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Peatland Restoration of Abandoned Oil and Gas Well Sites (GL# 13-AU-ERPC-08)

Year One Summary Report

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Scope of Proposed Research

Restoring peatlands following in situ industry activity in the boreal region of northern Alberta presents a set of challenges that have yet to be properly addressed. The lack of proven treatments for restoring peatlands, coupled with a tightening regulatory environment suggest that peatland restoration will likely result in substantial long-term liability, possibly even limiting further development for the oil sands resource. Expanding the array of restoration methods and technologies for peatlands is of utmost urgency given the important of oil sands extraction to Canada's overall economic wellbeing.

Our trials will assess and quantify six well pad removal options. Our trials will assess the use of donor site materials in plant establishment. Our trials will assess plant propagation and establishment methods. Our trials will apply risk management to climate uncertainty

- **Cost-effective and ecologically suitable pad removal techniques**

(Monitoring hydrology and topography on our peatland restoration research trials)
Our first large-scale restoration project, the "Inversion Pad" research site, was depleted of its clay pad in December 2011. Six different pad removal techniques were used. Hydrology and topography will monitored intensively over the first five years. The University of Calgary is our partner responsible for detailed studies of site hydrology. The results will help us to determine which of the pad removal techniques are promising for peatland restoration in a poor fen setting. Our subsequent trials will be based on knowledge acquired from the first trial and will focus on the most promising techniques. *Monitoring the existing Inversion Pad trial will enable us to make cost-effective operational recommendations to industry and reclamation enterprises.*

- **Cost-effective and ecologically suitable re-vegetation techniques**

(Monitoring plant community structure and dynamic on our peatland restoration research trials)
The re-introduction of peatland plants, specifically bryophytes, is the last step to peatland restoration. To assist industry in preparing for more stringent wetland reclamation criteria, NAIT Boreal Research Institute nBRI has re-vegetated the Inversion Pad site using various re-vegetation techniques for peatland plants. Plant community survival and structure will be monitored intensively over the first five years. Laval University is our partner responsible for detailed studies of plant ecology. Our short term goal is to restore typical peatland plant species. Our long term goal is to restore a functioning peatland in which peat accumulates. *Re-vegetation technique adapted to the deployment of peatland plant communities will be valuable tools to support the industry.*

- **Impacts of linear features in boreal peatlands**

(Describe hydrological properties of peatland types on each side of a well site access road)
The impact of linear features has been mentioned in the literature alongside the well pad reclamation issues. Hence, in an effort to reduce the impact of industry in wetland settings, NAIT Boreal Research Institute is including linear restoration in the project.

Progress Update: Feb. 27, 2013 to March 31, 2014

The official project initiation date is Feb. 27, 2013 with the first fiscal year ending on/before December, 15, 2013. However due to the late start of the proposed graduate candidate and the seasonal nature of field research, NBRI had officially requested and granted an extension of the first year funding to March 31, 2014. This report covers the progress made from the initiation date (Feb. 27, 2013) to the extended year one end date (March 31, 2014).

Inversion Pad Trial #1

The NAIT Inversion Pad research site is located 50 kms northeast of the Town of Peace River. Prior to disturbance, the site was a treed poor fen. Shell Canada built the 1.27 ha site in 2006 with borrow clay material, which created a 1.4 m thick pad. The pad was removed in 2011 via a combination of six different pad removal techniques developed by NBRI and Laval University.

A PhD student from Laval University was hired by NBRI under the PTAC grant to work on various aspects of the Inversion Pad. The student officially started in May 2013 when she first visited the site in Peace River and worked on the experimental designs and sampling schemes for the following years. Given the late start of the graduate student and her projects, NBRI requested an extension of year one to March 31, 2014 in order to complete the proposed research in time. This progress report reflects progress made since the grant initiation date (January 1st, 2013) to the extended finish date (March 31, 2014).

Determine effectiveness and cost of various pad removal strategies: On-going

Surface topography after clay pad removal plays an important role in reconnecting the water flow on the restored pad with the surrounding peatland. One of the key objectives of the proposed study is to monitor and assess the effectiveness of pad removal techniques in recreating a suitable substrate for peatland restoration. A sampling grid of 500+ data points in hexagon shape was set up in the summer of 2012. NBRI staff and the graduate student has been sampling the surface topography for the last two summer field seasons (fall 2012 and summer 2013). There is a stabilizing trend of the pad surface less than two years since the initial pad reclamation. Most of the topographical changes were observed in 2012, the summer immediately following the pad removal operations. In 2013, the overall site elevation has stabilized at -8.5 cm below the level of the surrounding hollows (Fig 3). As a comparison, the initial elevation of the site after pad removal was -10 cm below the level of the surrounding hollows. We did not observe surface rebound of compacted peat as we had expected. There was no significant peat settling either. The PhD student will continue to monitor the topography for a third year, but at a reduced frequency (twice per year).

Hydrologic Connectivity: On-going

Restoring hydrology is a critical step in restoring a peatland system. In the case of well pads constructed in peatlands, pad removal allows for a return of hydrological conditions. Our goal was to document the impact of the pad removal on well site and the hydrological conditions found following pad removal.

The hydrological conditions following clay pad removal was measured by NBRI in 2012 until the graduate student took over the routine monitoring in 2013. Water table position and near surface soil moisture were sampled monthly across the pad and in the surrounding peatland using a grid of hydrologic monitoring installations (wells and piezometers).

Water table fluctuations and connectivity with natural peatland were monitored for a complete growing season in 2013. New wells were installed on the research site itself as well as the surrounding peatland, including cut lines and winter roads. Level loggers were installed in a few designated wells. Permit for the water well installation (TFA 135077) was obtained from AESRD in 2013 and will be renewed in 2014. The hydrologic conditions will be further investigated over the next three years with collaboration from University of Waterloo.

Water samples were collected biweekly from monitoring wells on the inversion pad and from the surrounding natural peatlands. PH and conductivity was measured in the field. Additional analysis of water chemistry will be carried out once the analytical lab is set up at the NBRI facility. We will collect soil, water, and vegetation samples in the summer of 2014 and analyze for micro-nutrients as well as DON, DOC. These analyses will greatly improve our understanding of the soil processes and changes in the chemistry as the reclamation progresses over time.

Determine regeneration success of three peatland plant communities: On-going

In Eastern Canada, the use of live-moss transfer via donor sites has been largely successful in re-introducing, establishing and restoring plant communities in peat mines. However, conditions in the western boreal forest region are significantly different in terms of climate and industrial disturbance. Using the methods developed for restoration of peat mines in Eastern Canada (Quinty and Rochefort 2003), three commonly available peatland communities were harvested from cutlines and winter roads around the inversion pad and deployed on site in July 2012 by NBRI staff. Larch (*Larix laricina*) and black spruce (*Picea mariana*) were planted in selected areas on the Inversion Pad following a 1:10 ratio, at 1500 stems/ha. Control zones were left unplanted to determine if there is significant benefit in planting greenhouse seedlings compared to natural regeneration of woody species. Survival and health index of seedlings will be assessed every year for the next five years.

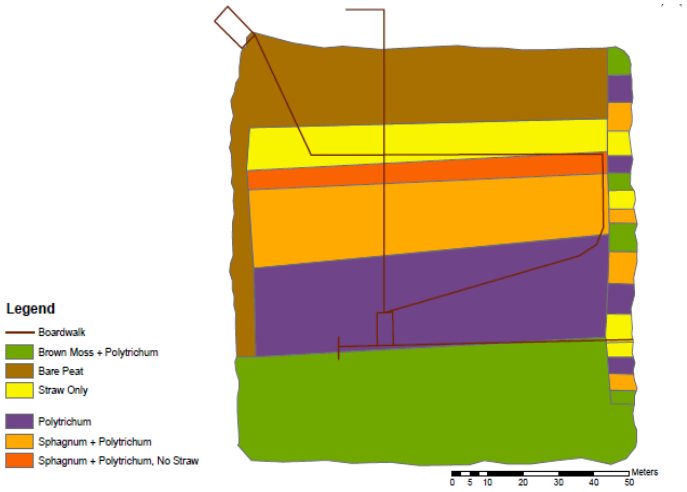

Figure 1. Re-vegetation treatment layout on the Inversion Pad #1

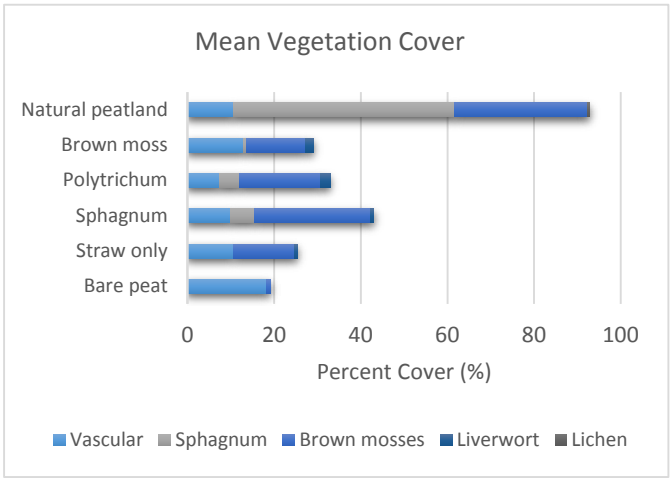

Figure 2. The mean cover of vegetation groups by re-vegetation treatments. Data collected in late summer 2013, one year after re-vegetation using the moss transfer approach.

Vegetation establishment, growth performance, and overall succession on the restored pad is being closely monitored by the graduate student from Laval University since May 2013. Vegetation establishment and dynamic is a core question of the student's thesis and data will be collected every year over the next 3 years.

In August, 2013, 40 permanent plots of 5m x 5m were established across the pad to monitor the vegetation change over time. The layout of permanent plots were designed based on the protocols of the PERG (Peatland Ecology Research Group, Laval University). Within each vegetation treatment (Fig. 1), eight permanents plots were established. Two additional permanent plots were established in the surrounding natural peatland as reference. Within each 5m x 5m plot, four 1m x 1m quadrats were setup to assess the percent coverage of all the vascular species present. Four subplots of 25cm x 25 cm were randomly placed in each permanent plot to assess percent coverage of the ground moss layer by specie.

Overall there were 49 vascular species growing at the end of growing season in 2013. Average vegetation coverage is about 30%, a very healthy start given the short growing period after the initial transfer in July 2012. As expected, natural surrounding peatlands had significantly higher vegetation cover than those on the pad, with poor plant establishment on bare peat. Vegetation coverage on the pad varied a lot between vegetation treatments (Fig. 2). Establishment of *Sphagnum* moss, the main peat forming species in boreal peatland, is higher on the *Sphagnum* and *Polytrichum* treatment and is lower when brown moss is present. Vascular plants are more abundant when there was neither vegetation treatment nor mulch cover.

Assessing peat-accumulation function: Start in May 2014 (Year TWO)

Peatlands are peat-accumulating wetlands where productivity rate exceeds the slow decomposition rate, thus leading to the accumulation of partially decomposed peat over time. Restoration of peatland functions should aim for returning the disturbed peatlands to peat accumulation status. Our specific goal of the inversion pad trial #1 was to set a trend towards peat accumulation within 3 years of pad reclamation.

Carbon accumulation will be assessed through the difference between biomass accumulation determined by harvesting small plots and litter decomposition determined with litterbags. Site carbon balance will also be determined with gas exchange measurements for carbon dioxide (CO2) and methane (CH4) using closed chambers. Restoration should result in progressively lower rates of carbon gas emissions from the former well pad with a trend towards carbon uptake during the growing season by the third year.

NBRI and collaborators from University of Calgary has started the gas flux collection in May 2014 and we will continue the C gas monitoring for the next three years. We should be able to identify key drivers in returning restored peatlands to a net C sink overtime.

Well Pad Peatland Restoration Trials #2 #3 and #4: Under Development

As part of the NAIT NSERC Industrial Chair in Peatland Restoration, NBRI has developed a research plan in which three new applied research trials will be conducted at operational scales. These trials will allow for the tracking and reporting of approaches to overcome logistical constraints, including accessing and operating on site with heavy equipment under frozen conditions.

The research program will look at removal of fill material and geo-textile along with managing grade and integration of site and landscape hydrologic function. Understanding the environmental context of the surrounding peatland is pivotal to successful re-integration of well site hydrology. The most versatile trial will be the one which is able to: (1) connect the surrounding peatland with the restored area, and (2) has the greatest degree of saturated but not inundated peat substrate for future vegetation establishment.

Based on the results from Inversion Pad Trial #1, at least three different well pad removal techniques will be tested: complete well pad removal, partial well pad removal, and heterogeneous well pad removal.

- Complete well pad removal: The entire well pad is removed. A risk with full pad removal is creating a shallow pond. Methods to de-compact the compressed peat will be explored with the objective of creating a saturated peat surface at the approximate level of the surrounding peatland for application of the moss transfer technique.

- Partial removal of well pad: The clay pad will be removed below the level of surrounding hollows. The result is a saturated mineral soil substrate of variable depth. This method has been tested for the successional fen approach by re-vegetating with *Carex* and *Salix* species. The objective is to investigate the potential for a broader application of the method for use with additional species.

- Heterogeneous well pad removal: Given the uncertainty of climate conditions in Alberta, a potentially safe restoration approach could involve restoring the well pad with highly variable microsite features. Operationally, this will involve removing or inverting portions of the pad to variable depths and building a series of artificial hummocks and hollows. In any given year, re-vegetation treatments would not be uniformly successful, but it would increase the probability of occurrence of suitable microsites and decrease the probability of complete failure due to natural climate driven variability in hydrology.

Application of these three well pad removal and restoration methods will vary depending on the surrounding peatland community types and hydrology. Each method could be applied to one entire well pad or two or three removal methods could be used on one well pad. NBRI is working closely with our industry partners and has identified two potential well pads for peatland restoration using the proposed methods. We will start preliminary data collection and site planning in July 2014 and will probably start civil earthwork and re-vegetation in the fall/winter of 2014.

Impacts of linear features in boreal peatlands: Planning/Under development

Linear features such as access roads in peatland interfere with hydrological flow paths resulting in backing up of water on one side of the feature, drying out on the opposite side and possible redirection of water to alternative flow paths. The absolute magnitude of these impacts on the peatland will depend on initial hydrologic conditions of the peatland (e.g. position within local and regional flow paths), the scale of the disturbance and its position/orientation within the peatland (parallel or perpendicular to local hydraulic gradients, within a recharge versus discharge area).

As ecology and bio-geochemical functioning of peatlands is closely linked to local hydrology (water table position, soil moisture, etc.) re-distribution of water within the peatland will have implications for whole ecosystem function. Restoration of roads should attempt to return local hydrologic properties and flow paths to the affected area of peatland to allow redistribution of water and return to more natural water table regime. We proposed to 1) study the hydrological impact of roads/linear features in surrounding peatlands; 2) to evaluate mitigation strategies (e.g. culverts, low impact road construction techniques); 3) to effectively restore a linear feature to re-connect water flows between upstream and downstream sides of peatlands.

Winter Road Reclamation: March 2014 – ongoing

A stretch of 300m x 6m winter road in the peatlands surrounding inversion pad #1 had been restored by NBRI and its collaborator from Laval University. Various soil placement and amendment methods were used to raise the road surface to the surrounding peatland levels. Islands of nearby peatland vegetation were placed onto the road surface to break up the light of sight of predators and to aid wood species establishment.

Water wells have been installed on the road and along two transects into the surrounding peatlands. Changes in water table position will be closely monitored starting May 2014. Fluxes of carbon will be measured monthly by our collaborators from University of Calgary. Vegetation success will be studied by the same graduate student from Laval University.

Project Outcome/Impact

Well pads and various roads and other linear features present big challenges to industry and restoration practitioners, especially when these disturbances are situated in a peatland setting. Altered hydrology as a result of the construction of these industrial features often lead to drastic decline in peatland vegetation and eventual loss of key peatland function and services. Our research aim to test various novel and practical techniques to assess the impact of industrial activities and to restore the disturbed areas by reconnecting hydrology and reintroducing suitable vegetation. We work closely with industry and partner with university research groups, SMEs, and practitioners to develop efficient methods to address challenges faced with peatland restoration. Our research

results will provide critical feedback to industry and practitioners for better planning and management of boreal landscape.

Since the initiation of our first inversion pad trial #1, we have produced three technical notes and one technical video, all of which are freely available on our website. The technical notes address key topics in peatland restoration including civil-earth work during pad inversion, machinery adjustment while working on wet substrate, and moss donor collection and transfer techniques to accelerate re-vegetation. We will produce at least one more technical note based on the winter road reclamation that was completed in the spring of 2014. Vegetation growth and monitoring on both well pad and winter roads will be featured in a separate technical note.

Communication/Extension Activities

Our research trials and results from post-restoration monitoring have been presented at over 8 national and regional conferences and workshops, including 1) CLRA Alberta Chapter Annual Meeting, March 2013; 2) CLRA Alberta Chapter Annual Meeting, March, 2014; 3) PTAC Workshop in Calgary, Nov. 2013; 4) Alberta Soil Science Workshop, Feb. 2014; 5) NAIT 3rd Annual Research Symposium, May 2013; 6) Peatland Ecology Research Group 20th Annual Workshop, Feb. 2014. The Ph.D student had successfully presented her research proposal in spring 2014.

HQP Training

Through the peatland restoration program we have hired and trained 7 summer field assistants from May to October, 2013. They worked on various projects related to the restored inversion pad and associated linear features. Majority of the summer students went back to school after the summer field season. Two of them were hired by AI-TF, and Paragon Consulting in the fall 2013.

Two full time research technicians had started at NBRI in January and May 2014 respectively. They are leading a team of 7 summer field assistants working on the inversion pad, winter roads, and newly developed peatland restoration projects.