Ecological Recovery Monitoring of Certified Reclaimed Wellsites in Alberta

Field Data Collection Protocols for Cultivated Lands

Version 2015-08-19

Prepared for:
Arnold Janz, AEMERA

Prepared by:
Alberta Biodiversity Monitoring Institute & Alberta Innovates Technology Futures

Acknowledgements
These protocols were developed by Anne McIntosh (ABMI), Dani Degenhardt (AITF), Christina Small (AITF), and Bonnie Drozdowski (AITF) using the ABMI Terrestrial Monitoring Protocols as a template and then condensing the monitoring protocols developed for sampling in grasslands. Input and review of the grasslands protocols were provided by the Ecological Recovery Monitoring of Certified Sites in Alberta Advisory Group.

Ecological Recovery Monitoring of Certified Sites in Alberta Advisory Group Members:

- Barry Adams – Head, Rangeland Resource Management Program, GOA (ESRD)
- Isaac Amponsah – Alberta Energy Regulator
- Meridith Ball – Senior Environmental Advisor, Husky Energy and interim CAPP representative*
- John Begg, Manager – Major Industrial and Reclamation, GOA (ESRD)
- Cindy Craig – Senior Environmental Planning Coordinator, ATCO Electric*
- Dani Degenhardt – Reclamation Scientist, AITF
- Gordon Dinwoodie – Reclamation Policy Specialist, GOA (ESRD)
- Bonnie Drozdowski – Reclamation Scientist, AITF
- Christina Small – Reclamation Scientist, AITF
- Dan Farr – Application Centre Director, ABMI
- Arnold Janz – Land Conservation Specialist, AEMERA
- Heather Jones – Environmental Protection Officer, GOA (ESRD)
- Donna Lawrence – Provincial Rangeland Specialist – Boreal, GOA (ESRD)
- Shauna Lee-Chai – Ecologist, ABMI/AITF
- Anne McIntosh – Project Ecologist, Assistant Professor, University of Alberta
- Delinda (Dee) Ryerson – Project Manager, ABMI
- Jim Schieck – Science Centre Co-director, ABMI

Suggested Citation: Alberta Biodiversity Monitoring Institute. 2015. Ecological recovery monitoring of certified wellsites field data collection protocols for cultivated lands, Version 2015-08-19. Alberta Biodiversity Monitoring Institute, Alberta, Canada.

Contact Information

If you have questions or concerns about this publication, you can contact:
Anne McIntosh
University of Alberta
Camrose, Alberta, Canada
E-mail: amcintos@ualberta.ca

Table of Contents

List of Figures

List of Tables

SUMMARY

This report describes sampling protocols (methodology) for the selected soil indicators for cultivated lands certified reclaimed sites.

BACKGROUND

After upstream oil and gas facilities or other industrial developments have been decommissioned on specified lands[1], reclamation is directed through the Environmental Protection and Enhancement Act (EPEA) to return the land to "equivalent land capability" (ELC). ELC is defined in the EPEA's Conservation and Reclamation Regulation as "the ability of the land to support various land uses after conservation and reclamation is similar to the ability that existed prior to an activity being conducted on the land, but that the individual land uses will not necessarily be identical." After specified lands have been deemed to have met the legislated requirements, a reclamation certificate is issued. Recovery of ecological functions at certified wellsites, pipelines and other specified lands in Alberta may continue long after the reclamation certificate issue date. However, the rate of this ecological recovery is currently not documented or monitored. Knowledge of this rate of recovery is essential for accurate forecasting, land use planning, and cumulative effects management. One of the recommendations from the Alberta Environment Land Monitoring Program Inventory and Needs Analysis report (Alberta Environment, 2006) is the establishment of a long-term reclamation benchmark monitoring program in Alberta to determine if reclaimed and certified site conditions and trajectories perform in a manner that satisfies the legislated mandate of ELC.

The ecological recovery monitoring of certified sites program (formerly known as the long-term reclamation benchmark monitoring program) is intended to evaluate and report on soil and vegetation quality trajectories at reclaimed cultivated, grassland and forested lands in Alberta using appropriate and sensitive physical, chemical and biological indicators. The Alberta Wellsite Criteria Documents developed by the Reclamation Criteria Advisory Group, the Long-term Reclamation Benchmark Monitoring Program developed by EBA, and the ABMI's monitoring protocols have all been proposed as potential data collection protocol resources that could be useful for development of long-term monitoring of certified wellsites and other specified lands. A series of three workshops held between December 2012 and March 2013 with members of the Ecological Recovery Monitoring of Certified Sites in Alberta Advisory Group, evaluated these existing resources for their ability to monitor long-term ecological recovery of wellsites and building on them Advisory Group members identified a set of landscape- and site-level indicators that could be used to evaluate the ecological recovery of certified sites. This manual describes ecological recovery long-term monitoring protocols for certified sites in Alberta that measure these landscape- and site-level indicators that were selected by the Ecological Recovery Monitoring of Certified Sites in Alberta Advisory Group. Note that this first iteration of the integrated protocols is focused on sampling of wellsites. Future versions may also include sampling of linear oil and gas disturbances.

PROJECT OBJECTIVES

The purpose of this project was to develop an integrated, scientifically robust and financially sustainable monitoring program to enable the assessment of ecological recovery of physical, chemical, and biological indicators at certified reclaimed industrial sites across Alberta. Data will be generated from measurement of soil, vegetation, and landscape indicators at certified and reference sites. The objective of this document is to provide sampling protocols for soil indicators in cultivated lands. The intention of this monitoring program is to track ecological recovery of reclaimed sites and not to assess whether current

[1] land used for specified industrial disturbances – in this case oil and gas industrial disturbance

reclamation criteria are adequate. Furthermore the intent of the program is not to lay blame on previous reclamation criteria or practices. Thus, this program will not be used to cancel reclamation certificates on previously certified sites. The development of these integrated monitoring protocols is a first step towards the successful development of this long-term monitoring program to assess ecological recovery of certified sites in Alberta.

It should be noted that this is a preliminary version of the cultivated protocols to be implemented during a pilot study in 2015, and will be amended based on advice from experts as well as from results and data from the 2015 field season.

FUNDING SOURCES

This project was initiated and funded by Alberta Environment and Sustainable Resource Development's Land Monitoring Team and is supported by the Alberta Biodiversity Monitoring Institute and Alberta Innovates - Technology Futures. It is now funded by AEMERA.

MONITORING PROTOCOLS FORMAT

This set of integrated monitoring protocols are documented in a set of chapters that describes the sampling layout for individual sites, followed by individual chapters with sampling protocols for each ecosystem component, and finally provides information related to management of personnel and data. Information related to analysis of the data collected in these protocols is beyond the scope of this document.

1. SAMPLING DESIGN

In this chapter the sampling design and layout for individual sites are described, including detailed information on accessing and laying out individual sampling sites for future measurement.

These sampling designs 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 ways that the sampling design and monitoring protocols could be implemented. The system that we have adopted samples two different areas within a single unit: the wellsite, 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 ecological recovery is assessed. In order to precisely measure the temporal change in the selected indicators, we need to minimize the spatial variability. This can be done by systematically selecting sampling points. The ease of use and the sampling efficiency makes it a better choice 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[2] 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[3].** 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 below-ground pipelines et al. will contact you to let you know whether or not there is a conflict and whether marking of lines will be required. 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 you can get information by going to: **https://maps.srd.alberta.ca/RecAccess/default.aspx?Viewer=RecAccess.** There will be an icon for identify 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.

[2] 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 (http://environment.alberta.ca/01520.HTML) .

[3] 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 – e.g., . http://www.firstaidsafetytraining.ca/ground-disturbance-course.php

2. Finally before going into the field, additional maps and descriptions are prepared and put together into a site information package that can be used to aid in locating the site, and access materials are compiled to facilitate data collection during future monitoring visits (see an example of this information in Appendix 1).
3. During the first visit to the site, the most efficient route is found, and potential hazards are described on Access Datasheets and supplied maps (e.g., Appendix 1).
    - 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 Site Coordinate Establishment datasheet (datasheet #1).

Field Equipment Needed:

- *Cellphone for communications*
- *2-way radios for communications among partners (optional)*
- *Datasheets and clipboard*
- *Site maps and wellsite information package*
- *GPS and compass*
- *46 pigtails to mark the 10x10 m corners and centres within the wellsite and reference sites. One additional pigtail to mark the wellbore location*
- *4- 50 m tapes, 4-100 m tapes and 4 – 30 m tapes (less tapes are needed if you do not keep the tapes laid out and lay out all of the quadrants of the wellsite or reference at once.*
- *Single color of flagging tape (e.g., pink = 10x10m)*
- *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 4)*
- *Datasheets #1-3*

B. Laying out the plot for sampling

For level and near-level sites, the following sampling design will be used (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 arrives onsite, the first step is to identify the wellbore – so that the GPS coordinates of it can be recorded and the crew ensures that they do not sample adjacent to the wellbore[4]. **Record the GPS coordinates at the wellbore on Datasheet 1**.The next step is for the crew to identify wellsite center using the GPS information that they were provided with in the site information packet. The wellsite center will also be the center point for the reclamation wellsite plot. It must be located as precisely as possible using a hand-held GPS with an accuracy of < 7 m (GPS coordinates will have been identified 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, this is noted on the site establishment **Datasheet 1**.
- At wellsite center place a pigtail in the ground and flag it so that you can readily identify the wellsite center. Note that in some cases with heavy cover and poor GPS signal, you may have troubles identifying the wellsite centre so you may have to measure the diagonals between the four corners and

[4] The person locating the wellbore will use the magnetic locator and should not be wearing steel-toed boots as this will interfere with the ability to locate the wellbore.

then identify the wellsite centre as the point where the two diagonal lines intersect. **Record the GPS coordinates at the wellsite centre on Datasheet 1**.

- The crew will need to lay out four sub-ordinal transects that are oriented towards 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 northwest 315°, northeast 45°, southeast 135°, southwest 225° - if not cardinal then adapt the directions of the four transects to angles as needed 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 1 and also record the GPS coordinates for the centre of each 10x10 m plot (i.e., 10 GPS measurements per site including wellsite centre and wellbore).**
- Establish the first transect for both the wellsite and adjacent reference site – it is most efficient to have both crew members establish each transect together and **use the plot layout cheatsheet.** Carry an extra 50-m tape and 30-m tape and 11 pigtails with you. Using a 100-m tape attached to the wellsite centre, lay out your tape along the bearing of the sub-ordinal transect. *Hint: it is helpful to use 2 people and triangulate with a single tape to complete the final 2 corners for the 10x10 m plots.*
    - 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 measuring tape until you reach 27.9 m from wellsite centre and insert a pigtail (this will be the near corner of your 10x10m 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 (this will be the far diagonal corner for the 10x10 m plots).
    - Insert pigtails for the remaining sides of the 10-m square by using the 30-m tape and triangulating between the 2 established corners of the 10x10 m plot.
    - 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 (if the wellsite is standard size of 1 ha, then this is a distance of 70.1 m.
- To establish the reference site plots (assuming the reference sites are contiguous with the wellsite), walk to the corner of the wellsite footprint (e.g., 70.1 m) and then roll out the 50-m tape and lay out the line transect at the same bearing as for the same sub-ordinal wellsite 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 #1 at 35 m (plot center for 10x10 m plot).**
    - Insert pigtails for the remaining sides of the 10-m square using the 30-m tape to triangulate.
- All flagging and pigtails **must** be removed after each visit.
- Care should be taken to minimize impact on crops/livestock at private sites. Refer to Land Access datasheet for site-specific instructions (access, impact on land, etc.).

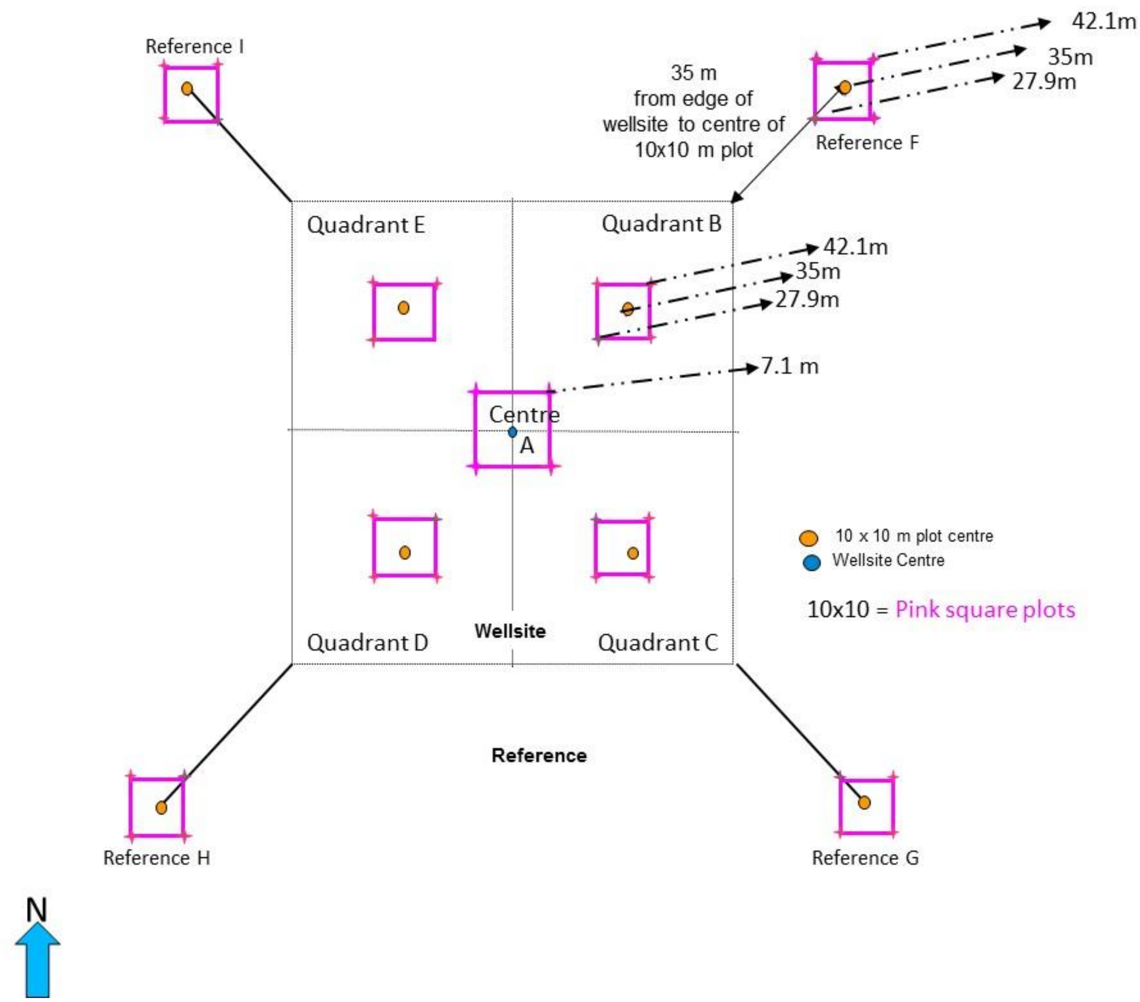


Fig. 1. Sampling layout of wellsites and adjacent reference sites, including identification of the square plots and pigtail placement for the 10x10 m (pink) plots, which are located within the four quadrants of the wellsite, wellsite centre (10x10 m plot), and the reference quadrants. Note: plot is not drawn to exact scale.

C. Site Sketch – Human Disturbance

Field Equipment Needed:

- *Datasheets 2A and 2B*

Procedure:

- Disturbances within the wellsite and reference sites are hand drawn based on what is observed 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, the diagram is reviewed to ensure that it accurately reflects the true size and shape of the human disturbances.

D. Site Photographs

This protocol is designed to provide permanent pictures of the site.

Field Equipment Needed:

- *Digital camera with extra batteries and charger if appropriate*
- *Some item, e.g., backpack for scale*
- *Datasheet 3*

Procedure:

- Use a digital camera with a 35 mm focal length and a quality setting of at least 3 Mega-pixels. Use "landscape" orientation.
- Take five photographs at each wellsite, and take five photographs of the reference site.
- Include a backpack 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 3.

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 3.

***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 [CUL]_[year]_[site]_"W"or"R"_[quadrant].jpg (e.g., CUL_2015_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.

All photos are to be copied to an office computer or an external hard drive/flash key for backup regularly

2. VEGETATION SAMPLING

A. Classification of Upland Vegetation Types – (copied from Alberta Environment 2010)

Cultivated Lands include lands managed under conventional, minimum or zero till practices for agricultural purposes. Land use changed from peatland, forested land or grassland to cultivated land is included. The cultivated land criteria also apply to trees planted for agroforestry (i.e., tree farms), tame forages, tame pasture, hay lands or areas seeded to perennial agronomic species.

For cultivated lands, there is no ground sampling of vegetation conducted. Instead crop yield data are used, so there are no vegetation sampling protocols included.

3. SOIL SAMPLING

This chapter describes the field-based protocols for sampling of soil indicators. Soil sampling should be conducted at 10x10 m plots only after all other sampling has been done at the sites to minimize the effects of the destructive sampling on the other measured indicators. Most of the lab analysis that will then be conducted on the samples is not described in detail in these protocols.

A. Description of number of samples, depths, and frequency

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. 2 & 3). Compositing samples to reduce analysis cost is suggested 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 the 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.

It is suggested that the bulking of samples should not be conducted in the field since it is unclear whether proper mixing is done. Preferably, samples should be stored separately and bulking should be done in the laboratory after they have been air-dried and ground to 2 mm and bulk density has been measured.

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, it will not be monitored for 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. EC and pH will also be monitored 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. 2).

Sampling Frequency

It is recommended 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. 3). Each sampling point will be located a minimum of 1 m apart from the previous sampling location.

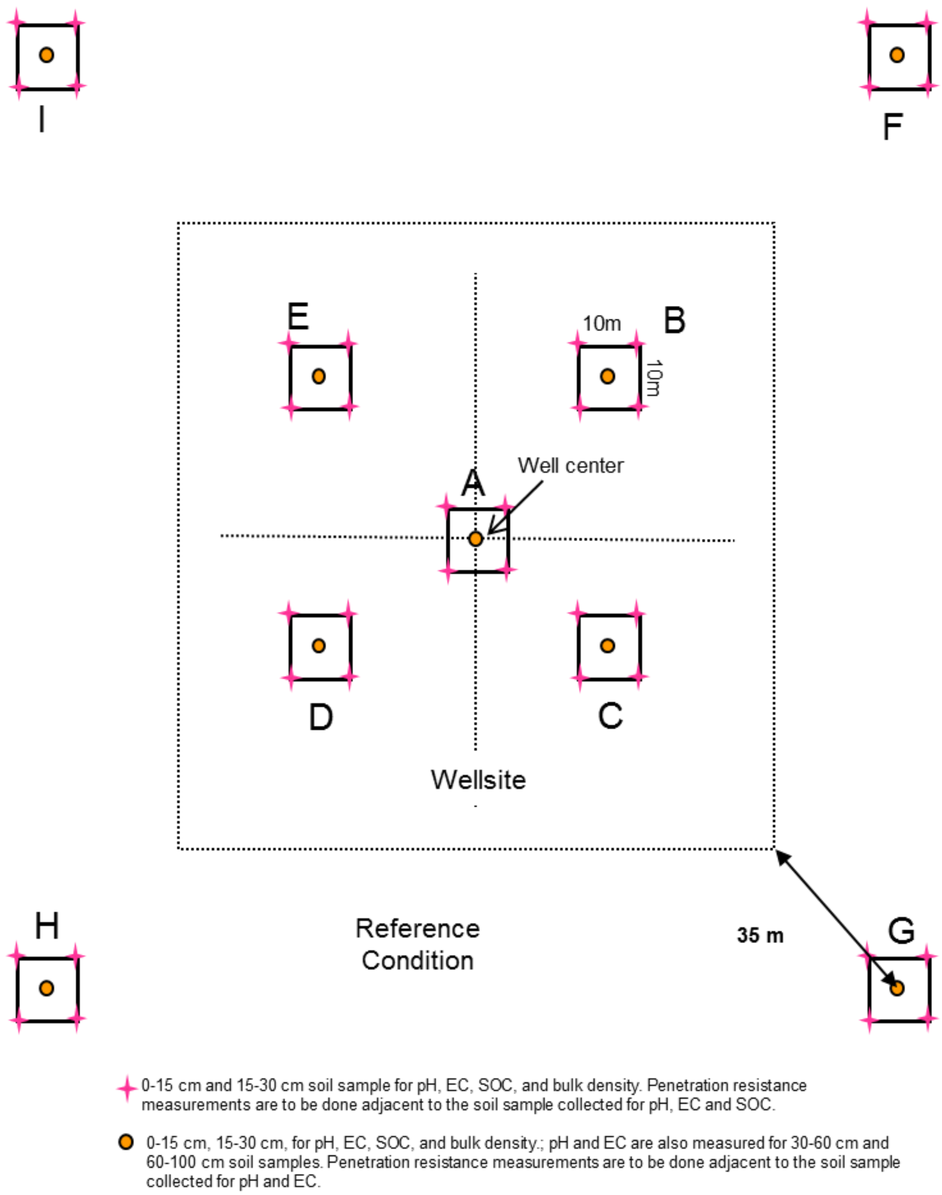


Fig. 2. The soils indicators are sampled within the 10x10 m plots identified in the diagram.

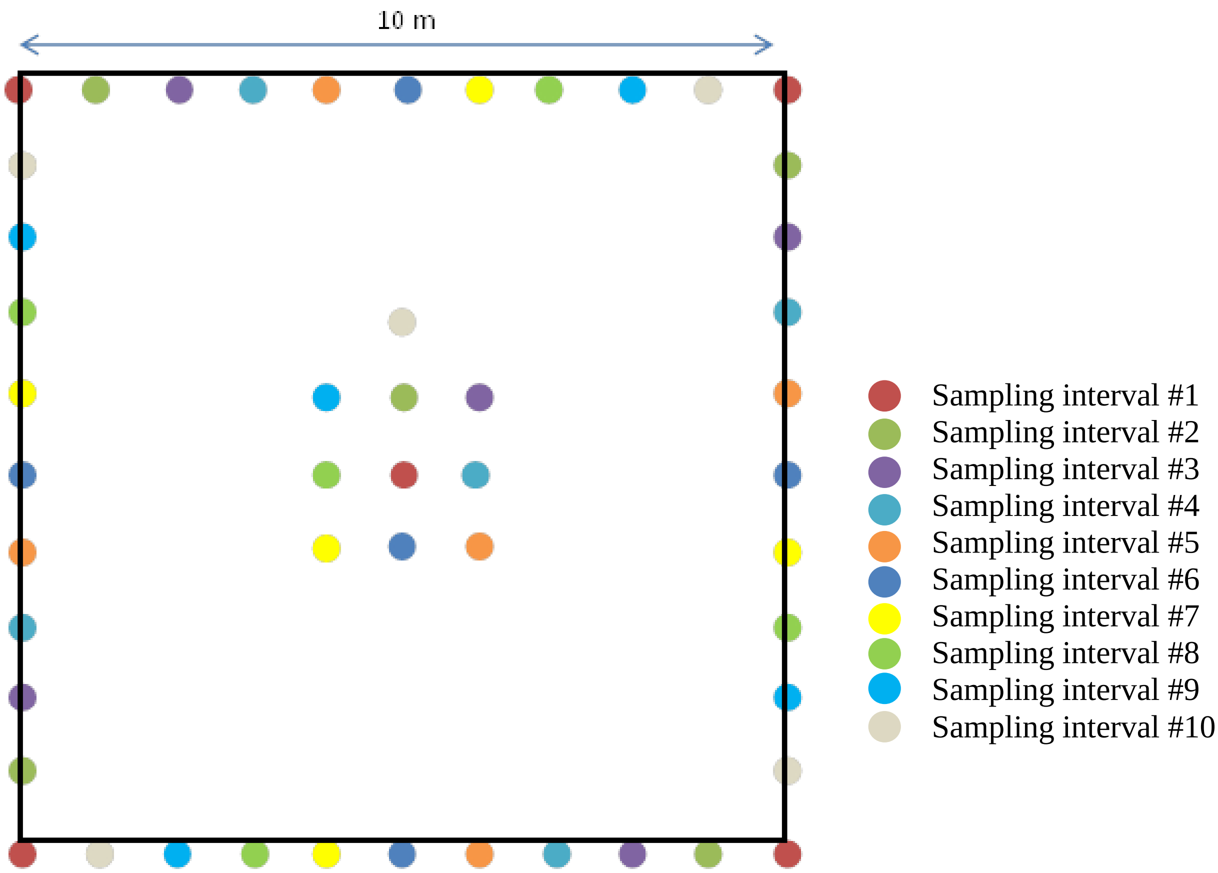


Fig. 3. Sampling layout within each 10x10 m plot on the wellsite and reference sites. Each color represents a different sampling interval, for a total of 10 sampling intervals.

B. Sample bag preparation – done in the lab prior to field season

Equipment needed:

- 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 - preprinted with the required information)
-

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 should be done in the laboratory before the samples are obtained to improve efficiency while in the field). Organize labeled samples into batches for individual quadrants within individual sites.

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 the excavation method is recommended.

Core Method (preferred method)

A double-cylinder, drop-hammer sampler with a liner core is designed to collect an undisturbed soil sample (Fig. 4). 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 range 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) (pre-labeled in the lab)
- Shipping tag labels (pre-labeled) – insert between the two 7 pound plastic bags.(pre-labeled in the lab)
- Pam cooking spray
- Tape measure (used to measure starting and ending depths of excavation
- **Datasheet #4**

Lab Equipment Needed:

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

Fig. 4. AMS Inc. double-cylinder, drop-hammer soil core sampler.

Procedure:

Lab (pre-sampling)

2. 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 should be done in the laboratory before the samples are obtained to improve efficiency while in the field). Organize labeled samples into batches for individual quadrants within individual sites.

Field

3. Select a smooth and relatively undisturbed surface at the appropriate sampling point.
4. Record the starting prior to driving the core sampler into the ground and then record the ending depth after the core has been retrieved on **Datasheet #4.**
5. 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.
6. 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. Any deviation from the original sampling scheme will be recorded by the field staff.
7. Store the sample in pre-labeled double-bagged 7 lb polyethylene bags. Store in large durable plastic bag for transport.

Lab (post-sampling):

8. 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. This information along with the volume of the core sampler liner can be used to calculate bulk density.

Excavation method (least preferred)

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. The volume of the excavation is determined by lining the hole with plastic film and filling it completely with a measured volume of water (or sand, or silicon beads). Coarse fragments (diameter > 2 mm) are sieved out and bulk density is calculated 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)

The digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter) can be used to measure soil resistance (Fig. 5). 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 penetration resistance is measured on site, we recommend taking at least three measurements for each discrete measurement point with the digital penetrometer.

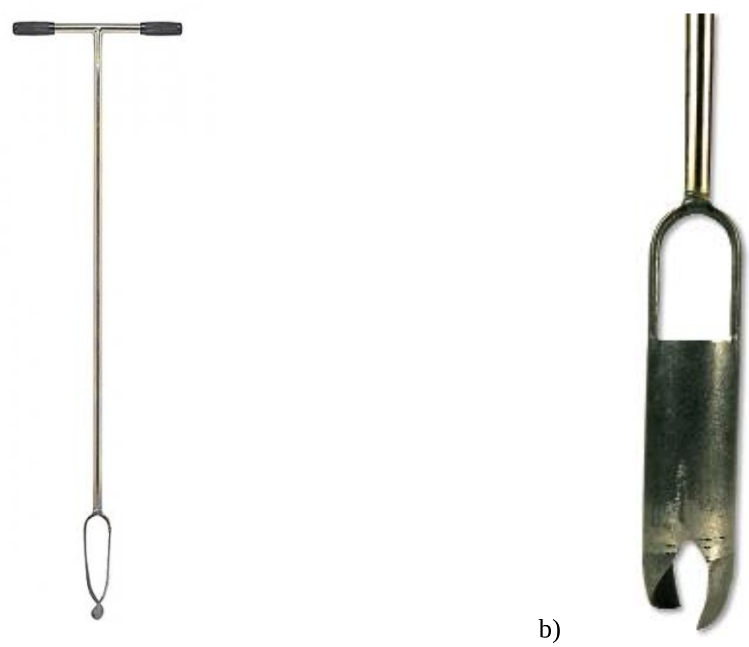
Fig. 5. Digital penetrometer (Spectrum Technologies FieldScout SC 900 Soil Compaction Meter).

E. Soil Organic Carbon, EC and pH

Soil organic carbon, EC and pH can be analyzed 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. 6a for dry, coarse textured soil and Dutch auger shown in Fig. 6b 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



a) b)

Fig.6. a) Dutch auger and b) Bucket auger

Procedure:

1. (In the lab) Before sampling, label bags with sample name, sampling date, location and soil depth (see soil labeling information described above).
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 that were 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 the desired depth is reached. 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 1.

Table 1. 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

F. Soil Mesofauna Sampling

Additional soil samples are to be obtained for the evaluation of soil mesofauna. Samples will be taken from the top 5 cm (0-5 cm) of the soil, including any surface litter. Samples should be collected at the start of each site survey as excessive surface trampling will disturb the fauna.

Equipment needed:

- Waterproof labels
- Pencils
- Soil corer, plunger, core tray (supplied by Stantec)
- Cooler
- Ice/cold packs

- Small Ziploc bags
- Measuring tape
- Knife

Procedure:

1. In the field, collect one (1) soil core 50 cm due north of the center soil sample point of each 10x10 m plot.
   - Soil fauna sample to be collected before any other sample work is completed or from a undisturbed location.
   - Total fauna samples collected at each wellsite will be 9 (5 onsite and 4 offsite).
   - Samples are **NOT** composite samples.
   - Total samples per week will be 9 samples x 5 wellsites = 45 samples
   - Total samples collected will be 9 samples x 30 wellsites = 270 samples
2. Push core from bottom out onto core tray using plunger.
3. Measure and remove top 0-5 cm section of soil core from tray. Try to keep core intact as much as possible.
4. Place section into medium Ziploc freezer bag.
5. Fill in data label in pencil. Use sample labeling scheme as rest of site but include "**- fauna**" on label.
6. Put data label into Ziploc bag with soil core sample. Make sure to leave air in the bag.
7. Place sample in cooler with ice, separated by newspaper.
8. Store samples in cooler or at 4^{o}C prior to extraction.

G. Soil Proximal Sensing – OpticMapper (Veris® Technologies)

The Veris® OpticMapper is a mobile instrument able to estimate percent organic matter (OM) and CEC underneath crop residue and dry surface soil by use of dual-wavelength optical and electrical conductivity (EC) sensors. This instrument is an on-the-go proximal sensor with a soil mapping platform that can be pulled by either a truck or tractor (Small and Underwood, 2015). The dual-wavelength optical sensor measures reflectance for estimating OM near the surface of the soil. The six coulter electrodes, map shallow (8 cm) and deep (30 cm) electrical resistance, simultaneously for estimating CEC. The EC array measurements are dependent on soil texture; soils with lower resistance allow for deeper arrays. The OpticMapper data permits the generation of site-specific maps matched to specific global positioning system (GPS) locations (Small and Underwood, 2015).

Equipment needed:

- OpticMapper Instrument
- Soil corer
- Sampling bags

Sensor Set-Up and Use (Small and Underwood, 2015):

The main components of the OpticMapper include the top link, row unit, controller, and EC coulter electrodes. There are two mounting options for the OpticMapper implement; the 3 point mount or the pull-tongue mount. If using the pull-tongue mount, ensure that the truck hitch is at the correct height to make the draw bar level. Additionally, turn the top link to adjust the tilt to ensure that the unit runs level. When using the 3 point mount, use the tractor to set the correct tilt by adjusting the mount. This is the optimal setting for all field conditions. It is important to check the integrity of the sapphire window in addition to the wear plate that houses the sapphire window for damage prior to use. Both are located in the row unit.

Soil Sampling and Sensor Calibration (Small and Underwood, 2015):
The OpticMapper instrument should be aligned with directional groundcover and farming implements, if substantial on-site. If this is not a consideration of importance, the north-south or east-west instrument orientation should be used for sampling.

For sites of low variability, an increased level of precision may not be necessary and 20 m passes are recommended as the minimum requirement. A reduced resolution (i.e. 20 m passes) may also be adequate for the continued monitoring and assessment of the same site over time. For heterogeneous sites and sites that are not well understood, increased soil passes (10 m maximum) and/or cross-hatching is recommended to permit a more thorough characterization of the site.

The OpticMapper sensor data must be calibrated using laboratory analyzed soil samples, taken from areas of both high and low % OM. Soil samples should be composited from 3 to 5 cores taken from the upper 15 cm of the soil to capture the range of instrument electrical arrays. Soil sampling should be done after the mapping is completed on the site; the SoilViewer software will identify adequate locations for soil sampling based on the greatest contrast in EC and reflectance on site. For the most optimal calibration, soil samples should be taken in areas of highest and lowest reflectance, as determined by the optical sensor. To do this in the field, the reflectance maps should be used to determine the high and low reflectance areas.

Appropriate data files should be emailed to the Veris® Data Processing Center (DPC) for a nominal fee ($0.25/acre) to conduct data quality review and calibration (omdata@veristech.com). Data will be processed using proprietary Veris® software algorithms for quantitative assessment. The DPC will also calibrate the sensor readings to CEC and OM laboratory results, generating EC and OM maps for each site.

4. MANAGING PERSONNEL, DATA QUALITY AND INTEGRITY

This chapter provides background information related to the number of individuals needed to collect the data, the training field staff should receive prior to data collection, how datasheets should be 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 entry of data after it has been collected.

A. Personnel and Sampling

These data collection protocols are optimally designed to be implemented by a field crew of 2 personnel working together or, at times, semi-autonomously. At least one of the field crew members should be familiar with reclamation and reclamation practices and regulations. The sampling should take place in late summer/early fall after the cultivated crops have been removed (i.e., after harvest).

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 that will be encountered, as well as conducting data collection at test sites. Crew members 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. Questions that arise during the training are discussed with the field supervisors. When possible, this training is provided by experts in the field. To ensure that data collection remains accurate throughout the field season and nothing is being missed, field crews are to review the protocols regularly.

C. Field Preparation Prior to Data Collection

The plastic bags and labels for the soil sample collecting should be completed 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, crews are instructed 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. “None” is used for text entries and “0” is used for numerical entries. For example, when field crews examine the canopy and find no “Veteran” trees in the canopy, this is to be recorded as “None”. When there is no slope at the site, this should be recorded as “0”. “0” can also be used as a code – for example, wind conditions can be recorded as “0”.

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

Data sheets must be checked every evening for legibility and completeness. If data on a sheet cannot be corrected so they are legible, the data must be transcribed onto a new data sheet and both copies filed. 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). Data sheets from one site cannot be taken to the field at another site. Crews must re-collect lost or missing data.

F. Transferring Field Data Sheets to a Secure Location

Data sheets are transferred 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 are not allowed to leave the secure office.

G. Processing of Specimens and Samples

Specimens and samples and datasheets are transported by crew members back to Edmonton – soil samples are processed at AITF – Mill Woods.

H. Data Entry and Verification

Data are entered into an electronic database. If data are entered at a different location than they are stored the data sheets are photocopied or scanned and data entry occurs from the copies. Data entry is verified by comparing the electronic information against the information on the original data sheet. Electronic verification routines are performed on the database to ensure that data are consistent with the allowable codes and among sites.

REFERENCES

Alberta Biodiversity Monitoring Institute. 2010. Terrestrial field data collection protocols (10001), Version 2010-04-20. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at: abmi.ca

Alberta Environment. 2006. Alberta Environment Land Monitoring Program Inventory and Needs Analysis. Alberta Environment, Edmonton, AB. T/861. 70 pp.

Alberta Environment, 2010. 2010 Reclamation Criteria for Wellsites and Associated Facilities for Native Grasslands Alberta Environment, Edmonton, Alberta. 125 pp.

Alberta Sustainable Resource Development. 2003. Ecological Land Survey Site Description Manual (2nd edition). Alberta Sustainable Resource Development, Edmonton, AB. T/036. 112 pp.

Barbier, S., Gosselin, F., and Balandier, P. 2008. Influence of tree species on understory vegetation diversity and mechanisms involved - a critical review for temperate and boreal forests. Forest Ecology and Management **254**: 1–15.

Blake, G.R., and K.H. Hartge. 1986. Bulk density, p. 363-375, *In* A. Klute, ed. Methods of Soil Analysis, Vol. 9. American Society of Agronomy, Madison, WI.

Blaylock, A.D., L.R. Bjornest, and J.G. Lauer. 1995. Soil probe lubrication and effects on soil chemical-composition. Communications in Soil Science and Plant Analysis 26:1687-1695.

Busscher, W.J. 1990. Adjustment of flat-tipped penetrometer resistance dta to a common water content. Transactions of American Society of Agricultural Engineers 33:519-524.

Campbell, D.J., and J.K. Henshall. 2001. Bulk density p. 315-348, *In* K. A. Smith and C. M. Mullins, eds. Soil and Environmental Analysis: Physical Methods. Dekker, New York, NY.

Carey, A.B., and Johnson, M.L. 1995. Small mammals in managed, naturally young, and old-growth forests. Ecological Applications **5**(2): 336-352.

Carter, R.E.L., L E. 1986. Lateral variability of forest floor properties under second-growth Douglas-fir stands and the usefulness of composite sampling techniques. Canadian Journal of Forest Research/Revue Canadienne de Recherche Forestiere 16:1128-1132.

Cathcart, J., K. Cannon, and J. Heinz. 2008. Selection and establishment of Alberta agricultural soil quality benchmark sites. Canadian Journal of Soil Science 88:399-408.

EBA Engineering Consultants Ltd. 2012. Reclaimed Benchmark Monitoring Protocol Design, Phase I: Literature Review and Evaluation of Indicators. Prepared for: Alberta Environment and Water. EBA File: E22201195.

Ellert, B.H., H.H. Janzen, A.J. VandenBygaart, and E. Bremer. 2006. Chapter 3: Measuring change in soil organic carbon storage, *In* M. R. Carter and E. G. Gregorich, eds. Soil Sampling and Methods of Analysis. CRC press, Boca Raton, Fl.

Gilliam, F.S. 2007. The ecological significance of the herbaceous layer in temperate forest ecosystems. BioScience **57**: 845-858.

Grossman, R.B., and T.G. Reinsch. 2002. Bulk density, p. 201-228, *In* J. H. Dane and G. C. Topp, eds. Methods of Soil Analysis, Part 4 - Physical Methods. Soil Science Society of America, Madison, WI.

Hannam, K., Quideau, S., and Kishchuk, B. 2006. Forest floor microbial communities in relation to stand composition and timber harvesting in northern Alberta. Soil Biology & Biochemistry **38**(9): 2565-2575.

Hart, S.A., and Chen, H.Y.H. 2006. Understory vegetation dynamics of North American boreal forests. Critical Reviews in Plant Sciences **25**: 381–397.

Légaré, S., Bergeron, Y., and Paré, D. 2002. Influence of forest composition on understory cover in boreal mixedwood forests of western Quebec. Silva Fennica **36**(1): 353–366.

Lieffers, V.J., Macdonald, S.E., and Hogg, E.H. 1993. Ecology of and control strategies for *Calamagrostis canadensis* in boreal forest sites. Canadian Journal of Forest Research **23**: 2070-2077.

Macdonald, S.E., and Fenniak, T.E. 2007. Understory plant communities of boreal mixedwood forests in western Canada: natural patterns and response to variable-retention harvesting. Forest Ecology and Management **242**(1): 34-48.

Mapfumo, E., and D.S. Chanasyk. 1998. Guidelines for safe trafficking and cultivation, and resistance-density-moisture relations of three disturbed soils from Alberta. Soil & Tillage Research 46:193-202.

Maynard, D.G.C., M P. 2006. Bulk density measurement in forest soils, *In* M. R. Carter and E. G. Gregorich, eds. Soil Sampling and Methods of Analysis. CRC Press, Boca Raton, Fl.

McIntosh, A.C.S. 2012. The ecology of understory and below-ground communities in lodgepole pine forests under changing disturbance regimes. PhD Dissertation, Dept of Renewable Resources. University of Alberta, Edmonton, AB, Canada.

Miller, J.J., and D. Curtin. 2006. Electrical conductivity and soluble ions *In* M. R. Carter and E. G. Gregorich, eds. Soil Sampling and Methods of Analysis. CRC Press, Boca Raton, Fl.

Naeth, M.A., D.J. White, D.S. Chanasyk, T.M. Macyk, C.B. Powter, and D.J. Thacker. 1991. Soil physical properties in reclamation ISBN 0-7732-0880-1, Edmonton, AB. RRTAC91-4. 216pp.

Nilsson, M.-C., and Wardle, D.A. 2005. Understory vegetation as a forest ecosystem driver: evidence from the northern Swedish boreal forest. Frontiers in Ecology and Environment **3**(8): 421-428.

Prescott, C.E. 2002. The influence of the forest canopy on nutrient cycling. Tree Physiology **22**: 1193–1200.

Rowell, M.J., and L.J. Florence. 1993. Characteristics associated with differences between disturbed and industrially-disturbed soils. Soil Biology and Biochemistry 25:1499-1511.

Shukla, M.K., R. Lal, and M. Ebinger. 2006. Determining soil quality indcators by factor analysis. Soil and Tillage Research 87:194-204.

Small, C., and Underwood, A. 2015. Development of standard operating protocols for soil proximal sensing technology in long-term reclamation monitoring. Prepared for Alberta Environment and Sustainable Resource Development. Edmonton, AB. 74 pp.

Vazquez, L., D.L. Myhre, E.A. Hanlon, and R.N. Gallaher. 1991. Soil penetrometer resistance and bulk density relationships after long-term no tillage. Communications in Soil Science and Plant Analysis 22:2101-2117.

Work, T.T., Shorthouse, D.P., Spence, J.R., Volney, W.J.A., and Langor, D. 2004. Stand composition and structure of the boreal mixedwood and epigaeic arthropods of the ecosystem management emulating natural disturbance (EMEND) landbase in northwestern Alberta. Canadian Journal of Forest Research **34**: 417-430.

APPENDICES

Appendix 1: Example of an Access Data Sheet/Information Packet for the field.

There is no single way to present this information – you could collect it differently if you prefer – just so long as you can access the site with the information provided (e.g., using Google Maps and/or directions from a farmer).

Example 1.

Ecological Recovery Monitoring Program **Reclamation SITE: R24**

Access Description

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

Maps Where Access Is Recorded

1:24,000 Map ________________________

1:62,500 Map ___X___________________

Direction & Distance to Nearest Town

_____Approx. 50KM NE of Slave Lake_

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**

1 – record decimal degrees (5 decimals)

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

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

Example 2. A more detailed example of the information package that is prepared in the office prior to visiting a field site for ERM field crew members:

Site 10-6: PWEI ET AL 03 GRDFKS 15-21-11-12

Age post certification	UTM Easting	UTM Northing	Spud Date	License
12	458172	5530943	Aug. 9 1994	0169162

CONTACT INFO: Note that the contact person for the grazing lease is Rick Nielson 403-546-6614. Contact 2 days before, says no access if livestock in field (may let you go though).
GROUND DISTURBANCE INFO: There does not appear to be any ground disturbance issues. Anne will confirm through Albertaonecall 3 days prior to you going in the field.

3. Take the **Trans canada Highway E/AB-1 E** ramp to **Medicine Hat**
750 m

4. Merge onto **AB-1 E**
8.6 km

5. Turn right onto **AB-875 S** (signs for **Rolling Hills/Alberta 875 S**)
33.4 km

6. Turn right to stay on **AB-875 S** (signs for **Rolling Hills/Hays**)
700 m

7. Take the 1st left to stay on **AB-875 S** (signs for **Hays**)
15.0 km

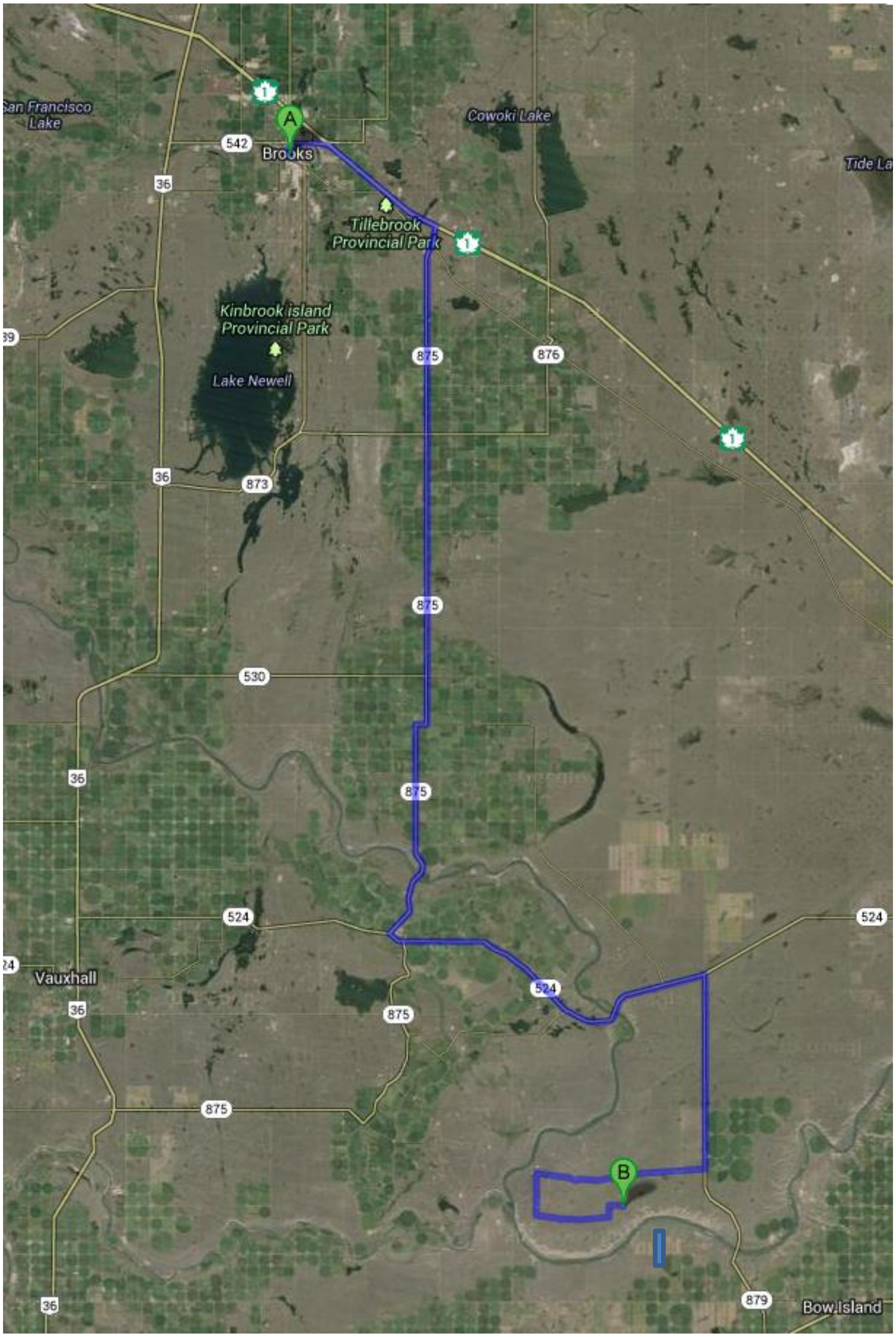
8. Turn left onto **AB-524 E/AB-875 S** (signs for **Bow Island/Hays**)
Continue to follow AB-524 E
24.5 km

9. Turn right onto **AB-879 S** (signs for **Bow Island**)
13.2 km

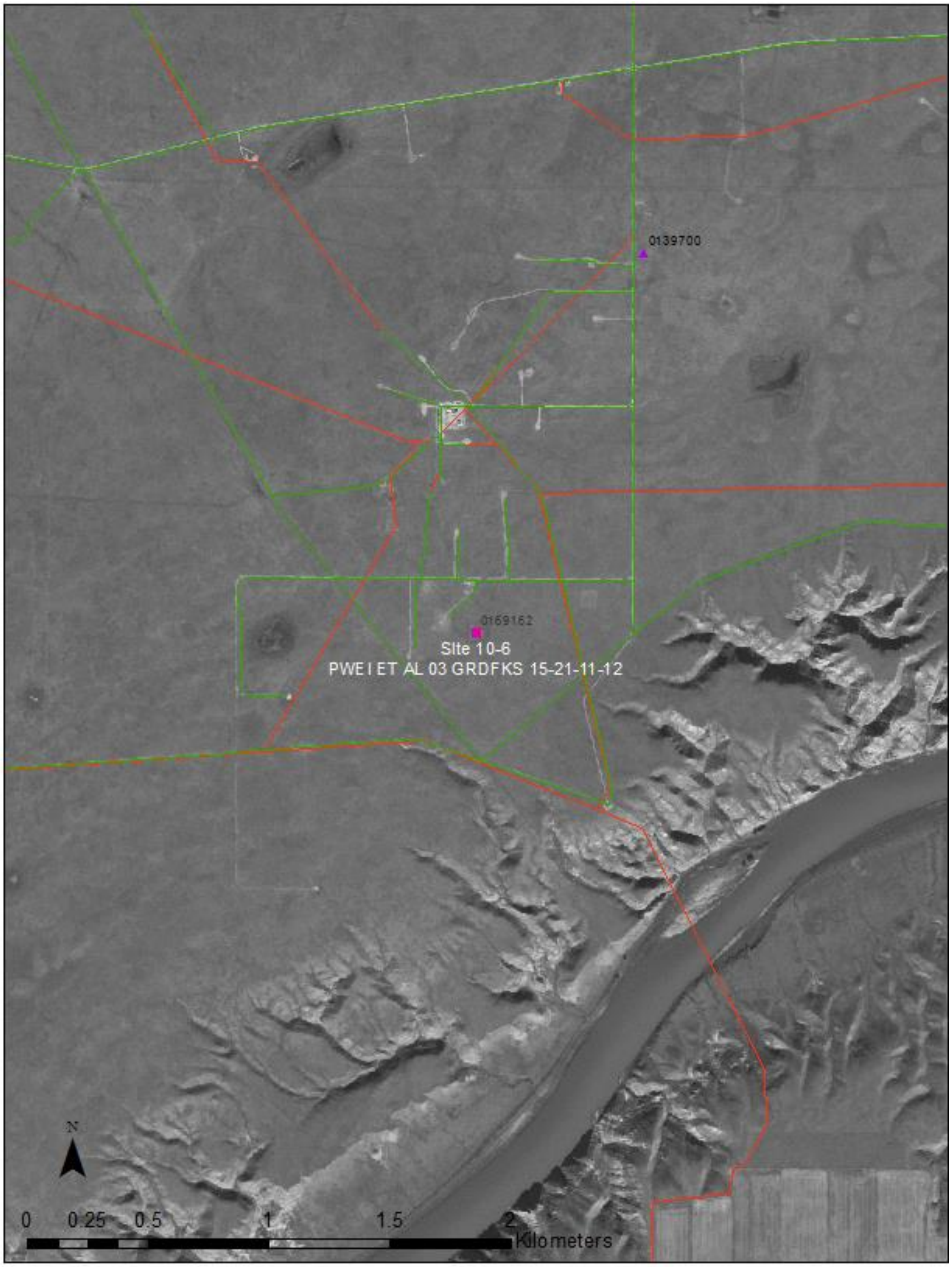
10. Turn right toward **Range Rd 123**
4.9 km

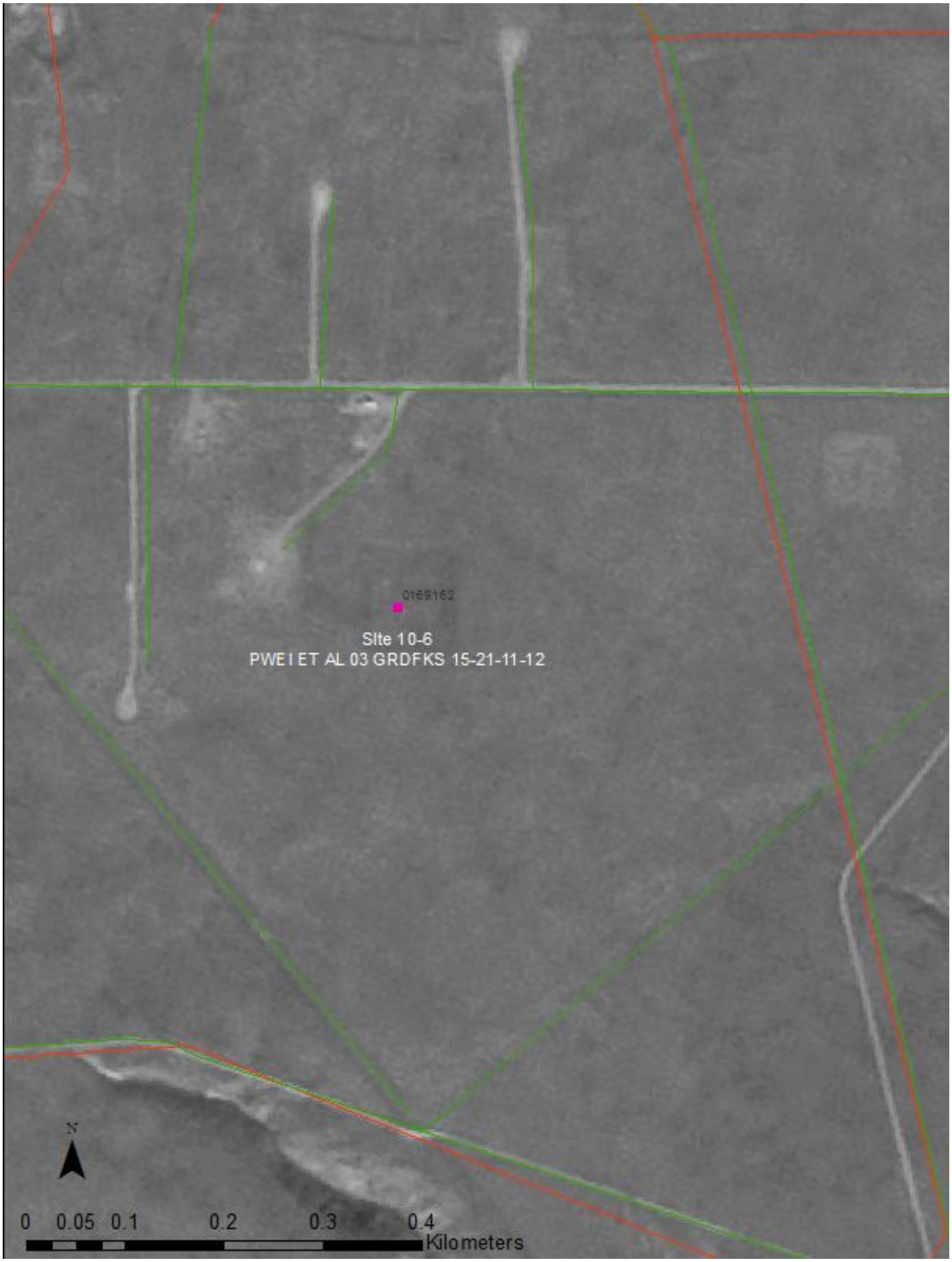
11. Turn left onto **Range Rd 123**
2.1 km

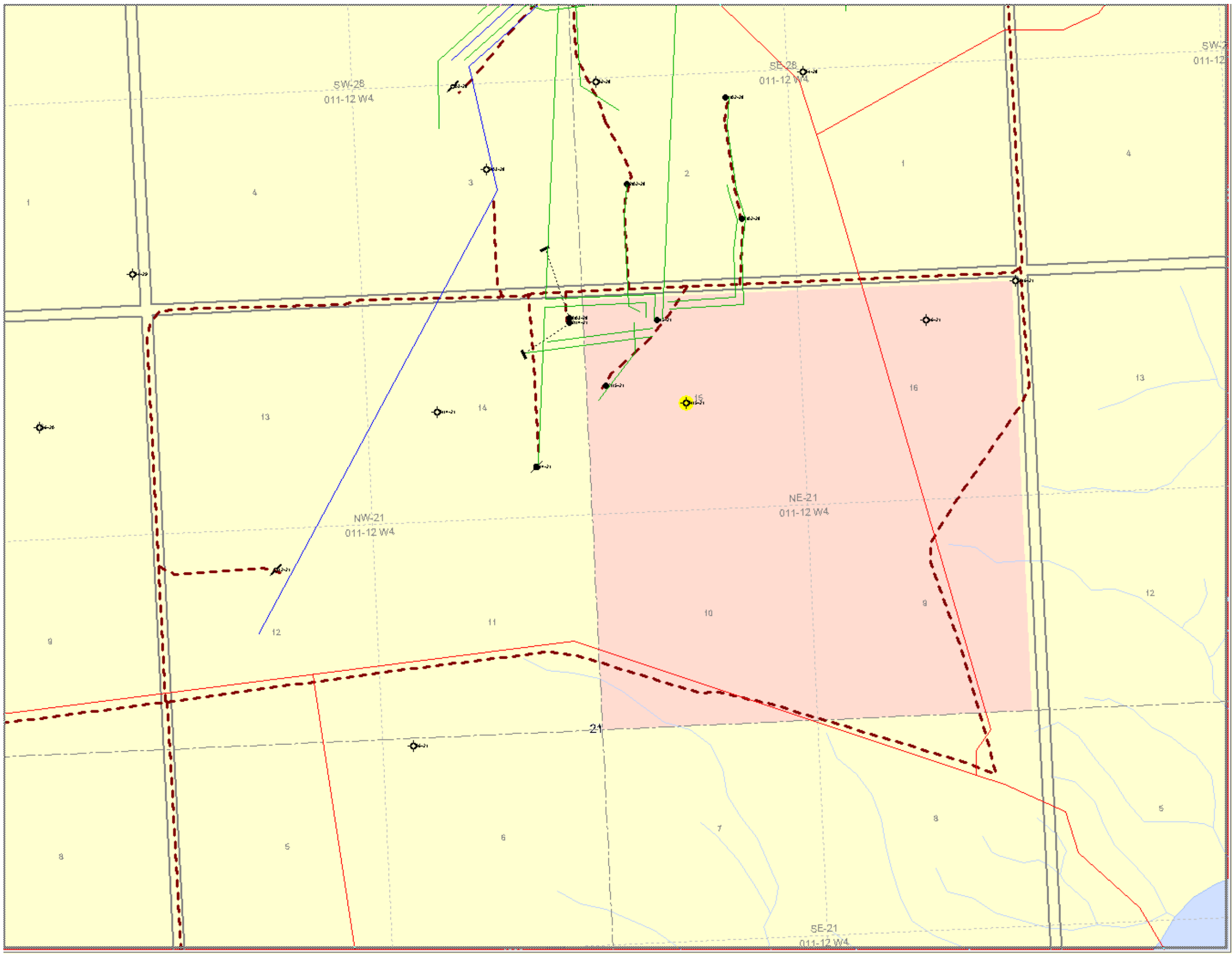
12. Turn right onto unnamed road. 0.7 km
13. Turn left onto unnamed road. ~ 150 m.


San Francisco Lake
Cowoki Lake
Tide La
542
Brooks
36
Tillebrook Provincial Park
Kinbrook Island Provincial Park
Lake Newell
875
876
873
530
524
Vauxhall
879
Bow Island
A
B


879
B
879


0139700
0169162
SIte 10-6
PWE I ET AL 03 GRDFKS 15-21-11-12
N
0 0.25 0.5 1 1.5 2
Kilometers

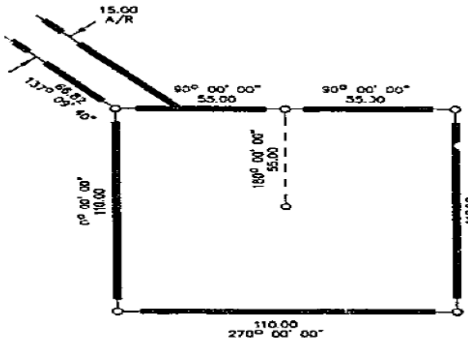

0169162
SIte 10-6
PWEI ET AL 03 GRDFKS 15-21-11-12
N
0 0.05 0.1 0.2 0.3 0.4
Kilometers



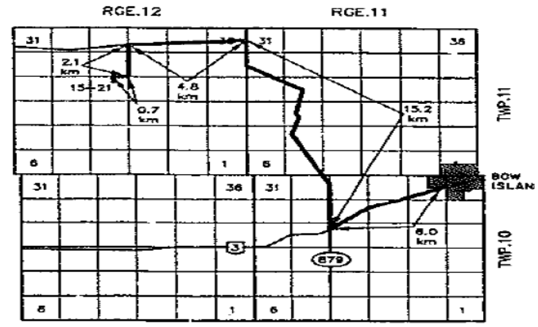
WELL INFORMATION
CURRENT TO MAY 31, 2013

EVENT: 0

WELL ID:	03 / 15-21-011-12 W4 / 0		RecCertified
LICENCE #:	0169162	**LICENCE DATE:**	AUGUST 2, 1994
WELL NAME:	PWEI ET AL 03 GRDFKS 15-21-11-12		
WITHIN:	15-21-011-12 W4	**H2S (mol/kmol):**	NOT AVAILABLE
LICENCEE:	TAQA NORTH LTD.		
SPUD DATE:	AUGUST 9, 1994	**FINAL DRILL DATE:**	AUGUST 11, 1994
STATUS:	ABD	**ABANDONED DATE:**	AUGUST 13, 1994
SURFACE:		**DOWNHOLE:**	
OFFSETS:	S 210 W 630.9	OFFSETS:	S 210 W 630.9
LATITUDE:	49.929455	LATITUDE:	49.929455
LONGITUDE:	111.58264	LONGITUDE:	111.58264
GROUND ELEVATION:	794.7 m 2607 '	TOTAL DEPTH:	951 m 3120 '
WELL TYPE:	NOT AVAILABLE	**SUBSTANCE:**	NOT AVAILABLE



DETAIL
SCALE — 1:2000



ROUTE MAP
SCALE — 1:250000

N

PLAN SHOWING LOCATION OF

MORRISON ET AL 03 GRDFKS 15—21—11—12

IN LSD. 15 SEC. 21 TWP. 11 RGE. 12 W. 4 M.

I certify that the survey represented by this plan is correct and true to the best of my knowledge and was completed on the 20th day of June, AD 1994.

W.H.JONES ALS Witness

NOTES:

	Yes	No
The proposed well is at least 1.5 km from the corporate limits of a city, town or village.	☒	☐
The proposed well is outside any potential coal development area.	☒	☐
The proposed well is at least 5.0 km from a lighted aerodrome.	☒	☐
The proposed well is at least 1.6 km from an unlighted aerodrome.	☒	☐

There are no Registered Plans or Surface Improvements within 200 m of Well Centre other than shown.

REVISION

ALL—CAN ENGINEERING & SURVEYS (1976) LTD.

Job No. 94—0823 | Checked EFT | Date 22/06/94

SURFACE CO—ORDINATES · 210.00 S. OF N. Bdy and 630.9 W. OF E. Bdy of Sec. 21—11—12 W.4 M.

AREAS	ha	Ac
Well Site	1.210	2.99
Access Road	0.065	0.16
TOTAL	1.275	3.15

WELL SITE CORNER ELEVATIONS
NE · 794.25
SE · 793.85
SW · 794.74
NW · 795.88

GROUND ELEVATION · 794.7

LEGEND
Survey monument found shown thus
30cm Iron Spike planted shown thus
Portions referred to shown thus
Distances are in metres and decimals thereof.

SCALE · 1:5000

For MORRISON PETROLEUMS LTD.

Appendix 2. Equipment needed for field data collection.

Sampling design and layout
- Cellphone for communications
- 2-way radios for communications among partners
- Datasheets and clipboard
- Site maps
- Laptop with card reader to download images onto
- GPS and compass
- 45 pigtails to mark the 10x10 m plots and wellsite center within the wellsite and reference sites.
- 4 -100 m tapes, 4- 50 m tapes, and 4 – 30 m tapes.
- At least one color of flagging tape
- Fine tipped colored marker (to delineate polygons on human disturbance sketch)

Field Photos:
- Digital camera and batteries (or adapter depending on camera needs)
- Backpack for scale

Soil sampling core method:

Field equipment:
- Durable large plastic bags to store the samples from each site in
- Double-cylinder core sampler. The most common core diameter range 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! They have definitely broken in the past!
- 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
- 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 - preprinted with the required information)
- Pam cooking spray to coat the stainless steel liners so they don't get stuck (1 bottle per site – may not need – depends on whether samples regularly stick or not)
- 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
- Tape measure (used to measure starting and ending depths of excavation

Lab equipment:
- Analytical balance
- Drying oven capable of heating up to 105 °C
- 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. 6b.
- Dutch auger shown in Fig. 6a.

- 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(s) to help carry equipment and soil samples (or a sled works well on uneven terrain)
- 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 3: Datasheets for Field Data Collection.

Ecological Recovery Monitoring of Certified Reclaimed Wellsites in Alberta

Cultivated Lands Field Data Sheets

Version 2015-08-17

August 2015

Prepared for:
Arnold Janz, Alberta Environment and Sustainable Resource Development

Prepared by:
Alberta Biodiversity Monitoring Institute & Alberta Innovates Technology Futures

Field DataSheets Table of Contents

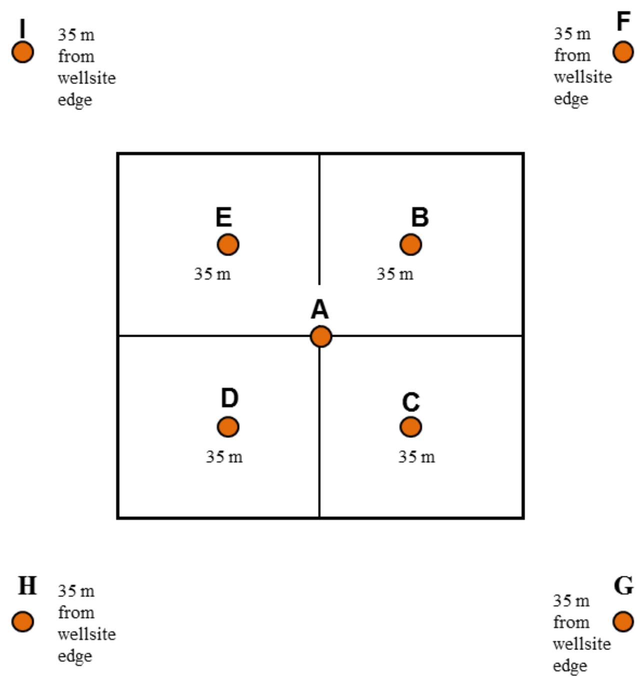
Ecological Recovery Monitoring of Reclaimed Wellsites

1. Site Coordinate Establishment – GPS Coordinates

Site:____________________________
Date: ____________________
Data collected by_______________________
Description of weather (e.g., overcast, sunny, raining):

	UTM coordinates[1]		Bearing [2] (0-359º)	Comments
Location	**Easting[2]**	**Northing[2]**		
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	

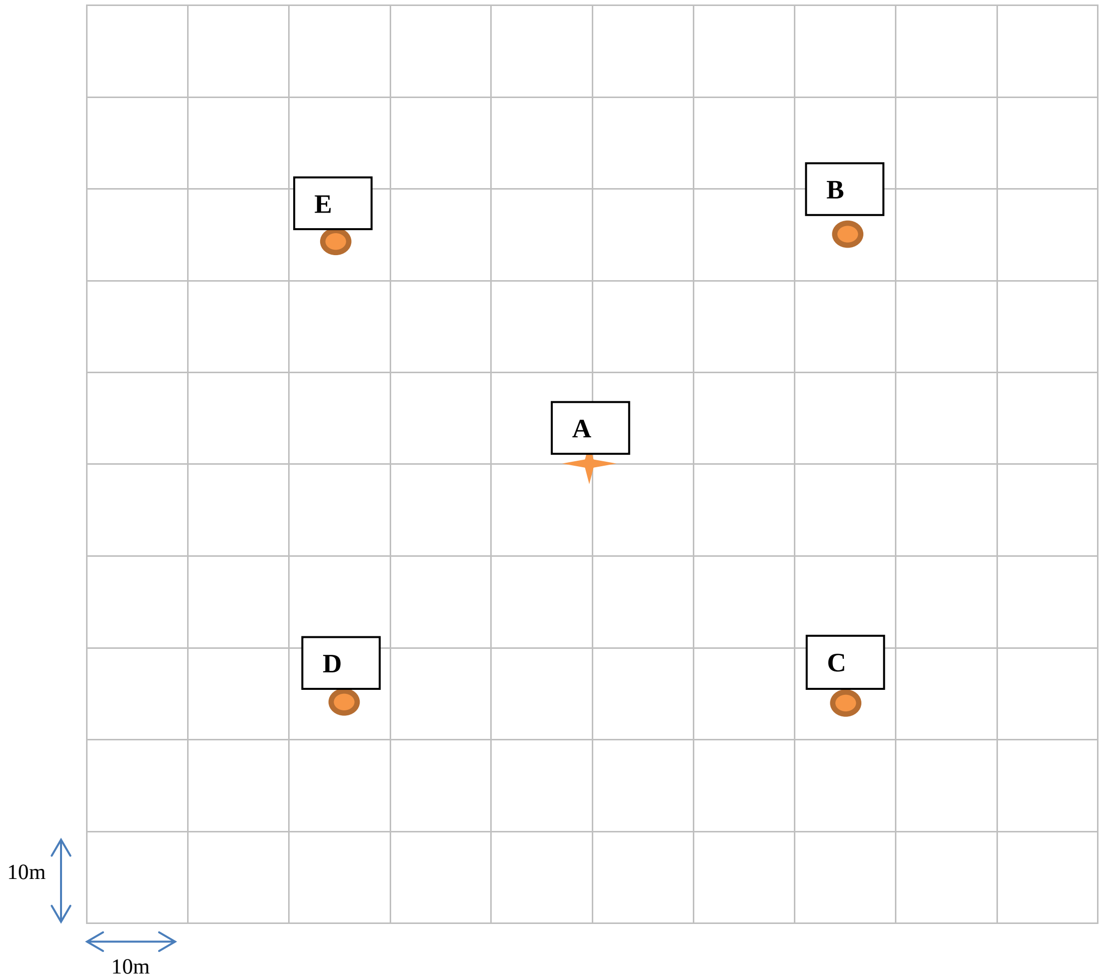
1 –Record coordinates when measuring out the site on the ground. Mark a waypoint and record the UTMS for each of the 9 plot centres listed.
2. – Record the bearing on your compass standing at wellsite centre of each of the four corners of the wellsite and record those bearings. Those will be the bearings for the 4 transects running from the wellsite centre to the wellsite corners.



2A. 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



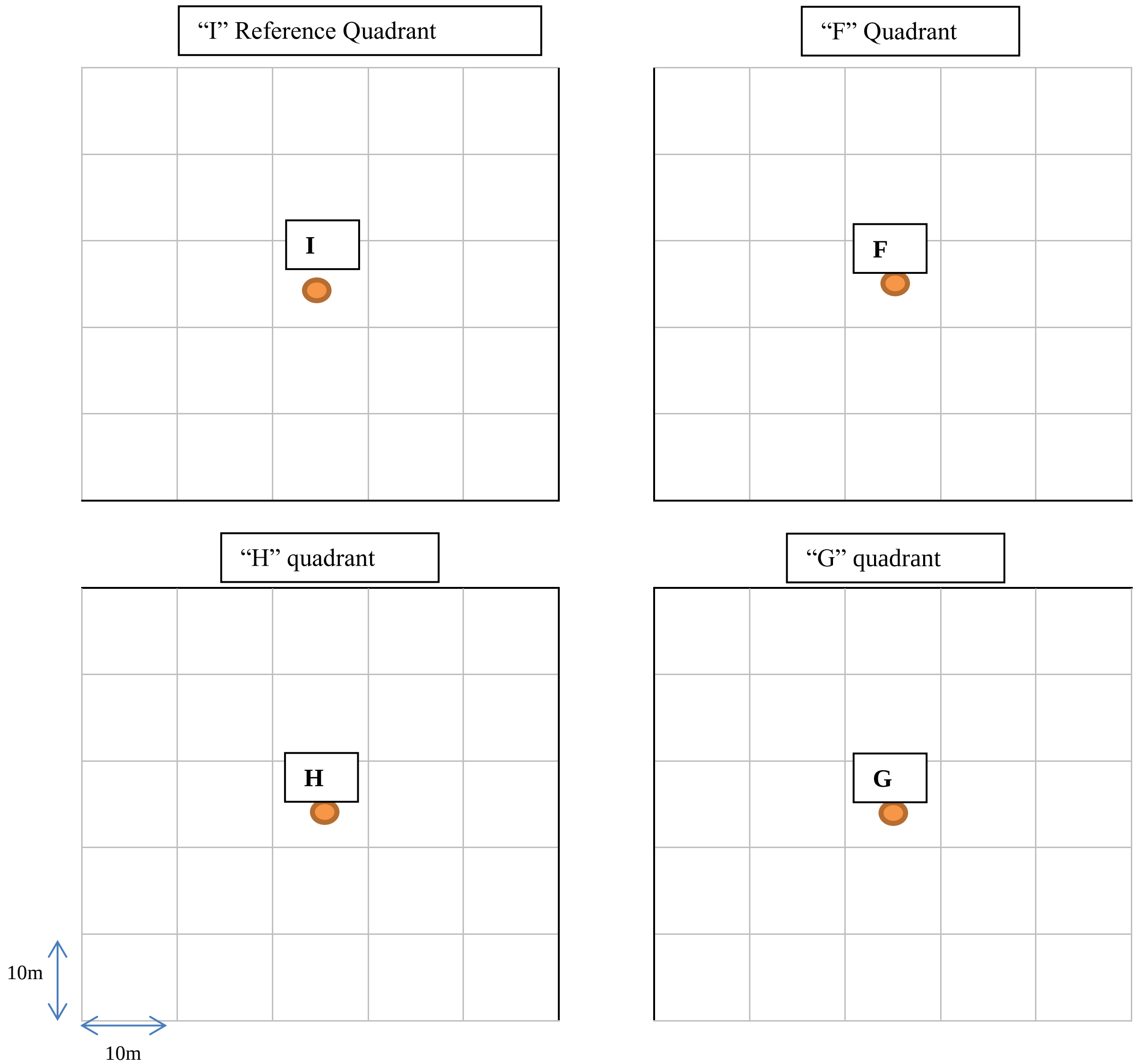
Human Disturbance Codes (in addition to the well pad disturbance which encompasses the entire wellsite):

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

2B. 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

3. Site Photos

Site:____________________________
Date:____________________________
Data collected by:_________________

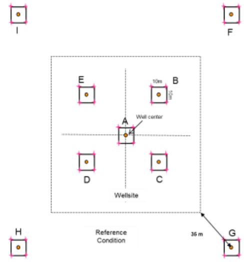
Which reference quadrant was selected as most representative of reference condition?_______________

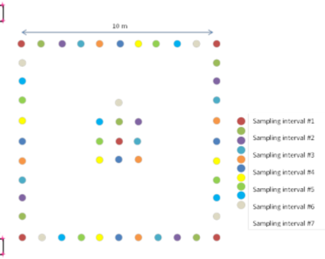
	Oriented in Direction of 10x10 m plot centre			
Site Photographs [1]	**B**	**C**	**D**	**E**
Wellsite Quadrant Photographs (Record Photo #)				
Wellsite Representative Photograph (Record Photo #)				
	From middle of each reference quadrant, facing in a single direction:			
	F	**G**	**H**	**I**
Reference 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 near corner of the 10x10 m plot of each of the four reference quadrants, and one representative site photo is taken from anywhere in the 1 ha reference area. 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.

Ecological Recovery Monitoring of Reclaimed Wellsites

4A. Soil Sample Collection





Site:______________________________

Date:_______________**Data collected by:**________________________

Sheet ___1__**of**__3___

	Profile Depth (cm)		Soil Mesofauna Sample	
Sample ID	Start	Finish		Comments/Topsoil Depth
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			n/a	
W-A-2-15			n/a	
W-A-3-0			n/a	
W-A-3-15			n/a	
W-A-4-0			n/a	
W-A-4-15			n/a	
W-A-5-0			n/a	
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			n/a	
W-B-2-15			n/a	
W-B-3-0			n/a	
W-B-3-15			n/a	
W-B-4-0			n/a	
W-B-4-15			n/a	
W-B-5-0			n/a	
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			n/a	
W-C-2-15			n/a	
W-C-3-0			n/a	
W-C-3-15			n/a	
W-C-4-0			n/a	
W-C-4-15			n/a	
W-C-5-0			n/a	
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			n/a	
W-D-2-15			n/a	

4A. Soil sampling cont'd

Site:____________________________
Date:________________**Data collected by:**________________________
Sheet __2___**of**__3___

	Profile Depth (cm)		Soil Mesofauna Sample	
Sample ID	Start	Finish		Comments/Topsoil Depth
W-D-3-0			n/a	
W-D-3-15			n/a	
W-D-4-0			n/a	
W-D-4-15			n/a	
W-D-5-0			n/a	
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			n/a	
W-E-2-15			n/a	
W-E-3-0			n/a	
W-E-3-15			n/a	
W-E-4-0			n/a	
W-E-4-15			n/a	
W-E-5-0			n/a	
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			n/a	
R-F-2-15			n/a	
R-F-3-0			n/a	
R-F-3-15			n/a	
R-F-4-0			n/a	
R-F-4-15			n/a	
R-F-5-0			n/a	
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			n/a	
R-G-2-15			n/a	

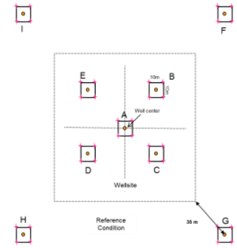
4A. Soil sampling cont'd

Site:____________________________
Date:_______________**Data collected by:**_______________________
Sheet __3___**of**__3___

Sample ID	Profile Depth (cm)		Soil Mesofauna Sample	Comments/Topsoil Depth
	Start	Finish		
R-G-3-0			n/a	
R-G-3-15			n/a	
R-G-4-0			n/a	
R-G-4-15			n/a	
R-G-5-0			n/a	
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			n/a	
R-H-2-15			n/a	
R-H-3-0			n/a	
R-H-3-15			n/a	
R-H-4-0			n/a	
R-H-4-15			n/a	
R-H-5-0			n/a	
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			n/a	
R-I-2-15			n/a	
R-I-3-0			n/a	
R-I-3-15			n/a	
R-I-4-0			n/a	
R-I-4-15			n/a	
R-I-5-0			n/a	
R-I-5-15			n/a	

Ecological Recovery Monitoring of Reclaimed Wellsites

4B. Penetration Resistance

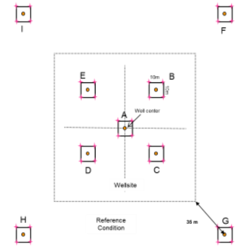


Site:____________________________
Date:_______________**Data collected by:**_______________________
Sheet _1__**of**___4__ Penetrometer model:____________________
Wind condition:____

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			
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

4B. Penetration Resistance cont'd

Site:_____________________________

Date:_______________**Data collected by:**________________________

Sheet __2__**of**__4___ Penetrometer model:____________________

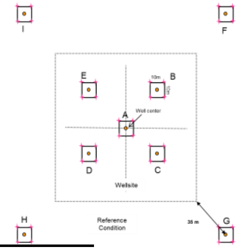
Wind condition:____

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	Start	Finish	Reading	Sample ID	Start	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



4B. Penetration Resistance cont'd

Site:___________________________

Date:______________**Data collected by:**______________________

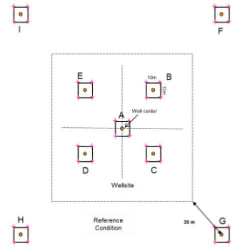
Sheet ___3__**of**__4___ Penetrometer model:___________________

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:



Ecological Recovery Monitoring of Reclaimed Wellsites

4B. 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				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:

5. OpticMapper Soil Sampling

Site:___________________________
Date:______________Data collected by:______________________
Was OpticMapper Calibrated on Site (circle)? Yes No
Number of OpticMapper Passes across the Site: ______________

OpticMapper Index Number	On/Off Site

<u>GPS Coordinates of Calibration Samples (On-Site):</u>

<u>GPS Coordinates of Calibration Samples (Off-Site):</u>

Appendix 4: "Cheat Sheets" that live in a separate power point file that can be used in the field to facilitate laying out of plots.

Ecological Recovery Monitoring of Certified Reclaimed Wellsites in Alberta

Field Data Plot Layout Cheat Sheets

Version 2015-08-17

August 2015

Prepared for:
Arnold Janz, AEMERA

Prepared by:
Alberta Biodiversity Monitoring Institute

These are the powerpoint slides that also live in a separate powerpoint file that can be used to help lay out plots. Copies of the slides with visuals can be printed out in color and laminated to be used in the field.

Plot Layout Pigtail Information

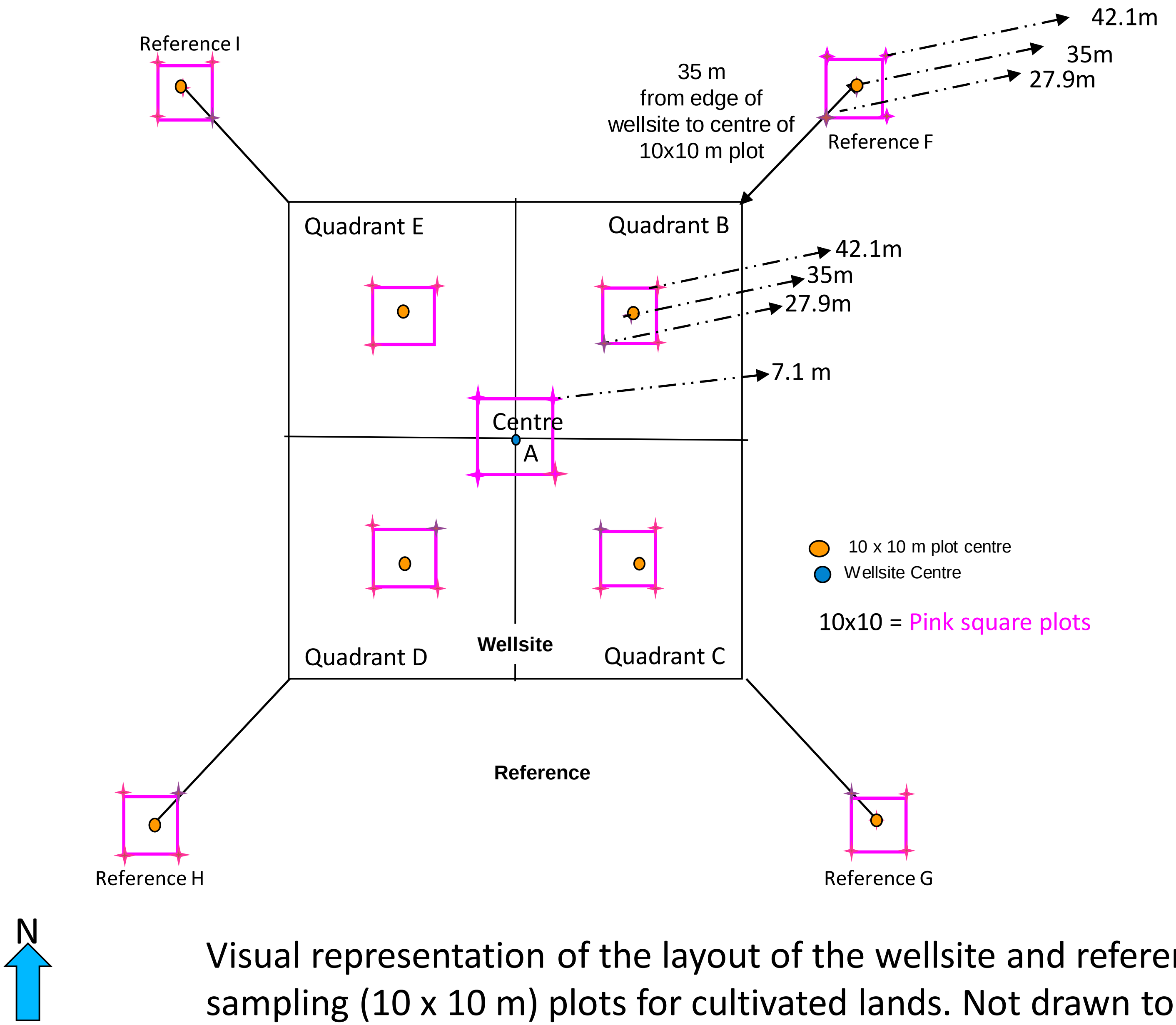
(requires 45 pigtails if laying out entire wellsite (n=25) and reference sites (n=20) at the same time)

Wellsite:

- 0 m – centre of wellsite quadrant “A” 10 x 10 m plot (1 pigtail)
- 7.1 m – (corner of centre “A” 10x10 m plot) (4 pigtails)
- 27.9 m – (near corner of 10x10 m plots) (4 pigtails)
- 35 m – (centre of 10x10 m quadrant plot) (4 pigtails)
- 42.1 m – (far corner of 10x10 m plot) (4 pigtails)
- 2 additional corners of the B-E 10x10 m plot (8 pigtails)

Reference:

- 27.9 m – (near corner of 10x10 m plots) (4 pigtails)
- 35 m – (centre of 10x10 m quadrant plot) (4 pigtails)
- 42.1 m – (far corner of 10x10 m plot) (4 pigtails)
- 2 additional corners of the 10x10 m plot (8 pigtails)



Visual representation of the layout of the wellsite and reference soil sampling (10 x 10 m) plots for cultivated lands. Not drawn to scale.