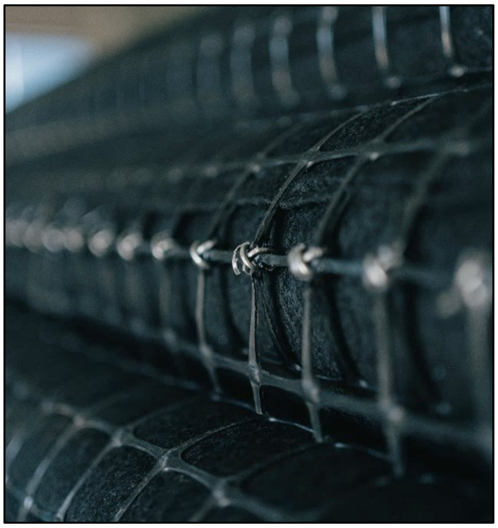

Spring Drain Treatment for Weakening Rail Embankment Subgrade
Current State of Development and Treatment Considerations

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S-Drains

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1.0 Introduction

The Spring Drain treatment improves rail subgrade performance amidst the effects of subgrade soil degradation. Dynamic and cyclic train loads can generate high excess porewater pressures within some subgrade materials. When the excess porewater pressures reach a critical level, weaking and softening of the soils through liquefaction or fluidization can occur. The loss of strength or stiffness can result in migration of the subgrade soils into or through the embankment fills and track ballast (ballast fouling) and railbed formations. In some cases, the collapse of the subgrade soils can occur leading to the formation of peat or silt (mud) boils. A significant and widespread loss of strength within the subgrade soils can also lead to reduced embankment stability and track bearing capacity.

The Spring Drain treatment was developed to allow treatment of problematic subgrade materials and conditions while maintaining the railbed and tracks in-place. Installation is conducted between trains and avoids costly site access issues i.e. Building an access road through swampy terrain, deep excavations, embankment reconstruction, track reconstruction, construction staging, material handling challenges, cost issues, staffing issues, remote area work, delays, and train traffic interruptions.

To date, the Spring Drain treatment has been used to successfully address peat subgrade issues, such as track deformations related to peat boils, peat migration and channelized peat migration. The Spring Drain subgrade treatment has been used successfully for eight projects, utilizing over 1,500 Spring Drains, to address problematic sites with peat subgrade. It is expected that the Spring Drain treatment will also be effective in treating silt subgrade issues. Currently, the Spring Drain treatment is not considered an engineered treatment. While past trials have proven to be effective, additional testing (such as large-scale direct shear testing with dynamic vertical loading) is planned in partnership with Lakehead University, to further understand the engineering properties and additional benefits of the Spring Drain system. The intent of this research is to obtain a better understanding of the expected performance components (as discussed below) of the treatment and to develop engineering design guidelines.

2.0 The Spring Drain

The Spring Drain is a patented product consisting of flexible weeping tile, wrapped with geotextile filters, which is encased in prestressed geogrid (a geosynthetic material that provides tensile soil reinforcement) . The product is filled with 19 mm clear stone. Installed vertically within the crib, track/tie removal is not required. The top of the Spring Drain is typically set 0.5 m below the base of tie. The base of the Spring Drain is installed at least 0.1 m into competent soils below the zone of problematic subgrade. Where soft or weak soils exist below the zone of problematic soil, a 1.0 m depth of embedment is suggested.

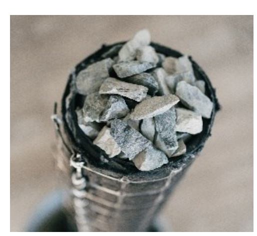


Figure 1

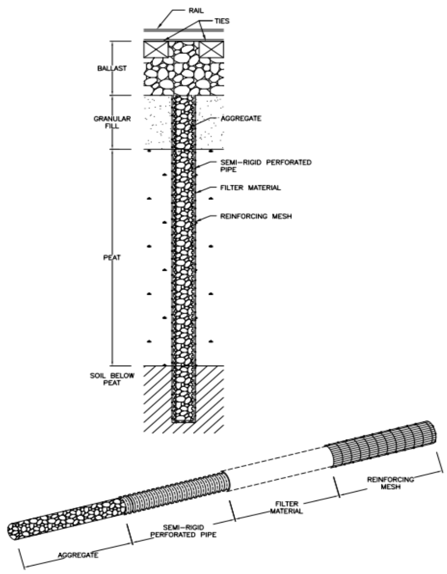


Figure 2

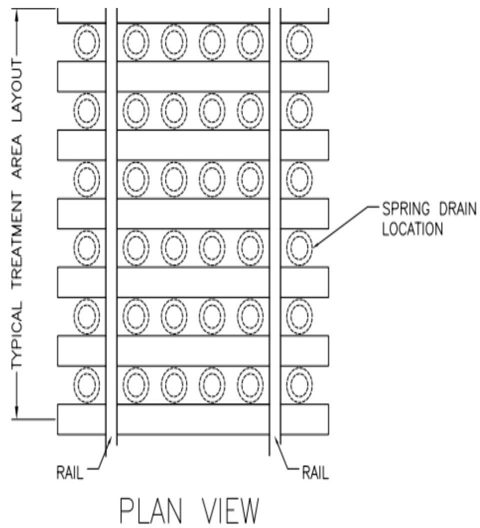


Figure 3

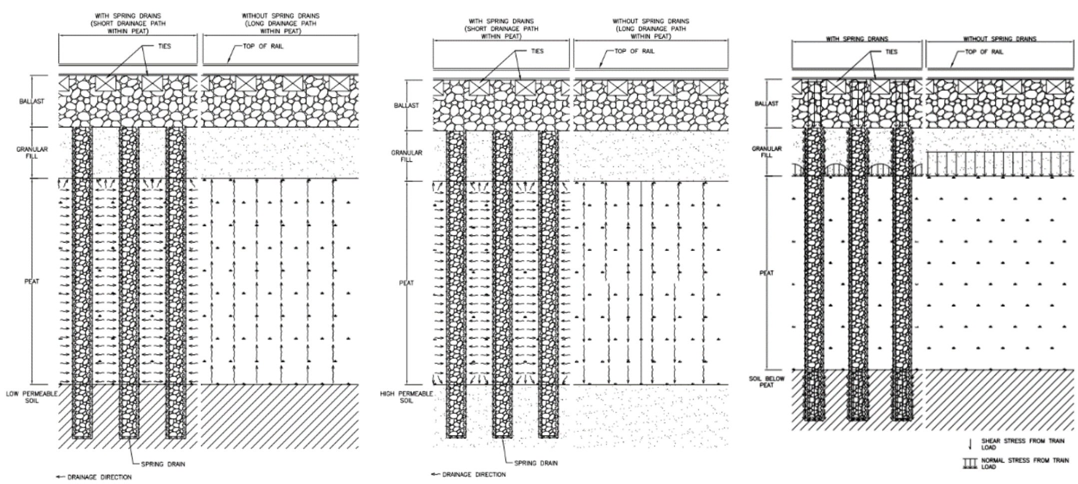


Figure 4

The main subgrade improvement components of the Spring Drain treatment are as follows:

- **Load Transfer Through the Problem Soils:**

  The Spring Drain is designed to be several times stiffer than the problematic soil, to permit some transfer of the train load to the more competent soils below. By reducing the train load on the problematic soils, porewater pressures generated from the compressive train loads are also reduced. The Spring Drain is not intended to be completely rigid with respect to problematic soils to limit the risk of jacking (lifting of the Spring Drain due to repeated compression and extension of the adjacent soil), twisting, torquing or breakage of the casement of the Spring Drain.

  Currently, Version 1 of the Spring Drain has been used at locations where the problematic subgrade consists of peat. For areas where the problematic subgrade consists of a loose silt or silty subgrade soils, the use of Version 2 should be considered. Version 2 boasts a notable increase in both stiffness and strength, measuring approximately double that of its predecessor, rendering it significantly more resilient and robust in comparison. Version 2, should be considered in areas with stiffer subgrade soils.

- **Reduce Excess Porewater Pressure:**
  The Spring Drain is highly permeable relative to the problematic subgrade soil. The Spring Drains allow for dissipation and relief of excess porewaters.

- **Shear Resistance:**
  The Spring Drain can also be considered as a soil reinforcement treatment, providing added resistance across potential shear zones. There is also the potential to reduce shear strain induced porewater pressures and improve embankment stability.

- **Dissipation of Travelling Waves of Porewater Pressure:**
  It is anticipated that during the passing of train, longitudinal waves a porewater pressure are generated and travel in the direction of the train.. It is suspected that the inclusion of the Spring Drain can aid in dissipation of travelling waves of excess porewater pressure.

- **Soil Consolidation:**
  Once the problematic subgrade soils have experienced liquefaction / fluidization, they present in a loosened state. Through various Spring Drain installation techniques, densification of the subgrade is promoted. This also improves the strength and liquefaction resistance of the soil.

- **Gas Dissipation**
  In the case of peat subgrade, decomposition of the peat over time can lead to the buildup of gases, which can make the peat less permeable and more prone to development of excess porewater pressure. The Spring Drain provides a pathway for trapped gases to escape.

- **Increased Track Bed Stiffness:**
  The inclusion of Spring Drains through the rail bed and into the subgrade soils is expected to increase the overall track bed stiffness as the Spring Drains are stiffer than the subgrade soils. By increasing the density of the treatment, it is expected that track bed modulus can also be increased.

The above Spring Drain treatment factors are currently hypothesized. A program of in-situ porewater pressure monitoring has been conducted which indicates porewater pressure reductions of 90%+. However, the comprehensive contribution of the various components is currently unknown. Additional research through a large-scale testing program at Lakehead University is currently in the planning stages.

3.0 Identification of Problem Areas

While the track may be constructed over an area of swampy terrain or over a loose silty subgrade that does not inherently guarantee the onset of subgrade-related challenges. Further study and research are warranted to identify and qualify risk factors that can lead subgrade liquefaction/fluidization (such as embankment construction, groundwater conditions, and condition of the subgrade soils, etc.).

The Spring Drain treatment is flexible, and the owner may wish to only target the most critical areas knowing that the treatment can be expanded later. Currently, problem track areas have been identified through the following methods:

- **Visual Inspection**
  During routine inspection of the tracks, attempt to visualize and mark areas of settlement, loss of standard ballast section, peat boils, mud spots, ballast fouling, channelized migration, rail anchor movements, or excessive track deformations. These deficiencies should be recorded and monitored over time, photographs should be considered. Special attention to exact location should be considered (paint marks on the rail with a sketch and GPS location). It has been observed that in areas with peat boils, the problem can often propagate over time, increasing the zone of weakened subgrade below the track, further increasing the risk of embankment failure.

Peat Boils

Figure 5

Channelized Peat Migration

Figure 6

Peat Migration

Figure 7

Excessive Track Deformations

Figure 8

- **Maintenance Records**
  Review of maintenance records pertaining to track lifting / leveling and ballast replacement should

be carried out to identify limits of problem areas.

- **Tech Car Data**
  Review of tech car data can be used to identify areas of track deformations. Look for settlements and loss of standard ballast section. Where video recordings of the track are available, this may also be reviewed to identified area of ballast fouling and/or boil formations.

4.0 Investigations

Various levels of subsurface investigations have been conducted prior to treatment. The level of investigation can vary depending on numerous factors and can also depend on the owner's current knowledge and understanding of the problem site.

4.1 Peat Subgrade Problem Areas

An investigation consisting of advancing boreholes through the embankment and hand operated peat probes near the embankment toes may be considered.
Key parameters to be identified would include:

- Ballast thickness (zones of thicker ballast may indicate ongoing settlement performance issues)
- Embankment fill thickness, type, and condition. If rock fill is anticipated or confirmed, alternate installation methods will need to be considered.
- Presence of corduroy
- Thickness and condition of peat subgrade (below and outside of embankment).
- Soil types and condition below the peat subgrade.
- Groundwater levels
- Terrain and embankment sections should be captured through topographic survey.
- Installation of piezometers may also be considered to provide a measurement of excess porewater pressure during train traffic.

This data will assist in planning Spring Drain treatment layout options, for consideration by the owner.

Analyses of bearing capacity and stability analysis of the embankment is encouraged. As a minimum, this would involve detailed laboratory consolidation and strength testing of the peat subgrade. Recommendations to improve stability of the embankment may be required and may include the construction of embankment flanking berms. At this time, further research is required to fully outline an accurate model of the load transfer and shear resistance provided by the Spring Drain treatment. However, the improvements to stability based on a reduced level of excess porewater pressure can be modeled and verified through a porewater pressure monitoring program.

4.2 Non-Peat Subgrade Problem Areas (Silt Boils / Mud Spots)

The Spring Drain was developed to address peat subgrade issues; however, some of the contributing performance mechanisms may provide benefit for areas subject to silt / silty mud spots. Should a trial Spring Drain treatment be considered in silty subgrade soils, it is recommended that sufficient data (subsurface investigations and monitoring of settlements and porewater water pressures before and after treatment) be obtained to quantify performance.

In addition to the date required for peat subgrade areas, the investigation for silt mud spots should also identify the depth of soils experiencing liquefaction/fluidization and the condition of the soils below the problematic zone. The use of geophysical methods, CPTu, DMT, or other means may be considered in addition to conventional boreholes.

5.0 Current Treatment Levels and Considerations – Peat Subgrade Issues

Various treatment levels have been tried to date. The density of the Spring Drain treatment has been defined as the number of Spring Drains installed per crib.

The level of treatments carried out to date are as follows:

5.1 At Peat Boil Locations, or Locations with Excessive Deformation Areas

At locations where peat boils (hole formations extending through ballast, or embankment with visible peat ejection), channelized peat migration (where a zone of peat has broken through the embankment or near the embankment toe), or where excessive deformations have been realized various treatment levels have been considered. The limits of the treatment have generally covered the main area of concern and extend track east and west 1 to 2 times the depth of peat. Coverage extending beyond the localized identified problem zone is recommended.

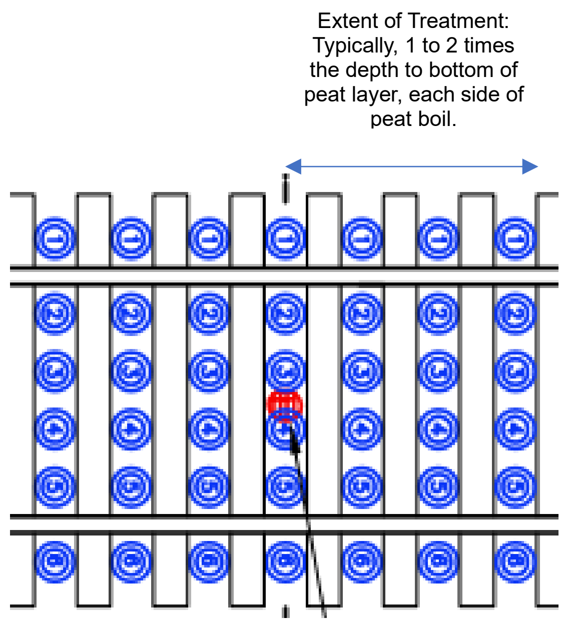
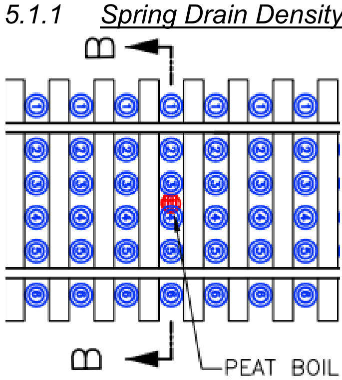
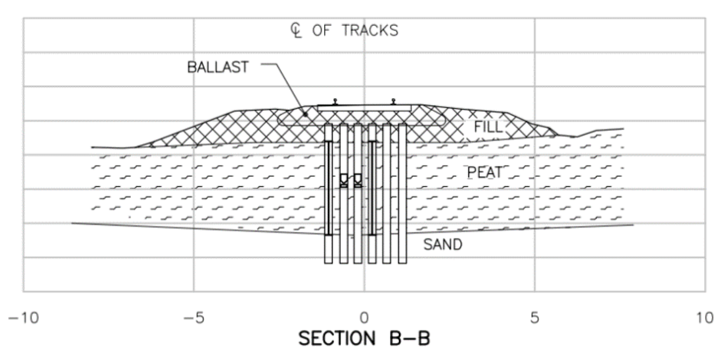


Figure 8

5.1.1 *Spring Drain Density – 6 Spring Drains / Crib*

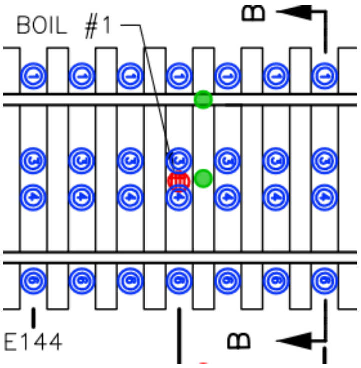


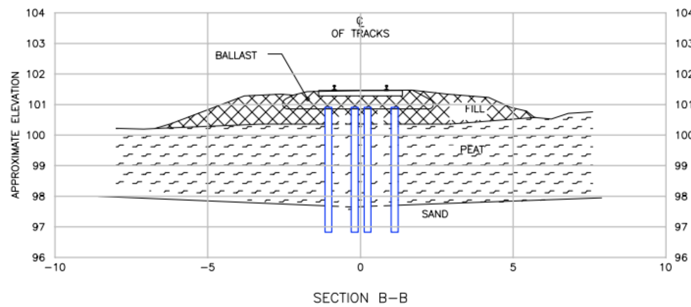


At one site, monitoring of porewater pressures during the passing of trains indicates a density of 6 Spring

Drains / Crib, reduced excess porewater pressures by 93 %, 1.5 months after treatment.

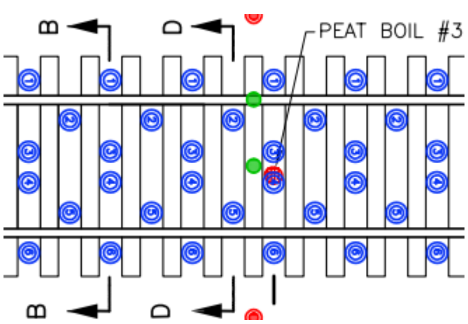
5.1.2 Spring Drain Density – 4 Spring Drains / Crib

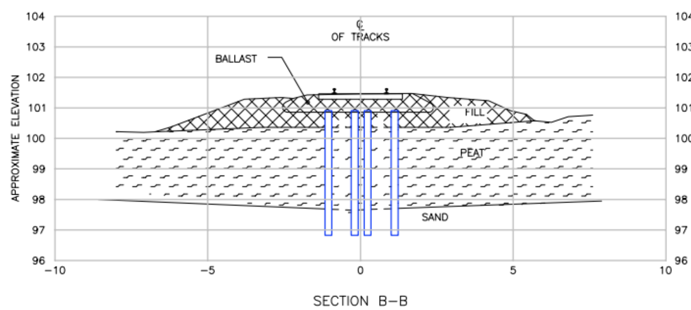


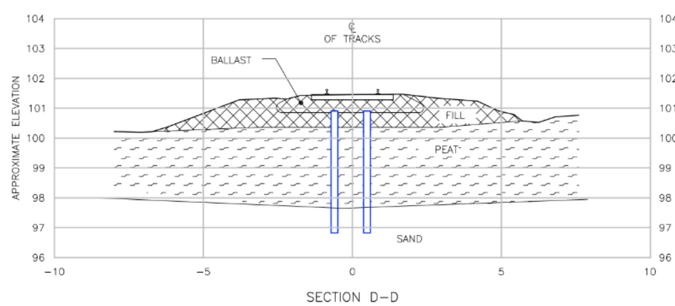


At one site, monitoring of porewater pressures during the passing of trains indicates a density of 4 Spring Drains / Crib, reduced excess porewater pressures by 92 %, 2.5 months after treatment.

5.1.3 Spring Drain Density – 3 Spring Drains / Crib

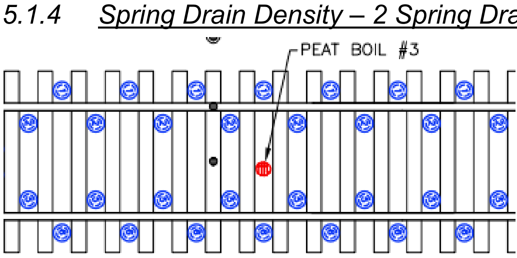






At one site, monitoring of porewater pressures during the passing of trains indicates a density of 3 Spring Drains / Crib, reduced excess porewater pressures by 69 %, 5.5 months after treatment.

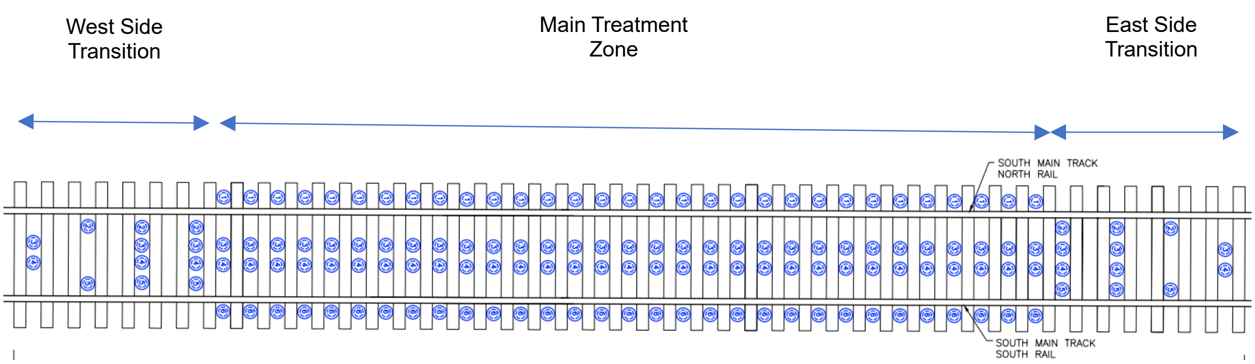
5.1.4 Spring Drain Density – 2 Spring Drains / Crib



This treatment level has been used; however, at one peat boil location excess water at some was observed, and the treatment was revised to a density of 3 Spring Drains per crib.

5.2 Transition Zones

As the Spring Drain is expected to increase the overall track bed stiffness, transition zones have been proposed at the ends of the main treatment areas as illustrated below. The transition zones have been conserved to provide a more gradual transition in track bed modulus and to reduce the effects of potential travelling waves of excess porewater pressure from entering the main treatment area. It should be noted that treatment without the use of transition zones has been carried out (due to budget and timing constraints) with no reported issues.



5.3 At Peat Migration Locations with Negligible Deformations

At some locations where only peat migration has been identified with no excessive deformations reported, Spring Drain treatment densities 2 to 3 Spring Drains per crib have been used without any reported issues.

6.0 Current Treatment Levels and Considerations – Silt / Silty Subgrade Issues

The Spring Drain treatment has not been tried at locations where the problematic subgrade consists of silt or silty type soils.

7.0 Installation Considerations

Prior to installation, careful planning by the owner and installation contractor should consider the following, as a minimum.

- **Site Access:** Identify nearest crossings and potential access routes.
- **Spring Drain Layout:** The proposed spring drain installation location should be marked in the field prior to installation.
- **Staging:** Identify staging areas adjacent to the tracks for product and equipment storage. Identify potential areas for excavators and crew to clear tracks (nearest siding, construction of staging area adjacent to tracks, maintain existing drainage ditches).
- **Flagging Protection**: Arrange for flagging protection where necessary.
- **Rule 42**: Consider working under Rule 42 as this has been used to expedite installation times.
- **Scheduling of Work Times:** Review of expected train traffic should be considered to select a work time with less train interruptions.
- **Lighting:** Lighting may be required where evening work schedules are anticipated.
- **Supply of 19 mm Stone:** The owner typically provides a supply of 19 mm Clear Stone to the site

for filling the Spring Drain. This should be placed as close to the treatment area as possible. The use of air dumps to place the stone along the side of the embankment has been used.

- **Maintain Symmetry**: During installation, the spring drain layout should be considered so as not to stiffen one side of the track more than the other.
- **Inspection:** Inspection during installation should be carried out to document the installation and to identify track deformations during installation. Settlements and heaves in the order of 10 to 20 mm have been experienced on past projects.
- **Track Clearing Plan:** For railway operation, it will be important to ensure the track can be cleared to facilitate operations. A plan should be considered to deal with potential issues, such as break down of the drilling equipment on the tracks.

To date spring drain installations have been carried out using a drill rig and modified drill mounted on an excavator. The use of the excavator mounted rig has proven to be significantly faster than a conventional drilling rig, given its improved mobility. The current method was considered for peat subgrade sites and may not be suitable for sites where the problematic subgrade consists of silty soils. The current method involves the use of an excavator with a modified drill rig attached (modified to accommodate a string of augers). Modified flighted hollow stem auger are used to drill through the ballast and embankment fill. Once through the embankment, flightless augers are introduced to the lead augers (to mitigate peat from circulating to the ballast while the augers are advanced). Once at the peat surface, the rotational speed of the auger is slowed and down pressure on the augers is increased to screw the auger through the peat to avoid bring the peat to surface and maximize densification of the peat. Once at the base of the peat, drilling of the augers is resumed to provide a seat into the underlying soils to set the Spring Drain. When the final depth is reached, the internal rods and plug are removed, and the Spring Drain is installed and backfilled. Once backfilled, the augers are spun in the reverse direction and removed. Reversal of the augers is carried out to pack and voids between the Spring Drain and surrounding soil.

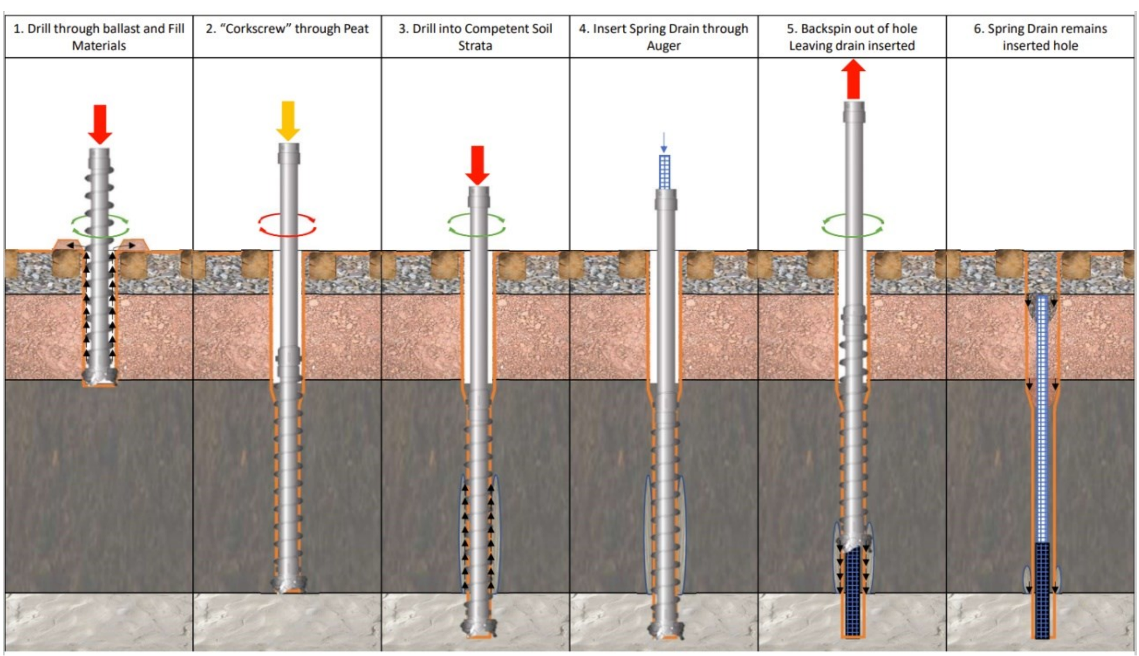


Figure 10

During removal of the auger plug, sanding in of the augers may occur. Where sanding in "blow up" occurs, maintaining a head of water within the augers during installation should be considered. A water source and a water swivel attachment to the auger set up may be considered to accommodate a head of water within the augers during installation.

To improve the installation times and cost effectiveness of the Spring Drain Treatment and for installations in non-peat subgrade sites, two alternate installation methods should be considered:

- *Proposed Installation Concept No. 1,* **Casing with Sacrificial Tip**:

  The use of auger stem auger through the ballast and embankment fill remains the same and the current installation method. Once the augers are at the top of the peat stratum, casing with a sacrificial tip would be installed and pushed / driven through the peat and into the underlying soil. Once at the prescribed depth, the Spring Drain would be installed, and the casing and augers removed. It is expected that this method would expedite installation times. This should also reduce the risk of sand "blow up" during installation. This method may not be suitable for silty subgrade sites as excessive heave may occur during installation.

- *Proposed Installation Concept No. 2,* **Casing Advancer/ Down Hole Hammer:**

  This method is applicable to peat and silty subgrade sites. The use of casing advancer / down hole hammer to advance the casing through the ballast / embankment fill and through the problematic subgrade soils may be considered. This is expected to be the fastest method; however, this may require a significant amount of water during installation. The reduce the risk of ballast fouling, the installation of an oversized casing through the zone of ballast may be considered. For the casing advancer, water would be used to flush the casing during advancement, the risk of sand blow up is reduced. There are no known uncomplicated ways to fill any void that may be present between the Spring Drain and the adjacent soils. The size of the casing should be minimized to reduce the size of the gap between the hole opening and the Spring Drain. Some future settlement may occur while the gap closes over time. This method does have the advantage of being able to install through a rock fill embankment and is expected to expedite installation times.

As the various installation methods are applied, and the individual benefits and shortcomings are discovered, it is anticipated that special rail equipment can be developed for quicker and cleaner installation.

8.0 Post Installation Considerations

The installation of the treatment involves disturbance of the existing embankment and subgrade. As such, track inspection of the treatment area should be conducted over a period of 1 to 2 months. A track leveling program may be required during this period. The track should also be inspected for any future signs of subgrade issues. A subgrade monitoring program (example, monitoring of subgrade porewater pressures) may be considered.

9.0 Potential Future Applications

The following applications of the Spring Drain Treatment have been identified for future consideration:

1) **Bridge Approach Treatment:** The installation of spring drains at bridge approaches may be considered to improve the track bed stiffness of the bridge approach. By varying the density of the treatment, a more gradual transition from soft to stiff track bed stiffness may be achieved.

2) **Permafrost Degradation Treatment:** During permafrost degradation, melting ice zones can lead to free water within the frozen structure leading to high excess porewater pressures leading to reduced shear resistance within the embankment. The Spring Drain may be considered to reduce the level of excess porewater pressure thus improving embankment stability. Embankment stability is further improved through vertical load transfer and shear resistance through the Spring Drain. Load transfer through the Spring Drain should also improve settlement performance.

10.0 Author Contact and More Information

For more information, or to discuss how Spring Drains may work for you, please feel free to contact the following:

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