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TORS COVE HYDROELECTRIC DEVELOPMENT: PENSTOCK TRESTLE REPLACEMENT

TORS COVE, NL

APRIL 3, 2013

Newfoundland Power

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April 3rd, 2013

D. Ball and G. Humby
Newfoundland Power
55 Kenmount Road
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Subject: Tor’s Cove Hydroelectric Development: Penstock Trestle Replacement

Dear Mr. Ball and Mr. Humby,

CASC Consulting is pleased to provide the attached final report for the Tor’s Cove Hydroelectric Development: Penstock Trestle Replacement. This report was completed as a requirement of the MUN Faculty of Engineering senior design project course, ENGI 8700.

Five concepts were selected for detailed design: rehabilitation, complete replacement of the existing structure, top support design, bottom support design, and a steel penstock design. This report outlines the selection process and design work completed by CASC Consulting in recommending a preferred concept for trestle replacement. Models and drawings of each concept can be found in the appendices of this document, along with a detailed cost estimate for each concept.

Should you have any questions or concerns regarding this report, we would be pleased to discuss them with you. It has been a pleasure working with Newfoundland Power over the past three months.

Regards,

The CASC Consulting Team

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William Carson, Project Lead

Attached: Tor’s Cove Hydroelectric Development: Penstock Trestle Replacement

CC: J. Skinner, A. Hussein

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*All site photos courtesy of Newfoundland Power

Executive Summary

The following report was completed as part of the MUN Faculty of Engineering senior design project course, ENGI 8700. CASC Consulting is comprised of four civil engineering students: Maria Adey, William Carson, Steven Collins, and Jessica Sinclair. CASC Consulting was paired with Newfoundland Power for the design of a new penstock trestle for the Tors Cove Hydroelectric Development.

Several design concepts for trestle replacement were explored during the preliminary design phase of the project. The client suggested several concepts, while CASC Consulting added others based on preliminary research. The concepts were evaluated using a decision matrix and five were selected for detailed design and analysis.

CASC Consulting focused on the development of several options for complete replacement of the trestle and also considered rehabilitation of the existing structure. The concepts were designed and analyzed using S-Frame and S-Steel software and drawings were completed using AutoCAD.

Upon completion of design, cost estimates were prepared for each concept. Concepts were compared and a recommendation made based on cost, constructability, and long-term replacement plans for the penstock (Section 11.0).

1.0 Project Description

The Tors Cove Hydroelectric Development is located approximately 40km south of St. John's, NL on the Avalon Peninsula (Figure 1). This small hydro plant was built in 1941 and is owned by Newfoundland Power (NL Power); it can generate up to 6.5 megawatts of electricity. Water is carried to the generating facility from Tors Cove Pond by a 2590mm woodstave penstock.

Figure 1 – Tors Cove Trestle Location

The woodstave penstock is supported by a 17-metre long trestle structure over a small stream, which is the spill channel for Tors Cove. In a condition assessment conducted by a consultant, it was noted that significant corrosion had affected several of the structural members and that repairs would be required within one year. The necessary repairs were completed in late 2012. A follow up report issued by the same consultant noted that the completed repairs were adequate to extend the life of the structure by three to five years.

2.0 Project Requirements

The project consisted of a preliminary design phase, a secondary design phase for selected concepts, and an evaluation phase based on the cost estimates. During preliminary design, several concepts were developed and ranked using a decision matrix in order to select the best concepts for further design. The selected concepts were developed and designed using S-Frame structural software and drawings completed using AutoCAD.

Following completion of design, a detailed cost estimate was prepared and the design concepts were evaluated to provide a recommendation for a preferred option. This cost estimate will be incorporated into NL Power's five-year capital plan.

In addition to this report, the following will be submitted to the client and course instructors in hard and soft copy form:

- Structural Calculations - Calculations for chosen designs, including structural analysis and code checks (steel, concrete, timber, etc).
- Structural Design Sketches - Preliminary sketches of design concepts and detailed AutoCAD drawing of final design.
- 3D Models - Three-dimensional visual models of the selected designs as developed in S-Frame and S-Steel.
- Cost Estimates - Cost estimates for all design concepts.

3.0 Preliminary Concept Design

3.1 PRELIMINARY INVESTIGATION

In the early stages of the project, CASC Consulting visited the Tors Cove development to observe the site characteristics and the conditions of the trestle structure. In addition to the Tors Cove woodstave penstock, CASC Consulting visited two other NL Power sites to observe instances of the steel pipe and anchor block design. Photographs from CASC Consulting's visit to the Tors Cove trestle structure, as well as a steel penstock, are found in Appendix A. The upstream side of the river was not accessible due to snowy conditions.

In addition, CASC Consulting was provided with two reports from the consultant, Bridger Design Associates Ltd., which detailed the results of a visual inspection and necessary repairs to the structure. CASC Consulting reviewed these documents and met with the consultant to understand the current structural condition of the structure.

3.2 PRELIMINARY CONCEPTS

Ten design concepts were considered during the preliminary design phase of the project. The client suggested several concepts, while others were researched and designed by CASC Consulting. Two concepts were eliminated before the completion of the preliminary design, as the concepts were impractical. A multi-plate bridge was eliminated, as it would decrease the flow capacity of the river. The second concept eliminated was a bottom half-truss concept, which was very similar to the bottom support design. Characteristics from this design were added to the first bottom support concept.

CASC Consulting completed sketches and a preliminary cost estimate for eight of the preliminary concepts. The preliminary sketches and cost estimates are included in Appendix A. The eight concepts considered were:

- Steel penstock concept
- Rehabilitation
- Complete replacement of existing structure
- Top support concept
- Bottom support concept
- Box culvert concept
- Suspension bridge concept
- Pre-fabricated Maybey Bridge concept

3.3 DECISION MATRIX

A decision matrix was developed to evaluate the preliminary concepts in order to select the best options for further design. The concepts were scored between 1 and 10 based on various criteria determined by CASC Consulting and the client. The concepts were not ranked against each other, but were each given a value for each category, with 10 being ideal and 1 being undesirable.

The categories evaluated in the matrix included:

- Plant downtime
- Length of construction
- Environmental impact
- Constructability
- Risk
- Impact of design on river hydrology
- Future ease of pipe replacement
- Site access
- Cost

Cost was the most important factor to the client in the selection of a design; therefore, the values in the cost category were increased by 25%. A summary of the matrix categories and concept rankings are included in Appendix B.

3.4 SELECTED CONCEPTS

Following preliminary evaluation, the top five concepts were selected for further design. The concepts selected included:

- Rehabilitation
- Complete replacement of existing structure
- Top support concept
- Bottom support concept
- Steel penstock concept

4.0 Load Cases

The following loads were applied to the selected design concepts. Detailed calculations for all loads and a summary of the load combinations can be found in Appendix C.

4.1 DEAD LOADS

Dead loads are forces that are generated due to gravity acting on stationary objects in a structural system; they act solely in the vertical direction. Both the weight of the penstock and weight of the support structure were considered as dead loads in each concept analysis.

4.1.1 Weight of the Penstock

The weight of the penstock varies depending on the material and unsupported length of the penstock in each concept. All concepts were modeled and analyzed in S-Frame, a structural analysis program. The application of the load on the support structures in S-Frame also varied depending on the concept.

Upon discussion with the client, the dead load was applied as a series of point loads acting along the centerline of the penstock at the support points. This was applied for the top support concept, the bottom support concept, and the existing structure. It ensures that the penstock will not act as a structural member in S-Frame, but will act solely as a load. It was assumed that each support point carried equal load.

The dead load of the steel penstock design was generated in S-Frame using a self-weight generator method. This was accomplished by creating a load case with a (-1) gravitational factor in the vertical direction (i.e. -1 x 9.81m/s^2).

The dead load of the woodstave penstock and steel bands around the penstock was calculated as follows:

$$DL = \frac{\gamma_w A_p L + \gamma_s A_b L_b n_b}{n_s}$$

Equation 1 – Calculation of Woodstave Penstock Dead Load

Where:

$$\gamma_w = unit\ weight\ of\ douglas\ fir\ (kN/m^3)$$
$$A_p = c/s\ \ area\ of\ penstock\ (m^2)$$
$$L = length\ of\ suspended\ pipe\ (m)$$
$$\gamma_s = unit\ weight\ of\ steel\ (kN/m^3)$$

$$A_b = c/s \ area\ of\ steel\ band\ (m^2)$$
$$L_b = length\ of\ steel\ band\ (m)$$
$$n_b = number\ of\ steel\ bands\ on\ penstock$$
$$n_s = number\ of\ supports$$

The dead load of the steel penstock was calculated as follows:

$$DL = \frac{\gamma_s A_p L}{n_s}$$

Equation 2 – Calculation of Steel Penstock Dead Load

Where:

$$\gamma_s = unit\ weight\ of\ steel\ (kN/m^3)$$
$$A_p = c/s \ area\ of\ penstock\ (m^2)$$
$$L = length\ of\ suspended\ pipe\ (m)$$
$$n_s = number\ of\ supports$$

4.1.2 Weight of the Support Structure

The dead load for each concept is based on the weight of the respective structures. Dead loads were calculated using the self-weight generator method in the S-Frame structural analysis software.

4.2 LIVE LOADS

Live loads have ability to alter the magnitude, direction, or position within a structural model. Live loads that were considered in penstock trestle design include a water load, an ice load, and a water hammer load.

4.2.1 Water Load

The water load is calculated assuming the pipe is full, as it is under significant pressure. For the bottom support, top support, and existing structure, the load was applied as a series of vertical point loads acting along the centerline of the penstock at the support points of the structure. The water load was applied as a distributive load for the steel penstock concept.

Two assumptions were made when calculating the water load. First, it was assumed that the penstock is full of water. Second, it was assumed that each of the support points on the structure carried equal load.

The live load from the water in the pipe was calculated as follows:

$$LL_{water} = \frac{\gamma_{water} A_{ID} L}{n_s}$$

Equation 3 – Calculation of Live Load due to Water in Penstock

Where:

$$\gamma_{water} = unit\ weight\ of\ water\ (kN/m^3)$$
$$A_{ID} = c/s\ \ area\ of\ inner\ pipe\ (m^2)$$
$$L = length\ of\ suspended\ pipe\ (m)$$
$$n_s = number\ of\ supports$$

4.2.2 Ice Load

An Ice load was considered in order to account for any ice buildup on the outside of the woodstave penstock as a result of leaking (Figure 2). Ice load was not considered for the steel penstock, as it is assumed to be seamless and therefore will not leak. Ice was assumed as a live load instead of a dead load because ice loading will only occur during the winter months and can vary in depth. A three-inch thick layer of ice around the entire penstock was assumed for the calculation. It was also assumed that the ice would have the same unit weight as water. The load was applied to the structure as a series of point loads acting along the centerline of the penstock at its support points.

Figure 2 – Ice Build-up on Penstock in Petty Harbour

The live load due to the ice built up from potential leaks that may develop in the wooden pipe was calculated as follows:

$$LL_{ice} = \frac{\gamma_{water} A_{ice} L}{n_s}$$

Equation 4 – Calculation of Live Load due to Ice Build-up

Where:

$$\gamma_{water} = unit\ weight\ of\ water\ (kN/m^3)$$
$$A_{ID} = c/s\ \ area\ of\ ice\ around\ the\ pipe\ (m^2)$$
$$L = length\ of\ suspended\ pipe\ (m)$$
$$n_s = number\ of\ supports$$

4.2.3 Water Hammer Load

During an emergency shutdown of the Tors Cove hydroelectric facility, a water hammer load within the pipe could occur. For simplicity, a special load case and water hammer load combination has been added. The load was assumed to have a magnitude equivalent to 25% of the live water load and acts in the longitudinal, lateral, and vertical directions. This methodology was suggested by the client as an approximate load, which is satisfactory for concept evaluation.

In order to evaluate the “worst case scenario”, the load was assumed to act in the same lateral direction as the wind loads, the downward vertical direction, and the same longitudinal direction as the direction of travel of the water. For most concept, the loads were applied as point loads acting along the centerline of the penstock, at the support points for the top support, bottom support and existing structure. It was applied as a distributive load for the steel penstock concept.

Live load due to water hammer is calculated as follows:

$$LL_{WH} = \frac{0.25LL_{water}}{n_s}$$

Equation 5 – Calculation of Live Load due to Water Hammer

4.3 SNOW LOADS

The snow load was calculated on the penstock assuming a unit weight of snow of 3 $kN/m^3$and a snow height of 0.5 m, resulting in a snow load pressure of 1.5 kPa. Snow loads were calculated for both a woodstave pipe and a steel pipe based on the various design concepts.

It is likely that more snow will accumulate on the woodstave pipe as a result of the rough surface created by the staves and steel bands. Snow will not cover the entire top of the pipe, but will instead taper off due to the curvature of the pipe. Therefore, the width of accumulated snow was assumed to be 50% of the diameter of the pipe for the woodstave penstock and 25% of the diameter of the pipe for the steel penstock.

The loads were applied as vertical point loads along the centerline of the penstock at the support points for the top support, bottom support, and existing structure and as a distributed load for the steel penstock concept. The snow load was not applied to the top of the members of the structural system because it was assumed that the effect would be negligible due to the relative size of the structural members.

The snow load on the penstock was calculated as follows:

$$SL = \frac{\gamma_s H_s W_s L}{n_s}$$

Equation 6 – Calculation of Snow Load on the Penstock

Where:

$$\gamma_s = unit\ weight\ of\ snow\ (kN/m^3)$$
$$H_s = height\ of\ snow\ on\ pipe\ (m)$$
$$W_s = width\ of\ snow\ on\ pipe\ (m)$$
$$L = length\ of\ suspended\ pipe\ (m)$$
$$n_s = number\ of\ hangers$$

4.4 WIND LOADS

The wind load was calculated assuming an air density of 1.2 kg/m^3, a shape factor of 1.5, and a wind speed of 34.7 m/s (from National Building Code of Canada). The load was applied as a series of point loads along the centerline of the penstock for the top support, bottom support and existing structure. It was applied as a distributed load for the steel penstock concept.

The wind load was assumed to act perpendicular to the pipe in opposing directions (i.e. from North or South). However the wind load was only applied in one of these directions as it was assumed both directions would be equivalent. For this reason, it would be redundant to include more load combinations to accommodate the extra wind load because it would yield similar results.

The wind load was not applied on the structural members of the top support and bottom support concepts because it was assumed that the effect would be small and negligible due to the relative size to the penstock.

The wind loads acting on the penstock were calculated using the following formula based on the force of a fluid:

$$F = \frac{1}{2}\rho_a {U_w}^2 C_s D$$

Equation 7 – Calculation of Wind Load on the Penstock

Where:

$$\rho_a = Density\ of\ air\ (kg/m^3)$$
$$U_w = Wind\ speed\ (m/s)$$
$$C_s = Shape\ factor$$
$$D = Diameter\ of\ pipe\ (m)$$

4.5 EARTHQUAKE LOADS

Upon discussion with the client, earthquake loads were neglected for analysis. It is assumed that the water hammer load accounts for the movement of the water in the penstock, similar to that which could occur as the result of an earthquake. Therefore, it is not necessary to complete additional load calculations for earthquakes.

4.6 LOAD COMBINATIONS

The load combinations were chosen and calculated according to the National Building Code of Canada (NBCC). The loads in the analysis followed the combination factors set out in the NBCC, except for the water hammer load case. This live load was neglected for all but one combination as water hammer, though severe, is considered a rare occurrence. For this reason, water hammer was applied in a special combination, with a specific load factor. All load combinations can be found in Appendix C.

5.0 Selected Concept Design

Five concepts were selected for detailed design and analysis. Two of the concepts, rehabilitation and complete replacement of existing structure, are based on updating and re-sizing the existing design based on current codes. The remaining three concepts differ substantially from the existing design. Top and bottom support concepts both involve constructing a new support structure for the penstock, while the steel penstock concept requires replacing the woodstave pipe and trestle structure with a new steel penstock and two concrete anchor blocks.

It is assumed that the plant will be operational throughout construction for all concepts, with the exception of the steel penstock design. The bottom and top support concepts will both be built around the current structure; the existing trestle can then be removed upon completion of construction. Rehabilitation and complete replacement of the existing structure assume that the old trestle members would be cut out piece by piece as new members are added.

The following section contains a description and analysis of the design process for each concept.

5.1 REHABILITATION OF EXISTING STRUCTURE

The current penstock trestle was constructed in 1941 and has a 17-metre span across the channel. Bridger Design Associates Ltd. completed a structural review and condition assessment of the structure in 2012. It was noted that the trestle was in poor condition and had severe rusting and corrosion on several members (Figure 3). Bridger Design made several recommendations regarding areas of concern and in need of rehabilitation (Bridger Design, Structural Assessment Report).

Following this structural review, it was advised that the following members be immediately replaced (Bridger Design, Penstock Truss Repairs):

- Three transverse angle members in the bottom horizontal truss
- Three angle cross braces in the bottom horizontal truss
- One penstock truss hanging support

In addition to these replacements, it was advised that most of the transverse and horizontal members in the bottom truss be replaced in the next three to five years, along with deteriorated hanging support.

Figure 3 – Corrosion of Trestle Members

Rehabilitation was the highest ranked concept in the preliminary design phase. This was largely due to the constructability and feasibility of the concept. This option was originally the most cost-effective because it involves less labour and equipment than other concepts, lower material costs, and less construction time. However, it is necessary to complete thickness testing in order to identify members for replacement, as well as paint and sand blasting. Both of these activities are very expensive and have increased the cost of rehabilitation.

5.1.1 Structural System

The current trestle is formed of a series of beams and truss members (Figure 4). The penstock is suspended by six C130x10 hangers that are attached to the top of the structure and extend around the underside of the woodstave penstock. The hangers are attached by a pin connection to plates welded to two sets of back-to-back channels. These channels are sized at C150x16 and are separated by 104mm. In addition, there are struts located along the bottom of the structure at each hanger to stabilize the penstock against lateral deflection.

Figure 4 – Existing Trestle

The bottom support of the structure extends on either side of the channel, with cross bracing along the top, bottom, and side of the trestle. The main beams along the bottom of the truss, perpendicular to the penstock, extend out past the trestle sides, with additional bracing continuing to the top of the trestle. The trestle is comprised of single and double angles.

5.1.2 Design Assumptions

There is a significant amount of uncertainty with this option. Estimating cost is difficult, as a thickness test would need to be conducted for each member to determine which members require replacement. For the cost estimate, it was assumed that one-third of the members in the structure would require replacement; therefore, the material costs were estimated at one-third of the material quantity for complete replacement of the existing structure (Section 5.2). To account for uncertainty in material quantities, a higher contingency was applied to this concept.

5.1.3 Modeling

The existing structure was modeled in S-Frame assuming complete replacement of the structure. This model was used for both the rehabilitation and the complete replacement option and is described in Section 5.2.3. Members were re-sized to meet the current code and to ensure the most economic sections. Drawings can be found in Appendix D.

5.2 COMPLETE REPLACEMENT OF EXISTING STRUCTURE

Complete replacement of the existing structure was ranked second in the decision matrix after the rehabilitation option. Complete replacement was consistently ranked high in all categories of the decision matrix and had the lowest cost upon completion of the preliminary cost estimate. Complete replacement involves building a new trestle using a similar design.

The existing penstock trestle has been in operation for more than 70 years. The trestle was modeled in S-Frame in order to check the adequacy of the design against current design codes. The advantage of complete replacement rather than rehabilitation is that an entirely new structure would be constructed and there would be reduced risk of member failure in the long-term.

5.2.1 Structural System

The existing structure is described in Section 5.1.1. Members were re-sized in S-Steel to meet the current code and to ensure the most economic sections.

5.2.2 Design Assumptions

When modeling and re-designing the existing structure, it was assumed that the loads were being transferred at the hangers and that the addition of bottom struts would stabilize against lateral deflection.

5.2.3 Modeling

The existing structure was modeled using S-Frame and S-Steel software. Loads were applied at the centerline of the penstock as point loads at the location of each hanger. Dead loads were applied for the weight of the structure and the penstock and live loads were applied for water, ice, and water hammer. In addition, both wind loads and snow loads were applied (Table 1).

Load Type	Load Case	Load Value* (kN/support)
Dead	Self-weight	**
Dead	Penstock	-19.36 (V)
Live	Water	-93.12 (V)
Live	Ice	-12.76 (V)
Live	Water Hammer	23.28 (V, La, Lo)
Wind	Wind	5.72 (La)
Snow	Snow	-3.96 (V)

* V = vertical, La = lateral, Lo = longitudinal.

** Load was generated in the S-frame software.

Table 1 – Trestle Replacement Loads

"Dummy" members were used to transfer forces and moments from the point of applied load to the hangers without causing additional self-weight, yielding, or deflection. These members were given a modulus of elasticity of 1000 GPa, a shear modulus of 77 GPa, a unit weight of 0 kg/ m3, and a round cross-section of 1m diameter.

It was not possible to model the struts with "dummy" members, as the load would then be split among the bottom beams instead of being transferred through the hangers and top beams. Using the existing design, the model did not pass an S16-09 steel code check, as several members were inadequate to current codes. For this reason, the sizes of the trestle members were re-designed using S-Steel and several new sizes were recommended (Figure 5). The beams on the bottom truss, which are perpendicular to the penstock, were increased, as well as several of the angles used for cross bracing. The remaining members sizes were decreased to be more economical. A model and drawings can be found in Appendix D.

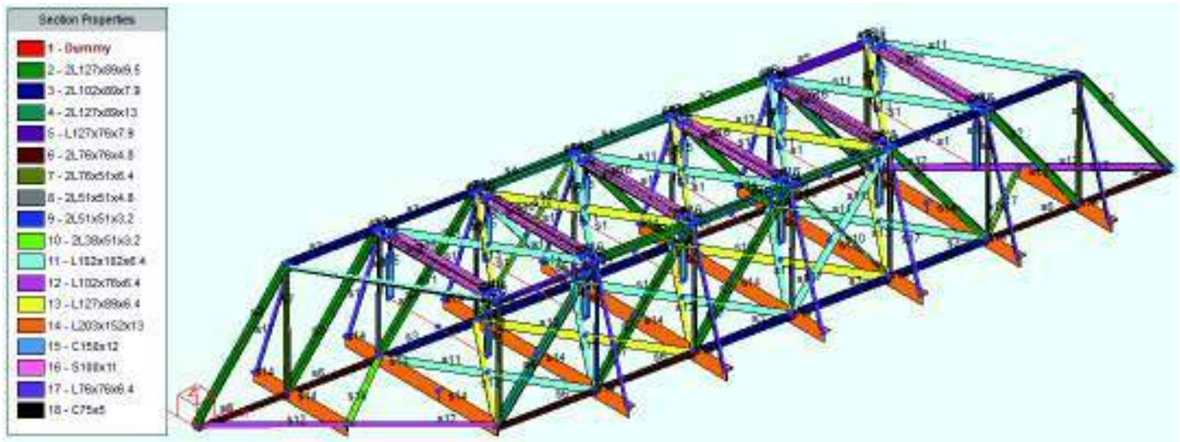

Figure 5 – S-Frame Model of Existing Trestle

A cost estimate has been provided for the new design. The difference in material costs was negligible and the new member sizes are recommended for both rehabilitation and complete replacement.

5.3 TOP SUPPORT CONCEPT

The top hanger design concept operates as a suspension support system (Figure 6). It was ranked fifth in the preliminary design phase of the project. The main advantage with this concept is that it can be constructed around the existing support system, allowing the penstock and hydroelectric facility to remain fully operational during construction. However, the main disadvantage of this concept is that it is very expensive due to the large beams required to support the penstock. It also requires large concrete foundations, which may be too large for the available space.

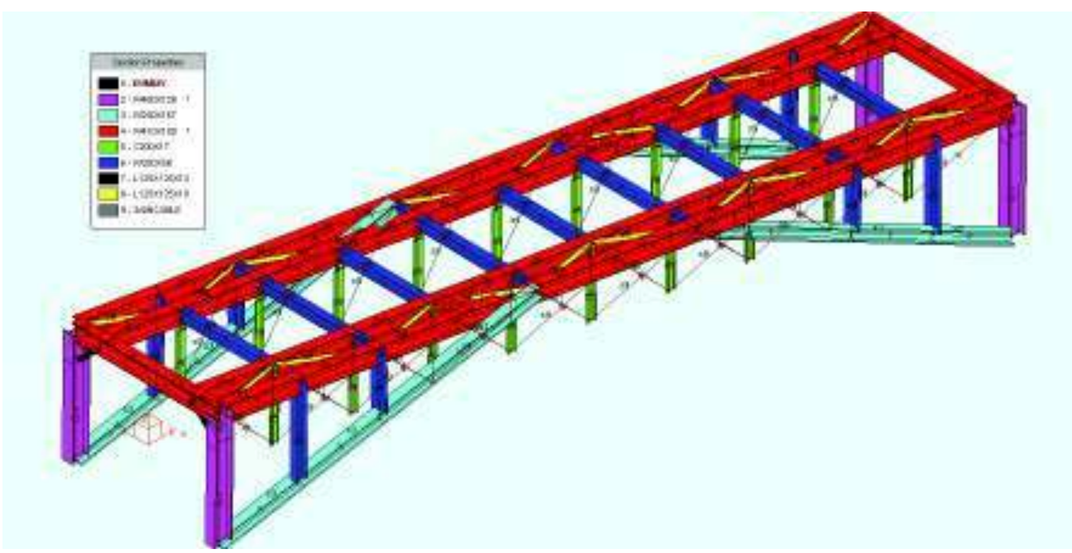

Figure 6 – S-Frame Model of Top Support Concept

5.3.1 Structural System

The design concept consists of nine C200x17 channels, spaced 2.2 meters apart, which are bent around the underside of the existing wooden penstock. The ends of these channels are connected to plates welded to the bottom flange of a series of beams, which run between the hanger channels. The beams are connected through moment connections to large W250x58 beams running parallel to the penstock. The outside beams are supported by shear connections to four columns and two large knee braces. Additional columns are bolted along the knee brace to increase strength and decrease deflection. Angles are also bolted to the top flange of W410x100 beams to provide additional lateral support as well as to reduce the un-braced length of the beam to prevent lateral torsional buckling.

The main longitudinal beams are installed similar to a Gerber system. Each 22-metre span consists of three beams connected together through shear connections. In addition, the columns are supported by two large concrete foundations with pin supports. All connections, drawings, and the model can be viewed in the concept drawings located in Appendix E.

Steel cables (19mm) are also attached between the main beams and the channels to provide lateral stability to the pipe in the event of a water hammer or high wind.

5.3.2 Design Assumptions

Several assumptions were made for the design of the top support concept. It was assumed that the hangers of the penstock would only support the applied loads from the section of the penstock that spans the river. It was also assumed that the existing wooden cradles within the support structure on the ground would carry any applied loads on the penstock directly to the ground.

The woodstave penstock was assumed to have the material properties of Douglas fir timber. In addition, the entire C200 channel was not drawn in the S-Frame model. It was assumed that all loads would transfer between the two “legs” of the channel and therefore it was not necessary to model them.

5.3.3 Modeling

The top support concept was modeled and designed using S-Frame and S-Steel software. Loads were applied at the centerline of the penstock as point loads at the location of each hanger. Dead loads were applied for the weight of the structure and the penstock and live loads were applied for water, ice, and water hammer. In addition, both wind loads and snow loads were applied (Table 2).

“Dummy” members were used to transfer forces and moments as described in Section 5.2.3.

Load Type	Load Case	Load Value* (kN/support)
Dead	Self-weight	**
Dead	Penstock	-18.62 (V)
Live	Water	-89.56 (V)
Live	Ice	-12.28 (V)
Live	Water Hammer	22.39 (V, La, Lo)
Wind	Wind	5.50 (La)
Snow	Snow	-3.81 (V)

* V = vertical, La = lateral, Lo = longitudinal.
** Load was generated in the S-frame software.

Table 2 – Top Support Loads

5.4 BOTTOM SUPPORT CONCEPT

The bottom support concept is comprised of a wooden cradle (Figure 7), which is supported by a steel structure spanning the channel. The steel structure consists of two large I-beams, parallel to the penstock, which are supported on the riverbed. The concept was ranked fourth during the preliminary design phase of the project.

The design of the wooden cradle is based on the existing cradles that support the penstock in Tors Cove. Since the penstock is over 1.83 m in diameter, it is recommended to use a wooden tension rod cradle, steel strut cradle, ring type steel cradle, or reinforced concrete cradle (National Wood Tank Institute). The wooden tension rod cradle was selected as for ease of future pipe replacement. A new penstock can simply be fitted in the existing cradle.

The layout of the steel structure is based on the existing trestle structure spacing. It is recommended that the spacing between each cradle not exceed 2.44m (National Wood Tank Institute). The maximum design spacing for the bottom support concept is 2.438m.

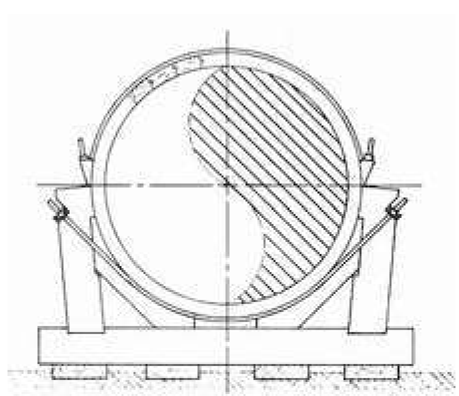

Figure 7 – Wooden Tension Rod Cradle (National Wood Tank Institute)

For the construction of the support structure, sand bags may be required to control river flows. In order to install the large I-beams, while keeping the existing structure in place, a supporting platform must be built out and tied into the retaining wall. If it is acceptable to support the penstock using temporary supports or adjustable columns, the existing structure could be removed and the I-beams installed on the edges of the riverbed. The penstock elevation is fixed; therefore, rock will be removed on either side of the channel to ensure the flood-capacity is not impacted. It is important to note that the depth of the steel beams into the river will reduce the cross-sectional area of the channel.

5.4.1 Structural System

The I-beams are supported on both sides of the river and run parallel to the penstock (Figure 8). All I-beam supports will be fixed and there will be an additional fixed support on each side of the river that attaches angle members to the ground.

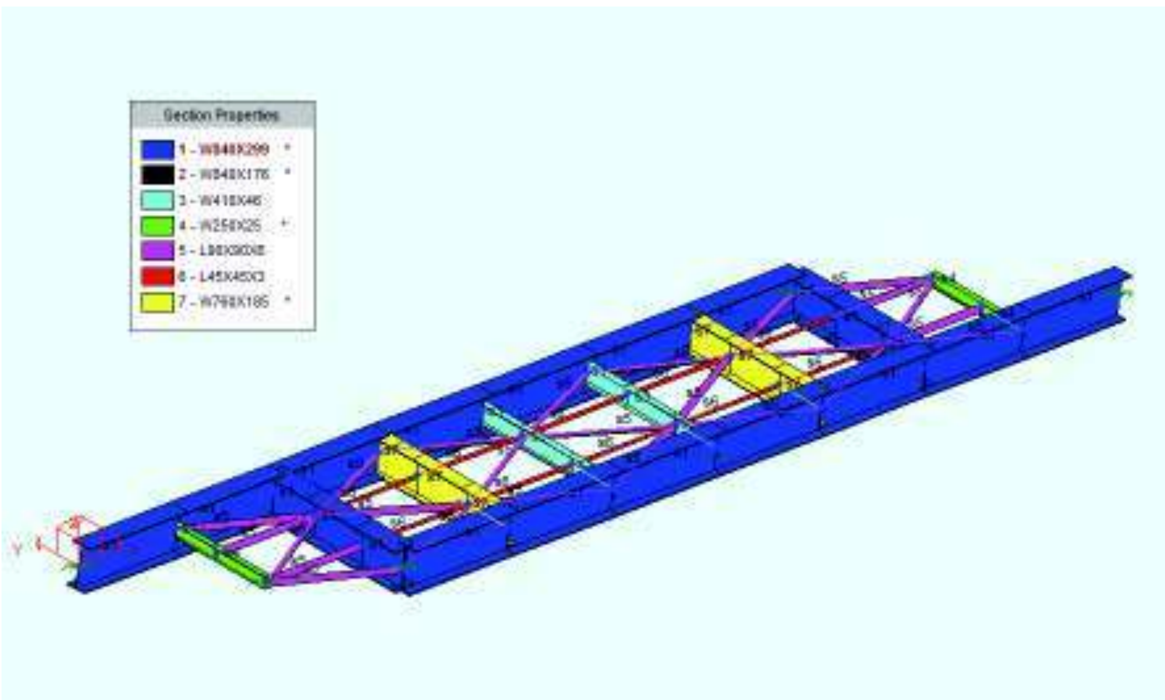

Figure 8 – S-Frame Model of Bottom Support Concept

The loads acting on the wooden penstock are transferred to the steel cable on which the penstock rests (Figure 9). The wooden cradle is then fixed to a beam (transverse to the penstock) in four locations. Two beams running parallel to the penstock support the transverse beam. Angle members, perpendicular to the penstock, prevent excessive deflection of the steel I-beams, while diagonal angles provide stability against twisting. Both the designed I-beams, parallel to the penstock, and the largest transverse beams are size W840x299.

5.4.2 Design Assumptions

The weight of the connections is not accounted for in the S-Frame model and is assumed to be negligible. The shape of the steel cable was approximated and the steel cable wraps around the circular penstock. The model of the steel cable is an approximation and in reality the cables do not cross the horizontal wooden member.

5.4.3 Modeling

The bottom support concept was modeled and designed using S-Frame and S-Steel software. Loads were applied to the structure as a series of point loads acting along the centerline of the penstock. Dead loads were applied for the weight of the woodstave penstock and steel bands and a live load was applied for the weight of the water in the penstock. In addition, ice loads, snow loads, wind loads, and water hammer loads were applied to the penstock (Table 3).

Load Type	Load Case	Load Value* (kN/support)
Dead	Self-weight	**
Dead	Penstock	-23.21 (V)
Live	Water	-111.67 (V)
Live	Ice	-15.31 (V)
Live	Water Hammer	27.92 (V, La, Lo)
Wind	Wind	6.86 (La)
Snow	Snow	-4.75 (V)

* V = vertical, La = lateral, Lo = longitudinal.
** Load was generated in the S-frame software.

Table 3 – Bottom Beam Support Loads

The distributed loads calculated in Appendix C were used for this design. Point loads to be applied to the wooden cradle were calculated using the tributary area method. It was assumed that the span between wooden cradles was 2.4384 m. This is a conservative assumption because end tributary areas are actually 2.286 m or 2.3622 m.

The reactions at the base of the wooden crib are applied as point loads on the steel structure model at the locations of the four fixed supports. The dead load of the steel structure, as well as wind load acting on the beams parallel to the penstock, (longitudinal beams), were also applied. Wind loads were calculated along one longitudinal beam using a shape factor of 2 (Appendix F). In addition, the maximum deflection allowed for the design of the structure was a ratio of L/360.

The governing load cases (Appendix F) were applied to the S-Frame model of the steel structure. In addition, load combination 14, which includes the water hammer load, was applied acting in the opposite direction.

The wooden cradle was also modeled in S-Frame. The shear force, normal force and bending moment diagrams from S-Frame were used to design the wooden members. The vertical wooden members are 394mm x 394mm, the wooden diagonals are 254mm x 127mm, the horizontal wooden member is 254mm x 254mm, and the steel cable is 50 mm in diameter (Figure 9). The material used for the design of the wooden cradle is Douglas fir.

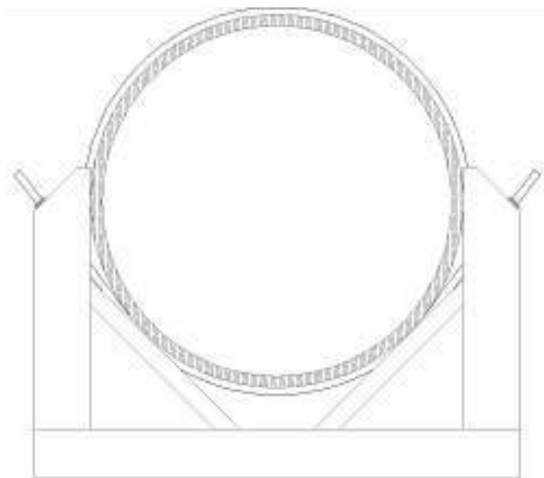

Figure 9 – Wooden Cradle Section

5.4.4 Bottom Truss Concept

In order to decrease material costs, the bottom support concept was redesigned to utilize trusses instead of I-beams (Figure 10). The concept is composed of four trusses aligned parallel below the penstock. The penstock will be supported by the same wooden cradles used in the design of the bottom beam concept. The layout of the truss structure will be based on the existing trestle structure spacing. Every second bay of the structure will support a wooden cradle, with a spacing of 2.08 metres, which is less than spacing used in the bottom beam concept. Varying sizes of steel angles will be used to construct the bottom truss.

The four bottom trusses will be supported on both sides of the river by pin connections. In order to ensure that the penstock remains at the same elevation, bedrock may have to be removed on either side of the river and the supports will be attached to a concrete foundation and retaining wall (Appendix G). The wooden cradles will be bolted in a channel section and welded to corresponding truss angles to provide a fixed connection. Cross bracing will be provided in lateral and horizontal directions to prevent excessive deflection and provide stability.

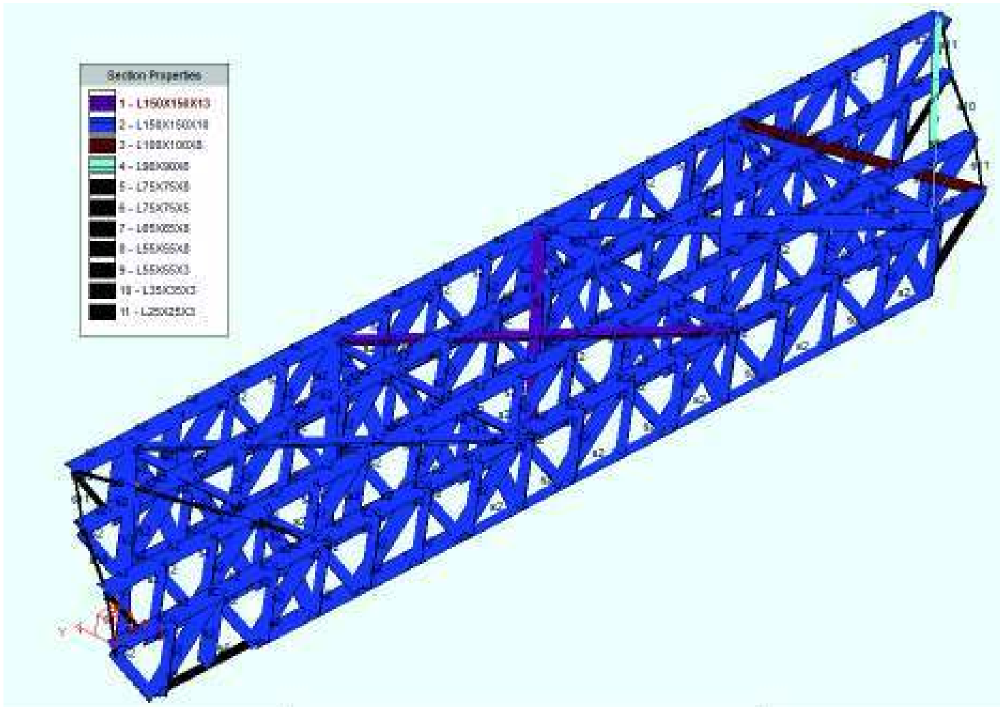

Figure 10 – S-Frame Model of Bottom Truss Concept

The bottom truss concept was modeled in S-Frame using similar loadings as the bottom beam concept (Table 4).

Load Type	Load Case	Load Value* (kN/support)
Dead	Self-weight	**
Dead	Penstock	-19.95 (V)
Live	Water	-95.97 (V)
Live	Ice	-13.16 (V)
Live	Water Hammer	22.99 (V, La, Lo)
Wind	Wind	5.90 (La)
Snow	Snow	-4.08 (V)

* V = vertical, La = lateral, Lo = longitudinal.

** Load was generated in the S-frame software.

Table 4 – Bottom Truss Support Loads

5.5 STEEL PENSTOCK CONCEPT

The steel pipe and anchor block concept is currently used by NL Power in several other hydroelectric developments. This option would involve the demolition of the existing penstock trestle and the construction of two anchor blocks on either side of the channel. A new steel penstock would span the channel between the anchor blocks (Figure 11). The steel penstock would be self-supporting and would not require a trestle structure. This concept was the lowest ranked concept of the five selected due to the high cost and considerable plant downtime.

The strengths of this concept include ease of constructability, low impact on channel hydrology, and long term cost savings. The woodstave pipe will be replaced with steel in approximately 20 to 25 years, as steel has a longer design life and reduced leakage and maintenance costs. Replacing the pipe now is more economical in the long term as it will not need to be replaced in the future. The future cost of all concepts will be considered in Section 9.5.

Due to the complexities of this design, many assumptions were made to simplify the analysis to achieve the level of detail required by the client.

Figure 11 – Steel Penstock and Anchor Block Design at Rocky Pond

5.5.1 Structural System

The steel penstock concept consists of two major components; the steel pipe that will replace the woodstave pipe and two concrete anchor blocks, which support the penstock, on either side of the channel. These 64 m^3 anchor blocks act as fixed supports and carry the loads generated over the length of the penstock span. The mass of the large anchor block resists vertical and horizontal forces, and moments. The steel penstock itself is able to resist applied forces as a result of the large diameter (2438mm) and wall thickness (12.7mm).

5.5.2 Design Assumptions

In order to simplify the complex nature of the design process, several assumptions were made when designing the steel penstock concept. The anchor blocks were conservatively designed based on information supplied by the client from previous project experience. In addition, a typical steel reinforcement array was drawn for the anchor block as the applied loads and reactions were within normal range.

Finally, it was assumed that ice loads would not be applicable, as the steel would prevent water from leaking and freezing in the winter months.

5.5.3 Modeling

The structure is susceptible to live loads, environmental loads and dead load. The only dead load represented for this concept was the self-weight of the steel penstock. The live loads included the water load and water hammer load. In addition, both wind and snow loads were applied to the steel penstock. All of the loads were distributed along the penstock (Table 5).

Load Type	Load Case	Load Value* (kN/m)
Dead	Self-weight	**
Live	Water	-45.8 (V)
Live	Water Hammer	11.45 (V, La, Lo)
Wind	Wind	2.8 (La)
Snow	Snow	-1.0 (V)

* V = vertical, La = lateral, Lo = longitudinal.

** Load was generated in the S-frame software.

Table 5 – Steel Penstock Loads

After loads were calculated, the structure was modeled in S-Frame to check reactions, deflection, and to develop bending and shear diagrams. The structure was modeled as a beam fixed at both ends (Figure 12). It was not possible to complete a code check, as cylindrical sections cannot be modeled in S-Steel. The bending and shear resistance were checked by hand, as the software does not recognize pipe members. See Appendix H for model and drawings.

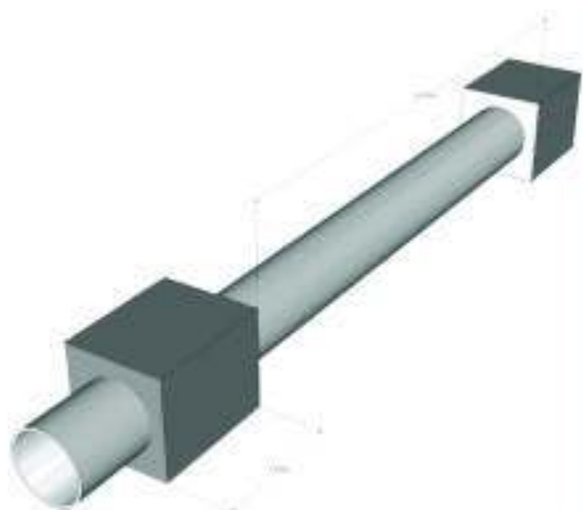

Figure 12 – 3D Model of Steel Penstock Concept

6.0 Retaining Wall

The existing walls along the channel and underneath the penstock structure are assumed to function as retaining walls. In some areas, the walls have experienced significant deterioration of the front face (Figure 13), presumably from Alkaline Aggregate Reaction (AAR). In order to evaluate the degree of damage, it is recommended that the wall be inspected more thoroughly by an experienced consultant. This investigation should include concrete coring to determine the extent of deterioration, as well as testing to determine if AAR is the cause of degradation of the wall face. If AAR is the cause, steps should be taken under the guidance of an experienced professional to mitigate reoccurrence by controlling elements of the concrete design mix.

Figure 13 – Existing Retaining Walls

Structural details and as-built drawings of the wall were not available; therefore, several assumptions were made in order to continue with a replacement design for the retaining wall. These assumptions were made based on past experience of CASC Consulting and on recommendations from the client. While the height of the wall varies along the length of the channel, the width of the wall was assumed to be consistent at a width of 300mm.

In addition, it was assumed that the footings of the trestle rest largely on bedrock, or at least sufficiently back from the retaining wall so as not to place a surcharge load on the wall. The wall does not provide structural support for the trestle; therefore, it is assumed that the primary function of the wall is to slow erosion of the bedrock. Over time, the erosion of the bedrock could undermine the trestle structure. It was assumed that the top 1-2m of the walls would act as retaining walls as they appear to be back filled.

It is recommended that 100-150mm of concrete be chipped and removed from the wall depending on the extent of degradation. The wall face would then be capped with new concrete, extending 300mm beyond the original face of the wall.

The new concrete section will be reinforced with 20M and 15M rebar spaced at 250mm in the lateral and longitudinal directions, combined with 10M hooked dowels placed in a 600x600 pattern (Appendix I). With the exception of the exterior deterioration, the wall appears to be structurally sound and provides no visual indication of overturning or sliding. The additional 300mm of concrete added to the front face would increase the mass of the existing system, increasing resistance to sliding and overturning forces.

7.0 Hydrotechnical Analysis

The design outflow of the river channel, or spillway, at Tors Cove Hydroelectric Development is 67 m^3/s. In order to ensure that the channel will be able to handle the designed outflow, the selected design concept should not restrict the cross-sectional area of the channel. If the channel is restricted, it is possible that fast moving water could damage or destroy the penstock and support structure.

Due to limited survey data, a complete hydrotechnical analysis could not be completed. Therefore, another technique was applied to estimate the required cross-sectional area of the channel using a nomograph obtained from the Handbook of Steel Drainage and Highway Construction (American Iron and Steel Institute, 2002). Using this nomograph, it was estimated that the required cross-sectional area for the channel must be a minimum of 20 m^2 in order to pass the peak flow rate. In addition, the headwater to depth ratio must be equal to 1.00. This implies that the water depth upstream of the penstock is equal to the total depth of the channel. Field measurements indicated that the cross-sectional area of the channel was approximately 20 m^2. For this reason, it was decided that the design concepts would not be permitted to infiltrate the channel at an elevation lower than the bottom of the current structure.

8.0 Detailed Cost Estimates

An initial cost estimate was completed during the preliminary design phase for all preliminary concepts. This was a high-level estimate that primarily compared material and labour costs of each concept; it did not consider engineering costs or contingencies. For this reason, the costs were very low in comparison to the final cost estimate and were used solely to compare each concept in order to select the most cost-effective option.

Unit prices were developed using individual experience, RS Means and client input. Several material costs were recommended by the client, such as the cost of steel per metric ton and the cost of concrete per cubic metre. Based on limited access to the site and difficulties associated with working around a river, it is expected that construction costs will be higher than costs identified in RS Means. In addition, the client advised on the costs associated with moving a utility pole in the area and the cost per day associated with plant downtime.

Bridger Design Associates Ltd. advised a cost of $100,000 for thickness testing to be completed for rehabilitation. Furthermore, 20% engineering and 5% mobilization/demobilization costs were added to each concept estimate. A percentage for contingency was also added, but varied for each concept based on the amount of uncertainty in material quantities. See Table 6 for the estimated cost of each concept. A detailed cost breakdown for each concept can be found in Appendix J.

Concept	Contract Cost	Total Cost
Bottom Support (Truss)	$450,122	$653,175
Bottom Support (beams)	$512,449	$742,926
Rehabilitation	$489,691	$798,300
Trestle Replacement	$575,815	$834,173
Steel Penstock	$608,950	$845,351
Top Support	$619,068	$896,457

Table 6 – Estimated Costs

9.0 Concept Comparison

In order to make a recommendation regarding the most desirable concept for the project, it is necessary to compare the strengths and limitations of each concept.

9.1 CONSTRUCTIBILITY

In terms of ease of replacement of the structure, the top support, bottom truss and steel penstock concepts are the most feasible. In order to ensure the penstock is supported during construction, the top support concept was designed to be constructed around the existing structure. Once construction is complete, the existing structure can simply be cut away. The steel penstock is also easy to replace as the plant will be shut down during construction and the woodstave penstock and trestle can be removed without requiring additional support. The bottom truss can be built underneath the existing structure and then be used to support the pipe while then demolishing the existing structure.

In the case of rehabilitation and replacement of the existing structure, members will be cut out and replaced piece-by-piece, increasing cost and duration of the project. The bottom beam support is also difficult to construct, as a large section of the bedrock will need to be removed to make room for the large bottom support beams. The steel penstock option is a simple design that will be easier to construct as there is not much work required in the river and there's no steel member work to be completed.

9.2 DESIGN IMPACT ON RIVER HYDROLOGY

In addition to removing bedrock to accommodate for the bottom support concept, the size of the beams will also compromise the flood-capacity of the river. The river channel is not large; the proposed changes to the retaining wall will reduce the width of the channel on both sides. It is important not to reduce the channel height in addition to the width (See Section 7.0). For this reason, bedrock would need to be removed along the bottom of the river to increase the depth of the channel. None of the remaining concepts will reduce the size of the channel or have any impact on the flood-capacity of the river.

9.3 EASE OF FUTURE PIPE REPLACEMENT

It is important that the existing woodstave pipe be easily accessible in the future for when it is replaced with a steel pipe. The most feasible concepts for future pipe replacement include the bottom support concepts and the steel penstock concept. A new pipe can simply be fitted into the wooden cradles for the bottom support design. The steel penstock concept is the best option, as the pipe will already have been replaced. The top support, rehabilitation, and complete trestle replacement options do not allow a new pipe to be easily fitted into the structure.

9.4 PRESENT-DAY COST

The most cost-effective concept is the bottom truss design. Optimizing the bottom beam design resulted in more economical section sizes, making this the most viable option in terms of cost. Rehabilitation is the most cost-effective option following the bottom support designs. However, there is a large amount of contingency associated with this concept and there is a risk that other members may require additional rehabilitation before the woodstave pipe is replaced in 15-20 years. For this reason, complete replacement of the existing structure would be a better design selection than rehabilitation.

The top support concept is the least viable design in terms of cost as the large section sizes make the design expensive. While the steel penstock concept option is also expensive, there are long-term benefits in selecting this concept, as it will reduce future costs when the woodstave pipe is replaced.

9.5 FUTURE ECONOMIC COSTS

The original woodstave penstock was built in 1941 and replaced in 1985, resulting in a design life of 44 years. It is assumed that the current woodstave penstock will need to be replaced in a shorter period of time, as maintenance practices have changed due to environmental concerns. The woodstave penstock was originally coated in creosote to preserve the wood and prevent leaks; however, it can have adverse environmental effects if the coating enters the river.

The only concept that involves replacing the existing woodstave pipe is the steel penstock option. The remaining concepts assume the woodstave penstock will be in use for additional 15-20 years before replacement. To account for the additional future cost of upgrading the woodstave pipe to steel, the following year-to-year inflation formula was applied to each concept cost:

$$FC = PC(1+i)^n$$

Equation 8 – Calculation of Future Costs adjusting for Inflation

Where:

$$FC = Future\ cost$$
$$PC = Present\ cost$$
$$i = yearly\ inflation\ rate(\%)$$

$$n = number\ of\ years$$

A yearly inflation rate of 3% was assumed based on historical trends and Bank of Canada predictions.

Once inflation was accounted for, the future price was returned to present value using the following formula:

$$PV = \frac{FV}{(1 + r)^t}$$

Equation 9 – Calculation of Present Value adjusting for Inflation

Where:

$$PV = Present\ Value$$
$$FV = Future\ Value$$
$$r = Capital\ interest\ rate$$
$$t = return\ period$$

A cost of $200,000 was assumed to be the present-day value of replacing the section of the woodstave penstock spanning the river. This price considers pipe material costs, labour, woodstave pipe demolition, bulkhead, scaffolding, crane, mobilization, and a contingency of 20%. See Table 7 for the inflated and present values for installing a new section of steel penstock.

Year	Inflated Value	Present Value
2015	$212,180	$185,326
2020	$245,974	$153,180
2025	$285,152	$126,610
2030	$330,569	$104,649
2035	$383,220	$86,497
2040	$444,257	$71,494
2045	$515,016	$59,093

Table 7 – Inflated and Present-Day Costs for Steel Penstock

Once these economic principles were applied, the present value of each concept was re-evaluated for the year 2030 (Table 8). Adjusting for the future cost of the steel pipe, the steel penstock concept is the most cost-effective option as it will result in long-term savings. A future cost analysis of each concept by year can be found in Appendix J.

The maintenance cost for the trestle portion of the penstock is estimated to be about $500 a year. Therefore, the cost of maintenance of a 17-metre section is minimal and is not included in the calculation of future costs.

Concept	Present Value	Total Cost
Steel Penstock	$608,950	$845,351
Bottom Support - Truss	$572,771	$853,429
Bottom Support -Beam	$617,098	$919,477
Rehabilitation	$594,340	$992,549
Trestle Replacement	$680,464	$1,013,892
Top Support	$723,717	$1,078,339

Table 8 – Present Value of each Concept Re-evaluated for 2030

10.0 Environmental Concerns

There are several important environmental factors that will need to be considered throughout construction of the project. The most significant environmental concern involves contaminants entering the river passing beneath the penstock trestle structure. Special care must be taken during replacement and demolition to ensure that paint from the original structure does not enter the river, as the paint is lead based.

Another environmental concern is site disruption that will occur as a result of clearing, grubbing, and the presence of heavy equipment. Proper procedures must be in place to ensure no leaking of fuel or other contaminants into the river from any machinery that might be used throughout construction. NL Power has a detailed environmental management system containing policies outlining safe work practices to ensure there are no adverse environmental impacts to the river.

In addition, it is important to minimize siltation by keeping debris out of the river and minimizing erosion. Most concepts involve scaffolding and work in the river, along with re-working the concrete abutment. It is important to ensure minimal disruptions to the river environment during these activities.

11.0 Recommendation

Upon completion of concept design, an analysis of the cost estimates, and taking into consideration future penstock replacement, it is recommended that the trestle structure and woodstave pipe be replaced with a steel penstock and concrete anchor blocks.

The steel penstock concept is a simple design solution that will be economically beneficial in 15-20 years. This concept is the only design that involves replacing the section of the woodstave penstock supported by the trestle. Adjusting for inflation, the steel penstock option becomes the most cost-effective concept. Therefore, if NL Power has the capital to replace the trestle with a steel penstock at the current time, then it is recommended to proceed with this concept.

In addition, this concept includes rehabilitating the retaining wall, which is in poor condition and contains signs of possible Alkali-Aggregate Reactivity (AAR). It will be necessary to hire a consultant to test the wall and determine the full extent of degradation. If the extent of damage is not extreme, it is recommended that a 300mm concrete overlay be installed with reinforcement.

The following report, cost estimate, and recommendation will be used by NL Power to select a suitable design concept, perform a site survey, and complete a detailed design and hydraulic analysis.

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Appendix A – Preliminary Concept Design

SITE VISIT PHOTOS

Figure 1
Woodstave penstock located in Tors Cove, Newfoundland

Figure 2
Woodstave penstock located in Tors Cove, Newfoundland

Figure 3
View of woodstave penstock and trestle structure looking South.
Tors Cove, Newfoundland

Figure 4
View of woodstave penstock and trestle structure looking North.
Tors Cove, Newfoundland

Figure 5
Surge tank located upstream of trestle structure.
Tors Cove, NL

Figure 6
Steel penstock located at Rocky Pond, NL

Figure 7
Woodstave/Steel penstock transition joint.
Petty Harbour, Newfoundland

PRELIMINARY DESIGN CONCEPTS

The following concepts were evaluated as potential penstock trestle designs:

Concept A: Anchor Block & Steel Pipe

- Two concrete anchor blocks on either side of the channel
- New self-supporting, steel pipe spanning across the channel

Concept B: Rehabilitation of Existing Members

- Testing of steel members
- Replacement of corroded members

Concept C: Complete Replacement of Structure

- Complete replacement of structure using existing design and all new members

Concept D: Top Support/Hanger

- 4 steel I-beam supports and 2 I-beams spanning river
- Pipe supported by square hangers similar to existing structure

Concept E: Steel I-Beams and Timber Cradle

- Steel I-beams spanning the river
- Pipe rests on timber or steel cradle, similar to existing

Concept F: Box Culvert/Concrete Arch

- Concrete arch spanning the river, acting as a culvert
- Pipe supported by timber or steel cradle, similar to existing

Concept G: Suspension Bridge

- Steel I-beam and footing on either side of the channel
- Pipe supported by cables spanning across the channel

Concept H: Multi-plate Arch

- Steel culvert with masonry face supporting the pipe

Concept I: Bottom Truss

- Bottom truss support for pipe using steel members

Concept J: Bailey Bridge

- Steel panel bridge, assembled in pieces from kit

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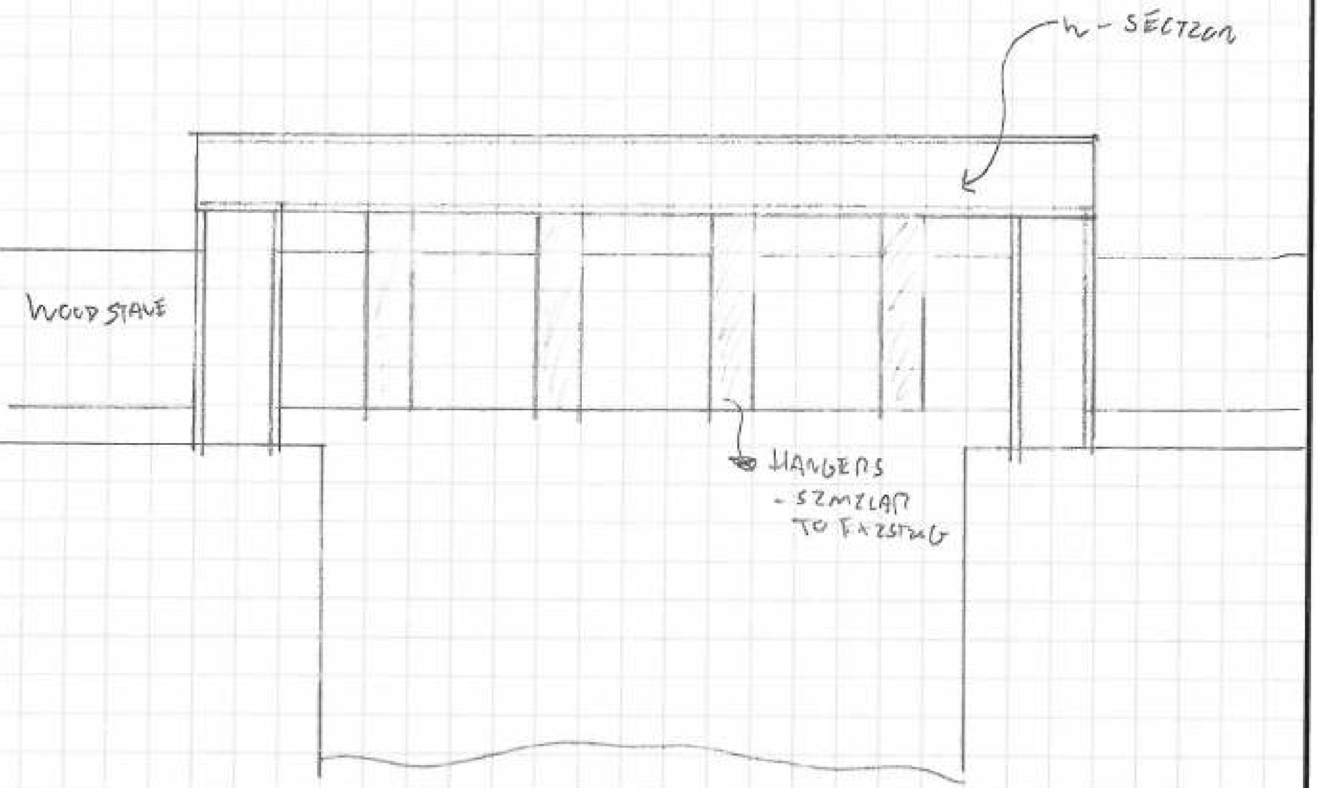

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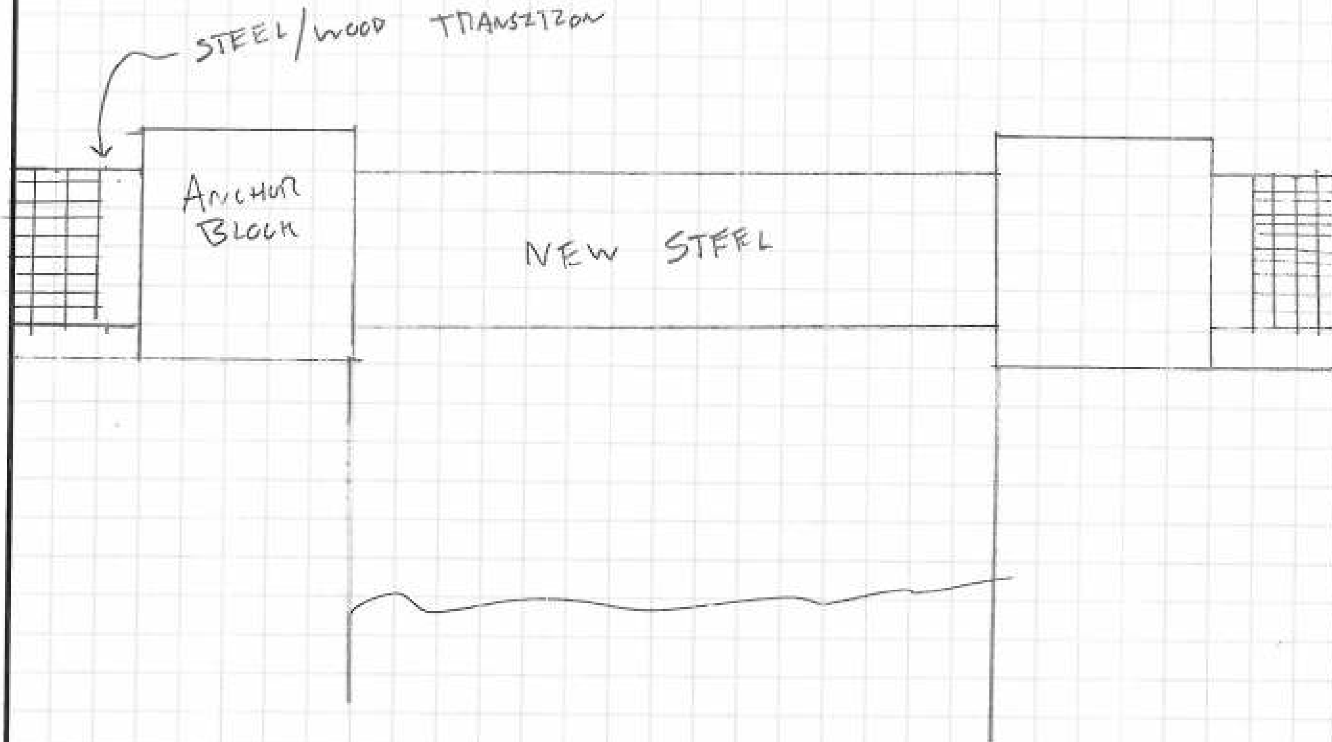

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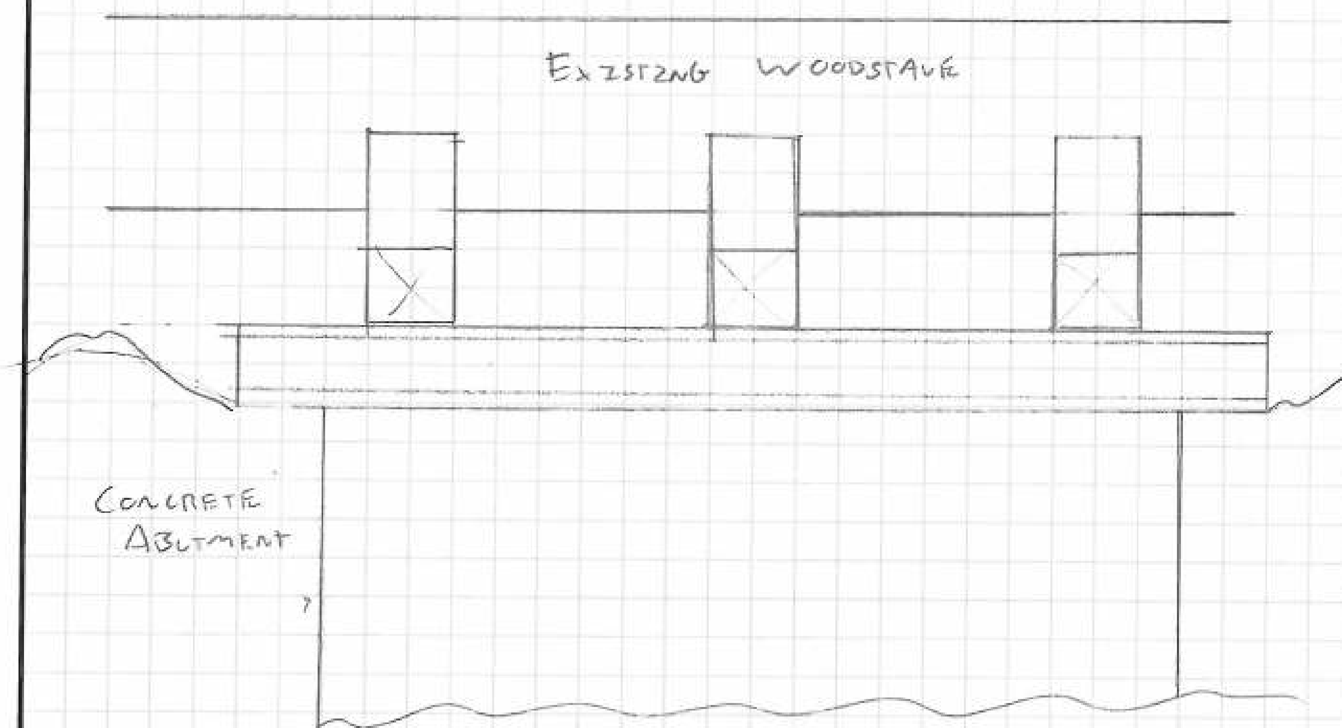

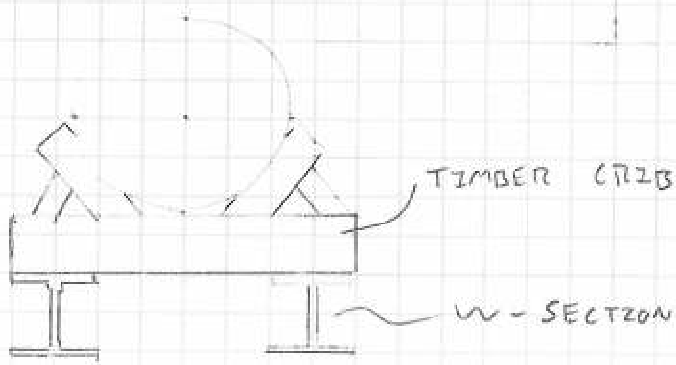

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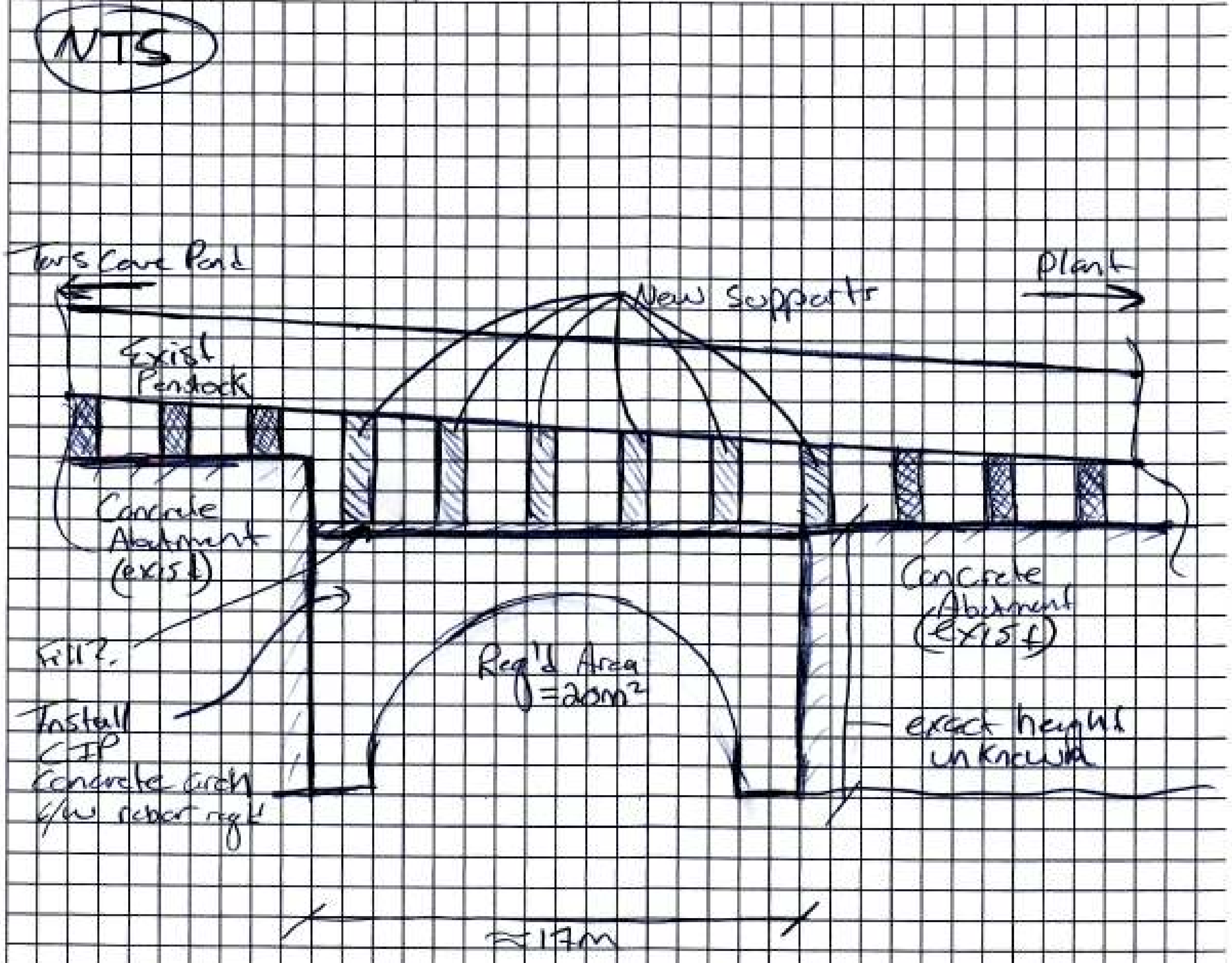

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Tors Cove Trestle	Mabey Bridge	**CASC CONSULTING** CASC CONSULTING SKETCH SHEET

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PSC		Feb 2013

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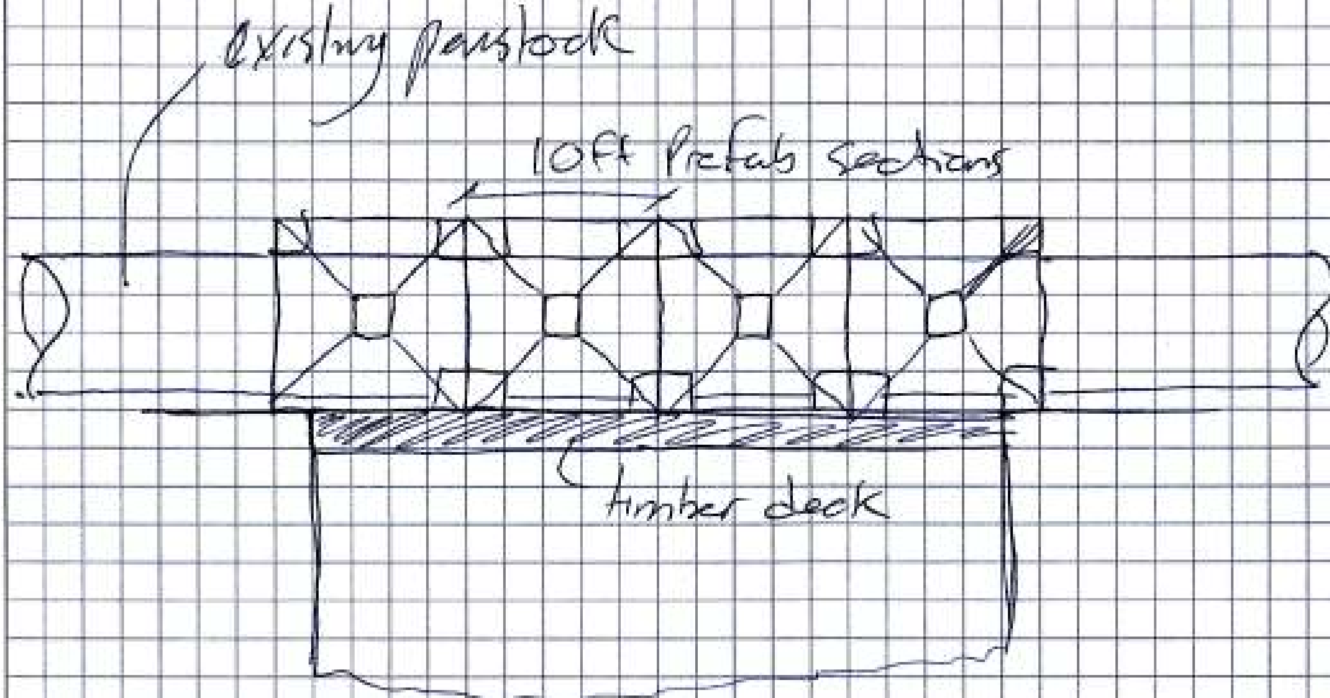

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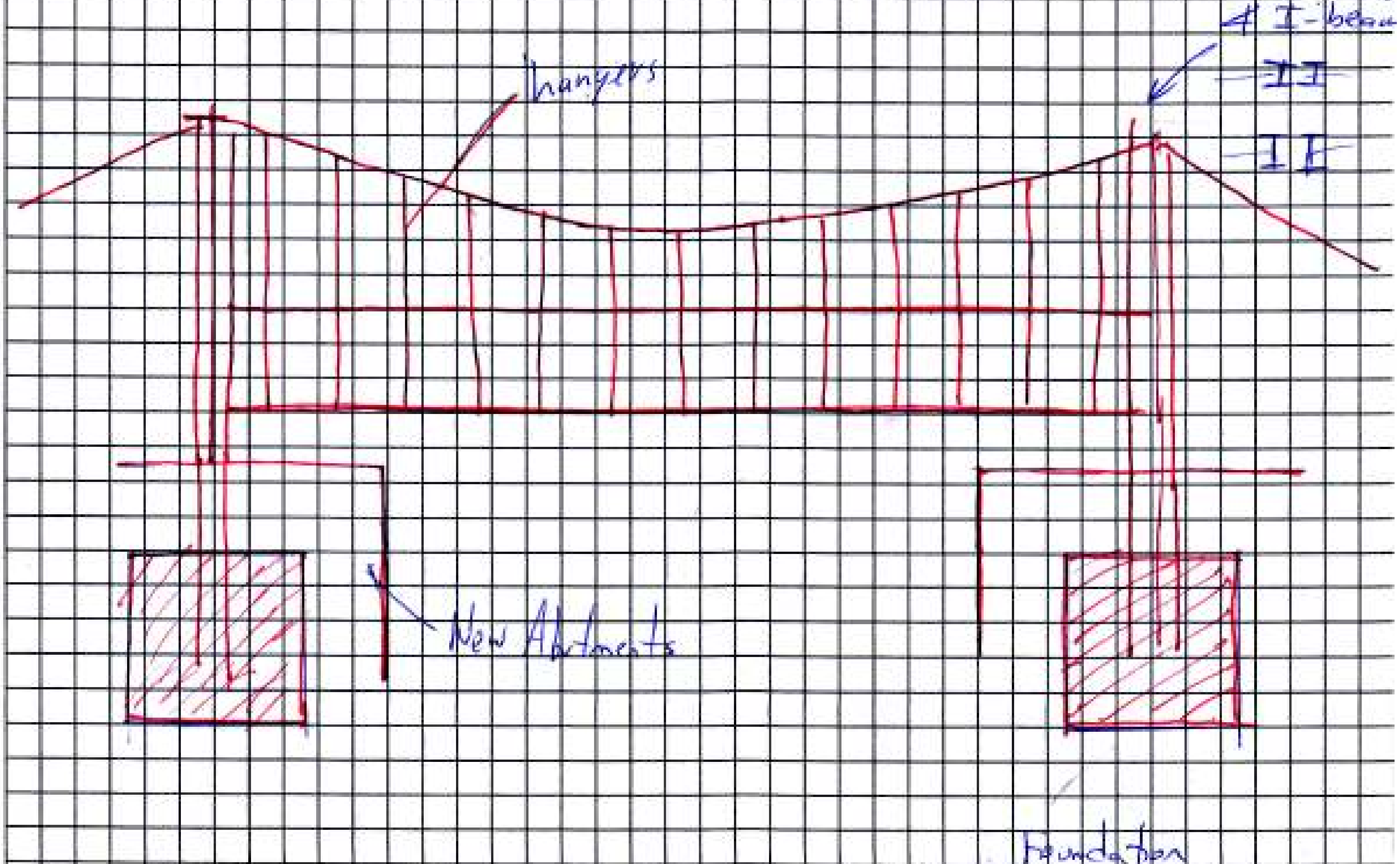


N.T.S

118 kg/m 550x200x22 6735

		RS Means Description	O&P	Unit	Note	Qty	$
A- Steel Pipe & Concrete AnchorBlocks							
Structural	Concrete	34 Mpa	$ 1,200.00	1 m3		50	$60,000.00
	Steel pipe		$ 7,000.00	met. ton		12.6	$88,200.00
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		12.5	$23,083.00
	Demolition	Approx. based on steel pipe demolition	$ 75.00	/m		400	$30,000.00
Cost of facility down time		Estimate 50% of construction time (6-8 wks)	$ 3,000.00	day		25	$75,000.00
A- Steel Pipe & Concrete AnchorBlocks							**$276,283.00**
J- Bailey Bridge							
	Bailey Bridge	Standard 10 ft section	$ 1,000.00	ft		60	$60,000.00
	Labor		$ 1,565.20	day		14	$21,912.80
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		10	$18,466.40
	Demolition	Approx. based on steel pipe demolition	$ 75.00	m		400	$30,000.00
J- Bailey Bridge							**$130,379.20**
C -Complete Truss Replacement							
127x89x7.9	Steel member	Angle framing, field fabricated, 100 mm and larger	$ 15,000.00	/met		0	$0.00
102x76.9.5			$ 15,000.00			0	$0.00
102x76x7.9			$ 15,000.00			0	$0.00
152x102x9.5			$ 15,000.00			0	$0.00
127x89x13			$ 15,000.00			0	$0.00
76x76x6.4			$ 15,000.00			0	$0.00
76x64x6.4			$ 15,000.00			0	$0.00
64x64x6.4		75mmx50mmx9mm	$ 15,000.00			0	$0.00
64x51x6.4		75mmx50mmx9mm	$ 15,000.00			0	$0.00
51x51x6.4		63mmx63mmx6mm	$ 15,000.00			0	$0.00
89x89x13		75mmx75mmx9mm	$ 15,000.00			0	$0.00
102x102x7.9			$ 15,000.00	kg		0.0915	$1,372.50
	Demolition	Approx. based on steel pipe demolition	$ 75.00	m		400	$30,000.00
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		10	$18,466.40
C -Complete Truss Replacement							**$49,838.90**
F - Concrete Arch							
Concrete		34 Mpa (not including labor?)	$ 1,200.00	1 m3		85	$102,000.00
Timber cribs (8x8)		heavy framing beams, single 150 x 250 mm	$ 962.19	m3		1.35	$1,298.96
Crushed stone		aggregate for eathwork	$ 61.01	m3		6.1	$372.16
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		10	$18,466.40
	Demolition	Approx. based on steel pipe demolition	$ 75.00	m		400	$30,000.00
Safety rails							
F - Concrete Arch							**$152,137.52**
D - Top support							
	Steel I beam	W 920 x 390 (incl. shop primer, bolted connections,	$ 10,000.00	/mt		0	$0.00
51x51x6.4	L	63mmx63mmx6mm	$ 15,000.00	/mt		0	$0.00
64x51x6.4	L	75mmx50mmx9mm	$ 15,000.00	/mt		0	$0.00
127x89x7.9	Steel member (L)	Angle framing, field fabricated, 100 mm and larger	$ 15,000.00	/mt		0	$0.00
102x102x7.9	L		$ 15,000.00	/mt		0	$0.00
C 130x13		C 150x12	$ 15,000.00	/mt		0	$0.00
C 200x28		200mm and larger	$ 15,000.00	/mt		0	$0.00
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		10	$18,466.40
	Demolition	Approx. based on steel pipe demolition	$ 75.00	m		400	$30,000.00
D - Top support							**$48,466.40**
G - Suspension Bridge							
structural concrete	Concrete	34 Mpa	$ 1,200.00	1 m3		40	$48,000.00
	Steel cable		$ 7,000.00			4	$28,000.00
	Steel columns		$ 10,000.00	/ton		11.328	$113,280.00
	Steel hangers		$ 7,000.00			2	$14,000.00
	Demolition		$ 75.00	m		400	$30,000.00
	Crane		$ 1,900.00	/day		10	$19,000.00
G - Suspension							**$252,280.00**
E - Steel I-beam and wood cradle							
	Steel I beam	W 920 x 390 (incl. shop primer, bolted connections,	$ 10,000.00	m		13.06	$130,600.00
	Wooden blocks	heavy framing, beams, single 200 mm x 400 mm	$ 1,163.03	m3		0.96	$1,116.51
	Smaller wooden block:	Miscellaneous framing, steel construction, (50 mm ›	$ 825.44	m3		0.5	$412.72
	Connections	Assume 20%					$26,425.85
	Crane	26 metric ton, truck mounted, include crew	$ 1,846.64	day		10	$18,466.40
	Demolition	Approx. based on steel pipe demolition	$ 75.00	m		400	$30,000.00
E - Steel I-beam and wood cradle							**$207,021.47**
B - Rehabilitation of Structure							
	Thickness Testing	Fom Bridger Estimate					$100,000.00
	Steel	Assume 30% replaced	$ 15,000.00	/ton		0.02745	$411.75
	Demolition		$ 75.00	m		100	$7,500.00
B - Rehabilitation of Structure							**$107,911.75**

Appendix B – Decision Matrix

MATRIX CATEGORY DESCRIPTIONS

The following areas were considered for each concept in order to select several for detailed design:

Plant Downtime:

- Concepts with lower plant downtime were ranked higher
- For most concepts, the woodstave pipe can be supported during construction. Therefore, little to no plant downtime
- Anchor block and steel pipe concept requires complete pipe replacement, resulting in large plant downtime
- Rehabilitation would be the most desirable option as members can be replaced individually
- Pipe dewatering affects pipe condition

Time of Construction:

- Projects with shorter construction lengths were ranked higher
- All concepts can be completed in a single summer season
- Concepts involving larger concrete works or more complicated design were ranked lower as time will be longer (concrete arch, multi plate, suspension)
- Rehabilitation, top support, and steel beams are simpler concepts and were ranked higher

Environmental Considerations:

- Concepts with smaller site disruption, clearing, grubbing, and equipment were ranked higher
- Rehabilitation was ranked higher because there would be less disruption to the site
- Concrete arch was ranked lower due to the risk associated with having a lot of equipment on site and for the disruption of the river bed
- Need to ensure no paint chippings get into the water during demolition

Constructability:

- Concepts were ranked based on the ease of constructability and long term effectiveness
- Multi-plate was ranked very low as is not easily constructed given the nature and size of the river and channel

- Rehabilitation, top support, and steel beam concept are simple designs that can easily be constructed using fewer materials and less time

Safety:

- Activities such as blasting require additional safety, as well as construction activities that include fall arrest. It is also important to evaluate what type of equipment will be on site when considering safety
- Multi-plate and concrete arch were ranked lower because most of the work would be taking place in the river, higher potential for washout
- All projects will be completed safely

Long Term Risk:

- Concepts were ranked based on long-term risks that could affect the structure
- Multi-plate has a large risk of completely washing away and was therefore ranked very low
- Rehabilitation was also ranked lower due to the fact that there will be a large mix of members in the structure. Down the road, many of the older members could deteriorate rapidly
- Anchor block and steel pipe was ranked higher because when the pipe won’t need to be replaced later and there would already be two anchor blocks in place

Hydrology:

- Concepts that affect the natural flow of the river and channel size were ranked lower (concrete arch, multi-plate)
- All other concepts will not have an effect on the hydrology of the river

Pipe Replacement:

- In approximately 25 years, it will be necessary to replace the pipe. For this reason, concepts that facilitate easy pipe replacement in the future were ranked higher
- Anchor Block and steel pipe was ranked highest as the pipe would already have been replaced
- Concrete arch, suspension and bailey bridge were ranked higher for ease of pipe replacement
- Rehabilitation, full replacement, and top support would be more complicated for future pipe replacement

Site Access:

- Site is difficult to access for large equipment (concrete truck, crane) due to the winding road to the site
- Rehabilitation and full replacement require less equipment and site clearing and were ranked higher
- The remaining concepts will require equipment and site clearing

Cost:

- The most cost effective concepts were full replacement, steel beams, and bottom truss concepts

Elimination Matrix

		Plant Downtime	Time of Construction	Environmental	Constructability	Risk	Hydrology	Pipe Replacement	Site Access	ost (25% more weigh	TOTAL	AVERAGE
B	Rehabilitation	10	8	9	10	5	10	2	8	7.5	69.5	**7.72**
E	Steel Beams & Timber Crib	7	9	7	7	7	10	6	6	10	69	**7.67**
D	Top Support / Hanger	7	10	7	9	7	10	2	6	8.75	66.75	**7.42**
C	Replacement	7	7	7	7	7	10	2	8	10	65	**7.22**
A	Anchor Block & Steel Pipe	3	6	7	9	8	10	10	7	3.75	63.75	**7.08**
J	Bailey Bridge	6	7	7	3	7	10	8	5	8.75	61.75	**6.86**
G	Suspension Bridge	7	6	7	7	7	10	7	6	3.75	60.75	**6.75**
F	Box Culvert / Concrete Arch	4	6	5	5	7	3	7	6	7.5	50.5	**5.61**
H	Multi-Plate Arch	7	5	6	3	3	5	7	4	N/A	40	**5.00**

Appendix C – Design Loads

LOAD COMBINATIONS USED FOR ANALYSIS

** ONLY GOVERNING COMBOS HERE, ASSUMING WIND AND WH IS SYMMETRICAL

#	NBCC #	LOAD COMBO	DESCRIPTION	DEAD LOADS			LIVE LOADS					SNOW	WIND
				DL - STRUCTURE	DL - PIPE	DL - CRIB	LL - WATER IN PIPE	LL - WATER HAMMER			LL - ICE	S - SNOW LOAD	WL - WIND LOAD
								LATERAL	LONG.	VERTICAL			
1	1	1.4D	Dead Load	1.4	1.4	1.4	0	0	0	0	0	0	0
2	2	1.25D+1.5L+0.5S	Dead, Live, Snow	1.25	1.25	1.25	1.5	0	0	0	1.5	0.5	0
3		1.25D+1.5+0.4W	Dead, Live, Wind	1.25	1.25	1.25	1.5	0	0	0	1.5	0	0.4
4	3	1.25D+1.5S+0.5L	Dead, Snow, Live	1.25	1.25	1.25	0.5	0	0	0	0.5	1.5	0
5		1.25D+1.5S+0.4W	Dead, Snow, Wind	1.25	1.25	1.25	0	0	0	0	0	1.5	0.4
6	4	1.25D+1.4W+0.5L	Dead, Wind, Live	1.25	1.25	1.25	0.5	0	0	0	0.5	0	1.4
7		1.25D+1.4W+0.5S	Dead, Wind, Snow	1.25	1.25	1.25	0	0	0	0	0	0.5	1.4
8	2	0.9D+1.5L+0.5S	Dead, Live, Snow	0.9	0.9	0.9	1.5	0	0	0	1.5	0.5	0
9		0.9D+1.5+0.4W	Dead, Live, Wind	0.9	0.9	0.9	1.5	0	0	0	1.5	0	0.4
10	3	0.9D+1.5S+0.5L	Dead, Snow, Live	0.9	0.9	0.9	0.5	0	0	0	0.5	1.5	0
11		0.9D+1.5S+0.4W	Dead, Snow, Wind	0.9	0.9	0.9	0	0	0	0	0	1.5	0.4
12	4	0.9D+1.4W+0.5L	Dead, Wind, Live	0.9	0.9	0.9	0.5	0	0	0	0.5	0	1.4
13		0.9D+1.4W+0.5S	Dead, Wind, Snow	0.9	0.9	0.9	0	0	0	0	0	0.5	1.4
14	5	1.0D+1.5WH+0.5L+0.25S	Dead, WH, Live, Snow	1	1	1	0.5	1.5	1.5	-1.5	0.5	0.25	0.4

DEAD LOADS

Dead Load of Structure
** Use SW generator in S- Frame

Dead Load of Pipe

KEY
INPUT
INTERMEDIATE STEP/KNOWN VALUE
APPLIED LOAD

WOOD

Length:		m	
OD		m	
ID		m	
C/S Area:	0	m^2	
Unit Weight:	5.2	kN/m^3	Assume Douglas Fir
Dead Load:	0	kN/m	
# Support Points:			
Load/Support:	#DIV/0!	kN/support	

$$DL = \frac{\gamma_w A_p L + \gamma_s A_b L_b n_b}{n_s}$$

Steel Bands

Spacing:	0.0508	m	
Diameter of Rod:	0.0254	m	
Area of Rod:		m^2	
Length of Rod:		m	** = circumference
Unit Weight:	76.8	kN/m^3	
Dead Load:	0	kN/Band	
Length:		m	
# Bands:			
Weight of Rods:	#DIV/0!	kN/support	

TOTAL LOAD	#DIV/0!	kN/support

STEEL

Length:		m	
OD		m	
ID		m	
C/S Area:	0	m^2	
Unit Weight:	76.8	kN/m^3	Assume Standard
Dead Load:	0	kN/m	
# Support Points:			
Load/Support:	#DIV/0!	kN/support	

$$DL = \frac{\gamma_s A_p L}{n_s}$$

LIVE LOADS

WATER LOAD		
Vertical Water Load		
ID:		m
C/S Area:	0	m^2
Unit Weight of Water:	9.81	kN/m^3
LOAD	0.00	kN/m
Length:		m
# Support Points:	9	
Load/Support:	0.00	kN/support

KEY
INPUT
INTERMEDIATE STEP/KNOWN VALUE
APPLIED LOAD

$$LL_{water} = \frac{\gamma_{water} A_{ID} L}{n_s}$$

WATER HAMMER LOAD		
** 25% of Water Load		
** Vertical, Lateral, and Long. Direction		
Load/Support:	0.00	kN/support
Vertical Load:	0.00	kN/support
Lat. Load:	0.00	kN/support
Long. Load:	0.00	kN/support

ORIENTATION
X - LONGITUDINAL - POS TOWARD LOWER END
Y - LATERAL - POS TOWARD DAM
Z - VERTICAL - POS TOWARD SKY

$$LL_{WH} = \frac{0.25 LL_{water}}{n_s}$$

ICE LOAD		
** Assume a 3" ice thickness, over whole pipe		
Thickness:	0.0762	m
OD:		m
OD+ICE	0.1524	m
C/S Area:		m^2
Unit Weight of Water:	9.81	kN/m^3
Load:	0.00	kN/m
Length:		m
# Supports:		
Load/Support:	#DIV/0!	kN/support

** NO ICE ON STEEL PIPE

$$LL_{ice} = \frac{\gamma_{water} A_{ice} L}{n_s}$$

SNOW LOADS

KEY
INPUT
INTERMEDIATE STEP/KNOWN VALUE
APPLIED LOAD

WOOD

Unit Weight of Snow:	3	kN/m^3	
Height of Snow:	0.5	m	** Assumed
OD:			
Width of Snow:	0	m	** Changes with material, Assumed Dia/2 here
Length:		m	
Load	0	kN/m	
# of Supports:			
Load/Support:	#DIV/0!	kN/support	

$$SL = \frac{\gamma_S H_S W_S L}{n_S}$$

STEEL

Unit Weight of Snow:	3	kN/m^3	
Height of Snow:	0.5	m	** Assumed
OD:			
Width of Snow:	0	m	** Changes with material, Assumed Dia/4 here
Length:		m	
Load	0	kN/m	
# of Supports:			
Load/Support:	#DIV/0!	kN/support	

$$SL = \frac{\gamma_S H_S W_S L}{n_S}$$

WIND LOADS

$$F = \frac{1}{2}\rho_a U_w{}^2 C_s D$$

Density of Air:	1.2	kg/m^3	
Wind Speed:		m/s	** From NBCC
Shape Factor:	1.5		
Diameter of Pipe:		m	
Wind Load:	0	kN/m	
Length:		m	
# Supports:			
Load/Support:	#DIV/0!	kN/support	

KEY
INPUT
INTERMEDIATE STEP/KNOWN VALUE
APPLIED LOAD

Bottom Support Concept Load Combinations

** ONLY GOVERNING COMBOS HERE, ASSUMING WIND AND WH IS SYMMETRICAL

				DEAD LOADS			LIVE LOADS					SNOW	WIND
				DL - STRUCTURE	DL - PIPE	DL - CRIB	LL - WATER IN PIPE	LL - WATER HAMMER			LL - ICE	S - SNOW LOAD	WL - WIND LOAD
#	NBCC #	LOAD COMBO	DESCRIPTION					LATERAL	LONG.	VERTICAL			
1	1	1.4D	Dead Load	1.4	1.4	1.4	0	0	0	0	0	0	0
2	2	1.25D+1.5L+0.5S	Dead, Live, Snow	1.25	1.25	1.25	1.5	0	0	0	1.5	0.5	0
3		1.25D+1.5+0.4W	Dead, Live, Wind	1.25	1.25	1.25	1.5	0	0	0	1.5	0	0.4
4	3	1.25D+1.5S+0.5L	Dead, Snow, Live	1.25	1.25	1.25	0.5	0	0	0	0.5	1.5	0
5		1.25D+1.5S+0.4W	Dead, Snow, Wind	1.25	1.25	1.25	0	0	0	0	0	1.5	0.4
6	4	1.25D+1.4W+0.5L	Dead, Wind, Live	1.25	1.25	1.25	0.5	0	0	0	0.5	0	1.4
7		1.25D+1.4W+0.5S	Dead, Wind, Snow	1.25	1.25	1.25	0	0	0	0	0	0.5	1.4
8	2	0.9D+1.5L+0.5S	Dead, Live, Snow	0.9	0.9	0.9	1.5	0	0	0	1.5	0.5	0
9		0.9D+1.5+0.4W	Dead, Live, Wind	0.9	0.9	0.9	1.5	0	0	0	1.5	0	0.4
10	3	0.9D+1.5S+0.5L	Dead, Snow, Live	0.9	0.9	0.9	0.5	0	0	0	0.5	1.5	0
11		0.9D+1.5S+0.4W	Dead, Snow, Wind	0.9	0.9	0.9	0	0	0	0	0	1.5	0.4
12	4	0.9D+1.4W+0.5L	Dead, Wind, Live	0.9	0.9	0.9	0.5	0	0	0	0.5	0	1.4
13		0.9D+1.4W+0.5S	Dead, Wind, Snow	0.9	0.9	0.9	0	0	0	0	0	0.5	1.4
14	5	1.0D+1.5WH+0.5L+0.25S	Dead, WH, Live, Snow	1	1	1	0.5	1.5	1.5	-1.5	0.5	0.25	0.4

Note that the load combinations highlighted in yellow were applied to the S-FRAME model of the bottom support concept.

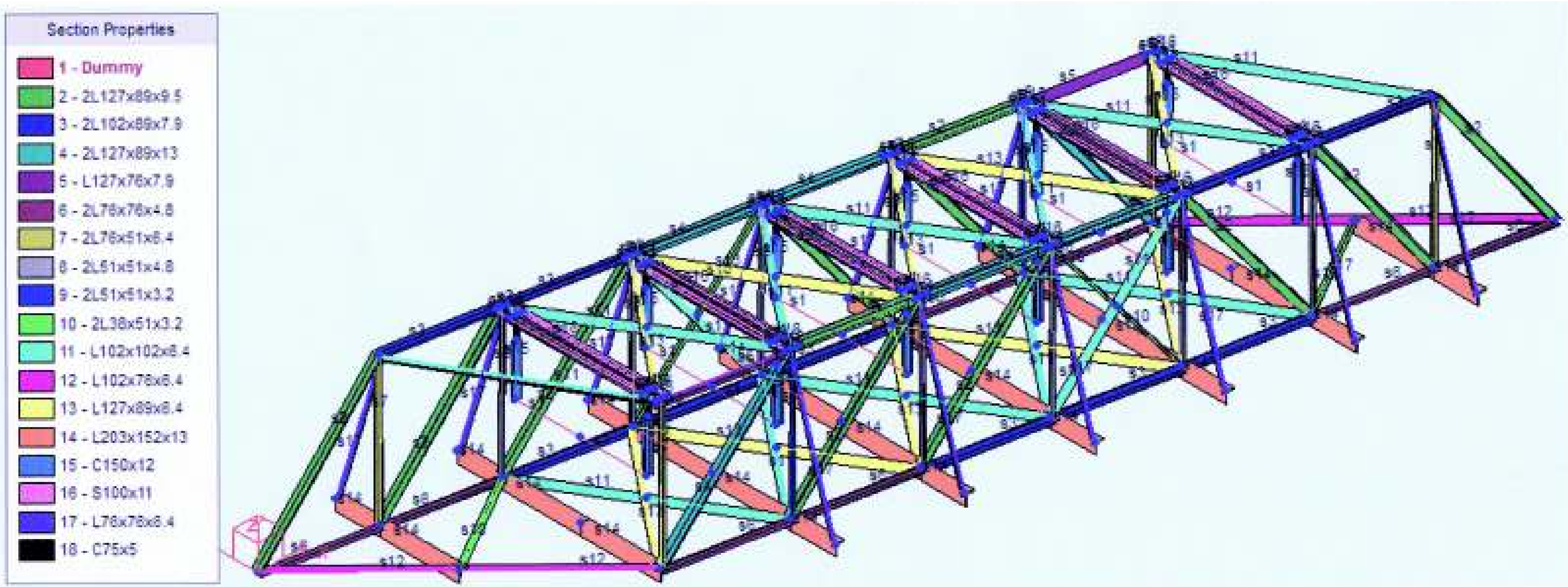
Bottom Beam Concept

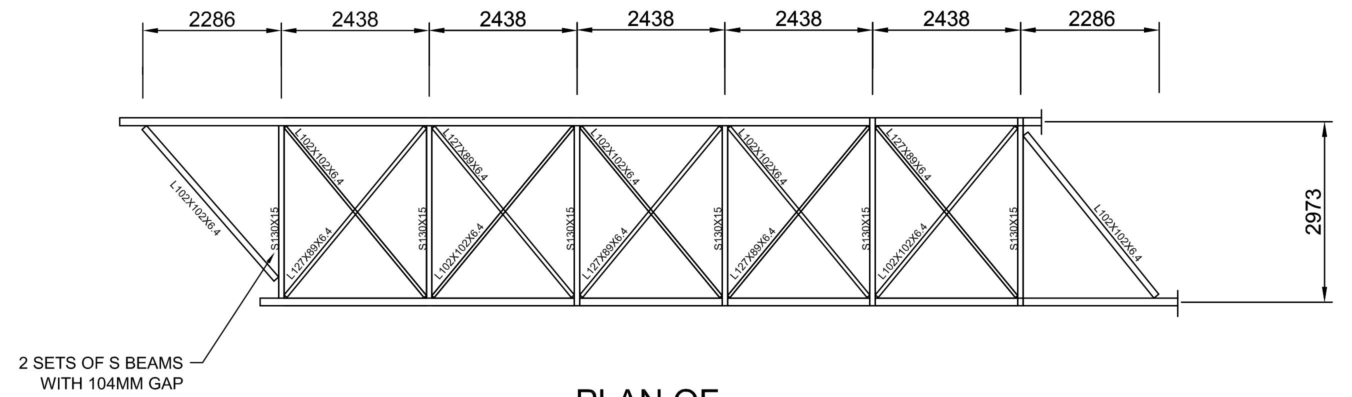
The wind load acting on a beam parallel to the penstock is calculated using the values in the table below.

LONGITUDINAL BEAM

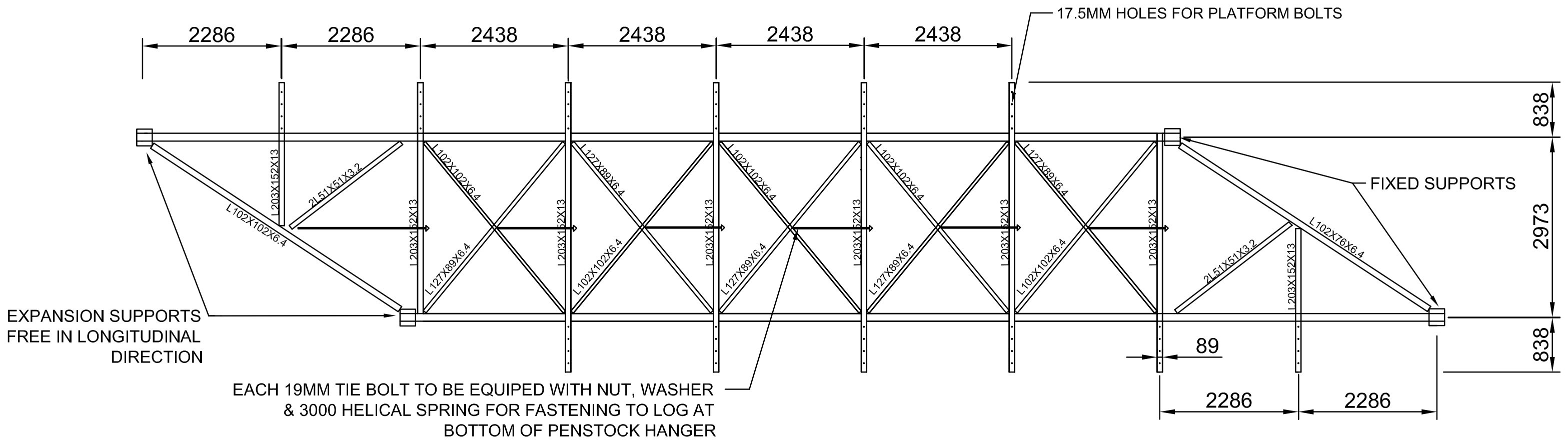
Density of Air:	1.2	kg/m^3	
Wind Speed:	34.7	m/s	** From NBCC
Shape Factor:	2		
W 840x299			
d	0.856	m	
Wind Load:	1.237	kN/m	

Appendix D – Replacement of Existing Structure Design


Section Properties
1 - Dummy
2 - 2L127x89x9.5
3 - 2L102x89x7.9
4 - 2L127x89x13
5 - L127x76x7.9
6 - 2L76x76x4.8
7 - 2L76x51x6.4
8 - 2L51x51x4.8
9 - 2L51x51x3.2
10 - 2L38x51x3.2
11 - L102x102x6.4
12 - L102x76x6.4
13 - L127x89x6.4
14 - L203x152x13
15 - C150x12
16 - S100x11
17 - L76x76x6.4
18 - C75x5



PLAN OF
UPPER CHORD



PLAN OF
LOWER CHORD

NOTES

1. All dimensions in millimeters (mm) UNO.
2. Dimensions and sketch obtained from Newfoundland Power. New members introduced based on results from structural analysis and drawn in the sketch for cost purposes only.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/20	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE: COMPLETE REPLACEMENT
PLAN VIEW

PROJECT: NL POWER TRESTLE REPLACEMENT

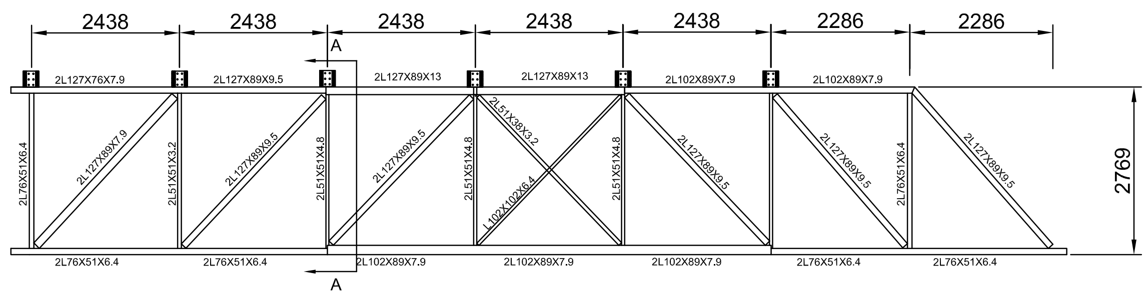
LOCATION: TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION: -

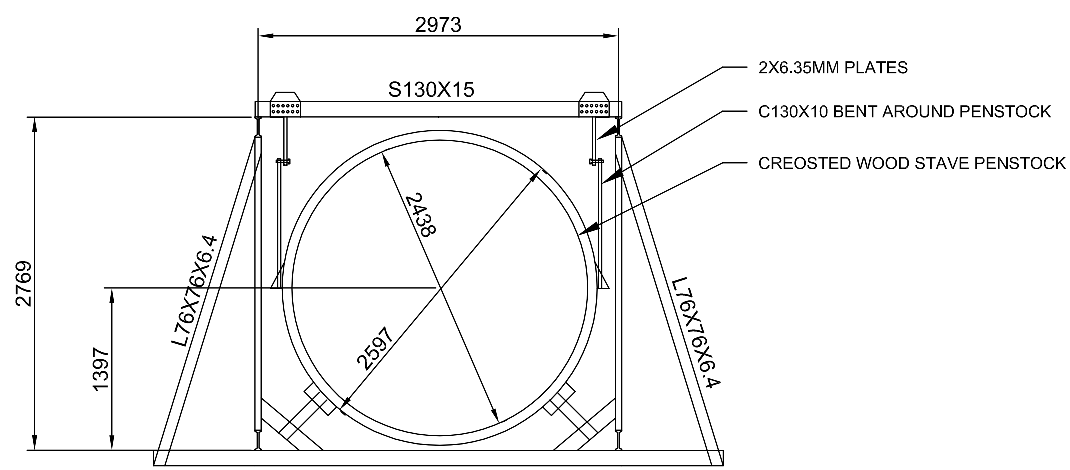
DESIGN BY: MCA	CHECK BY: WGC	
DRAWN BY: PSC	APPROVED BY:	
DATE: 03/10/20	SCALE: N.T.S	REVISION #: A

DRAWING REFERENCE NUMBER: REPLACE-001/002

NOT FOR FABRICATION USE



ELEVATION OF SOUTH TRUSS
(NORTH TRUSS IDENTICAL WITH FIXED AND MOVING ENDS REVERSED)



TYPICAL HANGER CROSS SECTION 'A-A'

NOTES
1. All dimensions in millimeters (mm) UNO.
2. Dimensions and sketch obtained from Newfoundland Power. New members introduced based on results from structural analysis and drawn in the sketch for cost purposes only.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/20	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

CASC CONSULTING

TITLE
COMPLETE REPLACEMENT
ELEVATION AND CROSS-SECTION VIEWS

PROJECT
NL POWER TRESTLE REPLACEMENT

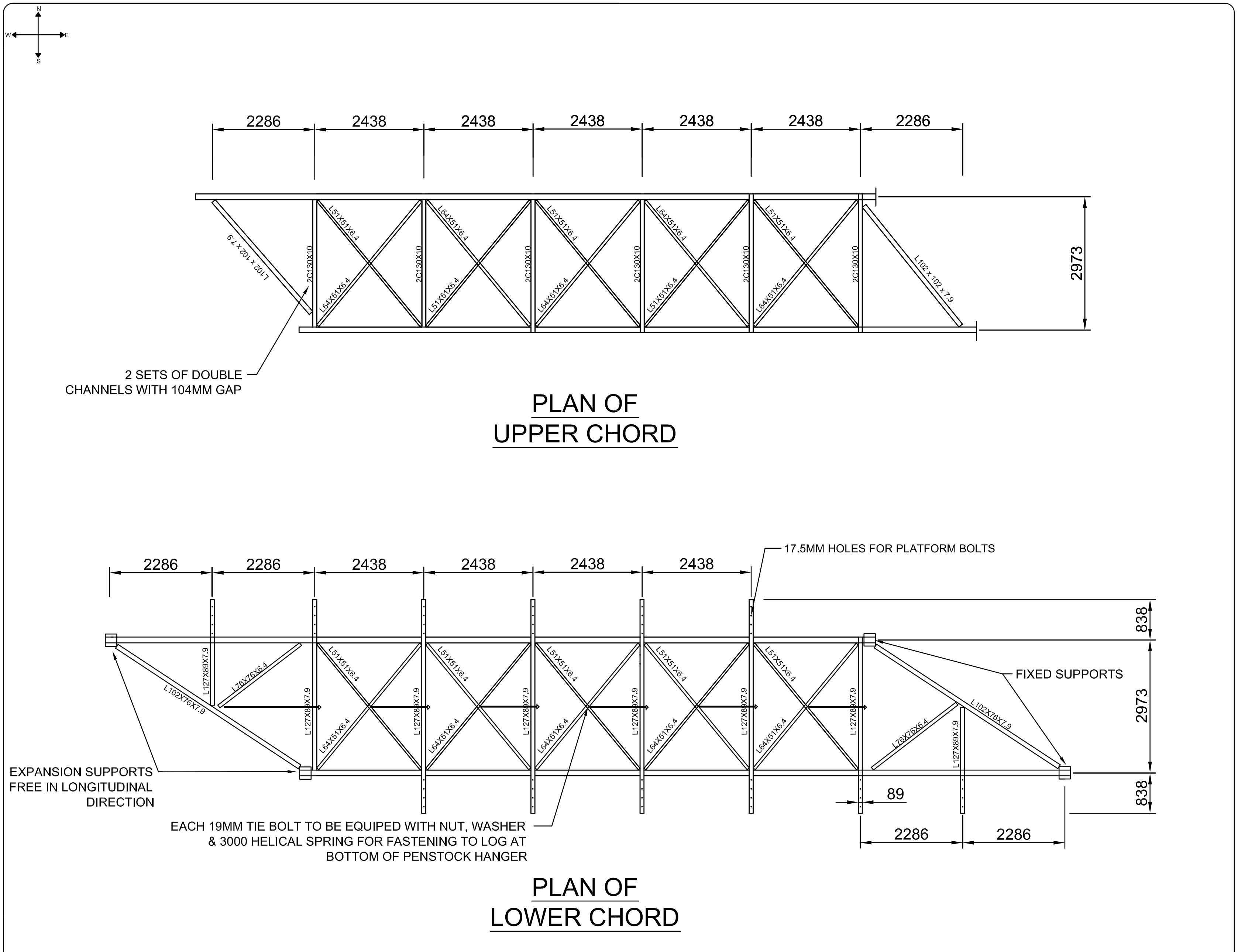
LOCATION
TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION
-

DESIGN BY: MCA	CHECK BY: WGC	
DRAWN BY: PSC	APPROVED BY:	
DATE: 03/10/20	SCALE: N.T.S	REVISION #: A

DRAWING REFERENCE NUMBER
REPLACE-002/002

NOT FOR FABRICATION USE



NOTES

1. All dimensions in millimeters (mm) UNO.
2. Dimensions and sketch obtained from Newfoundland Power. Members obtained from 1-614-10-5 Penstock Truss sketch from Newfoundland Power.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/20	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

CASC CONSULTING

TITLE: EXISTING STRUCTURE
PLAN VIEW

PROJECT: NL POWER TRESTLE REPLACEMENT

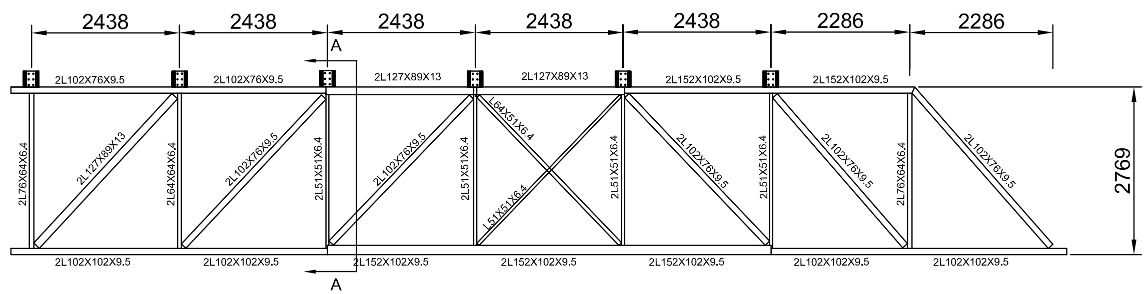
LOCATION: TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION: -

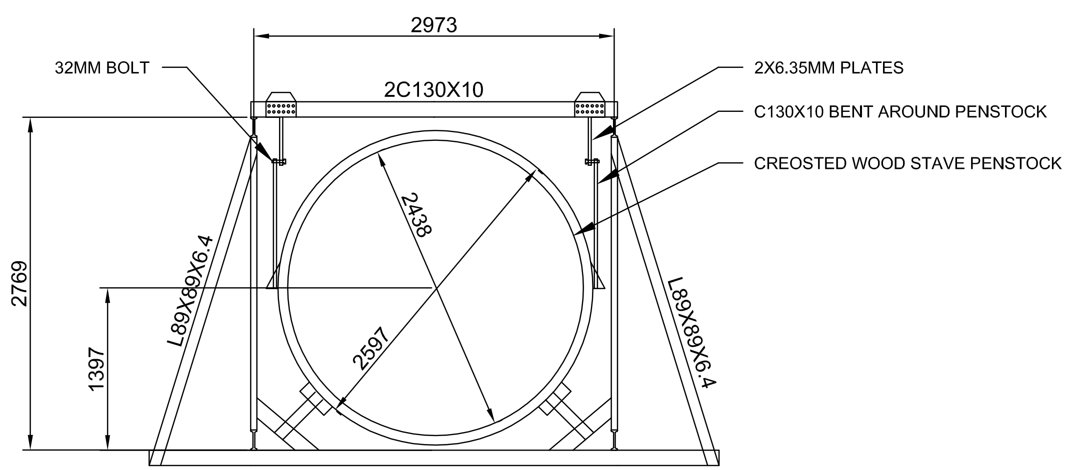
DESIGN BY: MCA		CHECK BY: WGC	
DRAWN BY: PSC		APPROVED BY:	
DATE: 03/10/25	SCALE: N.T.S	REVISION #: A	

DRAWING REFERENCE NUMBER: EXISTING-001/002

NOT FOR FABRICATION USE



ELEVATION OF SOUTH TRUSS
(NORTH TRUSS IDENTICAL WITH FIXED
AND MOVING ENDS REVERSED)



TYPICAL HANGER CROSS SECTION 'A-A'

NOTES
1. All dimensions in millimeters (mm) UNO.
2. Dimensions and sketch obtained from Newfoundland Power. Members obtained from 1-614-10-5 Penstock Truss sketch from Newfoundland Power.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/20	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
EXISTING STRUCTURE
ELEVATION AND CROSS-SECTION VIEWS

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION
-

DESIGN BY	MCA	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	

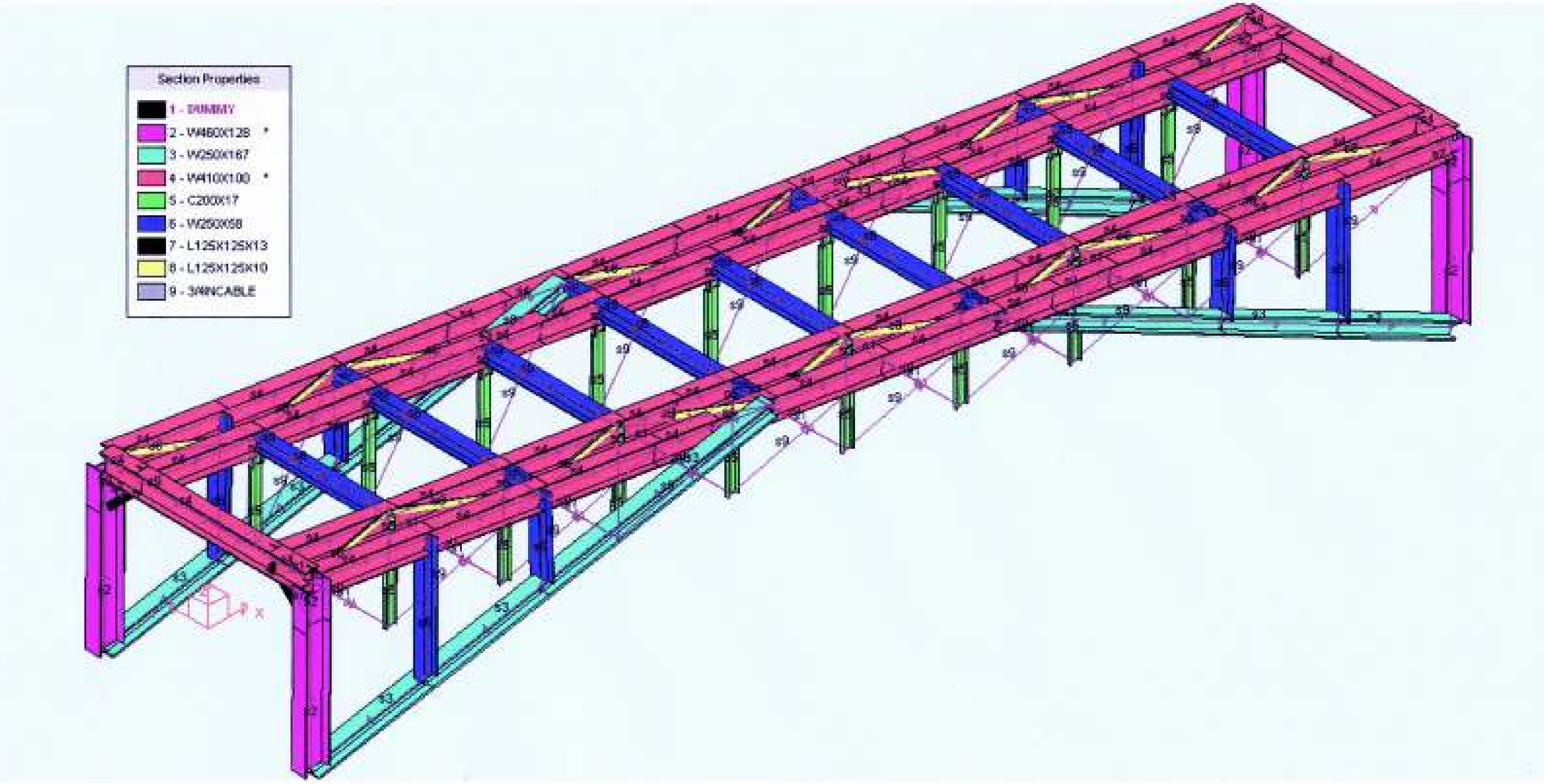
DATE	03/10/25	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
EXISTING-002/002

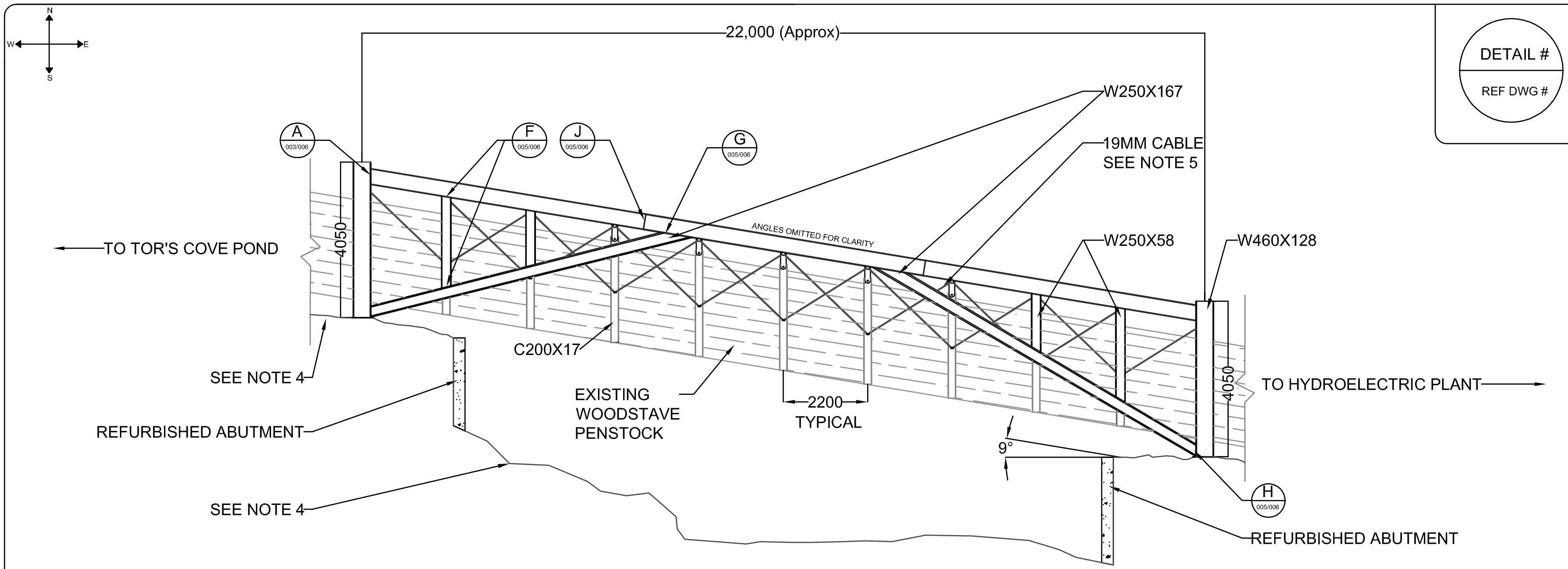
NOT FOR FABRICATION USE

CASC CONSULTING

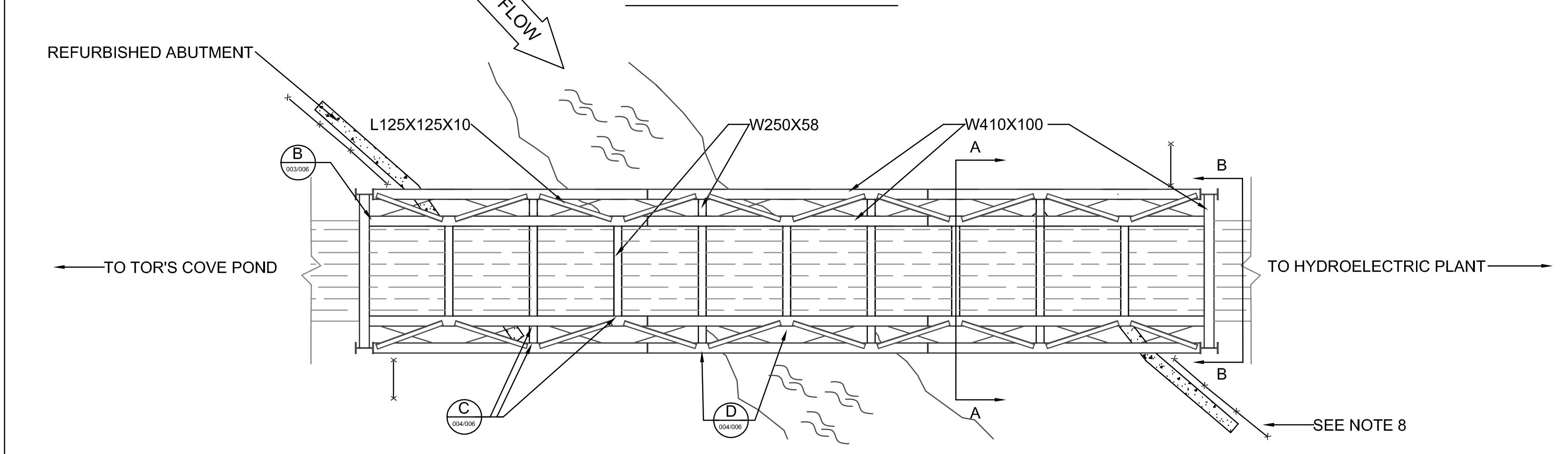
Appendix E – Top Support Design



Section Properties
1 - DUMMY
2 - W460X128 *
3 - W250X167
4 - W410X100 *
5 - C200X17
6 - W250X58
7 - L125X125X13
8 - L125X125X10
9 - 3/4INCABLE



ELEVATION VIEW



PLAN VIEW

DETAIL #
REF DWG #

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. New structure to be constructed above existing. Existing to be removed after construction.
4. Existing riverbed and land profiles unknown. Survey required.
5. All cables are 6x19 steel bright wire, fibre core.
6. All steel surfaces to be painted with corrosion resistant materials.
7. Penstock elevations to remain same as existing.
8. Supply and install new 3.0 meter chainlink fence. Omitted from Elevation view for clarity.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/13	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
TOP SUPPORT DESIGN
PLAN AND ELEVATION

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

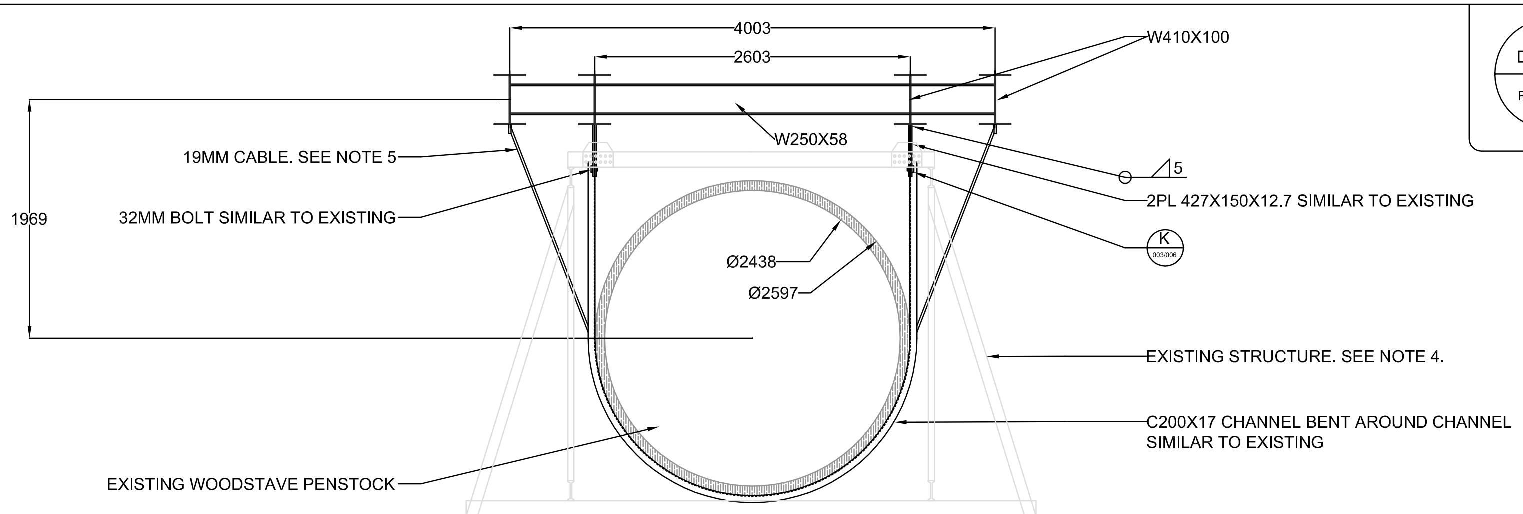
REVISION DESCRIPTION
-

DESIGN BY	PSC	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	

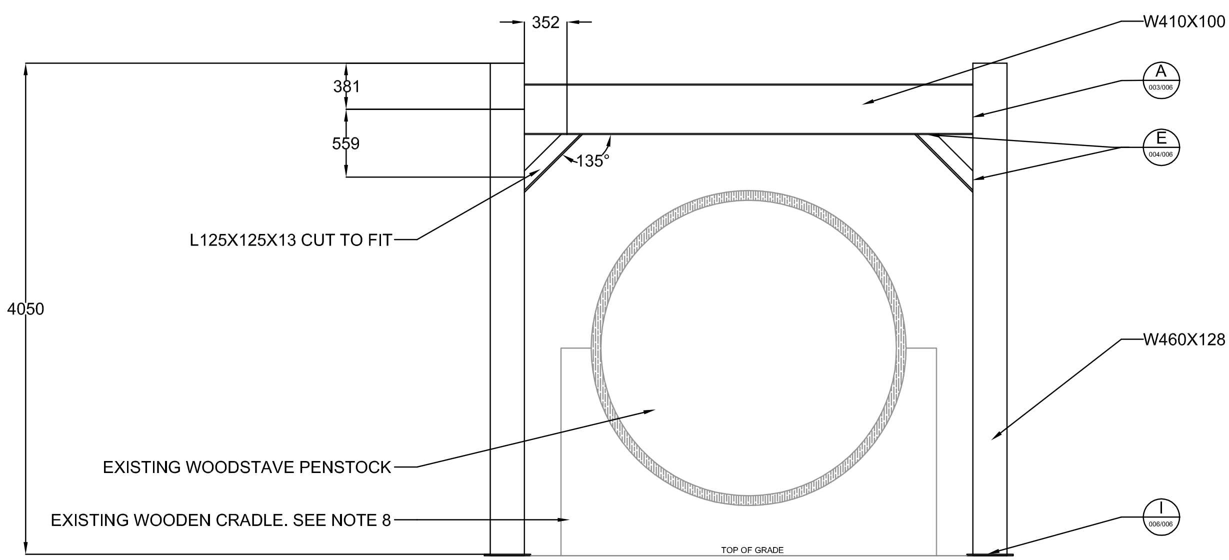
DATE	03/08/13	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
TOPHANGER-001/006

NOT FOR FABRICATION USE



TYPICAL HANGER
CROSS SECTION 'A-A'



TYPICAL END
CROSS SECTION 'B-B'

DETAIL #
REF DWG #

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. All bolts to be A325M (Fu = 825MPA) c/w nut and washer UNO.
4. New structure to be constructed above existing. Existing to be removed after construction.
5. All cables are 6x19 steel bright wire, fibre core.
6. All steel surfaces to be painted with corrosion resistant materials.
7. All welds to use E49XX weld metal (Fu = 490MPa).
8. Exact existing cradle arrangement unknown at time of design.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/13	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
TOP SUPPORT DESIGN
CROSS-SECTIONS

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

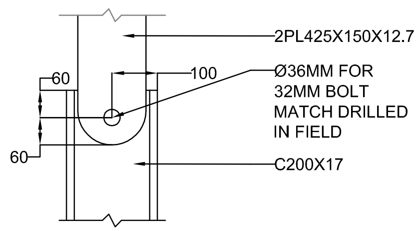
REVISION DESCRIPTION
-

DESIGN BY	PSC	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	

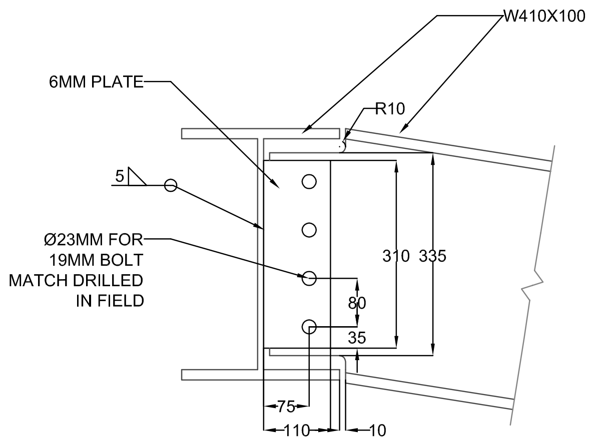
DATE 03/08/13 | SCALE N.T.S | REVISION # A

DRAWING REFERENCE NUMBER
TOPHANGER-002/006

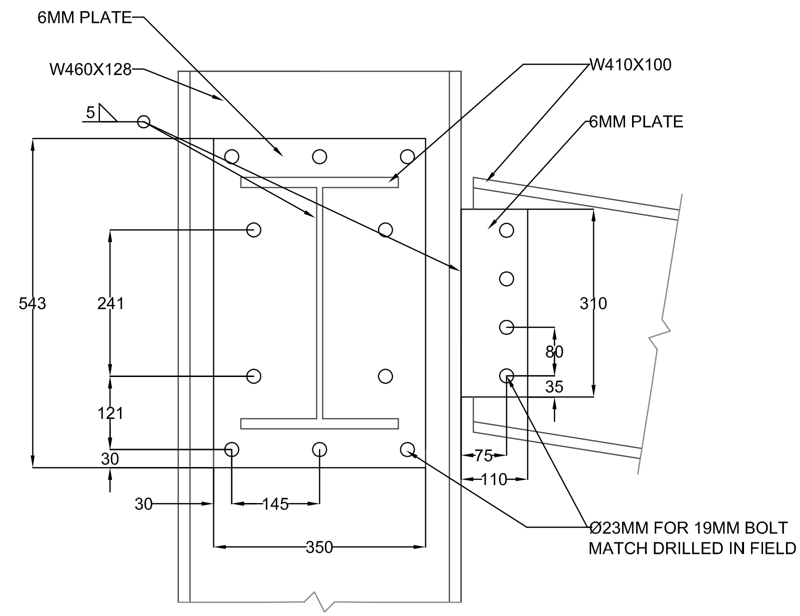
NOT FOR FABRICATION USE



DETAIL 'K'
TYPICAL CHANNEL
CONNECTION



DETAIL 'B'
TYPICAL
END BEAM/BEAM
CONNECTIONS



DETAIL 'A'
TYPICAL
COLUMN/BEAM
CONNECTIONS

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. All bolts to be A325M (Fu = 825MPA) c/w nut and washer UNO.
4. New structure to be constructed above existing. Existing to be removed after construction.
5. All steel surfaces to be painted with corrosion resistant materials.
6. All welds to use E49XX weld metal (Fu = 490MPa).
7. All end plates to be shop welded to beams.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/17	ORIGINAL DESIGN	--

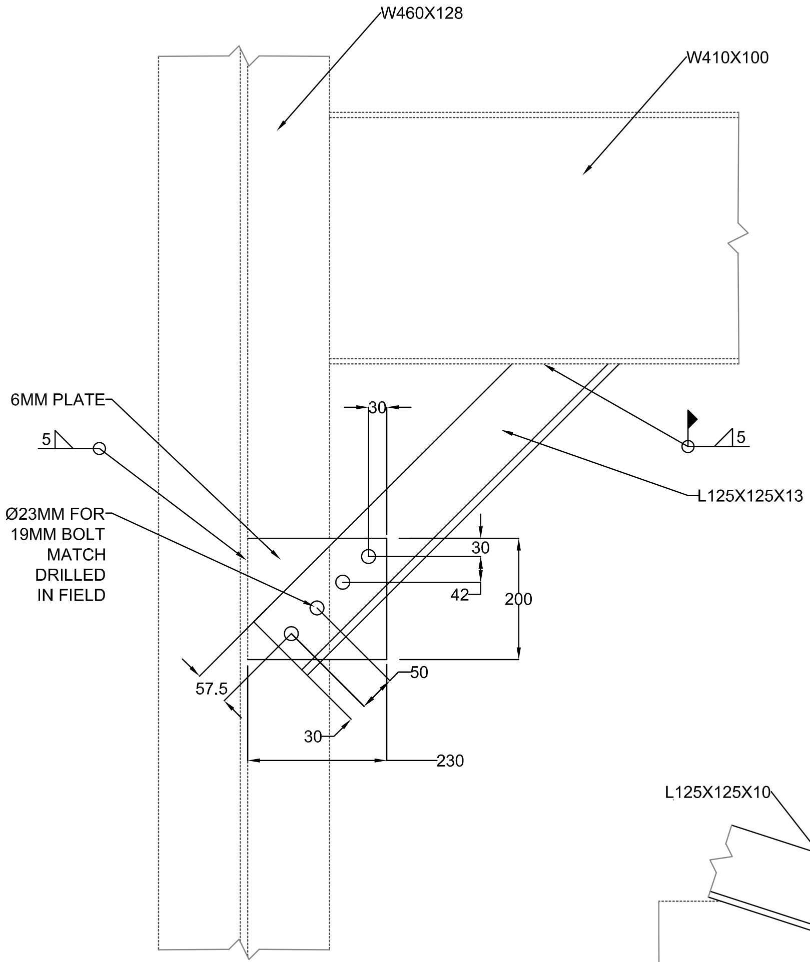
REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

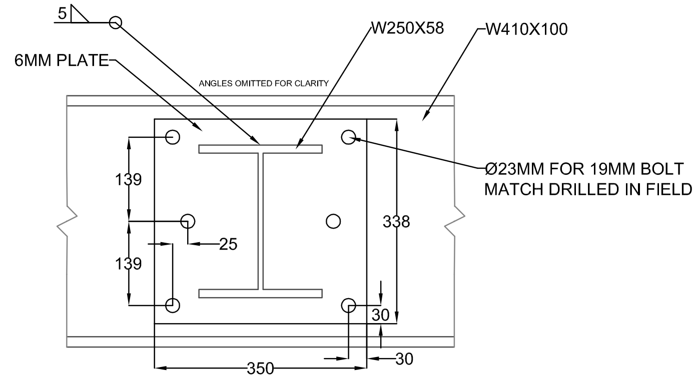
CASC CONSULTING

TITLE	TOP SUPPORT DESIGN CONNECTION DETAILS - 1/3		
PROJECT	NL POWER TRESTLE REPLACEMENT		
LOCATION	TOR'S COVE, NEWFOUNDLAND		
REVISION DESCRIPTION	-		
DESIGN BY	PSC	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	
DATE	03/08/17	SCALE	N.T.S
REVISION #	A		
DRAWING REFERENCE NUMBER	TOPHANGER-003/006		

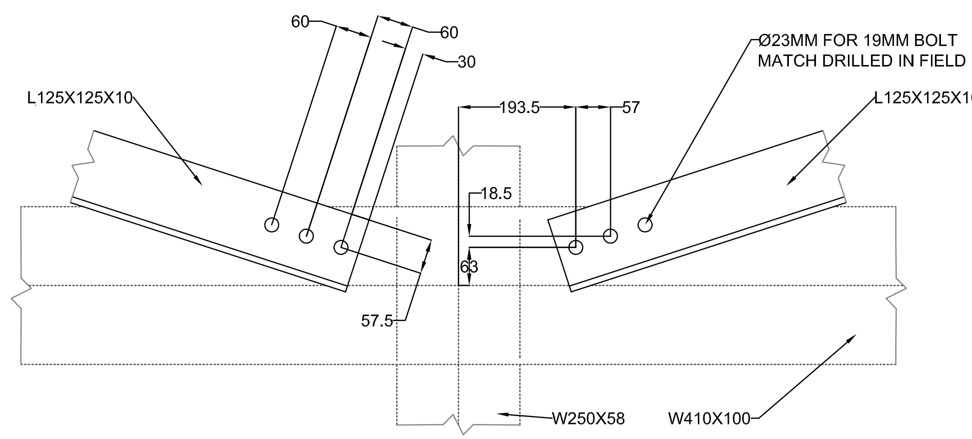
NOT FOR FABRICATION USE



DETAIL 'E'
TYPICAL SMALL
KNEE BRACE
CONNECTION



DETAIL 'C'
TYPICAL
LATERAL BEAM
CONNECTION



DETAIL 'D'
TYPICAL ANGLE
CONNECTION

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. All bolts to be A325M (Fu = 825MPA) c/w nut and washer UNO.
4. New structure to be constructed above existing. Existing to be removed after construction.
5. All steel surfaces to be painted with corrosion resistant materials.
6. All welds to use E49XX weld metal (Fu = 490MPa).
7. All end plates to be shop welded to beams.
8. Detail "D" may be welded if desired.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/17	ORIGINAL DESIGN	--

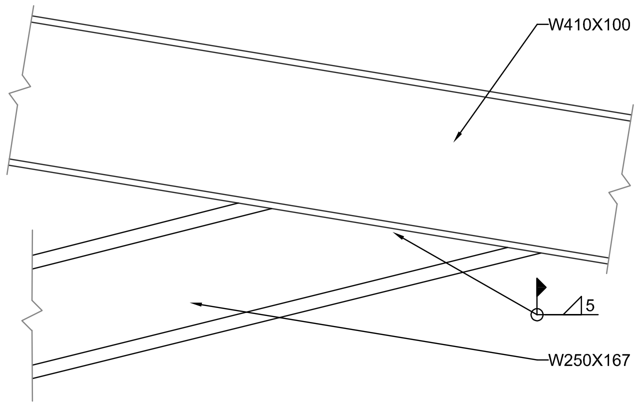
REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

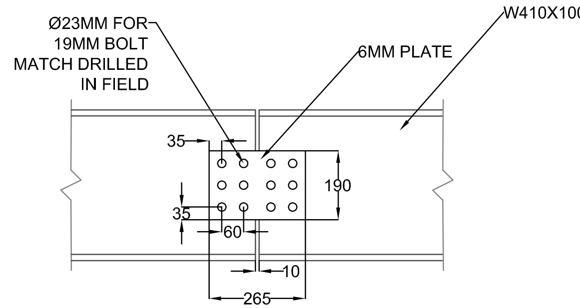
CASC CONSULTING

TITLE	TOP SUPPORT DESIGN CONNECTION DETAILS - 2/3
PROJECT	NL POWER TRESTLE REPLACEMENT
LOCATION	TOR'S COVE, NEWFOUNDLAND
REVISION DESCRIPTION	-
DESIGN BY	PSC
CHECK BY	WGC
DRAWN BY	PSC
APPROVED BY	
DATE	03/08/17
SCALE	N.T.S
REVISION #	A
DRAWING REFERENCE NUMBER	TOPHANGER-004/006

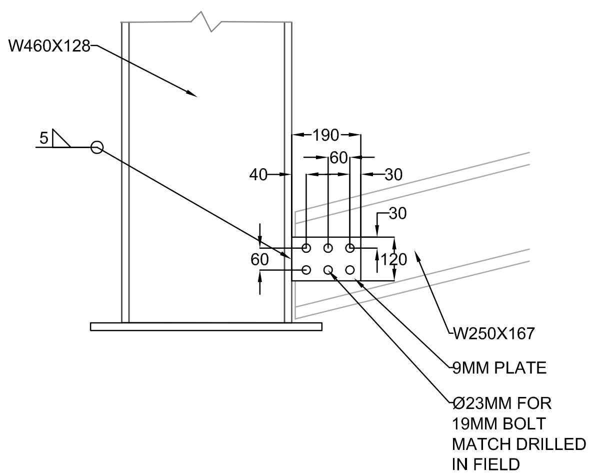
NOT FOR FABRICATION USE



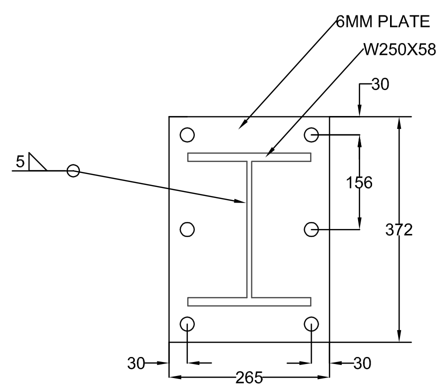
DETAIL 'G'
TYPICAL LARGE KNEE BRACE TO BEAM DETAIL



DETAIL 'J'
SHEAR BEAM CONNECTION



DETAIL 'H'
TYPICAL LARGE KNEE BRACE TO COLUMN DETAIL



DETAIL 'F'
TYPICAL SUPPORT COLUMN TO KNEE BRACE AND BEAM DETAIL

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. All bolts to be A325M (Fu = 825MPA) c/w nut and washer UNO.
4. New structure to be constructed above existing. Existing to be removed after construction.
5. All steel surfaces to be painted with corrosion resistant materials.
6. All welds to use E49XX weld metal (Fu = 490MPa).
7. All end plates to be shop welded to beams.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/17	ORIGINAL DESIGN	--

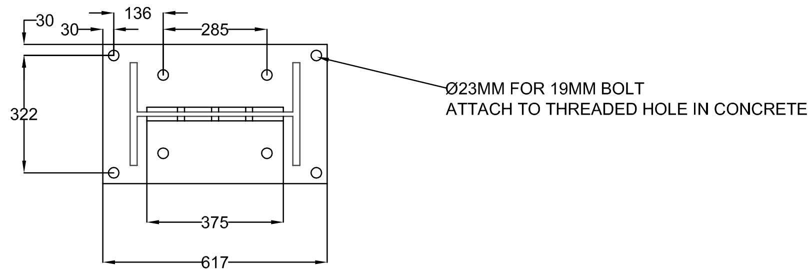
REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

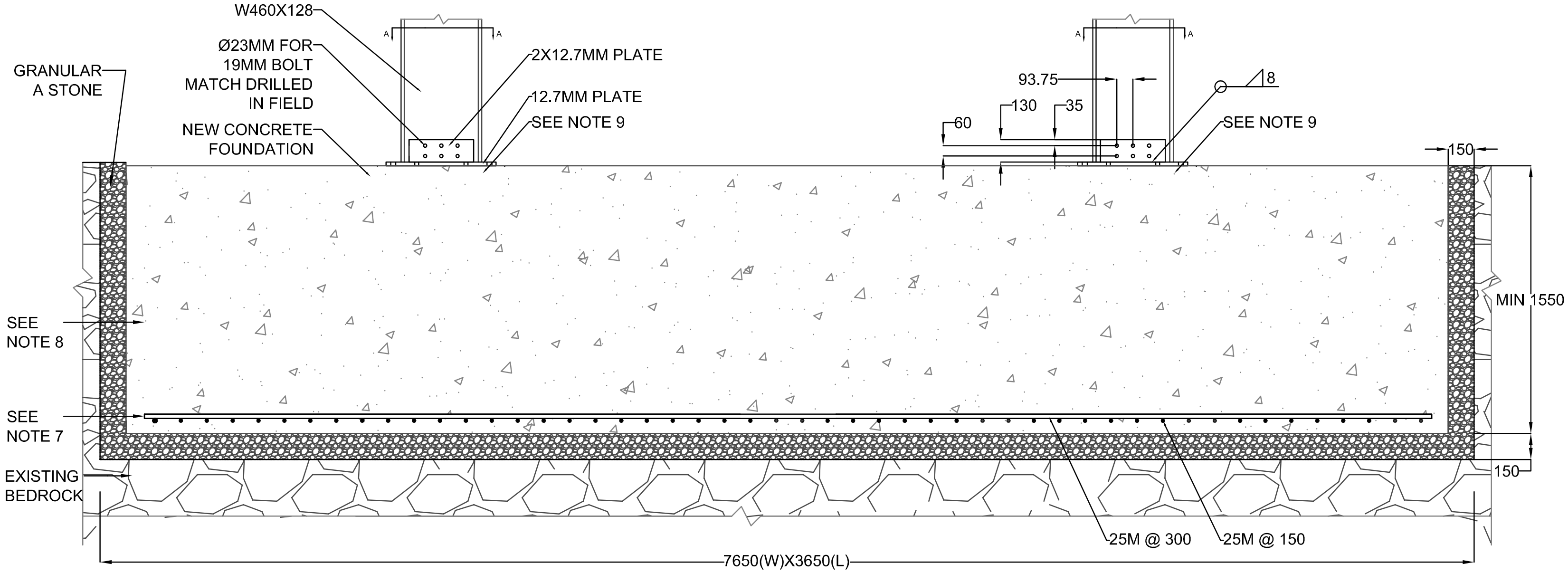
CASC CONSULTING

TITLE: TOP SUPPORT DESIGN CONNECTION DETAILS - 3/3	
PROJECT: NL POWER TRESTLE REPLACEMENT	
LOCATION: TOR'S COVE, NEWFOUNDLAND	
REVISION DESCRIPTION: -	
DESIGN BY: PSC	CHECK BY: WGC
DRAWN BY: PSC	APPROVED BY:
DATE: 03/08/17	SCALE: N.T.S — REVISION #: A
DRAWING REFERENCE NUMBER: TOPHANGER-005/006	

NOT FOR FABRICATION USE



TYPICAL CROSS-SECTION 'A-A'



DETAIL 'I'
TYPICAL FOUNDATION DETAILS

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All structural steel to be 350W steel (Fy = 350MPA, Fu = 450MPA) UNO.
3. All bolts to be A325M (Fu = 825MPA) c/w nut and washer UNO.
4. All steel surfaces to be painted with corrosion resistant materials.
5. All welds to use E49XX weld metal (Fu = 490MPa).
6. All concrete to be 35MPa.
7. Reinforcement shown is assumed for costing purposes only. Actual reinforcement to be designed prior to construction.
8. If 1550mm depth cannot be achieved, drill and dowel into existing bedrock until sufficient resistance is achieved.
9. Bolt anchors to be designed prior to construction.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/18	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE: TOP SUPPORT DESIGN
FOUNDATION DETAILS

PROJECT: NL POWER TRESTLE REPLACEMENT

LOCATION: TOR'S COVE, NEWFOUNDLAND

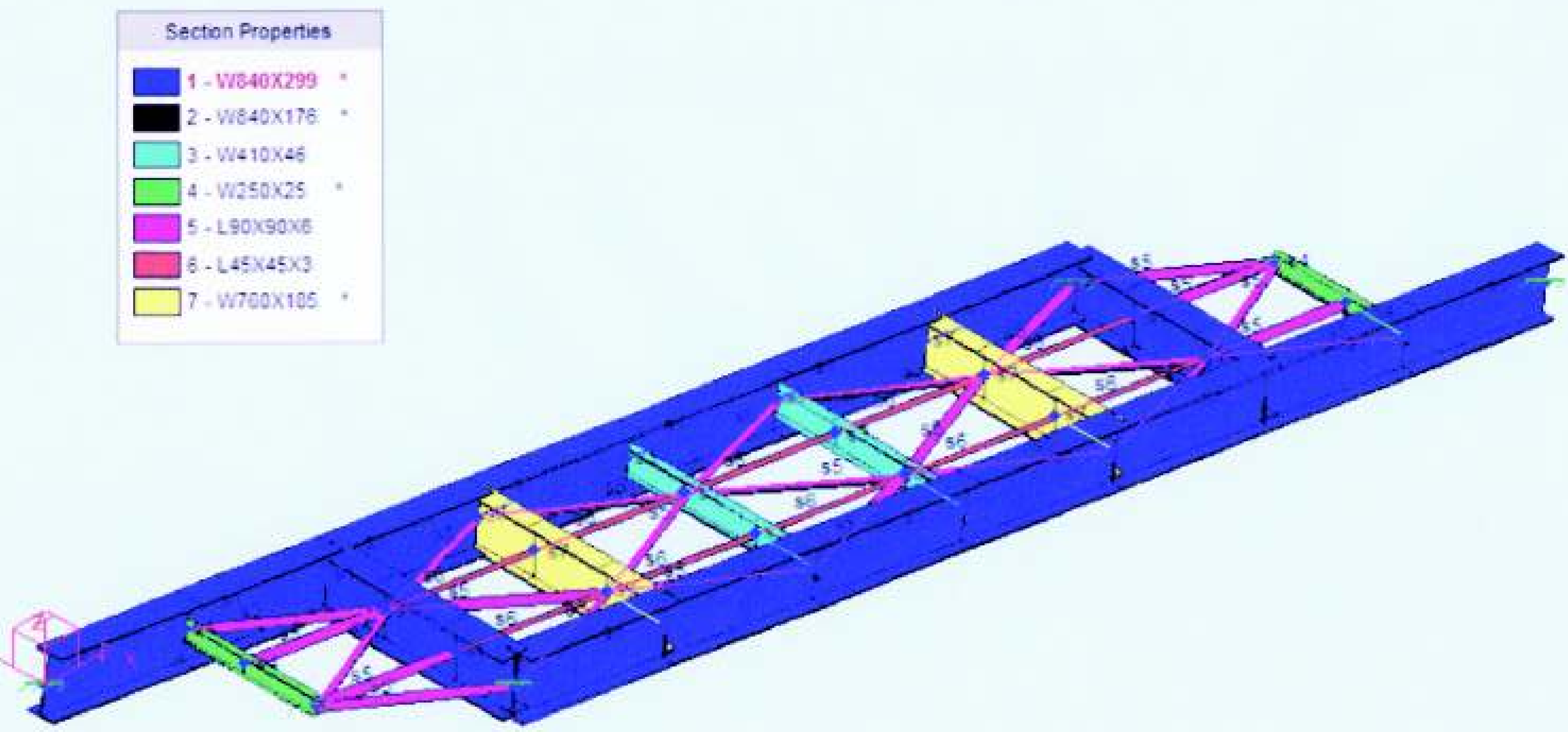
REVISION DESCRIPTION: -

DESIGN BY	WGC/PSC	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	
DATE 03/08/18	SCALE N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER: TOPHANGER-006/006

NOT FOR FABRICATION USE

Appendix F – Bottom Beam Design


Section Properties
1 - W840X299
2 - W840X176
3 - W410X46
4 - W250X25
5 - L90X90X6
6 - L45X45X3
7 - W760X185

Wood Pipe Cradles

CRADLES

The type of cradle, degree of support for the pipe and cradle spacing shall be specified to meet the specific service and location requirements following consultation with the pipe manufacturer.

The design of cradles is so dependent upon field conditions that it is impossible to set forth a standard design to meet all requirements. Some typical cradle designs are shown here.

The tendency for wood pipe to deform is related to the diameter, band spacing, head of water and thickness of stave. The pipe in deforming tends to bulge over the top of the cradle and if the spacing of the cradles is too large or the degree of support too small, large indeterminate stresses will occur in the staves which will be detrimental to the life of the pipe. The spacing, degree of support and type of cradle are determined by long experience. With the exception of very small diameters, all pipes need support.

Chock Block Type (Fig. 1) is sufficient for support of pipe up to 3 feet (.91 m) in diameter. Spacing varies from 10 feet (3 m) for 2 feet (.61 m) diameter to 8 feet (2.44 m).

Strut type (Fig. 2) is usually specified for pipe from 3 feet (.91 m) to 6 feet (1.83 m). The angle of support varies from 120 to 160 degrees.

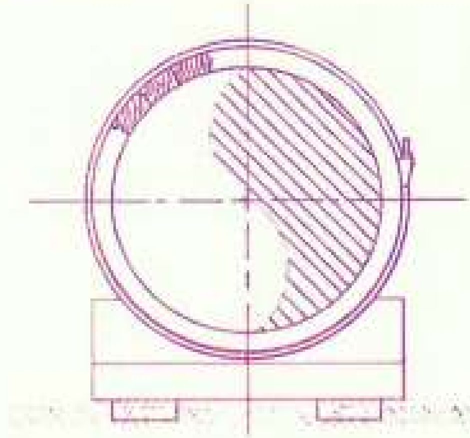
For diameters over 6 feet (1.83 m) the design becomes of extreme importance. It is recommended that the degree of support should be 180 degrees or more. Maximum cradle spacing shall not exceed 8 feet (2.44 m). There are four types of cradles commonly used in these sizes, WOODEN TENSION ROD CRADLE (Fig. 3), STEEL STRUT CRADLE (Fig. 4), RING TYPE STEEL CRADLE (Fig. 5) and REINFORCED CONCRETE CRADLE.

Where timber cradles are specified, they shall be constructed from sound wood, free from twist, large knots or wind shake. The milling shall be done in such a manner as to provide true joints and having as nearly perfect bearing surfaces as possible.

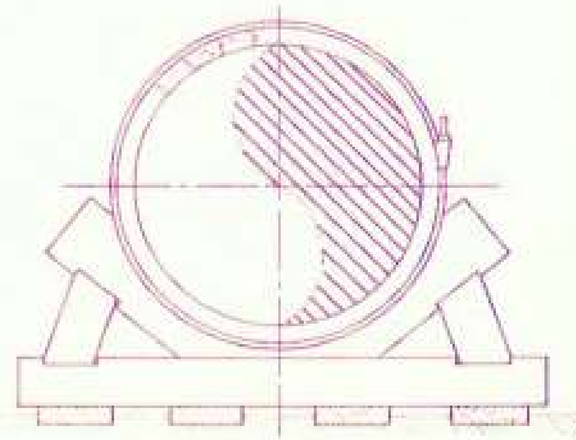
For that portion of the pipeline where the space between the bands is less than the thickness of the cradles, the cradles shall be grooved for the bands so that the weight of the pipe will be supported by the staves. Cradles need not be grooved if the band spacing is such that three or more bands will rest in each cradle.

Sills, mud-sills and cradles shall be treated in accordance with the wood preservation specification on page 4 of this Specification S82 and incised prior to preservative treatment; however, the curved or Band-sawn surfaces shall not be required to be incised.

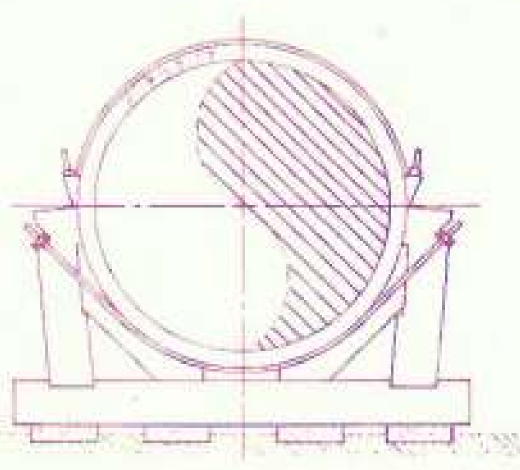
Stay-Brace Cradles (Fig. 6). Pipe of very large diameter or where conditions of heavy overburden exist, require reinforcement with stay-braces to prevent deformation. This permits the use of standard pipe where otherwise it would be necessary to increase the thickness of the staves and the number of bands used. The size and spacing of these braces vary with the depth and type of fill.



(FIG-1) CHOCK BLOCK TYPE

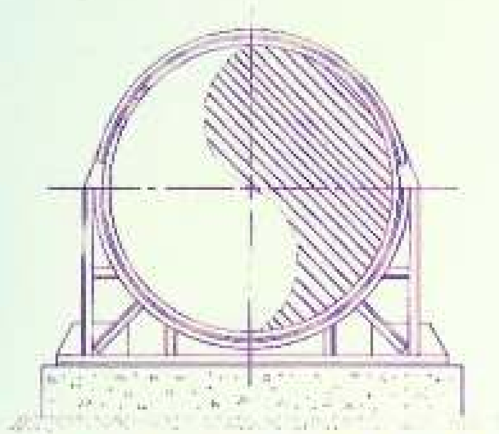


(FIG-2) STRUT TYPE

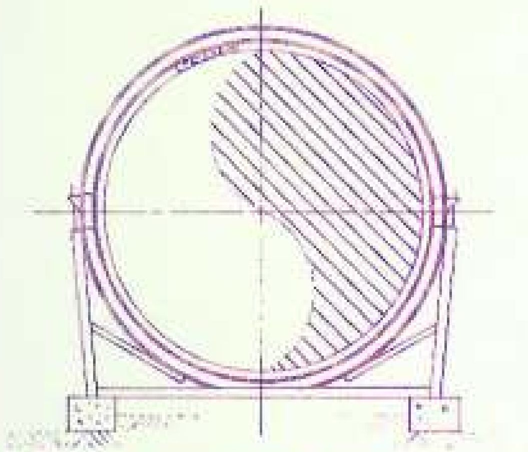


(FIG-3) WOODEN TENSION ROD CRADLE

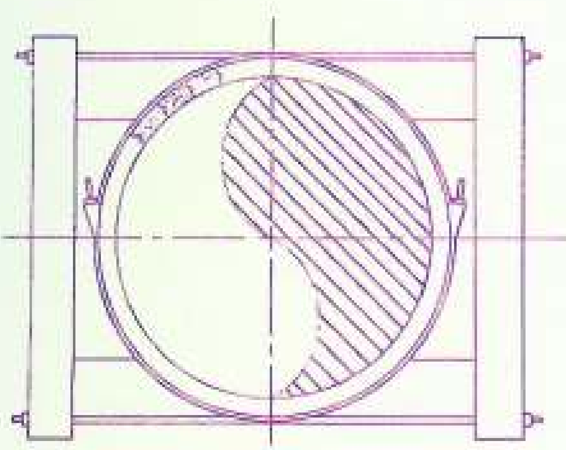
Wood Pipe Installation



(FIG-4) STEEL STRUT CRADLE



(FIG-5) RING TYPE STEEL CRADLE



(FIG-6) STAY-BRACE CRADLE

INSTALLATION OF CONTINUOUS STAVE WOOD PIPE

The installation of a continuous stave wood pipeline should be directed by an experienced supervisor. NWTI Members can contract for installation work or can furnish a skilled installation advisor who can work with your local labor.

General. Ends of adjoining staves shall break joints at not less than 24". Staves shall be placed and driven in such a manner as to avoid any tendency to cause crosswind or twist in the pipe. Staves shall be well driven to produce tight stave end joints. The pipe shall be rounded out to produce smooth inner and outer surfaces. Care shall be exercized in rounding out the pipe to avoid damage by tools.

Placing Bands and Shoes. Bands shall be accurately spaced in accordance with the schedule of band spacing furnished with the shipment and/or shown on the drawings.

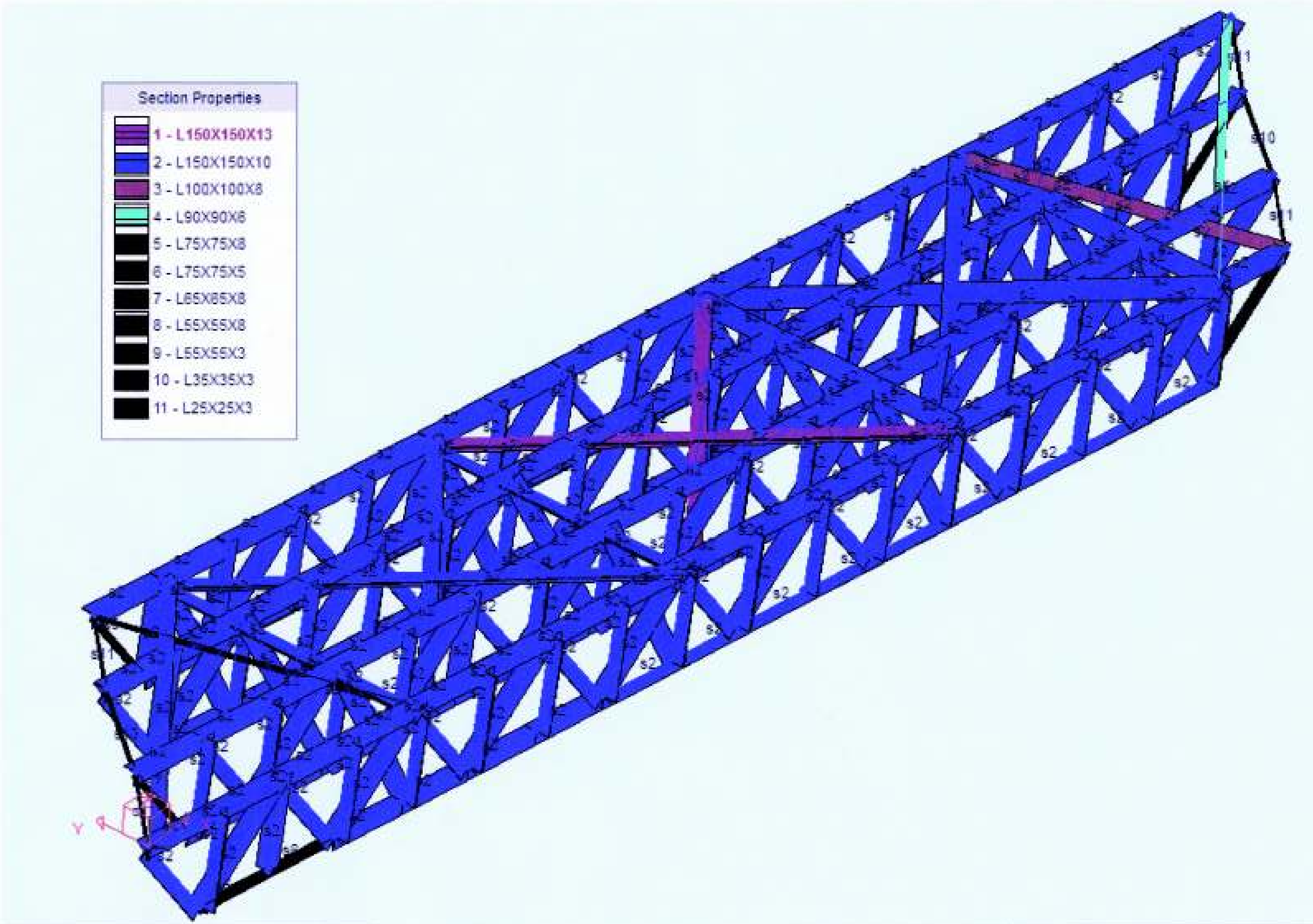
The bands shall be placed perpendicular to the axis of the pipe with the shoes placed so as to bear equally, as nearly as possible, on two staves. The shoes shall be placed alternatively on opposite sides of the pipe in a uniform manner. There shall be two or more rows of shoes on each side of the pipe to provide uniform bearing on a number of staves.

If necessary, bands may be hammered during the cinching process in order to remove irregularities and to insure proper seating. Extreme care shall be exercised to prevent bruising or breaking of the wood fibers. After erection, all metal work shall be retouched, where necessary with asphalt mastic or other specified coating.

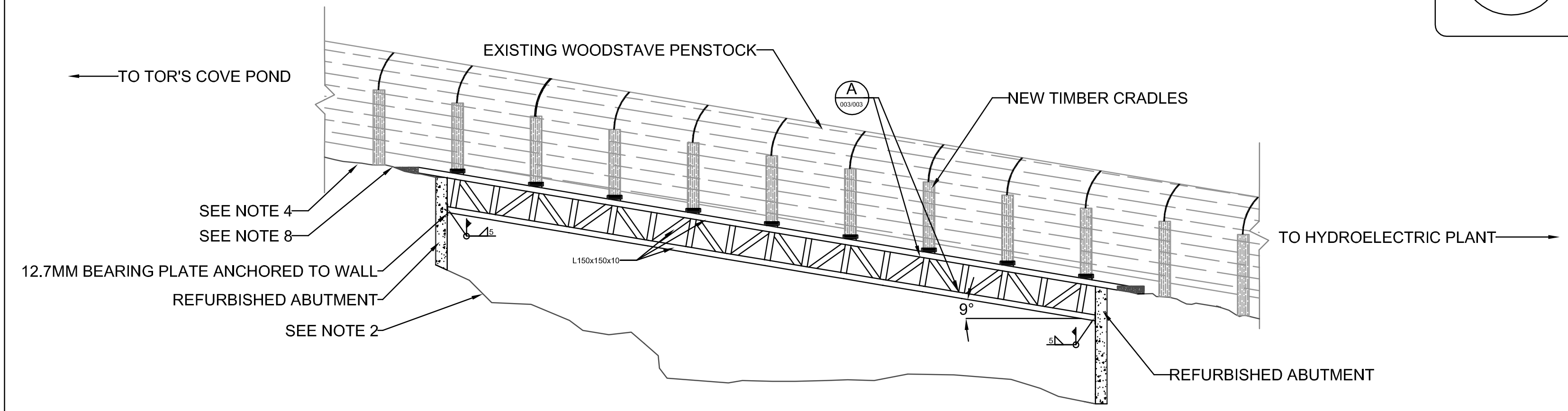
Backfilling. The pipe requires a uniform support for its full length. If situated in a trench, the pipe shall be backfilled and tamped to the horizontal diameter with material excavated from the trench, using the cleanest soil and clay available, and containing no organic matter. Following the test, the pipe shall be covered with the same grade of selected material. The balance of the backfill may be moved into place with no compaction required.

Testing. Water shall be admitted to the pipeline gradually, allowing time for the swelling of the staves before design pressure is applied. The pipe shall then be tested to full operating pressure and any running leaks closed.

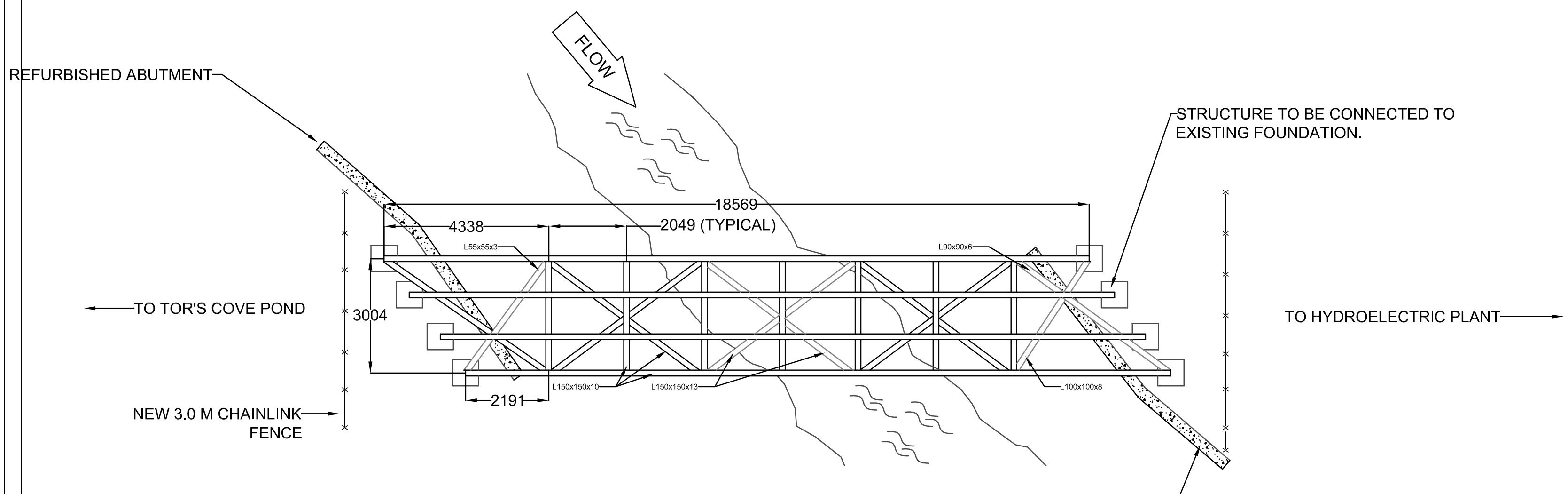
Appendix G – Bottom Truss Design



Section Properties
1 - L150X150X13
2 - L150X150X10
3 - L100X100X8
4 - L90X90X6
5 - L75X75X8
6 - L75X75X5
7 - L65X65X8
8 - L55X55X8
9 - L55X55X3
10 - L35X35X3
11 - L25X25X3



ELEVATION VIEW



PLAN VIEW

WOODSTAVE PENSTOCK OMITTED FOR CLARITY

NOTES

1. All dimensions in millimeters (mm) UNO.
2. Existing riverbed profile unknown. Survey required.
3. All concrete to be 35MPa.
4. Existing land profile unknown. Survey required.
5. Supply and install new 3.0 meter chainlink fence. Omitted from Elevation View for clarity.
6. All timber to be Douglas Fir timber.
7. All steel to be 350W grade steel (F_y = 350MPa).
8. Foundation connection assumed to be pinned connection. Connection to be designed prior to construction.
9. New structure to be constructed below existing. New structure to use same foundation as existing. Existing to be removed after construction.
10. All welds to be weld metal E49XX (F_u = 490MPa).

REV	DATE	DESCRIPTION	APPROVED
A	03/08/26	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
BOTTOM SUPPORT - TRUSS
PLAN AND ELEVATION

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

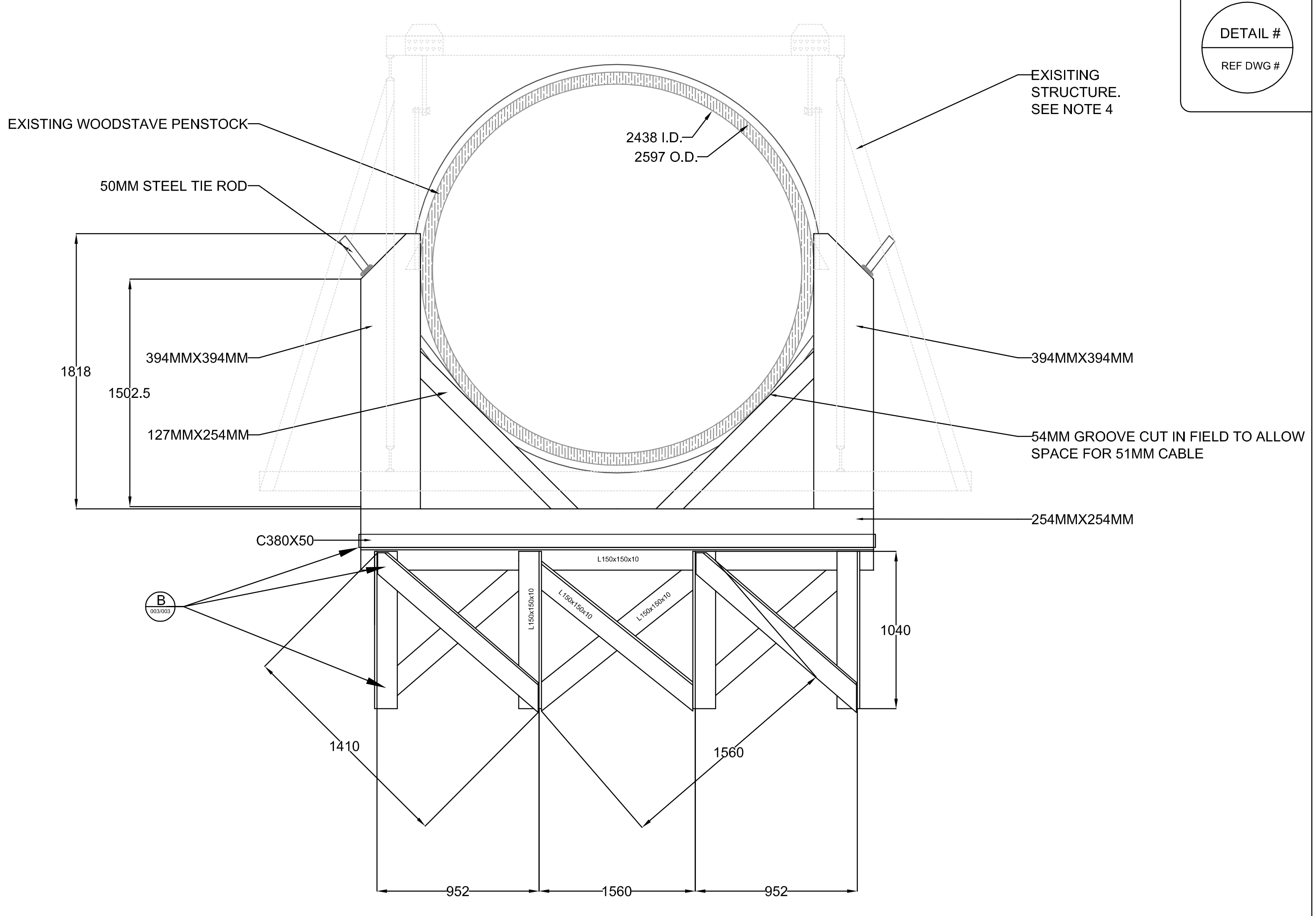
REVISION DESCRIPTION
-

DESIGN BY	WGC/JAS	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	

DATE	03/10/26	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
BTRUSS-001/003

NOT FOR FABRICATION USE



TYPICAL CROSS SECTION

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All timber to be Douglas Fir timber.
3. All steel to be 350W grade steel (Fy = 350MPa).
4. New structure to be constructed above existing. Existing to be removed after construction.
5. 254mm x 254mm wood cradle base to be connected to C380x50 shoe. Connection to be designed. Shoe to be welded on site with 10MM fillet weld.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/26	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
BOTTOM SUPPORT - TRUSS
CROSS-SECTION

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

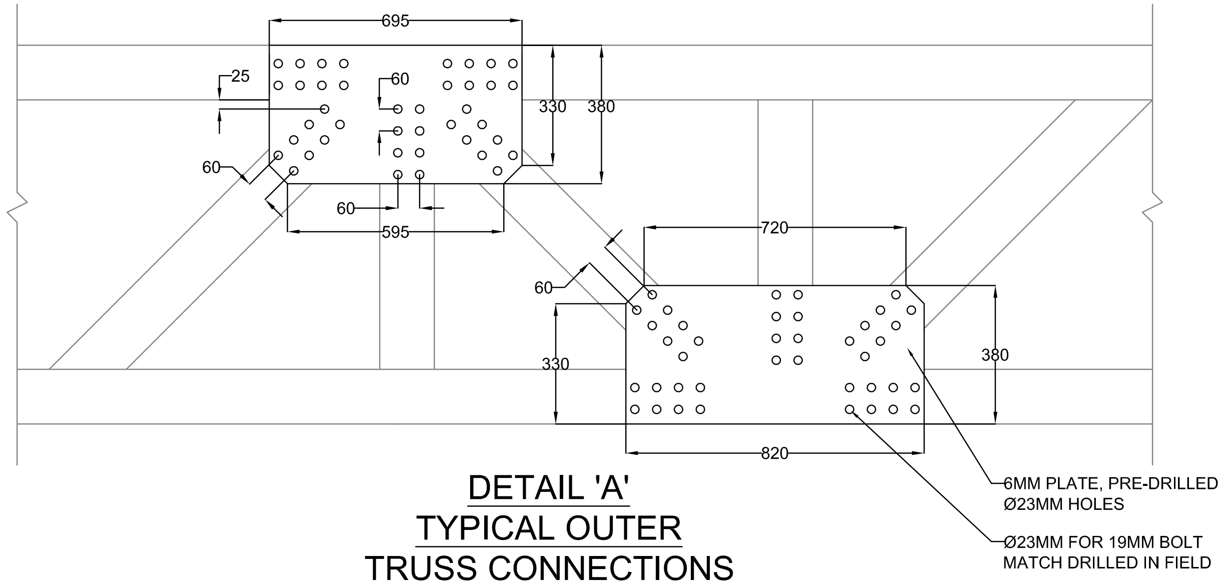
REVISION DESCRIPTION
-

DESIGN BY	WGC/JAS	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	

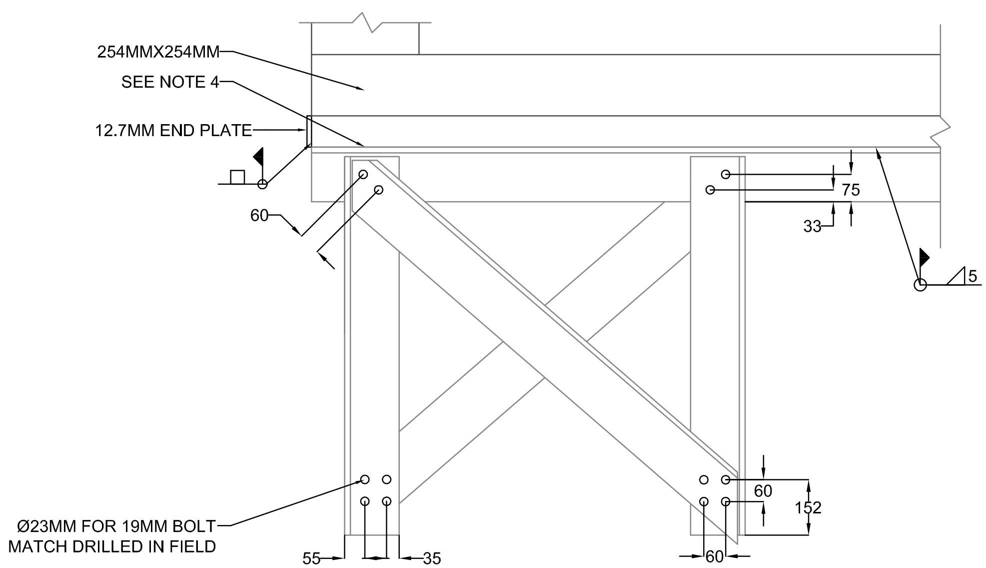
DATE	03/10/26	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
BTRUSS-002/003

NOT FOR FABRICATION USE



DETAIL 'A'
TYPICAL OUTER
TRUSS CONNECTIONS



DETAIL 'B'
TYPICAL CROSS-BRACING
CONNECTIONS

NOTES
1. All dimensions in millimeters (mm) UNO.
2. All bolted connections to be A325 bolts (Fu = 825MPa).
3. All welds to be weld metal E49XX (Fu = 490MPa).
4. 254mm x 254mm wood cradle base to be connected to C380x50 shoe. Connection to be designed. Shoe to be welded on site with 10MM fillet weld.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/26	ORIGINAL DESIGN	--

REVISION HISTORY

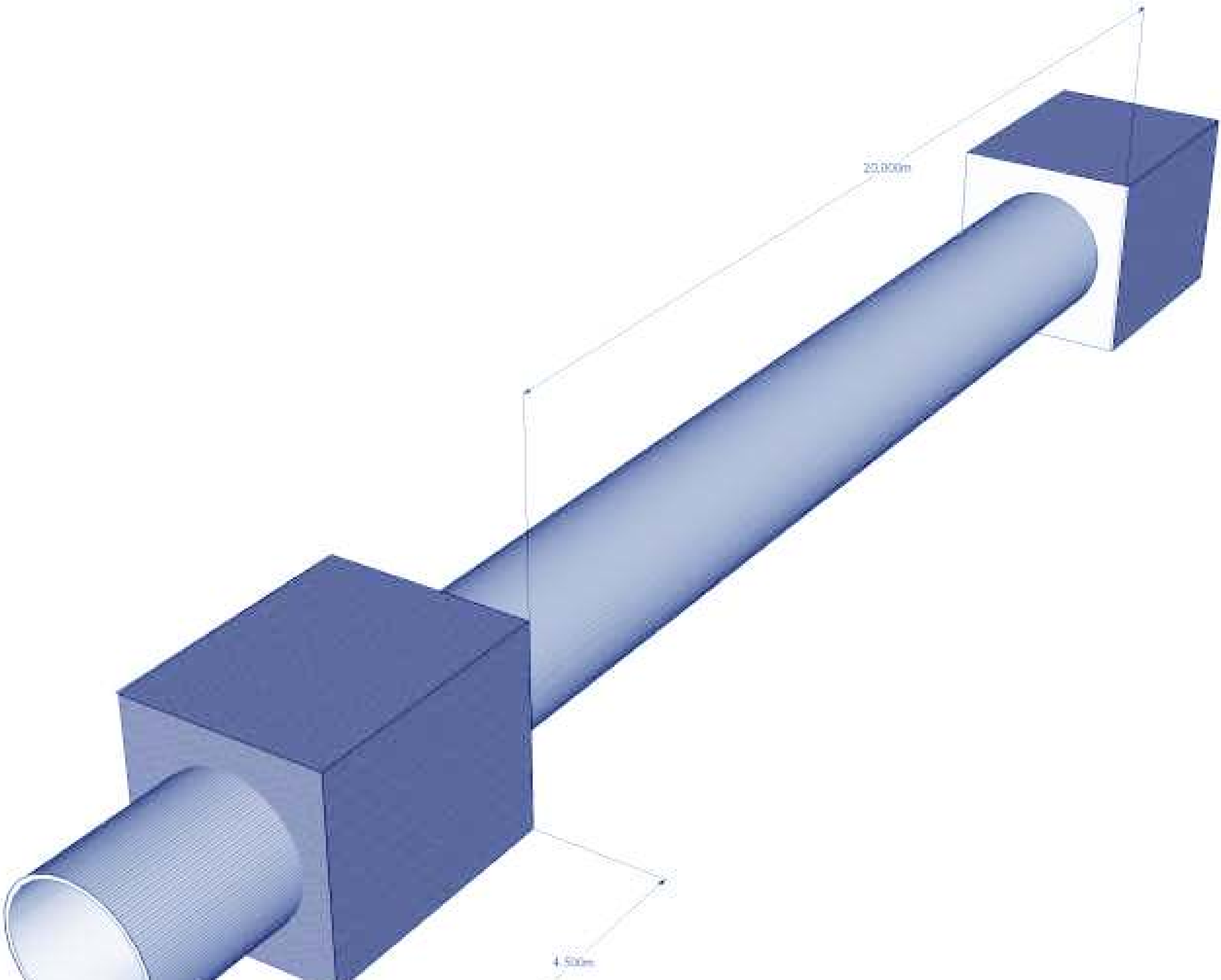
NEWFOUNDLAND POWER
A FORTIS COMPANY

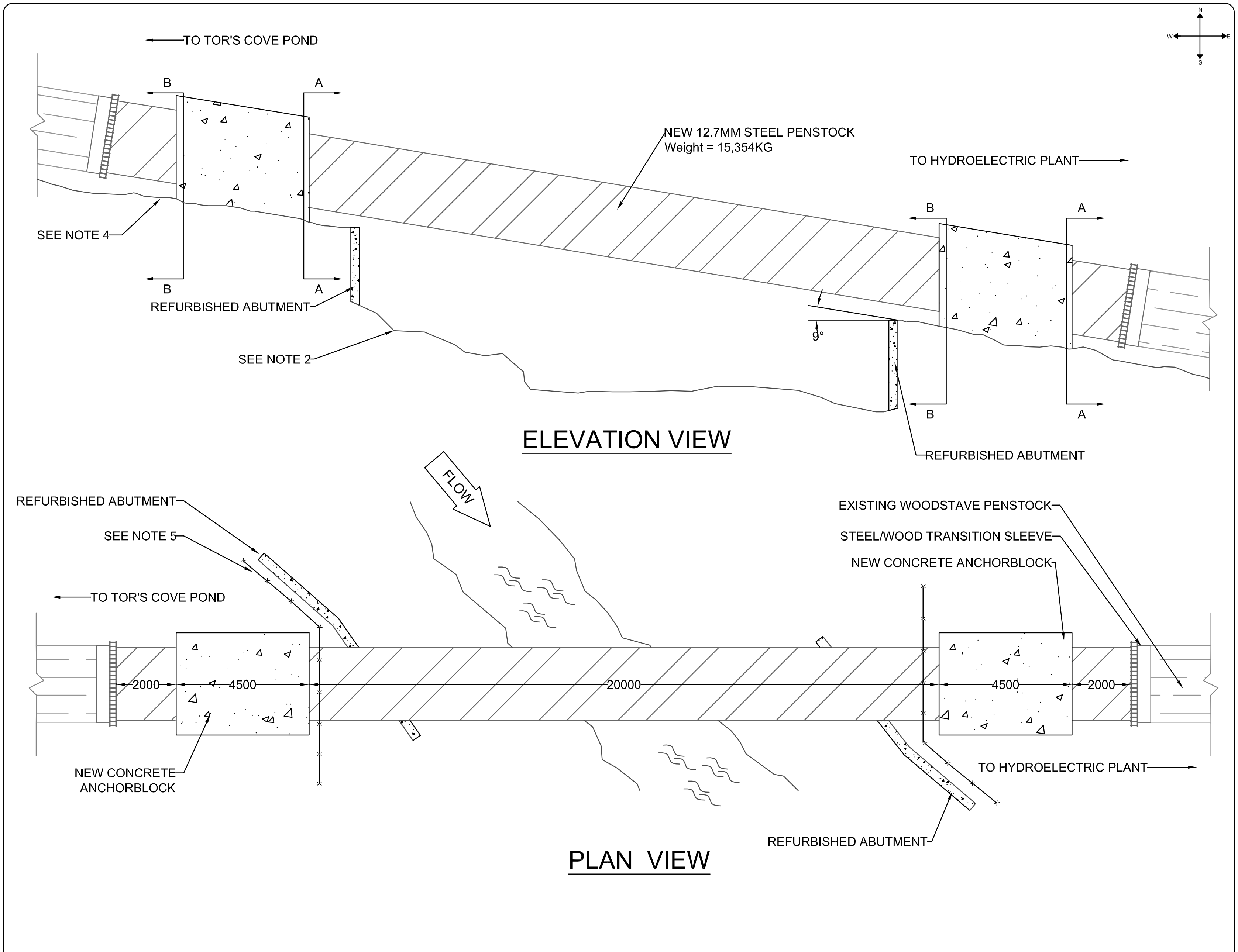
CASC CONSULTING

TITLE: BOTTOM SUPPORT - TRUSS CONNECTION DETAILS	
PROJECT: NL POWER TRESTLE REPLACEMENT	
LOCATION: TOR'S COVE, NEWFOUNDLAND	
REVISION DESCRIPTION: -	
DESIGN BY: WGC/JAS	CHECK BY: WGC
DRAWN BY: PSC	APPROVED BY:
DATE: 03/10/26	SCALE: N.T.S — REVISION #: A
DRAWING REFERENCE NUMBER: BTRUSS-003/003	

NOT FOR FABRICATION USE

Appendix H – Steel Penstock Design


20.000m
4.500m



NOTES

1. All dimensions in millimeters (mm) UNO.
2. Existing riverbed profile unknown. Survey required
3. All concrete to be 35MPa.
4. Existing land profile unknown. Survey required.
5. Supply and install new 3.0 meter chainlink fence. Omitted from Elevation View for clarity.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/13	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

CASC CONSULTING

TITLE
STEEL PENSTOCK DESIGN
PLAN AND ELEVATION

PROJECT
NL POWER TRESTLE REPLACEMENT

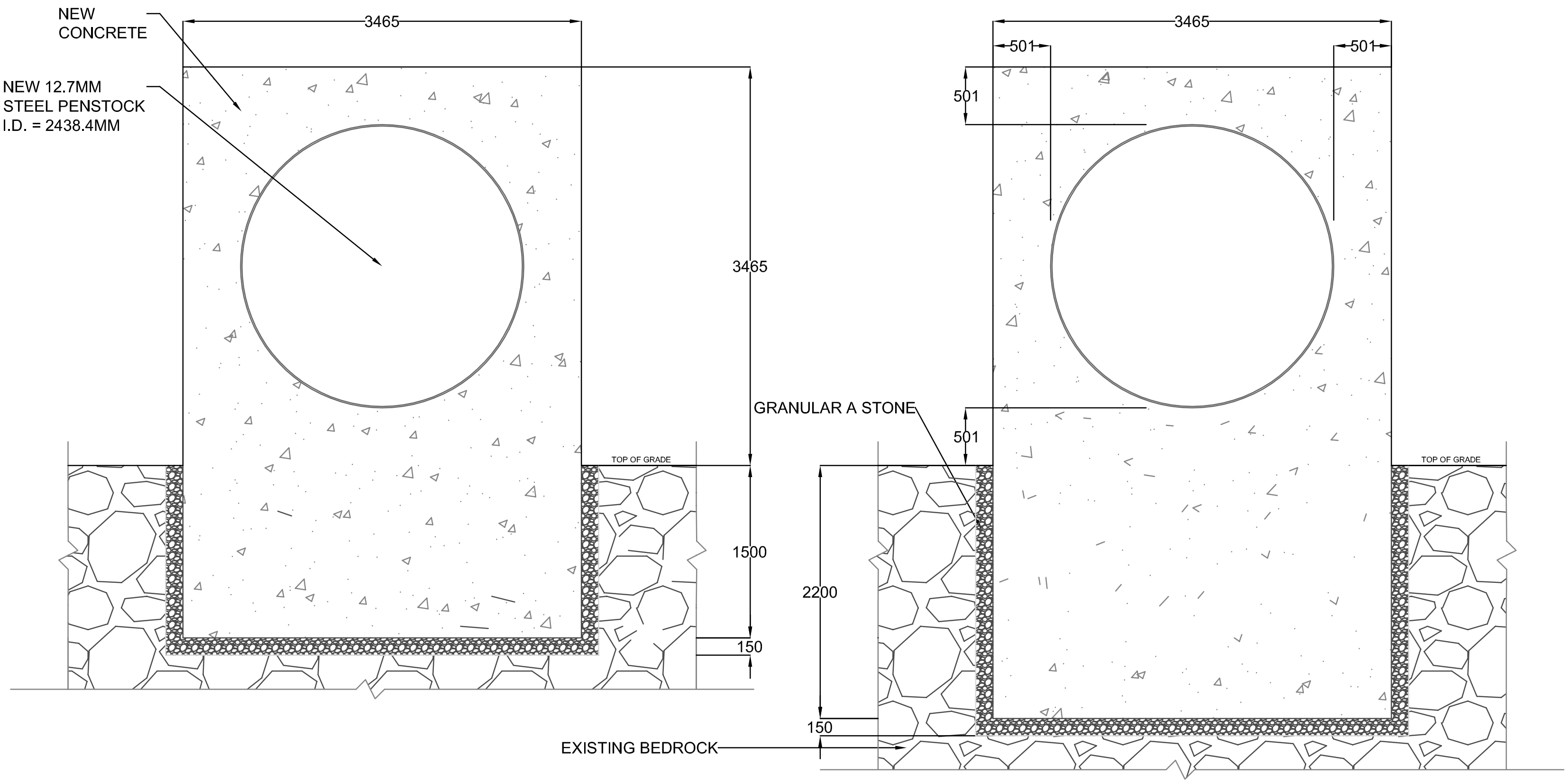
LOCATION
TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION
-

DESIGN BY	WGC/PSC	CHECK BY	WGC		
DRAWN BY	PSC	APPROVED BY			
DATE	03/10/13	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
STEELPEN-001/003

NOT FOR FABRICATION USE



TYPICAL
ANCHOR BLOCK
CROSS SECTION
A - A

TYPICAL
ANCHOR BLOCK
CROSS SECTION
B - B

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All concrete to be 35MPa.
3. See STEELPEN - 003/003 for typical reinforcement detail.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/13	ORIGINAL DESIGN	--

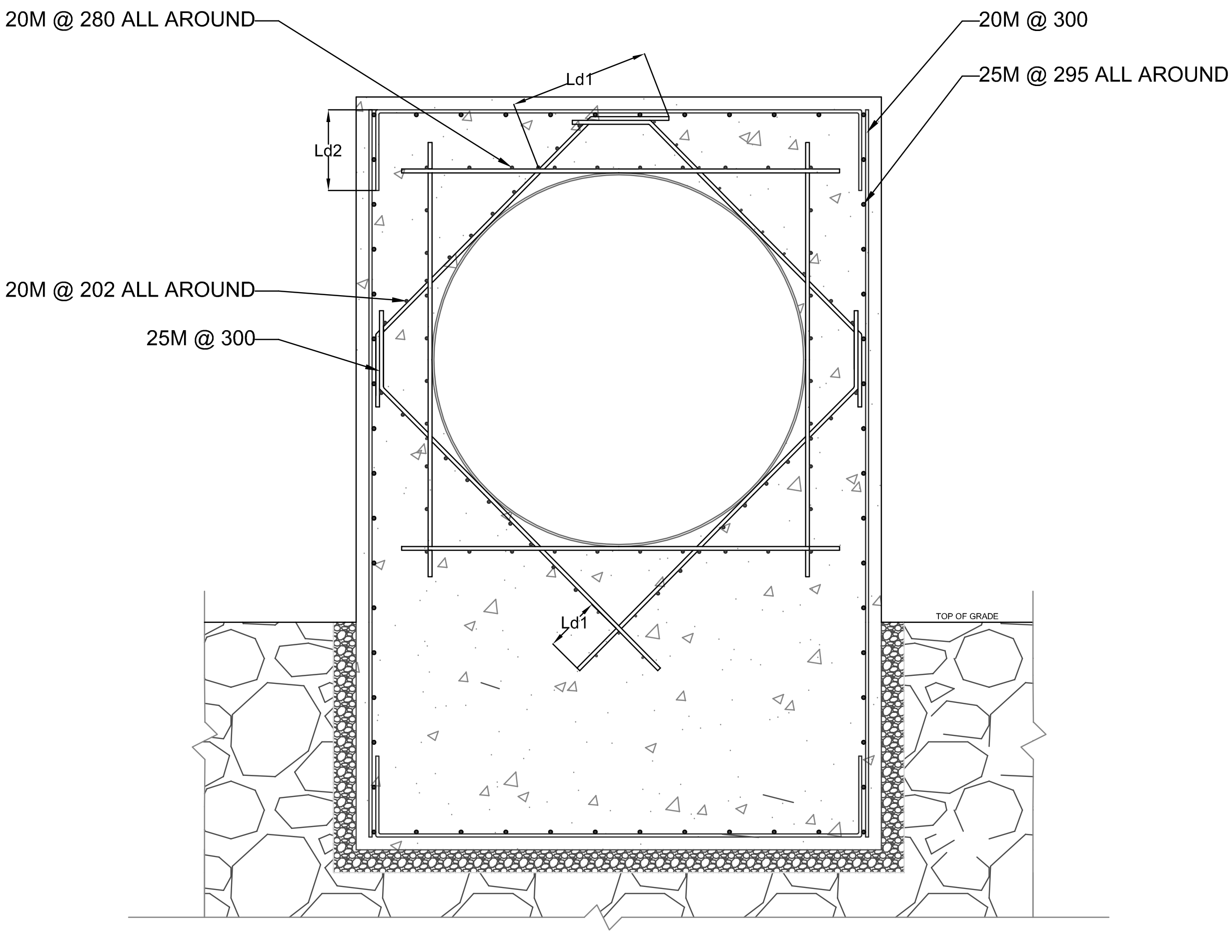
REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE	STEEL PENSTOCK DESIGN CROSS-SECTIONS
PROJECT	NL POWER TRESTLE REPLACEMENT
LOCATION	TOR'S COVE, NEWFOUNDLAND
REVISION DESCRIPTION	-
DESIGN BY	WGC/PSC
CHECK BY	WGC
DRAWN BY	PSC
APPROVED BY	
DATE	03/10/13
SCALE	N.T.S
REVISION #	A
DRAWING REFERENCE NUMBER	STEELPEN-002/003

NOT FOR FABRICATION USE



TYPICAL ANCHOR BLOCK REINFORCEMENT DETAIL

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All concrete to be 35MPa.
3. Reinforcement shown is assumed for costing purposes only. Actual reinforcement to be designed prior to construction.
8. Ld1 = Lap Length for 25M to be determined in design.
   Ld2 = Development Length for 20M to be determined in design.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/15	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

CASC CONSULTING

TITLE: STEEL PENSTOCK DESIGN
REINFORCEMENT DETAILS

PROJECT: NL POWER TRESTLE REPLACEMENT

LOCATION: TOR'S COVE, NEWFOUNDLAND

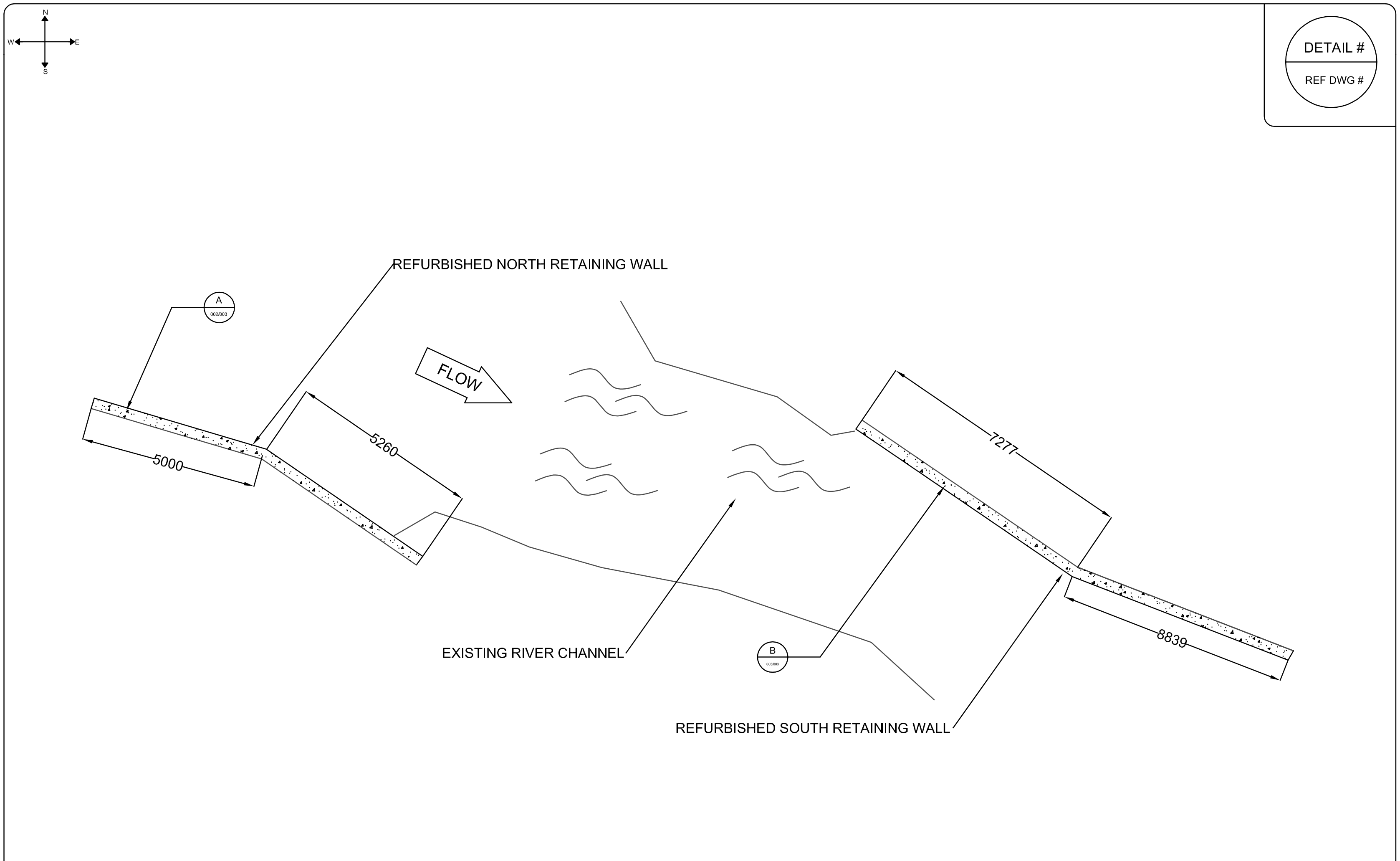
REVISION DESCRIPTION: -

DESIGN BY	WGC/PSC	CHECK BY	WGC
DRAWN BY	PSC	APPROVED BY	
DATE 03/10/15	SCALE N.T.S	REVISION # A	

DRAWING REFERENCE NUMBER: STEELPEN-003/003

NOT FOR FABRICATION USE

Appendix I – Retaining Wall



PLAN VIEW

NOTES
1. All dimensions in millimeters (mm) UNO.
2. All concrete to be 35MPa.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/15	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER A FORTIS COMPANY

CASC CONSULTING

TITLE: RETAINING WALL REHAB
PLAN VIEW

PROJECT: NL POWER TRESTLE REPLACEMENT

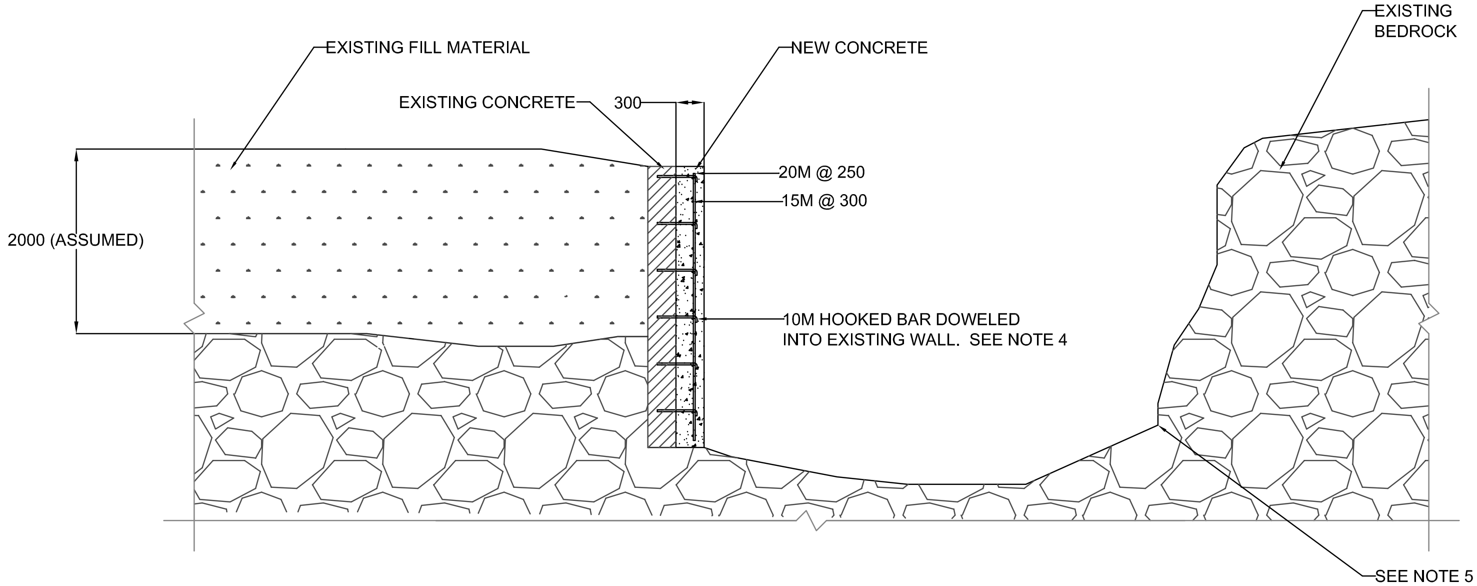
LOCATION: TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION: -

DESIGN BY: WGC		CHECK BY: PSC	
DRAWN BY: WGC/PSC		APPROVED BY:	
DATE: 03/08/15	SCALE: N.T.S	REVISION #: A	

DRAWING REFERENCE NUMBER: RW-001/003

NOT FOR FABRICATION USE



DETAIL 'A'
NORTH WALL
REFURBISHMENT

NOTES
1. All dimensions in millimeters (mm) UNO.
2. All concrete to be 35MPa.
3. Chip and remove deteriorated existing concrete face as directed by owner.
4. Install hooked reinforcement on a 600 x 600 grid.
5. Existing land and riverbed profiles unknown. Survey required.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/15	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE
RETAINING WALL REHAB
ELEVATION VIEW - NORTH WALL

PROJECT
NL POWER TRESTLE REPLACEMENT

LOCATION
TOR'S COVE, NEWFOUNDLAND

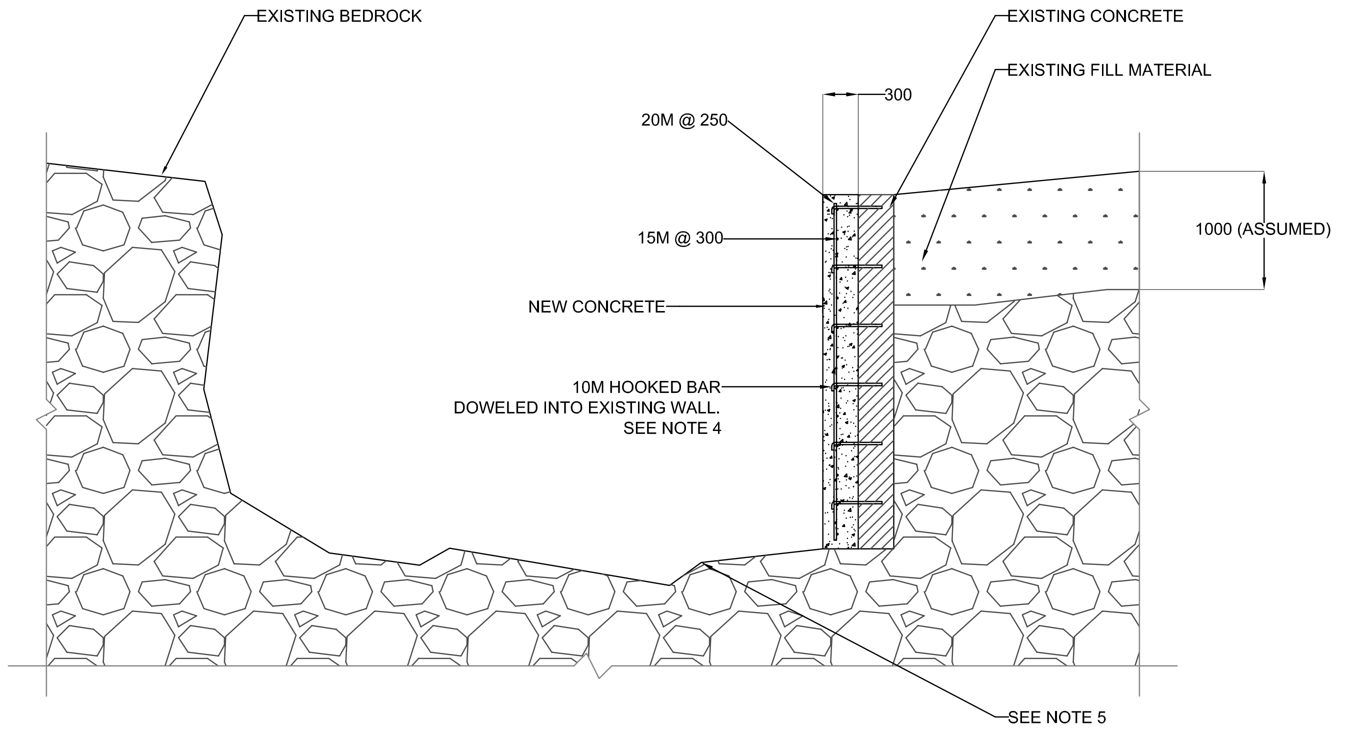
REVISION DESCRIPTION
-

DESIGN BY	WGC	CHECK BY	PSC
DRAWN BY	WGC/PSC	APPROVED BY	

DATE	03/08/15	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER
RW-002/003

NOT FOR FABRICATION USE



DETAIL 'B'
SOUTH WALL
REFURBISHMENT

NOTES

1. All dimensions in millimeters (mm) UNO.
2. All concrete to be 35MPa.
3. Chip and remove deteriorated existing concrete face as directed by owner.
4. Install hooked reinforcement on a 600 x 600 grid.
5. Existing land and riverbed profiles unknown. Survey required.

REV	DATE	DESCRIPTION	APPROVED
A	03/08/15	ORIGINAL DESIGN	--

REVISION HISTORY

NEWFOUNDLAND POWER
A FORTIS COMPANY

CASC CONSULTING

TITLE: RETAINING WALL REHAB
ELEVATION VIEW - SOUTH WALL

PROJECT: NL POWER TRESTLE REPLACEMENT

LOCATION: TOR'S COVE, NEWFOUNDLAND

REVISION DESCRIPTION: -

DESIGN BY	WGC	CHECK BY	PSC		
DRAWN BY	WGC/PSC	APPROVED BY			
DATE	03/08/15	SCALE	N.T.S	REVISION #	A

DRAWING REFERENCE NUMBER: RW-003/003

NOT FOR FABRICATION USE

Appendix J – Detailed Cost Estimates

Detailed Cost Estimates - Summary

Concept	Contract Cost	Total Cost
Bottom Support (Truss)	$468,122	$679,095
Bottom Support (beams)	$512,449	$742,926
Rehabilitation	$489,691	$798,300
Complete Replacement	$575,815	$834,173
Steel Penstock	$608,950	$845,351
Top Support	$619,068	$896,457

Detailed Cost Estimate - Steel Penstock

Summary	Cost
Contract Cost	$608,950.00
Contingency (20%)	$121,790.00
Engineering (15%)	$109,611.00
Subtotal	$840,351.00
Survey	$5,000.00
TOTAL	**$845,351.00**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$15,000.00
Demob	1	LS	2% of Contract	$10,000.00
Site Preparation				
Clearing and Grubbing	0.25	hect	17000	$4,250.00
Dewatering	45	day	250	$11,250.00
Bulkhead	1	EA	20000	$20,000.00
Structural				
Concrete Anchor Blocks	128	m^3	1000	$128,000.00
Steel penstock	32	LM	3000	$96,000.00
Exansion Joint	1	EA	10000	$10,000.00
Granular A fill	25	t	22	$550.00
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Safety Enclosure				
Chain link fencing	16	LM	400	$6,400.00
Equipment				
Crane	10	day	3600	$36,000.00
Scaffolding	20	day	750	$15,000.00
Utility Pole				
Relocation	1	EA	25000	$25,000.00
Demolition				
Demolition of Existing Trestle	400	m	75	$30,000.00
Pipe Demolition	35	m	500	$17,500.00
Plant Downtime				
Downtime	45	day	3000	$135,000.00
Total				**$608,950.00**

Detailed Cost Estimate - Rehabilitation

Summary	Cost
Contract Cost	$489,691.10
Contingency (35%)	$171,391.89
Engineering (20%)	$132,216.60
Subtotal	$793,299.58
Survey	$5,000.00
TOTAL	**$798,299.58**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$13,991.16
Demob	1	LS	2% of Contract	$9,327.44
Site Preparation				
Thickness Testing	1		100000	$100,000.00
Dewatering	45	day	250	$11,250.00
Survey	3	day	3000	$9,000.00
Trestle Components				
Steel	2.1	t	45000	$93,150.00
Connections				$13,972.50
Paint and sand blast	1		125000	$125,000.00
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Equipment				
Scaffolding	45	day	1000	$45,000.00
Demolition				
Demolition of Trestle	133.33	m	150	$20,000.00
Total				**$489,691.10**

Detailed Cost Estimate -Complete Replacement

Summary	Cost
Contract Cost	$575,814.75
Contingency (20%)	$115,162.95
Engineering (20%)	$138,195.54
Subtotal	$829,173.24
Survey	$5,000.00
TOTAL	**$834,173.24**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$16,451.85
Demob	1	LS	2% of Contract	$10,967.90
Site Preparation				
Clearing and Grubbing	0.25	hect	17000	$4,250.00
Dewatering	60	day	250	$15,000.00
Survey	3	day	300	$900.00
Trestle Components				
Structural Steel	6.2100	t	30000	$186,300.00
Connections				$27,945.00
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Equipment				
Crane	25	day	3600	$90,000.00
Scaffolding	60	day	1000	$60,000.00
Utility Pole				
Relocation	1	EA	25000	$25,000.00
Demolition				
Demolition of Trestle	400	m	225	$90,000.00
Total				**$575,814.75**

Detailed Cost Estimate -Top Support

Summary	Cost
Contract Cost	$619,067.65
Contingency (20%)	$123,813.53
Engineering (20%)	$148,576.24
Subtotal	$891,457.42
Survey	$5,000.00
TOTAL	**$896,457.42**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$17,687.64
Demob	1	LS	2% of Contract	$11,791.76
Site Preparation				
Clearing and Grubbing	0.25	hect	17000	$4,250.00
Dewatering	35	day	250	$8,750.00
Trestle Components				
W410X100	9.7190	t	10000	$97,190.00
W250X58	2.5800	t	10000	$25,800.00
C200X17	0.5600	t	15000	$8,400.00
L125X125X10	0.8790	t	15000	$13,185.00
W460X128	1.5920	t	10000	$15,920.00
W250X167	6.3020	t	10000	$63,020.00
L125X125X13	0.0960	t	15000	$1,440.00
19mm Steel Cable	100	m	125	$12,500.00
Connections				$33,743.25
Concrete Foundation	87	m^3	1200	$104,400.00
Granular A fill	70	t	22	$1,540.00
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Safety Enclosure				
Chain link fencing	8	LM	400	$3,200.00
Equipment				
Crane	10	day	3600	$36,000.00
Scaffolding	35	day	750	$26,250.00
Utility Pole				
Relocation	1	EA	25000	$25,000.00
Demolition				
Demolition of Trestle	400	m	150	$60,000.00
Total				**$619,067.65**

Detailed Cost Estimate -Bottom Support (Beam)

Summary	Cost
Contract Cost	$512,448.95
Contingency (20%)	$102,489.79
Engineering (20%)	$122,987.75
Subtotal	$737,926.49
Survey	$5,000.00
TOTAL	**$742,926.49**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$14,641.38
Demob	1	LS	2% of Contract	$9,760.92
Site Preparation				
Clearing and Grubbing	0.25	hect	17000	$4,250.00
Dewatering	35	day	250	$8,750.00
Chip and Remove Bedrock	25	m^3	400	$10,000.00
Structural Components				
W Steel Sections	13.518	t	12000	$162,216.00
L Steel Sections	0.581	t	15000	$8,715.00
Wood Crib	10	EA	1500	$15,000.00
Connections				$27,889.65
Concrete Foundation	1.48	m^3	1200	$1,776.00
50mm Steel Cable	140	m	125	$17,500.00
Temporary Supports	5	EA	200	$1,000.00
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Safety Enclosure				
Chain link fencing	8	LM	400	$3,200.00
Equipment				
Crane	15	day	4500	$67,500.00
Scaffolding	35	day	750	$26,250.00
Utility Pole				
Relocation	1	EA	25000	$25,000.00
Demolition				
Demolition of Trestle	400	m	150	$60,000.00
Total				**$512,448.95**

Detailed Cost Estimate -Bottom Support (Truss)

Summary	Cost
Contract Cost	$468,121.85
Contingency (20%)	$93,624.37
Engineering (20%)	$112,349.24
Subtotal	$674,095.46
Survey	$5,000.00
TOTAL	**$679,095.46**

Note: All unit prices include labour and materials required for installation and exclude HST

Item	Quantity	Unit	Estimated Unit Price	Cost
Mobilization				
Mob	1	LS	3% of Contract	$12,860.61
Demob	1	LS	2% of Contract	$8,573.74
Site Preparation				
Clearing and Grubbing	0.25	hect	17000	$4,250.00
Dewatering	50	m^2	250	$12,500.00
Chip and Remove Bedrock	25	m^3	400	$10,000.00
Structural Components				
L Steel Sections	9.314	t	15000	$139,710.00
Wood Crib	10	m^3	1500	$15,000.00
Connections				$34,927.50
Concrete Abutment				
Concrete (includes rebar)	35	m^3	1400	$49,000.00
Safety Enclosure				
Chain link fencing	12	LM	400	$4,800.00
Equipment				
Crane	15	day	3600	$54,000.00
Scaffolding	50	day	750	$37,500.00
Utility Pole				
Relocation	1	EA	25000	$25,000.00
Demolition				
Demolition of Trestle	400	m	150	$60,000.00
Total				**$468,121.85**

Future Economic Cost

Inflation Rate:	0.03
Capital Rate	0.07
Current Year	2013
2013 Steel Price	200000

Year	Inflated Value	Present Value
2015	$ 212,180.00	$185,326.23
2020	$ 245,974.77	$153,180.73
2025	$ 285,152.18	$126,610.98
2030	$ 330,569.53	$104,649.85
2035	$ 383,220.68	$86,497.95
2040	$ 444,257.80	$71,494.57
2045	$ 515,016.55	$59,093.58

Fields Highlighted in red are greater than steel penstock total cost of: $845,351.00

Rehabilitation		
Year	Contract	Total
2020	$642,871.83	$1,073,595.95
2025	$616,302.08	$1,029,224.47
2030	$594,340.95	$992,549.38
2035	$576,189.05	$962,235.72
2040	$561,185.67	$937,180.07
2045	$548,784.68	$916,470.42

Replacement		
Year	Contract	Total
2020	$728,995.48	$1,086,203.26
2025	$702,425.73	$1,046,614.33
2030	$680,464.60	$1,013,892.25
2035	$662,312.70	$986,845.93
2040	$647,309.32	$964,490.89
2045	$634,908.33	$946,013.41

Top Support		
Year	Contract	Total
2020	$772,248.38	$1,150,650.08
2025	$745,678.63	$1,111,061.15
2030	$723,717.50	$1,078,339.07
2035	$705,565.60	$1,051,292.75
2040	$690,562.22	$1,028,937.71
2045	$678,161.23	$1,010,460.23

Bottom Support - Truss		
Year	Contract	Total
2020	$621,302.58	$925,740.84
2025	$594,732.83	$886,151.91
2030	$572,771.70	$853,429.83
2035	$554,619.80	$826,383.51
2040	$539,616.42	$804,028.47
2045	$527,215.43	$785,550.99

Bottom Support - Beam		
Year	Contract	Total
2020	$665,629.68	$991,788.22
2025	$639,059.93	$952,199.29
2030	$617,098.80	$919,477.21
2035	$598,946.90	$892,430.89
2040	$583,943.52	$870,075.85
2045	$571,542.53	$851,598.37