Ecological Recovery Monitoring Program for Certified Reclaimed Sites in Alberta:

Monitoring Protocols for Cultivated Land Wellsites

By

InnoTech Alberta

ERMP Project Advisory Group

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Ecological Recovery Monitoring Program Development Project

The Alberta Biodiversity Monitoring Institute contracted InnoTech Alberta in 2017 to develop the direction, framework and implementation plan for the Ecological Recovery Monitoring Program. The Project has been divided into a series of Tasks:

Task 1: Describe the Goals and Objectives for a Long-Term Monitoring Program in Alberta

Task 2: Develop a Science-Based, Practical Protocol for the Long-Term Monitoring Program

Task 3: Develop an Information Distribution Plan

Task 4: Develop an Implementation Plan for the Long-Term Monitoring Program

Project Team

The Project was led by InnoTech Alberta Reclamation Team staff (Small, C., and Powter, C.) with the advice and guidance from a Project Advisory Group (PAG). The PAG consisted of members from: Alberta Environment and Parks, ABMI, the University of Alberta, InnoTech Alberta, Canadian Forest Service, ATCO Electric, and several technical specialist consultants. PAG members included:

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- Christina Small – InnoTech Alberta
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- Ivan Whitson – I Whitson Innovations Inc.

Documents produced for each Task were developed as drafts by InnoTech Alberta and then discussed with the PAG in a workshop format to develop a consensus position on the key

Program components. The final draft document of each Task informed development of the next Task document.

Report

This is one of three monitoring protocol reports, each with a separate report containing field datasheets, prepared under Task 2. The other reports provide protocols for forested land and grassland wellsites.

This report may be cited as:

ERMP Project Advisory Group, 2017. Ecological Recovery Monitoring Program for Certified Reclaimed Sites in Alberta: Monitoring Protocols for Cultivated Land Wellsites. 39 pp.

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1 INTRODUCTION

Alberta has a large industrial footprint, consisting of >400,000 oil and gas wells, >500,000 km of pipelines, hundreds of thousands kilometres of roadways, prairie and mountain coal mines, oil sands mines, oil production sites (in-situ oil sands sites), sand and gravel pits, quarries, plant sites and transmission lines. These disturbed sites, termed *specified land* in the *Conservation and Reclamation Regulation* (Government of Alberta, 1993), must be reclaimed and certified as having an equivalent land capability (*Environmental Protection and Enhancement Act*; EPEA; Government of Alberta, 2000).

Ecological recovery is achieved when the biological, physical and chemical properties (in terms of vegetation, soil and biota) of a reclaimed site return to similar structure and function as found in a representative undisturbed reference area or in the pre-disturbance site. Requirements for certification noted above may or may not fully facilitate return of ecological function at a site. Further complicating matters is the practice of certifying forested land, native prairie, or peatlands/wetlands sites that take decades to reach ecological maturity based on expectations or predictions of future performance (often referred to as being on an accepted trajectory to full recovery). As a result, immediately following reclamation certification, and for some unknown period of time afterwards, most sites will not have fully recovered their ecological function. Previous studies (e.g., Avrimed et al., 2014; Desserud et al., 2010) and site inspections have identified cases where soil and vegetation chemical and physical parameters (e.g., pH, organic carbon, bulk density, plant species composition, aboveground biomass, crop yield) and presence of invasive and/or undesirable plant species indicate a lack of full ecological recovery on reclaimed certified sites.

1.1 Ecological Recovery Monitoring Program

The Ecological Recovery Monitoring Program is enabled through section 15 of EPEA (Government of Alberta, 1993). The goals of the ERMP (ERMP Project Advisory Group, 2017a) are to:

1. Monitor, evaluate, and report to Albertans regarding the science of potential long term impacts of human disturbance on landscape, soil and vegetation; and,
2. Better inform Albertans on the rate, magnitude, direction, and extent of ecological recovery at reclaimed and certified industrial sites in Alberta and to support government evaluation of current reclamation policies and practices.

The objectives of the Ecological Recovery Monitoring Program are to:

1. Provide landowners, the public and Aboriginal communities better understanding of the effectiveness and limitations of land conservation and reclamation practices;
2. Provide regulators with data to support: refinements to land conservation and reclamation requirements; land reclamation certification criteria; and, appropriate liability timeframes for different types of specified lands;

3. Provide data to support analysis of the impacts of changes over time in regulatory requirements and industrial practices on environmental outcomes;
4. Provide data to support development of reclamation trajectories that will better predict future performance and therefore permit certification of sites prior to full ecological recovery;
5. Provide data to assess which monitored parameters are key determinants of ecological recovery for disturbance types in each ecological zone (and therefore provide insights to improve conservation, reclamation and site assessment practices); and,
6. Improve understanding of linkages between monitoring parameters, ecological recovery, natural variability and regulatory requirements.

The Ecological Recovery Monitoring Program consists of four core components, each supporting and interacting with the other in an adaptive management framework:

1. **Monitoring** – an annual field-based program to gather data on the ecological recovery status of reclaimed certified sites in Alberta. Methods to be used and the parameters to be evaluated are identified in Protocols developed for each disturbance type (e.g., wellsites, pits, mines) and each relevant site type (e.g., grassland, cultivated, forested).
2. **Evaluation** – analysis of monitoring data from individual sites and between sites within the same type of specified land, and, where applicable, synthesis of parameters into integrated measures of ecological recovery.
3. **Reporting** – public dissemination of monitoring results in the form of summary reports (by year and/or by type of specified land). Results can also be provided as raw data or in various summary data formats.
4. **Research and Development** (R&D) – ongoing development and refinement of the monitoring program protocols and evaluation methodology[1].

1.2 Monitoring Program Design

The sampling design and protocols sample two different areas within a single assessment unit (called the Monitoring Site): the wellsite, and a reference area (i.e., a paired comparison design)[2]. For the purposes of this protocol, the wellsite is restricted to the disturbance footprint of the well pad. The reference area, selected so as not to have a footprint of human disturbance, is the reference against which ecological recovery is assessed.

The design minimizes the effects of spatial variability of the monitoring site by systematically selecting sampling points – this increases the ability to precisely measure temporal change in

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[1] Additional research using ERMP data may be carried out by external organizations. The Program managers will need to maintain awareness of the findings so they can be incorporated into the Program as necessary.
[2] Definitions for key terms used in this document are provided in Section 8.

selected indicators. The ease of use and the sampling efficiency makes it a better choice than random sampling for this monitoring program.

1.3 Cultivated Land Protocols Report

This report provides the *monitoring protocols for cultivated land wellsites*. These protocols have been adapted from the Pilot program report *Ecological Recovery Monitoring of Certified Wellsites: Field Data Collection Protocols for Cultivated Lands* (Alberta Biodiversity Monitoring Institute and Alberta Innovates – Technology Futures, 2015). A separate report (ERMP Project Advisory Group, 2017b) contains the Field Datasheets to be used in conjunction with these protocols.

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

Cultivated land sites are currently subject to the *2010 Reclamation Criteria for Wellsites and Associated Facilities for Cultivated Lands* (Environment and Sustainable Resource Development, 2013).

Protocols for forested land and grassland wellsites, and their associated Field Datasheets, are available. Protocols for other forms of reclaimed and certified land disturbances will be developed through research as the program expands beyond wellsites.

2 MONITORING SITE SELECTION

The goal of the early stages of ERMP implementation is to expand on the range of key site characteristics (Appendix 1, Table 2) represented in the monitoring database developed as part of the Pilot. As the program progresses sites can be selected to build in replication of selected key site characteristics to add statistical power to data analysis and to improve representation in the region.

In addition, specific sites may be worth revisiting periodically (perhaps every 5 or 10 years) to monitor trends in key monitoring parameters – protocols for determining which sites to revisit will be developed as more data are gathered.

2.1 Site Selection Methodology

The following steps are followed to select a site for monitoring:

1. Obtain list of potential sites from AER and AEP databases for the region(s) to be sampled in a given year.

2. Determine Candidate Site Ratings from Appendix 1, Table 2 and identify the highest rated candidate sites[3].
3. Review available data in AER, AEP and AbaData[4] records to further help screen sites.
4. Identify final list of candidate sites and any lower-priority sites in the area of a candidate site that could be sampled if time permits.
5. Confirm landowner approval to sample and request current status of site (e.g., crop off) (see section 3.1 for more details).
6. Conduct a reconnaissance trip to the candidate site to make sure the site is suitable for inclusion in the Program. The site may be rejected permanently if clearly not reclaimed or another disturbance is present. Site logistics issues such as access are also assessed at this time.
7. Implement monitoring protocols on remaining sites.

Site selection should focus on sites that have higher ratings. Sites with lower ratings can be added to the Program where they are in proximity (short distance or travel time) to higher-rated sites[5] – this will help expand the range of monitoring sites while maximizing Program efficiency.

2.2 Site Records

The review of records provides information to help classify sites for future analysis and to help explain the monitoring results.

In addition to the information in Appendix 1, Table 2, records that should be captured (where available) include:

1. Reclamation certificate application form.
2. Reclamation certificate assessment data (e.g., Detailed Site Assessment, Phase I).
3. Comments by the Reclamation Inspector and landowner at the inquiry.
4. Spill and remediation records (potentially found on the Environmental Site Assessment Repository – http://aep.alberta.ca/lands-forests/land-industrial/programs-and-services/environmental-site-assessment-repository.aspx).
5. Complaint records (and any work required to address the complaint).
6. Whether or not the wellsite was deemed to be a potential problem site (Energy Resources Conservation Board, 2012) and the resulting adjustment to the site liability value.

[3] Note the factors and ratings in Table 2 are recommended for consideration – they can be varied to suit alternative priorities.
[4] See http://abadata.ca/; note, use of this site requires payment.
[5] These are called opportunistic sites.

These records may be found in databases of the Alberta Energy Regulator and Alberta Environment and Parks – some may be electronic and some may require access to paper archives.

3 PLOT ESTABLISHMENT

Plot establishment is designed to facilitate field sampling by having predetermined information identified, including the route to site centre recorded (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 as is recommended in step 6 above). Crews will have an estimated timeframe for getting to the site and knowledge of potential access hazards.

Several tools are available for developing the predetermined site access route. Oil Trax and Avenza PDF maps were used in the Pilot Program. The latter was the best but it requires that a modeler prepare the maps and import wellsite coordinates into an app-specific map.

Accessing monitoring sites has multiple components:

- 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 are needed to assist field crews in their first visit to the site.
  - The wellsite centre should be labeled and GPS coordinates from the map/GIS recorded for the wellsite centre and four corners.
  - The need for surveying for ground disturbance needs to be established prior to the first visit to the site. 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 etc. should contact you to let you know whether or not there is a conflict and whether marking of lines will be required (if you haven't heard back then you may need to check the site to see if it has been marked).
- 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.
- During the first visit to the monitoring site, the most efficient route is found, and potential hazards are described on maps.
  - Ensure that compass declination is set appropriately for the location. Declination for the region is determined by checking on the GPS and is recorded. The accuracy of the GPS used during site establishment is also recorded.
  - Where site access is complicated, 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 centre. This

will be most relevant for locations after you have turned off a main road/highway.

3.1 Securing Landowner Permission

Permission from the landowner, public land manager and occupants is required to access and sample land. Landowners may place timing restrictions on access[6] that may result in a decision to discard the site from the list of potential candidates.

Several counties and municipal districts have land ownership maps that will provide a starting point for current contact information. Depending on the time since certification, the certificate application and transmittal letter will also contain landowner information that may be current.

There are some key points to remember when accessing and working on private land:

- No materials can be left on site: no flagging, rebar, or equipment at all will be left at the site, and crews will be diligent to not leave any garbage of any kind on site.
- It is critical to the Program that crews be very respectful of land owners and be ambassadors for the program. This includes:
    - Notifying landowners when you will arrive, how long you will stay and when you leave.
    - No quadding on private property at all unless specifically requested by landowners.
    - Take corporate logos off the vehicle (or cover them up) while on private property.
    - If you find gates open, leave them open. If you find gates closed, close them.

3.2 Plot Layout

Field Equipment Needed:

- Cell phone for communications (be prepared that, depending on location, phones may not always work)
- 2-way radios for communications among partners
- 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 well bore location
- 4 – 50 m tapes, 4 – 100 m tapes and 4 – 30 m tapes

[6] For example due to irrigation equipment being onsite or having just completed or scheduling harrowing.

- Single colour of flagging tape (e.g., pink = 10x10m)
- Fine tipped coloured marker (to delineate polygons on human disturbance sketch)
- Pencils for recording data on datasheets
- Pin locator – magnetic metal detector
- Plot layout 'cheatsheet' (see Appendix 2)
- Datasheets #1 to #3

For level and near-level sites, the following sampling design will be used (Figure 1). On monitoring 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.

Every effort should be made to reduce the impact of the plot layout and sampling work (e.g., trampling, weed movement, damage to property such as fences and gates).

Procedures:

- When the field crew arrive onsite, the first step is to identify the wellsite centre, which will be the centre 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 (GPS coordinates will have been identified from the maps and GIS investigation prior to the site visit). If due to poor satellite coverage accuracy values from the GPS are > 7 m, this is noted on Datasheet #1.

- At wellsite centre place a pigtail in the ground and flag it so that you can readily identify the wellsite centre.
    - 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.
    - A permanent metal marker (or metal magnet) will also be inserted in the sample hole at wellsite centre after the soil sampling is complete so that the location can be readily identified with a metal detector during future visits to the site (obtain landowner approval first).

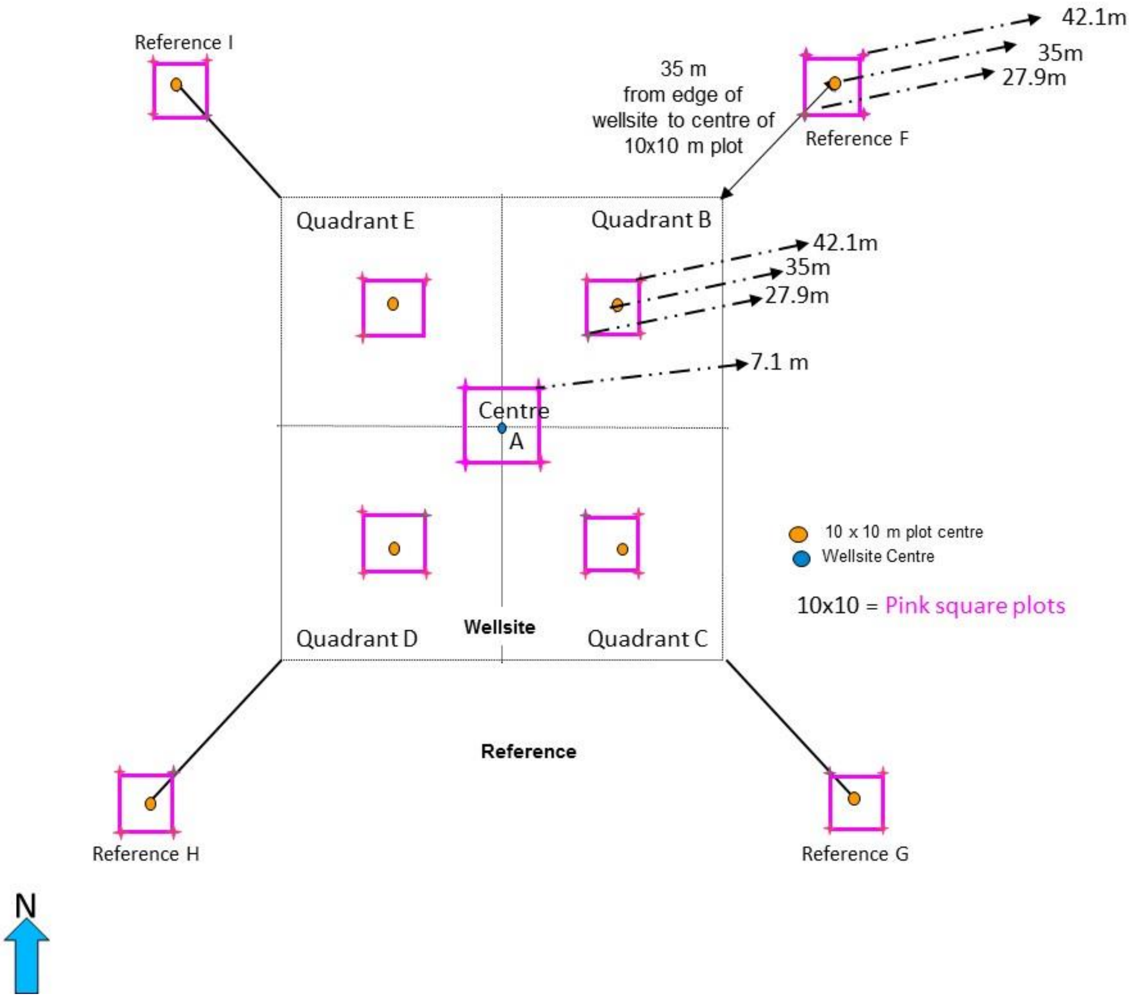


Figure 1. Sampling layout of wellsites and adjacent reference areas.
Pink squares (10x10 m plots) are located within the four quadrants of the wellsite, wellsite centre (10x10 m plot), and the reference quadrants.
Yellow dots are locations for pigtail placement.
Note: plot is not drawn to exact scale.

- 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 Figure 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 the well bore).

- Establish the first transect for the wellsite – it is most efficient to have both crew members establish each transect together and use the plot layout cheatsheet (Appendix 2). Leaving the tape on the ground is useful for the next steps. 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 pigtail, lay out your tape along the bearing of the sub-ordinal 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 centre of your 10x10 m plot). Record the GPS coordinates on Datasheet #1.
  - Continue to 42.1 m (this will be the far diagonal corner for the 10x10 m plots.
  - 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 70.7 m (this will apply if the wellsite is < 1 ha) record the distance from wellsite centre on Datasheet #2 and insert pigtail, or
    - if the edge of the wellsite is beyond 70.7 m from the plot centre then place the wellsite quadrant corner pigtail at 70.7 metres but still run the tape out to the edge of the wellsite and record the distance to the edge of the wellsite on Datasheet #1.

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

All flagging and pigtails must be removed after each visit.

3.2.1 *Selecting Adjacent Reference Areas*

The following section describes establishment procedures for an adjacent reference area. If you encounter a wellsite that is located in an area that does not have adjacent conditions that are suitable to be used as a reference area, 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 and you will not establish the reference 10x10 m square plots directly adjacent to the wellsite. See Section 3.2.2 below for non-adjacent reference area procedures.

Adjust the location of the reference area if necessary to ensure the location is undisturbed (e.g., not on a pipeline or access road).

To establish adjacent reference area plots, walk to the corner of the wellsite footprint and then roll out the 50-m tape and lay out the line transect at the same bearing as for 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 centre for the 10x10 m reference square plot). Record the GPS coordinates on Datasheet #1 at 35 m (plot centre for 10x10 m plot).
- Insert pigtails for the remaining sides of the 10-m square using the 30-m tape to triangulate.

3.2.2 *Selecting Non-Adjacent Reference Areas*

When the reference condition is not located directly adjacent to the wellsite then there will have to be an alternative strategy to locate reference areas. 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. GPS points should be marked for the centres of the 10 x 10 m plots that are sampled in the reference area sites.

4 SITE DESCRIPTION

Site description information allows for improved data analysis and reporting.

4.1 Site Observations

Sketches and photographs provide a permanent record of the site as of the date the monitoring was conducted. This will be particularly helpful in case a site is selected for later reassessment. Effective sketches and photographs can also be used to visually link monitoring findings to the site which may provide insights into patterns that raw data will not provide.

4.1.1 *Site Sketch*

Draw sketches of the wellsite and each of the reference areas – these can be combined if the reference areas are adjacent to the wellsite but may have to be separate sketches if the reference areas are at some distance. Sketches should represent both historical information culled from records (e.g., well bore and access road locations) and from onsite observations.

Field Equipment Needed:

- Datasheets #2A and #2B

Sketches will include, where available:

- North arrow to orient site
- Wellsite development information (e.g., wellhead, access road and sump location)
- Location of nearby roads
- Presence and/or evidence of standing water
- Arrows to indicate slope direction
- Bare soil areas
- Excessive weed areas
- Erosional and depositional areas
- Sample locations, plots and transects (based on the Plot Layout Protocols in Section 3)

Use the data sheet provided to complete a map outlining all disturbance evidence present at the site (e.g., wellhead bore location, roads nearby). Write the type of 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 reflects the site conditions.

4.1.2 *Site Photographs*

Field Equipment Needed:

- Digital camera with a 35 mm focal length and a quality setting of at least 3 Mega-pixels (take extra batteries and charger)
- Backpack (or some other suitable object) for scale
- Datasheet #3

Procedure:

- Use “landscape” orientation for all photos.
- Take five photographs at each wellsite:
    - Four Transect Photos – Standing at wellsite centre 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).
    - Representative Site Photo – From anywhere within the 1 ha wellsite take a single photograph that best represents the physical characteristics; provide the location and direction of this photo on the site diagram.
- Take four photographs of the reference areas – one of each 10x10 m plot that best represents the physical and vegetation characteristics. Record which plot you took each photo in.
- In each photo, include a back pack approximately 5 m from the camera for scale.
- Record each photo number on Datasheet #3.
- Check the resolution and quality of all photos at the site; re-take if the photo is blurry.
- Transfer photo files onto a laptop computer once back at camp or in the office and label them as follows:
    - Transect photos are labeled [Region]_[year]_[site]_“W” or “R”_[quadrant].jpg (e.g., CUL_2013_3_W_C.jpg).
    - Representative site photo for the wellsite is labeled with [Representative] at the end of the label name.
- Copy all photos to an external hard drive/flash key for backup.

4.1.3 *Field Notes*

Field notes should be written while on site. Notes should be recorded on rite-in-rain type of paper using a pencil. Write on one side of the paper only.

Documentation of the personnel involved and procedural issues that arose provides additional context for the data and can assist in future revisions to the Program. Examples of the types of notes to be taken include:

- Date and time of day
- Weather
- Mistakes made
- Changes required to the protocols
- Samples lost or damaged
- Comments on site accessibility and changes to route of travel
- Personnel names and associated roles

Scientifically-defensible, replicated data form the basis for the assessment of the status of ecological recovery for each site. However, there is considerable value in subjective field observations as an additional tool to help explain and validate the monitoring results. Of particular interest are obvious differences between the wellsite and the reference areas.

Examples of subjective observations that can be recorded include:

- General impressions of the monitoring site (e.g., easy to spot wellsite or not)
- Evidence of new disturbances (e.g., ATV tracks, etc.)
- Evidence of landowner management practices
- Soil horizon features in reference areas (based on the soil sample cores in section 5.2), such as cumulative thickness of mineral and organic topsoil horizons (Ah, Ae, Ahe, Ap), upper subsoil features (genetic horizon codes, structure, consistence, properties of mottles), slope positions – information that can be used to understand the soil and landscape context
- Uniformity of soils
- Difficulty/ease of digging soil (e.g., compacted, rocky, wet)
- Stubble or crop residue
- Evidence of weeds and potential source of ingress
- Sensory information (e.g., specific sights, sounds, smells)

In addition to the observations of the assessor, any comments by landowners or occupants who may be present at the time of the assessment or that are made during discussions about site access should be recorded.

5 SOIL ASSESSMENT

This Section describes the field-based protocols for sampling of soil parameters. Soil sampling should be conducted in the 10x10 m plots. Most of the lab analysis that will then be conducted on the samples is not described in detail in these protocols.

Soil measures include:

- Bulk density – because it has tremendous influence on the soil's capability for water partitioning, air exchange and plant growth.
- Soil organic carbon – because it is an important indicator of a soil's ability to sustain plant growth, rooting, water partition and air exchange.
- Soil electrical conductivity (EC) and pH – two useful indicators of soil quality and its capacity to support plant growth. EC in particular is a good indicator of salinity as well as admixing of the surface soil and sub-soil.
- Total Nitrogen (TN) – as it is used to calculate C:N ratios.

5.1 Sampling

> Offset the location of any of the soil sampling sites by approximately 1 m if they coincide with the location of the well bore.

5.1.1 *Number of Samples*

In a systematic grid sampling design, one composite sample per depth made up of 5 cores from each of the 10x10m square is sufficient for each indicator analysis with the exception of bulk density (Figures 2 and 3). Compositing samples to reduce analysis cost is suggested for measuring SOC, soil EC and pH.

Bulk mixing of samples should not be conducted in the field. Samples should be stored separately and bulking should be done in the laboratory after bulk density has been measured and the samples have been air-dried and ground to 2 mm.

For soil bulk density measurements, it is suggested on the first initial sampling interval to collect 5 core samples for the two depths (0 to 15 cm and 15 to 30 cm).

5.1.2 *Depth of Sampling*

The sample depth combinations were selected based on the indicator chosen. Two sample depths are recommended: 0 to 15 cm (0 to 6") and 15 to 30 cm (6 to 12"), for soil EC, pH SOC and bulk density. EC and pH will also be monitored at the 30 to 60 cm (12 to 20") and 60 to 100 cm (20 to 40") depths for the centre sampling point in each of the 10x10 m square (Figure 2).

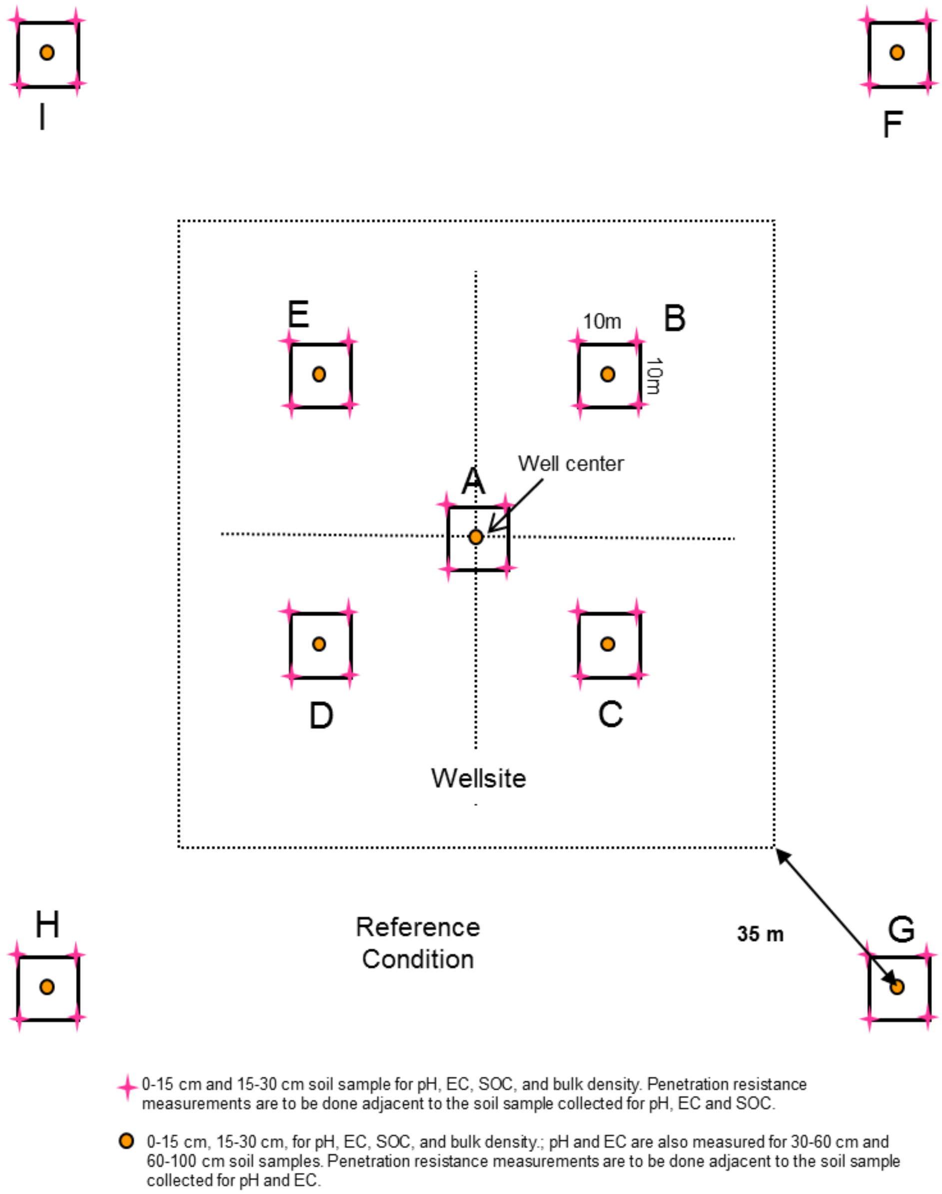


Figure 2. Soil parameters are sampled within the 10x10 m plots identified in the diagram.

5.1.3 *Locations for Repeat Sampling*

It is recommended that the sampling frequency for the soil parameters be 10 years or more depending on the parameter, budget and number of sites. The sampling frequency has not yet been determined and will be determined in a future version of the protocol. There are 10 different sets of sampling locations identified so that soils can be destructively sampled 10 times within each 10x10 m plot (Figure 3). Each sampling point will be located a minimum of 1 m apart from the previous sampling location.

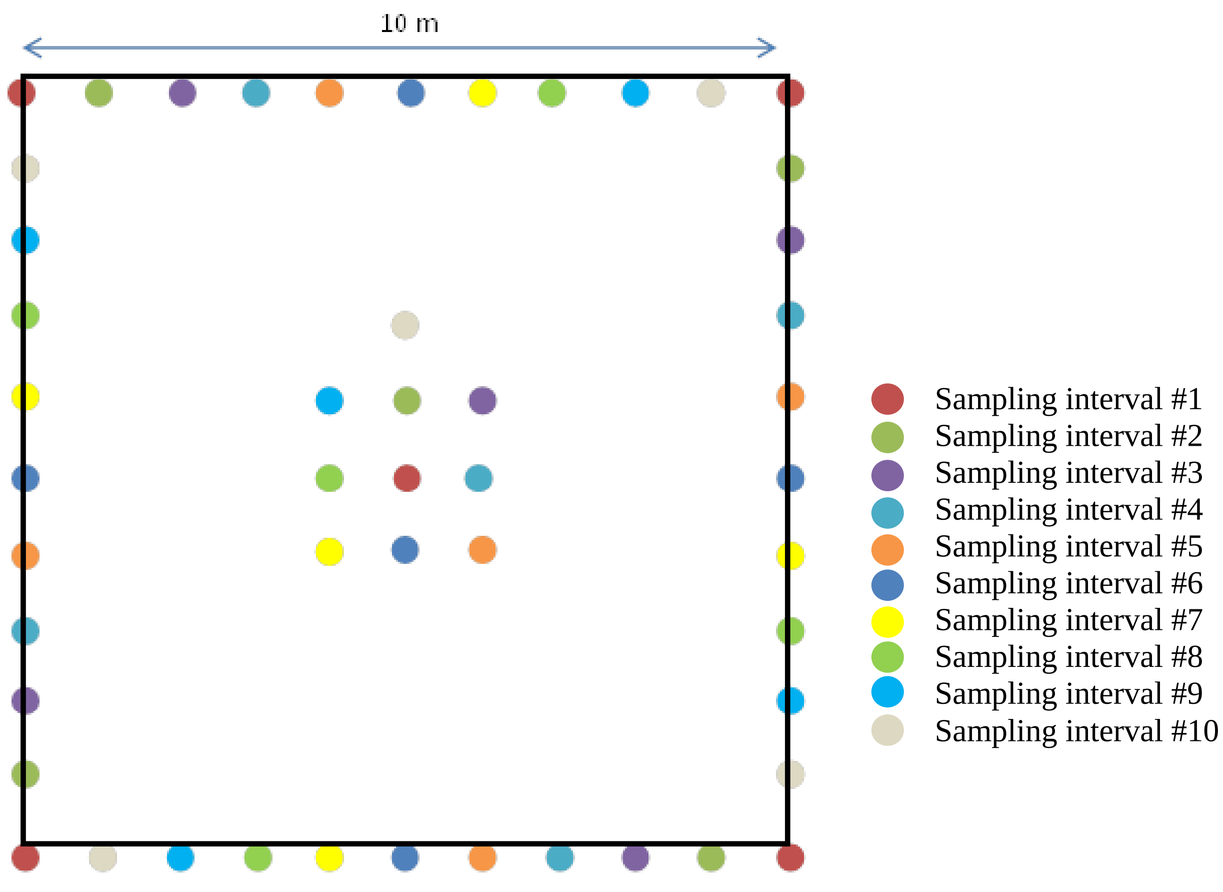


Figure 3. Sampling layout for repeat sampling within each 10x10 m plot on the wellsite and reference sites.
Each colour represents a different sampling interval, for a total of 10 sampling intervals.

5.2 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 and Curran, 2006).

5.2.1 *Core Method*

A double-cylinder, drop-hammer sampler with a liner core is designed to collect an undisturbed soil sample (Figure 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, where necessary, 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.

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

Field Equipment Needed:

- Double-cylinder core sampler. The most common core diameter range from 2” to 3” (5.1 cm to 7.6 cm). Having a second core sampler on hand in case one breaks is recommended
- Two crescent wrenches to tighten the core parts while in the field if they become loose (note that these should be checked regularly – for example, after each sample is collected, as they regularly become loose and this will weaken them and lead to them breaking)
- Clean, dry and uniform stainless steel liners with a known internal diameter and height for volume calculation
- 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
- Tape measure (to determine core hole depth)
- 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 Needed:

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

Procedure:

Lab (pre-sampling)

- 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).

Field

Avoid sampling in equipment/tire/ridges in the soil

- Select a smooth and relatively undisturbed surface at the appropriate sampling point.
- Remove live vegetation or crop residue so that the core is collecting the soil rather than vegetation (e.g., a quick kick of the vegetation with your boot).
- Drive or press the core sampler into the soil sufficiently to fill the inner liner without inducing compaction.
  - In frictional or dense soils, lubricant (e.g., Pam spray) may be required to prevent compaction of the soil and to facilitate emptying the collected core sample from the sampler.
  - When the corer is at the required depth, gently rock in a circular motion to break the contact of the soil core with the ground.
- Carefully remove the undisturbed soil core and trim the ends flush with the edge of the cylinder if necessary (most often the soil breaks off naturally).
  - 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.
- Be sure to measure the start and end depths using a tape measure to record the length of the core on Datasheet #4.
- Store the sample in the pre-labelled in polyethylene bags. Tie the bag closed. Store in large durable plastic bag for transport.
- Repeat a second time in the same hole to collect the 15 to 30 cm depth sample.

Lab (post-sampling):

- Place the sample in an oven set to 105°C for 24 h.
- Record the weight of the dry soil.

5.3 Chemistry

Soil organic carbon, TN, 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) for dry, coarse textured soil and Dutch auger for wet, finer textured soil (Figure 5)
- Pre-labelled heavy duty polyethylene bags (see information for bulk density described above)
- Wire brush
- Soil knife
- Perforated drum grinder with 2 mm perforations
- Tape measure

Procedure:

Field:

- Use the bulk density samples for chemistry of soils to 30 cm depth.
- For the deeper samples, drill the auger tip into the bulk density sample hole by turning the handle in a clockwise rotation to the desired depth (30 to 60 cm and 60 to 100 cm). 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).
    - Remove any surface materials that have fallen into the hole before starting the collection for the next depth.
- Empty the soil into the labeled bag, avoid any loss of soil.
    - Note that you only need to keep a representative subsample of each depth range – otherwise you will end up with excessive amounts of soil.
- Carefully place the auger in the same hole and repeat the process until the desired depth is reached (use tape measure to measure depth).
- Store the sample in polyethylene bag in a large durable plastic bag for transport.

Figure 5. Soil sampling tools.
Left – Dutch auger and Right – Bucket auger.

Laboratory:

- 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.
- 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.
- Thoroughly mix the 5 core samples after they have been coarsely ground to < 2mm and then subsample the soil for SOC, TN, 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 parameters.

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

6 VEGETATION ASSESSMENT

There are no vegetation sampling protocols for cultivated lands since no ground sampling of vegetation is conducted. Instead crop yield data from other sources and other analytical protocols are used (see, for example, ERMP Project Advisory Group, 2017c).

7 MANAGING PERSONNEL, DATA QUALITY AND INTEGRITY

This section 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.

7.1 Safety

A first aid kit, emergency contact information, and the location and route to the nearest hospital facility must be on site at all times. Additional safety gear (e.g., bear spray and bear bangers when working in bear country) should be readily available.

All field crews and laboratory personnel are required to follow the safety procedures stipulated by their employers for the type of work being conducted and to comply with all provincial and national safety laws.

If at any time during the season you feel safety (of yourself or anyone else) is being compromised, tell a field coordinator immediately. Safety ALWAYS comes before the objectives of data collection.

7.2 Personnel and Sampling

These data collection protocols are optimally designed to be implemented by a field crew of two (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).

7.3 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, datasheets and general field procedures. Then they practice the data collection in the types of cultivated lands 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.

Field crews are to review the protocols regularly to ensure that data collection remains accurate throughout the field season and nothing is being missed.

7.4 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 waterproof 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.

7.5 Completing Datasheets in the Field

Crews are responsible for filling information into the datasheets 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 should be reviewed by a supervisor before moving to the next site.

Datasheets 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)** – 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.

7.6 Checking Field Data and Storing Datasheets Daily

Datasheets 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 datasheet and both copies filed. Wet datasheets 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). Datasheets from one site cannot be taken to the field at another site. Crews must re-collect lost or missing data.

7.7 Transferring Field Datasheets to a Secure Location

Datasheets are transferred in person to the crew supervisor when the supervisor visits, or at the end of a shift. The completeness (i.e., all datasheets present and all data fields filled in) of the data sheets is confirmed during the transfer. Missing fields or datasheets must be re-collected. Field supervisors take the datasheets 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 datasheets are not allowed to leave the secure office.

7.8 Processing of Specimens and Samples

Soil samples and datasheets are transported by crew members to an accredited laboratory selected by the Program lead.

Chain of custody records must be maintained to track samples and specimens from field to laboratory.

7.9 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.

8 GLOSSARY OF TERMS AND ACRONYMS

8.1 Terms

Candidate Site

A site within the universe of available certified sites that has a high rating based on the Appendix 1, Table 4 criteria.

Monitoring Site

An area of land subject to the Ecological Recovery Monitoring Program that includes:

1. Land that has been disturbed while conducting a specified land activity as defined in s. 1(t) of the *Conservation and Reclamation Regulation* (Government of Alberta 1993); and, has been certified by a government agency as being reclaimed pursuant to the requirements of the *Environmental Protection and Enhancement Act* (Government of Alberta 2000) and the *Conservation and Reclamation Regulation* (Government of Alberta 1993); and,
2. The associated Reference Areas.

The area of land subject to the monitoring program may form all or part of the area occupied by the specified land activity and/or certified as reclaimed.

Opportunistic Site

A site that has a lower rating based on Appendix 1, Table 4 but is within a reasonable distance from a candidate site and could be added to the Program with minimal travel cost impacts.

Parameter

A specific characteristic such as plant height or bulk density that is evaluated as part of the Program.

Pilot Program

A four-year research program (2012-2015) to determine the need for, and if required the design of, an integrated, scientifically robust and financially sustainable program for the long-term assessment of ecological recovery of certified reclaimed specified lands. Partners in the Program included Alberta Environment and Parks (AEP) (formerly the Alberta Environmental Monitoring, Evaluation and Reporting Agency [AEMERA]), the Alberta Biodiversity Monitoring Institute (ABMI), and InnoTech Alberta (formerly Alberta Innovates – Technology Futures [AITF]).

Plot

A sampling unit of varying size depending on the parameter of interest. Usually a square (e.g., 10x10m for soils). Plots are located in the wellsite and in the reference areas.

Program

The Ecological Recovery Monitoring Program.

Quadrant

A sampled area that is 50x50m (or may be slightly smaller if the wellsite was smaller than 1 ha) that is sampled on and off the wellsite – there are four quadrants that collectively comprise the well pad and four quadrants that collectively comprise the reference area.

Reference Area (often called a control)

Undisturbed location adjacent to, or nearby, the certified site, from where data are collected for comparison to the certified site data. Each reference area represents the ecological target for the entire certified site, or for a specific portion of the certified site where there is more than one ecological target represented.

Site Characteristics

Parameters that are used to classify the site during data analysis and reporting.

Well Bore

The location on the well pad where the well was drilled (and, if produced, where the wellhead was located).

Well Pad

A subset of the area of land occupied by a wellsite. The well pad is usually a square (approximately 100 m x 100 m) or rectangular area which contains the wellhead and may have contained additional infrastructure for processing the oil or gas.

Wellsite

In regulatory language, a wellsite is an area of land leased for the purposes of drilling a well (defined in s. 1(aaaa) of the *Environmental Protection and Enhancement Act* (Government of Alberta 2000) as: an orifice in the ground that is completed or is being drilled: (i) for the production of oil, oil sands or gas, or (ii) for injection into an underground formation). The wellsite includes the well pad, and may include additional infrastructure such as an access road, a construction material borrow, or an off-site drilling waste sump.

However, for the purposes of the Ecological Recovery Monitoring Program, the term wellsite means the well pad.

Wellsite Centre

The middle of the well pad. This may or may not be the same as the well bore location.

8.2 Acronyms

ABMI	Alberta Biodiversity Monitoring Institute

AEMERA	Alberta Environmental Monitoring, Reporting and Evaluation Agency
AEP	Alberta Environment and Parks
AITF	Alberta Innovates – Technology Futures
D&A	Drilled and Abandoned
DBH	Diameter at Breast Height
DNC	Did Not Collect
VNA	Variable Not Applicable

9 REFERENCES

Alberta Biodiversity Monitoring Institute and Alberta Innovates – Technology Futures, 2015. Ecological Recovery Monitoring of Certified Wellsites: Field Data Collection Protocols For Cultivated Land. Version 2015-08-17. Alberta Biodiversity Monitoring Institute, Alberta, Canada. 47 pp. http://ftp.public.abmi.ca/home/publications/documents/444_ABMI_AITF_2015-08-19_ERMProtocolsCultivatedLands_ABMI.pdf

Avirmed, O., I.C. Burke, M.L. Mobley, W.K. Lauenroth and D.R. Schlaepfer, 2014. Natural Recovery of Soil Organic Matter in 30-90-Year-Old Abandoned Oil and Gas Wells in Sagebrush Steppe. Ecosphere 5(3):24.

Desserud, P., C.C. Gates, B. Adams and R.D. Revel, 2010. Restoration of Foothills Rough Fescue Grassland Following Pipeline Disturbance in Southwestern Alberta. Journal of Environmental Management 91: 2763-2770.

Energy Resources Conservation Board, 2012. Directive 001: Requirements for Site-Specific Liability Assessments in Support of the ERCB's Liability Management Programs. Alberta Energy Regulator, Calgary, Alberta. Directive 001. 32 pp. http://www.aer.ca/documents/directives/Directive001.pdf

Environment and Sustainable Resource Development, 2013. 2010 Reclamation Criteria for Wellsites and Associated Facilities for Cultivated Lands (Updated July 2013). Alberta Environment and Sustainable Resource Development, Edmonton, Alberta. 92 pp. https://extranet.gov.ab.ca/env/infocentre/info/library/8362.pdf

ERMP Project Advisory Group, 2017a. Ecological Recovery Monitoring Program for Certified Reclaimed Sites in Alberta: Proposed Implementation Plan. 38 pp.

ERMP Project Advisory Group, 2017b. Ecological Recovery Monitoring Program for Certified Reclaimed Sites in Alberta: Field Datasheets for Cultivated Land Wellsites. 8 pp.

ERMP Project Advisory Group, 2017c. Ecological Recovery Monitoring Program for Certified Reclaimed Sites in Alberta: Specialized Monitoring Protocols. 30 pp.

Government of Alberta, 1993. *Conservation and Reclamation Regulation*. AR 115/1993. Government of Alberta, Edmonton, Alberta. 21 pp. http://www.qp.alberta.ca/documents/Regs/1993_115.pdf

Government of Alberta, 2000. *Environmental Protection and Enhancement Act*. Ch E-12. Government of Alberta, Edmonton, Alberta. Revised Statutes of Alberta 2000. 158 pp. http://www.qp.alberta.ca/documents/Acts/E12.pdf

Maynard, D.G. and M P. Curran, 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, Florida. Chapter 66. pp. 863-869. http://www.cfs.nrcan.gc.ca/pubwarehouse/pdfs/27487.pdf

APPENDIX 1: Site Selection Criteria

Determine the Candidate Site Rating by:

1. Selecting the appropriate rating for each of the Factors in Table 2 (note: these are recommended factors and ratings – they can be varied to suit alternative priorities).
2. Subtracting
   a. 1 from the Factor rating if the monitoring database already has some representation of the sub-category component; or
   b. 2 from the Factor rating if the monitoring database already contains enough representation of the sub-category component
      Note: lowest possible rating value is 0
      Note: Doesn't apply to Soil type, Crop type or Cropping system Factors
3. Summing the Factor ratings to get the Candidate Site Rating (Maximum score is 80).

Table 2. Key characteristics to be considered in stratified site selection.

Factor	**Rating**			**Comments**
	1	**3**	**5**	
Time since spud date		Spud date before 1983	Spud date is 1983 or later	Spud date will often determine level of soil salvage
Time since abandonment date		Abandoned before 1995	Abandoned after 1995	Reclamation criteria were in effect in 1995 so sites abandoned afterwards are more likely to be reclaimed according to recent expectations
Time since certification		Less than 10 years	Greater than 10 years	Focus on sites that have had adequate time to settle and begin the long-term healing process; however there are also benefits to collecting early-stage recovery sites (i.e., <10 years)

Factor	Rating			Comments
	1	3	5	
Time From Abandonment to Certification	<5 years	5 to <10 years	>10 years	Sites that sit for a long period of time may indicate problems existed and/or are subject to deterioration that may impact reclamation success (e.g., soil loss or weed ingress)
Production history	Not produced		Produced	Production increases impacts due to traffic, soil loss and spills
Certification criteria	None	1995 Criteria 2007 Forested Criteria	2010 Criteria (and updates)	Emphasize sites certified under published criteria
Inquiry or Audit		Inquiry held	No inquiry	Sites certified prior to 2003 (1998 on Green Area public land) had inquiries
Soil type	Soil series well-represented	Soil series somewhat represented	Soil series not yet sampled	Want to get wide variety of soil series in the database
Crop type	Crop type well-represented	Crop type somewhat represented	Crop type not yet sampled	Want to get a wide variety of crops represented
Cropping system	Crop ping system well-represented	Cropping system somewhat represented	Cropping system not yet sampled	Want to get a wide variety of cropping systems (e.g., rotation, irrigation, organic, minimum till) represented

Factor	Rating			Comments
	1	**3**	**5**	
Number of Reference Areas	Site very complex – will require three or more sets of reference areas	Site moderately complex – will require two sets of reference areas	Site is apparently uniform – one set of references will be representative	Uniform site simplifies protocols and reporting; representative of most wellsites Moderately complex sites are easiest to address when there is clear demarcation in boundaries and site is split 50:50. Uncertain boundaries and/or different splits increases complexity and could reduce rating to 2 May still be worthwhile making observations about success if a very complex site is close to a sample site
Reference area location	Reference area in different section or different landowner	Suitable reference area within section and same landowner	Reference areas adjacent to site	Travel, access permission and interpretation difficulty increases
Infrastructure	Pipelines or wells within 100 m of the sampling location(s)			Ground disturbance rules require you stay 30 m away from a pipeline on either side and this makes sampling difficult
Adjacent or overlapping disturbances	Complete wellsite cannot be sampled		Complete wellsite can be sampled	Problematic if there will be difficulty in allocating responsibility for the results

Factor	Rating			Comments
	1	**3**	**5**	
Access impediments	Site only accessible by air or in winter	Site accessible year-round – long travel time from road, OR Site accessible year-round but travel route difficult (e.g., dense forest, wet areas) OR Site access in desired sampling window uncertain	Site accessible year-round – short travel time from road	Any site that requires additional access time and/or has uncertain access adds to time and reduces efficiency

Factor	Rating			Comments
	1	3	5	
Site proximity		Multiple sites of same ages and/or operators and/or production history in close proximity	Multiple sites of different ages and/or operators and/or production history in close proximity	Maximizes travel efficiency while allowing for replication of site characteristics in the database

AER (http://mapviewer.aer.ca/Html5/Index.html?viewer=aerabnwells) or AbaData (http://abadata.ca/) are sources for information on spud date, abandonment date and certification date.

APPENDIX 2: Cheat Sheets

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

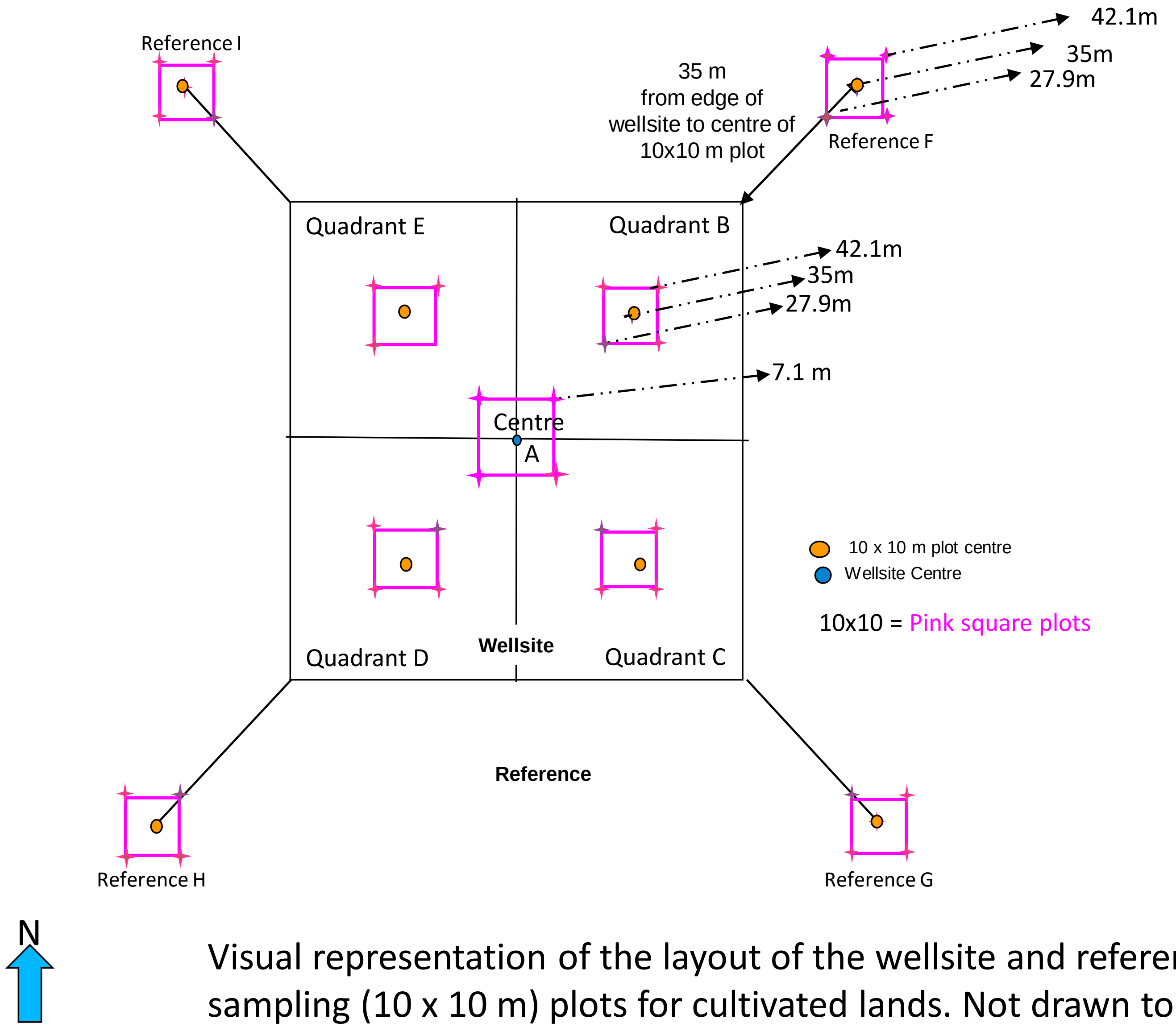
(requires 45 pigtails if laying out entire wellsite (n=25) and reference sites (n=20) at the same time)

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.