A-10

Vegetative Cover Layer Design Package

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CALCULATION PACKAGE COVER SHEET

Client: Honeywell **Project:** Onondaga Lake SCA Final Cover Design **Project/Proposal #:** GD5497

TITLE OF COMPUTATIONS **VEGETATIVE COVER LAYER**

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APPROVAL NOTES:

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VEGETATIVE COVER LAYER

PURPOSE

The purpose of this calculation package is to summarize the findings and limitations of the vegetative soil test plots presented in the "*SCA Vegetative Cover Test Plot Memorandum*" prepared by Parsons and dated March 7, 2016. The memorandum is presented in Attachment 1.

TEST PLOTS BACKGROUND

As discussed in the memorandum, Parsons constructed two full scale test plots in the SCA borrow pit during the 2015 growing season to evaluate four different types of material proposed to support native grassland growth for the SCA final cover. The first test plot was constructed on June 10, 2015 and seeded with a mix comprised of 16 native grassland species (i.e., no cover crop or species requiring cold stratification to germinate). The first test plot was monitored until August 17, 2015. The second test plot was constructed on August 25, 2015 and seeded with a mix comprised of 39 native grassland species and a cover crop of oats. Monitoring results through October 29, 2015 are currently available. Both test plots were constructed with four different vegetative cover layer types and three different fertilization levels. The components (i.e., borrow material, sand, and topsoil) of each vegetative cover layer type were tracked in separately and top dressed with an average 2-inch thick layer of compost (NYSDOT Type C). Seed mixes were evenly distributed on the compost and tracked in with a dozer and watered once. No routine maintenance was conducted following the seeding and initial watering.

KEY FINDINGS AND LIMITATIONS

The following notes, results, and conclusions presented in the memorandum are considered significant towards developing expectations for vegetation growth on the SCA final cover:

- 100% topsoil should not be used (based on input from Dr. Donald Leopold at SUNY ESF and the Audubon Society);
- Each of the four different vegetative cover layer types appeared capable of supporting germination and growth of the cover crop and native grassland species to varying degrees of coverage;
- Type #3 with 60% borrow material, 30% sand, and 10% topsoil showed the greatest percentage of cover growth, and the cover appeared denser and more robust than the other soil types;
- The addition of sand and topsoil at the surface appears to increase the percent cover of vegetation over at least the first few months as compared to borrow material alone. Test plots prepared by tracking the borrow material with a dozer (D6T with 2.6-inch grousers) followed by the placement and tracking of sand and topsoil with a dozer appeared to be

capable of supporting germination and growth of seed. It is anticipated that disking to combine the three materials (i.e., borrow material, sand, and topsoil), which is planned during full-scale implementation, would further improve long-term performance;

- Oats (i.e., cover crop) were the most abundant species, and some warm weather and volunteer species were present (i.e., limited data on species diversity and no data on cold weather species);
- The vegetation grew quickly and densely in most areas after seeds germinated;
- Vegetation growth appeared in narrow and evenly spaced rows (i.e., seeds settled into track depressions), and alternative methods should be explored if a more uniform vegetative cover is desired;
- Addition of fertilizer appeared not to have a significant influence on vegetation growth;
- Native grasslands require two to three years to fully establish (i.e., a couple years will likely be required to see mature vegetation on the SCA final cover);
- The test plots did not include a geomembrane (i.e., the geomembrane in the final cover soils results in less depth for root growth, which is another potential variable); and
- The memorandum does not discuss whether all 39 native grassland species are expected to grow.

SUMMARY

The purpose of the SCA borrow pit vegetative test plots was to assist decision making regarding the final SCA vegetative cover layer composition. In light of the observations of the test plots noted above, the soil cover type referred to as Type #3 (60% borrow material, 30% sand, 10% topsoil) appears reasonable for use with native grassland species. Based on organic content data available for the borrow material and the topsoil from the borrow area, it is anticipated that the organic content of the combined material will be around 1%. Compost will provide additional organic material at the surface. It is important to note that this is a variation from what would normally be incorporated into a landfill covering, however, the team recognizes the value of the use of native species. With this soil type it may be necessary to add amendments (e.g., fertilizer, etc.) after the first year to fully establish vegetation. As necessary, the addition of such amendments should be accounted for in the post-closure care phase of the project.

The relatively short growing periods of the test plots (i.e., approximately two months) results in several unknowns with the use of the Type #3 soil and long-term native species vegetation growth. In particular, the range of species density and diversity is not clearly understood. It seems reasonable to expect that not all planted species will survive. Based on observed performance of the vegetation growth, the vegetative cover layer may need to be incrementally reseeded to achieve the satisfactory conditions of vegetated areas defined in Specification 02910 Seeding and Rolled Erosion Control Product. Given that it takes two to three years to establish native species, it is

recommended an observational approach be used. After the first few years, the species that are doing well should be used in any subsequent reseeding. In addition, maintenance activities such as irrigation and placement of additional compost, fertilizer, or other amendments may be required to establish and sustain acceptable vegetation coverage on the SCA final cover.

Written by: **Ray Wu** Date: **03/07/2016** Reviewed by: **Sowmya Bulusu / Jay Beech** Date: **03/07/2016**

Client: **Honeywell** Project: **Onondaga Lake SCA Final Cover Design** Project/ Proposal No.: **GD5497** Task No.: **03**

Attachment 1

PARSONS

MEMORANDUM

Project: SCA Borrow Pit Test Plots - Summer 2015 **Date: 3/7/2016**

SUMMARY

Test plots were constructed during the 2015 growing season in the SCA borrow pit to assess the ability of borrow pit material to support growth of plants from seed. These test plots were intended to provide "proof of concept" that borrow material, or combinations of borrow and other material, could support sufficient plant growth to be considered for use as the vegetated cover layer at the SCA. The concept of using borrow material for the vegetated cover layer was based on input from Dr. Donald Leopold at SUNY ESF and the Audubon Society. They indicated that 100% topsoil should not be used when establishing native grassland cover (a goal for the SCA cap) because topsoil tends to naturally contain a high density of seeds from aggressive non-native weed and invasive species that have a significant competitive advantage when grown in the higher organic content of traditional topsoil.

During the winter of 2014/2015, prior to construction of the test plots, a small scale proof of concept study was conducted by Dr. Leopold to determine if borrow material was capable of supporting plant growth from seed. The study entailed installing a known number of seeds from several native grassland species (that did not require a cold stratification period to germinate) into pots containing either 100% borrow material, or borrow material mixed with 10% sand, or 10% topsoil. The seeded pots were watered daily and provided ideal temperature and humidity in SUNY ESF's research greenhouse. The results from this study showed that 100% borrow material and both mixture types were capable of germinating and initially supporting growth from seed. However, growth in the 100% borrow material declined over time. The decline is thought to be associated with the very low organic content of 100% borrow material and that it became hardened if not regularly watered (likely due to the high clay content). These results were used to refine a full scale test.

In the full scale plot, three combinations of borrow pit material with sand and topsoil were tested, as was a 100% bank run material. The first borrow pit test plot was constructed in early June 2015 and seeded with a mix comprised of 16 native grassland species (see Attachment 1) with no cover crop. The number of species used in the seed mix for the first test plot was smaller than will be used on the SCA because those species requiring cold stratification to germinate were not included. Initially the plot was expected to be monitored through the fall of 2015; however, because the underlying and surrounding material was needed for the SCA cap, monitoring was ended on August 17th, 2015, several months earlier than expected. At that time, growth was

generally sparse and consisted of mostly volunteer species that were not part of the original seed mix. The areas containing a higher proportion of sand placed on top of borrow material did appear to have a slightly higher vegetative cover than other areas, however the results from different combinations were not statistically significant.

Given the early termination to the first test plot study, a second test plot was constructed in another section of the borrow area on August 25th, 2015. A native seed mix of 39 species, comparable to what would be used on the SCA cap, in addition to a cover crop of Oats (*Avena sativa*) was applied (see Attachment 2). The goal is to monitor this area for one full growing season (through summer 2016) to allow both cool and warm season species the chance to germinate and grow. This memo provides a summary of findings through the end of the 2015 growing season.

Quantitative monitoring of the second test plot was conducted on October 29th, 2015. Overall, growth was much greater than at the first test plot (average of 70% cover compared to 15% in the first plot), indicating that the tested materials can support initial germination and growth from seed. Oats were the most abundant species, with warm weather species from the seed mix also common, as well as some volunteer species. Similar to the first test plot, the areas containing borrow material with the highest percentage of sand placed on top of borrow material had the highest vegetative coverage, but unlike the first plot this difference was statistically significant compared to the other three materials tested.

The results indicate the test plot was capable of supporting initial germination and growth from seed. Including sand and topsoil at the surface appears to increase percent cover of vegetation during the first few months. This information should be factored into decisions related to the final design of the vegetated cover layer for the SCA.

PLOT DESIGN

The locations of the first and second test plots are shown in Figure 1. The first test plot was 200’ x 100’. The second test plot, located in a different location, was slightly smaller and measured 140’ x 100’. In each test plot, the same four vegetative cover layer types were tested along with three different fertilization levels. Vegetative cover layer combinations were created by placing layers and tracking each layer with a D6T dozer with 2.6 inch grousers. Layers consisted of borrow material as the base layer, followed by sand then topsoil. The vegetative cover layer types are shown in Figure 2 and were as follows:

Type #1 = 80% borrow material, 10% sand, 10% topsoil
Type #2 = 70% borrow material, 20% sand, 10% topsoil
Type #3 = 60% borrow material, 30% sand, 10% topsoil

Type #4 = 100% bank run material

Granular 10-10-10 fertilizer was applied to each vegetative cover type at the three following rates:

Application Rate A = no fertilizer
Application Rate B = 200 lb/acre
Application Rate C = 500 lb/acre

The entire area was then top dressed with an approximately 2 inch layer of compost that was procured from Greenscapes in Jamesville, NY, and which met NYSDOT Type C compost specifications. Seed mixes were evenly distributed on the compost then tracked in with a dozer and watered once. No routine maintenance was conducted following seeding and initial watering.

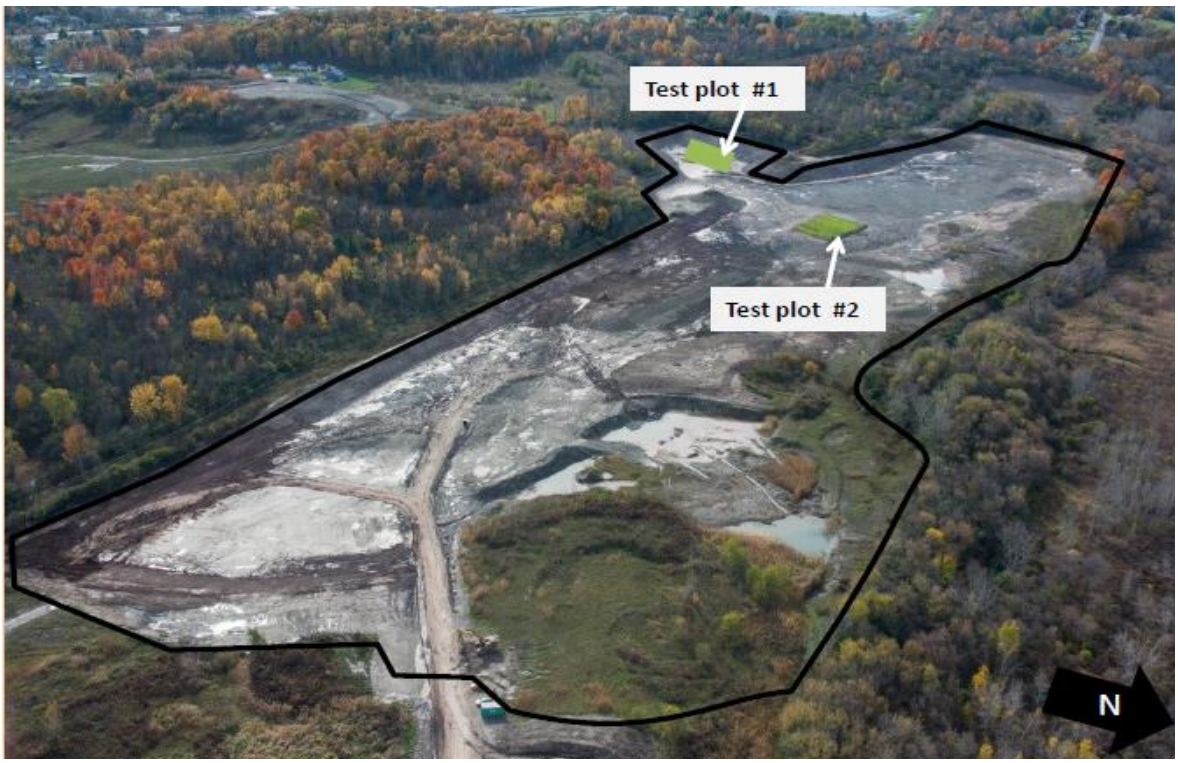


Figure 1. Locations of the two borrow pit test plots studied in the summer and fall of 2015.

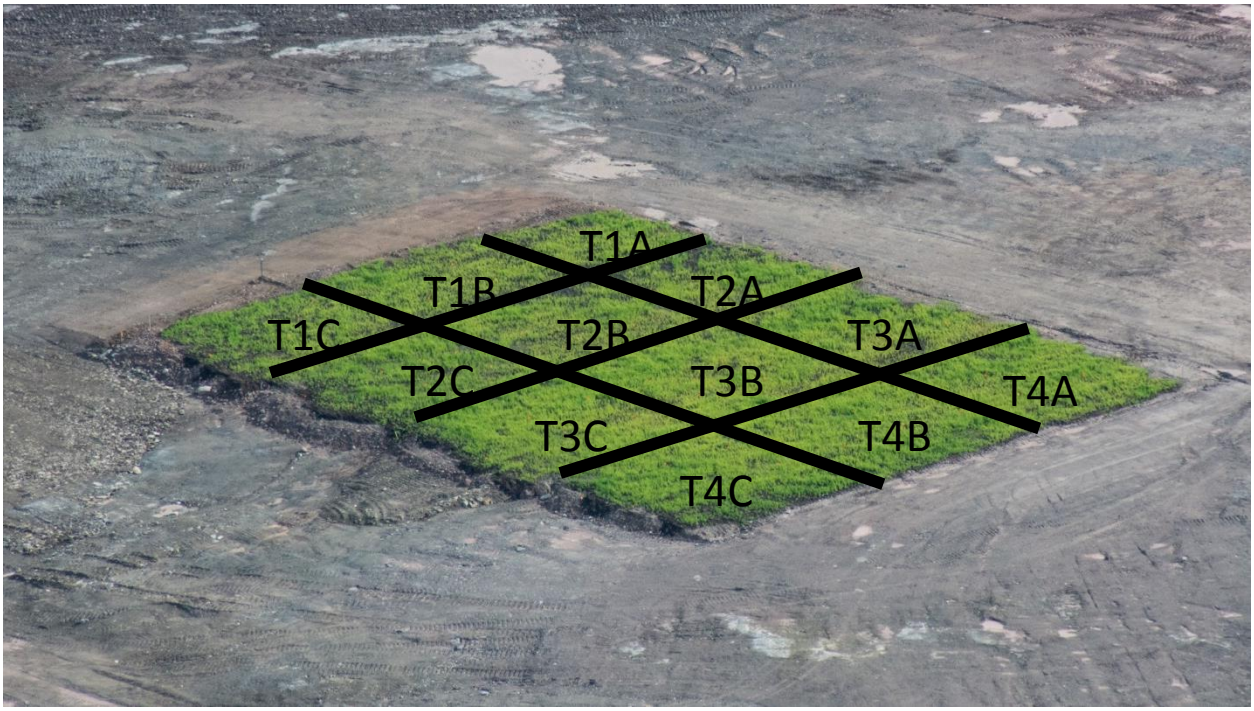


Figure 2. Aerial photo of completed plot showing subplot layout. Letters and numbers correspond with vegetative soil layer types and fertilization levels. For example, subplot T1C is vegetative cover layer Type #1 with fertilizer application rate C (80% borrow material, 10% sand, 10% topsoil with 500 lb fertilization application).

MONITORING METHODS

A monitoring program was designed to track the progress of the plots over time. The intent was to help determine if there were notable differences in growth between the four different vegetative cover layer types and three fertilizer application rates, and, if so, whether observed differences were statistically significant.

The first plot was visited on a weekly basis from June 10th, 2015 through August 17th, 2015. During each visit, photographs and general observations of new growth were documented. At the end of the monitoring period, the percent cover was quantitatively assessed within two 5'x16' sample areas per subplot (24 samples total).

Monitoring of the second plot was conducted weekly from August 25th 2015 through October 29th, 2015, with a final quantitative monitoring effort taking place at the end of the monitoring period. Compared to monitoring at the first plot, the size of the sample areas was decreased (four, one-square meter areas within each subplot) and the total number increased (48 total).

RESULTS

First Test Plot

Growth in the first test plot was sparse (avg. 15% cover) and the majority of plants observed were from volunteer species, not the seed mix. It is unclear if the generally sparse growth was related to the seed, material, timing, weather, or to a combination of these variables. The plants that were present appeared healthy and grew well. The subplots with vegetative cover Type #3 (60% borrow material, 30% sand, 10% topsoil) and #4 (100% bank run) had slightly higher percent cover than the other subplots, however only the difference between Type #3 and Type #1 material was statistically significant ($p<0.05$) (see Table 1). There were also no statistically significant percent cover differences between fertilizer application rates ($P>0.05$) (see Table 2). Few conclusions can be drawn from this test plot alone.

Table 1. Average percent cover by soil type in the first borrow pit test plot.

Vegetation Cover Type:	#1 (80-10-10)	#2 (70-20-10)	#3 (60-30-10)	#4 (Bank Run)
Avg. % cover:	12	13	16	17
Standard Deviation	3	5	7	12

Table 2. Average percent cover by fertilizer application rate in the first borrow pit test plot.

Fertilizer Application Rate:	0 lbs/acre	200 lbs/acre	500 lbs/acre
Avg. % cover:	17	13	14
Standard Deviation	11	3	7

Second Test Plot

Seed in the second test plot was slow to germinate with only minimal growth present a month following installation. This was to be expected, as optimum seeding periods are between mid-spring and early summer, typically May and June, for warm season species, and early spring or

mid to late fall for cool season species and those requiring a period of cold stratification. However, once seed began to germinate, it grew quickly. By the time the quantitative monitoring took place a month later, on October 29th, the average percent cover of vegetation ranged from 34% to 74% across the four vegetative cover types. The overall average across all material types was 52% and was significantly higher than the first plot ($p<0.05$). The difference in growth compared to the first test plot can be easily seen in the attached photographs 1 to 4 and 15 to 17.

The majority of the biomass appeared to be from the oats cover crop, although multiple species from the seed mix and several volunteer species were also present. This is not unexpected for native seed mixes with an annual cover crop. Cover crop puts most of its energy into above ground biomass and establishes quickly, helping to stabilize soils, while the native species grow more slowly during the first year. In the second and third years, the native species take on a more prominent role as species requiring a period of cold stratification germinate, and plants that germinated in the first growing season put additional energy into above ground growth.

Observations showed that most growth appeared in narrow and evenly spaced rows (see photographs 15 to 17). This appears consistent with the area having been tracked as intended and seed settling into the track depressions. Another possibility is that seed to ground contact was better in these depressions, allowing for increased germination (seed to ground contact is critical for achieving successful establishment). Compared to a more uniform growth pattern, tracking likely reduced the overall percent cover somewhat by concentrating growth into narrow bands. If the full scale project is implemented at the SCA and a more uniform vegetative cover is desired, then alternative methods for installing seed, such as a drill seeder, should be explored.

Throughout the monitoring period, the growth in the vegetative cover on Type #3 and #4 areas appeared denser and more robust than the other plots. This was substantiated by the quantitative sampling with the Type #3 material (60% borrow, 30% sand, 10% topsoil) having significantly more growth ($p<0.05$) than any of the other material types with an average of 74% cover (range of other plots was 34% to 60%) (see Table 3). The Type #4 material (100% bank run) also appeared to perform relatively well with an average of 60% cover, which was significantly more ($p<0.05$) than the Type #1 or #2 materials.

Differences amongst fertilization rates was minimal (see Table 4) and, like the first plot, there was no statistically significant difference in plant growth amongst the three fertilization rates ($p>0.05$). The reasons for this are unclear. It is possible that the compost was adequate to support growth at these early stages and the benefit of fertilizer, if any, may be more apparent during subsequent growing seasons as nutrients from the compost are depleted and roots penetrate deeper into the underlying material.

Table 3. Average percent cover by soil type in the second borrow pit test plot.

Vegetation Cover Type:	#1 (80-10-10)	#2 (70-20-10)	#3 (60-30-10)	#4 (Bank Run)
Avg. % cover:	34	42	74	60
Standard Deviation	17	24	15	21

Table 4. Average percent cover by fertilizer application rate in the second borrow pit test plot.

Fertilizer Application Rate:	0 lbs/acre	200 lbs/acre	500 lbs/acre
Avg. % cover:	55	45	55
Standard Deviation	26	23	24

CONCLUSIONS

Native grasslands require two to three years to fully establish and, given this, the relatively short growing window documented for the two SCA vegetative layer proof of concept test plots makes drawing firm conclusions difficult. However, the information obtained from these areas was useful and can be used to assist decision making regarding the final SCA vegetative cover layer composition. The first test plot did not have a high rate of seed germination, but did support volunteer species that appeared to grow well until the plot was removed at the end of August. Preliminary results from the second test plot were encouraging. Once seed germinated, it grew quickly and densely in most areas. Type #3 (60% borrow, 30% sand, 10% topsoil) presented significantly more growth (74% cover) than any of the other vegetative cover types. The addition of fertilizer did not appear to have a significant influence on vegetation growth in either the first or second plot.

Based on these findings, the addition of sand and topsoil appears to increase the percent cover of vegetation over at least the first few months as compared to borrow material alone. Test plots

prepared by tracking the borrow material with a dozer (D6T with 2.6-inch grousers) followed by the placement and tracking of sand and topsoil with a dozer appeared to be capable of supporting germination and growth of seed. It is anticipated that disking to combine the three materials (borrow material, sand, and topsoil), which is planned during full-scale implementation, would further improve long-term performance.

If a non-topsoil alternative is used for the vegetated cover layer at the SCA, then the preliminary findings from this study suggest that vegetative cover Type #3, top-dressed with a compost layer, should be considered. If a more uniform growth pattern is preferred, compared to the row-like pattern documented on the test plots, then an alternative to tracking should be considered, such as drill-seeding.

The ability of these or similar materials to support and maintain long-term plant growth cannot be ascertained from the findings of this study. In addition, there are a number of unknowns associated with the potential use of this material, including its ability to sustain adequate vegetation during dry periods, and whether the generally low organic content of the borrow material will affect plant growth once (if) available nutrients from the compost and topsoil are depleted. Reduced plant vigor due to low organic content can likely be remedied relatively easily by application of appropriate fertilizer (if addressed in time). How this material will perform during dry periods is not known, however the initial greenhouse study indicated that 100% borrow material dried and hardened rapidly. The hardened material allowed water to pool at the surface and evaporate instead of soaking into the soil. On a full scale cover system, this would likely exacerbate the effect of dry spells since periods of light rain that would normally provide some relief on typical soils may simply evaporate on an area composed of borrow material. This finding led to increasing the proportion of sand and topsoil in the test plot borrow material mixes. However the extent to which these mixtures are better or worse than typical soils or 100% borrow material is not well understood. This could still be problematic if a dry period is experienced when plants are especially susceptible to drought during their initial germination and growth period. As such, some level of irrigation may be advisable (or at the ready) during the early establishment stages, or during unusual dry periods for the first few years.

First Borrow Pit Test Plot

Representative Photos

Photo 1. View of Test Plot #1 showing vegetative cover type #1 (80% borrow material, 10% sand, 10% topsoil) in the foreground on August 12, 2015.

Photo 2. View of Test Plot #1 showing vegetative cover type #1 (80% borrow material, 10% sand, 10% topsoil) in the foreground on August 12, 2015.

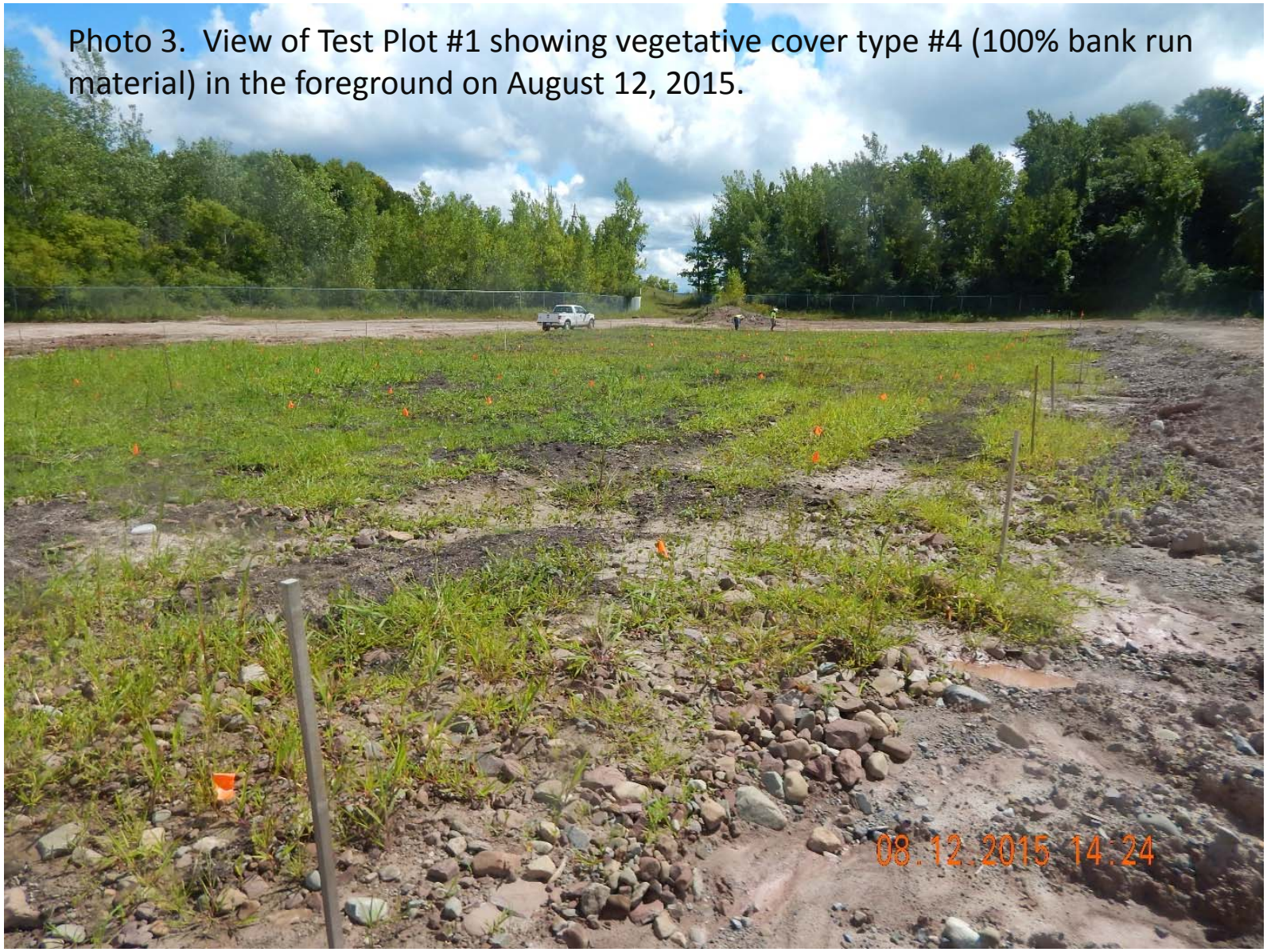


Photo 3. View of Test Plot #1 showing vegetative cover type #4 (100% bank run material) in the foreground on August 12, 2015.

Photo 4. View of Test Plot #1 showing vegetative cover type #4 (100% bank run material) in the foreground on August 12, 2015.

Type 1 (80% borrow material, 10% sand, 10% topsoil)
Representative photographs

Photo 5 & Photo 6. Photographs of monitoring plot locations taken during final plot monitoring on August 17, 2015.

Type 2 (70% borrow material, 20% sand, 10% topsoil)
Representative photographs

Photo 7 & Photo 8. Photographs of monitoring plot locations taken during final plot monitoring on August 17, 2015.

Type 3 (60% borrow material, 30% sand, 10% topsoil)
Representative photographs

Photo 9 & Photo 10. Photographs of monitoring plot locations taken during final plot monitoring on August 17, 2015.

Type 4 (100% bank run material)
Representative photographs

Photo 11 & Photo 12. Photographs of monitoring plot locations taken during final plot monitoring on August 17, 2015.

Second Borrow Pit Test Plot

Representative Photos

Photo 13. View of the approximate boundaries for Test Plot #2 vegetative cover types

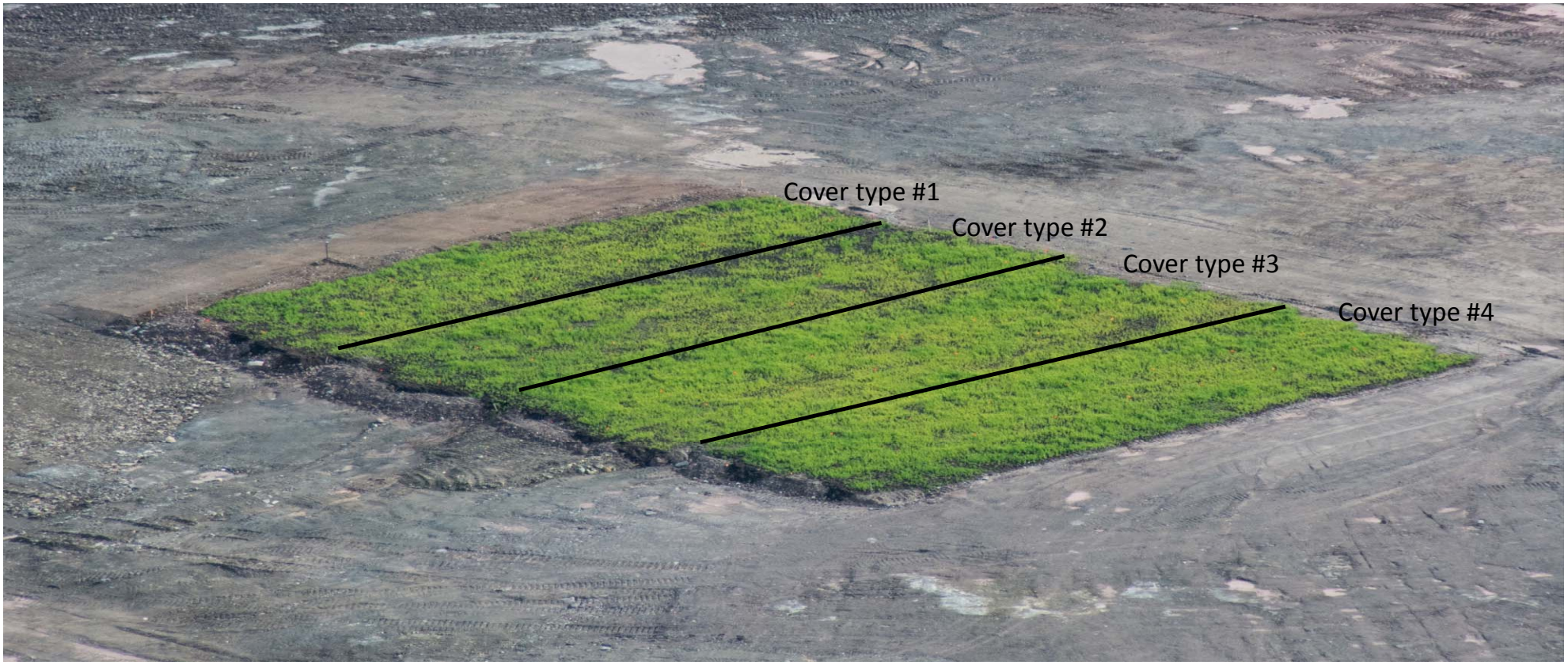


Photo 14. View of the approximate boundaries for Test Plot #2 vegetative cover types and fertilizer application rates.

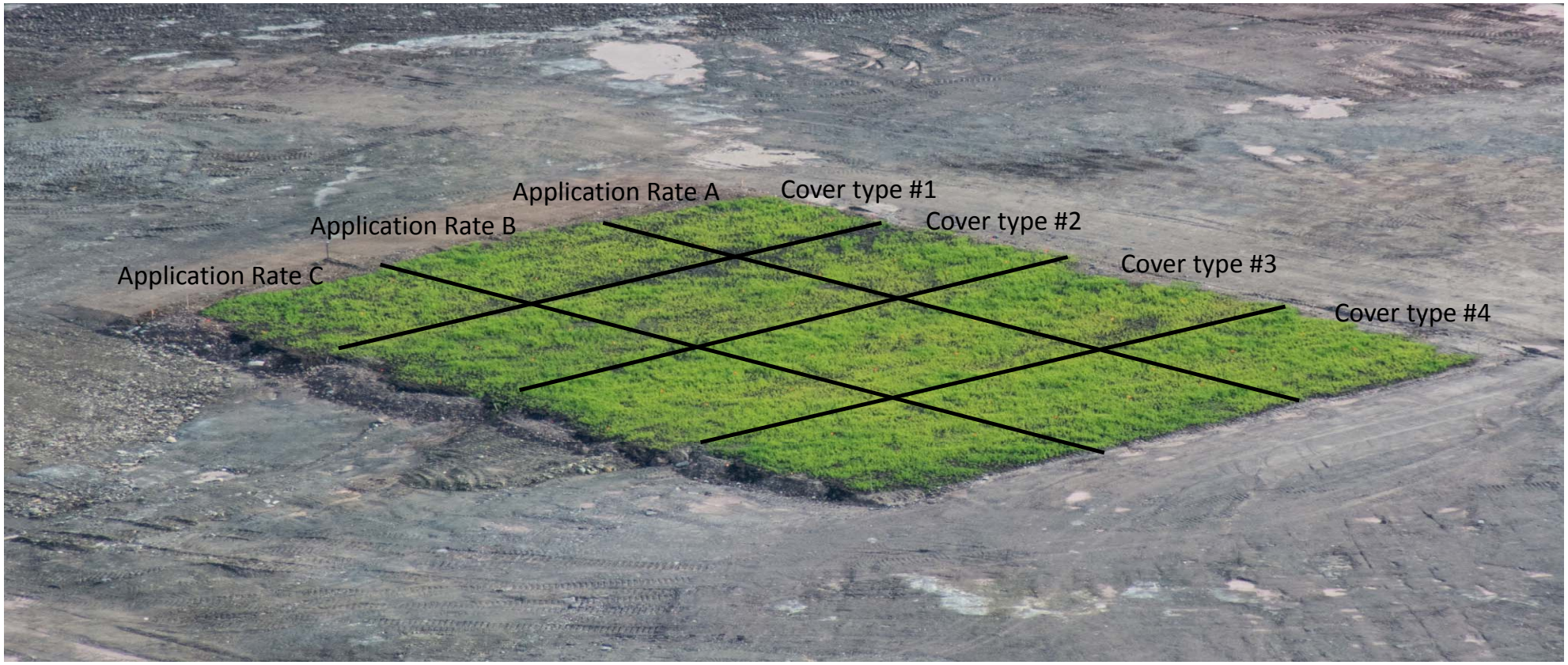


Photo 15. View of Test Plot #2 showing vegetative cover type #1 (80% borrow material, 10% sand, 10% topsoil) in the foreground on October 22, 2015.

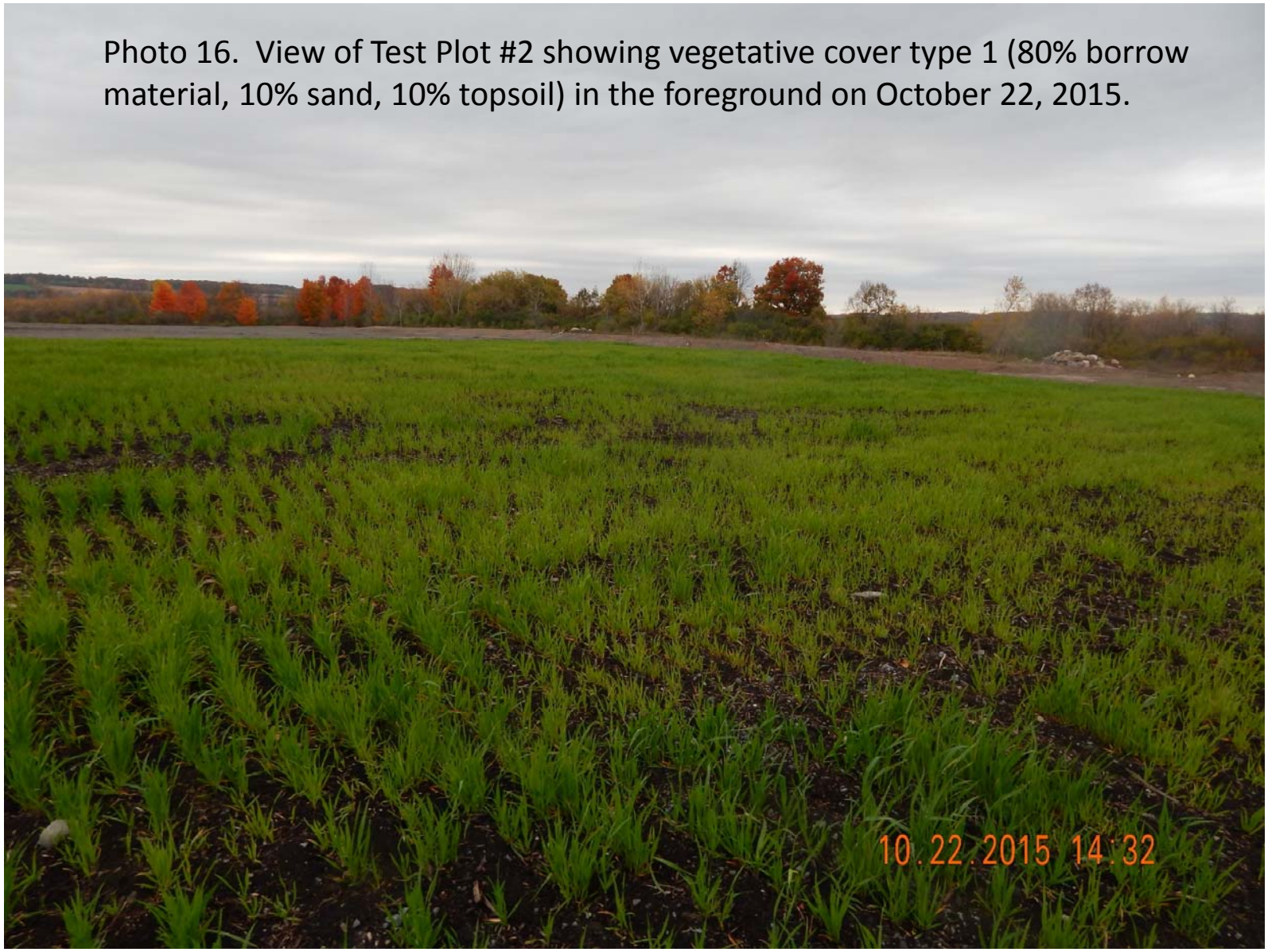


Photo 16. View of Test Plot #2 showing vegetative cover type 1 (80% borrow material, 10% sand, 10% topsoil) in the foreground on October 22, 2015.

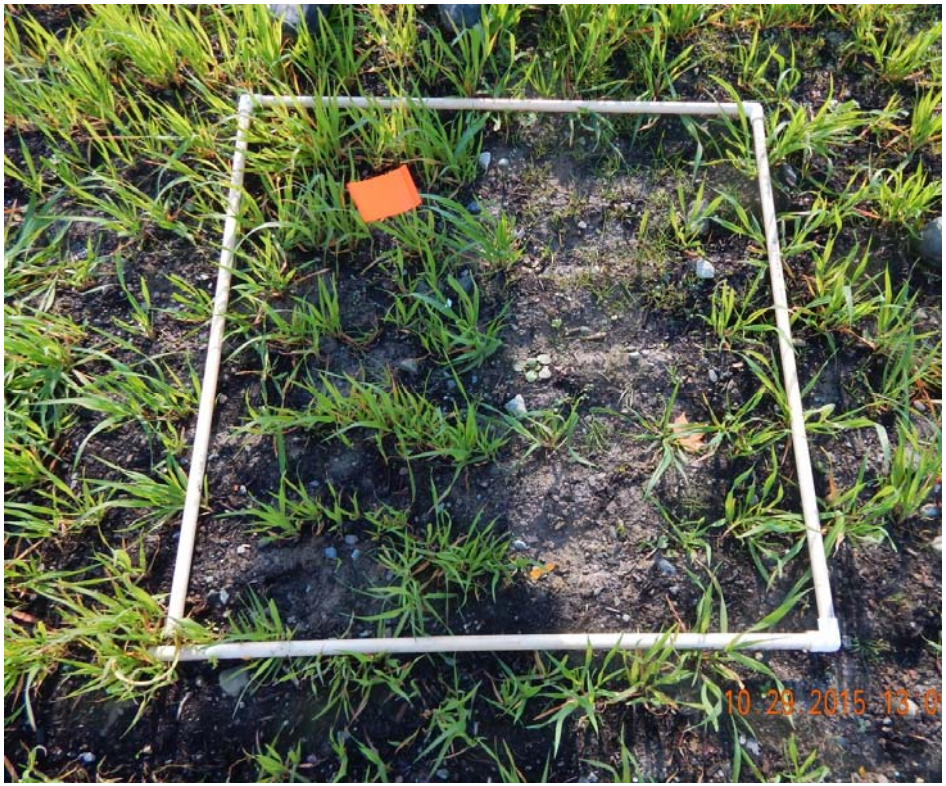
Photo 17. View of Test Plot #2 showing vegetation cover type #4 (100% bank run material) in the foreground on October 22, 2015.

Photo 18. View of Test Plot #2 showing vegetation cover type #4 (100% bank run material) in the foreground on October 22, 2015.

Type 1 (80% borrow material, 10% sand, 10% topsoil)
Representative photographs

Photo 19 & Photo 20. Photographs of monitoring plot locations taken during final plot monitoring on October 29, 2015.

Type 2 (70% borrow material, 20% sand, 10% topsoil)
Representative photographs



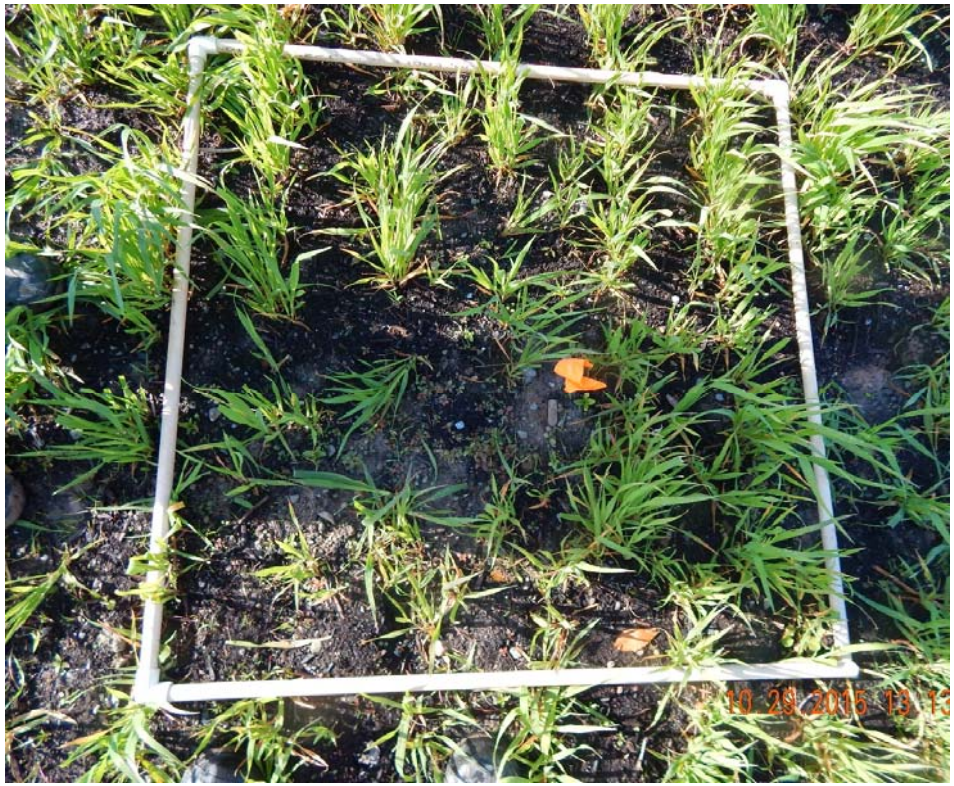
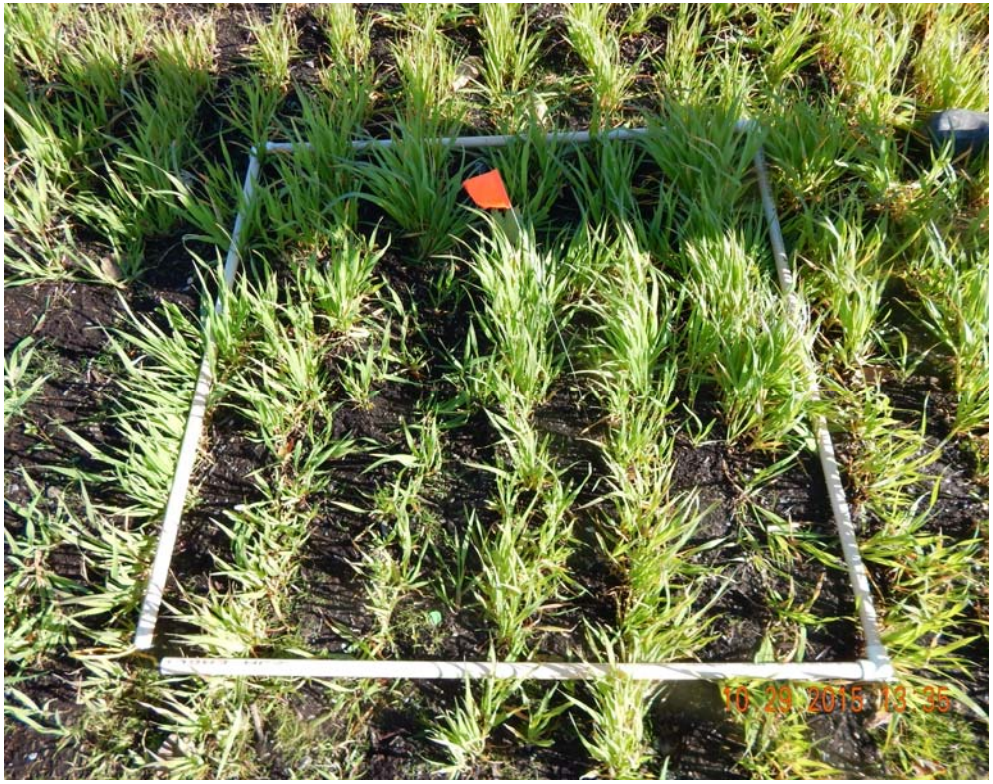


Photo 21 & Photo 22. Photographs of monitoring plot locations taken during final plot monitoring on October 29, 2015.

Type 3 (60% borrow material, 30% sand, 10% topsoil) Representative photographs

Photo 23 & Photo 24. Photographs of monitoring plot locations taken during final plot monitoring on October 29, 2015.

Type 4 (100% bank run material)
Representative photographs



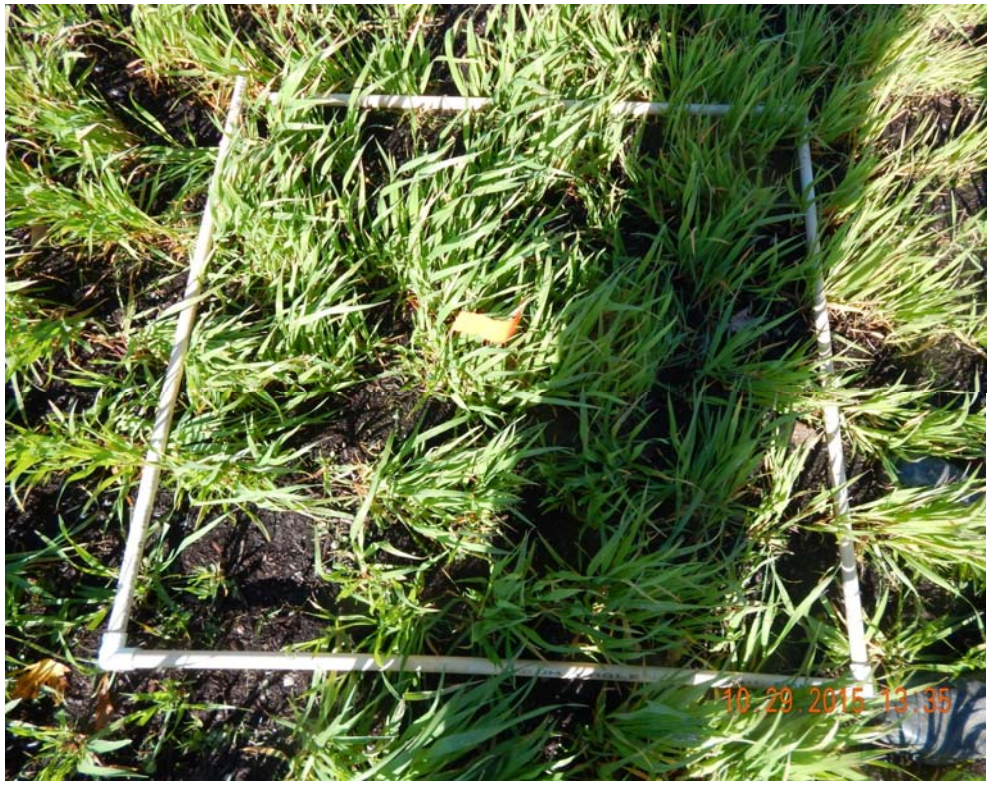


Photo 25 & Photo 26. Photographs of monitoring plot locations taken during final plot monitoring on October 29, 2015.