STREAMBANK STABILIZATION USING BIOENGINEERING AND BIOTECHNICAL METHODS

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1. ABSTRACT

Several untried environmentally sensitive erosion and sediment control methods were investigated and implemented into a large scale test site. Bioengineering and biotechnical mitigation designs were sought from specialists and incorporated into an unconventionally structured contract, which included the physical works as well as involving participants in field training and implementation of much of the work. The project success was a testament to the cooperation of the designers, the contractor and the owner. Bioengineering and biotechnical projects involve concepts that are difficult to 'engineer' and require significant flexibility in the structure of the contract and willingness of all parties to adapt to changing field conditions in order to field fit the designs With increased use of these methods, it is expected that more consultants will become comfortable with designs they cannot 'guarantee,' and contractors will develop skills to implement the designs, accepting the inherent risk of failure and the likelihood that changes will have to be accommodated during construction.

The participants in the associated workshop showed high levels of interest and enthusiasm. Course feedback was very favorable, and a follow-up course is being developed for the Fall of 2006. Interaction between Alberta Infrastructure and Transportation (AIT), consultants, and Department of Fisheries and Oceans (DFO) was especially encouraging, and the casual course setting offered ample opportunity to gain perspectives into each stakeholder's point-of-view. The project demonstrated to DFO that it is possible to construct along a riverbank without the use of costly isolation techniques. Several consultants indicated that they would try to incorporate some of the bio-designs, where appropriate, into future projects.

2. INTRODUCTION

Soil bioengineering methods use plants to arrest and prevent slope failures and erosion. Bio-technical methods combine the use of mechanical elements and biologic elements, to arrest and prevent slope failure and erosion. Bioengineering is not new to Alberta Infrastructure and Transportation (AIT); however, these environmentally sensitive designs are typically not part of mainstream designs. In 1986, bioengineering techniques were first used by the department to stabilize a cut backslope on Highway 68, in the Kananaskis Country, and also to stabilize streambanks and culvert inlets at a number of stream crossings along Highway 40 and the Forestry Trunk Road, south of Grande Prairie. Field inspections of these sites conducted in 2004 verified that these projects were successful over a long period of time, even through periods of drought, heavy rainfall and flood.

Through AIT's commitment to an Environmental Management System, to continuous process improvement and to innovation, a pilot project was developed to demonstrate the design and implementation of several new bioengineering and biotechnical methods. This paper describes the pilot project site conditions, the mitigation design process, the contract process, the implementation sequence and the integration of a hands-on field training course for stakeholders during the construction phase. A discussion of the long-term monitoring and pros and cons of bioengineering and biotechnical methods is also presented.

3. BACKGROUND

Classroom-based erosion control training sessions have been presented by AIT over the past several years, subsequent to the introduction of the Department's "Design Guidelines for Erosion and Sediment Control for Highways" and the associated field manual, which were issued in 2003. The primary intent of the training was to promote erosion and sediment control (ESC) design methods and best management practices amongst AIT and consultants. While the quality and appropriateness of ESC designs appear to be gradually improving, most stakeholders continued to use the traditional hard armour approach to ESC design. Unfamiliarity and uncertainty with bioengineering and biotechnical designs and associated warranty issues were commonly cited as impediments to the use of bioengineering methods. In order to overcome this resistance, the concept of holding a classroom and field workshop on Bioengineering and Bio-technical Streambank Stabilization Techniques was developed. An appropriate site and time for implementation was sought.

The Pembina River flows approximately 560 km, from the east boundary of Jasper National Park, to near the town of Athabasca, where it joins with the Athabasca River. Near the town of Robb, it is a modest-sized meandering mountain stream, with peak flows occurring in May and June. Normal flows of 20 to 30 cu.m/sec result in stream depths of about 0.75 m at the subject site. A maximum quartile flow rate of about 55 cu.m/sec is predicted by Alberta Environment for the Paddy Creek monitoring station. Resource development along the foothills of the Rockies, related to forestry, mining, and oil and gas development, has created a network of resource roads. These connect to the main highway network by Highway 734; a gravel surfaced, two lane road. A portion of the road alignment follows the Pembina River valley. At numerous locations, a meander loop of the river approaches very close to the road embankment. Portions of the road overlie infilled Oxbow Lakes, remnants of previous river alignments. Improvements to the horizontal alignment are envisioned on a long term horizon, however, local topography, marshlands and the river limit the extent of horizontal alignment improvements that can be made, notwithstanding a complete realignment of the roadway.

As it happened, a 2001 Functional Planning Study was undertaken for AIT to evaluate potential improvements to the alignment of Highway 734, between Robb and Nordegg. A dozen or so pinch points were identified, where the Pembina River was actively eroding the streambank in close proximity to the highway. These sites were prioritized for repair, based on a set of probability and consequence factors. Initial mitigation designs incorporated tried and true hard armour solutions. Upon collaboration with the design consultants and a bioengineering specialist, a decision was made to utilize these two sites as a bioengineering and biotechnical training opportunity. The sites are shown on Figure 1.

4. PILOT SITE DESCRIPTION

Two sites, in particular, were targeted for repair in 2005; Sites #1 and #9. Both of these sites are located along the outside bend of a meander in the river, with the road top about 2.5 m above the normal river water level. At these locations, the eroded bank was within 2 m of the edge of the road, creating unstable and unsafe conditions. At site #1, a prior effort had been made to stabilize the streambank, using a series of rock spurs intended to redirect the river away from the endangered streambank. However, the location and size of the spurs was not optimal, and erosion of the streambank in-between the spurs was occurring. The total length of streambank affected was about 200 m, and the width of the stream at this location was about 15 m. The site was inspected on several occasions and was deemed to be a high priority for mitigation work. A significant increase in streambank loss was noted after the peak flows of June 2005. The 2005 daily flow rate at the Paddy Creek monitoring station, downstream of the site, is shown on Figure 2.

At Site #9, along the outside bend of the river, the water had eroded the road embankment sufficiently to completely undermine a short stretch of the road and place adjacent areas at risk. About 5 m of guardrail was left unsupported. An exacerbating factor at this site was the presence of a centerline culvert, that drained a marshland from the opposite side of the road into the eroding area. The total length of streambank affected was about 100 m. Photos 1 and 2 show Sites #1 and #9 prior to construction.

5. DESIGN

The design consultant, Thurber Engineering, was directed to prepare environmentally sensitive mitigation designs for these two sites. Salix Applied Earthcare, of Sacramento, California, was added to the team. Mr. McCullah, of Salix, is an acknowledged expert in the application of bioengineering and biotechnical techniques. The design was a collaborative effort, involving the expertise of Salix to develop the bioengineering and biotechnical concepts; the engineering of Thurber to put the concepts into perspective and make contractual sense of the unusual designs, and the willingness of the owner, AIT, to accept the inherent risks involved with the untried, innovative and unwarranted nature of the work. A complicating factor in the design process was the desire to incorporate many different mitigation elements, in order to showcase them during a training course, whereby participants would provide the labour required to implement the designs.

Over the course of about 6 months, the design team developed mitigative designs for both sites. The designs incorporated environmentally sensitive elements that highlighted the use of natural elements, to both enhance hard armour designs and, in most cases, to replace hard armour designs. Materials suppliers willingly came forward with offers of free materials to support the project objectives. Buy-in from the Department of Fisheries and Ocean was forthcoming, a result of their interest in environmentally sensitive erosion control. Since the design was within and adjacent to a fish-bearing stream, special precautions were required during construction, and monitoring of sediment and turbidity was required prior to, during, and after construction. Long term monitoring of the success of the mitigation scheme was also a requisite of the DFO permit. The design methods used for this project will be incorporated in the next update of AIT's erosion control guidelines.

The design incorporated a fusion of new methods of hard armouring with bioengineering and biotechnical augmentations. The primary design element was the use of redirective vanes that tapered in both horizontal and vertical plan views and were pointed upstream at 30 degrees offset from the shore line. The top of the vane was set at two times the bank full height. Spacing of the vanes is somewhat of an art, but in principle, the flow lines from the tip of the upstream vane are directed into the middle section of the next downstream vane. It is recommended that the bank full height be determined by personnel experienced with such assessment. In between the vanes, the lower portion of the shore was protected with a longitudinal peaked stone toe protection (LPSTP). LPSTP is a continuous bank protection, consisting of a stone dyke placed at the toe of an eroding bank, usually just below bank full elevation.

Above the LPSTP, a variety of bioengineering and biotechnical methods were used, as described below:

- Live staking – Insertion of live woody stake cuttings, typically 0.5-1 m lengths, on slopes or stream banks. The portion of the stem in the soil will grow roots (reinforcing soil), and the exposed portion will develop into a bushy riparian plant.

- Pole planting – Larger and longer than live stakes, these can provide better mechanical bank protection during plant establishment. Dense array of posts can reduce velocities near the bank and posts reinforce banks against slumping.
- Live siltation – Installation of willow cuttings along a trench, excavated at the water’s edge. The cuttings are inclined to overhang the river, with soil placed back in the trench. This method increases the bank roughness, which encourages deposition and reduces bank erosion.
- Branch layering – Live brush layers are layers of live willow cuttings that alternate with successive lifts of soil fill. Several layers are built to reinforce the slope or embankment.
- Brush mattress – A thick blanket 6-12’’ of live brushy cuttings and soil fill. The dense layer of brush increases roughness, reduces velocities at the bank face and protects it from scour, while trapping sediment and providing habitat.
- Vegetated mechanically stabilized earth (VMSE) – consists of alternating layers of live willow cuttings with soil wrapped in natural fabrics, TRMs or geogrids. Several offset layers are built up to make the stream bank.
- Vegetated riprap (bent pole method/willow bundle method) – Willow poles or cuttings are placed at an incline, against a prepared slope, and a layer of stone and/or boulder armouring is placed on top of the willow cuttings and poles. The willows are woven up through the rock mat during the placing of the rock.
- Rolled erosion control products (RECP) – blankets made from straw, coconut fibres, or excelsior, and;
- Compost -- blankets, socks, and berms – The compost was a coarse fibrous wood processing byproduct.

Selected design plan drawings are provided as Figures 3 through 8

6. CONTRACT

The construction contract was unconventional. Bid items such as longitudinal peak stone toe protection, brush layering, vegetated mechanically stabilized earth and others have not been included in an AIT contract previously. The potential for rapidly changing water levels, the coordination of the fieldwork with the classroom training, and the untried nature of the work were of concern to all stakeholders. The consultant spent considerable effort developing special provisions and detailed drawings to describe the nature of the work, so that potential bidders would be able to understand the work, and bid accordingly. Not only was the type of work new, but the presence of 70 or more students onsite during construction, acting as unpaid labourers under the responsibility of the contractor, made the contract a difficult one to bring to tender.

The contractor’s perception of risk involved with the work was heightened, due to heavy rainfall during the tender preparation period, which resulted in very high river levels and an increased cost assigned to ‘isolation’ of the works, as required by DFO. As it turned out, the water levels dropped rapidly prior to the actual construction, and no significant isolation costs were incurred.

In mid-September, the construction contract was awarded to Farlinger & Associates. They mobilized to site and began site preparations a week or so in advance of the field training session. Much of the hard armour portion of the design was installed prior to the training course; this consisted of installation of redirective vanes in the river (Photo 3) and resistive measures, such as longitudinal peaked stone toe protection (LPSTP) (Photo 4). Turbidity monitoring (Photo 5) was done during placement of the instream works. If turbidity levels increased during instream work, the work was halted. Generally, the placement of the resistive vanes was done with little adverse effects on the river turbidity. The design for Site #1 involved removal of the previous spurs. It was assumed that these were composed of large rocks, however, the spurs were actually made up of a mix of rock and silt, making removal problematic and time consuming. However, with diligent monitoring, the work was done without containment.

The remainder of the work involved a mix of bioengineering and biotechnical techniques that were done in conjunction with a field training course.

7. STREAMBANK STABILIZATION TRAINING COURSE

A classroom and field workshop on Bioengineering and Bio-technical Streambank Stabilization Techniques was held Sept 27-29, 2005, at the Hinton Forestry Training Centre and the pilot project site. There were 67 registrants, consisting of 28 AIT staff, 21 consultants, 11 Department of Fisheries and Oceans staff, 2 City of Edmonton staff, 3 materials suppliers and other stakeholders. Course fees were $800 for non-AIT and non-government registrants, $500 for non-AIT registrants and $150 for AIT staff. The fees included room and board as well as bus transfer to the field training site. The costs of the instructor and a training video were covered by the course fee revenue. Day 1 was reserved for classroom training, which covered the erosion and sediment control practices to be implemented, a review of safety issues, and completion of the training waiver forms.

On Days 2 and 3 of the training, participants were shuttled to and from the field training site in school buses. The optimal number of participants for a course such as this, according to John McCullah, was about 35. Since there were twice that number in the field it, was necessary to divide the group into manageable numbers and divide the work accordingly. The first duty was to cut willow branches from the surrounding area, using the prescribed technique, and ensuring the willow cuttings were placed in water to prevent drying. Once a sufficient number of willows were obtained, the course participants installed the various biobased ESC measures, such as live siltation (Photo 5), vegetated riprap (Photo 6), vegetated mechanically stabilized earth (VMSE) (Photo 7) and brush layering (Photo 8). Finally, to complete the site repair, erosion control BMPs were applied on all disturbed land – consisting of seeding, and straw and coir erosion blankets. The application of compost blankets, berms and logs (Photo 9) was a highlight of Day 2 acivities.

There were a number of challenges involved in staging the training, including: safety of the course participants, traffic accommodation, and environmental issues. Safety issues were mitigated, by having all course participants take the contractor's mandatory Site Hazard Assessment and review of OH&S issues, prior to going to the site. Two registered first-aiders were onsite full-time. The hospital in Hinton was notified of all activities, and an evacuation plan was prepared. The field site was a dead zone for cell phones, so a satellite phone had to be used. Potable water, portable toilets and a warm up trailer were provided. Waders, life jackets, safety ropes and first aid kits were onsite. A waiver was signed by each attendee, in order to protect the department against possible injury liability. Environmental issues were mitigated through diligent water quality monitoring, which was a requirement of the DFO permit. Water quality monitoring was provided by a professional fish biologist, who monitored water turbidity and sediment deposition during construction (Photo 10).

As part of the training session, the proceedings were videotaped. The professionally prepared training video is available for ongoing department training purposes.

8. CONCLUSION

The pilot project provided a valuable learning experience. Several untried environmentally sensitive erosion and sediment control methods were investigated and implemented into a large scale test site. Bioengineering and biotechnical mitigation designs were sought from specialists and incorporated into an unconventionally structured contract, which included the physical works as well as involving participants in field training and implementation of much of the work. Bioengineering and biotechnical projects involve concepts that are difficult to 'engineer' and require significant flexibility in the structure of the contract and willingness of all parties to adapt to changing field conditions in order to field fit the designs With increased use of these methods, it is expected that more consultants will become comfortable with designs they cannot 'guarantee,' and contractors will develop skills to implement the designs, accepting the inherent risk of failure and the likelihood that changes will have to be accommodated during construction.

Initial project success was a testament to the cooperation of the designers, the contractor and the owner. Participant feedback has led to plans for follow-up training, and lessons gleaned from this pilot project have widened the knowledge base from which the viability of such new methods will be considered.

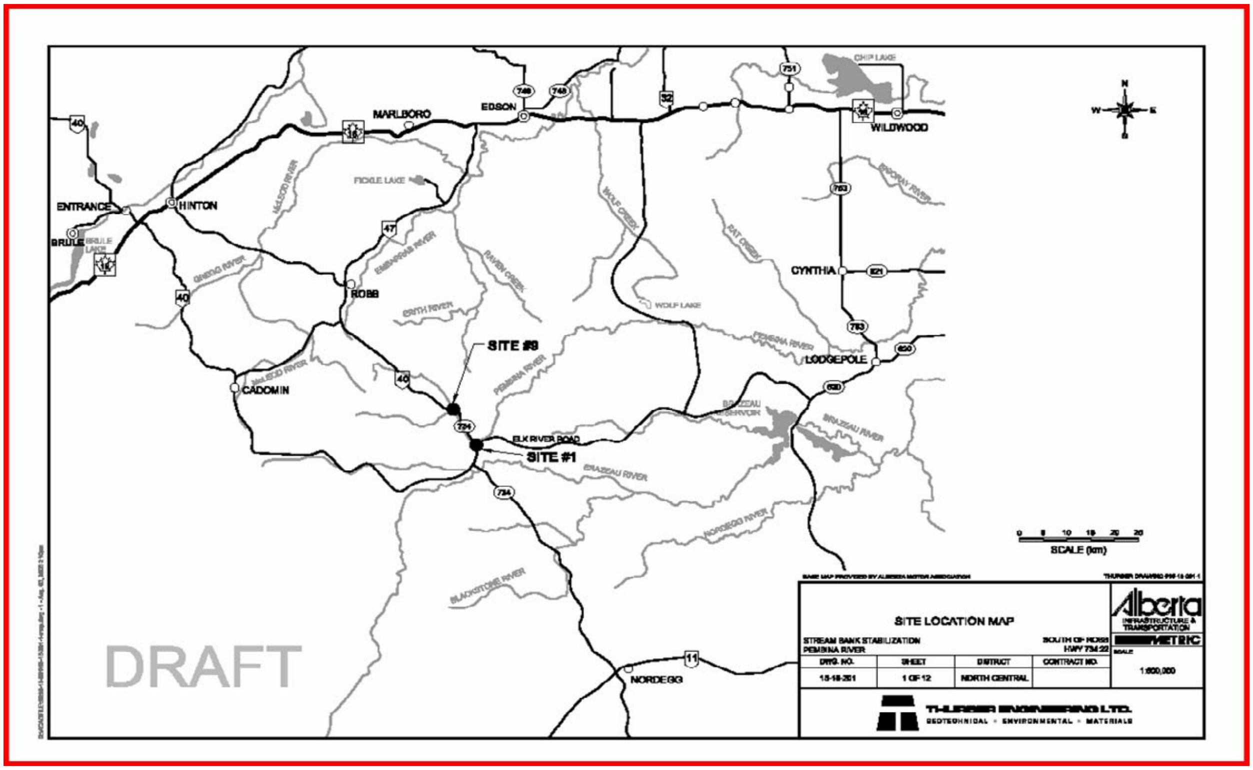

Figure 1 Site Plan

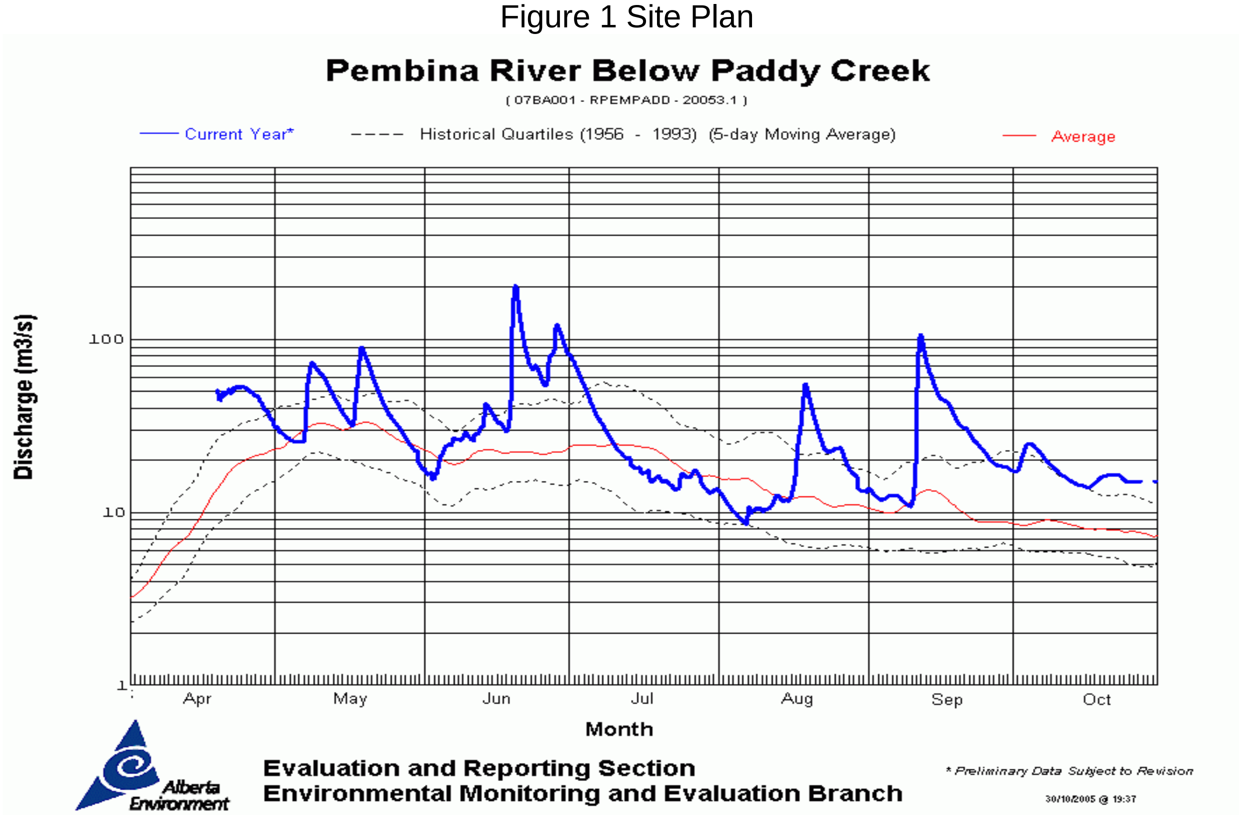

Figure 2 Daily Flow Rate

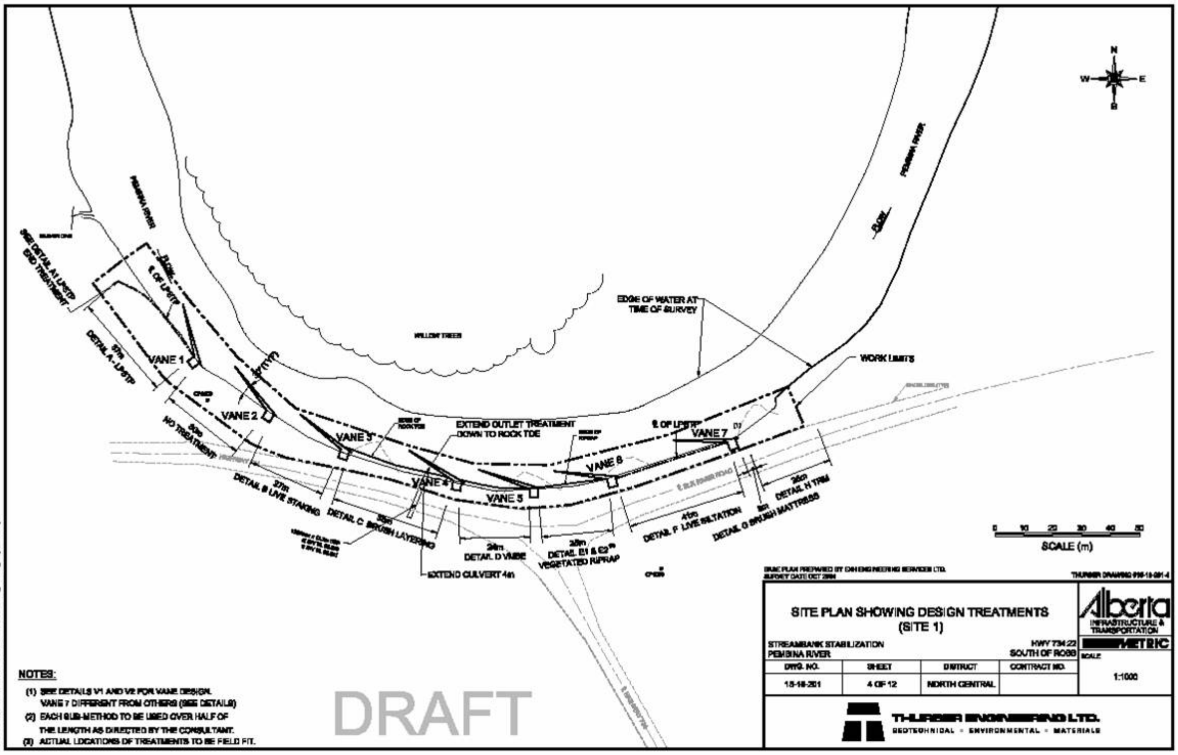

Figure 3 Mitigation Plan Site #1

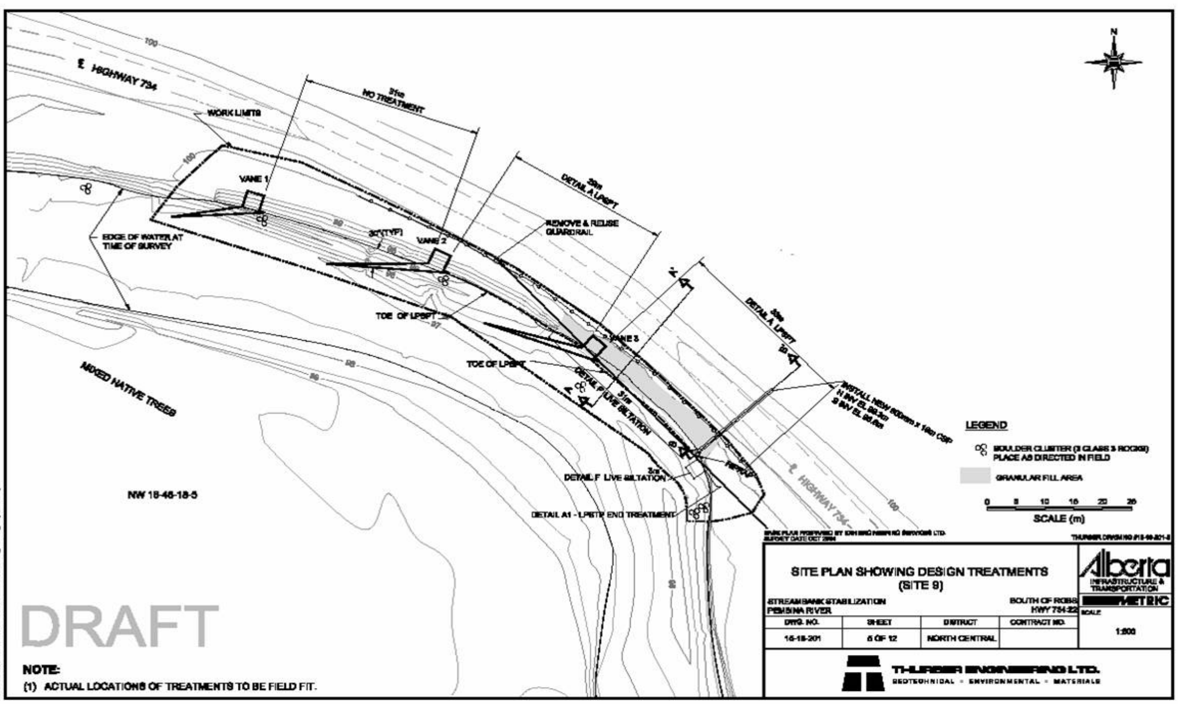

Figure 4 Mitigation Plan Site #9

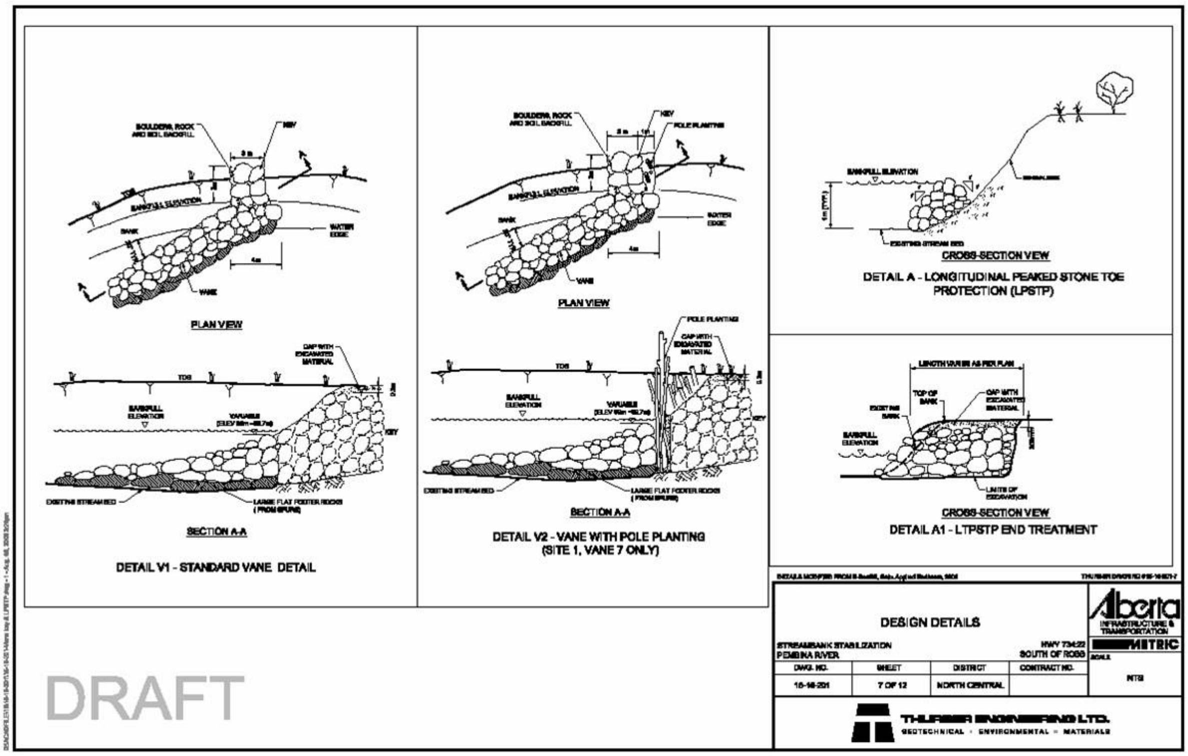

Figure 5 Vane Details

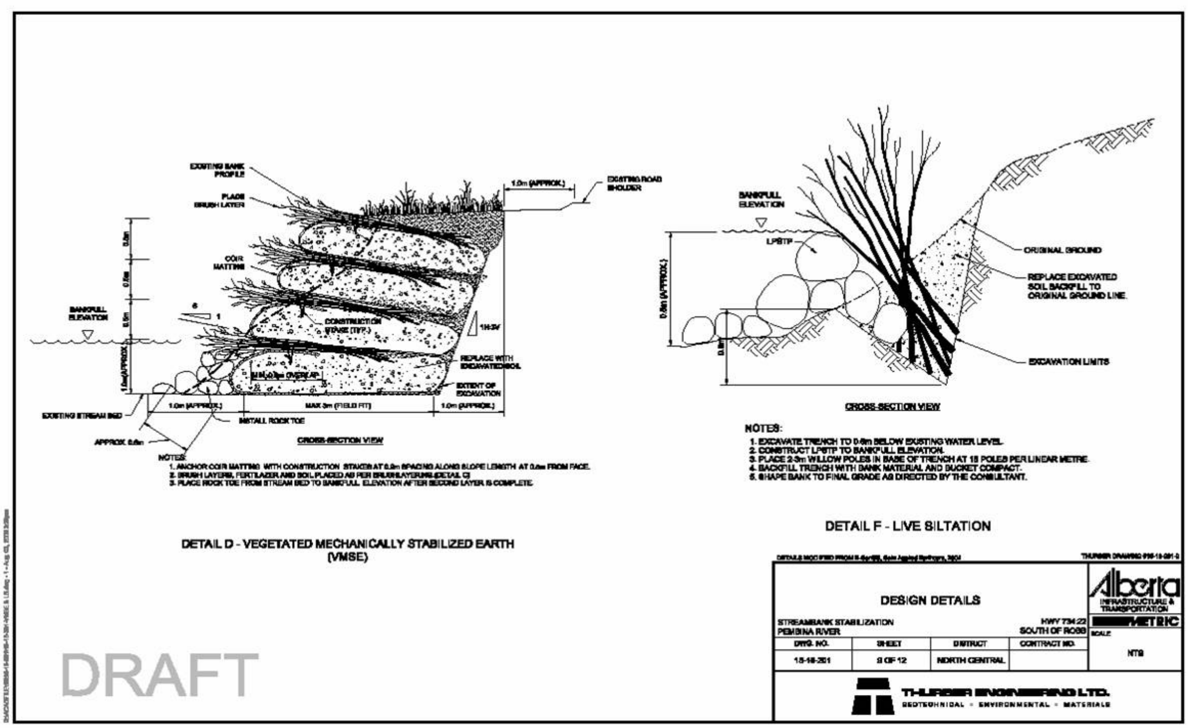

Figure 6 Vegetated Mechanically Stabilized Earth and Live Siltation

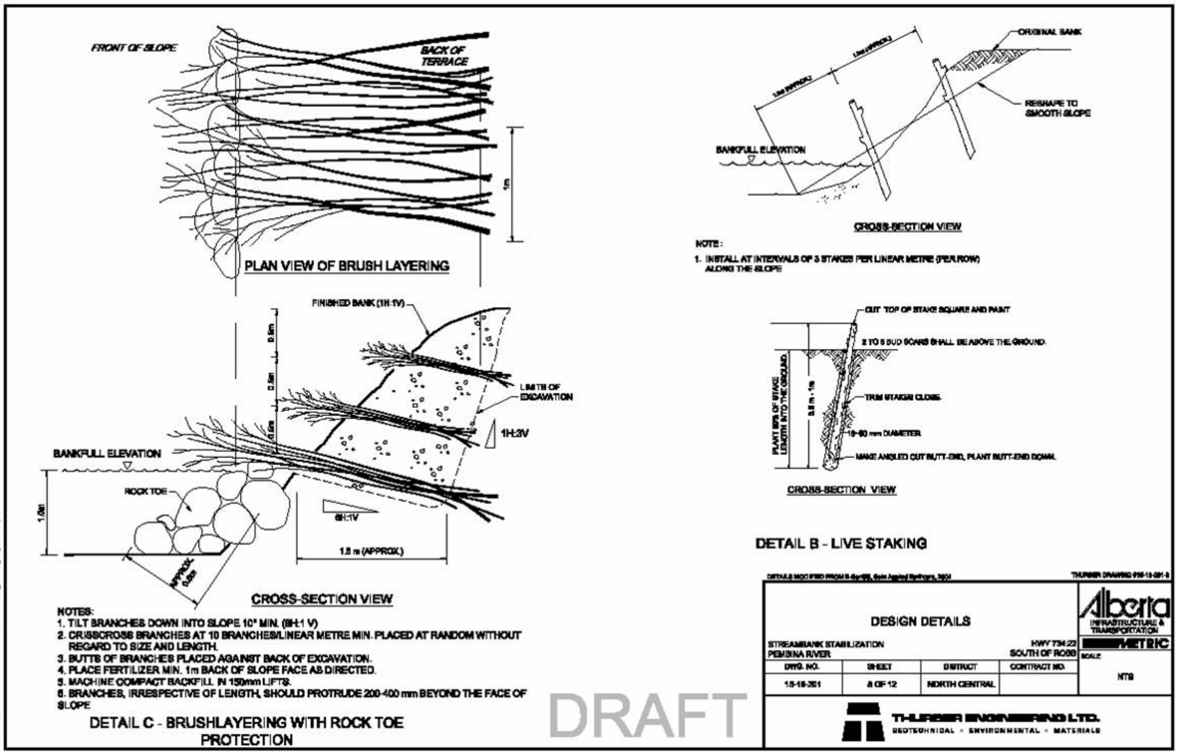

Figure 7 Brush Layering and Live Staking

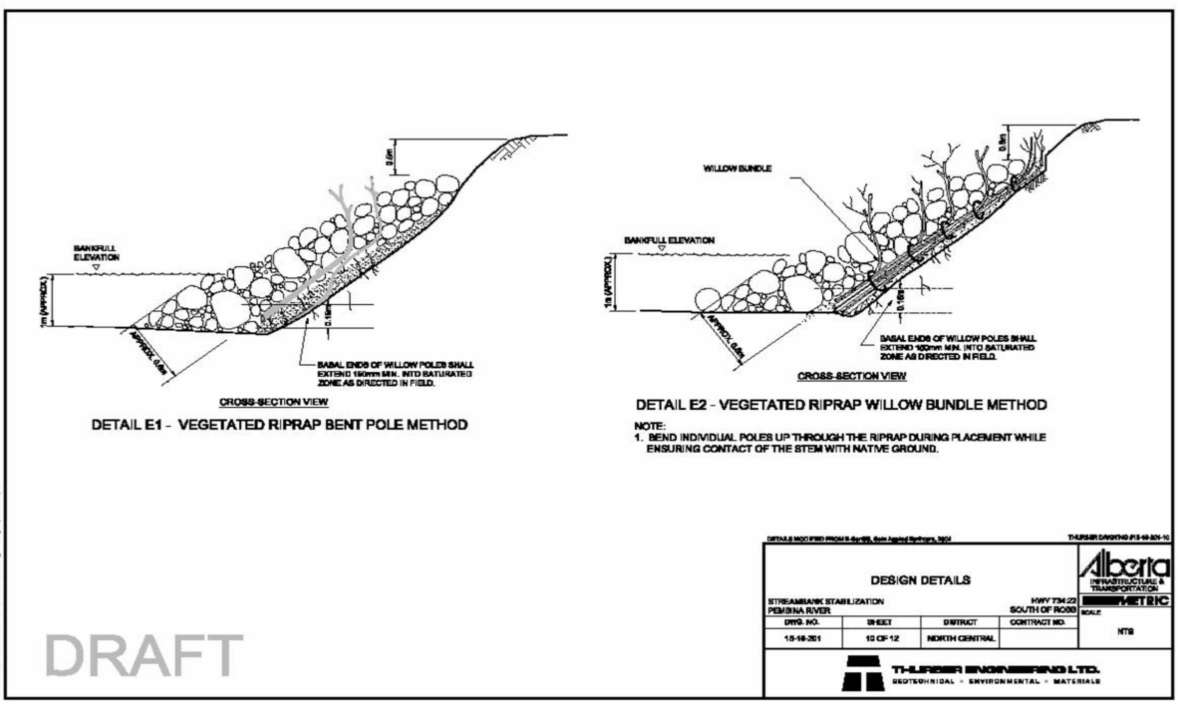

Figure 8 Vegetated Riprap

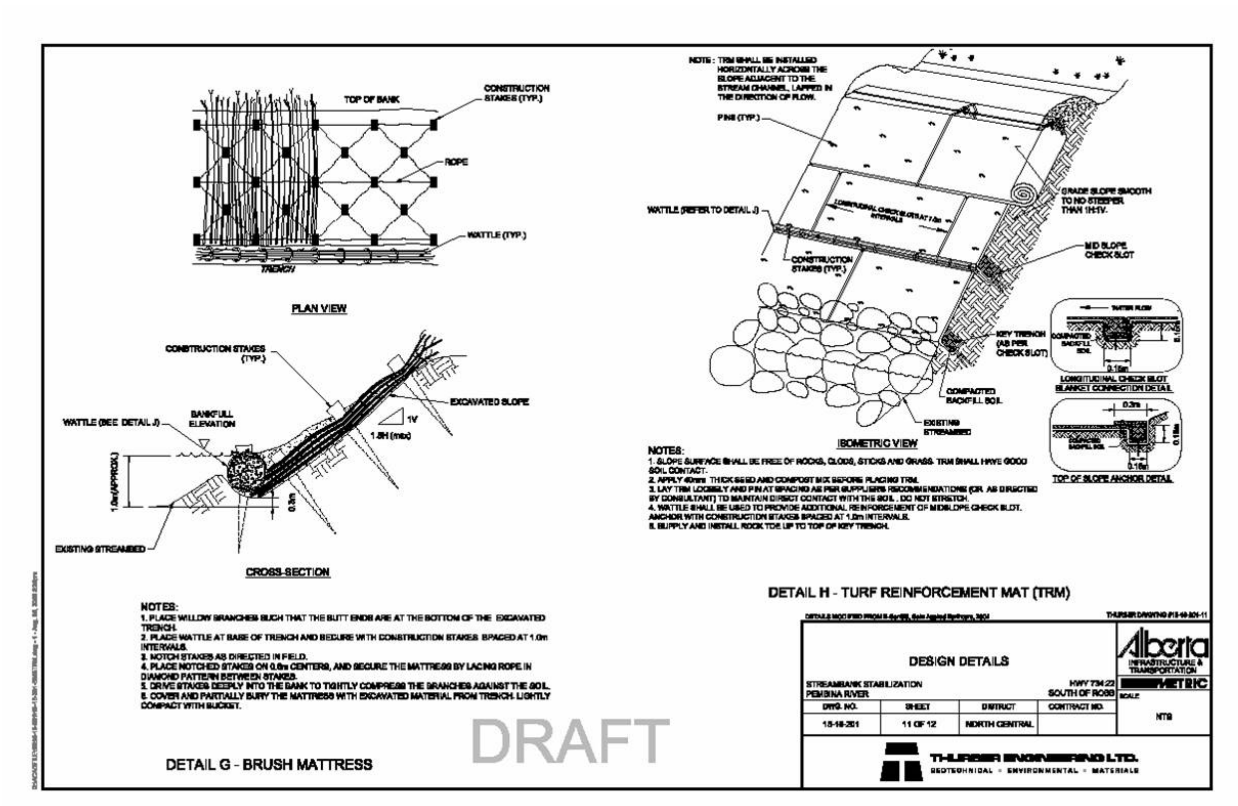

Figure 9 Brush Mattress

Photo 1 Site #1

Photo 2 Site#9

Photo 3 Construction of Redirective Vanes

Photo 4 Construction of Longitudinal Peak Stone Toe Protection

Photo 5 Live Siltation Implementation

Photo 6 Vegetated Riprap

Photo 7 Vegetated Mechanically Stabilized Earth

Photo 8 Brush Layering

Photo 9 Sprayed compost blanket

Photo 10 Turbidity monitoring