (DBH), Decay Stage, etc.). When a variable is recorded as "None," nested conditions do not apply and are recorded as "VNA." VNA is also used when the protocol calls for a modified sampling procedure based on site conditions (e.g., surface substrate protocol variant for hydric site conditions), or the data cannot be collected due to the site being in open water. The use of VNA indicates that the cell cannot have data present.

Did Not Collect (DNC) – Use "DNC" to describe variables that should have been collected but were not due to crew oversight, equipment failure, safety concerns, environmental conditions, or time constraints. The use of DNC highlights that the cell ordinarily would have contained data.

E. Checking Field Data and Storing Data Sheets Daily Check data sheets every evening for legibility and completeness. If data on a sheet are not legible, transcribe the data onto a new data sheet and file both copies. Wet data sheets are allowed to dry, and then all data sheets are stored in a secured area if possible while in the field (e.g., in a folder in the trailer). Do not take data sheets from one site to the field at another site. Crews must re-collect lost or missing data.

F. Transferring Field Data Sheets to a Secure Location Transfer data sheets in person to the crew supervisor when the supervisor visits, or at the end of a shift. The completeness (i.e., all data sheets present and all data fields filled in) of the data sheets is confirmed during the transfer. Missing fields or data sheets must be re-collected. Field supervisors take the data sheets to a secure office at the end of the shift, or sooner if possible. Data for each site are stored in a separate folder, with the folders organized by site number. Original data sheets must never leave the secure office.

G. Processing of Specimens and Samples Crewmembers must transport specimens, samples, and datasheets back to Edmonton, soil samples are processed at AITF, Mill Woods, and initial processing of vegetation samples is done at the University of Alberta Application Centre (Z-923).

H. Data Entry and Verification Enter data into an electronic database. If you enter data at a different location from which they are stored, the data sheets are photocopied or scanned and data entry occurs from the copies. Verify data entry by comparing the electronic information against the information on the original data sheet. Perform routine electronic verification on the database to ensure that data are consistent with the allowable codes and among sites.

Acknowledgements

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Appendices

Appendix 1: Example of an Access Data Sheet

Ecological Recovery Monitoring Program Reclamation SITE: R24 Access Description

Date:__May 14, 2013___________________ Crew:___JB/KB____________________

Maps Where Access Is Recorded
Direction & Distance to Nearest Town
1:24,000 Map ________________________
______Approx. 50KM NE of Slave Lake_
1:62,500 Map ___X____________________
Camp Location: Slave Lake (ATCO)___
Time From Camp to Site: 1 hour 15Mins
Location Of Site

		Township	**77**
Latitude[1]	**55.63xxx**	Range	**3**
Longitude[1]	**114.37xxx**	Section	**3**
		Meridian	**5**

Site Description Comments: Site is wet in the NE quadrant, crews will need rubber boots.

1 – record decimal degrees (5 decimals)

Truck Access to Site

GPS Label at Start Point with Latitude & Longitude	**Road Name & Type**	**Direction and Dist. to Site Center or Next Waypoint**
(Slave Atco) 55.78xxx/114.09xxx	Hwy 88 north - Paved	20 KM North (N) to marthillrd
(marthillrd) 55.79xxx/114.09xxx	Martin Hills RD – Good Gravel	42.3 KM East (E) to T721-2
(T721-2) 55.50xxx/114.16xxx	Meridian Tower RD – Good Gravel	16.4 KM Northwest (NW) to T721-3
(T721-3) 55.61xxx/114.30xxx	Unnamed – Gravel Road	1.6 KM North (N) to T721-4
(T721-4) 55.62xxx/114.30xxx	Unnamed – Gravel Road	4.1 KM West (W) to Q721-1 (Wellsite)

ATV Access to Site

GPS Label at Start Point with Latitude & Longitude	**Trail Description**	**Direction and Dist. to Site Center or Next Waypoint**
(Q721-1) 55.62xxx/114.37xxx	Cutline (Good Shape)	1.6 KM North (N) to W721-1

Walking Access to Site Center

GPS Label at Start Point with Latitude & Longitude	**Trail Description**	**Direction and Dist. to Site Center or Next Waypoint**
(W721-1) 55.63xxx/114.37xxx	Through Cutblock	200 M at 286 degrees to site center

Appendix 2: Ecological Site Classification Descriptions

Simplification of Upland Forest Ecosite Types To Be Used In The Ecological Recovery Monitoring Program – note that this is not very useful for grasslands as the ecosite by default is simply "NT" so is not quantified in grasslands.

We have simplified the ecosite types from the "Field Guide to Ecosites of Northern Alberta" by Beckingham and Archibald (1996), "Field Guide to Ecosites of West-Central Alberta" by Beckingham et al., (1996), "Field Guide to Ecosites of Southwestern Alberta" by Archibald et al., (1996), "Range Plant Community Types and Carrying Capacity for the Upper Foothills Subregion of Alberta" by Willoughby (2005), "Range Plant Community Types for the Subalpine and Alpine Subregions" by Willoughby and Alexander (2006), "Range Plant Community Types and Carrying Capacity for the Montane Subregion of Alberta" by Willoughby et al., (2005), "Range Plant Community Types and Carrying Capacity for the Lower Foothills Region of Alberta" by Lawrence et al., (2005), "Guide to Range Plant Community Types and Carrying Capacity for the Dry and Central Mixedwood Subregions in Alberta" by Willoughby et al., (2006), and Range Plant Communities and Range Health Assessment Guidelines for the Foothills Fescue Natural Subregion of Alberta" by Adams et al., (2005). Twelve broad categories of vegetation types were created from the above sources – these were labeled based on the common moisture/nutrient level. The categories were then subdivided based on composition of overstory trees. Note that the classifications of ecosites are based on vegetation communities and not soil information. The first letter in the moisture code indicates nutrient status (P=Poor, M=Medium, R=Rich, V=Very Rich), and the second letter indicates moisture conditions (X=Xeric, M=Mesic, G=Hygric, D=Hydric, OW=Open Water). Acronyms noted under the ecosite categories follow the literature that was summarized with the following additions: BM=Boreal Mixedwood, BH=Boreal Highlands, SB=Subarctic, CS=Canadian Shield, WC=Ecosites described for West-Central Alberta, SW= Ecosites described for Southwestern Alberta, LF=Lower Foothills, UF=Upper Foothills, MN=Montane, and SA=Subalpine.

Upland Vegetation Communities and Corresponding Ecosite Types

7. Not Treed --- NT

The shrub/ground stratum is either non-vegetated or dominated by shrubs, grasses, sedges and forbs. A very wide variety of nutrient levels and moisture regimes are present.

7a) Alpine – Sites occur at elevations above tree line. The shrub/ground stratum is either non-vegetated or dominated by heathers, grasses, sedges and forbs. Trees are absent due to climatic conditions.

7b) Flood – Sites are usually found at the edge of rivers, streams, lakes and wetlands where vegetation is disturbed frequently by flooding. The shrub/ground stratum is either non-vegetated or dominated by shrubs (often willow), grasses, sedges and forbs. Trees are absent due to the frequent flooding.

Ecosites Included:

- WC_LF g1 (shrubby meadow)
- WC_LF g2 (forb meadow)
- WC_UF f6 (bracted honeysuckle, willow)
- WC_UF g1 (shrubby meadow)
- WC_UF g2 (forb meadow)
- WC_MN e1 (meadow)
- WC_MN e2 (forb meadow)
- WC_SA e1 (shrubby meadow)
- WC_SA e2 (forb meadow)
- SW_SA g1 (dwarf birch/tufted hair grass)

7c) Ice – Sites are usually at higher elevations, where the vegetation is disturbed frequently be ice and snow. The shrub/ground stratum is either non-vegetated or dominated by shrubs, heathers, grasses, sedges and forbs. Trees are absent due to the action of ice and snow.

7d) Dry – Sites are usually in the grassland and parkland, where moisture stress limits establishment and growth of trees. The shrub/ground stratum is either nonvegetated or dominated by shrubs, grasses, sedges and forbs.

7e) Geo – Geological features (e.g., rocky outcrops, sand dunes, etc) limit tree establishment and growth. The shrub/ground stratum is either non-vegetated or dominated by heathers, grasses, sedges and forbs.

7f) Human – Human disturbance or activity limiting or preventing tree growth. The shrub/ground stratum is either non-vegetated or dominated by invasive species, grasses, sedges, or forbs.

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Appendix 3. Equipment needed for field data collection

<u>Sampling design and layout</u>

- Cellphone for communications
- 2-way radios for communications among partners
- Datasheets and clipboard
- Site maps
- Laptop with card reader to download images onto
- Folding handsaw/"Swede-saw"
- GPS and compass
- 5 – 1.5 m orange steel or aluminum bars/site
- 27 (3 per 10-m square plot) permanent magnetic metal markers per site

- 81 pigtails to mark the nested 5x5 m, 10x10 m, and 25x25 m plots, and wellsite center within the wellsite and reference sites. (1 wellsite centre, 13 per quadrant with bryophytes/lichens, 9 pigtails per quadrant without bryophytes/lichens)

4 -100 m tapes, 4- 50 m tapes, and 4 – 30 m tapes.

- Multiple colors of flagging tape (e.g, brown, pink, blue, and green)
- Fine tipped colored marker (to delineate polygons on human disturbance sketch)

Field Photos:

- Digital camera and batteries (or adapter depending on camera needs)
- Calipers or backpack for scale

General Vegetation Sampling:

- ABMI Ecosite Classification Chart
- Plant Field Guide (e.g. Common plants of the western rangelands - Volume 1 - grasses and grass-like species, Olds College and GOA - Kathy Tannas)
- Calipers for scale when taking photos
- Plot frame (0.5 m x 0.5 m)
- Plant press

Lichen and Bryophyte sampling:

- Vascular plant field guide
- Mora knife
- Hand lens
- Toilet paper for fragile specimens
- Squares of paper for small specimens
- 20 paper bags (Kraft #8) per site
- 1 larger grocery sized paper bag per site
- Sharpie
- Water
- Watch

Soil sampling core and excavation method: Field equipment:

- Durable plastic bags to store the samples from each site in
- Double-cylinder core sampler. The most common core diameter ranges from 2” to 3” (5.1 cm to 7.6 cm). Note that it is good to have a minimum of 2 core samplers per field crew in case of breakage
- A couple of large crescent wrenches that can be used to adjust the double-cylinder core samples if needed
- Clean, dry and uniform stainless-steel liners with a known internal diameter and height for volume calculation
- Trowel for excavation method
- Shovel (in case you have to dig out the double-cylinder core sampler if it is stuck)
- Soil knife or metal spatula
- Polyethylene plastic bags (2 - 7-pound bags per sample (we are currently using - 7 lb – 7” x 3” x 15” multipurpose clear plastic bags – Pur value brand which we order through U of Alberta Lab Stores) = 216 sample bags per site sampled)

- Labels on shipping tags that will be put in between the two 7 lb bags for each sample collected. – 108 labels on shipping tags per site sampled (we are currently using the following:

- https://www.officemaxcanada.com/en/product/013036_Avery_Manila_Shipping_Tags.aspx and https://www.officemaxcanada.com/en/product/5159_Avery_White_Mailing_Laser_Labels.aspx)
- Pam cooking spray to coat the stainless steel liners so they don't get stuck (1 bottle per site)
- 2 buckets with lids – it is useful to have a couple of buckets per field crew to help with storage of samples as they are being collected

Lab equipment:

- Analytical balance
- Drying oven capable of heating up to 105 °C

LFH sampling method:

- Trowel
- Ruler (measured to the scale of mm)

Penetration Resistance:

- Digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter)

Soil Organic Carbon, EC and pH:

- Bucket auger (also known as barrel and core auger) shown in Fig. 14b. Dutch auger shown in Fig. 14a.
- Heavy duty polyethylene bags (we are currently using - 7 lb – 7" x 3" x 15" multipurpose clear plastic bags – Pur value brand which we order through U of Alberta Lab Stores – the number needed per site are all included in the soil sampling list above)
- Wire brush
- Soil knife

Additional General Equipment Needs

- First-aid kit
- Ensure datasheets are printed on rite in the rain paper
- Wagon to help carry equipment and soil samples
- Emergency Contact Information
- Extra pencils for recording data
- Laptop with card reader to download images onto (this can also be done after you are back at the lab)
- Safety gear – e.g., bearspray and bear bangers when working in bear country
- Emergency contact information and nearest medical facilities – field emergency information package

Appendix 4: Datasheets for Field Data Collection

Ecological Recovery Monitoring of Reclaimed Wellsites

1. Access Description

Date:_________**Crewmember(s):**_____

____

Location of Site Center:[1]

Maps Where Access Is Recorded: 1:24,000

GPS Information: Accuracy [2]

Distance and Direction from Nearest Town:

Latitude[1] Longitude

Establishment and

1,62,500 Declination[3]

____

Other Established[4] ______________________________

Access Summary[5]:

Camp Location: ______________________________

Time from Camp To Site:

Truck Access to Site ______________________________

GPS Label at Start Point with Latitude & Longitude	Road Name & Type (Condition)	Distance and Direction to Site Centre or Next Waypoint

19 **Quad Access to Site**

GPS Label at Start Point with Latitude & Longitude	Trail Description	Distance and Direction to Site Centre or Next Waypoint

20 **Walking Access to Site Centre and 4 Corners of the Wellsite**

GPS Label at Start Point with Latitude & Longitude	Trail Description	Distance and Direction to Site Centre or Next Waypoint

21 1 – record decimal degrees (5 decimals) 2 – record GPS accuracy (in meters) 3 – record declination used to establish site
22 4 – check off when site is established or indicate in summary why site not established.5 – Describe in brief how to
get 23 to the site and any access challenges (boat required, river crossing, winch etc.)

Ecological Recovery Monitoring of Reclaimed Wellsites

2. Site Coordinate Establishment – GPS Coordinates

Site: ________________________________

Date: ________________________

Data collected by____________________________

Description of weather (e.g., overcast, sunny, raining):

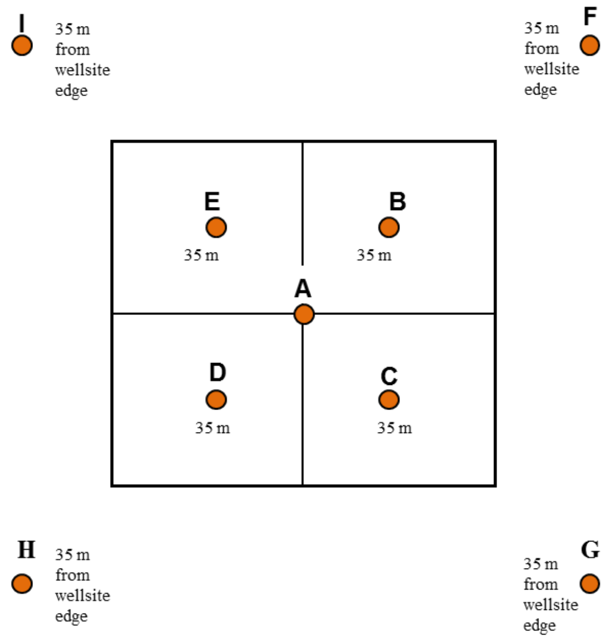
Which **wellsite** quadrant will include bryophyte/lichen plot?[5]__ Which **reference** quadrant will include bryophyte/lichen plot?_______

	UTM coordinates[1]		**Bearing [2]**	**Comments**
Location	**Easting[2]**	**Northing[2]**	**(0-359°)**	
Wellsite Center - A			n/a	
Well BORE			n/a	
B - Center of B 10x10 m plot				
C - Center of C 10x10 m plot				
D - Center of D 10x10 m plot				
E- Center of E 10x10 m plot				
F - Center of F 10x10 m plot			n/a	
G- Center of G 10x10 m plot			n/a	
H - Center of H 10x10 m plot			n/a	
I - Center of I 10x10 m plot			n/a	

1 –Record coordinates when measuring out the site on the ground. Mark a waypoint and record the UTMS for each of the 9 plot centres listed.

3. – Record the bearing on your compass standing at wellsite centre of each of the four corners of the wellsite and record those bearings. Those will be the bearings for the 4 transects running from the wellsite centre to the wellsite corners.

[5] Ideally select the quadrant that looks like it has more microhabitat for lichens and bryophytes – otherwise randomly select one of the four quadrants for both the wellsite (B-E), and reference sites (F-I).



Ecological Recovery Monitoring of Reclaimed Wellsites

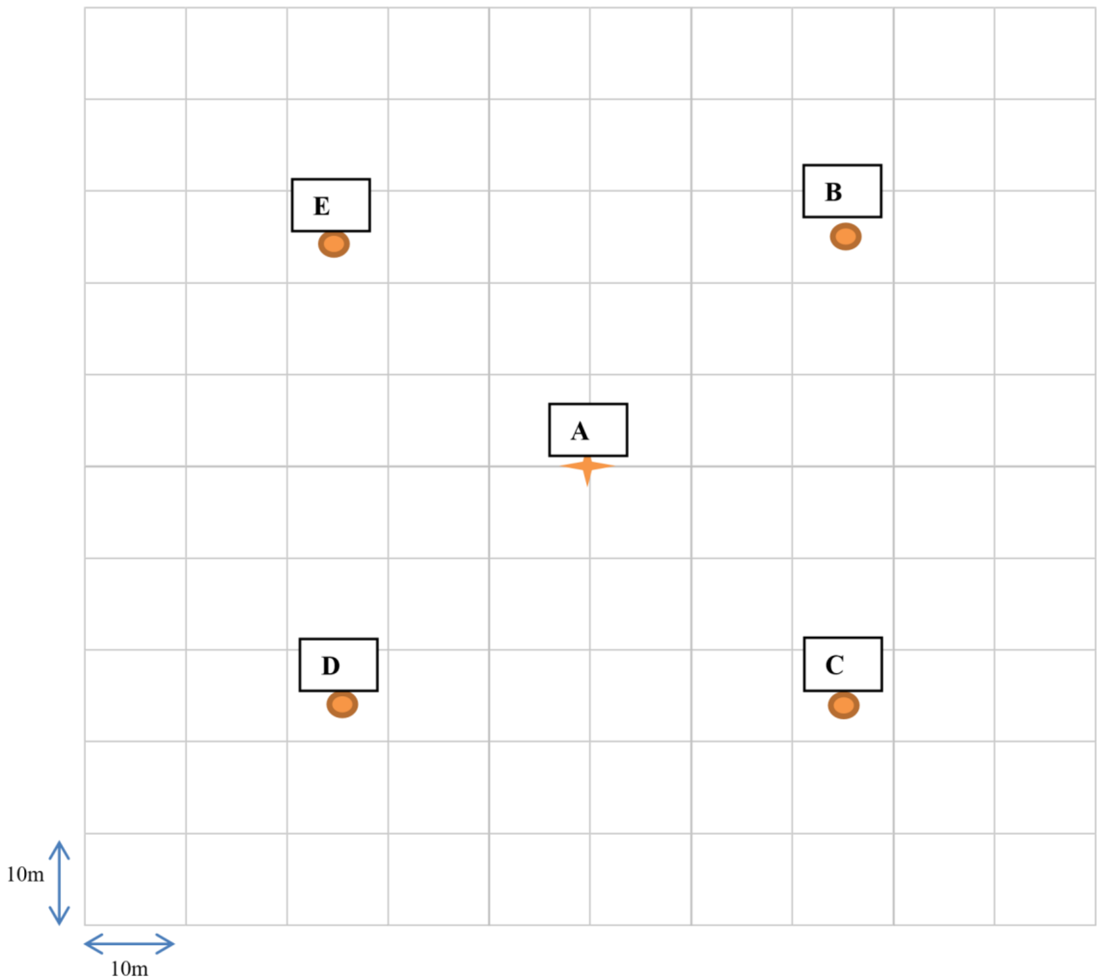
3A. Site Level Human Disturbance (Within the 1 Ha): Wellsite

Site: ______________________________

Date: ______________________

Data collected by: ______________________

Place arrow point north on sheet to indicate direction of North



Human Disturbance Codes (in addition to the well pad disturbance which encompasses the entire wellsite):

None **(NONE) –** No human caused disturbance

Linear-pipeline **(PIPE)**

Linear-powerline **(POWER)**

Linear-seismic **(SEIS) –** Any type of cutline or seismic line

Railway **(RAIL)**

Road-paved **(ROADP)** – Any type of road with paved surface

Road-unpaved **(ROADG) –** Any type of road with an unpaved but improved surface (i.e. gravel)

Trail **(TRAIL)** – Any type of truck or ATV trail with an unimproved surface

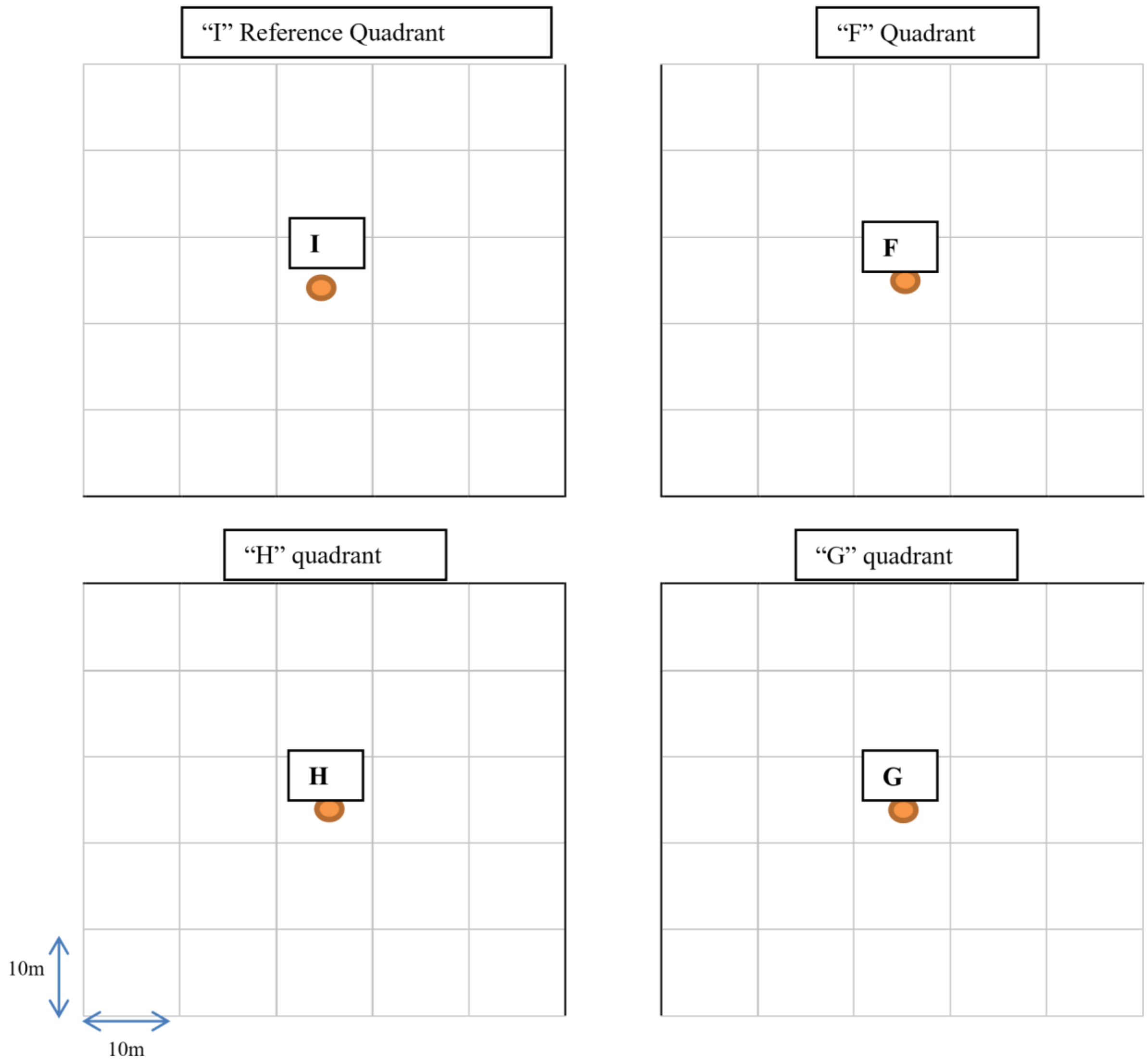
Cultivated crop/field **(CULT) –** Any type of cultivated field that is used to grow agriculture crops Pasture **(PAST)** – Any type of pasture (tame or native), grazing reserve, etc.

Residential **(RES)** – Any type of human dwelling, farm building, or farm yard in a rural or acreage setting

Bare ground- undetermined cause **(BARE)** – Human caused bare ground for which the cause cannot be determined

Other **(OTHER) –** Specify other disturbance type

3B. Site Level Human Disturbance (Within the 1 Ha): Reference



Site:

Date: **Data collected by:**

* Each quadrant represents one of the reference sites – recognizing they are not contiguous in the field

Human Disturbance Codes:

Well pad **(WELL)** – Any type of area cleared for oil/gas/CBM pump jacks or well heads

None **(NONE) –** No human caused disturbance

Harvest **(HARV)** – Any type of forest harvesting (clear-cut, partial cut, understory retention, etc.) <30 years old

Linear-pipeline **(PIPE)**

Linear-powerline **(POWER)**

Linear-seismic **(SEIS) –** Any type of cutline or seismic line

Railway **(RAIL)**

Road-paved **(ROADP)** – Any type of road with paved surface

Road-unpaved **(ROADG) –** Any type of road with an unpaved but improved surface (i.e. gravel)

Trail **(TRAIL)** – Any type of truck or ATV trail with an unimproved surface

Cultivated crop/field **(CULT) –** Any type of cultivated field that is used to grow agriculture crops

Pasture **(PAST)** – Any type of pasture (tame or native), grazing reserve, etc.

Residential **(RES)** – Any type of human dwelling, farm building, or farm yard in a rural or acreage setting

Urban **(URB) –** Any type of human dwelling, associated building, or yard/driveway/road in an urban setting

Industrial **(IND) –** Any type of building, roadway, yard, etc. associated with industrial development

Bare ground- undetermined cause **(BARE)** – Human caused bare ground for which the cause cannot be determined

Other **(OTHER) –** Specify other disturbance type

Ecological Recovery Monitoring of Reclaimed Wellsites

4. Site Photos

Site: ____________________

Date: ____________________

Data collected by: ____________________

Which reference quadrant was selected as most representative of reference condition? __________

	Oriented in Direction of 10x10 m plot centre			
Site Photographs [1]	**B**	**C**	**D**	**E**
Wellsite Quadrant Photographs (Record Photo #)				
Wellsite Representative Photograph (Record Photo #)				
	From middle of each reference quadrant, facing in a single direction:			
	F	**G**	**H**	**I**
Reference Site Quadrant Photographs (Record Photo #)				
Reference Site Representative Photograph (Record Photo #)				
Comments				

1 – Standing at the wellsite centre - one photo is taken in the direction of each sub-ordinal transect (i.e. towards wellsite corners) (total of 4 photographs), one representative site photo is taken from anywhere in the 1 ha wellsite area. For the reference site quadrant photos, photos are taken from the center of the 10x10 m plot of one of the four quadrants that is selected as most representative of the reference condition, in each of four sub-ordinal directions. All photos are taken at eye level using a lens with a 35 mm focal length. Check the quality and focus of each photo and re-take if necessary.

5. 2-Dimensional Cover (5x5 m plot)

Site:

Data collected by:________________ **Date:**

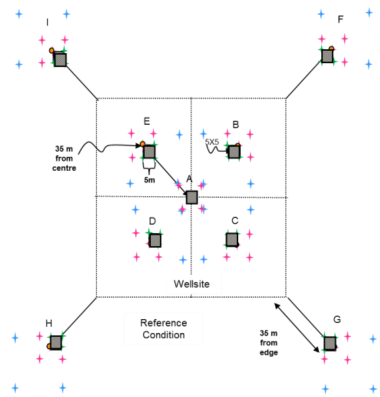
Shrub Cover	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Slope and Aspect[1]		/	/	/	/	/	/	/	/
Total Shrub Cover 0.5-2m (%) [2]									
Total Shrub Cover >2m (%) [3]									
2-Dimensional Cover [4]									
Forbs/Herbs: Other Vascular Cover (%)									
Shrub Cover (<0.5 m) (%)									
Grass Cover (includes sedge/rush) (%)									
Moss Cover (%)									
Lichen Cover (%)									
Fungi Cover (%)									
Wood Cover (%) [5]									
Litter Cover (%)									
Water Cover (%)									
Bare Mineral Ground Cover (%)									
Rock (%)									
Animal Matter (%)									
Comments									

1 – Record Slope (degree of slope) as: C= crest, T= toe, D= depression, L= level (0-2°), S1= 2-5°, S2= 6-10°, S3= 11-30°, S4= >30°. Record Aspect in degrees (direction water would flow) 2 – Cover estimates that would be obtained if a photograph had been taken from a height of 2 m, with shrubs <0.5 m removed. 0%, <1%, 5% increments.

3 – Cover estimates that would be obtained if a photograph had been taken above all shrubs, with shrubs <2 m removed. 0%, <1%, 5% increments.

4 – Cover estimates (0, <1%, and 5% increments) obtained if a photograph had been taken from a height of 0.5 m; **estimates must sum to 100%** 5 – Includes DWD >2 cm plus the bases of live trees

Ecological Recovery Monitoring of Reclaimed Wellsites 6. Shrub and 2-D Cover: Shrub Species Cover 5x5m



________________________ **Site:**

____

Data collected by: ________________

of __________ **Date:**

Sheet ____________

Shrub Species [1,2]	A	St[3]	B	St	C	St	D	St	E	St	F	St	G	St	H	St	I	St

1

1 – List all shrub species (7-letter code) rooted within each of the 5 x 5 m plots. If a species cannot be identified then collect the specimen and preserve it in a plant press and be sure to label the specimen in the plant press too. Unknown specimens are given a unique ID (UIS-Site#Well/Ref-Specimen#). Collect specimens from populations with more than 5 individuals, and

collect from outside the 5x5 m plot if possible. Use caution to not repeat specimen numbers within a site.

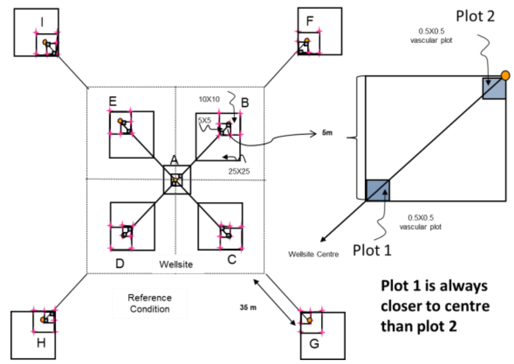
2 – Record the percent cover estimates (0, <1, or 5% increments) of each shrub species present within each plot; Due to overlapping of leaves at different heights, percent cover for all species combined can be greater than 100%.

3- Follow Strata Codes provided below.

Code	**Strata**	**Definition**
T1	Tree (main canopy)	Trees that make up the upper part of the height distribution population and form the general layer of the canopy or foliage
T2	Tree (understory)	Trees and/or shrubs whose crowns extend into the bottom of the general level of the canopy or are located below the main canopy. Trees and/or shrubs must exceed 5 m height
S1	Shrub (tall)	All woody plants between 2-5 m tall (includes regeneration of taller trees)
S2	Shrub (medium)	shrubs and regenerating trees between 0.5-2 m tall
S3	Shrub (low)	All woody plants up to 0.5 m tall

7A. Plant and Lichen Cover by Species: Wellsite

(0.25 m^2 plot)



Site:

Data collected by:____________________

________ **of** __________

Date:

Page:

Comments:

Species [1]	A-1	St[2]	A-2	St[2]	B-1	St	B-2	St	C-1	St	C-2	St	D-1	St	D-2	St	E-1	St	E-2	St
Rock																				
Mineral soil																				
Litter																				
Water																				

Begin survey at the wellsite centre. The wellsite plot A-1 is located in the "B" quadrant of the 5x5 m wellsite centre plot, and plot A-2 is located in the "D" quadrant .

1– List the vascular plants (seven letter species code = 4 letter genus and 3 letter species of scientific name) that are present within the 0.5m x 0.5m plot and estimate percent cover (0, <1, or 5% increments) in each plot the species occurs. If a species cannot be identified then collect the specimen and preserve it in a plant press. Unknown specimens are given a unique ID (UIS-Site#-PlotLetter-Specimen#). Collect specimens from populations with more than 5 individuals, and collect from outside the 5x5 m plot if possible. Use caution to not repeat

specimen numbers within a site. Note that Plot 1 for a given quadrant is always the closer plot and Plot 2 is always the plot furthest from wellsite centre.
In addition, estimate percent cover for rock/bare mineral soil, litter, and water in the quadrat. Plants must be rooted within the quadrat to be included in the estimation.

2- Follow Strata Codes provided below.

Code	Strata	Definition
T1	Tree (main canopy)	Trees that make up the upper part of the height distribution population and form the general layer of the canopy or foliage
T2	Tree (understory)	Trees and/or shrubs whose crowns extend into the bottom of the general level of the canopy or are located below the main canopy. Trees and/or shrubs must exceed 5 m height
S1	Shrub (tall)	All woody plants between 2-5 m tall (includes regeneration of taller trees)
S2	Shrub (medium)	shrubs and regenerating trees between 0.5-2 m tall
S3	Shrub (low)	All woody plants up to 0.5 m tall
H	Herbs (forbs)	record all forb species regardless of height
G	Grass/graminoid	record graminoids (grasses, sedges, rushes)
M	Moss	record all bryophytes
L	lichen	lichen species growing on dominant substrate (usually mineral or organic soil) included
E	epiphytes	Lichens or mosses growing on other plants, usually trees or shrubs
F	fungi	Fungi (excluding lichen) growing on dominant substrate - mushrooms

Ecological Recovery Monitoring of Reclaimed Wellsites
7B. Plant and Lichen Cover by Species: Reference

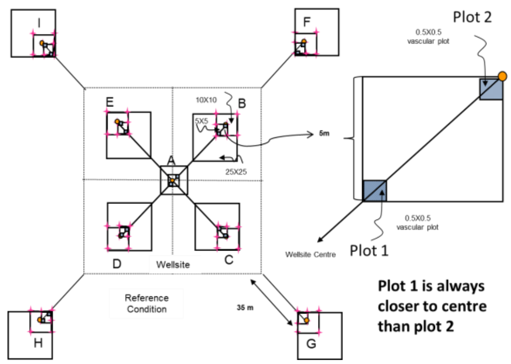
(0.25 m^2 plot)

Site: ____________________________

____

Data collected by: ____________________________

______ **of** ________ **Date:**



Page:

<u>Comments:</u>

Species [1]	**F-1**	**St[2]**	**F-2**	**St[2]**	**G-1**	**St**	**G-2**	**St**	**H-1**	**St**	**H-2**	**St**	**I-1**	**St**	**I-2**	**St**
Rock																
Mineral soil																
Litter																
Water																

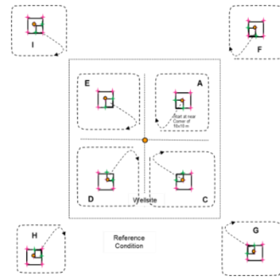
1– List the vascular plants (seven letter species code= 4 letter genus and 3 letter species of scientific name) that are present within the 0.5m x 0.5m plot and estimate percent cover (0, <1, or 5% increments) in each plot the species occurs. If a species cannot be identified then collect the specimen and preserve it in a plant press. Unknown specimens are given a unique ID (UIS-Site#-Plot LetterWell/Ref-Specimen#). Collect specimens from populations with more than 5 individuals, and collect from outside the 5x5 m plot if possible. Use caution to not repeat specimen numbers within a site. Note that Plot 1 for a given quadrant is always the closer plot and Plot 2 is always the plot furthest from wellsite centre. In addition estimate percent cover for rock/bare mineral soil, litter, and water in the quadrat. Plants must be rooted within the quadrat to be included in the estimation.

2- Follow Strata Codes provided below.

Code	Strata	Definition
T1	Tree (main canopy)	Trees that make up the upper part of the height distribution population and form the general layer of the canopy or foliage
T2	Tree (understory)	Trees and/or shrubs whose crowns extend into the bottom of the general level of the canopy or are located below the main canopy. Trees and/or shrubs must exceed 5 m height
S1	Shrub (tall)	All woody plants between 2-5 m tall (includes regeneration of taller trees)
S2	Shrub (medium)	shrubs and regenerating trees between 0.5-2 m tall
S3	Shrub (low)	All woody plants up to 0.5 m tall
H	Herbs (forbs)	record all forb species regardless of height
G	Grass/graminoid	record graminoids (grasses, sedges, rushes)
M	Moss	record all bryophytes
L	lichen	lichen species growing on dominant substrate (usually mineral or organic soil) included
E	epiphytes	Lichens or mosses growing on other plants, usually trees or shrubs
F	fungi	Fungi (excluding lichen) growing on dominant substrate - mushrooms

Ecological Recovery Monitoring of Reclaimed Wellsites

8. Vascular Plant Search



Sheet _____of_____

Site: ________________________________

Data collected by: ________________ **Date:**

	Wellsite			
Species [1]	**B**	**C**	**D**	**E**

	Reference Condition			
Species [1]	**F**	**G**	**H**	**I**

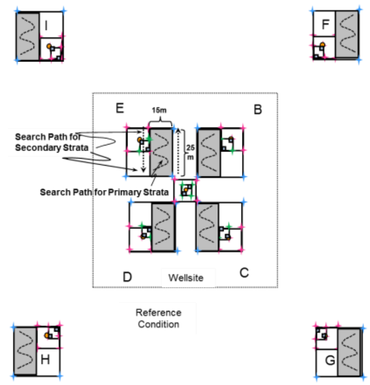
Begin surveys in the B quadrant and move in a clockwise direction through quadrants.

Start at the centre of each quadrant, working your way toward site centre, then walk through each quadrant in a clockwise direction, approximately 10 m from the edges, stopping every 4-5 steps to survey the immediate surroundings.

1 – List the vascular plants (seven letter species cod= 4 letter genus and 3 letter species of scientific name) that are present within the central 1 ha area and place a tick mark in each quadrant that the species occur in (1^{st} col); if a species cannot be identified then collect the specimen and preserve it in a plant press. Unknown specimens are given a unique ID (UIS-Site#-Well/Ref - Specimen#). Collect specimens from populations with more than 5 individuals, and collect from outside the 1-ha if possible.

9A. Bryophyte Collection - Detailed

Detailed Survey 1: 25X15 m Plot



Site:

Data collected by:____________________

Date:

Wellsite quadrant sampled(B,C,D,E):_______
Reference condition quadrant (F,G,H,I) sampled:__________

Method: For the quadrant with the most diversity of microhabitats (or if they all appear similar randomly select one) - survey the 25x15 m plot starting at the most diverse microhabitat you can find in the plot. Continue the survey by covering the entire plot in a "W" path (see figure). Stop every 4 or 5 steps to examine microhabitats and collect walnut-sized plugs of unique species.

Time searched:

Minimum 5 min → No Microhabitats found → Terminate search
→ Microhabitats found → Minimum 10 min
Continue searching until all examples of microhabitats are searched up to 25 min maximum (Most sites need 25 min)

Data entry: Mark the cells of the table as follows
C: microhabitat present and specimens collected
None: microhabitat present but no specimens found
VNA: microhabitats absent

	Time Searched	Time Searched
	Wellsite	**Reference**
Logs and Stumps (samples in 1 bag)		
LS: Soft stumps & logs (decay classes 3-5) sample roots and all sides		
LH: Hard stumps & logs (decay classes 1-2) sample roots and all sides		
Wetlands and Peatlands (samples in 1 bag)		
WMF: Wetlands, marshes, & fens - within the wetland survey both under and away from trees		
WSB: Shores/banks of wetlands, ponds, lakes, & streams survey on organic or mineral soil adjacent the water's edge		
WDS: Moist depressions/seasonal wetlands dry at time of survey sample sides and bottom in the area influenced by water		
WPW: Peatlands with or without standing water survey both standing water and vegetation hummocks		
Rocks and Cliffs (samples in 1 bag)		
BC: Boulders (>50 cm diam.) survey all surfaces (top, sides, and base) from the soil upwards		

Ecological Recovery Monitoring of Reclaimed Wellsites

RR: Rocks (<50 cm diam.) survey all surfaces (top, sides, and base) from the soil upwards		
CL: Cliffs (steep high rock face) - survey all of the faces, ledges, and crevices that can be accessed safely		

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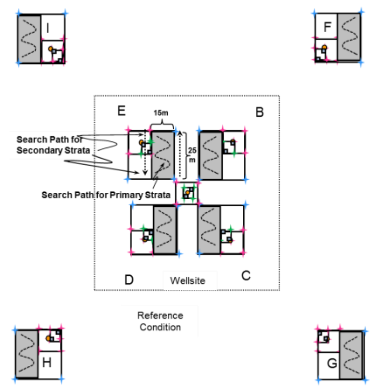
9B. Bryophyte Collection - Belt



Belt Transect Survey: 2x25 m Belt Transect

Site: ________________________

Data collected by: ________________________ **Date:**

Wellsite quadrant sampled(B,C,D,E):_______

Reference condition quadrant (F,G,H,I) sampled:__________

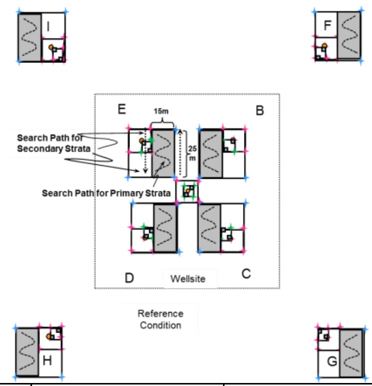
Method: Move in a clockwise direction along east and west plot boundary for the 15x25 m plot that you sampled. Stop every 4 or 5 steps to examine microhabitats and collect within 1 m of either side of perimeter.

Time searched:

Exactly 10 min

Data entry: Mark the cells of the table as follows
C: microhabitat present and specimens collected
None: microhabitat present but no specimens found
VNA: microhabitats absent

	Time Searched	**Time Searched**
	Wellsite	**Reference**
Trees and Other Vertical Structures (samples in 1 bag)		
TD: Deciduous Trees - all sides of the roots, bases, trunks, and branches of both live and dead deciduous trees		
TC: Coniferous Trees - all sides of the roots, bases, trunks, and branches of both live and dead coniferous trees		
TS: Shrubs - all sides of the roots, bases, stems, and branches of live & dead shrubs		
HB: Human Structures - vertical and horizontal parts of the structures (survey from the ground)		
Upland Soils (samples in 1 bag)		
UC: Humus soils under trees/shrubs (shaded by canopy) survey as large a variety as possible		



UO: Humus soils without trees/shrubs (open to sunlight) survey as large a variety as possible		
DC: Agriculturally cultivated soils		
DM: Mineral soil in upland areas from any causes		

10A. Lichen Collection - Detailed

Survey 1: 25 x 15 m Plots

Site: ____________________

Date: ____________________

Data collected by:____________________

Wellsite quadrant sampled(B,C,D,E):_______

Reference condition quadrant (F,G,H,I) sampled:__________

Method: For the quadrant with the most diversity of microhabitats (or if they all appear similar randomly select one) survey the 25x15 m plot starting at the most diverse microhabitat you can find in the plot. Continue the survey by covering the entire plot in a "W" path (see figure). Stop every 4 or 5 steps to examine microhabitats and collect walnut-sized plugs of unique species.

Time searched:

Minimum 5 min → No Microhabitats found → Terminate search

→ Microhabitats found → Minimum 10 min

Continue searching until all examples of microhabitats up to 25 min maximum (Most sites need 25 min)

Data entry: Mark the cells of the table as follows
C: microhabitat present and specimens collected
None: microhabitat present but no specimens found
VNA: microhabitats absent

Time Searched	**Time Searched**
Wellsite	**Reference**

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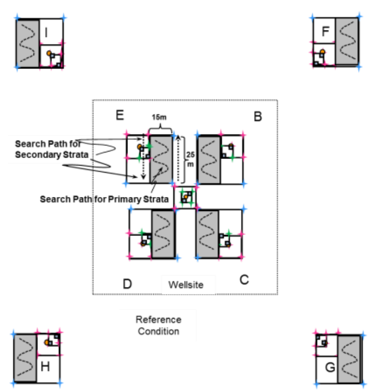
Logs and Stumps (samples in 1 bag)		
LS: Soft stumps & logs (decay classes 3-5) sample roots and all sides		
LH: Hard stumps & logs (decay classes 1-2) sample roots and all sides		
Trees and Other Vertical Structures (samples in 1 bag)		
TD: Deciduous Trees - all sides of the roots, bases, trunks, and branches of both live and dead deciduous trees		
TC: Coniferous Trees - all sides of the roots, bases, trunks, and branches of both live and dead coniferous trees		
TS: Shrubs - all sides of the roots, bases, stems, and branches of live & dead shrubs		
HB: Human Structures - vertical and horizontal parts of the structures: (e.g., posts, buildings) survey from the ground		
Rocks and Cliffs (samples in 1 bag)		
BC: Boulders (>50 cm diam.) survey all surfaces (top, sides, and base) from the soil upwards		
RR: Rocks (<50 cm diam.) survey all surfaces (top, sides, and base) from the soil upwards		
CL: Cliffs (steep high rock face) - survey all of the faces, ledges, and crevices that can be accessed safely		

Ecological Recovery Monitoring of Reclaimed Wellsites

10B. Lichen Collection – Belt

Survey 2: 2x25 m Belt Transects



Site:

Data collected by:____________________

Date:

Wellsite quadrant sampled(B,C,D,E):_ Reference condition quadrant (F-I) sampled:

Method: Move in a clockwise direction along east and west plot boundary of the 15x25 m plot that you sampled for lichens. Stop every 4 or 5 steps to examine microhabitats and collect within 1 m of either side of perimeter.

Time searched:
Exactly 10 min

Data entry: Mark the cells of the table as follows
C: microhabitat present and specimens collected
None: microhabitat present but no specimens found
VNA: microhabitats absent

Time Searched	**Time Searched**
Wellsite	**Reference**

Wetlands and Peatlands (samples in 1 bag)		
WMF: Wetlands, marshes, & fens - within the wetland survey both under and away from trees		
WSB: Shores/banks of wetlands, ponds, lakes, & streams survey on organic or mineral soil adjacent the water’s edge		
WDS: Moist depressions/seasonal wetlands dry at time of survey sample sides and bottom in the area influenced by water		
WPW: Peatlands with or without standing water survey both standing water and vegetation hummocks		
Upland Soils (samples in 1 bag)		
UC: Humus soils under trees/shrubs (shaded by canopy) survey as large a variety as possible		
UO: Humus soils without trees/shrubs (open to sunlight) survey as large a variety as possible		
DC: Agriculturally cultivated soils		
DM: Mineral soil in upland areas from any causes		

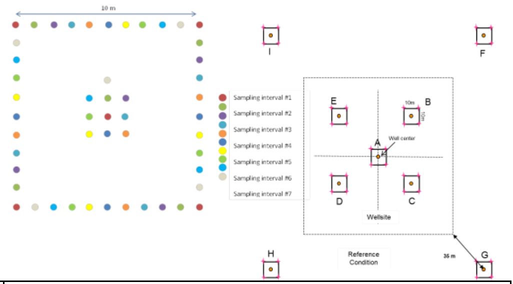
Ecological Recovery Monitoring of Reclaimed Wellsites

11A. Soil Bulk Density, EC, pH, SOC,LFH samples

Site: ______________________________

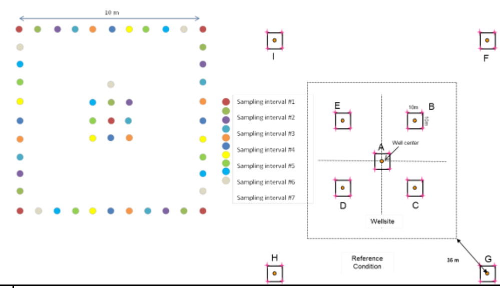
Date:_________Data collected by:

Sheet ___1__**of**__3___



			Profile Depth (cm)		
Sample ID	% elevation	LFH depth (mm)	Start	Finish	Comments/photo #'s
W-A-1-0					
W-A-1-15		n/a			
W-A-1-30		n/a			
W-A-1-60		n/a			
W-A-2-0					
W-A-2-15		n/a			
W-A-3-0					
W-A-3-15		n/a			
W-A-4-0					
W-A-4-15		n/a			
W-A-5-0					
W-A-5-15		n/a			
W-B-1-0					
W-B-1-15		n/a			
W-B-1-30		n/a			
W-B-1-60		n/a			
W-B-2-0					
W-B-2-15		n/a			
W-B-3-0					
W-B-3-15		n/a			
W-B-4-0					
W-B-4-15		n/a			
W-B-5-0					
W-B-5-15		n/a			
W-C-1-0					
W-C-1-15		n/a			
W-C-1-30		n/a			
W-C-1-60		n/a			
W-C-2-0					
W-C-2-15		n/a			
W-C-3-0					

Ecological Recovery Monitoring of Reclaimed Wellsites



W-C-3-15		n/a			
W-C-4-0					
W-C-4-15		n/a			
W-C-5-0					
W-C-5-15		n/a			
W-D-1-0					
W-D-1-15		n/a			
W-D-1-30		n/a			
W-D-1-60		n/a			
W-D-2-0					
W-D-2-15		n/a			

11A. Soil sampling cont'd

Site: ______________________________

Date:___________Data collected by:___________

Sheet __2___**of**__3___

			Profile Depth (cm)		
Sample ID	% elevation	LFH depth (mm)	Start	Finish	Comments/photo#'s
W-D-3-0					
W-D-3-15		n/a			
W-D-4-0					
W-D-4-15		n/a			
W-D-5-0					

W-D-5-15		n/a			
W-E-1-0					
W-E-1-15		n/a			
W-E-1-30		n/a			
W-E-1-60		n/a			
W-E-2-0					
W-E-2-15		n/a			
W-E-3-0					
W-E-3-15		n/a			
W-E-4-0					
W-E-4-15		n/a			
W-E-5-0					
W-E-5-15		n/a			
R-F-1-0					
R-F-1-15		n/a			
R-F-1-30		n/a			
R-F-1-60		n/a			
R-F-2-0					
R-F-2-15		n/a			
R-F-3-0					
R-F-3-15		n/a			
R-F-4-0					
R-F-4-15		n/a			
R-F-5-0					
R-F-5-15		n/a			
R-G-1-0					
R-G-1-15		n/a			
R-G-1-30		n/a			
R-G-1-60		n/a			
R-G-2-0					
R-G-2-15		n/a			

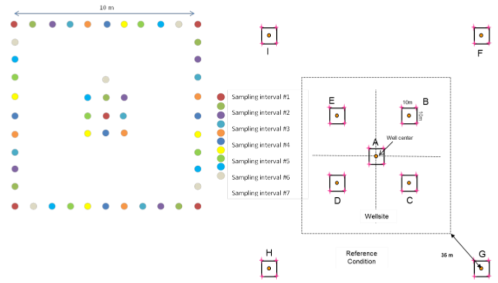
Ecological Recovery Monitoring of Reclaimed Wellsites

11A. Soil sampling cont'd

Site: ______________________________

Date:___________Data collected by:___________

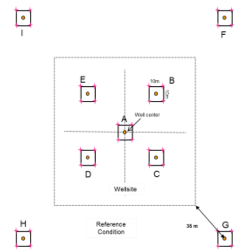
Sheet __3___of__3___



			Profile Depth (cm)		
Sample ID	% elevation	LFH depth (mm)	Start	Finish	Comments/photo#'s
R-G-3-0					
R-G-3-15		n/a			
R-G-4-0					
R-G-4-15		n/a			
R-G-5-0					
R-G-5-15		n/a			
R-H-1-0					
R-H-1-15		n/a			
R-H-1-30		n/a			
R-H-1-60		n/a			
R-H-2-0					
R-H-2-15		n/a			
R-H-3-0					
R-H-3-15		n/a			
R-H-4-0					
R-H-4-15		n/a			
R-H-5-0					
R-H-5-15		n/a			
R-I-1-0					
R-I-1-15		n/a			
R-I-1-30		n/a			
R-I-1-60		n/a			
R-I-2-0					
R-I-2-15		n/a			
R-I-3-0					
R-I-3-15		n/a			
R-I-4-0					
R-I-4-15		n/a			

Ecological Recovery Monitoring of Reclaimed Wellsites

R-I-5-0					
R-I-5-15		n/a			



11B. Penetration Resistance

Site: ______________________________

Date:___________**Data collected by:**_________________________

Sheet _1__**of**___4__ Penetrometer model:_________________

___

Wind condition:____

Target measurement depths are 0-5, 5-10, 10-15, 15-20, 20-30 cm depth (5 per location)

	Measurement depth (cm)				Measurement depth (cm)		
Sample ID	Start	Finish	Reading	Sample ID	Start	Finish	Reading
W-A-1				W-B-3			
W-A-1				W-B-3			
W-A-1				W-B-3			
W-A-1				W-B-3			
W-A-1				W-B-3			
W-A-2				W-B-4			
W-A-2				W-B-4			
W-A-2				W-B-4			
W-A-2				W-B-4			
W-A-2				W-B-4			
W-A-3				W-B-5			
W-A-3				W-B-5			
W-A-3				W-B-5			
W-A-3				W-B-5			
W-A-3				W-B-5			
W-A-4				W-C-1			
W-A-4				W-C-1			
W-A-4				W-C-1			
W-A-4				W-C-1			
W-A-4				W-C-1			
W-A-5				W-C-2			
W-A-5				W-C-2			
W-A-5				W-C-2			
W-A-5				W-C-2			
W-A-5				W-C-2			

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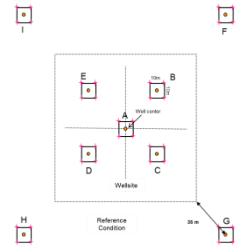
W-B-1				W-C-3			
W-B-1				W-C-3			
W-B-1				W-C-3			
W-B-1				W-C-3			
W-B-1				W-C-3			
W-B-2				W-C-4			
W-B-2				W-C-4			
W-B-2				W-C-4			
W-B-2				W-C-4			
W-B-2				W-C-4			

Comments:

Ecological Recovery Monitoring of Reclaimed Wellsites



11B. Penetration Resistance cont'd Site: ______________________________

Date:_______________Data collected by:________________________
Sheet __2__**of**__4___ Penetrometer model:_______________________
Wind condition:____

Target measurement depths are 0-5, 5-10, 10-15, 15-20, 20-30 cm depth (5 per location)

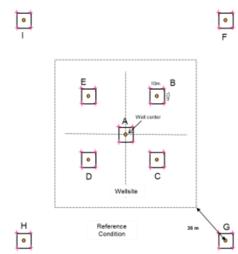
	Measurement depth (cm)				Measurement depth (cm)		
Sample ID	depth(cm)Start	Finish	Reading	Sample ID	Start (c n)	Finish	Reading
W-C-5				W-E-2			
W-C-5				W-E-2			
W-C-5				W-E-2			
W-C-5				W-E-2			
W-C-5				W-E-2			
W-D-1				W-E-3			
W-D-1				W-E-3			
W-D-1				W-E-3			
W-D-1				W-E-3			
W-D-1				W-E-3			
W-D-2				W-E-4			
W-D-2				W-E-4			
W-D-2				W-E-4			
W-D-2				W-E-4			
W-D-2				W-E-4			
W-D-3				W-E-5			
W-D-3				W-E-5			
W-D-3				W-E-5			
W-D-3				W-E-5			
W-D-3				W-E-5			
W-D-4				W-F-1			
W-D-4				W-F-1			
W-D-4				W-F-1			
W-D-4				W-F-1			
W-D-4				W-F-1			
W-D-5				W-F-2			

W-D-5				W-F-2			
W-D-5				W-F-2			
W-D-5				W-F-2			
W-D-5				W-F-2			
W-E-1				W-F-3			
W-E-1				W-F-3			
W-E-1				W-F-3			
W-E-1				W-F-3			
W-E-1				W-F-3			

Comments:

Ecological Recovery Monitoring of Reclaimed Wellsites

11B. Penetration Resistance cont'd Site: ________________________________



Date:________________Data collected by:__________________________

Sheet ___3__**of**__4___ Penetrometer model:________________________

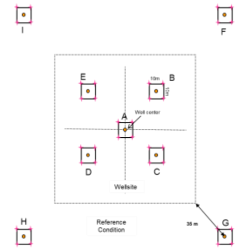
Wind condition:____

Target measurement depths are 0-5, 5-10, 10-15, 15-20, 20-30 cm depth (5 per location)

	Measurement depth (cm)				Measurement depth (cm)		
Sample ID	Start	Finish	Reading	Sample ID	Start	Finish	Reading
W-F-4				W-H-1			
W-F-4				W-H-1			
W-F-4				W-H-1			
W-F-4				W-H-1			
W-F-4				W-H-1			
W-F-5				W-H-2			
W-F-5				W-H-2			
W-F-5				W-H-2			
W-F-5				W-H-2			
W-F-5				W-H-2			
W-G-1				W-H-3			
W-G-1				W-H-3			
W-G-1				W-H-3			
W-G-1				W-H-3			
W-G-1				W-H-3			
W-G-2				W-H-4			
W-G-2				W-H-4			

W-G-2				W-H-4			
W-G-2				W-H-4			
W-G-2				W-H-4			
W-G-3				W-H-5			
W-G-3				W-H-5			
W-G-3				W-H-5			
W-G-3				W-H-5			
W-G-3				W-H-5			
W-G-4				W-I-1			
W-G-4				W-I-1			
W-G-4				W-I-1			
W-G-4				W-I-1			
W-G-4				W-I-1			
W-G-5				W-I-2			
W-G-5				W-I-2			
W-G-5				W-I-2			
W-G-5				W-I-2			
W-G-5				W-I-2			

Comments:



11B. Penetration Resistance cont'd Site: ______________________________

Date:___________Data collected by:_________________________ Sheet ___4__**of**_4___ Penetrometer model:_________________
Wind condition:____

Target measurement depths are 0-5, 5-10, 10-15, 15-20, 20-30 cm depth (5 per location)

		Measurement depth (cm)				Measurement depth (cm)	
Sample ID	Reading	Start	Finish	Sample ID	Reading	Start	Finish
W-I-3							
W-I-3							
W-I-3							
W-I-3							
W-I-3							
W-I-4							
W-I-4							

W-I-4							
W-I-4							
W-I-4							
W-I-5							
W-I-5							
W-I-5							
W-I-5							
W-I-5							

Comments:

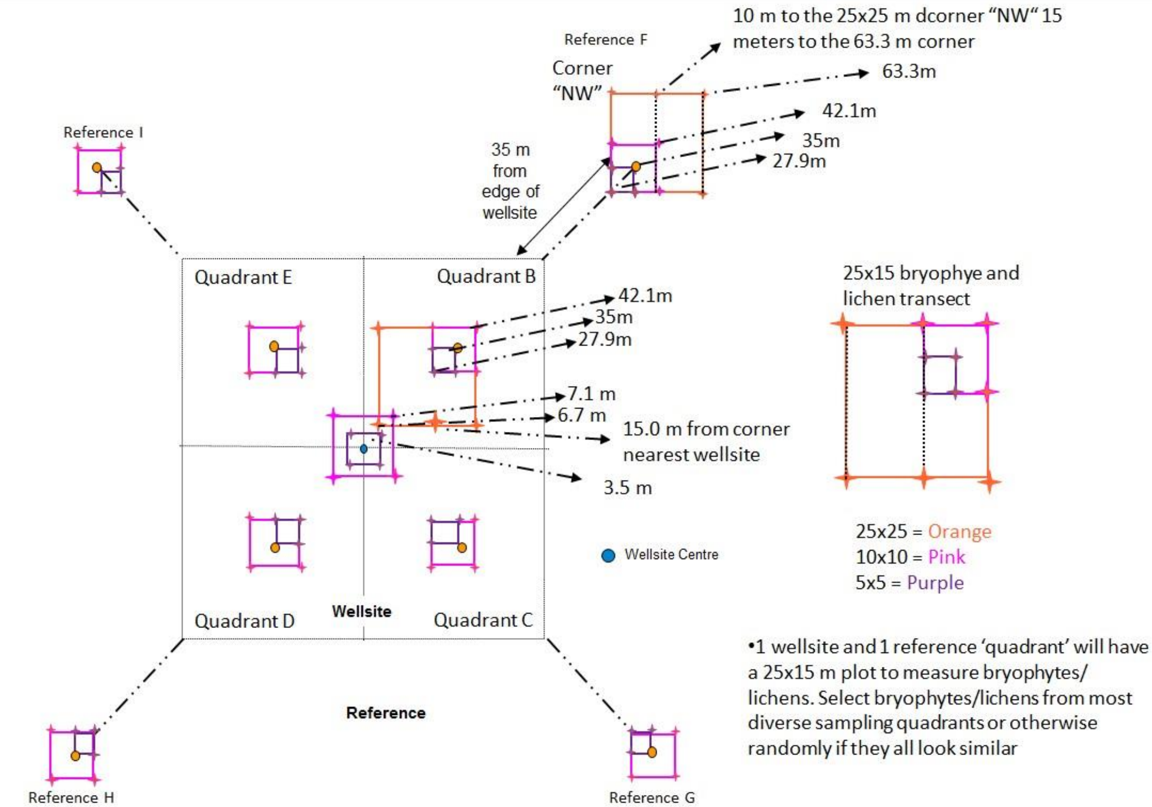
Appendix 5: "Cheat Sheets" that live in a separate power point file that can be used in the field to facilitate laying out of plots.

Create 2 different cheat sheets

- One for the quadrant where we include the bryophytes and so need a 25x25 m plot
- One for the quadrant where we don't include the bryophytes and so don't need the 25x25 m plot

Distances & Colors – with Bryophyte & Lichens – 1 wellsite & reference quadrant only

- Wellsite centre - BLUE
- 6.7 m – ORANGE - (near corner of 25x25 m plot)
- 7.1 m – PINK (corner of centre 10x10 m plot)
- 27.9 m – PINK & PURPLE (near corner of 10x10 m and 5x5 m quadrant plots)
- 35 m – PURPLE (centre of 10x10 m quadrant plot and far corner of the 5x5 m plot)
- 42.1 m – PINK & ORANGE (far corner of 10x10 m and 25x25 m plot).
- Using the 100 m tape:
    1. Triangulate the 5x5 m plot to fill in the other 2 corners of the 5x5 m – PURPLE
    2. Triangulate the 10x10 m plot to fill in the other 2 corners of the 10x10 m – PINK
    3. Triangulate the 25x25 m plot to fill in the other 2 corners of the 25x25 m plot - ORANGE



*not to scale

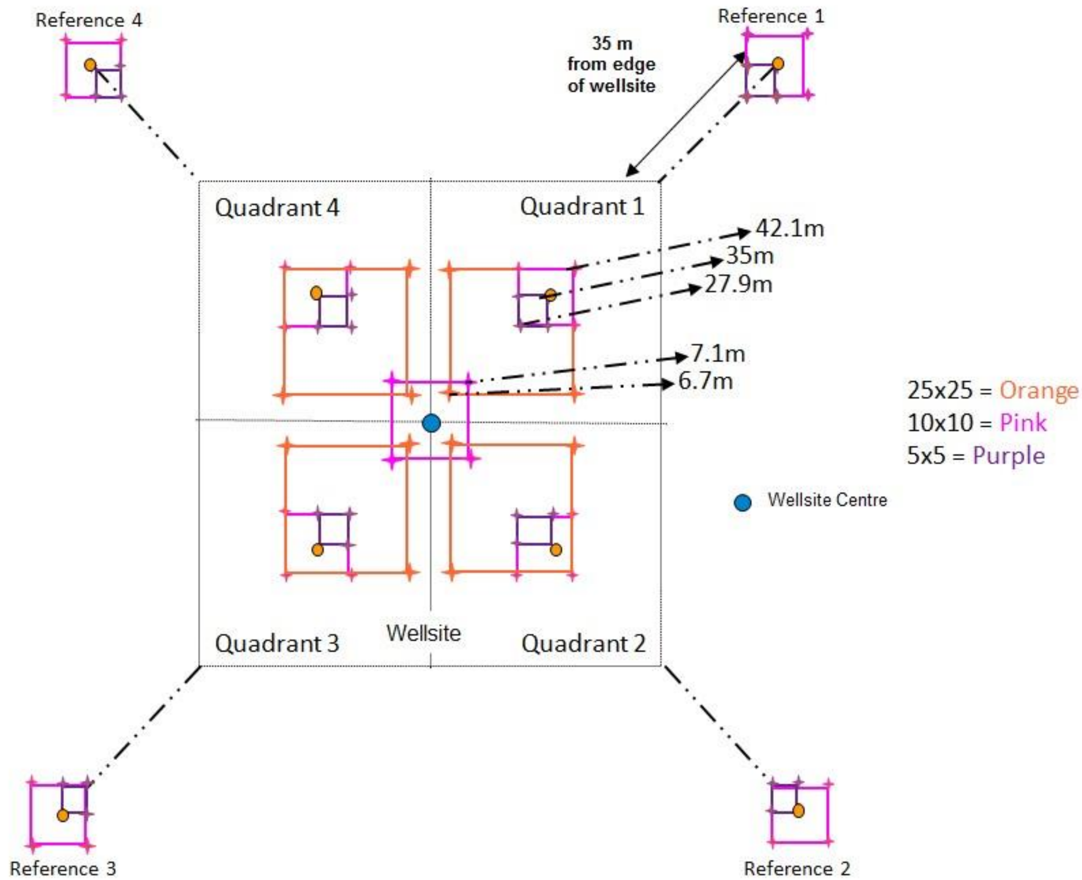
Remember - only 1 quadrant on wellsite and reference with 25x15 m plots

Distances & Colors – without Bryophyte & Lichens – 3 wellsite & reference quadrants

- 7.1 m – PINK (corner of centre 10x10 m plot)
- 27.9 m – PINK & PURPLE (near corner of 10x10 m and 5x5 m quadrant plots)
- 35 m – PURPLE (centre of 10x10 m quadrant plot and far corner of the 5x5 m plot)
- 42.1 m – PINK (far corner of 10x10 m and 25x25 m plot)
- Using the 100 m tape:
  1. Triangulate the 5x5 m plot to fill in the other 2 corners of the 5x5 m – PURPLE
  2. Triangulate the 10x10 m plot to fill in the other 2 corners of the 10x10 m – PINK

1

2



*not to scale

1