UNDERTAKING J15.5

Undertaking

To review the list of Tier 1 Business Case Summaries referred to at Attachment 1 of L-4.2-AMPCO-17 to determine whether there have been any updates to the Tier 1 Business Case Summaries.

Response

There have been three updates to the Tier 1 Business Case Summaries since November:

(a) 31710 - DN Shutdown Cooling Heat Exchanger Replacement (see Attachment 1 which has confidential content as marked)

(b) 38948 - DN Zebra Mussel Mitigation Improvements (see Attachment 2 which has confidential content as marked)

(c) 80022 - DN OH180 Aging Management Hardware Installation (see Attachment 3 which has confidential content as marked)

ONTARIO POWER GENERATION

Records File Information:
Records SCI/USI Retention
- See Guidance Section

OPG-FORM-0076-R005*

Type 3 Business Case Summary

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076.

Executive Summary and Recommendations

Project Information			
Project #:	16-31710	**Document #:**	D-BCS-33410-10003
Project Title:	Darlington Shutdown Cooling Heat Exchanger Replacement		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Sustaining
Phase:	Execution	**Release:**	Partial
Facility:	Darlington	**Target In-Service or Completion Date:**	2020-Oct-30 (Completion Date)

Project Overview

We recommend the Gate 3B approval to proceed and the release of $ 43,307 k, including [redacted] of contingency.

This brings the total-to-date release to $ 82,136 k, including [redacted] of contingency.

The total project cost is estimated at $ 112,845 k (including [redacted] of contingency). The quality of the estimate for this release is Class 3, and for the total project is Class 3.

Following the first heat exchanger replacement (completed in Q3 2016), the total project estimate has increased over the previous estimate of $ $56,085k (including [redacted] of contingency) due to a number of project risks realized as well as several new discovery items which were not anticipated in the previous release. All items are now included in the total project estimate with the detailed variance included below.

This release will fund the following scope of work:

- **Complete revision of engineering change packages for remaining 7 SDC HX replacements.**
- **Complete non-long lead procurement and execution (installation planning, installation, commissioning, & engineering change control (ECC) close-out) for the 2nd, 3rd, 4th and 5th Shutdown Cooling Heat Exchanger (SDC HX) replacements.**
- **Complete installation planning for the 6th SDC HX replacement.**
- **Complete preparation of Full Execution Release Business Case Summary for the last 3 SDC HX replacements.**

Problem Statement/Business Need:

The baffle supports in all SDC HX's are deteriorated due to microbiologically induced corrosion (MIC). Consequently, the SDC HX tubing is susceptible to damage arising from flow induced vibrations, tube fretting and circumferential cracking. To date, no tubes have leaked*; however, as baffle plate corrosion continues, the risk of a tube leak will increase. A tube leak would result in significantly increased emissions of tritium to the lake, which would be a violation of the environmental and radiation protection requirements of the station Power Reactor Operating License.

***Note:** Following replacement of the first HX (2-33410-HX2) in Q3 of 2016, a partial tube side eddy current inspection was performed on the old HX in December 2016 in order to identify the extent of degradation. Results of the inspection indicate that the degradation of the baffle supports had not resulted in any observable damage to the HX tubing. While this inspection indicates the risk of a tube leak is lower than initially expected, it is not necessarily representative of the condition of the remaining 7 HX's that still require replacement. This is further supported by recent OPEX in January 2017 when tube degradation resulted in a tritium leak on a HX (1-33410-HX2) as identified in SCR D-2017-00195. This recent event supports the urgency to replace the heat exchangers as soon as possible, as the degradation of each heat exchanger and its remaining service life is unpredictable.

Ultrasonic testing (UT) of the SDC HX shells indicate that the shell wall thickness is reduced in locations due to pitting caused by MIC. Based on the currently estimated corrosion rates for the SDC HX's with the greatest amount of corrosion, the minimum allowable shell wall thickness could be reached at isolated pit locations within 3.5 years (from the time of inspection in 2012), resulting in the operation of the Shutdown Cooling system outside of the design basis.
In order to prevent the onset of additional corrosion pits in the shell and baffle supports, the operating procedure has been

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Project Overview

revised to enable continuous service water flushing of the SDC HX's during the chlorination season. This improvement will mitigate the onset of MIC in new locations due to stagnant water conditions; however, it will not stop or slow down the corrosion of the SDC HX's at existing pit locations.

A tube or shell side leak would require the SDC HX to be taken out of service, isolated, and repaired, which would be a loss in redundancy of the Shutdown Cooling system and a reduction in system reliability. A tube side leak could also cause a forced shutdown of a reactor unit, resulting in a loss of production and increasing the Unit Forced Loss Rate. Furthermore, for any planned outage, the unavailability of a SDC HX would increase the time for Primary Heat Transport (PHT) system cool down, thereby extending outage duration and further increasing the forced loss rate. The unavailability of a SDC HX would also have a negative impact on Unit Refurbishment flow defueling activities, resulting in an increase in the period of time for flow defuel. This would negatively impact Refurbishment outage critical path and overall duration.

Summary of Preferred Alternative:

In order to address the ongoing corrosion of the Shutdown Cooling Heat Exchangers and the impending end of service life, a complete replacement of all eight (8) SDC HX's is recommended. Replacement of the SDC HX's will be dimensionally compatible with the existing heat exchangers, and almost identical from a thermal and hydraulic performance point of view. There will be no change to the tubing (I-800) or shell material (SA516 GR70), and the material chosen for the internal components (segmental baffle plates, tie rods, etc.) will be changed from carbon steel to stainless steel grade 316L, a material more resistant to MIC. The new SDC HX's will have an increased service life of 40 years, thereby ensuring their availability until the end of station life following refurbishment, approximately 2055.

Each SDC HX will be planned for replacement with the reactor unit at power, and prior to the corresponding reactor unit's planned Refurbishment outage. For specific heat exchangers, this may be not be possible and therefore the heat exchanger will be replaced during the Refurbishment outage or as soon as possible post-Refurbishment in accordance with Darlington Online and Refurbishment work planning processes.

Disposal will be performed by Nuclear Waste Management Division (NWMD).

History of BCS releases and project cost estimates:

The total project cost is now estimated at $[redacted] plus [redacted] k of contingency, compared to [redacted] k, plus $[redacted] k of contingency in the previous release.

The total project cost has increased by $ 56,760 k due to the following:

Two key factors resulted in the increased project cost estimate. The first is an increase in the field execution duration for each HX replacement, and the second is the increase in the engineering cost estimate as a result of additional design analysis activities.

1. Field Execution Duration:

The 1st SDC HX was replaced in Q3 2016 and took approximately 68 days working 24/7 (and 4 weeks each on pre-requisites and post-requisites working 40hrs/week). This was a significant increase from the estimated duration of 30 days and is attributed to the following major factors which either added additional activities to the critical path and/or impeded productivity in the field:

- Installation of temporary piping supports to account for seismic and Condensation Induced Waterhammer (CIWH) loadings during the period of time when the old HX is removed and the new HX has not been fully installed.
- Significant complexities associated with the fit-up and welding of small bore nuclear class stainless steel piping and large bore nuclear class carbon steel piping connections to the new SDC HX.
- The implementation of radiological proteotion measures (set-up and operation of portable air driers, installation of temporary lead shielding blankets, flushing of the HX with demineralised water, set-up and removal of tented areas) to contain and minimize radiological dose fields and radiological dose uptake in the work areas.
- The summer of 2016 was the hottest on record with 38 days when the temperature reached above 30 degrees Celsius. This resulted in ambient temperature and breathing air temperatures in the work areas (inside containment) approaching 40 degrees Celsius. This presented a significant concern for worker heat stress and resulted in work stoppages or reduced field work hours in order to minimize the risk of worker injury.
- This was a first-of-a-kind (FOAK) installation that had many first-in-a-while (FIAW) aspects to it. Several attributes were not fully understood in advance, and led to issues being identified during field execution, which delayed the progression of work while a path forward was obtained.

Based on the experience gained on the first replacement and incorporating lessons learned and expected efficiencies,

OPG Confidential

OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003

Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Project Overview

subsequent HX replacements are planned for a 40 day field execution window working 6x20's (and 3 weeks each on pre-requisites and post-requisites working 40hrs/week).

2. Engineering:

Additional engineering modifications and piping stress analysis required the Design Packages to be revised to address legacy design items which were not initially known to the project, specifically Condensation Induced Waterhammer (CIWH) loadings, and non-rigid (flexible) Heat Exchanger Design. In addition, the engineering support required during construction for Field Initiated Changes (FIC's) was significantly underestimated, and the effort to incorporate lessons learned into the engineering packages was originally not included.

This BCS is prepared on the basis that engineering modifications for seismic and CIWH loadings are no longer required for the remaining 7 HX installations, and therefore the engineering, procurement, construction and OPG support costs have been removed and reassigned to contingency.

Key Variances are as follows:

- Estimated OPG resource costs have increased from approximately $10.6 M to $13.9 M. The variance is primarily a result of increased resource requirements to support the 40 day HX replacement duration.
- Estimated ES MSA vendor costs have increased from approximately [redacted] to [redacted]
  - Vendor Design cost has increased from [redacted] to [redacted] as a result of the engineering changes highlighted above.
  - Vendor Procurement cost has increased from [redacted] to [redacted] as a result of increased materials to fabricate temporary piping supports in support of revised Engineering, new piping spool piecies, and an increase in the required tooling and equipment to support construction activities.
  - Vendor Construction cost has increased from [redacted] M to [redacted] M. The variance is is attributed to the increased resources required to support the field duration which increased from 30 to 40 days. In addition, the crew size per shift was significantly underestimated and has been revised to account for approximately 30 trade's individuals per shift.
  - Vendor Project Management cost has increased from [redacted] to [redacted] This is attributed to the increased overall project duration, and the addition of a dedicated Project Manager, Construction Lead, and Modification Team Leader in order to ensure continuity and knowledge transfer of key expertise across all 8 HX replacements.
- Estimated OPG Interest cost has increased from [redacted] to [redacted] The increase is proportionate to the increase in estimated project cost.
- Estimated Contingency cost has increased from $ [redacted] to [redacted] For each remaining HX installation, [redacted] of contingency has been allocated to the risk of designing and installing engineering modifications associated with temporary piping supports for seismic and CIWH loadings. In addition, [redacted] of contingency has been allocated to the risk of each field execution extending beyond the planned 40 day duration as a result of unexpected field conditions or unpreventable delays or reductions in field productivity attributed to station delays, transients or extreme weather conditions.

History of scope and schedule changes:

There have been no scope or schedule changes since the previous BCS.

Key Assumptions and Risks:

It is assumed that all HX's will be replaced with the reactor units online, with the exception of the Unit 2 HX #2, which will be replaced during Unit 2 Refurbishment. It is also assumed that no HX degradation or failures of the existing HX's will occur prior to HX replacement. If degradation of an existing HX necessitated immediate replacement of the HX, this could have an impact on the project schedule and would require a change to the approved project strategy identified in this BCS. A change to the project strategy could potentially extend project duration in order to rearrange HX replacements around the planned unit outage and refurbishment windows, and necessitate one or more HX's to be replaced during Darlington Refurbishment.

The HX's will be replaced using similar maintenance practices utilized for HX Channel Cover removal. If engineering modifications are required to enable HX replacement (temporary piping supports), the field installation duration will be increased from 40 days to 50 days, and additional time will be required to prepare engineering packages and fabrication piping supports. Therefore, the timeline to replace all 7 HX's will be extended, and the commitments outlined in the BCS will need to be updated to reflect the impact. Contingency has been allocated to this risk.

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-31710
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Document #: D-BCS-33410-10003

Project Cash Flows, NPV, and OAR Approval Amount									
k$	LTD	2017	2018	2019	2020	2021	2022	Future	Total
Currently Released	25,966	12,663							38,629
Requested Now		22,815	16,480	2,212					43,307
Future Required			18,583	12,092	34				30,709
Total Project Cost	25,966	35,478	37,063	14,304	34				112,845
Ongoing Costs	-								
Grand Total	25,966	35,478	37,063	14,304	34				112,845
Estimate Class:	Class 3			Estimate at Completion:	[redacted]				
NPV:	N/A			OAR Approval Amount:	$ 112,845 k				
Additional Information on Project Cash Flows (optional): Annual Cash flows include Contingency									

Approvals			
	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Glenn Jager Nuclear President & CNO			16 FEB 2017
I concur with the business decision as documented in this BCS.			
Finance Approval: Ken Hartwick SVP Finance, Strategy, Risk & CFO per OPG-STD-0076			Feb 21, 2017
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Jeffrey Lyash President & Chief Executive Officer per OAR 1.1			

ONTARIO POWER GENERATION

Records File Information:
Records SCI/USI Retention
- See Guidance Section

OPG-FORM-0076-R005*

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Business Case Summary

Part A: Business Need

The Shutdown Cooling System is required to remain operational and available through the design life of the station, with no impact on Darlington reliability and safety targets due to equipment failures and/or tritium leaks to the environment.
The baffle supports in all HX's have deteriorated due to MIC. Consequently, the SDC HX tubing is susceptible to damage arising from flow induced vibrations, tube fretting and circumferential cracking. To date, no tubes have leaked*; however, as baffle plate corrosion continues, the risk of a tube leak will increase. A tube leak would result in significantly increased emissions of tritium to the lake, which would be a violation of the environmental and radiation protection requirements of the station Power Reactor Operating License.

*Note: Following replacement of the first HX (2-33410-HX2) in Q3 of 2016, a partial tube side eddy current inspection was performed on the old HX in December 2016 in order to identify the extent of degradation. Results of the inspection indicate that the degradation of the baffle supports had not resulted in any observable damage to the HX tubing. While this inspection indicates the risk of a tube leak is lower than initially expected, it is not necessarily representative of the condition of the remaining 7 HX's that still require replacement. This is further supported by recent OPEX in January 2017 when tube degradation resulted in a tritium leak on HX (1-33410-HX2) as identified in SCR D-2017-00195. This recent event supports the urgency to replace the heat exchangers as soon as possible, as the degradation of each heat exchanger and its remaining service life is unpredictable.

Ultrasonic testing (UT) of the SDC HX shells indicate that the shell wall thickness is reduced in locations due to pitting caused by MIC. Based on the currently estimated corrosion rates for the SDC HX's with the greatest amount of corrosion, the minimum allowable shell wall thickness could be reached at isolated pit locations within 3.5 years (from the time of inspection in 2012), resulting in the operation of the Shutdown Cooling system outside of the design basis.

In order to prevent the onset of additional corrosion pits in the shell and baffle supports, the operating procedure has been revised to enable continuous service water flushing of the SDC HX's during the chlorination season. This improvement will mitigate the onset of MIC in new locations due to stagnant water conditions; however, it will not stop or slow down the corrosion of the SDC HX's at existing pit locations. Eddy Current inspections may be performed on each SDC HX once removed in order to identify any degradation that occurred due to pitting or fretting. This information will be used to plan additional inspections on other SDC HX's in-service, and to enable plugging of degraded tubes to prevent tube leaks. These actions will help to mitigate the risk of a shell or tube side leak; however, they will not eliminate the risk.

The onset of a tube or shell side leak would require the HX to be taken out of service, isolated, and repaired, which would be a loss in redundancy of the Shutdown Cooling system and a reduction in system reliability. A tube side leak could also cause a forced shutdown of a reactor unit, resulting in a loss of production and increasing the Unit Forced Loss Rate. Furthermore, for any planned outage, the unavailability of a SDC HX would increase the time for PHT system cool down, thereby extending outage duration and further increasing the forced loss rate. The unavailability of a SDC HX would also have a negative impact on Unit Refurbishment flow defueling activities, resulting in an increase in the period of time for flow defuel. This would negatively impact Refurbishment outage critical path and overall duration.

The SDC HX's have a service life of 30 years, consequently, replacement of the existing Darlington SDC HX's is required to ensure the continued and reliable operation of the Shutdown Cooling system until the end of station design life (approximately 2055), and thus, support the continued and safe operation of the Darlington reactor units in compliance with the licensing and design basis.

Replacement of the SDC HX's is also a regulatory requirement for completion before the end of the Darlington Life Extension Window, as identified in the Darlington Integrated Implementation Plan [R-5].

Part B: Preferred Alternative: Full Replacement of the Shutdown Cooling Heat Exchangers Prior to Refurbishment

Description of Preferred Alternative

In order to address the ongoing corrosion of the Shutdown Cooling Heat Exchangers and the impending end of service life, a complete replacement of all eight (8) SDC HX's is recommended. Replacement of the SDC HX's will be dimensionally compatible with the existing heat exchangers, and nearly identical from a thermal and hydraulic performance point of view. There will be no change to the tubing (I-800) or shell material (SA516 GR70), and the material chosen for the internal components (segmental baffle plates, tie rods, etc.) will be changed from carbon steel to stainless steel grade 316L, a material more resistant to MIC. The new SDC HX's will have an increased service life of 40 years, thereby ensuring their availability until the end of station life following refurbishment, approximately 2055.

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Part B: Preferred Alternative: Full Replacement of the Shutdown Cooling Heat Exchangers Prior to Refurbishment

Description of Preferred Alternative

Each SDC HX will be planned for replacement with the reactor unit at power, and prior to the corresponding reactor unit's planned Refurbishment outage. For specific heat exchangers, this may be not be possible and therefore the heat exchanger will be replaced during the Refurbishment outage or as soon as possible post-Refurbishment in accordance with Darlington Online and Refurbishment work planning processes.

Disposal will be performed by Nuclear Waste Management Division (NWMD).

Deliverables:	Associated Milestones (if any):	Target Date:
This Release • Online Replacement of the 2nd, 3rd and 4th Heat Exchangers. Current replacement sequence is U3HX2→U4HX1→U1HX2 • Refurbishment Replacement of the 5th Heat Exchanger (U2HX1). Replacement Window is undefined but assumed to be within Q1 and Q2 of 2018. • Full Execution Business Case Summary for May 2018 Board Approval for the 6th, 7th and 8th Heat Exchanger Replacements.	***This Release*** 1. Start of Installation – 2nd HX 2. Available for Service Completed – 2nd HX 3. Start of Installation – 3rd HX 4. Available for Service Completed -3rd HX 5. Start of Installation – 4th HX 6. Available for Service Completed – 4th HX 7. Start of Installation – 5th HX 8. Available for Service Completed – 5th HX (contingent upon U2 restart following Refurbishment) 9. BCS Approved	***This Rls.*** 1. 2017-May-29 2. 2017-Aug-18 3. 2017-Aug-21 4. 2017-Nov-10 5. 2017-Nov-06 6. 2018-Jan-26 7. 2018-Apr-30 8. 2019-Oct-30 9. 2018-Jun-15
Future Release • EPC Contract Awarded for Phase 3 of Project • Online Replacement of the 6th, 7th and 8th Heat Exchangers. Current replacement sequence is U1HX1→U4HX2→U3HX1 • Project Complete Milestone	***Phase 3 - Future Release*** 1. Installation Contract Awarded 2. Start of Installation – 6th HX 3. Available for Service Completed – 6th HX 4. Start of Installation – 7th HX 5. Available for Service Completed – 7th HX 6. Start of Installation – 8th HX 7. Available for Service Completed – 8th HX 8. Plan Complete (PCM)	***Phase 3– Fut. Rls.*** 1. 2018-July-30 2. 2018-Aug-07 3. 2018-Oct-26 4. 2018-Nov-05 5. 2019-Jan-25 6. 2019-Jan-31 7. 2019-Apr-23 8. 2020-Oct-30

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case: Status Quo – No Project

The option of Status Quo (Do Nothing) is not recommended. Choosing not to pursue a Shutdown Cooling Heat Exchanger replacement, and instead implementing repairs as required, does not represent a permanent solution to corrosion of the shell and internal components, and carries significant Nuclear Safety and Environment Risk.

As the SDC HX's continue to degrade, the likelihood of SDC HX failures due to shell or tube side leaks will increase. A single or simultaneous failure of multiple SDC HX's on one or several reactor units could result in significant tritium emissions to the environment, a reduction in redundancy of the SDC system, and could significantly impair the ability of the SDC system to perform its credited safety function.

Following repair of any HX failure, it cannot be guaranteed that future SDC HX failures will not occur with the same results as identified above. When the number of tubes plugged is more than available margin (60 U-Tubes), the efficiency of the HX will be affected, resulting in increased duration to cool PHT D2O down, hence delaying any planned outage.

This alternative was considered and eliminated, therefore, not included in the financial evaluation.

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Alternative 3: Delay Work – Replacement of SDC HX's during Darlington Refurbishment

The option of delaying the work until Darlington Refurbishment is not recommended.

In order to replace the SDC HX's with the reactor unit online, one SDC HX would be unavailable, while the second SDC HX would be available for use. During replacement of each HX, the SDC system would have a complete loss of redundancy, which could potentially impair the ability of the SDC system to perform its credited safety function. Therefore, the SDC HX's would be replaced during Darlington Refurbishment when the SDC system is not required to be operational. This would eliminate any operational issues associated with a loss of redundancy that is experienced during online SDC HX replacement.

Replacement would be scheduled during the reactor unit refurbishment outages (starting with U2 as early as 2016, U3 in 2019, U1 in 2020 and U4 in 2022), however, this would significantly extend the overall timeline for replacement of all 8 HX's. Based on the degraded condition and the estimated rate of corrosion of the SDC HX's, there is significant risk of a heat exchanger failure occurring during this timeframe. The project was initially scheduled for Darlington Refurbishment; however, based on the urgency to replace the SDC HX's as soon as possible, the project was re-scheduled to take place prior to the start of Darlington Refurbishment. Specific heat exchangers may be replaced during Refurbishment based on challenges in planning and scheduling the work online, however, this will be a contingency measure only.

This alternative was considered and eliminated, therefore, not included in the financial evaluation.

Alternative 4: Purchase Heat Exchangers as Spares, and Replace as Required.

The project would provide the design, fabrication and supply and staging of 8 spare SDC. Based on the degradation observed during the routine HX periodic inspections or based on sudden HX tube leaks that arise, the SDC HX's would be replaced as required. Field execution activities would be managed and funded through the Darlington Operations and Maintenance organization.

This alternative was considered and eliminated, therefore, not included in the financial evaluation.

Alternative 5: N/A

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2017	2018	2019	2020	2021	2022	Future	Total
Currently Released	25,966	12,863							38,829
Requested Now		22,615	18,480	2,212					43,307
Future Required			18,583	12,092	34				30,709
Total Project Cost	25,966	35,478	37,063	14,304	34				112,845
Ongoing Costs	-								
Grand Total	25,966	35,478	37,063	14,304	34				112,845

Estimate Class:	Class 3	**Estimate at Completion:**	[redacted]
NPV:	N/A	**OAR Approval Amount:**	$ 112,845 k

Additional Information on Project Cash Flows (optional): Annual Cash Flows include Contingency

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Alternative 4	Alternative 5
Project Cost	112,845	N/A	N/A	N/A	N/A
NPV		N/A	N/A	N/A	N/A
Other (e.g., IRR)		N/A	N/A	N/A	N/A

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Summary of Financial Model Key Assumptions or Key Findings:
1. Discount rate (WACC) of 7 % 2. Annual Interest rate of 5% on Capital costs.

Part F: Qualitative Factors
The modification supports Darlington's "Zero Emissions" cornerstone initiative. Interest in nuclear power plant tritium emissions in other countries is expected to generate increased public and regulatory scrutiny going forward. A significant tritium emission to the lake as a result of a tube leak would have a detrimental impact on public support for nuclear power in the community.

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that the HX's cannot be replaced using similar maintenance practices as are utilized for HX Channel Cover removal. If engineering modifications are required to enable HX replacement (temporary piping supports), the field installation duration will be increased from 40 days to 50 days, and additional time will be required to prepare engineering packages and fabricate piping supports. Therefore, the timeline to replace all 7 HX's will be extended, and the commitments outlined in the BCS will need to be updated to reflect the impact. There is a risk that the OPG resource costs and Vendor equipment and resource costs are underestimated, resulting in project expenditures exceeding approved funding release and requiring project activities to be placed on hold.	Accept: For each remaining HX installation, [redacted] of contingency has been allocated to the risk of designing and installing engineering modifications associated with temporary piping supports for seismic and CIWH loadings. Mitigate: 1. A weekly review of project expenditures, forecasted costs, and project risks is performed in order to evaluate the cost performance of the project and to determine if project contingency needs to be requested, or an additional project funding release is required. 2. Cash expenditures and resource allocations from the 1st HX installation were utilized to develop the current project cost estimate and to assign specific contingency for the realization of project risks.	Low	Medium
Scope	There is a risk that discovery issues on existing PULSW or SDC system components that will not be replaced as part of this project may lead to added scope for replacement or cause delays during execution to address.	Mitigate: 1. Known issues with degraded piping and components on the PULSW system and SDC system have been communicated to the Station in order to ensure these items are addressed prior to field execution (E.g. replacement of degraded PULSW isolation valves). 2. Pre-requisite activities for construction include Ultrasonic Inspection of piping cut locations to ensure appropriate wall	Low	Medium

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Part G: Risk Assessment				
Risk Class	**Description of Risk**	**Risk Management Strategy**	**Post-Mitigation**	
		thickness is available and to adjust location and/or plan for mitigating activities if required. 3. Contingency materials and components have either been purchased by the project, or requested from OPG inventory for items that may pose challenges during construction.		
Schedule	There is a risk of discovery issues, station/unit transients, and/or extreme summer or winter conditions causing delays during field execution window, and resulting in an extension to the 40 day field execution duration.	Mitigate: 1. Detailed walk downs performed by engineering and construction leads in order to validate field configuration and to minimize the risk of discovery issues during execution. 2. Breathing Air system and Vault Cooling System preventative maintenance will be prioritized with Station Operations and Maintenance in order to ensure acceptable performance during scheduled summer and winter HX replacements. In addition, specific contingency has been assigned to each HX installation to account for increased field execution duration.	Medium	Medium
Resources	There is a risk that the installation timeline conflicts with other work being done inside the station (e.g PULSW Piping Replacement), and as a result field execution work is delayed (until required resources are available) or field execution is extended (work of higher priority may be in execution inside the station that will interfere with the project, be it conflict in resource allocation, use of space, or use of equipment). A key concern is with Refurbishment or Planned Outage related activities, which may be scheduled to take place in parallel with this project.	Mitigate: 1. Communicate and engage affected OPG work groups well in advance to ensure support will be available during the required time. 2. Schedule tasks where possible when resources will be available. (I.e. outside of planned outages). 3. Ensure WO's are provided to Work Control in accordance with the N-PROC-MA-0022 timelines for Project Work. 4. During periods of inactivity on this project, the vendor will attempt to retain key skilled resources by assigning them to different projects that are in execution.	Medium	Medium
Quality/ Performance	There is a risk that the Design Engineering Change (EC) Packages are of poor quality and lack the necessary detail, and/or the construction activities are performed poorly, thus leading to delays because of rework.	Mitigate: 1. 3rd Party Review of Engineering Change packages. 2. Constructability reviews of EC packages by Construction Staff prior to approval. 3. Field Initiated Changes from the 1st HX installation are being incorporated into revisions of EC packages for the remaining 7 HX's. This will be repeated as required following each installation to incorporate Lessons Learned. 4. A Weld Mock-up of the HX nozzle to SDC piping connection will be built and utilized to train welding staff on critical welding activities prior to execution in the field.	Low	Medium
Technical	There is a risk that the tooling and equipment used for lifting and transporting the old & new HX out	Mitigate: 1. Tooling and Equipment will be inspected and tested prior to use on site. Issues identified	Low	Medium

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
	of/into the station, flushing and drying the old HX, and installing the new HX will require troubleshooting once installed, thereby negatively impacting schedule / work quality.	with the tooling and equipment during the 1st HX replacement have been incorporated into Lessons Learned and will be addressed prior to subsequent HX replacements.		

Additional Risk Analysis:

[See Guidance Section in the Appendix pages for detailed Part G instructions.]

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Comprehensive PIR	2020-10-30 (Project Completion)	2021-10-30

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Replace all SDC HX's (Qty=8) in all four Darlington Units (1, 2, 3 &4)	Current SDC HX's have experienced accelerated degradation of internal tube support structures and shell material due to MIC.	SDC HX's are more resistant to MIC degradation and their service life is sufficient to reach the projected end of Darlington operation.	Installation of new SDC HX's containing internal components (tube support structures) with greater resistance to MIC, and with a service life of 40 years.	Darlington Components & Equipment Engineering
Operation of SDC HX's	The operation of the SDC HX's pose a risk of tritium leaks to the environment, and could limit the SDC system's ability to cool down the PHT system, or limit its ability to provide maintenance cooling as a result of reduced thermal performance caused by secondary side fouling and degraded baffle plates.	The operation of the SDC HX's does not limit the SDC system's ability to cool down the PHT system, or limit its ability to provide maintenance cooling.	Evaluation of the SDC system operation during its first use following replacement of a SDC HX.	Darlington Components & Equipment Engineering

Part I: Definitions and Acronyms

ALARA – As Low as Reasonably Achievable
BCS – Business Case Summary
COMS – Constructability, Operability, Maintainability and Safety
EC – Engineering Change
ECC – Engineering Change Control
EM - Equipment Manufacturer
EPC - Engineer Procure Construct
ES MSA – Extended Services Master Service Agreement
HX - Heat Exchanger
PHT– Primary Heat Transport
IMS – Inspection & Maintenance Services
MIC - Microbiologically induced corrosion
NWMD - Nuclear Waste Management Division
PMP – Project Management Plan
PO - Purchase Order
PULSW – Powerhouse Upper Level Service Water System
SDC - Shutdown Cooling
UT - Ultrasonic Testing
WWMF – Western Waste Management Facility

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

This page is intentionally left blank

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

For Internal Project Cost Control

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Appendix A: Summary of Estimate										
Project Number:	16-31710									
Project Title:	Darlington Shutdown Cooling Heat Exchanger Replacement									
k$	**LTD**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**Future**	**Total**	**%**
1. OPG Project Management	971	483	630	271	34	-	-	-	2,389	2
2. OPG Design	528	147	153	151	-	-	-	-	979	1
3. OPG Procured Materials	-	-	-	-	-	-	-	-	-	-
4. OPG Other	3,066	2,954	3,244	1,243	-	-	-	-	10,507	9
5. EPC - Design	[redacted]									
6. EPC - Procurement										
7. EPC - Construction										
8. EPC - Project Management										
9. Interest										
Subtotal										
Contingency										
Total	25,965	35,479	37,063	14,304	34	-	-	-	112,845	100

Note: NWMD is responsible for the transport of the SDC HX's off-site to either the Western Waste Management Facility (WWMF) for long term storage, or to an external vendor for recycling and waste volume reduction. Management and funding of these activities is provided by NWMD, and therefore the associated expenditures are not included in the Estimate at Completion, or in the Removal Costs.

Notes			
Project Start Date	2012-06-29	**Total Definition cost** (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	2019-10-30 Final AFS	**Contingency included in this BCS** (Nuclear only)	
Target Completion Date	2020-10-30 Project Completion	**Total contingency released plus contingency in this BCS** (Nuclear only)	
Escalation Rate	2.90%	**Total released plus this BCS without contingency** (Nuclear only)	
Interest Rate	5.0%	**Total released plus this BCS with contingency** (Nuclear only)	$ 82,136 k
Removal Costs	$24 M included	**Estimate at Completion** (Includes only spent contingency for Nuclear)	[redacted]

Prepared by:	Approved by:
James Philipps FEB 13, 2017 Date	Marc Clemente Feb 13, 2017 Date
James Philipps Darlington and Refurbishment Projects Project Leader II	Marc Clemente Darlington and Refurbishment Projects Acting Section Manager

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2012	2013	2014	2015	2016	2017		
Definition	Partial	Nov 2012	19	1,314	18,858	15,977	6,505	3,696	1,160	47,529
Definition & Execution	Partial	March 2014	5	511	2,268	6,255	17,728	14,605	14,713	56,085
Execution	Partial	March 2017	5	511	962	2,374	22,113	35,479	51,401	112,845

Project Variance Analysis

k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
1. OPG Project Management	971	4,500	2,389	(2,111)	The increase in support for the extended project duration was offset by the removal of some costs (Field Engineering, Contract Management staff) that were reallocated to 'OPG Other'.
2. OPG Design	528	642	979	337	Increased to capture design oversight for EC revisions to address new scope items.
3. OPG Procured Materials	-	-	-	-	N/A
4. OPG Other	3,066	5,466	10,507	5,041	Reallocated Field Engineering and Contract Management staff from 'Project Management.' Increased to capture additional costs associated with 40 day execution window.
5. EPC - Design	[redacted]				
6. EPC - Procurement					
7. EPC - Construction					
8. EPC - Project Management					
9. Interest					
Subtotal					
Contingency					
Total	**25,966**	**56,085**	**112,845**	**56,760**	

Type 3 Business Case Summary

Project #: 16-31710 Document #: D-BCS-33410-10003
Project Title: Darlington Shutdown Cooling Heat Exchanger Replacement, <Partial> <Execution> Release

Appendix C: Financial Evaluation Assumptions

Key assumptions used in the financial model of the Project are (complete relevant assumptions only):

Project Cost:

1. The replacement heat exchangers will be identitical in design to the existing heat exchangers (except for internal supports changed to MIC resistant material), and therefore there will be no changes to the current thermal and stress analysis of the shutdown coolilng heat exchangers. The shell material will remain unchanged [R-3].
2. OPG internal cost estimate was developed in house and covers all phases of the project.

Financial:

1. Annual Interest Rate of 5% on capital costs.

Project Life:

1. The new Shutdown Cooling Heat Exchangers shall have a 40 year design life so that they remain operational until the end of station life following refurbishment, approximately 2055.

Energy Production:

N/A

Operating Cost:

N/A

Other:

N/A

List further detail below as appropriate from the Financial Evaluation:

N/A

Appendix D: References

[R-1] D-PCH-33410-10001, Project Charter
[R-2] NK38-PLAN-39780-0489198, Project Management Plan
[R-3] NK38-CORR-33410-0444878, Memo Re: SDC HX Replacement Project
[R-4] NK38-REP-33410-10016-R004, CCA 001465-system 0067 Shutdown Cooling-heat Exchangers
[R-5] NK38-REP-03680-10185-R000, Darlington NGS – Integrated Implementation Plan (IIP)
[R-6] NK38-CORR-33410-0462000, Project 16-31710- RS Impact Of Unavailability Of Shutdown Cooling Hx's During Replacement

ONTARIO POWER GENERATION

Records File Information:
Records SCI/USI Retention
- See Guidance Section

OPG Confidential

OPG-FORM-0076-R005*

Type 3 Business Case Summary

To be used for investments/projects meeting Type 3 criteria in OPG-STD-0076

Executive Summary and Recommendations

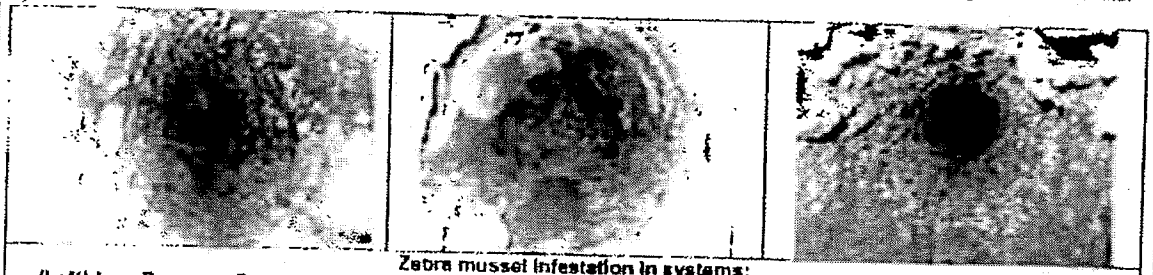
Project Information			
Project #:	16-38948	Document #:	D-BCS-72100-10006
Project Title:	DN Zebra Mussel Mitigation Improvements		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	Investment Type:	Sustaining
Phase:	Execution	Release:	Superseding
Facility:	Darlington	Target In-Service or Completion Date:	2017-08-30

Project Overview

We recommend the Gate 3b approval to proceed and release of $7,774k, including [redacted] contingency for the Zebra Mussel Mitigation Project. The total project is estimated at $29,255k including [redacted] contingency. This is a Class 2 estimate for this release and a Class 2 estimate for the entire project.

Issue:

Zebra mussel fouling has impaired the reliability of plant systems that use lake water, due to the undesired presence of the invasive freshwater mussel. These service water systems provide cooling water to a number of safety and safety related loads such as shutdown cooling heat exchangers, shutdown cooling pump motor coolers, moderator heat exchangers, liquid zone control, and critical air conditioning units. See below for examples of zebra mussel infestation in the Darlington Service Water systems.



Zebra mussel infestation in systems:
(Left) Low Pressure Service Water (LPSW) booster pump 4-72100-P5, (Middle) Powerhouse Upper Level Service Water (PULSW) 1-72300-NV317, and (Right) PULSW 1-72300-V195

A World Association of Nuclear Operators (WANO) evaluation at Darlington identified as an area for improvement (AFI) as zebra mussel fouling in low-flow end stagnant areas.

Total project cost changes are attributed to scope change via four Project Charter Revisions since the start of the project. The Full Execution scope change is related to the completion of feasibility studies for implementing closed loop supply for Primary Heat Transport (PHT) & Shutdown Cooling (SDC) pump motor cooling and replacement of Low Pressure Service Water (LPSW) Strainers in these systems and completion of the scope definition phase for installing strainers on Powerhouse Upper Level Service Water (PULSW) & LPSW supply to safety and safety related loads in critical systems. In the requested release, a design change is needed to relocate the permanent Sampling Station from the roof of the Condenser Cooling Water (CCW) structure to ground level to maintain safe work conditions during winter conditions. In addition, the conversion of the temporary modification (TMOD) to a permanent modification (PMOD) for the Inactive Drainage Lagoon aeration system is needed to ensure the total residual chlorine (TRC) is maintained below the MOE limits as a result of 4-unit continuous chlorination.

The original design was ineffective at controlling zebra mussel infestation as it allowed intermediate chlorination (ability to chlorinate only one LPSW unit pump house & the ESW pump house). This enhanced design (Master Design EC 122616 &

*Associated with OPG-STD-0076, Developing And Documenting Business Cases

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release

Document #: D-8CS-72100-10006

Project Overview

122617) improves the reliability of the existing system and allows 4-unit continuous chlorination and the installation of a permanent dechlorination system that would naturalize the chlorine concentration at the outfall before releasing to the environment.

Below are details in the change of scope from each previous release:

Scope of work for Partial Definition release (total project cost was [redacted], plus [redacted] of contingency):

1) Value Engineering Sessions for the full project scope
2) Scope Definition phase (modification Design Requirements (MDRs), Master ECs, Design Scoping Check lists & associated forms for 4-unit Chlorination & Permanent De-Chlorination.
3) Request for Purchase (RFP) packages completed & Proposals obtained via competitive bids.

Scope of work for Partial Definition & Execution release (total project cost was [redacted], plus [redacted] of contingency):

1) Bridging strategy with temporary de-chlorination to support 4- unit continuous chlorination has been completed and placed into service.
2) Detailed design for permanent de-chlorination and piping upgrades for chlorination system improvement has been completed.

Removal from the Scope of work for Full Execution release (total project cost was [redacted], [redacted] of contingency):

1) Complete feasibility studies for implementing closed loop supply for Primary Heat Transport (PHT) & Shutdown Cooling (SDC) pump motor cooling and replacement of Low Pressure Service Water (LPSW) Strainers in these systems.

2) Complete scope definition phase (Modification Design Requirements/MDR, Modification Outline/MO and associated forms) for installing strainers on Powerhouse Upper Level Service Water (PULSW) & LPSW supply to safety and safety related loads in critical systems.

Additional Scope of work for the Superseding release (total project cost is [redacted], plus [redacted] of contingency):

1) The MDR for de-chlorination system (NK38-MDR-74950-10003) has been revised to include design change for permanent sampling station. The additional design effort to relocate permanent sampling station to ground level to address worker/personnel safety related concerns has increased the project total by $1,733k and changed the permanent sampling station ready date to the 2017 chlorination season.

2) The design conversion of the TMOD to a PMOD for the Inactive Drainage Lagoon aeration system will be completed in-house by the OPG design team. The design effort along with the purchase of the new aeration system and the installation costs has increased the project cost by $290k.

Recommendation:

We recommend the gate 3b approval to proceed and release of a $7,774k, including [redacted] for a Superseding Release of the Zebra Mussel Mitigation Improvements project.

This release will fund the following scope of work:

- Complete Installation, Commissioning, and Final AFS of the 4-unit (continuous) chlorination and (permanent) de-chlorination modification.
- Conversation of the TMOD to a PMOD for the Inactive Drainage Lagoon aeration system and purchase of equipment for the permanent aeration system.
- Design, Installation, and Final AFS of the Sampling Station
- Project close-out

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	10,889	10,592							21,481
Requested Now	-	5,750	1,952	72					7,774
Future Required	-								
Total Project Cost	10,889	16,342	1,952	72					29,255
Inventory			204						204
Ongoing Costs	-		750	750	750	750	750	3,750	7,500
Grand Total	10,889	16,342	2,906	822	750	750	750	3,750	36,959

Estimate Class:	Class 2	**Estimate at Completion:**	[redacted]
NPV:	N/A	**OAR Approval Amount:**	$36,959k

Additional Information on Project Cash Flows (optional):
Spare parts inventory for new installed chlorination & de-chlorination systems is estimated at $204k
Ongoing chemical (sodium hypochlorite (NaOCl) & Sodium Bi-sulphite (SBS)) cost is estimated at $750k per year.

Approvals

	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Glenn Jager Nuclear President, and CNO			SEP 28 2016
I concur with the business decision as documented in this BCS.			
Finance Approval: Ken Hartwick SVP Finance, Strategy, Risk & CFO per OPG-STD-0076			Sept 29, 2016
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Jeff Lyash President & CEO per element 1.1			Oct 3/16

ONTARIO POWER GENERATION

Records File Information:
Records SCI/USI Retention
- See Guidance Section

Internal Use Only

OPG-FORM-0076-R005*

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release

Document #: D-BCS-72100-10006

Business Case Summary

Part A: Business Need

Zebra mussel fouling has been an issue in service water systems effecting equipment reliability. Service water provides cooling to a number of safety and safety related loads such as shutdown cooling heat exchangers, shutdown cooling pump motor coolers, moderator heat exchangers, liquid zone control, and critical air conditioning units. Zebra mussel fouling can and has in the past resulted in unavailability of this equipment.

Zebra mussel fouling has resulted in unavailability of the shutdown cooling pumps on numerous occasions. Zebra mussel fouling has also resulted in debris blocking cooling lines, significant vault vapour recovery heat exchanger fouling and flow blockage. Other systems that were also affected by zebra mussels fouling were liquid zone control heat exchangers, vault coolers, confinement dryer heat exchangers and primary heat transport pump motor coolers. Flow blockages are typically a result of zebra mussel debris being introduced into these systems as a result of valving in of stagnant lines such as use of the LPSW inter-unit tie and PULSW recirculation at Darlington.

Zebra mussels are an invasive species not native to North America. Accordingly, the original design of the Darlington service water systems did not consider the need for zebra mussel mitigation and hence zebra mussel infestation became a problem after the service water systems were put in service. Presence of adult zebra mussels in station piping indicated that they are entering as veligers and growing to adulthood inside the piping over a period of time.

There is a significant increase of Station Condition Records (SCRs) trending over the past 8 years relating to low flow and pressure due to zebra mussel fouling such as LPSW Supply line to Instrument Air Compressors Cooling, PULSW Supply lines to Shutdown Cooling, and zebra mussels found in pump housing/piping.

Zebra mussel fouling in low flow and stagnant areas was the basis for an Area for Improvement (AFI) in Darlington's previous World Association of Nuclear Operators (WANO) evaluation.

A chlorination system was completed years ago to control zebra mussels but the frequencies of chlorination dosing (semi-continuous) were not adequate over time for effective zebra mussel control due to zebra mussels adapting to the dosing frequencies. Therefore implementation of continuous chlorination across all units is required to ensure effective zebra mussel control while maintaining Ministry of Environment (MOE) limits/requirements for outfall into lake.

There is also an operability reliability risk with the current service water chlorination system which presently have two types of sodium hypochlorite piping:

- Chlorinated Polyvinyl Chloride (CPVC), which has shown numerous leaks with the majority on threaded or glued joints; and,
- Polyvinyldiene Fluoride (PVDF) piping, that has reached its end of design life.

Pickering station has implemented a De-Chlorination Systems to support continuous chlorination to eliminate zebra mussels fouling in service water systems. Operating Experience (OPEX) from the Pickering project scope is used for implementation at Darlington.

A Service Water Reliability Program – Strategy Manual completed in 2012 identified a program for minimizing/eliminating challenges to equipment reliability and plant operation due to zebra mussel fouling (as one of the factors) that may occur in open service water systems. Condition Assessments & Self-Assessments were completed in the past to identify areas for improvements with regards to Service Water Reliability Program and zebra mussel fouling. A short & long term strategy/program has been put in place to address service water reliability issues which include this project scope.

The business objective of this sustaining project is to:

1) Upgrading existing service water chlorination systems. These presently have two types of sodium hypochlorite piping; CPVC Piping which has shown numerous leaks & PVDF Piping which has reached its end of life.
2) Prevent zebra mussel attachment to service water equipment (Emergency Service Water (ESW), LPSW, PULSW) downstream of chlorination points.
3) Implement continuous chlorination across all units. The present dosing schedule provides semi-continuous 90 minutes ON, 270 minutes OFF (in unit pump houses) and continuous in ESW pump house during the zebra mussel season (May to December).
4) Meeting ministry of Environment (MOE) limits for outfall.
5) Eliminate introduction of zebra mussel debris in critical station systems to prevent potential PULSW & LPSW outages which could result in unit outage extensions.

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Part B: Preferred Alternative: Implementation of the Recommended Modifications

Description of Preferred Alternative

During the initiation phase of the project a vendor was consulted to evaluate the issues & mitigation improvements of Zebra Mussel fouling in Service water systems. A conceptual design report was issued which addresses various areas in the Darlington service water systems. Value engineering sessions were also held to refine and prioritize the scope of the project considering their impact on the station and associated risks.

As per the project charter (D-PCH-72100-10003), there was no scope drop from previous releases. However there was additional scope that increased that total project cost as per the following:

- Revise the design for the permanent sampling station to relocate from the top of the CCW discharge structure to ground level. This additional scope increased the total project cost by 1.1M.
- Prepare a temporary modification (TMOD) to support aeration system in the IAD lagoons and rent the aeration equipment for the 2016 chlorination season. This additional scope increased the project cost by 290k.

The original design that allowed intermediate chlorination (chlorinate one LPSW unit pump house & the ESW pump house) was ineffective at controlling zebra mussel infestation especially during the worm summer months due to the high LPSW & ESW system flow rates. The additional scope, as identified above, was approved to support this modification (Master Design EC 122616 & 122617) to allow 4-unit continuous chlorination and the installation of a permanent dechlorination system that would naturalize the chlorine concentration at the outfall before releasing to the environment.

The recommended modifications are to be implemented as part of the long term strategy/program for eliminating & preventing zebra mussel fouling in station service water systems. The scope of this project is restricted to complete:

A - Liquid Chlorination System Improvement

1) CPVC Chlorination piping to be replaced with new PVDF piping.
2) Replacement of existing PVDF chlorination piping with new PVDF Piping since its reaching its end of life.

   Implementation of 4-unit (continuous) chlorination including an automatic interface with a permanent de-chlorination system.

B - De-chlorination System Installation

1) Installation of a new (permanent) de-chlorination system to permit 4-unit (continuous) chlorination.

Deliverables:	Associated Milestones (if any):	Target Date:
Complete 4-Unit Chlorination and Permanent De-Chlorination Modifications AFS.	Chlorination/De-Chlorination – Final AFS (AFS)	30Jan17
Available For Service for PMOD of IAD Aeration System	IAD Aeration System – Final AFS (AFS)	30DEC16
Complete revised Design of Sampling Station	Design Completion	14MAR17
Start of Installation for Sampling Station	Sampling Station – Start Of Installation (SOI)	12JUN17
Available For Service of the Sampling Station	Sampling Station – Final Available For Service (AFS)	30AUG17
Project Closeout	Project Closeout	11SEP18

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project

Failure to complete this modification would result for the continued need for outage extensions due to the need for LPSW outages: 4 days outage extensions per planned outage for LPSW for 2/3 of Darlington Nuclear (DN) Outages to effect zebra mussel abatement. These outages would have to take place at the end of each outage when heat loads are lowest. This option

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Alternative 2: Base Case – No Project

would reduce the reliability of the Service Water Systems and zebra mussel fouling could increase due to no continuous chlorination. In addition, it would also increase maintenance to attempt to continue manage the leaks through vigorous maintenance procedures.

Alternative 3: Delay Work – Delay Work

Station has OPEX and a history of adverse conditions relating to zebra mussels and zebra mussel debris fouling the service water systems cooling lines. Zebra mussel fouling has been an issue in service water systems effecting equipment reliability and resulting in unavailability of safety and safety related systems. Delaying this project increases the risk of re-occurring events which could potentially de-rate units.

Alternative 4: Implement portion of the scope.

Implement the 4-unit (continuous) chlorination modification only and continue to use the temporary de-chlorination system currently in service i.e. do not implement the (permanent) de-chlorination system. However, this alternative is not a long term viable option for the station due to the following:

- Current temporary de-chlorination system was designed to support two-unit continuous chlorination only.
- There will be lack of (automatic) communication interface between the chlorination system and the de-chlorination system. Lack of automatic systems creates the risk scenario if the de-chlorination system becomes impaired; the continuous chlorination would not stop and could result in exceeding ministry of environment limits. Current de-chlorination injection rates are based on manual inspections and operator rounds necessitating significant human intervention. There is a potential risk of human error.
- Increase storage of chemicals. No space available to store more chemicals using rental equipment.
- Potential costs increases in the long term due to rental of equipment, associated mobilization and demobilization costs incurred each season and increase of oversight to support the de-chlorination system vendor with day to day operation of the system.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	10,889	10,592							21,481
Requested Now	-	5,750	1,952	72					7,774
Future Required	-								
Total Project Cost	10,889	16,342	1,952	72					29,255
Inventory			204						204
Ongoing Costs	-		750	750	750	750	750	3,,750	7,500
Grand Total	10,889	16,342	2,906	822	750	750	750	3,750	36,959

Estimate Class:	Class 2	**Estimate at Completion:**	[redacted]
NPV:	N/A	**OAR Approval Amount:**	$36,959k

Additional Information on Project Cash Flows (optional):

Spare parts inventory for new installed chlorination & de-chlorination systems is estimated at $204k.
Ongoing chemical (sodium hypochlorite (NaOCl) & Sodium Bi-sulphite (SBS)) cost is estimated at $750k per year.

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case	Delay Work	Alternative 4	Alternative 5
Project Cost	$29,255				
NPV	N/A				
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Summary of Financial Model Key Assumptions or Key Findings:
Sustaining Investment, NPV not required.

Part F: Qualitative Factors
- WANO evaluation of Darlington Station for Areas of Improvement - Reliability of Darlington Station Systems/Equipment.

Part G: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk of the Sampling Station Design will not be complete within the budgetary quote provided due to a low quality estimate. This will inherently increase the cost of the design.	Estimates are based on design work completed and that contingency has been set aside for unforeseen conditions and/or delays.	Medium	Medium
Scope	Due to incomplete sampling station design, budgetary quote for installation may be inadequate. This may increase cost and delay execution.	Contingency will be allocated for Sampling Station installation.	Medium	Medium
Scope	Numerous design changes and discovery work during the chlorination installation have resulted in cost increase/schedule delays. There is a risk that these design changes may be applicable to the de-chlorination system as well.	This risk can be mitigated through engineering oversight and vendor design agency on site to minimize any design impact.	Medium	Medium
Schedule	There is a risk of not achieving Final AFS for the 4-unit Chlorination/De-chlorination post commissioning due to potential Open Items developed from commissioning.	This risk can be mitigated by engaging stakeholders prior to AFS to disposition/resolve any potential open items.	Low	Medium

Additional Risk Analysis:
N/A

Part H: Post Implementation Review (PIR) Plan

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Comprehensive PIR	2017-08-30	2018-09-11

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
Number of Leaks on Chlorination Piping	Approximately 35 leaks on CPVC Chlorination during 3 years of operation	Leaks will be significantly reduced by 90%	Comparisons of Corrective Maintenance WOs before and after mod. implementation	Performance Engineering, Chlorination SRE
Residual Chlorine in LPSW outfall	Residual chlorine is being discharged in the LPSW outfall	Reduce residual chlorine level to current acceptable level for allowing 4 unit chlorination	Residual levels: Below limit set in the Certificate of Authorization	Chemistry and Environment
Adult Zebra Mussels found in the LPSW System	Live adult zebra mussels found in the LPSW Bioboxes	Zero live adult zebra mussels found in the LPSW Bioboxes and during the D1711	Observation of Bioboxes and field observations from the D1711 PULSW	Chlorination Program Co-ordinator Or

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
		PULSW Outage	Outage	Chlorination SRE

Part I: Definitions and Acronyms

PHT: Primary Heat Transport
PVDF: Polyvinylidene Fluoride
CPVC: Chlorinated Polyvinyl Chloride
SDC: Shutdown Cooling
PULSW: Powerhouse Upper Level Service Water
LPSW: Low Pressure Service Water
ESW: Emergency Service Water
AFS: Available for Service
RCW: Re-circulated Cooling water
MOE: Ministry of Environment
EPC: Engineering, Procurement, Construction
WANO: World Association of Nuclear Operators
AFI: Area for Improvements
EC: Engineering Change
OPEX: Operating Experience
MDR: Modification Design Requirements

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release

Document #: D-BCS-72100-10006

This page is intentionally left blank

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

For Internal Project Cost Control

OPG Confidential
OPG-FORM-0076-R005

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Appendix A: Summary of Estimate										
Project Number:	16-38948									
Project Title:	DN Zebra Mussel Mitigation Improvements									
K$	LTD	2016	2017	2018	2019	2020	2021	Future	Total	%
OPG Project Management	1,441	162	160	[redacted]					1,802	6
OPG Engineering (including Design)	1,130	170	189						1,489	5
OPG Procured Materials										
OPG Other	398	135	59						592	2
Design Contract(s)	[redacted]									
Construction Contract(s)										
EPC Contract(s)										
Consultants										
Other Contracts/Costs										
Interest										
Subtotal										
Contingency										
Total	10,889	16,341	1,952	72					29,255	100

Notes			
Project Start Date	2013-01-03	**Total Definition cost** (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	2017-08-30	**Contingency included in this BCS** (Nuclear only)	
Target Completion Date	2018-09-11	**Total contingency released plus contingency in this BCS** (Nuclear only)	
Escalation Rate	2.5%	**Total released plus this BCS without contingency** (Nuclear only)	
Interest Rate	5.0%	**Total released plus this BCS with contingency** (Nuclear only)	$29,255k
Removal Costs	$60k	**Estimate at Completion** (includes only spent contingency for Nuclear)	[redacted]

Prepared by:		Approved by:	
P. Hetzel	2016-03-22		2016-03-28
Philip Hetzel Engineering Intern Design Projects	Date YYYY-MM-DD	Rajbir Singh (Acting) Manager Refurb and Outage Projects	Date YYYY-MM-DD

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release

Document #: D-BCS-72100-10006

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			2013	2014	2015	2016	2017	2018		
Definition	Partial	2012-11-30	631	4,396	5,537	2,562	2,268	2,231	1,254	18,879
Definition & Execution	Partial	2014-03-29	323	10,587	7,423	5,448	1,169	2,095	11,259	38,303
Execution	Full	2015-10-07	323	2,491	12,643	5,642	382	0	0	21,481
Execution	Superseding	Q3 2016	323	2,492	8,075	16,341	1,952	72	0	29,255

Project Variance Analysis

k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management	1,441	1,817	1,802	(15)	Project Management costs were previously over estimated. Project Closeout is requested one year later than last BCS.
OPG Engineering (including Design)	1,130	1,500	1,489	(11)	Variance due re-location of the Sampling Station, additional Design is required to complete the modification.
OPG Procured Materials					
OPG Other	398	0	592	592	OPG Other costs were divided between OPG PM and ENG costs in the previous release. These include Station support during the installation.
Design Contract(s)	[redacted]				
Construction Contract(s)					
EPC Contract(s)					
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
Contingency					
Total	22,979	21,481	29,255	7,774	

Type 3 Business Case Summary

Project #: 16-38948
Project Title: DN Zebra Mussel Mitigation Improvements, Superseding Execution Release
Document #: D-BCS-72100-10006

Appendix C: Financial Evaluation Assumptions
Key assumptions used in the financial model of the Project are (complete relevant assumptions only):
N/A

Appendix D: References
1) Charter: D-PCH-72100-10003 R003 2) Conceptual Design Report: NK38-DRT-72100-10009 3) Value Engineering Study: NK38-REP-72100-0478327 4) ESW & LPSW Chlorination Upgrade MDR: NK38-MDR-74950-10004. 5) Installation of Permanent De-Chlorination System MDR: NK38-74950-10003 6) Zebra Mussel Mitigation Improvements – Phase I (4-Unit Continuous Chlorination and De-Chlorination) Scope of Work NK38-SOW-74950-10002.

Type 2 Business Case Summary

To be used for investments/projects meeting Type 2 criteria in OPG-STD-0076.

Project Information			
Project #:	16-80022	**Document #:**	D-BCS-60800-10005 R000
Project Title:	OH180 Aging Management Hardware Installation		
Class:	☐ OM&A ☒ Capital ☐ Capital Spare ☐ MFA ☐ CMFA ☐ Provision ☐ Others:	**Investment Type:**	Sustaining
Phase:	Definition	**Release:**	Full
Facility:	Darlington	**Target In-Service or Completion Date:**	Q4, 2027

Project Overview

We recommend the release of $5,892k, including [redacted] of contingency

The total project release to date is $7,290k, including [redacted] of contingency

The estimated total project cost is $90,032k, including [redacted] of contingency. At this initial phase of the project there is significant risk on the execution, planning, and resourcing estimates. The scope is significant with 1344 controllers to be isolated, power supplies and boards swapped out, and function testing performed. Some of the controllers require a 4 unit outage and others impact multi-units. Conservative decision for this Business Case Summary was to include full amount of contingency (100%) in the future release. After the project has executed the pilot phase and obtained relevant OPEX, future releases will incorporate this OPEX into the costing and the contingency will be reduced and in alignment with a Class 3 estimate.

The total cost of the OH180 aging management programme, including the nearly complete project to reverse engineer and qualify replacement components is $95,086k, including [redacted] contingency.

The quality of the estimate for this release is Class 3, and for the total project is Class 4

This release will fund the following scope of work:

- Work planning, including detailed installation/commissioning work plan preparation and work order task assessments, for OH180 Programmable Controllers (PK) online replacements in 2017 and Online/Outage replacements in 2018
- Materials procurement for online replacements in 2017 and Online/Outage replacements in 2018
- Field replacement of approximately 3% of total PKs in 2017 as a pilot execution
- Preparation and approval of Execution Partial Business Case Summary (BCS) for next phase (year 2018 to 2020) PK replacements

History of BCS releases and project cost estimates:

The total project cost is now estimated at $90,023k, including [redacted] contingency, compared to $47,203 k, including [redacted] of contingency in the previous release.

History of scope and schedule changes:

The proactive replacement of all fibre optic transceiver boards in the OH180 Communication Modules (2 boards per module) has been added to the scope of this project following review of aging management strategy with the project sponsor.

The target date for full AFS of all PK replacements is now 2027, compared to 2022 in the previous BCS. The variance is due to completing this work in planned unit outages, as opposed to Refurbishment outages assumed previously, and also due to a significant number of PKs that require four unit shutdown, that will need to be replaced during VBO in 2027.

Part A: Business Need

The OH180 Programmable Logic Controller (PK) is an essential piece of plant equipment at Darlington. It was designed by Ontario Hydro (OPG's predecessor) and built by a third party manufacturer to replace the electro-mechanical relays used for

*Associated with OPG-STD-0076, Developing and Documenting Business Cases

Type 2 Business Case Summary

Project #: 16-80022 Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Part A: Business Need

control logic implementation in the previous CANDU stations. The OH180 is used to control the majority of process systems (including special safety and safety related systems), electrical distribution system breakers and the Class 3 Transfer System. Each OH180 PK consists of several printed circuit boards (Central Processing Unit (CPU), Erasable Programmable Read Only Memory (EPROM) and, depending on the application, up to two power supplies, up to eight input and output boards and, in some cases, communications modules.

There are 1,344 OH180 programmable controllers currently installed at Darlington Nuclear Generating Station, consisting of over 12,000 printed circuit boards. Although the OH180s still operate quite reliably, the circuit boards are over 25 years old and are not expected to last until the extended end of station life. It is anticipated that the failure rate of the legacy OH180 boards will increase in the near future due to aging electronic components.

The existing hardware has been reverse engineered under Project#34011, so that replacement boards can be manufactured and spare parts procured. Investment in proactive replacement of OH180 hardware needs to be undertaken as all boards are not expected to last until end of station life, and will place a significant burden on operation and maintenance resources due to OH180 board failures. Some of the PKs are deemed Single Point Vulnerability (SPVs) and failure can result in a forced outage.

Part B: Preferred Alternative: Install Re-engineered OH180 Hardware Components

Description of Preferred Alternative

The preferred alternative is to complete proactive replacement of the following OH180 hardware components that are susceptible to failure due to aging:-

- Procure and install re-engineered OH180 Power Supplies (1,930)
- Procure and install re-engineered Communication Module Power Supplies (431)
- Procure and install re-engineered Communication Module Fibre Optic Transceiver boards (862)
- Procure and install re-engineered Input Boards (2,493)
- Procure and install re-engineered Output Boards (3,787)
- Upgrade EPROMs the OH180 executive program from version 112 of the OH180 executive program to version 117 for all OH180s in the plant as required (note: a number of OH180s have already been upgraded to version 117).
- Verify the existing OH180 database, so that it may be used as an approved tool to facilitate the preparation of commissioning plans for ladder logic changes

The previous release of this project completed the following work:-

1. Non-Identical Component Replacements or NICR EC packages for PK/Communication Module Power Supply Boards, and Item Equivalency Evaluation or IEE for the Input/output boards
2. Installation planning contract by external vendor to complete
   a) A comprehensive review of system condition requirements for each OH180 replacement to enable creation of a high level project schedule. Preliminary findings of this review indicate that approximately 632 PKs can be replaced with the unit under normal operating conditions (i.e. Online), 602 PKs require a Unit shutdown (i.e. Outage) and 108 PKs that require four unit shutdown (i.e Vacuum Building Outage or VBO). For this reason the project schedule has extended into 2027 when the next station VBO is planned. The project will review/challenge the number of PKs, that require outage or VBO replacement, during detailed planning (this release) and attempt to schedule these for Online replacements to reduce outage scope.
   b) Future releases of the BCS would allow creation of workplans to complete replacement of PKs under this contract

Due to the variation in complexity of this project and the large quantity of controllers in the plant, a pilot phase consisting of 3% PK replacement is planned in this Definition release. The purpose of the pilot execution is to complete hardware replacements on a varied selection of high/medium/low complexity PKs to obtain lessons learned and operating experience (OPEX), which will be used to refine the work planning/assessing for future PK replacements, and cost/schedule estimate for future execution releases. The scope of the pilot is strictly a maintenance type activity (replacement with equivalent components), and does not constitute a modification of the system or equipment function. If the installation were to be unsuccessful, the old components

Part B: Preferred Alternative: Install Re-engineered OH180 Hardware Components

Description of Preferred Alternative

can be reinstalled to return the equipment to its original condition. Therefore, the risk associated with the pilot is minimal.

The list of PKs selected for this pilot phase execution is included in the Appendix C of this document.

Deliverables:	Associated Milestones (if any):	Target Date:
Current Release		
Work Planning and Assessing Ready for 2017 Online Scope (Pilot Execution)	SOI - 2017 Online Scope (Pilot)	30- Jun-2017
Work planning and Assessing Complete for 2018 Online and Outage (D1831) Scope		02-Jan-2018
Materials staged for Online 2017 scope		1-Jun-2017
Complete pilot installations in 2017 and Available for Service (AFS)	AFS – 2017 Online Scope (Pilot)	29-Dec-2017
Execution Partial (Gate 3A) Business Case Summary	Execution Partial (Gate 3A) BCS Approved	29-Mar-2018
Future Releases		
Start of Installation for D1831 Outage	SOI – D1831 Outage Scope	30-Apr-2018
AFS of Installation of D1831 Outage	AFS – D1831 Outage Scope	30-Jun-2018
Start of Installation – 2018 - 2020 Scope	Start of Installation – 2018 Online Scope	30- Apr -2018
AFS Gate 3A - 2018 – 2020 Scope	AFS – 2018 Online Scope	31-Jan-2019
Execution Partial (Gate 3B) Business Case Summary	Execution Partial (Gate 3B) BCS Approved	31-Dec-2020
Execution Full (Gate 3C) Business Case Summary	Execution Partial (Gate 3C) BCS Approved	31-Dec-2023
All PK Replacements complete	Final AFS	31-Dec-2027
Project Complete	PCM - Project Complete	30-Jun-2028

Part C: Other Alternatives

Summarize all viable alternatives considered, including pros and cons, and associated risks. Other alternatives may include different means to meet the same business need, and a reduced or increased scope of work, etc.

Alternative 2: Base Case – No Project

This option entails replacement of OH180 boards upon failure, and not proactive replacement. Project#34011 has completed re-engineering of the OH180 boards and will stock 10% lifetime spares to replace components as they fail. This option is not recommended since all OH180 boards, selected for proactive replacement per the OH180 aging management study, are expected to eventually fail prior to station end of life, and threatens safe plant operation due to failure of vital control/monitoring equipment.

Pros:

- No upfront cost for proactive aging management replacement

Cons:

- As the OH180s continue to age, the failure rate will continue to increase exponentially as the population of OH180s enter the wear-out region of electronics reliability curve [R-1]. The burden on maintenance would become too large to keep up with the repairs as maintenance only has so many refreshed boards ready for replacement at a time.
- Waiting for a field failure to occur brings down the OH180 and the associated controlled system in an unplanned manner, thus creating a large burden on Operations and Maintenance.
- This alternative would result in unreliable operation of the OH180s which has the potential to impact safety and production as the OH180s control the majority of process systems including special safety and safety related systems. If multiple OH180 failures were to occur during a shift, Operations and Maintenance may not have the resources

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Alternative 2: Base Case – No Project

available to make the repairs and might be forced to shut down the Unit.

- System health will decline as components will not be replaced until they fail. There are not likely to be enough spares on hand to support the expected failure rate.

[R-1] *Evaluating the Effects of Aging on Electronic Instrument and Control Circuit Boards and Components in Nuclear Power Plants*. EPRI, Palo Alto, CA: May 2005. 1011709.

Alternative 3: Replace The OH180 System With An Off The Shelf Programmable Controller

Investigation into off-the-shelf technology indicates that there is nothing on the market that is a direct replacement. Adapting one of these systems would require:

- Extensive re-wiring of the station
- Re-qualification of the hardware and software
- Re-programming of the control logic for each of the process systems with a possibly new programming language and the resulting need for testing.
- Re-commissioning each system in which an OH180 was replaced
- Re-training of staff
- This alternative would be expensive and require long unit outages to implement. Furthermore, the new PLCs would not have the field diagnostic capabilities (ground fault detection, open wiring etc.) of the present OH180 system.

Part D: Project Cash Flows, NPV, and OAR Approval Amount

k$	LTD	2016	2017	2018	2019	2020	2021	Future	Total
Currently Released	295	478	625	-	-	-	-	-	1,398
Requested Now	-	-	4,863	1,029	-	-	-	-	5,892
Future Required	-	-	-	7,469	9,115	7,973	8,049	50,136	82,742
Total Project Cost	295	478	5488	8,498	9,115	7,973	8,049	50,136	90,032
Ongoing Costs	-	-	-	-	-	-	-	-	-
Grand Total	295	478	5488	8,498	9,115	7,973	8,049	50,136	90,032

Estimate Class:	Class 4	**Estimate at Completion:**	[redacted]
NPV:	Not Required (Sustaining Investment)	**OAR Approval Amount:**	$ 7,290k

Additional Information on Project Cash Flows (optional):

[redacted] contingency is included in the currently released, [redacted] of contingency is included in this requested release; [redacted] contingency is included in future releases.

Cash flow forecast based on high level PK replacement schedule assuming work Online, Unit Outages (non-Refurbishment) and VBO2027

Part E: Financial Evaluation

k$	Preferred Alternative	Base Case			
Project Cost	90,032				
NPV	N/A				
Other (e.g., IRR)					

Summary of Financial Model Key Assumptions or Key Findings:

Financial evaluation not required as this is a Sustaining investment.

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Part F: Risk Assessment

Risk Class	Description of Risk	Risk Management Strategy	Post-Mitigation	
			Probability	Impact
Cost	There is a risk that the cost of materials and labour will increase beyond the estimate between the start and end of the execution phase, as a result of an increase in the cost of raw materials and labour rates. There could be unexpected increases over the 10 year span of execution.	The risk of emergent cost escalation cannot be mitigated at this time. Sufficient contingency has been allocated to deal with this risk.	Medium	Medium
Cost	There is risk that the Operator and Maintainer field effort required for aligning the controllers to the conditions required for shutdown and board replacement is significantly greater than estimated, because work planning is not complete at this time. Each controller has not been assessed, and installation instructions have not been written for the replacement work. Execution could take longer than planned; project completion delayed. Cost could be greater than estimated.	This risk will be mitigated partly by completion of definition phase (work planning and assessing). To mitigate the remaining risk, the project will conduct a pilot installation of approximately 40 PKs (3%) to evaluate the effort required for the execution phase. The lessons learned from the pilot will be incorporated into the work planning, work assessing, and cost estimate for the execution phase.	Medium	Medium
Scope	There is a risk of discovering legacy configuration management and or programmatic issues. The effort required to correct legacy issues could result in significant project scope increase due to the large number of controllers.	There is no practical method to identify potential issues at this time. The issues will be addressed upon discovery. Sufficient contingency has been allocated to deal with this risk.	Low	Medium
Schedule	There is a risk that installation of some controllers cannot be executed as scheduled. The causes could be misunderstanding of equipment shutdown requirements; equipment outage consequences not considered; operator not comfortable with taking the equipment out of service at the scheduled time; emergent issues prevent the equipment from being removed from service; and/or scheduled outage windows shift. Failure to complete outage work could prolong the project duration beyond 2027, due to the three year outage cycle.	The project has contracted former maintainers and licensed operators to develop the installation strategy. The usage of this expertise will minimize the risk of PKs being classified incorrectly as online or outage. The project is also planning the installation to align with known unit outages, functional equipment group outages, and maintenance work. Finally, the project will continuously review the installation schedule with work control to identify conflicts that can prevent installation from being performed as scheduled and to identify opportunities to recover and improve the schedule.	High	Medium
Resources	There is a risk that Assessing, Operations and Maintenance resources are not available to perform installation and prerequisites, due to emergent work and or competing priorities. The impact would be delay to the installations and extension of project schedule. Outage prerequisites (milestones) could be missed.	The project has obtained commitments from Maintenance to provide qualified resources (either regular staff or temporary staff). The project will work with the Assessing and Work Plan Reviewer organization (s) to secure resources to support this project. Similarly, the project will present the execution plan to Operations, and obtain resource commitments prior to finalizing the execution schedule.	Medium	Low

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Part F: Risk Assessment				
Risk Class	**Description of Risk**	**Risk Management Strategy**	**Post-Mitigation**	
Resources	There is a risk of a shortage or unavailability of new boards to meet the installation schedule, due to obsolescence of raw materials and or suppliers going out of business over the 10 year span of execution. Impacts include delay to installation schedule and cost increase.	The supplier will implement a materials management strategy to minimize the risk of materials shortages for the total production quantity of new boards. The board design uses basic electronic parts; therefore, if materials do become obsolete, then substitutes can be used with minimal engineering effort. OPG owns the intellectual property rights for the new boards. If manufacturers go out of business, OPG will be able to contract the manufacturing to others. Also, as part of Project#34011, 10% lifetime spares would be ordered at the beginning of project (i.e. 2016/2017), hence sufficient spares would be on hand to deal with any board failures.	Low	Low
Technical/ Operation	There is a risk that the new boards respond unexpectedly after they are installed and put into service, due to design flaw that was not caught in design reviews, testing, and commissioning. Potential consequences range from unexpected individual equipment response to unit trip, depending on the impacted equipment/system.	The new boards have been designed, manufactured and tested to the extent possible under appropriate quality assurance programs. To mitigate this risk, the project will install the new boards in less critical systems at the start of the execution. This will allow the new boards to be evaluated in an in-service condition while minimizing the impact of any failures.	Low	Low
Technical/ Operation	There is a risk of discovering field conditions that do not match design documentation, including hardware configuration and differences between the ladder logic loaded in to the controller and the OH180 database. There is also risk that equipment may fail to start when the controller is returned to service, due to deteriorated and aging components. The impact ranges from minor delay to significant delay for equipment return to service.	There is no practical way to verify software configuration management prior to installation. There is also no practical method to identify degraded equipment. These risks cannot be mitigated at this time, and contingency has been allocated to respond to this risk if realized.	Medium	Low
Quality	There is a risk that the new boards may fail prematurely after they are installed and placed into service, as a result of material and or manufacturing defects. Most significant impact would be schedule delay.	The new boards have been designed, manufactured and tested to the extent possible under appropriate quality assurance programs. This risk cannot be mitigated any further prior to installation. The project will start the installation on lesser critical controllers. The old boards removed during the replacements will be salvaged and stored until the new boards have demonstrated adequate level of confidence. This will allow the controllers to be returned to service if the new boards experience problems.	Low	Low

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

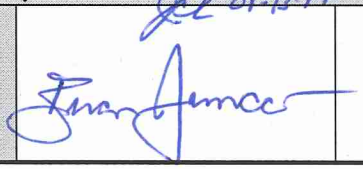
Part G: Post Implementation Review (PIR) Plan

☐ It is determined appropriate that only a Project Closure Report (PCR) is needed as the PIR for this project, due to its straight forward deliverables, which do not require any measures other than confirmation of completion or delivery.

Type of PIR Report	Target In-Service or Completion Date	Target PIR Completion Date
Comprehensive PIR	Q4, 2027	Q2, 2028

Measurable Parameter	Current Baseline	Target Result	How will it be measured?	Who will measure it? (person/group)
OH180 Hardware Replacement	Legacy boards in service	All boards identified for proactive replacement, replaced with new re-engineered boards	OH180 Configuration Tracking Database	Computers and Control Design Engineering
OH180 Failure Rate	0.025 failures per device year	Less than 0.025 failures per device year	Trending of failures and through the OH180 Programmable Controller Health Report	Computers and Control Design Engineering

Approvals

	Signature	Comments	Date
The recommended alternative, including the identified ongoing costs, if any, represents the best option to meet the validated business need.			
Recommended by (Project Sponsor): Rick Hohendorf Director Components Engineering			Jan. 6, 2017
I concur with the business decision as documented in this BCS.			
Finance Approval: George Turner Director, Controllership per OPG-STD-0076			JAN 10/2017
I confirm that this project, including the identified ongoing costs, if any, will address the business need, is of sufficient priority to proceed, and provides value for money.			
Approved by: Brian Duncan Senior Vice President, Darlington Nuclear per OAR 1.1		None	JAN 13/2017

OPG Confidential
OPG-FORM-0075-R004

Type 2 Business Case Summary

Project #: 16-80022
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Document #: D-BCS-60800-10005 R000

Appendix A: Summary of Estimate										
Project Number:	16-80022									
Project Title:	OH180 Aging Management Hardware Installation									
k$	**LTD**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**Future**	**Total**	**%**
OPG Project Management	97	106	366	162	184	224	174	965	2,278	3
OPG Engineering (including Design)	61	-	48	134	156	157	141	1,241	1,937	2
OPG Procured Materials	-	-	1,803	2,793	2,344	1,843	2,537	13,029	24,349	27
OPG Other	-	-	266	78	91	76	59	505	1,075	1
Design Contract(s)	[redacted]									
OPG Installation	-	-	116	426	659	714	208	2,653	4,776	5
EPC Contract(s)	[redacted]									
Consultants										
Other Contracts/Costs										
Interest										
Subtotal										
Contingency										
Total	**295**	**478**	**5,134**	**8,962**	**9,059**	**7,925**	**7,998**	**50,180**	**90,032**	**100%**

Notes			
Project Start Date	2014-12-15	**Total Definition cost** (excludes unspent contingency for Nuclear)	[redacted]
Target In-Service (or AFS) Date	2027-12-31	**Contingency included in this BCS** (Nuclear only)	
Target Completion Date	2028-06-30	**Total contingency released plus contingency in this BCS** (Nuclear only)	
Escalation Rate	2.0%	**Total released plus this BCS without contingency** (Nuclear only)	
Interest Rate	5.5%	**Total released plus this BCS with contingency** (Nuclear only)	$7,290 k
Removal Costs	$115k	**Estimate at Completion** (includes only spent contingency for Nuclear)	[redacted]

Prepared by:		**Approved by:**	
US	22 Dec 2016		04 Jan 2017
Usman Siddiqi Technical Engineer/Officer Projects & Modifications	Date	Mike Nairne Section Manager Projects & Modifications	Date

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Appendix B: Comparison of Total Project Estimates and Project Variance Analysis

Comparison of Total Project Estimates

Phase	Release	Approval Date	Total Project Estimate in k$ (by year including contingency)						Future	Total Project Estimate
			LTD 2015	2016	2017	2018	2019	2020		
Definition	Full	Nov 2014	1357	2,562	7,301	7,454	7,179	-	21,350	47,203
Definition	Full	Dec 2016	295	478	5488	8,498	9,115	7,973	58,185	90,032

Project Variance Analysis

k$	LTD	Total Project		Variance	Comments
		Last BCS	This BCS		
OPG Project Management	203	2,295	2,278	(17)	
OPG Engineering (including Design)	61	5,698	1,937	(3,761)	Engineering effort reduced as the Installation planning (Workplans) is being contracted to external vendor. Transferred to 'Other Contracts'
OPG Procured Materials	-	22,620	24,349	1,729	Added materials for 832 Communication Module Fibre Optic Boards, and new estimate received from OEM
OPG Other		9	1,075	1,066	This is to incorporate cost of WO Assessing and Workplan Reviews (Ops/Maintenance etc). Part of this cost was carried under 'OPG Engineering' previously.
Design Contract(s)	[redacted]				
OPG Installation	-	0	4,776	4,776	Installation to be completed by OPG Ops/Maintenance resources
EPC Contract(s)	[redacted]				
Consultants					
Other Contracts/Costs					
Interest					
Subtotal					
Contingency					
Total	**612**	**47,203**	**90,032**	**42,829**	

Appendix C: List of 40 OH180 Controllers selected for 3% replacement under this release

The OH180 Programmable Controllers control various systems around the station, hence presents a wide degree of complexity in ability to remove each PK from service for replacement of hardware components. Due to this reason, a good estimate is difficult to obtain. The purpose of the pilot phase execution during 2017 (approximately 40 PKs or 3% of total scope) is to perform hardware replacements on a representative sampling of PKs to obtain lessons learned (OPEX), and cost/schedule estimate for the project Execution release. The following list details the list of PKs selected for this pilot execution, along with justification.

Unit				SCI	Device	Complexity (High/ Medium/ Low)	Criticality Level (1/2/3/4)	Half Rack or Full Rack	Fibre-optic Loop (CM)	EPROM Upgrade Required (Y/N)	Comments for addition to 3% Pilot Phase
0	1	3	4								
	x	x		67210	PK0001-11	Low	3	Half Rack	N	Y/N	Ability to execute work by aligning scheduled work on same system. Observation of completing work with reduced redundacy.
		x		63660	PK0012-11	Low	3	Half Rack	N	Y	Low risk equipment to establish comfort level with replacements, and rountine system alignments performed via WOTIs.
	x	x		67230	PK0013-11	Low	3	Half Rack	N	N	Observations for replacing safety system replaced PKs of low complexity. Ability to execute work by aligning with FEG Work Week.
	x		x	63341	PK0014-11	Medium	1	Half Rack	N	N	Executing a work plan for medium complexity PKs, use findings to determine applicability of WOTI for medium complexity work.
	x	x		64830	PK0077-11	Low	3	Full Rack	N	Y/N	Observations from replacing a PK with multiple controlled components, other than pumps and valves.
	x		x	67210	PK0157-11	Low	3	Full Rack	N	Y/N	Observations from replacing a PK with multiple controlled components.
	x	x		65330	PK0193-11	Low	3	Full Rack	N	N	Simple full rack PK, to establish comfort level with replacements of multiple boards and power supplies.
	x		x	67230	PK0313-21	Low	3	Half Rack	N	N	Observation of replacing EVEN PK, and comparing responses to ODD PK replacement findings.
	x	x	x	63341	PK0314-21	Medium	1	Half Rack	N	N	Observation of using a work plan for replacing EVEN PK, and comparing responses to ODD PK replacement findings.
		x		63617	PK0327-21	High	3	Full Rack	N	N	Establish a comfort level in executing work plans for high complexity PKs. Completing replacement on a system requiring specific unit alignments on major equipment.
	x		x	67210	PK0409-21	Low	3	Full Rack	N	Y	Ability to execute work by aligning with FEG Work Week. Observation of completing work with reduced redundacy
		x	x	65330	PK0483-21	Low	3	Full Rack	N	N	Low complexity replacement to establish comfort level with replacements of full rack PK
		x		65330	PK0485-21	Low	3	Full Rack	N	N	Low complexity replacement to establish comfort level with replacements of full rack PK
		x		64300	PK0489-21	High	2	Full Rack	N	N	Establish a comfort level in executing work plans on a safety system for high complexity PKs. Completing replacement on a system requiring specific unit alignments on multiple components.

OPG Confidential
OPG-FORM-0075-R004

Type 2 Business Case Summary

Project #: 16-80022
Document #: D-BCS-60800-10005 R000
Project Title: OH180 Aging Management Hardware Installation, <Full> <Definition> Release

Unit				SCI	Device	Complexity (High/ Medium/ Low)	Criticality Level (1/2/3/4)	Half Rack or Full Rack	Fibre-optic Loop (CM)	EPROM Upgrade Required (Y/N)	Comments for addition to 3% Pilot Phase
0	1	3	4								
	x	x	x	67390	PK0761-21	High	3	Half Rack	FOL 0040	Y/N	Ability to execute similar work plan across different units, expecting same result. Observation of fiber-optic loop response across each unit.
x				65330	PK1001-11	Low	3	Full Rack	N	N	Multiple PKs associated with annunciation only responses. To establish comfort level with replacements of full rack PK
x				65330	PK1003-11	Low	3	Full Rack	N	N	Multiple PKs associated with annunciation only responses. To establish comfort level with replacements of full rack PK
x				67210	PK1007-11	Low	3	Half Rack	N	Y	Unit 0 PK associated with a Unitized PK replacement to see if any differences in replacement in field.
x				63426	PK1069-N1	Low	3	Full Rack	FOL 0012	Y	Addresses a PK that affects multiple units, and is a monitoring PK in the fiber-optic loop. Will require operations cooridination to communicate annunciation acknowledgment.
x				67210	PK1111-21	Low	3	Half Rack	N	Y	Unit 0 PK associated with a Unitized PK replacement to see if any differences in replacement in field.
x				63432	PK1133-21	Medium	3	Full Rack	FOL0019	N	This is a monitoring PK, and observations can be made to the predicted reaction from other CMs in the firber-optic loop. Multiple PKs are associated with this PK.
		x		63432	PK2001-52	Medium	4	Half Rack	FOL0042	N	Will provide OPEX to be used for completing ECI non-test PKs. Multiple PKs are associated with ECI testing logic, where replacement will provide insight of system response, and scope of like-replacements.
		x		63432	PK2015-K2	Medium	4	Half Rack	FOL0041	N	Will provide OPEX to be used for completing ECI non-test PKs. Multiple PKs are associated with ECI channel test logic, where replacement will provide insight of system response, and scope of like-replacements.
x				67280	PK2431-62	High	3	Full Rack	FOL0048	N	Ability to execute work complex work online. Obseravtion of PK response due to multiple scans required.
		x	x	60311	PK3107-11	Low	3	Half Rack	N	Y/N	Multiple PKs associated with annunciation responses. PK without defined criticality from SRE, replacement provides required info to make this determination.
x				65855	PK3364-21	High	3	Half Rack	N	N	Many PKs are associated with Class 3 bus work. Ability to align this type of work with planned SRSTs can help determine the readiness for performing more bus work online.

UNDERTAKING J15.6

Undertaking

For the Chiller Replacement to Reduce CFC Emissions, to provide when the project was substantially completed and the capital was placed into service.

Response

This undertaking is by reference to cross-examination by AMPCO related to a table that purported to derive variances from a original project targeted in-service date to final in service date (K15.1, pages 32-34).

The DN Chiller Replacement project was substantially complete on January 23, 2013, with 92% of capital project cost ($20.2M) declared in-service. Key milestone dates as well as dates of in-service declarations for when the capital was placed into service for this project are set out in Attachment C to the Business Case Summary found at Ex. D2-1-3 Attachment 1, Tab 6. As shown in Attachment C, in-service amounts were spread out over 3 years tied to the installation schedule. The remaining 8% was not declared in service despite all hardware being installed and the project used and useful, while close out work is being undertaken to address low load vibration.

Part of the increase in the project's cost estimate from $14.9M to $30.0M was driven by the schedule delays discussed above The cost increase also resulted from experience gained from installations of the first two units, which proved more complex than initially planned as well as a change in installation strategy to ensure sufficient cooling during the chiller replacement period. The $30M Class 1 cost estimate reflected in the Full Release BCS (Ex. D2-1-3 Attachment 1, Tab 6) was a direct result of lessons learned and actual cost information associated with the installation of the initial chillers. The $14.9M cost estimate in the Phase 1 BCS was established before the design was complete.