FOAM COLUMN INJECTION TO A HIGHWAY EMBANKMENT FOUNDATION - RESULTS OF A FULL SCALE PILOT STUDY

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Abstract

Highway 759 is a secondary highway located approximately 100 km west of Edmonton, Alberta. The road was originally constructed by placing the highway embankment on deep peat and organic soil deposits, which have settled over time to form dips in the pavement surface. One such settlement site is the NC 22 site, approximately 1.5 km north of the junction of Highway 759 and Highway 39. Four metres of embankment fill and asphalt pavement was placed over four metres of peat, overlying soft organic clay. In the spring of 2008, when EBA first inspected this site, there was a dip in the pavement surface of approximately 0.5 m.

An innovative treatment of injecting polyurethane foam columns in the peat foundation soils was recommended. The purpose of the columns was to support the highway embankment and transfer the load through the peat to the underlying clay. Lateral compression of the peat due to foam expansion was also believed to have beneficial effects by reducing foundation compressibility. A pilot study to assess the feasibility of the foam column injection was approved by Alberta Transportation. The pilot study consisted of two spacing designs of foam columns, 1.2 m and 2.4 m on centre. The foam columns were injected in fall 2010, an asphalt overlay was placed and survey monitoring points were installed.

The design, planning, construction and post-construction monitoring for the foam injection repair of the NC 22 site is discussed herein. Applications of this repair method to other sites are identified where possible.

Purpose and Scope

The information presented herein describes an Alberta Transportation (AT) pilot project of the selection, design, construction and post construction monitoring of injecting expanding foam into a highway embankment foundation. This innovative technique was used to remediate and stabilize an approximate area of 25 m by 12 m of settlement which resulted in a 0.5 m dip on Hwy 759 identified by AT in their Geo-Hazard Risk Management Program (GRMP), as site NC 22. See Figure 1 for the location of this site.

AT has several other sites with similar dips; however, before applying the foam injection technology to them, a pilot study was conducted at the NC 22 site. The scope of work was to stabilize the settlement of this site, reduce the effects of the dip by reprofiling the roadway surface and because this was a pilot study to provide post construction monitoring. The process of stabilization consisted of injecting expanding polyurethane foam into containment units installed in boreholes throughout the affected area. The primary purpose of the confinement unit was to prevent the injected foam from migrating away from the area being treated.

Background and Site Information

Highway 759 is a secondary highway located approximately 100 km west of Edmonton, Alberta. The road was originally constructed many years ago by placing the highway embankment on deep peat and organic soil deposits, which have settled over time to form dips in the pavement surface. One such settlement site is approximately 1.5 km north of the junction of Highway 759 and Highway 39. The sub-section of Highway 759 where this site was located is Highway 759:02.

Four metres of embankment fill and asphalt pavement was placed over 4 m of peat, overlying soft organic clay. The compression of the peat resulted in the dip of the pavement which has been historically repaired with asphalt patch overlays. However, the additional weight of the asphalt would cause additional peat compression. This cycle of repeated overlays to repair a perennial dip has continued for many years. In the spring of 2008, when EBA first inspected this site, there was a dip in the pavement surface of approximately 0.5 m as seen in Photo 1 and identified in Figure 2.

The site could be generally described as a poorly draining and swampy. Evidence of this is seen from the wetlands on either side of the roadway and by the water that pooled on both sides of the highway at the invert and outlet of a culvert located just south by about 20 m from the centre of the dip, as identified in Figure 2.

A soil investigation was completed by Jacques Whitford & Associates Ltd. (JWAL) in 2006, where, at the center of the dip, a layer of peat approximately 4 m thick was observed. This layer of peat tapers off to a thickness of about 0.3 m, approximately 6 m north and south of the affected area. To gain a better understanding of the subsurface conditions EBA did a soil testing program from two additional boreholes identified as D7 and M8 as seen in the site plan of Figure 2. These boreholes were drilled with a truck mounted auger. Lab testing of these boreholes included moisture contents, organic contents, and an Atterberg limit analysis. A brief summary of materials encountered while drilling is given below:

Material Type	Depth Range (m)
Asphalt Concrete Pavement	0.0 to 0.3
Granular Base Course	0.3 to 1.2
Stiff Clay	0.9 to 4.9
Peat	3.0 to 8.2
Soft Clay	3.3 to 13.7+
	End of hole

Increasing Depth

Laboratory testing indicated that the moisture contents for the peat and the underlying clay are as follows:

- Peat - 174% to 241% from depths of 4.5 m to 5.3 m respectively; and
- Soft Clay - 63% to 149% from depths of 5.5 m to 8.2 m respectively.

The organic content range for the clay was 9.0% to 19.8% from depths of 5.5 m to 8.2 m.

An Atterberg Limit test conducted on borehole D7 at a depth of 7.6 m classified the soil as high plastic clay with a liquid limit of 75%, a plastic limit of 31%, and a plasticity index of 44%.

However, the sample plots in close proximity to the A-Line on the Plasticity Chart and thus also close to being classified as organic clay.

Selection of Polyurethane Foam

In an effort to reduce remediation costs, a foam injection treatment was selected to compact the peat and transfer the loads from the stiff fill to the soft clay below the peat. The process consisted of injecting expanding polyurethane foam into containment units installed in boreholes throughout the affected area. As this was a new technology, a pilot study approach was adopted to assess the feasibility of the foam injection technology.

As cited in The Uretek Method (1), the following properties were benefits of selecting a polyurethane foam treatment:

- It's a durable hydro-insensitive material.
- The time for complete remediation is shorter. The foam formulation reaches 90% of full compressive strength within 15 minutes from injection. It requires 24 hrs to fully cure and will not expand further after reaching its initial cure of 90% compressive strength.
- The cured foam is inert, environmentally neutral and does not contribute to soil or water contamination, leaching or pollution.
- Is lightweight, weighs less than 10% of cement grouts.

Design

As part of the study, two different spacings were selected for the foam injection, as seen in Figures 3 to 5 attached. On the south half of the project, 1.2 m spacing was chosen, and for the north section of the site, 2.4 m spacing was used. The two different spacings were selected to determine if there was any benefit to having a denser spacing of foam columns.

Construction

The prime contractor for this project was Carillion Canada Inc. (Carillion), who was responsible for the traffic control, paving, and sideslope re-grading. Poly Mor, the subcontractor, was responsible for drilling and foam injection. Beck Drilling and Environmental Services Ltd. (Beck) was brought on site halfway through construction to assist Poly Mor with drilling.

<u>Layout, Drilling and Foam Injection Schedule</u>

Prior to construction, EBA laid out the injection points as shown in Figure 3 and Photo 2.

Work commenced for this project on August 25, 2010 and was completed by September 10, 2010. The following is a brief breakdown of the schedule.

- August 26 to September 1, 2010 - 52 of the 60 holes in the northbound lane completed by September 1, 2010 - Rate of installation was 7 to 10 holes per day.
- September 2, 2010 - Beck arrived. Beck and Poly Mor moved over to the southbound lane prior to completing the remaining holes in the northbound lane.
- September 3 to 6, 2010 - Temporary shutdown (Labour Day long weekend).
- September 7, 2010 - Construction resumed. Drilling in the southbound lane.
- September 8, 2010 - Southbound lane completed
- September 9, 2010 - The remaining eight holes in the northbound lane completed.

Containment Unit Installation

The containment units were constructed on site and adjusted based on the soil stratigraphy encountered as seen in Photo 3. The containment units were periodically measured by EBA and compared with design, and were constructed to lengths of 6.3 to 6.4 m, with bag lengths of 3.8 to 4.0 m. Once installed in the hole, an extension of varying lengths was attached to the unit to bring the containment bag to the required depth. Within the containment bags, two tremie hoses were fixed to the conduit at one-third and two-thirds of its length so that the entire bag was filled with foam as seen in Photos 4 to 5.

Foam Injection and Asphalt Patching

Injection of the containment units with foam was a relatively quick and simple process. A foam gun was attached to each tube and conduit, and then each was injected with foam simultaneously. When injecting foam with two guns, both the conduit and the lower of the two tubes would be injected first. The second tube would only be injected if required.

A total of 60 lbs. of polyurethane foam was injected into each hole. Following foam injection, the conduit and tubing remaining above ground was cut a couple inches below the road surface. If any foam spilled onto the road it was also removed to a couple inches below road surface. A ready-mix asphalt cold-mix was used to patch the hole and bring it to grade as seen in Photo 6. The site after paving can be seen in Photo 7.

Construction Difficulties

Early in the program a group of 21 containment units placed in the northbound lane were installed to a depth around 6.7 m, but were not embedded in the clay below the peat as prescribed by EBA during start-up, as can be seen in Figure 6. This was evident when comparing the depths at which the containment units were installed with the stratigraphy interpreted from the boreholes conducted by EBA and JWAL.

Six other units were terminated short of the peat/clay boundary as a result of difficulties Poly Mor had while installing the containment units, in holes where slough-in or the cuttings were not cleared from the hole while drilling. This resulted in Poly Mor requiring 2 to 3 workers to try and push the unit deep enough into the ground, and often resulted in the unit not being placed at the required depth. Locations of these injection points can be seen in Figure 6.

The pattern selected to install the containment units entailed completing every other foam injection borehole in a row before moving onto the next row and then once all rows were complete, the remaining foam injection boreholes were infilled. The remaining infill boreholes in this area were installed to the required depth. Settlement data collected to-date indicates early detection of this permitted adequate mitigation.

In general, EBA observed higher variability of the thickness of the peat layer than predicted from EBA and JWAL boreholes.

Settlement Monitoring

An initial survey was completed by EBA, on August 26, 2010 to establish relative road elevations before construction. Survey monitoring points were established on the roadway surface along the centerline, east edge of pavement (EOP) and west edge of pavement (EOP) to assess the relative elevation of the road profile prior to drilling and to asses if there was uplift of the asphalt surface during treatment. The survey pins were replaced and re-surveyed upon completion of asphalt overlay works conducted at the end of foam injection as seen in Photo 8. As part of this pilot study the site will be surveyed three times per year during the frost free months, over the next two years to monitor the results of the treatment.

Conclusion

Since completion of foam injection and asphalt overlay, negligible settlement has occurred. The site will continue to be monitored for settlement over the next two years. The results of the pilot project will assist in determining whether foam injection is a feasible option as a method for remediating portions of highways where underlying highly compressible soils have resulted in significant settlement.

Acknowledgements

Roger Skirrow, P. Eng., Sabhago Oad, P. Eng. and Neal Reynolds of Alberta Transportation, for considering this technology for use on this project and approving this paper.

References

1) Poly Mor (2009, January), The Uretek Method

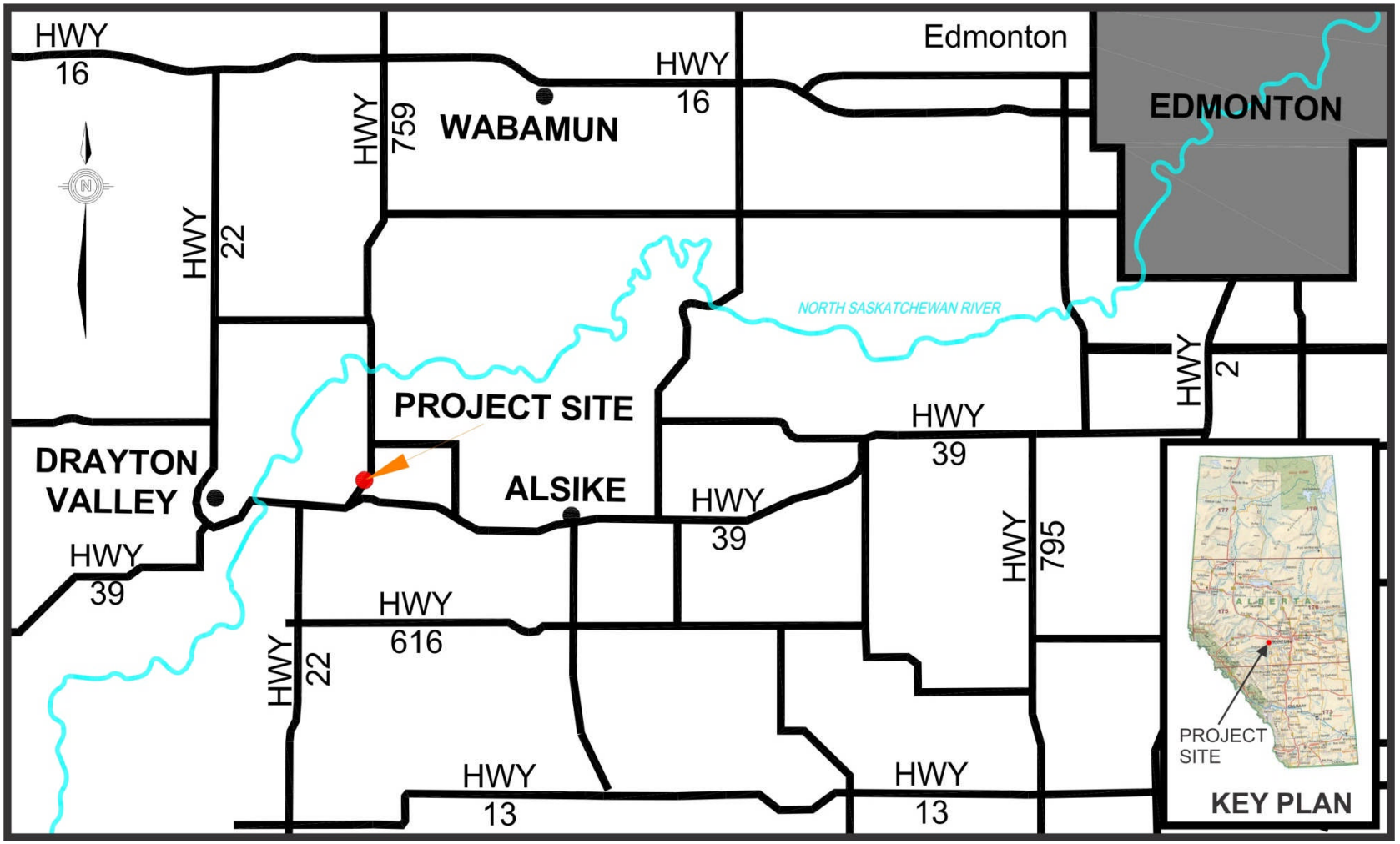
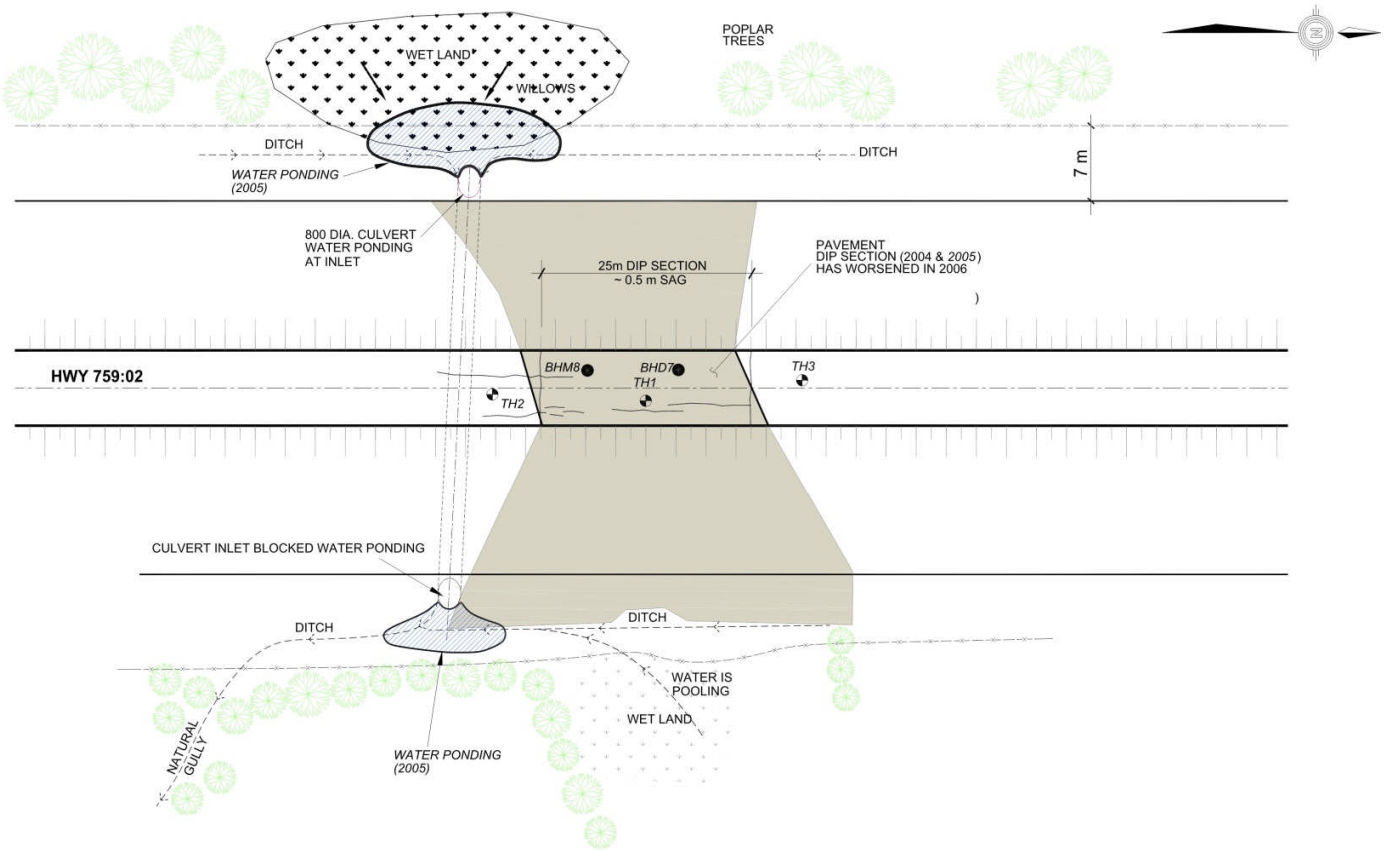


Figure 1. Site Location Plan



LEGEND :

- BOREHOLE DRILLED BY JACQUES WHITFORD (2006)
- BOREHOLE DRILLED BY EBA (2010)

NOTES :

1. FEATURE LOCATIONS ARE APPROXIMATE.
2. SITE INSPECTION CARRIED OUT IN MAY, 2004

Figure 2. Site Layout Plan

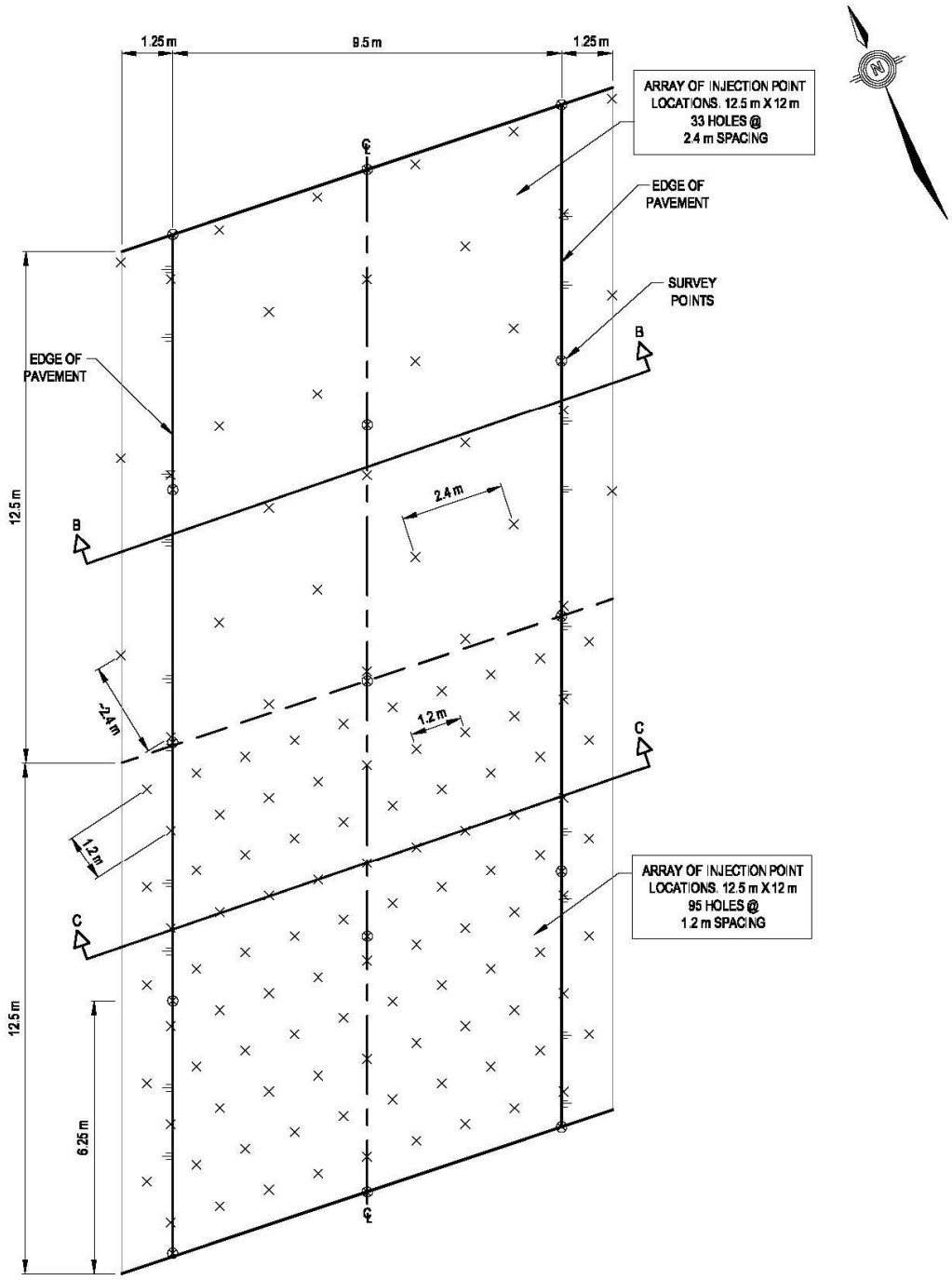


Figure 3. Borehole Layout Plan

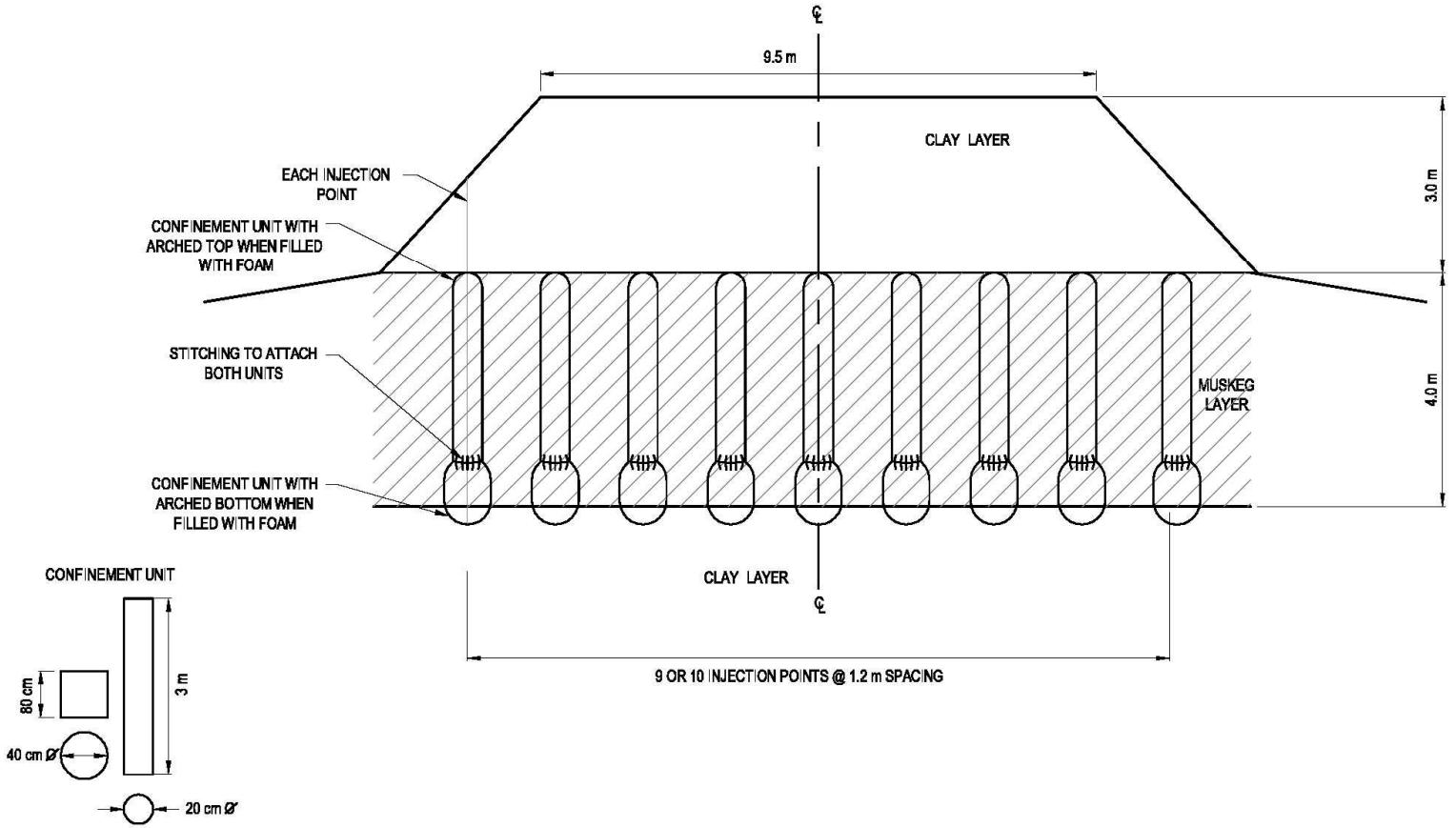


Figure 4. Cross-section of 1.2 m spaced units

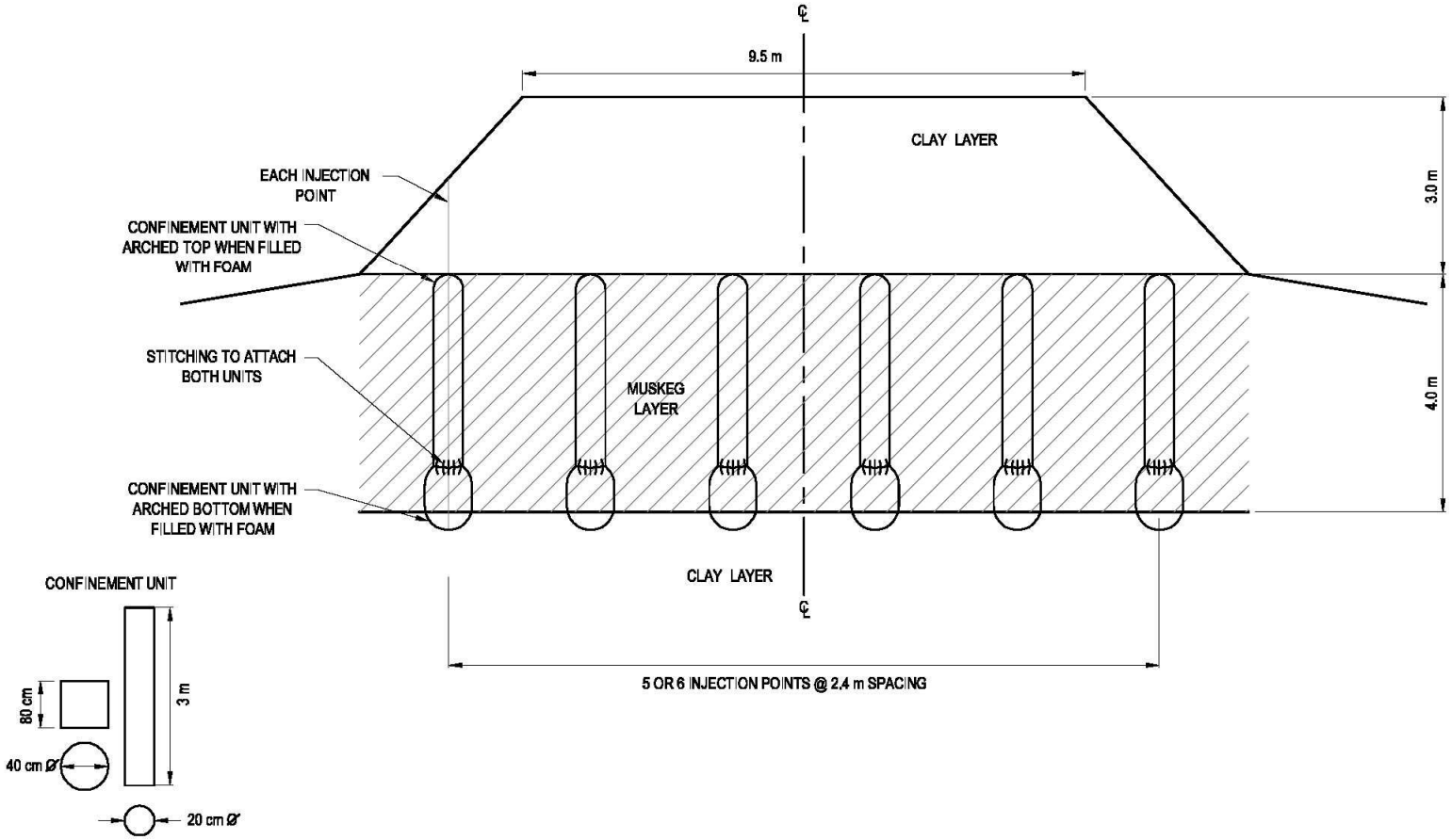


Figure 5. Cross-section of 2.4 m spaced units

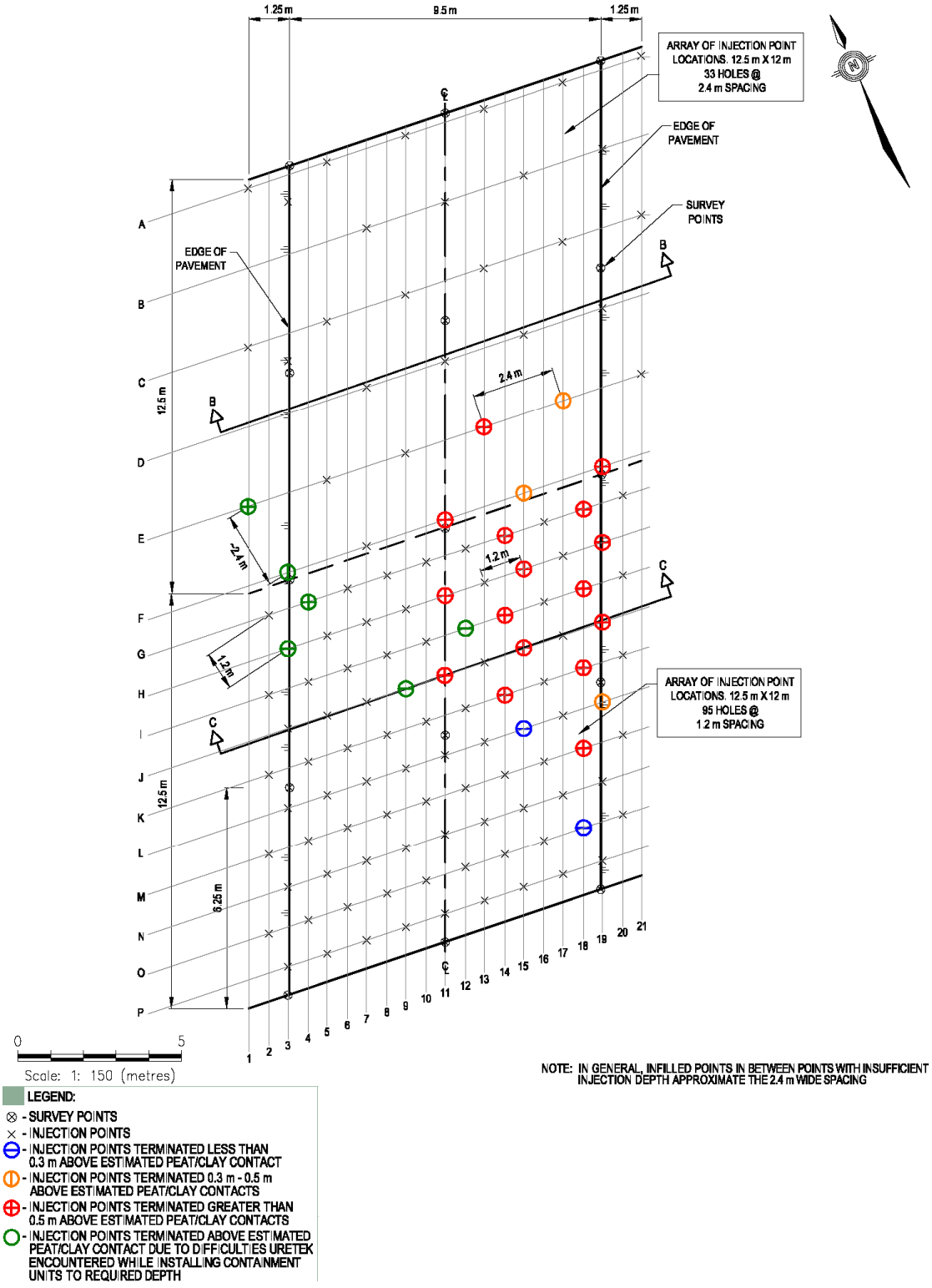


Figure 6. As-built layout. Highlighted injection points had special circumstances of note.

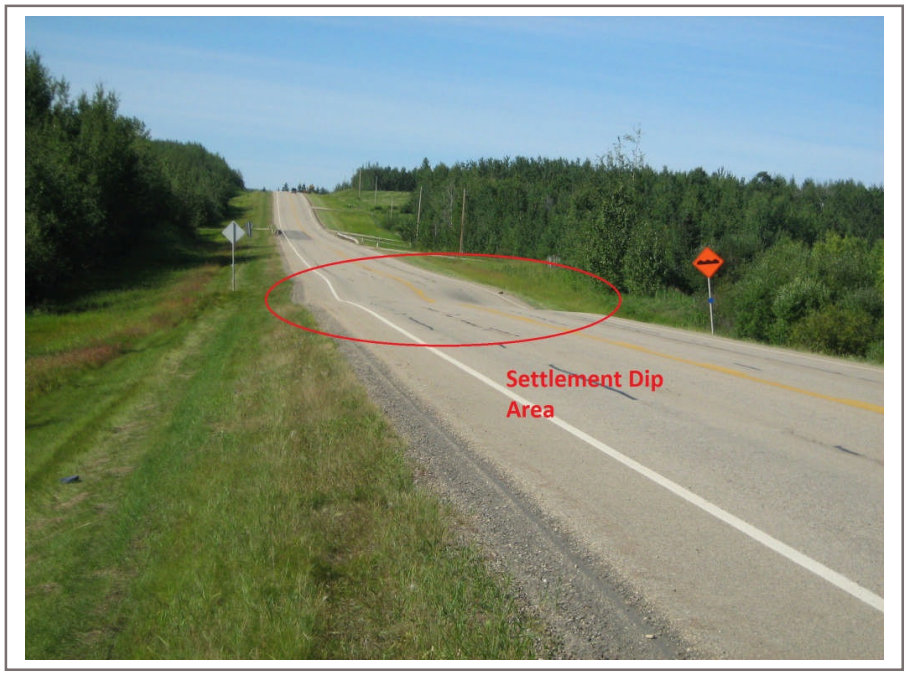


Photo 1. Site prior to construction identifying the dip, looking south

Photo 2. Injection point layout

Photo 3. Containment unit assembly and installation

Photo 4. Finished installing confinement unit and hose into borehole. Workers attaching tremie hoses to foam guns.

Photo 5. Foam injection

Photo 6. Site after foam injection, looking south. Notice asphalt patched injection points

Photo 7. Site after asphalt paving to reprofile dip in the roadway, looking north

Photo 8. Looking south. Re-establishing the survey points after the asphalt overlay was placed