Newfoundland and Labrador Hydro
Hydro Place. 500 Columbus Drive
P.O. Box 12400. St. John's. NL
Canada A1B 4K7
t. 709.737.1400 | f. 709.737.1800
nlhydro.com

March 29, 2023

Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, NL A1A 5B2

Attention: Cheryl Blundon
Director of Corporate Services and Board Secretary

**Re: Application for Approval of Capital Expenditures for Section Replacement and Weld Refurbishment for Bay d'Espoir Hydroelectric Generating Facility Penstock 1 – Penstock Lining Assessment**

On February 7, 2022, Newfoundland and Labrador Hydro ("Hydro") filed its reply to party comments made on its application before the Board of Commissioners of Public Utilities ("Board") requesting approval for section replacement and weld refurbishment of Penstock 1 at the Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir"). Newfoundland Power Inc. ("Newfoundland Power") had referenced Hydro's response to request for information NP-NLH-005 of this proceeding, specifically Hydro's statement that it had requested its consultant, Kleinschmidt, to document its findings on the suitability of the fibre wrap alternatives and why they are not the preferred alternatives for Bay d'Espoir Penstock 1. At the time of Hydro's reply,[1] the final version of Kleinschmidt's report had not been received; however, Hydro advised that it had no objection to filing the report once it was received.

Attachment 1 provides the memorandum from Kleinschmidt evaluating the structural lining options for Penstocks 1 through 3 at Bay d'Espoir. The options were based on two categories of structural liner technologies, which include spray-in-place pipe and fibre-reinforced polymer. As Hydro noted in its reply, Kleinschmidt's review did not change the previously-made recommendation of penstock section replacement as the preferred option.

Should you have any questions, please contact the undersigned.

Yours truly,

**NEWFOUNDLAND AND LABRADOR HYDRO**

SWalsh

Shirley A. Walsh
Senior Legal Counsel, Regulatory
SAW/sk

[1] "Application for Approval of Capital Expenditures for Section Replacement and Weld Refurbishment for Bay d'Espoir Hydroelectric Generating Facility Penstock 1– Hydro's Reply," Newfoundland and Labrador Hydro, February 7, 2023.

ecc:

**Board of Commissioners of Public Utilities**
Jacqui H. Glynn
PUB Official Email

**Labrador Interconnected Group**
Senwung F. Luk, Olthuis Kleer Townshend LLP
Nicholas E. Kennedy, Olthuis Kleer Townshend LLP

**Newfoundland Power Inc.**
Dominic J. Foley
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**Island Industrial Customer Group**
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**Consumer Advocate**
Dennis M. Browne, KC, Browne Fitzgerald Morgan Avis & Wadden
Stephen F. Fitzgerald, Browne Fitzgerald Morgan Avis & Wadden
Sarah G. Fitzgerald, Browne Fitzgerald Morgan Avis & Wadden
Bernice Bailey, Browne Fitzgerald Morgan Avis & Wadden
Bernard M. Coffey, KC

# Attachment 1

## Bay d'Espoir – Penstock Lining Assessment & OPCC
## Front End Engineering and Design (2670034.01)

March 23, 2023

**Via Email**

Dylan Drake
Newfoundland and Labrador Hydro
Hydro Place, 500 Columbus Drive
St. John's, NL A1B 47K

Re: Bay d'Espoir – Penstock Lining Assessment & OPCC
Front End Engineering and Design (2670034.01)

Dear Mr. Drake.:

Kleinschmidt Associates Canada Inc. (Kleinschmidt) is providing Newfoundland and Labrador Hydro (NL Hydro) this memorandum evaluating structural lining options for Penstocks 1 through 3 at the Bay d'Espoir (BDE) Hydroelectric Project. The options are based upon two categories of structural liner technologies which include spray-in-place-pipe (SIPP) and fiber-reinforced polymer (FRP).

Other structural lining technologies were considered but ruled out from further evaluation due to cost and constructability issues. These lining technologies are discussed in Section 3.3 of this memorandum and include shotcrete cast-in-place pipe (CIPP) liners, and PVC wound liners.

Kleinschmidt evaluated the two different structural lining technologies for rehabilitation of the 5.2-meter diameter section and compared them to Option 3, replacement of the 5.2-meter diameter section as recommended during the FEED project.

The SIPP liner was found to be the lowest cost option of the two lining options evaluated; however, the cost is greater than the recommended Option 3. This study finds that a structural lining system is expected to cost more than a steel replacement, have higher performance risks than replacement, a shorter expected service life, and potentially negatively impact generation. Moving forward with Option 3 of the FEED study to replace the 5.2-meter diameter section with new steel pipe is recommended.

## 1.0 PURPOSE

The existing Penstocks 1 through 3 at the Bay d'Espoir Hydroelectric project require rehabilitation to provide asset integrity and reliability. As part of the Front-End Engineering and Design (FEED) project, Kleinschmidt was requested to evaluate the feasibility of utilizing structural lining technologies to rehabilitate Penstocks 1 through 3 at the Bay d'Espoir Development. Option 3, the replacement of the 5.2-meter (17-foot) diameter section, was selected as the option to move forward with during the FEED Project. Therefore, the cost, reliability, and overall service life expectancy of the lining technologies considered were evaluated and compared to Option 3. Only the 5.2-meter section was considered for lining instead of replacement, the remainder of the penstock refurbishment remains the same.

## 2.0 BACKGROUND AND EXISTING CONDITIONS

On May 21, 2016, a crack in Penstock 1 was found 260 meters downstream of the intake. The crack was inspected and repaired. Subsequent failures in September 2016 and November 2017 prompted extensive investigations and inspections to determine the root cause of the failures of Penstock 1. Since Penstock 2 and 3 are of similar vintage, design and construction, there was concern of further weld failures in all three penstocks leading to the inspection of Penstocks 2 and 3 in the succeeding years. Like Penstock 1, cracks were identified in Penstocks 2 and 3. The cracks were repaired and NLH initiated a penstock inspection program requiring an inspection of each penstock every year until the penstocks have been refurbished or replaced. The inspection program was initiated due to the identified cracking, weld deterioration, and corrosion.

Measurements of the shell thickness for each penstock have indicated some small loss of material thickness in comparison to initial design. Moderate corrosion and pitting of the plate steel has been noted in inspection reports for each penstock.

As a part of the inspection program, approximately 10% of the longitudinal welds in each penstock are inspected yearly, via magnetic particle non-destructive testing. Since 2016 weld indications have primarily been observed within the 5.2-meter diameter section of the penstocks which is constructed of a different steel grade compared to the 4.65-meter and 4.1-meter diameter sections. Throughout the inspection program, multiple indications have been observed in refurbished welds. This may be the result of one or a combination of known stress contributors including the peaking phenomenon, cyclic loading, or the weakening of the base material in the heat affected zone.

Multiple indications observed along refurbished welds has yielded low confidence in the reliability of the weld repairs and a lack of confidence in prolonging the service life of the penstocks by only weld refurbishment in the 5.2-meter diameter section. As a result, it has been recommended that the 5.2-meter diameter section be completely replaced for Penstocks 1 through 3 with the remaining sections of the penstock to be refurbished. This memo explores the option of lining the 5.2-meter section instead of replacing.

## 3.0 DESCRIPTION OF LINING OPTIONS

Two feasible categories of structural lining technologies were evaluated for Penstocks 1 through 3 at the Bay d'Espoir Development, spray-in-place pipe (SIPP) and fiber-reinforced polymer (FRP) linings. The FRP category includes carbon fiber and fiber glass.

Each option was evaluated based on cost to supply and install, potential head losses that could impact generation, penstock strength increase, estimated service life, and future maintenance and monitoring requirements. All options would require adequate preparation of the existing penstock interior to ensure a clean dry environment to promote adequate adhesion between the steel plate substrate and structural lining. The information presented and discussed in Sections 3.1 through 3.3 has been provided to Kleinschmidt from vendors during previous penstock structural lining projects. No vendors were contacted for the purpose of developing this memorandum and evaluation.

### 3.1 Option 1 – Spray-In-Place Pipe Liner

Option 1 consists of a spray-in-place structural pipe lining of the penstock. SIPP liners generally include the application of cement mortars, epoxies, geopolymers and polyureas. However, an epoxy-based SIPP liner would be best suited for the rehabilitation of the penstocks at Bay d'Espoir. Cement mortars and geopolymers would need to be much thicker than an epoxy impacting headloss while also not being as durable as an epoxy, so they were not considered further. A polyurea can be both stronger and more flexible than an epoxy liner; however, it is more expensive, so this study moved forward with an epoxy liner for comparison purposes.

Epoxy SIPP liners are generally applied in a one coat application up to a thickness of 13 mils but can be applied in multiple lifts. Thickness is based upon the required structural capacity of the lining. SIPP liners are typically semi-structural liners which work compositely with the existing pipe and are not a fully independent structural system. Given that stresses in the existing penstocks are approaching industry standard recommended factors of safety, the thickness of the liner could be increased to provide additional structural capacity as needed. No engineering or design was completed to determine an appropriate SIPP lining thickness for this evaluation, therefore; the actual required thickness is unknown and estimated for this study based on judgement. The system relies on the bond between the steel plate substrate and the SIPP liner, therefore; it is imperative that the interior surface of the penstock is cleaned and appropriately prepped prior to application. This would consist of the interior being pressure washed to remove the organic buildup on the surface of the penstock, followed by sand blasting. These processes can be completed by hand, or by robotic technology.

During application of the SIPP liner, moisture within the penstock would need to be controlled to maintain dry conditions to ensure adequate bond between the steel and epoxy. If moisture on the surface of the steel plate is present during application, adhesion between the SIPP liner and steel plate can be compromised. Any leakage around the headgate could introduce moisture to the interior of the penstock and will need to be managed.

Periodic inspection of the steel plate thickness may still be required after the application of the liner to ensure adequate plate thicknesses in this composite system. Access to the bare plate steel beneath the liner could be provided by a combination of saw cutting and heavy grit sanding to reveal the plate steel to facilitate ultrasonic thickness (UT) measurement of the steel. Inspection of the plate steel is especially important if no exterior coating to prevent corrosion is present. After completion of the inspection, a hand application of epoxy can be used to repair the liner. While this method is possible, it is an added cost and complexity which would require the mobilization of a specialty contractor to prepare the steel and reapply the liner. Additionally, this method may compromise the integrity of the coating and introduce a "weak point" in the liner. An alternative to this method is to excavate the exterior of the penstock to gain access to the plate steel to facilitate UT measurements. This method would also be costly to implement and introduce added risk of damaging the penstock during excavation. Applying a thicker epoxy liner could mitigate the need to monitor the steel plate thickness but would add construction cost.

Applying the SIPP liner to the interior of the penstock will reduce the interior diameter of the existing penstock and may result is some head loss depending on the required thickness of the liner. The liner has a relatively low roughness and manning coefficient which may mitigate some head loss. It is unknown how the penstock would perform without engineering and design of the liner. The SIPP material is inherently corrosion resistant, does not rust and would require less maintenance than steel or a normal paint coating system.

### 3.2 Option 2 – Fiber-Reinforced Polymer Liner

Option 2 is a fiber-reinforced polymer (FRP) lining of the penstock. FRP composite liners consist of thin laminates that are internally bonded to structural elements using an epoxy adhesive and can significantly increase the load carrying capacity of the element. Like SIPP systems, FRP composite systems range in thickness depending on the specific FRP material used (carbon fiber, glass fiber, or synthetic) and the structural requirements. The system can be designed to be structurally integrated with the existing steel plate capacity or as a stand-alone structural system. Based on the capacity of the existing plates we have moved forward with a structurally integrated system. FRP systems are relatively low in profile and typically range between 9.5 mm (3/8") and 25.5 mm (1"), or greater in thickness, depending on application. For the penstocks located in BDE, it is likely that the liner thickness would be greater than the typical range due to the large diameter of the penstocks.

FRP composite liner systems for pipes are applied in alternating circumferential and longitudinal plies. Each fabric ply is saturated in an epoxy matrix and bonded together. A durability topcoat is applied to the final surface of the system. The fabric plies used within the system are usually fiber glass, carbine fiber, or mixture of both with the carbon fiber layers being applied over the fiber glass layers. There are a selection of fiber glass and carbon fiber fabrics strengths available that contain varied properties including tensile strength and thickness.

The surface preparation of the interior penstock would be similar to the preparation as described above for SIPP liners. Additionally, the same issues with moisture would also hold true. Depending on if the lining is a stand-alone structural system, inspection of the underlying steel will be required. If capacity relies on both the FRP system and the existing steel penstock, periodic inspection of the plate via UT measurement would be required to ensure no deterioration in the steel. Similar to above, the liner would need to be removed in small areas to facilitate the inspection. However, if the liner is designed as a standalone structural system not requiring capacity from the existing penstock, inspection of the underlying steel would not be required.

FRP liners can also be steel reinforced with the reinforcement sandwiched between the layers of fabric. The reinforcement is continuously wound producing a helical pattern. The steel reinforcement is then encapsuled in polymer or grout. Due to the system utilizing steel reinforcement, the cost would be significantly more compared to a fabric-epoxy composite system.

FRP structural lining systems considered as part of this review include the StrongPIPE V-Wrap and StrongPIPE SCL systems developed by Structural Technologies, and the Quakewrap system developed by Quakewrap, Inc.

### 3.3 Alternatives

In addition to the structural systems discussed above, other systems are available but were ruled out for application to the Bay d'Espoir Penstocks. Application of these alternatives were removed from further consideration due to cost, hydraulic performance, constructability, and/or service life.

#### 3.1.1 Shotcrete

Cast-in-place-pipe (CIPP) liners such as shotcrete are typically used to rehabilitated existing concrete pipes, storm sewers, and corrugated steel culverts. In some instances, it has been used to line existing wood stave penstocks.

Similar to other methods described above, the interior of the existing penstock would need to be cleaned prior to application. Steel reinforcement would be wound around the penstock interior with a gap being maintained between the reinforcement and the penstock shell. Application of bonding coat to the existing steel plate would be required to promote bonding between the shotcrete and penstock. Typically, shotcrete would be robotically applied to the surface to ensure consistency but can also be applied by hand. The thickness of the shotcrete would be significantly more compared to a structural SIPP or FRP liner which would decrease hydraulic performance. Additionally, the finished concrete surface would have a higher manning coefficient compared to an SIPP or FRP lining increasing head losses. The shotcrete liner could be designed to behave compositely with the existing penstock, or as a standalone structural system.

A shotcrete structural lining would not be economically feasible for the penstocks at the BDE Hydroelectric Project primarily based on cost and hydraulic performance.

Other factors include the maintenance and service life. As a result, this option was not further evaluated. Cost would be significantly more compared to other options due to the need of steel reinforcement in addition to the labor and equipment required for shotcrete application. The thickness of the shotcrete would be substantially thicker than a FRP or SIPP liner given the loads and large diameter of the penstocks which would negatively affect the hydraulic performance. Regular inspection of the liner would also be required to ensure no cracking, spalling, or deterioration of the shotcrete liner occurs. Depending on if the liner is designed to behave compositely with the existing steel penstock, inspection of the steel plate would also be required. In addition to these above factors, structural shotcrete linings applied to the interior of steel penstocks is not a common practice within the industry. A significant amount of engineering and design would be required for this option.

### 3.1.2 PVC

Polyvinyl Chloride (PVC) wound linings are typical applied to sewers, storm drains, and culverts. They can be applied to both circular and non-circular pipes. They are a fully structural system constructed of a steel reinforced PVC strip and grout system. An example of this system is the SPR structural lining system developed by Sekisui. The strips are offered as a stand-alone PVC strip.

The PVC strip is continuously wound into the pipe via a winding machine. The strips contain stiffeners which are orientated perpendicular the outer surface of the strip which leaves a void between the surface of the strip and existing penstock shell. The void is typically filled with a structural grout, depending on capacity requirements. This system was ruled out due its high cost and size and load limits.

## 4.0 EVALUATION OF LINING OPTIONS

The factors considered for the evaluation of the options presented in Section 3.0 include impact on generation, constructability, cost, service life, and maintenance. A discussion of each considered factor is presented in the following sections.

### 4.1 Impact on Generation

A hydraulic analysis was not completed as a part of this evaluation to determine the effects of a reduced diameter and different Manning's coefficient on generation or head loss. Both the epoxy SIPP and FRP liners will reduce the internal diameter of the existing penstock. This reduction could range from 50 to 150 or more millimeters, depending on the type of liner and the structural capacity requirements of the liner. FRP liners are typically thicker compared to SIPP liners, and stronger. A thinner liner would have less impact on hydraulic performance and generation. The Manning's coefficient would be similar between the two liners and would be lower compared to the corroded interior surface of the existing penstock.

### 4.2 Constructability

Due to the large diameter of the BDE penstocks, application of both an SIPP and FRP liner would involve significant labor and equipment costs compared to application to a smaller penstock. Custom scaffolding and robotic systems for hydro blasting, sandblasting, and product application would be required to facilitate the installation of these liners. However, this is not significantly different than the cleaning methods currently proposed for cleaning and coating the existing penstocks.

FRP liners are more labor intensive to install compared to the installation of SIPP liners due to the fabric layers being installed and rolled by hand. As the structural capacity requirements of a FRP system increase, there are more layers of fabric added to the system resulting in more manhours being required. A custom scaffold would be required to facilitate the installation of the fabric on the crown of the pipe. Small sections could only be installed at one time before needing to move the scaffold, complicating installation, and significantly slowing installation times.

SIPP liners can be applied either by hand or by robotic systems. Compared to FRP liners, SIPP liners are less complicated and quicker to install as application of the structural epoxy is applied monolithically. Considering a robotic system can be used to facilitate the application of the SIPP liner, fewer manhours are needed for installation in comparison to the FRP liner. However, the robotic system would likely need to be custom fabricated as common systems are not intended for use on pipe diameters as large as the BDE penstocks.

### 4.3 Service Life

Typical service life for both the FRP and SIPP structural lining systems is approximately 50 years, or more. Factors that can influence this include the amount of sediment passing through the penstock, surface prep prior to installation, and humidity during installation.

### 4.4 Maintenance

Maintenance requirements of both the FRP and SIPP structural systems are similar. Periodic inspection of the liner would be required to ensure sufficient performance of the systems. The inspections would likely start after the first year of operation and then approximately every 5 years after that depending on observed performance.

As indicated in Sections 3.1 and 3.2, inspection of the existing steel plate would be required, particularly if the system is dependent on capacity of the existing penstock. To facilitate UT measurement of the steel plate, small areas of the liner would need to be removed from the inside, or the penstock would need to be uncovered from the outside in several small areas risking damage during excavation. After inspection from the inside, the affected areas would need to be repaired, adding cost to the long-term operation of the system. Additionally, these repaired areas would create weak points within the lining. The steel inspection requirement would only be necessary if the lining relied on the existing penstock for capacity (semi-structural lining), which is assumed for all cases in this study. If the structural lining was designed as a standalone system, inspection of the underlying steel plate would likely not be required or imperative. A standalone structural system for BDE will be significantly more costly due to increased thickness and potential for increasing head losses which may decrease generation.

### 4.5 Advantages and Disadvantages

There are both advantages and disadvantages of each of the evaluated structural lining technologies. A comparison table of each option is presented in Table 1.

**Table 1 Option Comparison Table**

| Option | Advantage | Disadvantage |
|---|---|---|
| **SIPP** | • Less labor intensive to install<br>• Could be installed in a single BDE construction season<br>• Installation is cheaper<br>• Can be applied robotically<br>• Can be applied monolithically and in various layers<br>• Usually thinner compared to other technologies, lessening the impact on internal diameter. | • Predominantly a semi-structural system requiring inspection of the underlying steel plate<br>• Tends to rely on capacity from existing pipe<br>• Not as robust<br>• No reinforcing material within system<br>• More likely to crack than FRP |
| **FRP** | • Can be designed as a semi-structural or stand-alone system.<br>• Robust system offering varying strengths of fiberglass and carbon fiber mats<br>• Can be designed to not rely on existing penstock eliminating the requirement to inspect the underlying steel plate<br>• More durable and less likely to crack | • Labor intensive installation as fiber mats are installed and rolled by hand<br>• More expensive<br>• Usually thicker compared to SIPP liners<br>• May not be possible to install in a single construction season. |

### 4.6 Opinion of Cost

Kleinschmidt has compiled an opinion of probable construction costs (OPCC) in line with an AACE Class 5 estimate for each of the evaluated structural lining options outlined within this memorandum for Penstock No. 1.

Unit costs for the FRP and SIPP liners were developed from costs obtained from Kleinschmidt's data base containing quotes from previous projects. The unit costs were used in conjunction with costs referenced from the FEED Project Execution Report by Kleinschmidt. The purpose of utilizing the costs from the Execution Report was to facilitate equal grounds to compare the structural lining options with replacement of the 5.2-meter diameter section of penstock. The OPCC's developed for the structural lining of the 5.2-meter diameter section of penstock also include the costs for refurbishment of the remaining length of penstock. The scope of the refurbishment was assumed to be the same as outlined within the project execution report.

For costing we assumed a semi-structural system because there is significant remaining capacity in the existing steel penstock. The intent of the lining would be to increase this capacity and reduce stress on the joints. A fully independent structural system would be more costly than the costs that follow. The following sections summarize the results of the cost analysis, and the assumptions from which the OPCC's were based.

#### 4.6.1 Cost Summary

The contractor only costs are summarized in Table 2 for the FRP and SIPP structural liner systems and Option 3, refurbishment of Penstock 1. Based on these estimated costs, Option 3, replacement of the 5.2m section of penstock recommended in the FEED study is the lowest cost alternative.

**Table 2 Cost Summary Table**

| Option | Cost (CAD) |
|---|---|
| **FRP** | $80,553,000.00 |
| **SIPP** | $40,913,000.00 |
| **Option 3 - Penstock Replacement[1]** | $33,990,000.00 |

Notes: 1) Cost referenced from "Project Execution Strategy and Plan: Penstock No. 1 Report"

These costs are based entirely on the information provided and reflect the expected accuracy of an AACE Class 5 Cost Opinion as described in Section 4.6.3 of this document. The recommended budget is comprised of an Opinion of Supply and Construction Costs in addition to a Contractor's Profit and Contingency Costs.

### 4.6.2 Project Scope Description

Much of the scope outlined within the FEED Project Execution report applies to the scope which the OPCC's are based. All scope items in reference to the replacement of the 5.2-meter diameter section of penstock does not apply to this evaluation. The scope of work which the OPCC is based includes the following:

- Installation of 6,012 $m^2$ of structural lining within the 5.2-meter dia. section of penstock including hydro blasting, sandblasting, application of the lining, and testing.
- Refurbishment of the remaining length of penstock including earthworks, crack mapping, weld repair and testing, application of interior coating, and testing of the coating.
- Installation of silt fencing and environmental controls.
- Site preparation including a laydown area.
- Site restoration and commissioning.

### 4.6.3 Estimating Classification and Assembly Methodology

Based on AACE Recommended Practice (RP) 69R-12: Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Hydropower Industry, a Class 5 Cost Estimate is appropriate when:

- the maturity level of project deliverables (expressed as a percentage of complete) is in the 0% to 2% range; and
- the intended End Usage (purpose) of the Cost Estimate is concept screening.

The expected accuracy range of a Class 5 Cost opinion is:

- Low: -20% to -50%
- High: +30% to +100%

The state of technology, availability of applicable reference cost data, and other risks affect the expected accuracy range. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of P50 contingency for a given scope.

Class 5 Cost Opinions generally use stochastic estimating methods such as cost/capacity graphs or curves and factors, historical data and other parametric cost and modeling techniques in accordance with AACE RP 69R-12.

Kleinschmidt typically develops its Class 5 Cost Opinions using a combination of Unit Costs and quantity take-offs where information is available in the design documents, and assumption-based scoping to fill in where design details are more limited. Where design details or scoping information are lacking, experienced based assumptions are made that allow us to generate quantities of work and/or select appropriate Unit Costs/Lump Sums from our reference project data base.

### 4.6.4 Reference Projects and Historical Database

The unit rates for each of the FRP and SIPP liners were derived from historic vendor costs from similar scopes of work. Factors were applied to the historic costs to interpolate with respect to pipe diameter, length, pressure class, and hoop stress.

As described above, scope of work and associated costs was referenced from the FEED "Project Execution Strategy and Plan: Penstock No. 1 Report" by Kleinschmidt.

### 4.6.5 Assumptions

The Cost Estimate reflects the following key assumptions:

1. Scope of work is only for Penstock No.1.
2. Installation of the structural lining within the 5.2-meter diameter section of penstock and refurbishment of the remaining sections of penstock occur concurrently.
3. Structural lining is applied to only the 5.2-meter section of penstock.
4. Structural lining is a semi-structural system relying on the existing steel for some strength.
5. Unit rates referenced from the Project Execution Report do not change based on addition of structural lining scope.

6. Application of the FRP liner is completed by hand.
7. Application of the SIPP liner is completed robotically.
8. Liner installation duration is interpolated from historic information by square footage.
9. Unit cost for FRP and SIPP liners is interpolated from historic information by pipe diameter, pressure class, length, and hoop stress.

This list in not exhaustive and is intended only to supplement the means, methods and sequencing premise of the Cost Opinion as detailed elsewhere in this document.

### 4.6.6 Exclusions

In addition to exclusions mentioned elsewhere in the Basis of Estimate document, the following costs are expressly excluded from the Cost opinion:

1. No Owner's Costs other than Contractor Profit and Contingency and recommended Owners Contingency have been incorporated into the Cost Opinion. Owner Costs that are not provided in the Cost Opinion include but are not limited to engineering costs, project management costs, owner's overheads – direct and indirect, construction management, finance and interest expense and other matters of like import.
2. The costs of permits are not included.
3. Taxes if applicable are not included.
4. Any escalation in labor, material, and equipment costs incurred beyond the year end 2022.

## 5.0 CONCLUSION

Kleinschmidt has evaluated two different structural lining technologies for rehabilitation of the 5.2-meter diameter sections of penstocks 1 through 3. Each structural lining system has advantages and disadvantages. SIPP liners are less cost and easier to install, and are typically a semi-structural system that relies on the existing penstock capacity. FRP liners tend to be more expensive due to the intensive labor during installation but can be designed as a stand-alone structural system.

The SIPP liner was found to be the lowest cost option of the two lining options evaluated. However, the cost is greater than the recommended Option 3 cost which is to replace the 5.2-meter diameter section of penstock. Furthermore, if a semi-structural liner was installed, periodic inspection of the existing penstock would need to continue. A fully structural independent liner would be cost prohibitive, and this is in-line with industry experience. Structural liners are best used in applications where the existing pipe cannot be easily accessed or removed and replaced. At BDE the section in question can be easily accessed, dug up, and removed making replacement an attractive option.

Findings from this study indicate that installation of a structural lining is expected to cost more than a steel replacement, have potentially higher performance risks than replacement, a shorter expected service life, and potentially impact generation. For these reasons we recommend moving forward with Option 3 of the FEED study to replace the 5.2-meter diameter section with new steel pipe.

## 6.0 CLOSURE

We appreciate the opportunity to assist you with this project. If you have any questions regarding this memorandum, please call or e-mail Chris Vella at 902.708.1082 or chris.vella@kleinschmidtgroup.com.

Sincerely,

**KLEINSCHMIDT ASSOCIATES CANADA INC.**

Chris Vella, P.Eng.
Principal Consultant

Attachments: Appendix 1: Opinion of Cost
Appendix 2: Vendor and Product Information

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# APPENDIX 1

# OPINION OF COST

Kleinschmidt

| | |
|---|---|
| Project: | 2670034 |
| By: | NPT |
| Checked By: | CMV |
| Date: | 27.01.2023 |

Project: **Newfoundland and Labrador Hydro - Bay d'Espoir**

Subject: **FRP Structural Lining Assessment**

| Item | Description | Quantity | Units | Unit Cost | Total |
|---|---|---|---|---|---|
| **1.0** | **Mobilization & Demobilization** | 5% | | $ 2,622,719 | $ 2,622,800 |
| | | | | | **$ 2,622,800** |
| **2.0** | **General** | | | | |
| 2.1 | Dewatering/ Water Management | 40 | WEEK | $ 750.00 | $ 30,000 |
| 2.2 | Generators | 40 | WEEK | $ 7,490.00 | $ 299,600 |
| 2.3 | Laydown Area | 1 | LS | $ 93,138.00 | $ 93,200 |
| 2.4 | Silt Fence & Environmental Controls | | | | |
| | | | | | **$ 422,800** |
| **3.0** | **Structural Lining 17' Dia. Section** | | | | |
| 3.1 | Pressure Wash Pipe | 6,012 | $M^2$ | $ 13.00 | $ 78,200 |
| 3.2 | Robotic Abrasive Blasting | 6,012 | $M^2$ | $ 77.00 | $ 462,954 |
| 3.3 | Water Treatment | 1 | LS | $ 100,000.00 | $ 100,000 |
| 3.4 | Air Ventilation | 280 | DAYS | $ 2,309.00 | $ 646,520 |
| 3.5 | FRP Liner Testing & Inspection | 6,012 | $M^2$ | $ 2.38 | $ 14,309 |
| 3.6 | Dehumidifyer (During FRP Application) | 40 | WEEK | $ 4,670.00 | $ 186,800 |
| 3.7 | Custom Interior Scaffolding | 40 | WEEK | $ 15,000.00 | $ 600,000 |
| 3.8 | Supply and Install FRP Liner | 6,012 | $M^2$ | $ 7,373.67 | $ 44,333,400 |
| | | | | | **$ 46,422,184** |
| **4.0** | **Refurbish 15.25' & 13.5' Dia. Penstock Sections** | | | | |
| 4.1 | Temporary Person Access | 1 | LS | $ 69,010.00 | $ 69,100 |
| 4.2 | Air Ventilation | 1 | LS | $ 877,360.00 | $ 877,400 |
| 4.3 | Earthwork | 1 | LS | $ 841,667.00 | $ 841,700 |
| 4.4 | Crack Mapping | 1 | LS | $ 366,615.00 | $ 366,700 |
| 4.5 | Weld Repair | 1 | LS | $ 785,846.00 | $ 785,900 |
| 4.6 | Welding NDT Testing | 1 | LS | $ 47,294.00 | $ 47,300 |
| 4.7 | Scaffolding Support | 1 | LS | $ 1,089,911.00 | $ 1,090,000 |
| 4.8 | Interior Coating | 1 | LS | $ 1,756,820.00 | $ 1,756,900 |
| 4.9 | Coating Test | 1 | LS | $ 24,971.00 | $ 25,000 |
| | | | | | **$ 5,860,000** |
| **5.0** | **Site Finalization & Restoration** | | | | |
| 5.1 | Wet commissioning | 1 | LS | $ 16,291.00 | $ 16,300 |
| 5.2 | Silt Fence Removal | 1 | LS | $ 8,072.00 | $ 8,100 |
| 5.3 | Staging Area Restoration | 4,000 | $M^2$ | $ 10.64 | $ 42,600 |
| 5.4 | Staging Area Hydroseeding | 4,000 | $M^2$ | $ 3.00 | $ 12,000 |
| | | | | | **$ 79,000** |

| | | |
|---|---|---|
| | Sum: | $ 55,078,000 |
| Civil Contractor Contingency: | 5% | $2,754,000 |
| Civil Contractor Profit | 12% | $6,610,000 |
| **Opinion of Contractor Price** | | **$ 64,442,000** |
| **Recommended Owner Contingency** | 25.0% | $16,111,000 |
| **Recommended Owner Budget** | | **$ 80,553,000** |

Notes:

[1] Project scope is to line 17' Dia. section of penstock with FRP Structural Lining and Refurbish remaining penstock

[2] Prices do not include HST

[3] Cost do not include indirects including engineering, legal fees, staff, etc.

[4] Prices rounded to nearest $100

[5] It is assumed that Refurbishment of the 15.25' dia. and 13.5' dia. sections of penstock and FRP lining of the 17; dia. section of penstock occurs concurrently.

[6] Costs in Section 4 References from Chant Class 3 AACE Estimate

| Kleinschmidt | Project: | 2670034 |
|---|---|---|
| | By: | NPT |
| | Checked By: | CMV |
| | Date: | 27.01.2023 |

Project: **Newfoundland and Labrador Hydro - Bay d'Espoir**

Subject: **SIPP Structural Lining Assessment**

| Item | Description | Quantity | Units | Unit Cost | Total |
|---|---|---|---|---|---|
| **1.0** | **Mobilization & Demobilization** | 5% | | $ 1,332,095 | $ 1,332,100 |
| | | | | | **$ 1,332,100** |
| **2.0** | **General** | | | | |
| 2.1 | Dewatering/ Water Management | 29 | WEEK | $ 750.00 | $ 21,800 |
| 2.2 | Generators | 29 | WEEK | $ 7,490.00 | $ 217,300 |
| 2.3 | Laydown Area | 1 | LS | $ 93,138.00 | $ 93,200 |
| 2.4 | Silt Fence & Environmental Controls | 2,100 | M | $ 19.00 | $ 39,900 |
| | | | | | **$ 372,200** |
| **3.0** | **Structural Lining 17' Dia. Section** | | | | |
| 3.1 | Pressure Wash Pipe | 6,012 | $M^2$ | $ 13.00 | $ 78,200 |
| 3.2 | Robotic Abrasive Blasting | 6,012 | $M^2$ | $ 77.00 | $ 462,954 |
| 3.3 | Water Treatment | 1 | LS | $ 100,000.00 | $ 100,000 |
| 3.4 | Air Ventilation | 203 | DAYS | $ 2,309.00 | $ 468,727 |
| 3.5 | SIPP Liner Testing & Inspection | 6,012 | $M^2$ | $ 2.38 | $ 14,309 |
| 3.6 | Dehumidifyer (During FRP Application) | 29 | WEEK | $ 4,670.00 | $ 135,500 |
| 3.7 | Custom Interior Scaffolding | 29 | WEEK | $ 15,000.00 | $ 435,000 |
| 3.8 | Supply and Install SIPP Liner | 6,012 | $M^2$ | $ 3,146.00 | $ 18,915,000 |
| | | | | | **$ 20,609,691** |
| **4.0** | **Refurbish 15.25' & 13.5' Dia. Penstock Sections** | | | | |
| 4.1 | Temporary Person Access | 1 | LS | $ 69,010.00 | $ 69,100 |
| 4.2 | Air Ventilation | 1 | LS | $ 877,360.00 | $ 877,400 |
| 4.3 | Earthwork | 1 | LS | $ 841,667.00 | $ 841,700 |
| 4.4 | Crack Mapping | 1 | LS | $ 366,615.00 | $ 366,700 |
| 4.5 | Weld Repair | 1 | LS | $ 785,846.00 | $ 785,900 |
| 4.6 | Welding NDT Testing | 1 | LS | $ 47,294.00 | $ 47,300 |
| 4.7 | Scaffolding Support | 1 | LS | $ 1,089,911.00 | $ 1,090,000 |
| 4.8 | Interior Coating | 1 | LS | $ 1,756,820.00 | $ 1,756,900 |
| 4.9 | Coating Test | 1 | LS | $ 24,971.00 | $ 25,000 |
| | | | | | **$ 5,860,000** |
| **5.0** | **Site Finalization & Restoration** | | | | |
| 5.1 | Wet commissioning | 1 | LS | $ 16,291.00 | $ 16,300 |
| 5.2 | Silt Fence Removal | 1 | LS | $ 8,072.00 | $ 8,100 |
| 5.3 | Staging Area Restoration | 4,000 | $M^2$ | $ 10.64 | $ 42,600 |
| 5.4 | Staging Area Hydroseeding | 4,000 | $M^2$ | $ 3.00 | $ 12,000 |
| | | | | | **$ 79,000** |
| | | | | Sum: | $ 27,974,000 |
| | Civil Contractor Contingency: | | | 5% | $1,399,000 |
| | Civil Contractor Profit | | | 12% | $3,357,000 |
| | **Opinion of Contractor Price** | | | | **$ 32,730,000** |
| | **Recommended Owner Contingency** | | | 25.0% | $8,183,000 |
| | **Recommended Owner Budget** | | | | **$ 40,913,000** |

Notes:

1 Project scope is to line 17' Dia. section of penstock with FRP Structural Lining and Refurbish remaining penstock

2 Prices do not include HST

3 Cost do not include indirects including engineering, legal fees, staff, etc.

4 Prices rounded to nearest $100

5 It is assumed that Refurbishment of the 15.25' dia. and 13.5' dia. sections of penstock and FRP lining of the 17; dia. section of penstock occurs concurrently.

6 Costs in Section 4 References from Chant Class 3 AACE Estimate

# Appendix 2

## Vendor and Product Information

SEKISUI SPR
Leading-Edge Trenchless Solutions

# Spiral Wound

# PIPE REHABILITATION

SEWER PIPE LINING

CULVERT LINING

STORM DRAIN LINING

## 6” - 200+”

TRENCHLESS PIPE LINING SOLUTIONS

1-866-627-7772

www.sekisui-spr.com

sekisui.info@sekisui-spr.com

# WHY CHOOSE SPIRAL WOUND

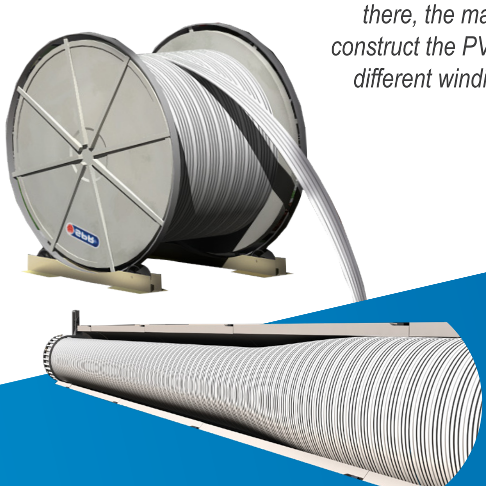
Spiral Wound liners are a structural rehabilitation solution for gravity pipe applications from **6" to over 200"**. Utilizing machinery, a continuous strip of PVC is constructed as a uniform liner. Spiral Wound lining is 100% trenchless; only existing access points are used for rehabilitation.

With over **4 million ft.** installed in the United States, and over **20 million ft.** globally, Spiral Wound offers numerous advantages compared to other pipe renewal methods.

- FULLY STRUCTURAL REHABILITATION
- LIVE FLOW INSTALLATIONS
- 100% TRENCHLESS TECHNOLOGY
- ASTM F1697-18 & ASTM F1741-18 STANDARDS

# INNOVATIVE INSTALLATIONS

*For installations, a continuous strip of PVC is fed from a spool above ground into the winding machine. From there, the machine continuously winds the profile to construct the PVC liner within the host pipe. We offer 3 different winding methods based upon the host pipe.*



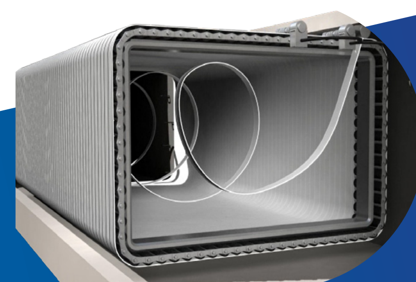
## SPR™EX | 6" - 42"

The SPR™EX liner is formed by a static machine that pushes the liner from access chamber to access chamber. A wire within the liner is then pulled, severing a secondary lock. This expands the PVC liner to fit tightly against the host pipe, requiring no annular space grouting.

## SPR™TF/RO | 40" - 60"

SPR™TF is a tight-fitting liner that does not require annular space grouting. Profile is fed into a traverse winding machine which forms a continuous liner between access points.

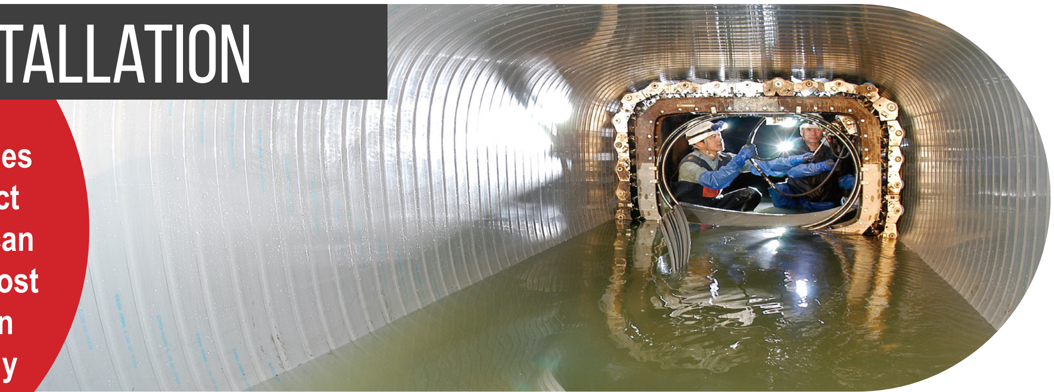
SPR™TF features 2 different winding machines depending on the project; a lightweight, compact machine or one featuring rotating hydraulic arms. Both machines traverse the pipeline while constructing a tight-fit liner.



## SPR™ | 32" - 200+"

SPR™ renews large diameter, round and non-round shaped pipelines. The PVC is wound by a traversing machine that forms the liner while traveling the pipe segment. The liner is constructed leaving a gap between the PVC and pipe wall. This annular space is subsequently grouted.

# LIVE FLOW INSTALLATION



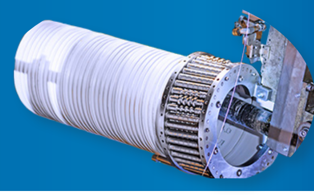
**Bypass pumping often reaches 15% - 25% of the total project bid. As Spiral Wound liners can be installed in live flow, the cost of flow management is often eliminated if not significantly reduced.**

## STATIC & TRAVERSE WINDING MACHINES

SPR™EX is a stationary installation process. The equipment pushes the wound PVC liner from access chamber to access chamber.

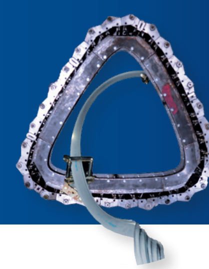
In contrast, SPR™TF and SPR™ traverse the pipeline while winding and pulling the liner along with the machine.

*SPR™EX Static Winding Machine*



*SPR™TF Traverse Winding Machine*

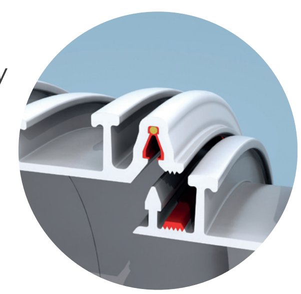
*SPR™ Traverse Winding Machine*

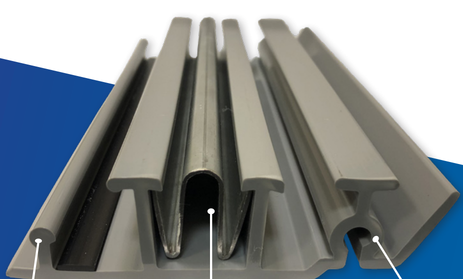


# PVC PROFILE

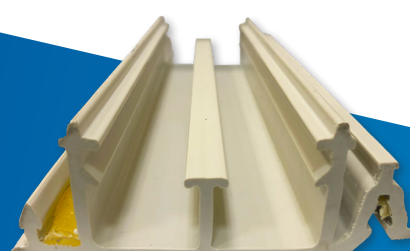
# LINING MATERIAL

*The liner material is a pipe grade PVC with a ribbed profile design, which is for added strength. The profile features a male and female lock along the edge of the material. These are interlocked as successive wraps of the strip are wound by the machine.*

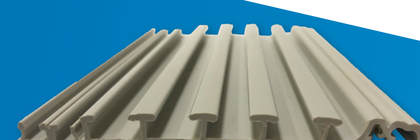





**SPR™ | 32” - 200+”**



**SPR™TF | 40” - 60”**



**SPR™EX | 6” - 42”**

- Pipe Grade PVC
- Mechanical Lock with Gasketing Material
- Impervious to I/I & Root Intrusion
- .009 Manning’s N Value

# 2 DECADES OF SPR™EX

# CASE STUDY

The City of San Diego's Metropolitan Wastewater Division has been rehabilitating their deteriorated sewers for nearly twenty years. This program however was not completely voluntary. The City entered a Consent Decree with the Environmental Protection Agency in 2001 to address the chronic problem of sanitary sewer spills.

Before 2000, the City had hundreds of sewer overflows each year, largely due to root intrusion and deteriorating pipe joints. As part of their EPA agreement, the City of San Diego embarked on an aggressive Sewer Spill Reduction Program.

"We've reduced the problem dramatically and anticipate even fewer overflows as we continue to renew our sewers."

Craig Whittemore, P.E., San Diego Metropolitan Wastewater Department

**+1M LF**
*Installed since '01*

**8" - 42"**
*Pipe Diameters*

**+ 90%**
*Reduction in Spills*

Since the program was implemented, the spill problem has been reduced dramatically. In 2001 the City had 365 sewer spills – one a day. By 2015 that number was down to 35; a greater than 90% reduction.

As of 2020, the City has inspected over 2040 miles of sewer and have identified 779 miles for replacement/rehabilitation. Over 300 miles of sewers have been rehabilitated with more slated for repair.

Since 2001, Sekisui licensees have bid on over 50 sewer rehabilitation projects and to date have installed **over 1 million feet of SPR™EX liners on City projects** with several projects currently in construction.

Though the mandatory repairs as outlined in the EPA Consent Decree were completed in 2015, the City continues a robust rehabilitation schedule.

The current CIP program is funded through 2024 with an annual goal of 40 to 45 miles of sewer to be replaced or rehabilitated per year. With the cost savings associated with trenchless technologies, the focus is to use structural liners where possible.

# CASE STUDY

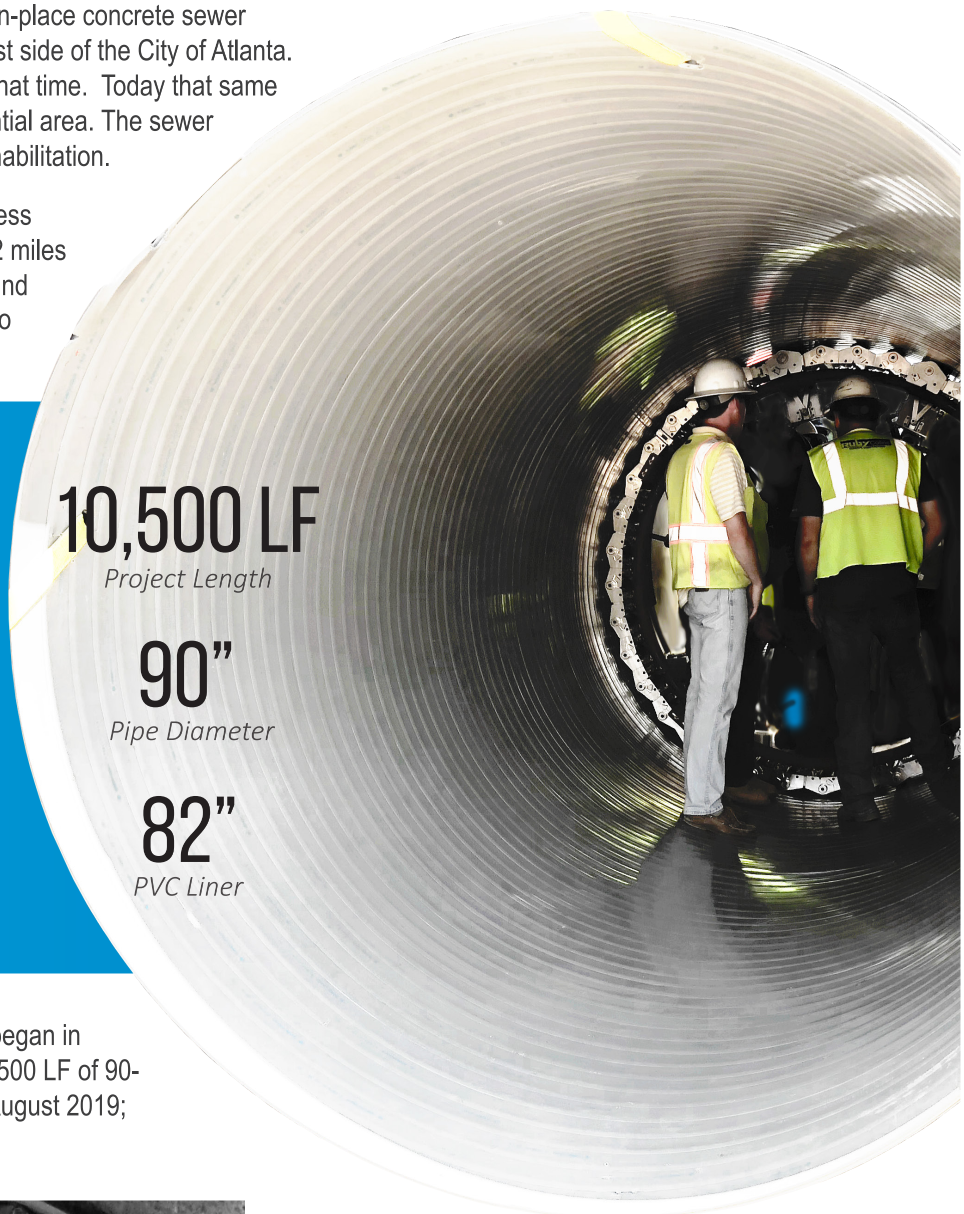
# LARGEST SPR™ PROJECT IN USA

The Peachtree Creek Trunk is a 90" arched cast-in-place concrete sewer pipeline constructed in the 1930's on the northwest side of the City of Atlanta. This section of town was largely undeveloped at that time. Today that same pipe alignment is surrounded by a thriving residential area. The sewer recently showed signs of failures and need for rehabilitation.

With the area being densely populated, a trenchless lining solution was needed to fully restore nearly 2 miles of the sewer. The City determined that Spiral Wound liners were the best trenchless pipe lining option to fully restore the old sewer.

The SPR™ design called for installation of an 82" PVC liner inside the 90" arch sewer. The annular space was to be filled with lightweight grout to serve as load-transfer for the PVC liner.

Installation began in the Fall of 2018, where Ruby-Collins set out to rehabilitate over 10,500 linear feet of sewer. The combination of innovative technology and efficient installers resulted in early project completion.



**10,500 LF**
*Project Length*

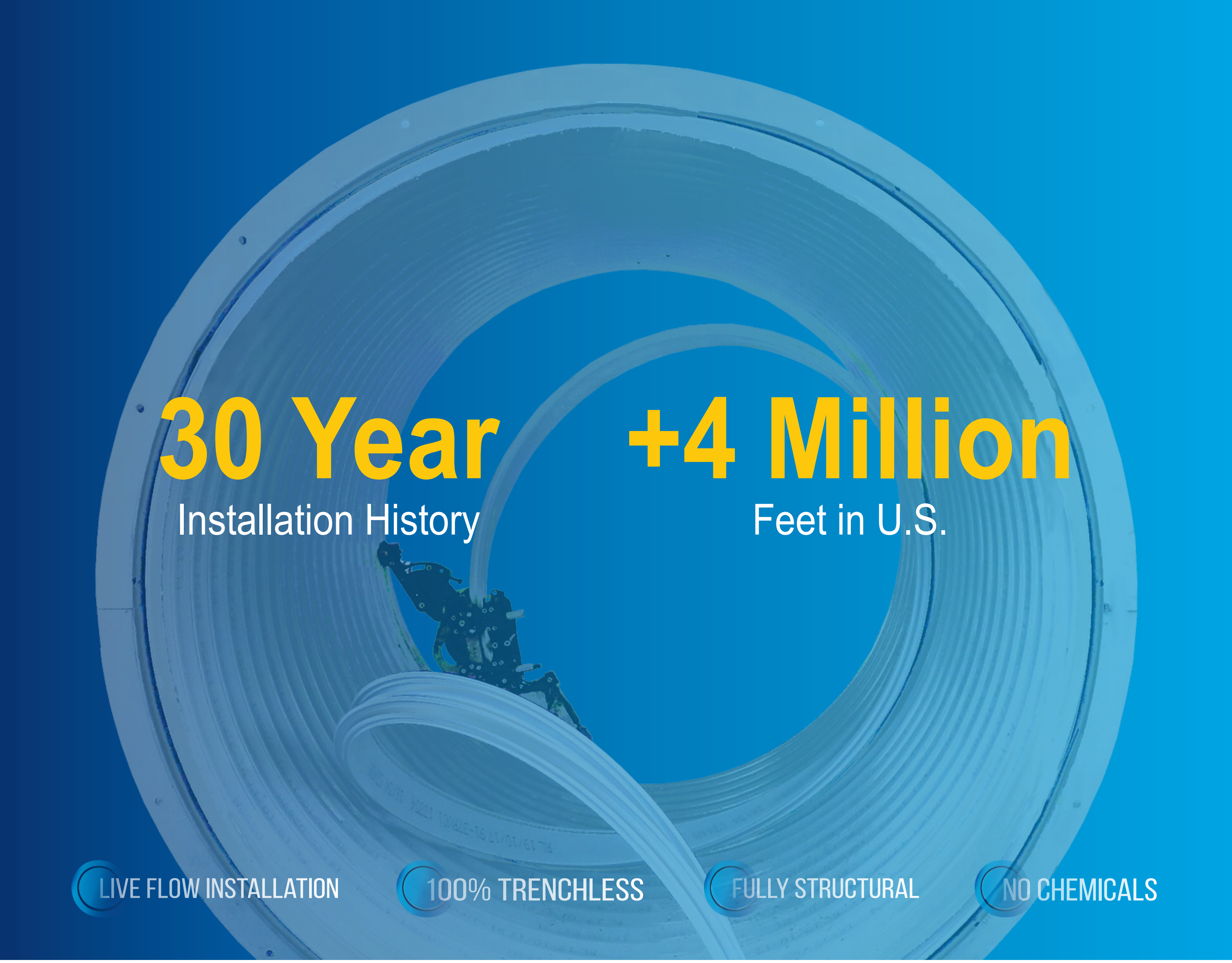
**90"**
*Pipe Diameter*

**82"**
*PVC Liner*

The Peachtree Creek Trunk Stabilization project began in October 2018. The rehabilitation of more than 10,500 LF of 90-in. arched sewer finished just 10 months later in August 2019; **roughly four months ahead of schedule.**

"The SEKISUI SPR Lining Technology was the perfect fit for the specific needs of this project. The technology was able to accommodate variable flow conditions and continuous rehabilitation through numerous curves in the pipe alignment with ease."

- Scott Cline, President & COO
Ruby-Collins Inc.




**www.sekisui-spr.com**
sekisui.info@sekisui-spr.com

5000 Austell-Powder Springs Rd.
Austell, GA 30106

1-866-627-7772

**See Spiral Wound in action on YouTube and LinkedIn**

SEKISUI SPR
Leading-Edge Trenchless Solutions

# SPR™

SPIRAL WOUND
PIPE LINER

Structural liner for circular and non-circular gravity pipelines between 32” - 200”+

**32” - 200”+ • ROUND/NON-ROUND • FULLY STRUCTURAL**

SEKISUI SPR
Leading-Edge Trenchless Solutions

1-866-627-7772 www.sekisui-spr.com sekisui.info@sekisui-spr.com

# Spiral Wound
## Technology Overview

**Gravity** Pipe Renewal

**Live Flow** Installations

**Zero** Chemicals

Spiral Wound pipe liners are a structural rehabilitation solution for gravity pipe applications from 6” - 200”+. Utilizing machinery, a continuous strip of PVC is constructed as a uniform liner. Spiral Wound lining is 100% trenchless; only existing access points are used for rehabilitation.


SEWER STORM DRAIN CULVERT

## Spiral Wound Lining Methods

**SPR™EX**
**6” - 42”**
No Grout

**SPR™TF/RO**
**40” - 60”**
No Grout

**SPR™**
**32” - 200”+**
Round/Non-Round

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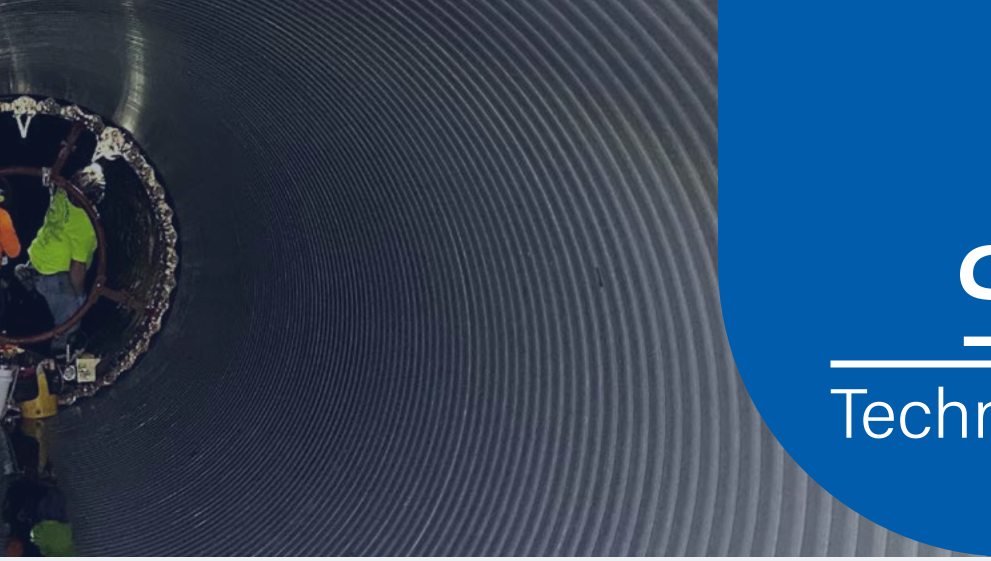

# SPR™

## Technology Overview

| 32" - 200"+ | Round/Non-Round | Fully |
|---|---|---|
| Diameters | Shapes | Structural |

SPR™ is a Spiral Wound pipe lining method for large diameter sewers, storm drains and culverts. SPR™ lines both round and non-round shapes, providing fully structural rehabilitation. The machine travels the length of the pipeline while constructing the liner at a fixed diameter.

**SPR™ is an entirely mechanical process that does not require curing or chemicals.**

## Installation Process

A steel-reinforced PVC profile strip is wound into the pipe by a traverse winding machine. The machine travels the length of the pipeline while constructing the liner at a fixed diameter. Grout is then introduced to fill the annular space; either part of the structural liner or just as a gap filler to uniformly transfer loads onto the liner. Grout type depends upon dimensions of the pipe and overall project conditions.

SEKISUI SPR
Leading-Edge Trenchless Solutions

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Austell, GA 30106

**www.sekisui-spr.com**
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1-866-627-7772

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SPIRAL WOUND PIPE LINING

VERSION 22.1