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October 16, 2024

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

On December 7, 2022, Newfoundland and Labrador Hydro ("Hydro") filed an application for approval of capital expenditures for section replacement and weld refurbishment of Penstock 1 at the Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir").[1] Hydro's application noted that the project was required for the safe and reliable operation of Penstock 1 in Bay d'Espoir; project execution was expected to take three years with an estimated project cost of $50,606,700. After a regulatory process including Requests for Information and comments filed by the Intervenors to the application, who did not object to the proposed project, the Board of Commissioners of Public Utilities ("Board") approved the application.[2]

Hydro and its consultant have completed a refresh of the project budget based on several factors including the completion of detailed engineering, refinement of scope, and updated market factors such as commodity pricing and inflation. The resulting revised Class 3 estimate indicates an increase in the projected [redacted]; however, the proposed and currently approved alternative is the least-cost technically feasible option that addresses the issues with the penstock and ensures the safe, reliable operation of the penstock and the Bay d'Espoir assets. The project remains the least-cost solution to ensure the continued safe, reliable, provision of power to Hydro's customers in an environmentally responsible manner.

[1] "Penstock 1 Section Replacement and Weld Refurbishment – Bay d'Espoir Hydroelectric Generating Facility," Newfoundland and Labrador Hydro, December 7, 2022.
[2] Board Order No. P.U. 6(2023).

Enclosed with this correspondence, as Attachment 1, is detailed information regarding the costs incurred to date on this project, as well as the sources of the increased budget for the section replacement and weld refurbishment of Penstock 1. Also described in Attachment 1 are the reasons supporting this option, as approved in Board Order No. P.U. 6(2023), as the most appropriate alternative including a refreshed opinion completed by Kleinschmidt Group regarding its assessment of the liner options. Hydro requests approval to proceed with the project, at the higher estimated cost, with continued reporting to the Board in the capital expenditure reports and the capital budget applications, as previously ordered. Due to the criticality of the schedule, as noted in Attachment 1, Hydro requests that the Board consider this request on an expedited schedule.

Attachment 1 and its appendices contain commercially sensitive information that could have implications for contract negotiations and an ongoing public procurement process.[3] A version in which this information has been redacted is enclosed. The Board has been provided with a complete copy as well as a copy of the redacted version. Hydro requests that this information be kept confidential and not be made publicly available.

Should you have any questions, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

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

Encl.

ecc:

Board of Commissioners of Public Utilities
Jo-Anne Galarneau
Jacqui H. Glynn
Katie R. Philpott
Board General

Labrador Interconnected Group
Nicholas E. Kennedy, Olthuis Kleer Townshend LLP

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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

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3 [redacted]

Attachment 1

Executive Summary

The Bay d'Espoir Hydroelectric Generating Facility ("Bay d'Espoir") produces an average of 2,650 GWh annually, making it the largest hydroelectric generating facility on the Island. The station, from which service began in 1967, relies on penstocks to supply water to each generating unit. In total, four penstocks supply water to seven units, with Bay d'Espoir Powerhouse 1 consisting of six hydro units fed by three penstocks.

Penstock 1 is an integral component of Bay d'Espoir Units 1 and 2, which together, supply 153 MW of generation and are required for Newfoundland and Labrador Hydro ("Hydro") to meet current customer requirements. From 2016 to 2019, Bay d'Espoir Penstock 1 experienced four ruptures within the 17-foot diameter section. These ruptures have resulted in Units 1 and 2 being unavailable for service for extended periods and significant unplanned expenditures. As a result of the investigations and consultant recommendations, annual inspections have been completed since 2019, and operational restrictions have been put in place on Units 1 and 2 to manage the risk of further failures.

In 2022, Hydro filed an application for approval of capital expenditures for section replacement and weld refurbishment for Penstock 1 at Bay d'Espoir.[1] At the time of the application, Hydro anticipated project execution would take three years at an estimated cost of $50.6 million. The Board of Commissioners of Public Utilities ("Board") approved the application in Board Order No. P.U. 6(2023), noting that the alternative proposed by Hydro was the most appropriate.

Coinciding with the issuance and receipt of responses to the Request for Proposals ("RFP") for the civil scope of the project, Hydro worked with its EPCM[2] consultant to refresh the original project budget. The refreshed budget which includes new and refined information, has identified a forecasted requirement of [redacted]. This is an increase of [redacted] over the original estimate. Hydro has considered this increased budget in the context of the other alternatives in the original application; however, the section replacement and weld refurbishment of Penstock 1 continues to be the least-cost, technically feasible solution to fully address the issues that impact safe, reliable operation of the penstock and

[1] "Penstock 1 Section Replacement and Weld Refurbishment – Bay d'Espoir Hydroelectric Generating Facility," Newfoundland and Labrador Hydro, December 7, 2022.
[2] Engineering, Procurement and Construction Management ("EPCM").

ensure safe, reliable service to customers in an environmentally responsible manner. Hydro believes that proceeding with the project at the revised budget is the prudent course of action.

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List of Appendices

1.0 Introduction

Bay d'Espoir produces an average of 2,650 GWh annually, making it the largest hydroelectric generating facility on the Island. The station, from which service began in 1967, relies on penstocks to supply water to each generating unit. In total, four penstocks supply water to seven units, with Bay d'Espoir Powerhouse 1 consisting of six hydro units fed by three penstocks.

Penstock 1 is an integral component of Bay d'Espoir Units 1 and 2, which together, supply 153 MW of generation and are required for Hydro to meet current customer requirements. From 2016 to 2019, Bay d'Espoir Penstock 1 experienced four ruptures within the 17-foot diameter section. These ruptures have resulted in Units 1 and 2 being unavailable for service for extended periods and significant unplanned expenditures. As a result of the investigations and consultant recommendations, annual inspections have been completed since 2019, and operational restrictions have been put in place on Units 1 and 2 to manage the risk of further failures.

Since 2016, Hydro has engaged three engineering consultants—Hatch Ltd., SNC-Lavalin Group Inc., and Kleinschmidt Group ("Kleinschmidt")—to support failure investigations, condition assessments, life extension options analyses, and front-end engineering and design ("FEED"). All three consultants agree that when considering the complete data set over multiple failure investigations, the root cause of the cracking found in the penstocks was high stresses in the longitudinal weld seams due to "peaking," which is further exacerbated by corrosion and cyclic stresses.

During the investigation of the most recent failure that occurred in 2019, it was determined that the failure had developed in a previously refurbished weld, indicating that the weld repairs in this section of penstock are not reliable. This was confirmed following the 2021 and 2022 annual inspections of Penstock 1, which found that additional cracks had formed in the longitudinal welds of the 17-foot diameter section, which had been previously repaired.

Based on a comprehensive review of four life extension options for Penstock 1 completed by Kleinschmidt for Hydro in 2021, Hydro filed an application for approval of capital expenditures for section replacement and weld refurbishment of Penstock 1.[3] Hydro submitted that this option would present the greatest level of risk mitigation and provide the highest level of reliability of the available

[3] *Supra,* f.n. 1.

options. Section replacement and weld refurbishment was the only option that adequately addressed the peaking and fatigue issues in the 17-foot diameter section, returning Units 1 and 2 to normal operation. At the time of the application, project execution was anticipated to take three years at an estimated cost of $50,606,700. After a regulatory process including Requests for Information and comments filed by the Intervenors to the application, who did not object to the proposed project, the Board approved the application in Order No. P.U. 6(2023). In their Order, the Board noted that the alternative proposed by Hydro was the most appropriate, stating that section replacement and weld refurbishment of Penstock 1 "is the only option to fully address the design issues in the 17-foot diameter section. While this is the most expensive alternative, it has the lowest risk rating and highest level of reliability."[4]

2.0 Revised Budget

2.1 Original Budget

As part of Hydro's application, Hydro provided a project budget for the proposed solution based on an AACE[5] Class 3 construction cost estimate developed by Kleinschmidt. The cost estimate included the construction costs from the perspective of a general contractor operating under a fixed-priced contract.

In addition to the construction costs, Hydro developed a cost estimate comprised of the owner's costs including the owner's project management, owner's project engineering, detailed design engineering, owner's site representatives, and specialty quality assurance/quality control ("QA/QC") testing related activities. Hydro forecasted the cash flow of the owner's cost estimate and the construction cost estimate over the years 2023, 2024 and 2025 using Kleinschmidt's construction schedule.[6]

The budget provided in the application was prepared using the following key assumptions:

- Based on an AACE Class 3 estimate (Plus 30%, Minus 20%).
- Priced in 2021 dollars and escalated based on escalation assumptions known at that time (approximately 12.8%).
- The civil works component would be executed in 2025.

[4] Board Order No. P.U. 6(2023), p. 7/17–19.
[5] Association for the Advancement of Cost Engineering ("AACE").
[6] The project cost estimate for Penstock 1 (Phase 1) is shown in "Penstock 1 Section Replacement and Weld Refurbishment – Bay d'Espoir Hydroelectric Generating Facility," Newfoundland and Labrador Hydro, December 7, 2022, sch. 1, p. 23, Table 7.

To date, Hydro has incurred approximately $4.1 million in costs for the project. Table 1 summarizes the costs to the end of August 2024.

Table 1: Costs Incurred to August 31, 2024 ($000)[7]

Description	Amount
FEED	529.6
Project Management Costs	412.0
Internal Engineering	660.9
EPCM Support	800.5
Civil Construction Costs	1,341.4
Internal Construction Support	252.4
IDC[8]	83.0
Total	**4,079.9**

The civil construction costs of $1.3 million are related to the acquisition of steel plates to be used in the penstock replacement. Hydro expects to incur the majority of the remaining costs in 2025 in relation to the civil execution and associated construction management costs.

2.2 Revised Budget

Hydro issued an RFP for the primary civil component of the work, which consists of a significant portion of the overall budget. To aid in the evaluation of the proposals received in response to this RFP, Hydro initiated a review of the project budget with consideration being given to the latest information available, including:

- Completed detailed engineering;
- Refinement of scope;
- Updating of market factors such as commodity pricing and inflation;
- Enhanced knowledge of site and project conditions; and
- Revised execution and oversight approach (i.e., moving to an EPCM model, with additional internal project support services).

[7] Numbers may not add due to rounding.
[8] Interest during construction ("IDC").

The budget update was broken down into three steps as follows:

1) Update the budget associated with the primary civil portion of the project. This analysis was conducted by the EPCM contractor and refined by Hydro. A memorandum from Kleinschmidt regarding the refresh of the cost opinion is attached as Appendix A to this report;
2) Update the budget associated with the remainder of the project. This analysis was conducted by Hydro and involved assessing costs incurred to date and revised forecast; and
3) Consolidation of the above into a revised project budget.

Table 2 sets out the original budget, the revised budget, and the associated budget increase or decrease in each category.

Table 2: Revised Budget ($000)[9,10]

Category	Original Base Budget	Revised Budget	Budget Increase (Decrease)
FEED	551.1	[redacted]	[redacted]
Project Management Costs	928.4		
Internal Engineering	1,529.1		
EPCM Support	1,599.2		
Civil Construction Costs	43,765.2		
Internal Construction Support	530.2		
IDC	1,703.5		
Total	**50,606.7**	[redacted]	[redacted]

[9] [redacted]

[10] Numbers may not add due to rounding.

The overall increase in budget of approximately [redacted] is a cumulative result of several key factors. These are summarized in Table 3 and discussed in the subsections that follow.

Table 3: Key Factors Contributing to Budget Increase ($)

Description	Increase
[redacted]	[redacted]
[redacted]	[redacted]

2.3 [redacted]

[redacted]

2.4 Refinement of Project Deliverables

Detailed engineering performed by Kleinschmidt as part of the EPCM contract resulted in several updates that were necessary inclusions in a refreshed cost estimate and contributed to an estimate increase in the project deliverables. The most significant updates are as follows:

[redacted]

- Findings from the 2023 Penstock 1 inspection, completed after the approval of the Life Extension Project, supported a recommendation by Kleinschmidt that in addition to the 5.2-meter diameter section included in the original budget, the first 49 meters of the 4.65-meter diameter section should also be completely replaced for Penstock 1, with the remaining sections of the penstock to be refurbished. This section of penstock is of smaller diameter but the steel is the same thickness (11.11 mm) as the 5.2-meter diameter section and inspection findings indicate replacement is required to ensure long-term reliability of the penstock.
- Dam stabilization work required to facilitate the penstock access at the toe of the existing dam required a more robust design which will result in higher construction costs.

2.5 [redacted]

[redacted]

2.6 Increase in Budgeted Project Oversight

Although the original project budget included consultant costs for detailed design, it was assumed that Hydro's engineering department would be able to oversee many aspects of the engineering, procurement and construction as is typically done on its regular capital projects. Due to the complexity of this project, it was appropriate to involve external expertise, mainly focused on project controls and construction management, to supplement Hydro's team to ensure the project is executed efficiently, effectively and safely.

2.7 [redacted]

[redacted]

[redacted]

3.0 Civil Construction Costs

Hydro received four responses to RFPs[12] associated with the civil scope of the project. [redacted]

Table 4: [redacted] ($000)[14]

Category	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
FEED	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Project Management Costs					
Internal Engineering					
EPCM Support					
Civil Construction Costs					
Internal Construction Support					
IDC					
Total	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Nominal Over (Under) Budget	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Percentage Over (Under) Budget (%)					

[redacted]

[12] The RFP can be found at https://nlhydro.bidsandtenders.ca/Module/Tenders/en/Tender/Detail/5b7408ae-3b6d-4e5e-be2a-0b6b1fca64e7/#Document.

[redacted]

[14] Numbers may not add due to rounding.

[redacted]

4.0 Alternatives

In its original application, Hydro identified three options other than maintaining the status quo which was not recommended due to unacceptable levels of risk. The other options involved weld refurbishment or weld reinforcement. Those alternatives, as noted by the Board, involved significant capital expenditures and did not address the issues with weld peaking, fatigue, and design and would not eliminate the requirement for operational restrictions and annual inspections.[15] A further alternative, discussed in additional detail in the Request for Information process, involved advancing technology with respect to the structural lining of the penstock interior. The Board noted that the structural lining option was estimated to cost more than the replacement of the 17-foot diameter section of the penstock and would have potentially higher performance risks than replacement, a shorter expected service life, and could potentially impact generation.[16]

Hydro requested Kleinschmidt to review its assessment of the liner options with updated pricing reflecting the escalation and scope change. Kleinschmidt's report is included as Appendix B. The conclusion of the updated analysis is consistent with the previous recommendation, that the installation of a structural lining is expected to cost more than a steel replacement, has potentially higher performance risks than replacement, a shorter expected service life, and potentially impacts generation. Kleinschmidt continues to recommend the currently approved option. It is important to note that the cost estimates for the liner options are at a Class 5 which has an expected range of -50% to +100%. The refreshed Class 3 estimate for the replacement option would have a tighter accuracy range[17] than the original Class 3 estimate as the detailed design is complete and tender pricing is available.

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[15] Board Order No. P.U. 6(2023), p. 7/12–15.
[16] Board Order No. P.U. 6(2023), p. 7/6–9.
[17] Kleinschmidt states that "it would be reasonable to conclude this Class 3 estimate should fall within the -10% to +10% range." Please refer to Appendix A, page 2.

5.0 Implications of Delay in Proceeding

The RFP contemplated an award in the third quarter of 2024 with work to begin in the fourth quarter. It is critical to award the contract to the successful proponent, and begin that work, within that timeframe for the following reasons:

- [redacted]
- Other Hydro capital projects are planned during the Penstock 1 outage window. Changes to the project execution schedule will have an impact on other site-specific work scopes that will need to be considered, including:
  - Refurbishment of Intake #1 in Bay d'Espoir;
  - Refurbishment of the Surge Tank on Bay d'Espoir Penstock 1; and
  - Overhaul of Unit 1 and Unit 2 at Bay d'Espoir.

Hydro has incorporated the outage associated with Penstock 1 refurbishment in the provincial generation plan. Changes to this schedule may have implications to Hydro's scheduled capital improvements and maintenance plan for assets both within and outside Bay d'Espoir.

[redacted]

6.0 Conclusion

After the original 2023 approval to proceed with section replacement and weld refurbishment of Penstock 1 at an estimated cost of $50.6 million, Hydro and its consultant have completed a refresh of

[redacted]

the project budget based on several factors including the completion of detailed engineering, refinement of scope, and updated market factors such commodity pricing and inflation. The resulting revised Class 3 estimate indicates an increase in the projected project cost to [redacted]. Hydro understands [redacted]; however, the proposed and currently approved alternative remains the least cost technically feasible alternative that addresses the issues with the penstock and ensures safe, reliable operation of the penstock and the Bay d'Espoir assets. The project remains the least cost solution to ensure continued safe, reliable, provision of power to Hydro's customers in an environmentally responsible manner.

Appendix A

Kleinschmidt Cost Opinion Memo

MEMORANDUM

To:	Dylan Drake, Steve Hiscock – Newfoundland and Labrador Hydro		
From:	Tim Saville – Kleinschmidt Associates		
Date:	October 10, 2024	**Document No.**	2670050_ME006
Re:	Updated Cost Opinion Memo		

Kleinschmidt Associates (Kleinschmidt) was asked to support Newfoundland and Labrador Hydro (NL Hydro) during the tendering process of engaging a General Contractor to perform the replacement and refurbishment scopes on the Penstock 1 Project.

Kleinschmidt's scope of service is to refresh the Front End Engineering and Design (FEED) Project Class 3 Cost opinion, completed in 2021.

Class 3 Cost Opinion refresh

There were several updates that required inclusion in the new refreshed cost opinion, the most significant of which included:

- Completed design definition of the project which included detail design for the dam stabilization work required to facilitate the penstock access at the toe of the existing dam.
- Additional length of penstock added to the scope of replacement at downstream end of originally contemplated replacement section.
- Additional length of penstock for rehabilitation between the upstream end of the replacement section and the dam intake.
- [redacted]
- [redacted]
- [redacted]
- [redacted]

The refreshed Class 3 cost opinion for the Penstock 1 Rehabilitation and replacement Project is [redacted]

A Class 3 Cost Opinion's typical purpose is that of a Budget Authorization or Budget Control Estimate. The expected accuracy range of a Class 3 Cost opinion falls between -10% to -20% on the low end and +10% to +30% on the high end. With the level of project definition at the Issue for Tender stage it would be reasonable to conclude this Class 3 estimate should fall within the -10% to +10% range making the expected cost range [redacted]

Sincerely,

KLEINSCHMIDT ASSOCIATES CANADA INC.

Tim Saville

Tim M Saville, P.Eng.
Project Manager

TMS:SCB

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Appendix B

Penstock Lining Assessment and Opinion of Probable Construction Costs, 2024 Update

October 8, 2024

Via Kiteworks

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, 2024 Update
Penstock 1 Life Extension Project (2670050.01)

Dear Dylan:

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).

Kleinschmidt originally conducted this assessment in 2021 and found that replacement of the 5.2-metre (m) diameter section of penstock and the refurbishment of the remaining section of penstock was more economical and carried less risk compared to installing a structural lining system within the 5.2-m diameter section. This refreshed memorandum details the findings of the assessment with updated pricing reflecting escalation and scope change since the FEED project.

The structural lining assessment and Opinion of Probable Construction Costs (OPCCs), presented herein, have been updated to reflect additional escalation since originally completing the OPCC(s) in 2021, and the changes in scope that have occurred throughout the Penstock 1 Life Extension Project. In order to more accurately compare costing for replacing the penstock versus installing a structural lining within the penstock, the OPCC(s) were updated to be more in line with the refreshed Class 3 Cost Estimate conducted by Chant in 2024. The updates made to the structural lining OPCC(s) include the following:

- OPCC revised to include lining of 49 m of the 4.65-m diameter section of penstock. During the Penstock 1 Life Extension Project, this section of the penstock was added to the replacement section of penstock. In order to provide a fair comparison, the lining OPCC(s) have been revised to include the costs associated with the installation of a structural lining in this area. The lining OPCC(s) consider lining the penstock from the end of the concrete encasement, Station 47.24, to 49 m downstream of Bend 4A (Historic Drawing Number F-106-C-7), inclusive of all steel measuring 11.11 millimeter (mm) thick.

- [redacted]
- Refurbishment of the welds within the sections of penstock to be lined is now included within the OPCC(s). The lining systems that were evaluated are semi-structural systems, and rely on the existing steel penstock; therefore, it is imperative that the welds are inspected and repaired prior to the installation of a structural lining.
- Indirect Costs were added to the OPCC(s). To facilitate reasonable comparison, the indirect costs were added to the lining OPCC(s) as the Class 3 Cost Estimate includes indirect costs.

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 m and 4.65-m diameter sections of the penstock and compared them to Option 3 - replacement of the 5.2-m 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 section of penstock constructed from 11.11 mm thick plate with new steel pipe is still 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-m (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. Since the completion of the FEED Project in 2022, the design of the life extension project has been completed. Additional scope was added during the design, including the replacement of the 11.11 mm thick steel, which includes the first 49 m of the 4.65-m diameter section of the penstock.

2.0 BACKGROUND AND EXISTING CONDITIONS

On May 21, 2016, a crack in Penstock 1 was found approximately 260 m downstream from the start of the penstock. 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. Furthermore, during the annual inspection of Penstock 1 in October of 2023, as a part of the penstock inspection program, multiple cracks and indications were found prompting a significant inspection effort and emergency repairs. 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 have been inspected yearly, via magnetic particle non-destructive testing. Since 2016 weld indications have primarily been observed within the 11.11 mm thick sections of the penstocks. Due to the findings from the 2023 Penstock 1 inspection, the percentage of welds within the section of penstock constructed from the ASTM A285 has been increased to 20%, including welds at or near the crown, previously not required to be inspected. Throughout the inspection program, multiple indications have also been observed in refurbished and previously repaired 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 and previously repaired 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 sections constructed from 11.11 mm thick steel, with the exception of the area constructed through the embankment dam, which is encased in concrete. As a result, it has been recommended that the 5.2-m diameter section and the first 49 m of the 4.65-m diameter section be completely replaced for Penstock 1 with the remaining sections of the penstock to be refurbished. This memo explores the option of installing a structural lining in the interior of the penstocks where the plate thickness is only 11.11 mm thick.

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, carbon 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 man-hours 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 outlined in Sections 3.1 and 3.2, inspection of the existing steel plate and welds would likely be required, particularly if the system relies on the existing capacity of the steel shell. Given the repeated failure of welds in the 11.11 mm thick section, the lining would need to be sufficiently thick to reduce stress within the steel shell and mitigate the risk of weld failure. If this risk cannot be reduced to an acceptable level, inspecting the existing welds becomes essential. However, accessing the welds from inside the penstock would not be practical with a structural liner. Inspecting from the exterior would also be impractical, time consuming, and cost prohibitive.

A failure of a longitudinal weld could result in catastrophic failure if it occurs under the lining. An undetected crack could expand over time leading to a rupture and potential penstock failure with the lining unable to support the stresses without the steel intact. Therefore, a thicker lining would be necessary to significantly reduce stress and mitigate this risk. However, a fully independent structural system would be more expensive than the costs summarized in Table 2.

If a fully independent structural lining system were implemented, inspection of the underlying steel plate would not be required. However, this option would be significantly more costly due to the increased thickness required and the potential for increased head losses, which could reduce 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 • Could be installed in a single BDE construction season • Installation is cheaper • Can be applied robotically • Can be applied monolithically and in various layers • Usually thinner compared to other technologies, lessening the impact on internal diameter.	• Predominantly a semi-structural system requiring inspection of the underlying steel plate • Relies on capacity from existing pipe • Not as robust • No reinforcing material within system • More likely to crack than FRP • More failure risk than replacement
FRP	• Can be designed as a semi-structural or stand-alone system • Robust system offering varying strengths of fiberglass and carbon fiber mats • Can be designed to not rely on existing penstock eliminating the requirement to inspect the underlying steel plate • More durable and less likely to crack	• Labor intensive installation as fiber mats are installed and rolled by hand • More expensive • Usually thicker compared to SIPP liners • 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 11.11 mm thick section of the penstock. The OPCC's developed for the structural lining of the 11.11 mm thick section of the penstock (excluding of the section of penstock extending from the intake to the toe of the embankment dam) 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.

We assumed a semi-structural lining system for the cost analysis, as the existing steel penstock retains significant capacity and that a self-relying structural lining system would not be economical or practical. The purpose of the semi-structural lining is to enhance the existing capacity and reduce stress on the longitudinal joints. No calculations were performed during this assessment to determine the required lining thickness. The following sections provide an overview of the cost analysis results and the assumptions on which the OPCCs are based.

4.6.1 Cost Summary

Table 2 summarizes the revised costs for the FRP and SIPP structural liner systems, as well as for Option 3, which involves the replacement and refurbishment of Penstock 1. [redacted] It should be noted that the cost estimate for Option 3 is classified as an AACE Class 3 OPCC, while the estimates for the FRP and SIPP options are classified as Class 5 OPCC. Although the OPCC for the structural lining alternatives was developed using costs from Option 3 where applicable, the overall accuracy is not equivalent to a Class 3 OPCC. The unit rates for the structural lining systems were not developed with the same level of detail, and the pricing referenced from the Option 3 OPCC was not specifically intended for structural lining applications. Based on these estimates, Option 3, which includes replacing the section of penstock constructed from 11.11 mm thick steel, is the most cost-effective alternative.

Table 2 Cost Summary Table

Option	Cost (CAD)
FRP	[redacted]
SIPP	[redacted]
Option 3 - Penstock Replacement[1]	[redacted]

Notes:
1) Cost referenced from Kleinschmidt Memorandum titled "Updated Cost Opinion and Contingency Analysis", October 2024. "

The costs developed for the FRP and SIPP structural lining alternatives 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 costs developed for Option 3 reflect the accuracy of an AACE Class 3 Cost Opinion. 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 11.11 mm thick steel does not apply to this evaluation. The scope of work which the OPCC is based includes the following:

- Installation and testing of 6,012 m^2 of structural lining within the 5.2-m diameter. section of penstock including hydro blasting, sandblasting, application of the lining, and testing.
- Installation of 712 m^2 of structural lining within the 4.65-m diameter. section of penstock including hydro blasting, sandblasting, application of the lining, and testing.
- Refurbishment of the welds within the proposed lined section of penstock.
- Refurbishment of the remaining length of penstock including earthworks, crack mapping, weld repair and testing, application of interior coating, and testing of the coating.

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 11.11 mm thick section of penstock and refurbishment of the remaining sections of penstock occur concurrently.
3. Structural lining is applied to only the 11.11 mm thick 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 2025.

5.0 CONCLUSION

Kleinschmidt has evaluated two different structural lining technologies for rehabilitation of the section of penstock constructed from 11.11 mm thick steel for Penstocks 1 through 3. Each structural lining system has advantages and disadvantages. SIPP liners are less cost, 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 11.11 mm thick section of penstock. Furthermore, if a semi-structural liner was installed, periodic inspection of the existing penstock would likely need to continue, which would not be practical. 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 the BDE Development, the penstock sections 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 11.11 mm thick section of penstock 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: Attachment 1: [redacted]
Attachment 2: Vendor and Product Information

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ATTACHMENT 1

[redacted]

[redacted]

[redacted]

ATTACHMENT 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+"

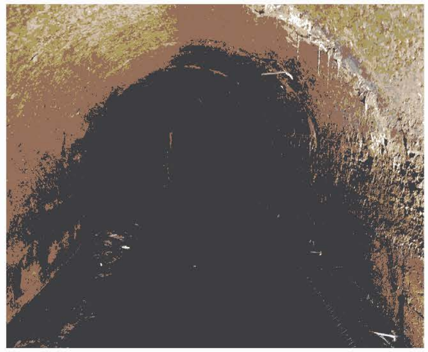
TRENCHLESS PIPE LINING SOLUTIONS

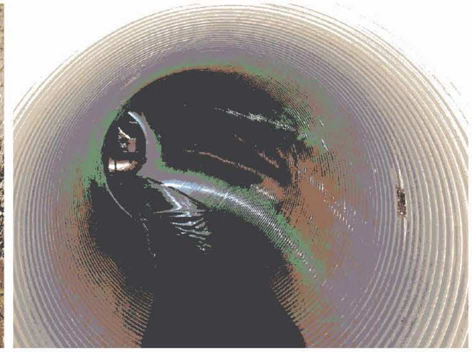
1-866-627-7772 www.sekisui-spr.com sekisui.info@sekisui-spr.com

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.

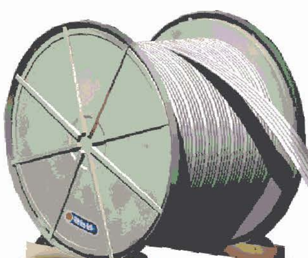




- FULLY STRUCTURAL REHABILITATION
- LIVE FLOW INSTALLATIONS
- 100% TRENCHLESS TECHNOLOGY
- ASTM F1697-18 & ASTM F1741-18 STANDARDS

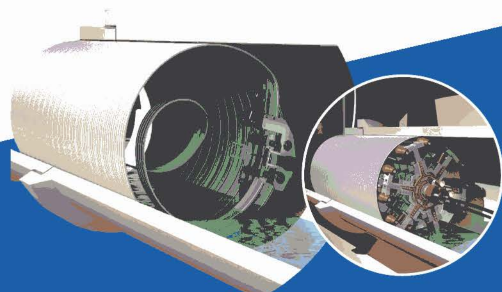
INNOVATIVE INSTALLATIONS

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"

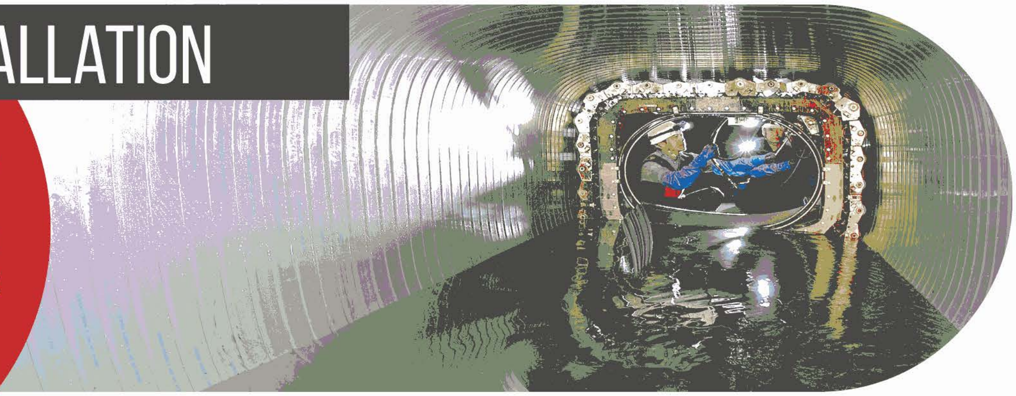
SPR™TF is a tight-fitting liner that does not require annular space grouting. Profile is fed into a traverse winding machine which forms a continuous liner between access points.

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



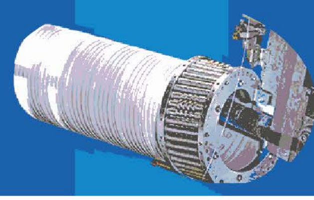
Bypass pumping often reaches 15% - 25% of the total project bid. As Spiral Wound liners can be installed in live flow, the cost of flow management is often eliminated if not significantly reduced.

STATIC & TRAVERSE WINDING MACHINES

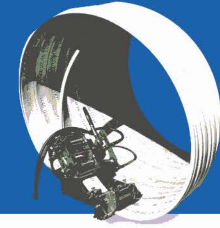
SPR™EX is a stationary installation process. The equipment pushes the wound PVC liner from access chamber to access chamber.

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

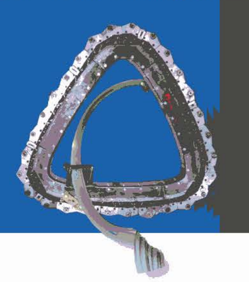
SPR™EX Static Winding Machine



SPR™TF Traverse Winding Machine



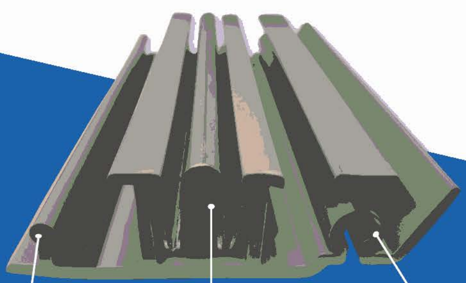
SPR™ Traverse Winding Machine



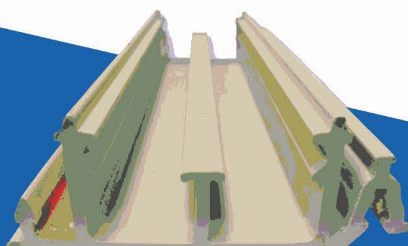
PVC PROFILE

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.

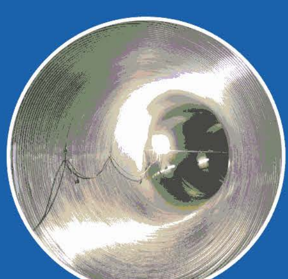


SPR™ | 32" - 200+"



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

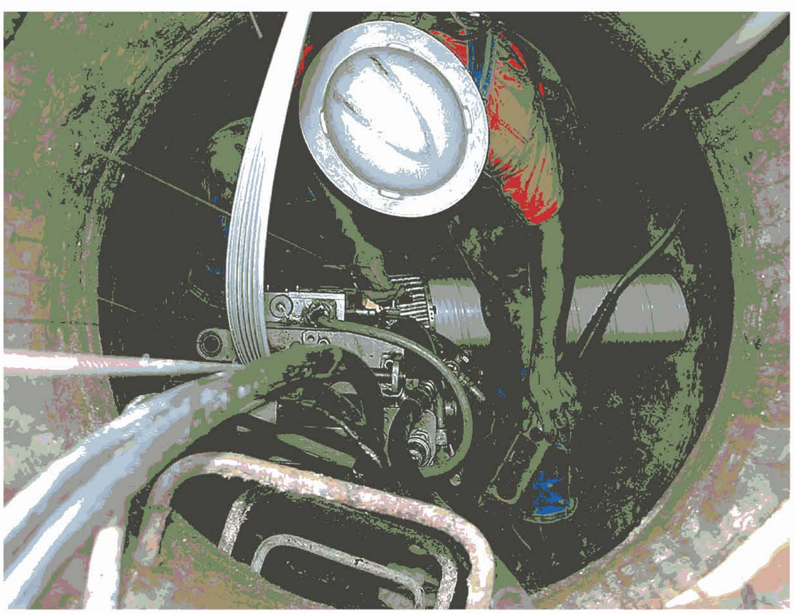
8" - 42"
Pipe Diameters

+ 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

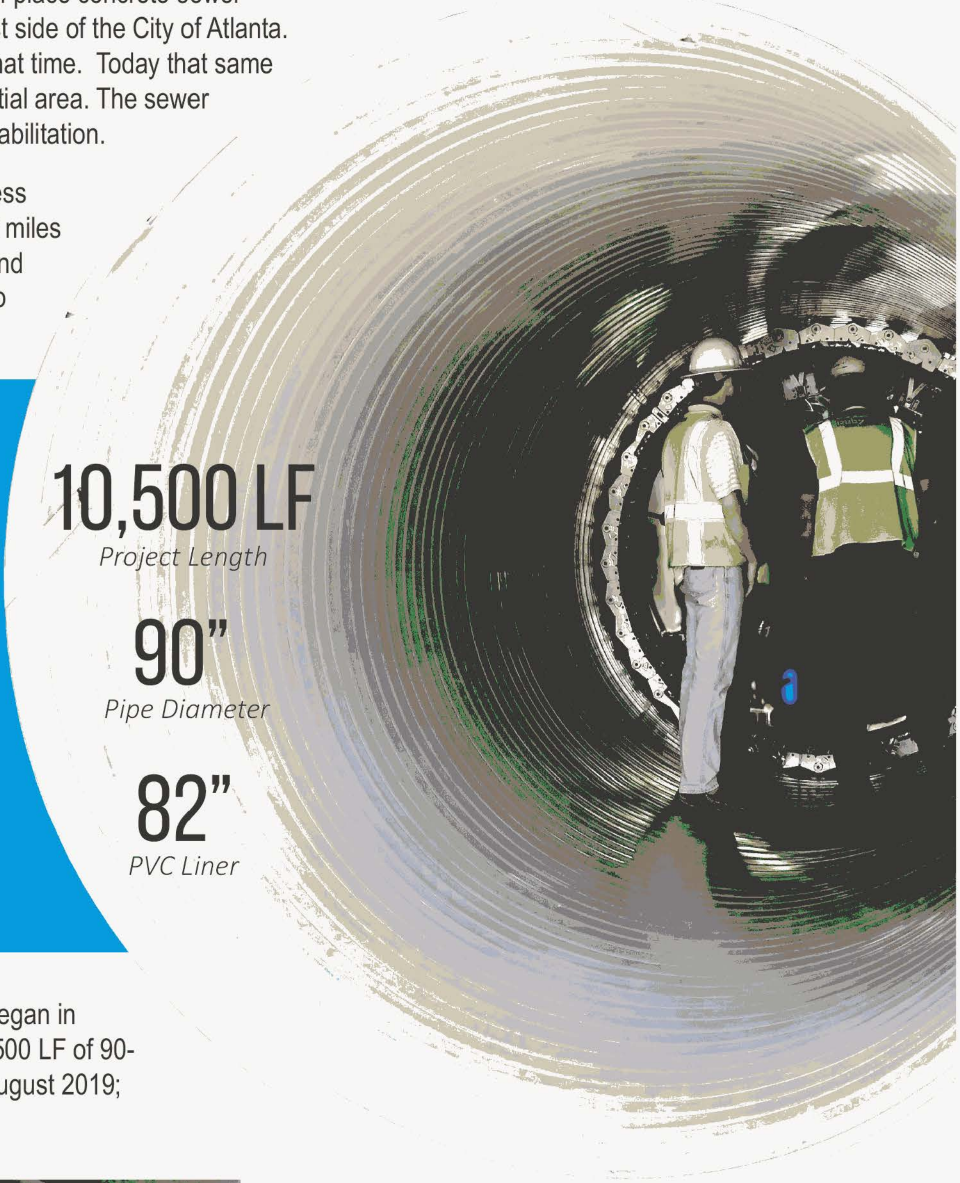
LARGEST SPR™ PROJECT IN USA

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

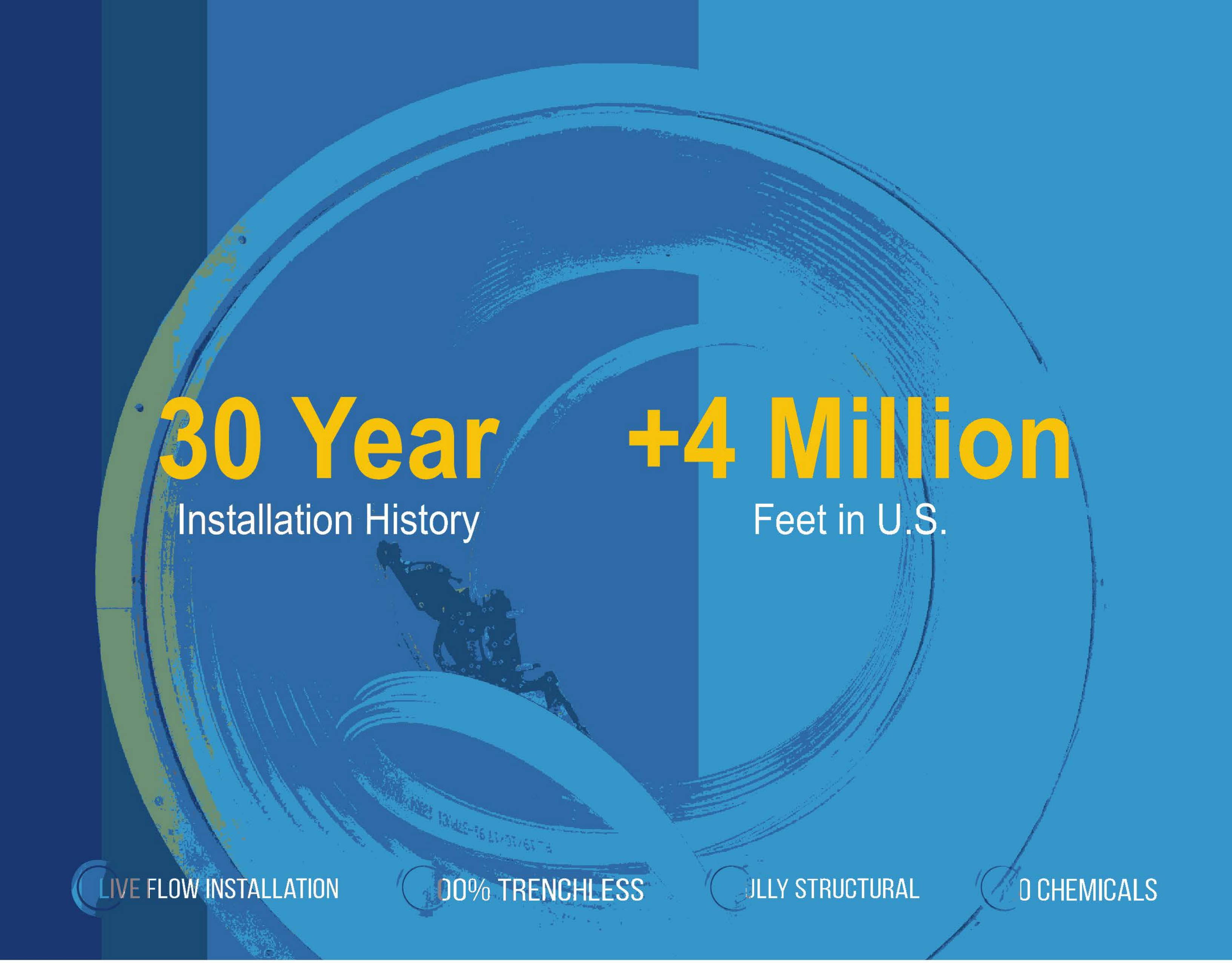
90"
Pipe Diameter

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.



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See Spiral Wound in action on YouTube and LinkedIn

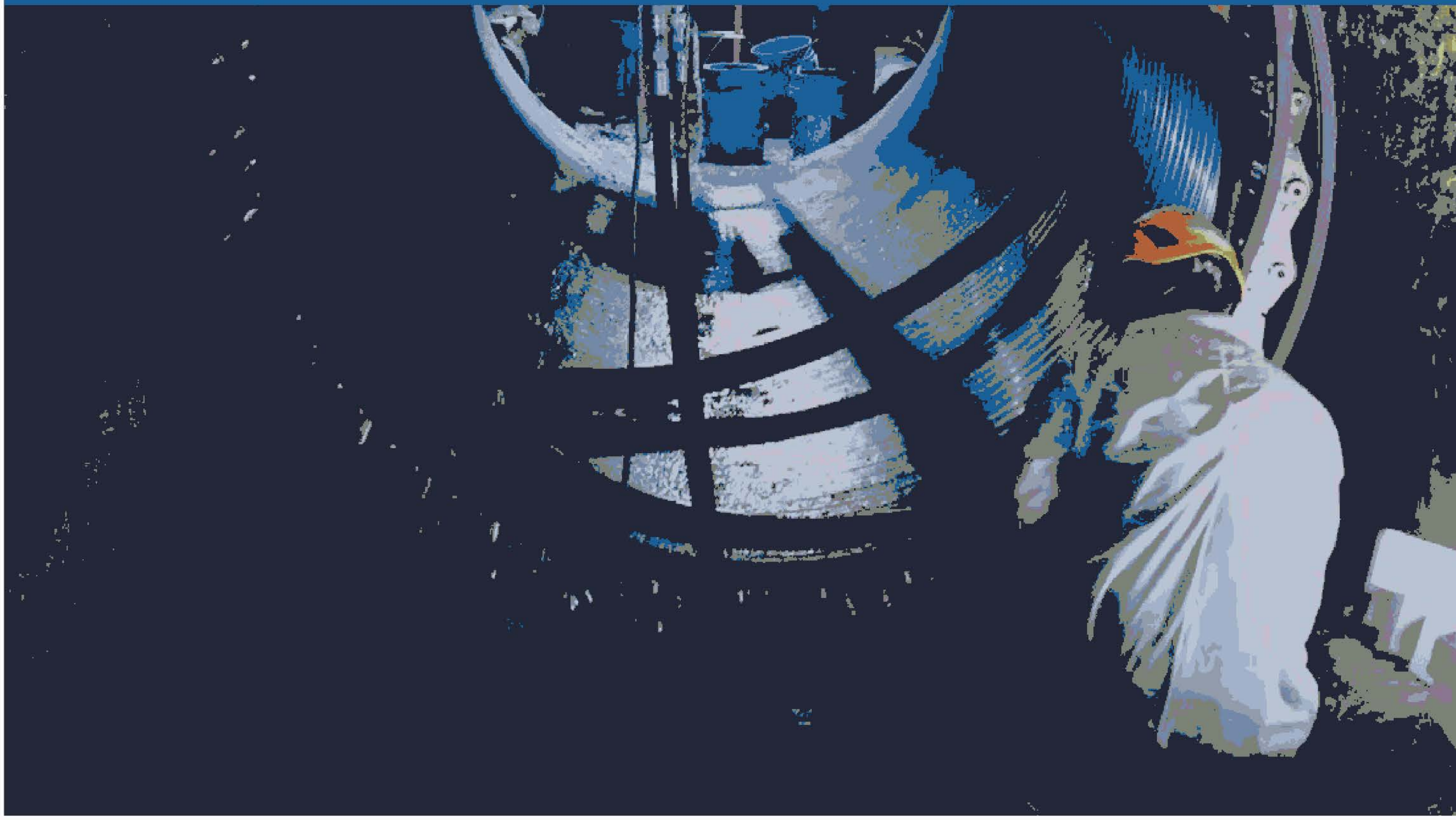
SEKISUI SPR
Leading-Edge Trenchless Solutions

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
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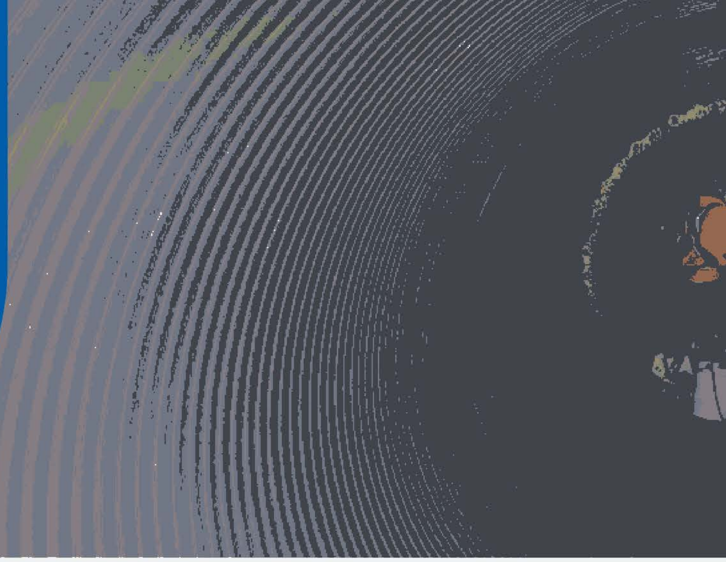
Spiral Wound

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.

20,000,000
LF Installed

SEWER

STORM DRAIN

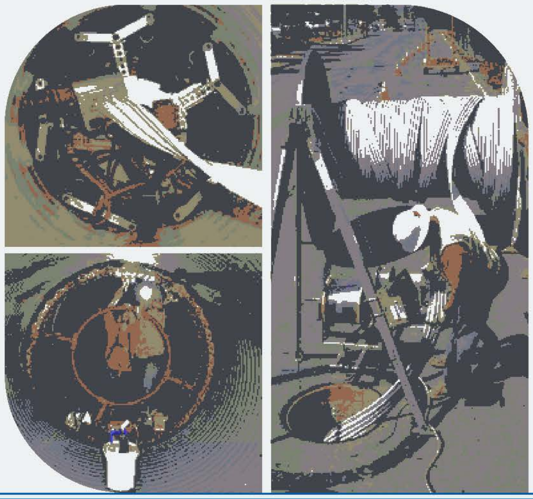
CULVERT

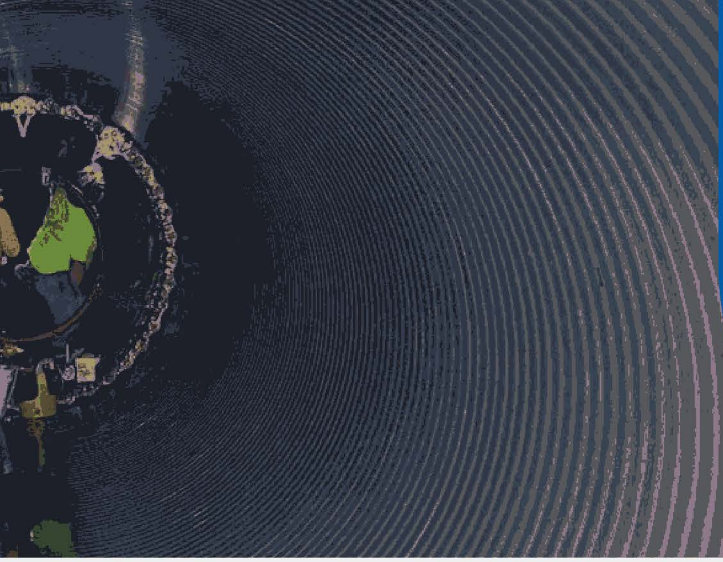
Spiral Wound Lining Methods

SPR™EX
6” - 42”
No Grout

SPR™TF/RO
40” - 60”
No Grout

SPR™
32” - 200”+
Round/Non-Round





SPR™
Technology Overview

32" - 200"+
Diameters

Round/Non-Round
Shapes

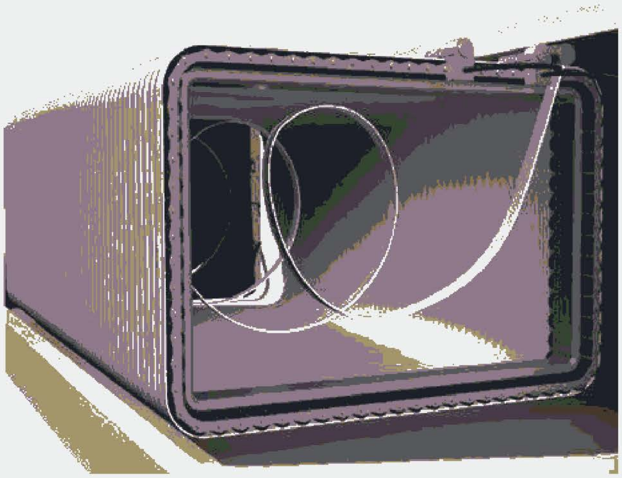
Fully
Structural

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.



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SPIRAL WOUND PIPE LINING

VERSION 22.1