A Case History on the use of High Strength Woven Geotextiles to Reinforce a Oil Sands Tailings Pond Closure

Andrew Mills, C.E.T.
Layfield Environmental Systems, Edmonton, Alberta, Canada

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ABSTRACT
The use of high strength woven geotextiles to provide reinforcement for sludge pond caps has been common practice for a number of years. To date the use of woven geotextiles to provide reinforcement for oil sands tailings pond closures has been limited. This paper presents a case history of the first large scale use of high strength woven geotextiles to cap an oil sands tailings pond filled with tailings. This high strength woven geotextile project is Canada's largest to date. The closure of an oil sands tailings pond differs from other pond capping operations due to the scale of the pond and the low bearing capacity of the soft tailings areas. The pond in this case history is approximately 2 by 3 kilometres in extent; much too large to cover with a single fabric panel. This pond closure required the creation of 13 kilometres of roads 100 m wide to create an access grid to enable covering of the remaining area. Building these roads required working in the winter in order to use the frozen surface of the pond for construction support. This paper covers the work and processes developed during construction of this grid of access roads in the winter of 2010.

RÉSUMÉ
L'utilisation de géotissé (géotextile tissé) à haute résistance pour renforcer la couche de recouvrement des bassins de boue est une pratique courante depuis des années. Or, à ce jour, l'utilisation de géotissé pour renforcer le recouvrement des bassins de résidus de l'exploitation des sables bitumineux est limitée. Cet article présente l'historique de la première utilisation à grande échelle de géotissé à haute résistance pour recouvrir un bassin de résidus de l'exploitation de sables bitumineux. Il s'agit, à ce jour, du plus grand projet de ce genre au Canada. Le recouvrement des bassins de résidus de l'exploitation des sables bitumineux diffère des autres techniques de recouvrement de bassins en raison de la taille de ces derniers et de la faible portance des résidus mous. Le bassin faisant l'objet de cette étude est de 2 km de largeur par 3 km de longueur; il est donc beaucoup trop grand pour être recouvert d'un seul panneau textile. Le recouvrement du bassin a donc nécessité la construction d'un réseau de 13 km de routes de 100 m de large afin de permettre le recouvrement de l'ensemble de la zone. La construction de ces routes a eu lieu en hiver afin de profiter de la surface gelée du bassin pour installer la structure routière. Cet article se penche sur le travail effectué et les procédures mises en place durant la construction de ce réseau routier à l'hiver 2010.

1 INTRODUCTION

The Alberta oil sands deposits in Ft McMurray are one of the largest sources of oil in current development. Quantities of oil sand are retrieved through conventional mining and then washed to retrieve the desired oil. Bitumen is recovered through the Clark Hot Water Extraction process, with the residual sand, fines and water transferred to tailings ponds for settling and future reclamation. The fines, consisting of clays, silts and some residual bitumen, are partially trapped within the sand beaches with the remainder transported into the water column of the ponds. Much research has been done on oil sands tailings; however, the fines fraction has proven to be a persistent challenge with a predicted settling time of over 30 years (Wells, 2010).

The difficulty in effectively addressing oil sands tailings has resulted in a large inventory of tailings ponds at mines around Ft McMurray. Recently the Alberta government, through the Energy Resources Conservation Board (ERCB), has required all oil sands operators to develop methods to deal with fine tailings as part of Directive 074 Tailings Performance Criteria and Requirements for Oils Sands Mining Schemes (ERCB, 2009). This directive requires that the mines will convert fluid fine tailings into trafficable deposits. The directive sets a target that 50% of fines production will need to be captured before June of 2013. This directive has caused a rededication of effort to deal with tailings in the oil sands including new ideas and methods, increased cooperation, and an acceleration of tailing management practices from all mining operators.

Figure 1. Preparing to sew a seam on the ice. Note stockpile of coke in the background.

Suncor Energy Inc is the operator of the first large scale oil sands mine in Ft McMurray. As part of their ongoing continuous improvement programme, and as part of their response to Directive 074, Suncor developed a Tailings Reduction Operations (TRO) process that will effectively dry their production of fines. This TRO process is on track to eliminate fine tailings from the existing Suncor tailings stream by 2013. But Suncor has also been looking at their large inventory of legacy tailings. One of the first statements of this was in their ERCB tailings plan (Suncor, 2009):

> **Pond 5:** Pond 5 infilling with CT (Consolidated Tailings) is complete in 2009. The pond will be ready for reclamation activities in 2010. An application for the approval of the non-energy use of coke to place a 3 m coke layer over soft areas of the pond from which accelerated dewatering can take place was submitted in August 2009. About 6 Mm3 of heavy MFT (Mature Fine Tailings >50% solids) will be left in the pond to be reclaimed in place. Pending approval, approximately 5.9 Mm3 of petroleum coke will be placed on the pond to cap the soft deposit areas during 2010 to 2012. Placement of a sand cap, then reclamation cover soils on the pond is planned for the period 2012 to 2016.

Suncor was looking to not only deal with their existing tailings stream with TRO but was also planning to start work on reclaiming the existing legacy tailings on site. The cap design on Pond 5 would use high strength geosynthetics to support an initial cap of petroleum coke (a by-product of oil sands upgrading) leading to an installation of vertical strip (wick) drains to dewater the deposit. Once the tailings pond is dewatered to a “trafficable” state, reclamation and landscaping will occur. Initial trials took place in 2009 to test the capping method (Wells 2010) and the wick drain functions (Wells, Caldwell, 2009). Essentially the method chosen would be a sludge pond cap with wick drains for dewatering.

The use of high strength woven geotextiles for capping sludge ponds is a well developed practice that has been in use for many years. Normally the geotextile is assembled on site into a large panel that is then pulled across the pond and secured. Once in place the geotextile is backfilled to provide a working surface for reclamation activities. This practice assumes that you can make and deploy a sufficiently large geotextile panel to cover the pond. To cover Pond 5 at Suncor would require a cap that was 2 by 3 kilometres in extent and was going to require some intermediate steps.

The first problem was that the scale of Pond 5 prevented it from being covered with one large piece of fabric. The total weight of geotextile fabric for this pond would be in the order of 5 million kg. This required some sort of staged approach. The solution involved two innovations. The first was to build a checkerboard of roads first and then fill in the inside of these areas with additional fabric later. The second part of the solution was to place the geosynthetics in the winter on the frozen ice of the pond. These designs were developed by Suncor Reclamation Research Engineering, Robertson Geotechnical, and AMEC Earth and Environmental.

This paper details the development of the materials and placement techniques that were used to create the roadways on Pond 5 in the winter of 2009/2010.

2 MATERIALS AND FABRICATION

Layfield became involved in this project on November 25th 2009 when we were asked to bid on the project materials. In this initial inquiry there was no provision for seaming either in the shop or the field.

The specifications for the woven geotextile were very simple. The critical value was that final geotextile strength (in both directions) after seaming needed to exceed 82.5 kN/m. Since strength in sewn, woven geotextiles is limited by seaming efficiency, the getotextile strength had to be sufficient to allow final seam strengths of 82.5 kN/m. To accomplish a specific seam strength a fabric with a higher initial strength was needed. Typical seam efficiencies for woven geotextiles are between 50 and 60% when tested with a wide width tensile test (ASTM D4884-96, 2003). That meant that to meet the 82.5 kN/m a fabric with an initial strength of between 138 and 165 kN/m would be needed.

In the original response to the request for geotextile the proposal was for an existing commercially available fabric with a tensile strength in both directions of 175 kN/m (PP200S by TenCate Geosynthetics). With this strength of geotextile the seams could be prepared in both directions and meet the required specification.

The next step was a site meeting to outline the design of the roads and to clarify the seaming requirements. The initial request for geotextile had not including seaming details and the site meeting on December 3rd 2009 explained the road design in detail. At this meeting the requirements for the road construction for the winter of 2009/2010 were laid out and the vendors were asked to prepare their sewing fabrication pricing.

The 2009/2010 road project involved 13 kilometres of road 90 m wide (Figure 3). The cross section of the road began with a 100 m wide layer of sewn high strength biaxial woven geotextile with a finished strength of 82.5 kN/m (Figure 2). On top of that was an 80 m wide layer of a biaxial geogrid (30 kN/m) overlapped 20 m in the centre. Then drainage pipes were added in the direction of the road. Coke fill was then placed on top of these geosynthetics. The first lift was 1 m thick and 90 m wide. The second lift increased the centre 60 m of road to a 2 m thickness. Then the centre 30 m wide portion of the road was increased to a 3 m thickness. The initial 1 m

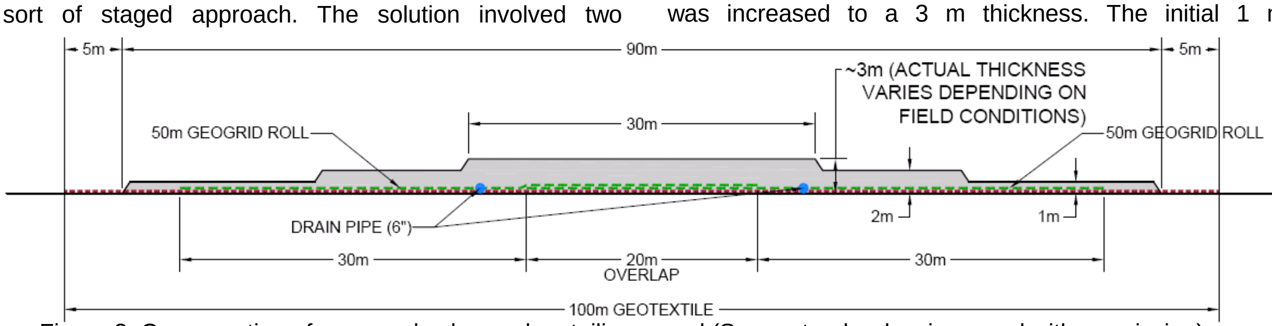

Figure 2. Cross section of proposed coke road on tailings pond (Suncor tender drawing, used with permission).

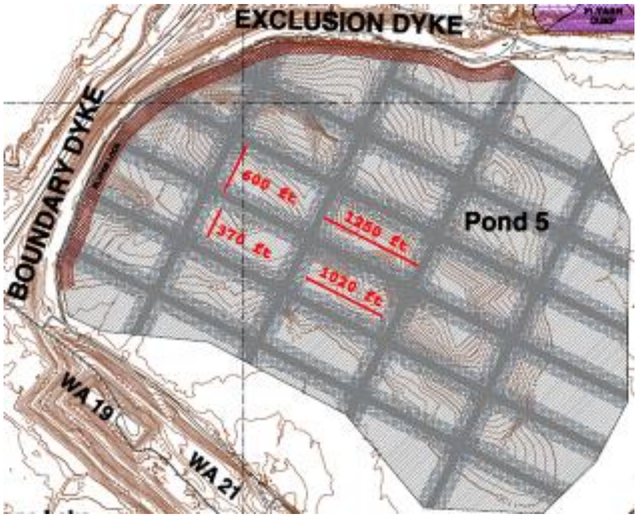

Figure 3. Proposed road layout on pond 5.
(Suncor Tender drawing, used with permission).

thickness was to be placed with snow-cats while the other lifts were to be placed with small dozers. The centre road was for truck access with 40 ton articulated mine trucks. A more detailed review of the road design is contained in the paper Suncor Pond 5 Coke Cap – The Story of Its Conception, Testing, and Advance to Full Scale Construction (Wells, Caldwell, and Fournier 2010).

Now that the intent of the project was clear the next step was to find a fabrication solution that would offer the best value. With all roads 100 m wide there was an opportunity to sew all seams across the roads (cross-road fabrication) which would eliminate cross seams. Cross-road sewing was also a better fit for the type of sewing fabrication done in the available fabrication plant. Using cross road sewing meant that the fabric had to be strong enough in the cross machine direction (where the seams would be) but could then be weaker in the machine direction (no cross seams). Ordering rolls of fabric to the exact length needed for this technique was not a problem on this large of an order. The two problems were that typical woven geotextile fabrics are usually weaker in the cross direction and that the road crossings on this project would require some sort of cross seam.

On the Pond 5 project there were 23 road crossings to deal with. At these crossings one seaming direction would always require cross seams. Each road crossing was 100 m by 100 m and on all four sides of these crossings the seams would need to meet the 82.5 kN/m strength requirement. That meant that a fabric with strength in both directions was required in these crossings. The initial solution for this requirement was to use the 175 by 175 kN/m material for the road crossings and then a lighter weight material for the balance of the pond. This lighter material would need to have a strength in the cross machine direction of between 138 to 165 kN/m but only needed to have a machine direction strength of 82.5 kN/m. This particular combination of strengths did not yet exist in a commercial fabric.

At this point the geotextile manufacturer (TenCate Mirafi Geosynthetics) stepped in to help. They had a line of specialty fabrics that were used to make the Geotube® soil containers that had higher strengths in the cross machine direction so they had the capability to make the kind of fabric that was needed.

A custom fabric design for this project was discussed. The two main specification requirements were strength and a specific opening size (to retain tailings but promote drainage). The starting point was an existing material design that had a strength of 105 by 105 kN/m (HP 770). At the time the factory was just completing a production run of the 105 by 105 kN/m material so a loom was all set up and ready (Figure 4). Higher cross direction fibres were woven into the fabric but the strengths were still not high enough. The final solution involved stacking the tapes two high and changing the weave pattern so that more high strength tapes could be packed into a denser weave pattern.

The resulting fabric had a strength of 105 kN/m in the machine direction and 155 kN/m in the cross machine direction. Because the loom was already set up and available this new fabric design was prototyped and tested within 7 days to meet the requirements of this bid.

Figure 4. High strength woven geotextile loom that can make geotextiles with stacked tapes.

The new proposal for Pond 5 high strength woven geotextile road fabrics included 23 road crossings using the 175 by 175 kN/m fabric and the balance of the 13 kilometres of road with the newly developed 105 by 155 kN/m fabric. This change in fabric meant that the project seaming requirement of 82.5 kN/m could be met in both directions while reducing the cost and the weight of materials substantially. This change saved $3,263,000 in direct material costs and a further $130,000 in fabrication fees. It also allowed larger panels. The lighter weight material could be fabricated into panels 5-wide (22.5 m x 100 m) at the same weight as a 3-wide panel of the 175 kN/m fabric (15 m x 100 m). This transferred more sewing from the field back to the shop reducing the amount of on-site sewing required. These larger panels led to a 40% reduction in the number of field seams.

This proposal was accepted on the 16th of December 2009. Since speed was of the essence the manufacture of material started immediately. Two containers of 175 by 175 kN/m fabric that were in stock were dispatched from Holland and the 105 by 155 kN/m geotextile started production within days. The first mixed truckload of 175 by 175 kN/m and 105 by 155 kN/m fabric was shipped 7 days after award on December 23rd and arrived in Edmonton on the 29th of December. After qualification of materials and equipment the first panels of material were fabricated and shipped to site on January 11, 2010.

Figure 5. Shop fabrication sewing

3 INSTALLATION PREPARATION

The key issue on this project was how to place and seam the geotextile on the pond. The intent was to place the geotextile on the frozen surface of the pond in the winter months. As this was new ground for geotextile placement and seaming there were initially more questions than answers. There were questions on whether sewn seams could be produced to specification on the surface of the frozen pond; whether the geotextile could be handled in the cold weather; whether geotextile placement would be slower than coke placement; how snow and cold would affect operations; and how off-pond fabrication could be used to reduce field seams.

The development of on-ice sewing required a number of new ideas while dealing with the safety restrictions as outlined in the project requirements. The main restriction was that all personnel and equipment employed on the pond had to have floatation and that initially there was a restriction that all operations had to take place on top of the fabric and not on the surface of the ice. This restriction required a lot of discussion as it was not clear how the fabric could be deployed while standing on top of it. Ice safety was the key factor on this project and there was going to be a full time engineering crew surveying ice conditions ahead of geotextile placement.

The biggest issue with field sewing was that sewing machines are not designed for cold temperature work. The mechanical clearances in a sewing machine are very tight and changes in operating temperature would affect machine operation. Even the oil used in a sewing machine was not rated for cold temperature operations. This meant that a heated structure would be needed for sewing. The sewing machine used by our crews is the Union Special 80200Z high strength sewing machine (Figure 5). This sewing machine sews two stitch lines at a time and is designed to sew the heaviest geotextile materials. This machine is usually mounted to an overhead support that is attached to the back of a truck or trailer. If a heated structure was needed then it needed to be built with a strong enough roof structure to support this sewing machine.

A number of sewing structure designs were put forward and evaluated. The final design was a trailer structure with an overhead rail to hold the sewing machine. The trailer was pulled by an amphibious vehicle and had another small trailer set up behind the main trailer to hold the generator and heater. A small video camera and monitor were rigged so that the driver of the towing vehicle could match speed with the sewing.

During the time that the sewing structure design was coming together there was a cold snap in Edmonton. This allowed an evaluation of the fabric materials in -30C conditions. Fortunately the woven geotextile appeared to remain flexible at low temperatures and could be folded to form the required seams in the cold.

The last problem with field sewing this geotextile was how to test the seams produced. Wide width geotextile seam testing equipment is not widely available (ASTM D4884-96, 2003). Seam test coupons from the site would have to be sent to a lab in either Quebec or Texas for testing. Ft McMurray does not have overnight courier service to these labs. If samples were sent out then it would have taken about three days to receive results. At the proposed installation rate of 15,000 m2 per day this would result in 45,000 m2 of material exposed on the pond that couldn't be backfilled until test results were received. There was a concern that this might hold up coke placement.

Figure 6. Completed sewing trailer.

A possible solution was a wide width tensile testing unit for the field. An on-site testing unit would allow the testing of seams to allow backfilling to take place immediately. A search revealed that a unit suitable for field testing did not exist commercially.

The alternative was to see if a testing unit could be built. The wide width tensile grips were available in stock from a supplier in the US. Working with a local calibration company a specially designed hydraulic power pack and pressure transducer was found that was designed for testing equipment. It looked like it would be possible to create a field testing machine if the bid went ahead.

With a work plan in place and designs completed for a field installation sewing structure and a wide width tensile tester a bid for field seaming was submitted on December 22nd. On December 23rd at 3 pm the job was awarded.

A job kick-off meeting took place on Monday the 28th of December and construction of the sewing trailer and tensile tester began on the following day. The sewing trailer was fabricated and the tensile tester was engineered assembled and calibrated by the 9th of January. Mobilization to site took place on the 11th of January.

4 SEWING DEVELOPMENT

Although the new 105 by 155 kN/m geotextile material met all the strength criteria in manufacturing it was not clear initially if it would meet the 82.5 kN/m sewn seam requirement. To reach the 82.5 kN/m seam strength the seams would need an efficiency of 53%. Samples of the material and thread were rushed to Edmonton for trials with the first materials arriving shortly after fabrication award on December 16th. Full rolls of the 105 by 155 kN/m material arrived on December 29th for full scale trials.

Figure 7. J-Seam stitch type

Both fabrication and field installation personnel were involved in the evaluation of sewn seams. Sewing of the 175 by 175 kN/m material was successful on the first attempt. Initial trials tested on December 31st showed that the 175 by 175 kN/m material achieved 112 kN/m seam strengths with a J-Seam (Figure 7) and 121 kN/m with a butterfly seam (Figure 8). The 175 by 175 kN/m material was considered qualified for sewing and fabrication began with this material immediately. QC testing of the first ten rolls of 175 by 175 kN/m geotextile took place on January 5th and 8th. The lowest value was 89.4 kN/m with an average over the 10 seams of 99.9 kN/m. Note that the 89.4 kN/m value is a seam efficiency of 51%.

The new 105 by 155 kN/m material did not do as well. The sewing of high strength woven geotextiles varies according to the construction of the geotextile. Since the 105 by 155 kN/m fabric was a new material with a new construction sewing would have to be developed from scratch. Initial seams were prepared using standard sewing practice. These initial seams produced 67.2 kN/m

Figure 8. Butterfly stitch type

with a J-Seam, 69.4 kN/m with a butterfly seam, and 64.0 kN/m with a prayer seam (a flat seam with no folds). Obviously more work was needed to get reliable seams in this unique new material.

Working closely with the fabric manufacturer there were four aspects of the sewing that were reviewed. The first aspect was the thread. The thread used was a custom thread designed for high strength geotextile sewing of soil containers. This thread is one of the strongest available and was meeting seam strengths on the 175 by 175 kN/m fabric. The thread appeared to be suitable. The second aspect was the seam type. There are two widely used seam types in high strength geotextiles; the J-seam (Figure 7) and the Butterfly seam (Figure 8). Both of these seams put four layers of fabric in the seam area and will generally produce a similar strength. The Butterfly seam has the advantage that all layers of material are easily seen while in the J-seam the bottom layer is hidden. The J-seam is easier to sew and initial development was focused on this seam type.

That left two aspects of sewing that could be controlled. The first was stitch density and the second was the distance of the seam from the folded edge of the fabric. The sewing machines in use had a variation in stitch density of between 3 and 6 stitches per 25 mm. Work initially focussed on stitch density. Since the 105 by 155 kN/m fabric was quite slippery it was found that the material was not feeding properly in the sewing machine. This was resulting in stitch densities of 5 to 6 stitches per 25 mm. This is usually too dense a stitch to be effective as the additional needle holes can reduce the strength of the fabric. Initial adjustments were to improve the feed of the material to get the stitch densities down to between 3 and 4 stitches per 25 mm.

The material manufacturer also recommended adjusting the distance from the first stitch line to the folded edge of the material. When this distance became too large the strength of the seams could suffer. A number of variations in the distance from the stitch line to the folded edge of the fabric were tried.

On January 6th and 7th we received test results that showed that a lower stitch density and shorter distance to the folded edge of the fabric would make a successful seam. Table 1 shows the results of these tests.

ID	Type	Stitches/25mm	Distance	Strength
2	J	3.45	25 mm	78.0 kN/m
3	J	3.85	25 mm	74.5 kN/m
4	J	4.12	25 mm	74.9 kN/m
5	J	2.92	12 mm	82.0 kN/m
6	J	3.34	12 mm	86.0 kN/m
7	J	4.09	12 mm	104 kN/m

Table 1. Seam strengths in 105 by 155 kN/m fabric

Seaming criteria were established where the seam had to be no more than 20 mm from the folded edge of the seam and that the stitch density needed to be between 3 and 4.5 stitches per 25 mm. Each sewing machine was then set up and qualified. A qualification seam was sent out for testing and once successful that machine was available to sew. Once this initial sewing development work was completed all field and shop sewing machines were able to sew and meet specification.

5 QUALITY CONTROL

As part of the preparation for shop and field sewing Layfield worked with AMEC to develop a QC plan that would ensure that job requirements were met. The overarching requirement was that a strength of 82.5 kN/m would be developed in both the machine and cross directions of the geotextile cap.

Sewn seams in high strength geotextiles typically develop 50 to 60% of the material strength when tested using a wide width seam test (ASTM D4884). The selection of geotextile with a machine direction strength of 105 kN/m and a cross direction of 155 kN/m meant that seams could be prepared in the cross direction (along the edges of the fabric) that would meet the 82.5 kN/m requirement with a seam efficiency of 53%.

Complicating the quality control discussion was the problem that with reduced strength in the machine direction (105 kN/m) there would not be an effective method of making a cross seam. If cross seams were made then an additional repair technique would be needed to reinforce the cross seam such as another layer of material overlapped onto the seam. At the beginning of the project it was not known if the tailings would exude up through overlap joints and render them ineffective. This guided discussions to eliminate cross seams and to limit repairs as much as possible.

Restricting cross seams had a number of effects on the quality control plan. First it meant that all rolls needed to be full lengths with no short rolls. Since this was a large order of custom material this not a problem and all rolls were manufactured to fit the project. The other effect was to create an environment where repairs would be avoided if at all possible. In the early stages of the project there was a great deal of discussion to figure out ways to deal with small defects without actually needing to make repairs.

The more important discussion was how to monitor the effectiveness of sewn seams. Since cross seams needed to be avoided this affected where and how samples could be removed for testing. Typical quality plans for geomembrane installations include the periodic removal of seam specimens from the seams produced. In this project specimens could not be removed from the main part of the seam without a repair or patch that would involve some cross seaming. The question then was how to sample seams for testing without leading to a requirement for repair of the seam.

The eventual solution was to remove specimens from the ends of the seams produced. In the Pond 5 road design there is a 5 m section on each side of the road that is not backfilled. This 5 m section facilitated the removal of test specimens without causing damage to the road seams. In the fabrication and installation proposals it was indicated that samples would be removed at a rate of one specimen from each panel produced in the shop (one for every 4 seams) and one from every seam produced in the field. This appeared to be a good compromise between effective sampling and avoiding the need to repair seams in the middle of the roads.

In order to verify that the seams produced were consistent and that test specimens were representative of the final seams a detailed visual inspection was conducted on all seams. In the shop there was a full time inspector assigned to monitoring the number of stitches in a seam and the position of the seam relative to the edge of the seam. In the field the seams were inspected while being made and then once more after the seam was completed. The number of stitches and the seam position were found to be the defining factors in consistent seam strength.

After a series of discussions these proposals were accepted into the quality control plan for the project. AMEC supplied additional quality auditors to monitor the sewing operations in both the shop and the field. The auditors monitored the preparation of seams, collected and reviewed manufacturer's test reports, monitored the removal of seam samples, reviewed seam test results, and observed the actions of the seaming inspectors.

As with any new type of material there can be unexpected issues. In the initial sewing of the geotextile the shop was using the J-seam type as this is the easiest to produce (Figure 7). In the J-seam both layers of material are folded in one direction and then sewn. This hides the bottom layer and there were instances where the bottom layer was not captured by the sewing thread. These areas were re-sewn in the field. After this incident the fabrication technique moved to the "butterfly" seam type (Figure 8). In the butterfly stitch type each layer of material is folded away from the other. When sewn the butterfly seam lets the inspector see both sides of the stitching and the inspector can easily see if all layers of material have been captured in the seam.

There were also some small defects that occurred in a couple of rolls. Since the general consensus was that repairs were to be avoided if at all possible a solution was needed to deal with panels and rolls that contained minor defects. The solution here was to mark panels that had issues and then set these panels aside for use in non-critical areas. A typical small defect would be a missed fibre in the weaving of the geotextile. These defects were rare and there were only 4 detected in this order. The other issue was a low seam test result. In the beginning of the sewing there were two panels where the sewn seam strength as tested was lower that specified. These were identified as having too many stitches in a close area (puncturing the material more than necessary). These panels were all set aside for use in non-critical areas. Overall 6 panels had defects that would normally have required some sort of repair (less than 1% of the panels). These panels were all used in road crossings.

6 FIELD CONSTRUCTION

Field construction began on January 12th 2010. Initial construction was intended as an experimental phase where deployment (Figure 9) and seaming techniques (Figure 10) would be evaluated. Two field seaming companies were employed on this part of the project each associated with a separate earth moving contractor who was installing the other materials and backfilling the geotextile with coke.

Figure 9. Deployment of a fabricated panel on the ice

Installation began with the preparation of road tie-ins at the edge of the pond. These anchors used the 175 by 175 kN/m fabric so that cross seams and diagonal seams could be prepared. Most of these anchors had triangular sections so that the road would start out in the right direction. The panels were field cut and re-sewn to make anchors of the correct shape.

Once the anchors were in place the road construction began. It was determined quickly that the panels needed to be placed on the ice for most efficient installation. The restriction against movement on the ice was relaxed and placement proceeded swiftly. Placing the panels on the ice did not present any significant problems. Using amphibious vehicles to assist in pulling out the panels and a labour crew the panels were placed without difficulty. Fortunately there were no significant snowfall events during field operations.

Another issue that was resolved soon after construction began was the issue of road crossings. The original intent had been to use the 175 by 175 kN/m fabric in the road crossings so that the 105 by 155 kN/m fabric could sewn perpendicularly to start the cross roads. Since there would be a delay between sewing the north/south and east/west roads the thought was that the fabric could not be recovered from the ice to make this sewn connection. The solution was to simply use another layer of 105 by 155 kN/m fabric and run right over the previous road. This put two layers of fabric in each road crossing.

Figure 10. Field seams being sewn in the heated sewing trailer

The use of two layers in the road crossing led to the solution of what to do with the 6 panels that had minor defects. These rolls were now tagged for use in the road crossings. Since the second layer of fabric was now in a non-critical area this easily took care of these panels without requiring repairs.

Sewing of the panels on the ice was easier than originally thought. The use of heated trailers protected the crews doing the sewing and the sewing machines worked well. Samples taken from the sewn seams were tested on site with the field tensile tester and all field seams produced passed their associated tensile test.

During field installation, two conditions proved to be primary controls on the rate of placement. The first was ability to transport and place the coke. This could not keep up with the high strength geotextile installation given the equipment type and number of units. This differed from the original assumption that the installation of the fabrics was the potential bottleneck. The initial production rate of 15,000 m^2 of fabric per day (about 6.6 panels per day) was very close to the manufacturing rate of the roll goods, equal to the fabrication rate of sewn panels, and could have been exceeded by field placement if coke placement could have kept up. Significant improvements in coke placement were implemented before 2011 construction.

The second impact on production was due to an early spring. An early and sustained warm spell early in March meant that by the middle of March the ice had thinned to a

Figure 11. Last few panels placed before spring melting stopped on-ice activities

point where construction had to stop (Figure 11). At the end of 2010 winter construction, 4.5 km of the planned 13 km of roads had been placed.

7 LESSONS LEARNED

There were a number of important things learned on this project. The first and most important was that placement and sewing of high strength woven geotextile could take place safely on the ice of a frozen tailings pond. The placement and sewing was difficult in poor weather but, with the use of heated sewing trailers, produced seams that met the project specifications fully. The second was that the deployment and seaming of the geotextile was not the bottleneck that was originally anticipated. Large prefabricated panels (100 by 22.5m) moved most of the seaming off the ice and into the fabrication shop which reduced the field seaming to a minimum.

An interesting aspect of this job was how fast everything happened. Because this project took place in the winter there were considerable resources available for manufacturing, fabrication and installation of the geotextile. This project could not have achieved the same turn-around times or rates of production in a summer installation. In this winter time frame all resources needed were available on short notice.

Figure 12. Extent of roads at end of construction in winter of 2010

8 RESULTS

The geotechnical performance of the roads has been better than expected, and this enabled the reduction of coke layers to a thickness of 2 m (compared to a planned 3 m) to speed placement without trafficability issues during construction (Pollock et all 2010). The construction of the roads on the ice proceeded safely and without incident.

The paper Suncor Oil Sands Tailings Pond Capping Project (Pollock, et all, 2010) summarizes the construction and performance of the cap indicating that the high strength woven geotextile was not the limiting factor of installation, that installation and coke placement proceeded well on ice that was 0.38 m thick (15 "), and that the materials and seam strengths exceeded specifications.

Monitoring of the roads took place throughout 2010, watching for settlement and trafficability. Field trafficability tests with a loaded 40 ton articulated truck were conducted, and except for some limited areas of the 2 m cap, the roads performed well. Additional fill was added to improve trafficability in the soft areas.

9 CONCLUSIONS

In the winter of 2010 a custom high strength woven geotextile was successfully designed, manufactured, fabricated and installed as part of a trafficability coke cap constructed on Suncor's Pond 5. New materials and techniques were developed to meet specifications and work on the ice of a frozen pond. Testing methods and equipment were developed and successfully deployed. All of this occurred in a very short time line in an effort to place the most material possible in the limited time available on the frozen surface of the pond.

The initial coke roads are performing well and are providing a working surface to prepare for the next steps in the capping of this tailings pond ultimately leading to full reclamation.

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