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OPG HEAVY WATER STORAGE MANAGEMENT AND DRUM HANDLING - STUDY OF PREFERRED SOLUTION

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OPG Heavy Water Storage Management and Drum Handling – Study of Preferred Solution

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KINECTRICS

OPG Heavy Water Storage Management and Drum Handling – Study of Preferred Solution

Kinectrics Report: K-012667-001-RA-0001-R01

March 2007

Prepared for Ontario Power Generation Inc.

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Kinectrics Report: K-02667-001-RA-0001-R01
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List of Acronyms

DG – downgraded
DIOTS – Darlington Incoming Outgoing Transfer System
DND – Darlington Nuclear Division
HW – Heavy Water
HWMB – Heavy Water Management Building
IXCU – Ion eXchange Clean Up
LLDS – Low Level Drain State
PHT – Primary Heat Transport
PIOTS – Pickering Incoming Outgoing Transfer System
PND – Pickering Nuclear Division
SCO – Station Containment Outage
S&I – Storage and Inventory
Sulzer B – Pickering High Curie Upgrader B
SUP – Darlington Mixed Curie Upgrader
TOC – Total Organic Carbon
TDO – Tritiated Deuterium Oxide
TRF – Tritium Removal Facility
UPPB – Pickering Low Curie Upgrader B
UV – UltraViolet
VBO – Vacuum Building Outage
VLLDS – Very Low Level Drain State

1. Executive Summary

At OPG, issues with heavy water and drum management coupled with the low reliability of the Darlington Tritium Removal Facility (TRF) over the last number of years has focused attention on improving the storage and segregation needs of the OPG Heavy Water Inventories.

In 2004, a strategic study was commissioned to develop an OPG Heavy Water Storage and Drum Handling strategy (Kinectrics Report : K-011043-001-RA-0001-R00A, December 2004). The major conclusions of the study were:

- Lack of operational flexibility during Station and TRF outages
- Lack of adequate bulk storage for reactor grade and downgraded heavy water
- Inability to empty out, clean and dispose of surplus drums

On the basis of this study a preliminary project scope was developed leading to, in November 2005, the project charter (N-PCH-03800-10000). The present work, as part of the project definition phase, examines in detail the heavy water and drum management issues. Through the gathering of detailed operational information, interviews with stakeholders, review of outage schedules, review of OPG strategy documents and business plans, options for dealing with the issues are identified. For each option the pros and cons, risks and benefits are presented and discussed. The costs and schedules for implementation of the various options are provided. Analysis of the heavy water storage and drum handling needs for Darlington, Pickering and OPG as a whole leads the study to recommend the following preferred options.

- *At Darlington Nuclear a 12 x 26 m^2 extension to the Heavy Water Management building to accommodate 400 m^3 of additional heavy water storage tanks and improved drum handling facilities and drum storage space.*

- *At Pickering Nuclear an additional 97 m^3 of downgraded heavy water storage in addition to a drum cleaning facility.*

Implementation of the preferred options is estimated to cost:

- $27.1 million at Darlington Nuclear and,
- $12.7 million at Pickering Nuclear.

The costs estimates include all materials, engineering, installation, commissioning, OPG project coordination, and interest on capital with an overall contingency of 25%.

The schedule for implementation of the preferred options estimates project completion to occur in,

- late 2010 at Darlington Nuclear and,
- mid-2010 at Pickering Nuclear.

Benefits from the additional storage at DND are:

- Improved operational flexibility by mitigating dependence on a functioning TRF
- Ability to accommodate up to an 18 month TRF outage.
- Eliminates the need for off-site shipments during planned moderator drains (high risk that space may not be available externally because of competing storage demands at external sites).
- Avoids Outage extension due to limited PHT storage capability (medium risk of outage extension due to D_2O storage shortfall)

- Eliminates use of reactor grade storage tanks for contingency downgraded D_2O recovery storage (medium risk of a major downgrading event whenever reactor grade tanks are used for downgraded storage).
- Avoids increasing PHT tritium concentration by being able to segregate PHT and moderator recoveries during extended TRF outages.
- Allows SCO and VBO outage requirements to be met.
- Accommodates an Upgrader outage of 8 weeks
- Enhances the ability to pursue external commercial opportunities thereby maximizing OPG's revenue potential, estimated up to $10 million/yr.
- Permits an increase in TRF throughput
- Can provide heavy water storage relief for PND during its outages

Benefits from additional storage and drum cleaning at PND are:

- Corrects the lack of 'recovery' storage issue which contributes to growing drum problem and the depletion of D2O from circulation,
- Mitigates the risk of an Upgrader failure to meet operational requirements,
- Improves performance of the Clean Up System by providing flexibility to manage the various qualities of downgraded water,
- Improves PND's flexibility to detritiate by allowing more inventory to be available (instead of being stored in drums) in the detritiation cycle between PND and TRF,
- Provides DND with drum cleaning service,
- Controls the growing drum problem which has drawn scrutiny from the CNSC, improves housekeeping and worker's safety.

The risks associated with the DND option are:

- Failure to recover cost of investment due to sales benefits not materializing,
- Higher costs from discovery work during detailed design,
- Continuing unreliability of the TRF negating the benefits provided by the increased storage and negatively impacting cost recovery through external sales,
- Disruption of HWMB operations during construction and commissioning.

The recommended option for PND carries the following risks:

- Failure to recover the cost of investment in the remaining life of PNDB (earliest end of life 2014)
- UPPB performance degradation continues unabated,
- Higher costs from discovery work during detailed design, in particular, additional work required to address seismic requirements.

2. Background – Heavy Water Management at OPG

According to the Project Charter, N-PCH-03800-10000R00, "Ontario Power Generation (OPG), at its Pickering (PND) and Darlington (DND) sites, needs to improve its overall ability to manage its Heavy Water (HW) inventories to support continuous station operations in a safe and cost efficient manner."

Improvements are needed in the:

- detritiation process to support continuous station operation
- flexibility to segregate different heavy water (HW) streams for normal station operation and during an outage
- utilization of the Darlington Tritium Removal Facility (TRF)
- management of its inventory of drums

2.1. Improving Detritiation

Tritium in the Moderator and PHT systems is required to be controlled in order to:

- Meet regulatory limits for allowable concentrations in Moderator and Heat Transport Systems
- Maintain tritium emissions to the environment as low as reasonable achievable (ALARA); minimizing public health and safety risks and environmental impacts,
- Minimize worker dose; maintaining a safe and healthy working environment.

Tritium is constantly being produced at the CANDU plants and must be removed on a regular basis; this is the function of the TRF. In order to accomplish the tritium removal, heavy water at the stations is required to be transported to the TRF for processing. Thus, detritiation of the heavy water requires management of the heavy water inventories. In order to effectively manage the heavy water inventories sufficient storage capacity, outside of the reactors, is required.

Two approaches to detritiation are practiced: on-line (bleed and feed) and off-line (moderator swap). The on-line detritiation technique involves replacing of a volume of high Curie moderator water with an equal amount of low Curie (maybe higher isotopic) water while the Unit is operating. Off-line detritiation also replaces high Curie with low Curie water but it is performed during an outage when a Unit moderator has been drained. These techniques perform the same function, that is, replace high Curie heavy water with low Curie heavy water. Each technique has its pros and cons as highlighted below. Appendix A provides a detailed example of the effects of one technique versus the other.

2.1.1. On-line Detritiation (Bleed and Feed)

On-line detritiation has the following benefits:

- Performed while the unit is running.
- Does not create a heavy water stream which needs quarantining; no gadolinium in heavy water due to unit shutdown.
- No need to treat water prior to shipment to TRF.
- Moderator isotopics may improve since the water used in the swap is often upgraded product
- Is not dependent on the outage schedule

The negatives of on-line detritiation are:

- For an equivalent volume of heavy water exchanged it less effective than off-line swaps due to mixing of the TRF product with the moderator inventory.

2.1.2. Off-line Detritiation (Moderator Swap)

Off-line detritiation has the benefit of:

- Performed during an outage when the unit is shutdown. Detritiation can be scheduled to coincide with moderator drains performed for system maintenance.
- Moderator isotopics may improve since the water used in the swap is often upgraded product
- For an equivalent volume of water swapped achieves a larger detritiation (this is also true for moderator isotopic improvements)

The negatives of off-line detritiation are:

- The drained heavy water may have to be quarantined because of gadolinium (Gd) present in the water due to shutdown procedures (eg. PND-B) and this reduces availability of S&I storage.
- Additional processing of water may be required to remove Gd prior to processing by the TRF; increased resource usage.
- Must be completed within a short duration (ie. 5 days) in order not to threaten the outage schedule
- Must be approved by CNSC since the gadolinium content in the moderator water must be controlled
- Monitoring of the mixing conditions must be done to prevent undesired flux tilts; large amount of sampling must be done during process to ensure reactor safety

2.2. Improve flexibility to segregate different heavy water (HW) streams

Sufficient heavy water storage is required for the proper segregation of different streams of D_2O so that a station can effectively operate during normal operations and during outages. Segregation of different quality waters are based on:

- Tritium concentration – e.g. low tritium concentration for PHT make-up versus high tritium concentration for moderator; TRF grade D2O (outside of virgin heavy water lowest tritium concentration heavy water),
- Isotopic concentration – e.g. reactor grade versus downgraded,
- System chemistry – e.g. lithiated PHT D2O cannot be sent to the moderator system since this would pose a risk of Gd precipitation,
- Cleanliness –e.g. downgraded, oily or high TOC versus clean downgraded water,

The management of these different qualities of water of different volumes requires flexibility in the heavy water management system. A main component in the heavy water management system that determines flexibility is the storage capacity of the heavy water management system. If the water storage capacity is insufficient then the system will impact station operations and station outages. Since station operation and maintenance are critical, work arounds (non-standard procedures) are often found on order to meet the needs.

2.3. Tritium Removal Facility Operation Not Optimized

The continuing poor reliability of the TRF brings into question the feasibility of the current detritiation plan which requires high availability of the TRF operating at 60% capacity factor over the next 5 years. The average lifetime capacity factor of the TRF is about ~60%. However, the capacity factor is inconsistent from year to year due to unpredictability of forced outages that the TRF has experienced; this is shown in Figure 1 below:

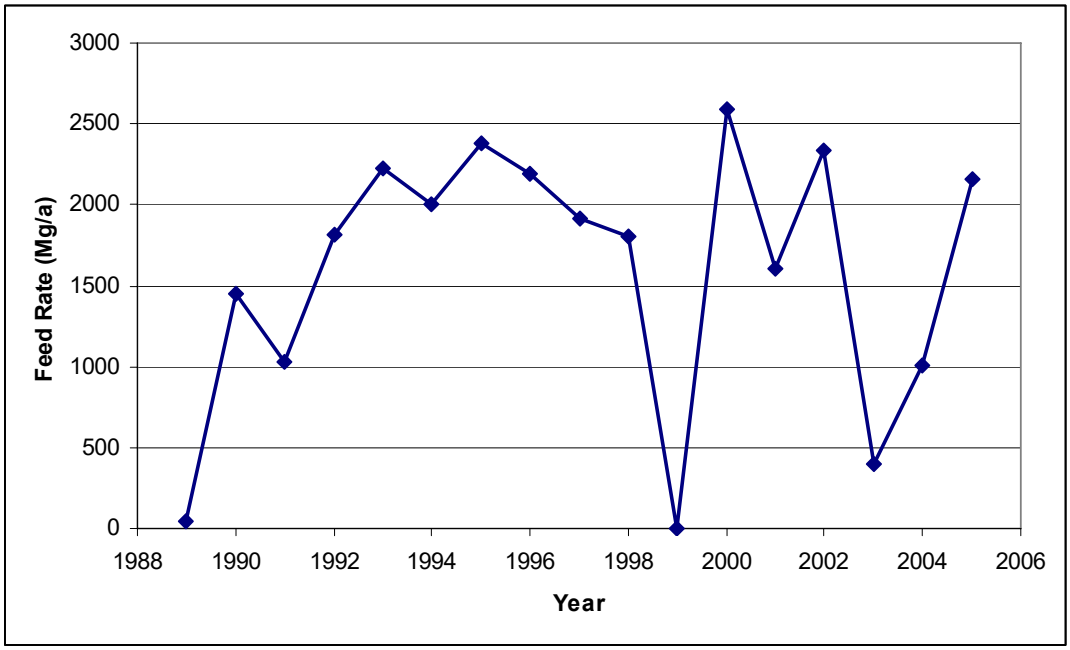

Figure 1. TRF historical throughput.

The TRF has limited storage capacity in the product and feed side of the process as a result, for effective detritiation, the TRF has to operate efficiently and at a 60% capacity factor. Based on recent history, there is a risk of not being able to meet the current strategy.

Furthermore, optimum usage of the TRF requires:

- A steady feed from DND, PND and from external sources (eg. contractual obligation with Bruce Power) and,
- High tritium concentration in the feed.
- Effective coordination between sites to transport heavy water between stations.

The reliability and performance of the TRF reflects its age, the condition of the facility and lack of redundancy in its original design. The difficulty in meeting contractual requirements (detritiation services for Bruce Power) and the rising tritium levels in the OPG heavy water system (eg. PND-B) is indicative of a lack of flexibility within the OPG Heavy Water Management system to manage TRF outages. Increasing the available heavy water storage will mitigate (decouple) the strong dependence on an unpredictable TRF and improve the utilization of the DTRF when it is operating.

2.4. Lack of Drum Handling Facilities

At present there are a large number of drums (empty and filled) at the stations, in particular, PND which has over 3000 drums. Permanent storage of heavy water in drums is not an option. The large number of drums poses the following problems:

- Occupies valuable station space,
- Increases the risk of worker injury from the man-handling of the drums,
- Increases the risk of heavy water spills,
- Increases the risk of worker dose.
- Removes valuable D2O inventory from normal circulation

Additionally, at PND the lack of drum cleaning facilities leads to:

- Re-usage of dirty drums to store relatively clean downgraded heavy water (ie. cross-contamination),
- Further increases the number of drums on site,
- Complicates the disposal of drums to Nuclear Waste Management

At DND commercial opportunities utilizing drums are restricted because of:

- Lack of drum pressure testing capabilities. A drum prior to re-use for D2O shipment requires to be pressure tested.
- Improper facilities to receive third party shipments (eg. unloading ISO containers and drums).
- Lack of drum storage space limiting the size of drum shipments.

Facilities to handle, clean, pressure test and store drums is needed to allow stations to recover valuable space, reduce safety hazards and generate external revenue.

2.5. Heavy Water Cycle

There are two main components of heavy water management at OPG:

- Heavy Water Recovery, Cleanup, Upgrading and Detritiation
- Heavy Water Storage and Handling

A schematic of the heavy water management cycle is shown in Figure 2. This figure shows that the feed to the TRF is taken from the moderator system via water swaps. The general intent is to make up for losses in the PHT via the TRF product and to improve the isotopic of the Moderator via the Upgrader product. However, the system has to be necessarily flexible to balance the losses and meet OP&P limits. Therefore, both TRF and Upgrader product can go to the Moderator or PHT. The separate Heavy Water make-up input indicates the heavy water required to make-up for the net losses from the system via virgin (undesirable) or external heavy water sources.

Under normal operations heavy water needs to be managed because of leaks in the PHT and Moderator systems to the station and external environment which results in:

- downgraded (lower isotopic and tritium concentrations) heavy water which requires storage, clean-up and upgrading,
- heavy water inventory losses which requires storage of the replacement water.

Additionally, tritium concentrations in the system need to be maintained to the set targets.

Under outage situations heavy water requires managing to permit the maintenance of systems via draining of the systems. Drained water requires storing and in some cases isolation (eg. gadolinium containing moderator water). Under outage situations the heavy water system undergoes shrinking or swelling which requires additional volumes of HW to be stored.

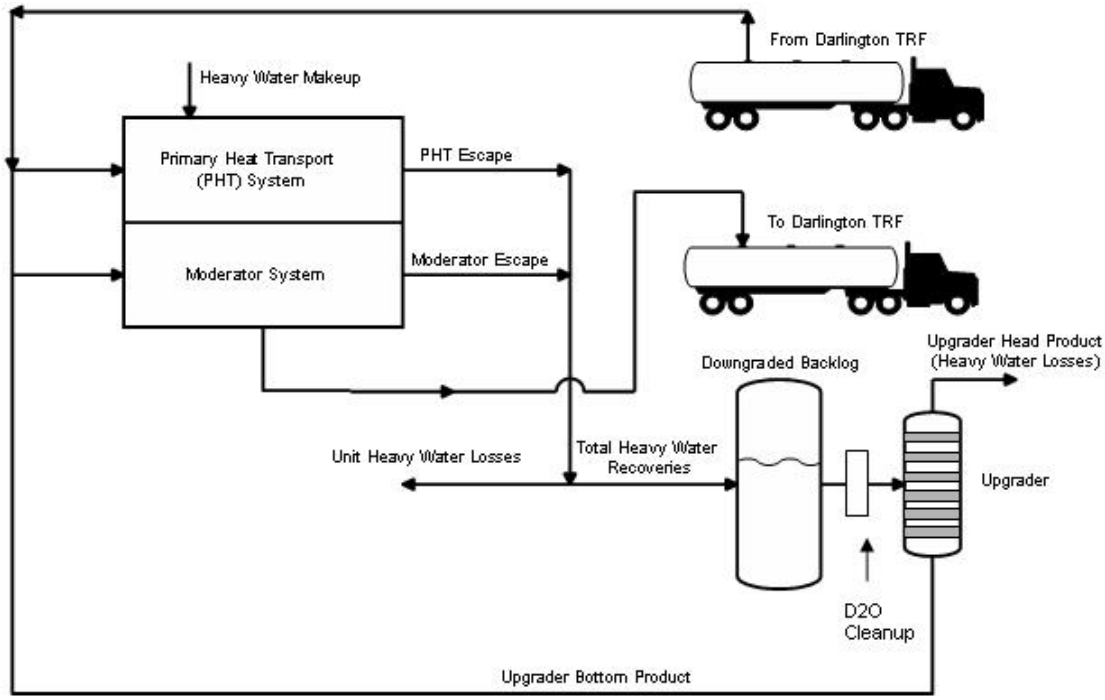

Figure 2. Schematic of Heavy Water Cycle in a CANDU station.

3. Preferred Options Study Objectives

A study to examine Heavy Water (HW) management at Pickering and Darlington was conducted by “Kinectrics Inc” (Kinectrics Report : K-011043-001-RA-0001-R00A) in December 2004. The study identified a number of modifications to improve OPG’s management of its heavy water (D2O) inventory. The option recommended by the study was to install additional D2O storage at Pickering and Darlington sites. The option included drum cleaning and testing facilities. This recommended option has been designated as the preliminary project scope.

In November 2005 a project charter was issued (N-PCH-03800-10000). As part of the initiation phase (Project Management Life Cycle, N-INS-00120-10013) this “Preferred Options” study was conducted to better define the heavy water storage and drum handling needs within OPG. *The study assesses various options that will address OPG’s long-term needs in heavy water management and not its short term operational issues.* The study defines the preferred options for the various OPG sites. In addition the study identifies the pros and cons, risks and benefits of each option while providing the cost and schedule for implementation.

The preferred options will be evaluated with respect to providing augmented storage capacity to improve the following:

- The detritiation process to enable continuous station operation within the approved OP&P tritium concentration limits

- Improve operational flexibility in heavy water management during normal operation and during outages

- Reduce bottlenecks to optimization of the usage and efficiency of the Tritium Removal Facility

- Improve drum handling capability, safety and inventory

4. Scope of Work

The scope of work for the study is as follows [7]:

- Perform plant walkdowns, interview pertinent station stakeholders and review OPG documentation
- Define OPG's long term heavy water storage and drum handling requirements
- Conduct study, analyze all pertinent data and information. Provide options that can support the above objectives. Each option to include the following:

  - Assumptions made to substantiate the option
  - Identification and explanation of "wants versus needs", "pros versus cons", benefits and risks
  - Conceptual cost estimate
  - Schedule estimate for execution
  - Breakdown of the estimates including removal of existing equipment, tie-ins to interfacing systems, commissioning, etc.
  - Proposed locations for major equipment and associated layout sketches

- Present and justify the "preferred Option"
- Support the Project in presenting and obtaining acceptance of the preferred option to senior management
- Support the review of the cost estimate to be performed by OPG or its independent reviewer
- Support OPG's needs analysis challenge meeting
- Assist in the completion of OPG's Design Scoping Checklist

5. Methodology

Kinectrics' approach to the study consisted of four main phases: an exploratory phase, analysis and options development phase, a costing phase based on the developed options and a reporting phase.

In the exploratory phase information on the present status of the system was gathered. Stakeholders and individuals from the following areas were contacted for information and definition of needs. The information was exchanged by way of emails, documents or meetings with the following groups:

- Common Services Operations
- Common Services Engineering
- ALARA
- Outages
- System Engineering

- Design Engineering
- Performance Engineering
- Civil Maintenance
- Field Engineering
- Isotope Sales and Heavy Water Programming
- Construction

Multiple field walkdowns were performed both at Darlington and Pickering examining potential locations for increased storage and/or drum handling facilities.

Assumptions for each site were developed, reviewed and agreed upon with the stakeholders over several meetings during the month of May. These assumptions were the basis for the development of the options. Many documents were reviewed during the development of the options.

- OPG general reports
- Meeting notes
- OPEX
- OPG strategic reports
- Outage schedules

The information examined was in the areas of:

- heavy water storage capacity,
- heavy water inventory,
- heavy water practices during operations and outages,
- drum usage and handling practices,
- drum inventory
- space availability to accommodate additional tanks and drum facility
- systems classification
- seismic requirements within PND and DND
- financial impact of inadequacies in HW Management

The collected information was analyzed for the purpose of developing options which addressed the defined needs. Subsequently costs and schedule for the implementation of the options were produced.

This report presents the assumptions, the analysis leading to the options, the costs and schedule for implementation of the options. The defined options are discussed in terms of meeting the needs, the benefits arising from their implementation and the risks associated by moving forward with the options.

6. OPG's Long Term Heavy Water Storage and Drum Handling Requirements

As the study began collecting information assumptions were developed which defined OPG's long term operational and maintenance needs. These assumptions were developed through the consultation of OPG strategy documents, future outage schedules and stakeholders. The assumptions once identified were reviewed and agreed upon with the stakeholders. The agreed upon assumptions for PND and DND are presented in Tables 1 and 2 respectively.

Table 1. Pickering Assumptions Used to Develop Options for Heavy Water Storage and Drum Handling Long Term Needs

1	Present drum backlog and dirty water in drums dealt with separately; out of this scope
2	Disposal or storage of drums not in scope
3	1000 drums per year required for operations
4	One (1) unit moderator volume and one PHT VLLDS volume simultaneous drain per year (250 Mg &100 Mg respectively)
5	A drum cleaning facility capable of processing 10 drums/day would be sufficient. Cleaning of legacy drums of ~2500 to be reviewed as incremental cost to proposed facility. Anticipated 5 to 10% of 2500 drums may be disposed off as waste.
6	Drums are utilized to facilitate transportation of recovered heavy water from its collection point to the clean-up system
7	Storage of cleaned, downgraded, HW from UPPA and drums out of scope
8	~160 Mg of clean, upgraded water recovered from oily drums and ~30 Mg from UPPA in scope
9	Nuclear Units operate to planned life
10	TRF operates to planned life
11	Moderator 3.5 Ci/kg/yr increase with no detritiation
12	PHT 0.05 Ci/kg/yr increase with no detritiation
13	Capability to perform moderator swaps of 100 to 150 Mg during moderator drains
14	D2O management during VBO is not an issue as per Kickoff meeting
15	Detritiation by bleed and feed (on-line swap)
16	TRF to meet PND's operational needs
17	Maximum TRF outage of 6 months
18	HW turbidity no impact on storage or drum requirements
19	PHT water from units 2 and 3 not in scope (~280 Mg). Presently 200 Mg is in circulation.
20	UPPA tanks are carbon steel, and are not suitable for long term storage of D2O
21	HW losses out of system ~25 Mg/yr
22	Permanent Gd removal capabilities at S&I tanks available (ECR)
23	UV oxidation system operational
24	UV oxidation because of downgrading can process both Hi and Low Ci IXCU trains
25	No return of UV oxidation product to IXCU for further cleanup

26	IXCU processing of ~150 kg/hr for oily water, non-oily at ~400 kg/hr (confirm)
27	70% of IXCU load from PHT, 30% from Moderator
28	Longest upgrader outage 1 month
29	Present efficiencies and throughputs of upgraders to remain constant (Sulzer - 110 kg/hr, UPPB - 150 kg/hr)
30	Control, maneuver and segregation will be performed as per the current mode of operation
31	Sampling and analyzing of contents prior to storage or clean-up is to be done manually.

Table 2. Darlington Assumptions Used to Develop Options for Heavy Water Storage and Drum Handling Long Term Needs

1	The cleanup, disposal, processing and storage of the backlog of legacy drums at DNGD are not part of the scope of this project.
2	The normal, yearly usage of drums at DNGD is as follows:
	(a) ~ 40 drums to support station operational needs
	(b) 25 ~ 30 drums for boiler lancing (whenever required, i.e. these are not required on a regular basis)
	(c) 30 drums recovered during moderator heat exchanger maintenance
	(d) 30-50 drums of high TOC downgraded D2O collected during feeder maintenance
	(e) 5 ~ 6 drums for PHT transmitter calibration (drums not required to be cleaned or pressure tested)
	(d) 20 ~ 30 drums for downgraded D_2O from station
	(e) 3 ~ 4 drums for virgin D_2O (drum cleaning not required)
3	DND cleaning requirements are for less than 170 drums/year. DND requires a drum cleaning facility with a capacity of less than 1 drum/day.
4	The bulk storage design for supporting ongoing operation will be based on accommodating the complete drain of one Moderator (345 Mg) and the drain to the low-level state of 1 PHT system (130 Mg)
5	DND will share a Drum Cleaning Facility with PND if it is installed at PND
6	DND will require pressure tested drums to be used for shipping D2O off-site
7	DND will have on site on an ongoing basis ~150 drums for operational needs and on an occasional basis to handle an additional two ISO containers of 96 drums from external sales. Consideration should be given in any new design to maximizing the space available for drum storage and handling.
8	DND and TRF to operate to design life.
9	A planned TRF outage of up to 6 months will not raise tritium concentrations beyond the OP&P limits for Moderator and PHT systems.
10	On-line Moderator Feed and Return simultaneously is used for detritiation. Bulk swaps are not used.
11	Segregation of HW is required, based on tritium concentration, during an extended TRF

	outage (similar to the current TRF outage) since low-Ci HW can only be used for PHT make-up.
12	HW losses from the 4 units at DND are ~ 10 Mg/year
13	DNGD has no permanent Gd removal capability for the S & I tanks. Capability is available for downgraded HW.
14	DNGD UV Oxidation system is Class 6 and is limited to less than 10 Ci/kg HW concentration.
15	DNGD UV product needs to be recycled for further IXCU treatments. Lack of storage of UV product is an issue.
16	DNGD IXCU is not used for removing bulk oil contamination. This is accomplished by settling in a tank and subsequent decanting of the oil.
17	A normal upgrader outage is 8 weeks duration
18	DNGD upgrader efficiencies and throughputs (to be confirmed):
	(a) Recovery high Isotopics 160 Kg/h
	(b) Recovery low Isotopics 200Kg/h
	(c) On-line 260 Kg /h
19	Additional Heavy Water storage will tie in to existing control system
20	The system will maintain the current mode of operation
21	Sampling and analyzing of contents prior to storage or clean-up is to be done manually
22	SCO and VBO requirements are in scope combined with a PHT low level drain and Moderator drain
	(a) 2003 SCO – 430 Mg of PHT D2O available prior to the outage
	(b) The low level drain can be accommodated through coordination between the station and HWMB – the original transfer from the HWMB to the station to accommodate shrinkage will free up tank space to allow a 1 unit low level drain.
	(c) During SCO and VBO outage the TRF will be shut down due to no available steam
	(d) The SUP will be operating on backup steam
23	The total inventory of D2O outside the reactor units prior to the current TRF outage was 420 Mg (320 Mg of PHT D2O and 100 Mg of Moderator D2O). This number can be used in all scenarios.
24	DND currently has 430 Mg PHT storage capacity (class 6) and 360 Mg Moderator capacity (class 3)
25	The HWMB must maintain 210 Mg of PHT D2O to be available to the station to accommodate the shrinkage during a 4 unit shutdown.
26	Recovery water isotopic is 27% - Based on 2003 and 2004 Upgrader and Heavy Management reports the total amount of recovery water was 1100 Mg – from this a total of ~ 300 Mg of 100% D2O was recovered. From these numbers the average isotopic of

	the recovery water is 27%.
27	The split between Moderator and PHT recovery water is 50/50 – this is based on the latest trends that the HWMB is seeing and through confirmation with the SRE that it will continue.
28	A planned 18 month TRF outage is to be considered. From the D&D report # 91705 (April 1991) it was determined that the TRF availability is 35% or 3 months/year and unavailable for 9 months/year. If two 9 month outages were to occur back to back the TRF would effectively have an 18 month outage.
29	SUP would operate during the entire 18 month TRF outage.
30	When switching the SUP between processing PHT and Moderator D2O it is understood that 25 to 30 Mg of downgraded low Curie feed must be processed to flush the SUP before the Curie content would be low enough for PHT makeup.
31	The tritium content in the PHT system increases approximately 0.1 Ci/kg/yr if no detritiation is performed.
32	The tritium content in the Moderator system increases at 4 to 4.5 Ci/kg/yr if no detritiation is performed.
33	The tritium level in the Moderator can be lowered ~ 1 Ci/kg using an online swap of 40 mg of 3 Ci/kg D2O
34	All tanks are assumed filled to 90% capacity.

7. Present Heavy Water Management Situation

This section reviews the status of the heavy water management system at DND and PND at the time of this study. This information was gathered in the fashion outlined in section 5. The various subsections cover the following topics:

- Heavy water storage capacity for each site.
- Assessment of the HW storage needs during each outage situation, during normal operations and for collection and processing of downgraded water.
- Identification of issues and problems associated with a lack of storage capacity.
- Actions taken to deal with the issues and problems and the costs incurred to do so.

A discussion of the drivers for increased heavy water storage and drum facilities follows and the needs for various options are defined.

7.1. Darlington Nuclear

Sufficient storage is required at Darlington to meet operational needs during normal operation as well as during station outages. The Heavy Water management cycle at Darlington is different than at Pickering (or other CANDU stations) due to the presence of a single, mixed recovery Upgrader; this makes for situations unique to DND. Upgrader product is utilized as make-up to the Moderator system and is useful in keeping the isotopics in the Moderator system at a very high level (approx. 99.98% D_2O). The TRF is integrated into the heavy water management cycle at Darlington and is used to produce low-Curie make up to compensate for PHT losses, thus, removing the requirement to segregate recoveries during normal operation of the TRF. When the TRF is down, recoveries must be segregated imposing additional storage requirements.

The existing storage capacity available at Darlington is summarized in Tables 3 and 4 below and schematically represented in Figures 3, 4 and 5.

Table 3. Existing Reactor Grade D_2O Storage Tanks at Darlington

Purpose	Capacity: m^3
PHT S&I tanks	4x100
PHT Weigh Tank	1x30
Moderator S&I Tanks	3x100
Moderator Storage	1x47
Moderator Weigh Tank	1x10
Upgrader Product Tank	2x12
Upgrader On-Line Feed Tank	1x9
TRF Feed Day Tanks	2x10
TRF Product Day Tanks	2x10
TRF External Feed Tank	1x53
TRF External Product tanks	2x25

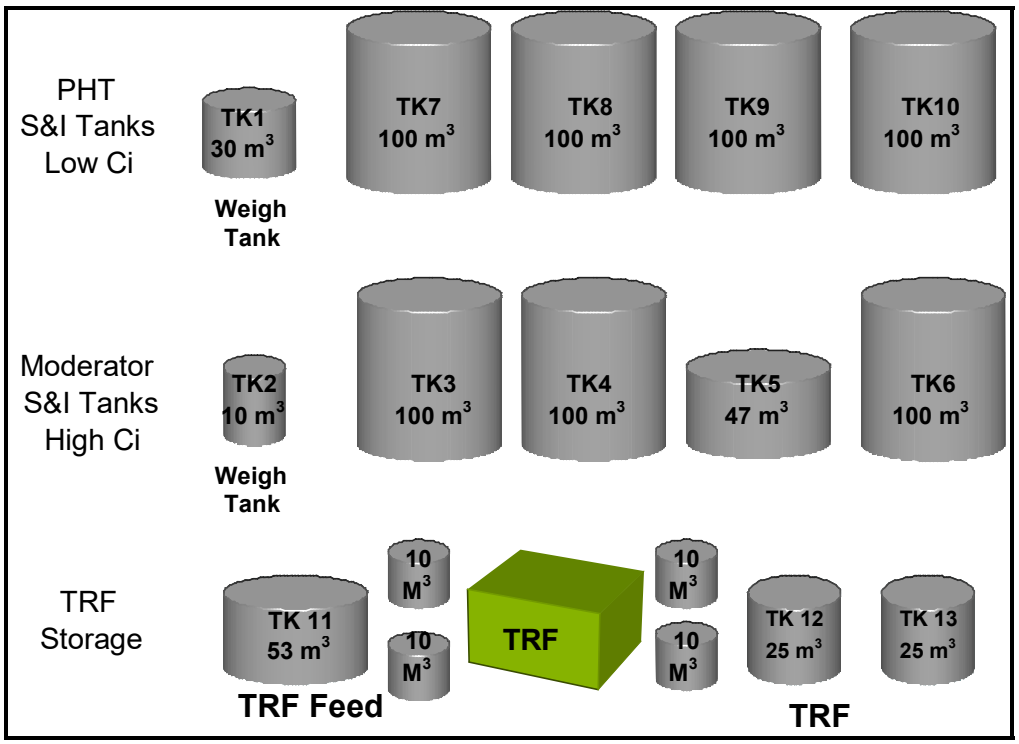

Figure 3. Visual representation of Reactor Grade Storage and Inventory at DND

Table 4. Existing Downgraded D_2O Storage Tanks at Darlington

Purpose	Capacity: m^3
Downgraded Dirty Tanks	2x25
Downgraded Clean Tanks	2x50

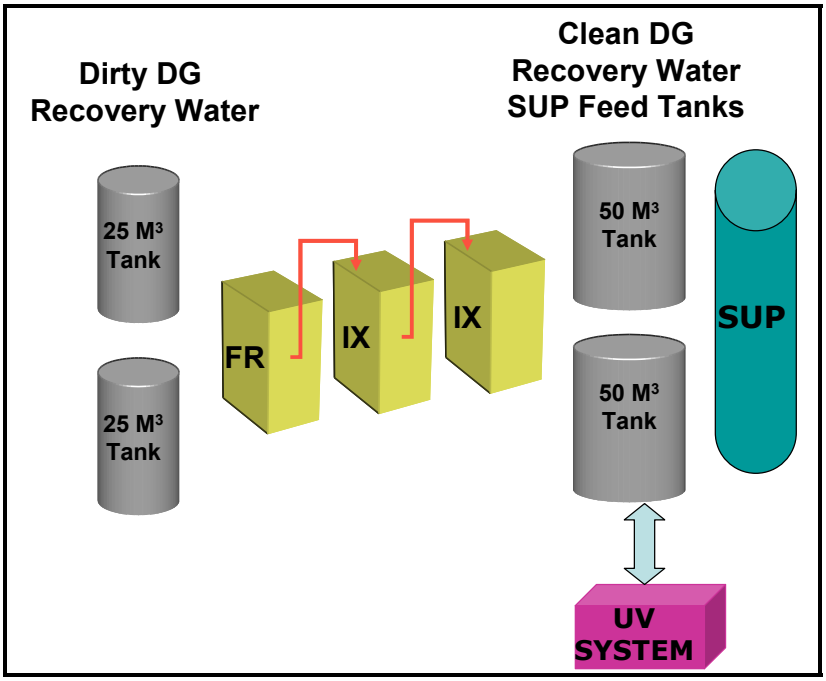

Figure 4. Visual representation of downgraded storage capacity at DND.

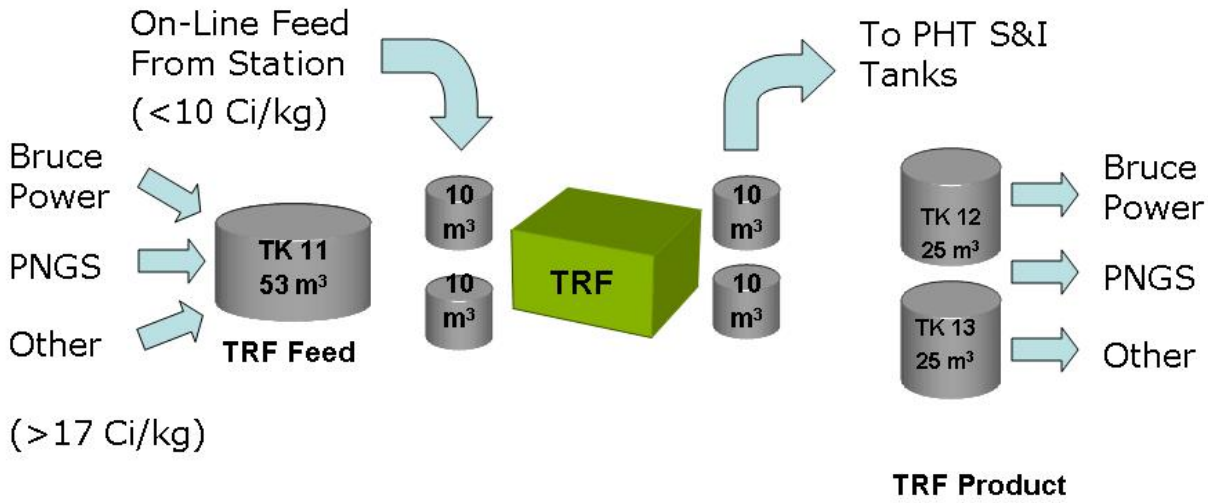

Figure 5. Visual representation of TRF storage capacity at DND.

7.1.1. DND Storage Requirements during Normal and Outage Situations

Various scenarios are examined and the heavy storage needs identified. The scenarios examined are:

- Normal Operations
- Outage plus a moderator drain
- Outage plus a moderator drain and a Low Level Drain State (LLDS) for the PHT system
- Station Containment Outage (SCO) or Vacuum Building Outage (VBO) plus a moderator drain and LLDS
- 6 and 18 month TRF outage
- 8 week Upgrader outage
- Meeting external contractual obligations

Normal Operation

During normal operation, the following inventories are held in the S&I system (Assumption 23):

PHT S&I Tanks and Weigh Tank:

- 210 Mg PHT D2O minimum for shrinkage requirement

- 110 Mg PHT D2O
  - 30 Mg for Deuteration
  - 80 Mg for leakage make-up

MOD S&I Tanks:

- 100 Mg Mod D2O is held as operating reserve

During normal operations there is adequate S&I heavy water storage at DND. At IXCU there is sufficient storage unless there is a high TOC (Total Organic Carbon) event which then forces the IXCU into recycle and potentially places the Upgrader into reflux.

Scenario A: Outage + Moderator Drain

During a moderator drain 347 Mg of storage space is required utilizing the four Moderator S&I tanks; thus, the 100 Mg D2O held as operating reserve requires alternate storage. Therefore, there would be a periodic need to move this inventory out of the S&I tanks during planned or forced moderator drains. To accomplish this, other temporary storage on-site (e.g. DIOTS tank or external TRF Feed Tank) would need to be utilized or water shipped off-site. If on-site tankage was used, during this time, the TRF would not be available to process water from Bruce, Pickering or external customers. This situation would compromise the ability to generate external revenue, unless the 100 Mg of moderator operating reserve was moved to the PHT tanks after detritiation through the TRF in preparation for the Outage. It is clear that all this would require scheduling, planning to meet OPG's obligations and inefficient use of the TRF. Therefore, in case of a forced moderator drain, there is a high risk that the Outage could be delayed.

Scenario B: Outage + Moderator Drain + LLDS for PHT

This Scenario considers Scenario A together with the requirement to take the PHT system to a Low Level Drain State (LLDS). All of the above considerations in Scenario A would apply, together with the following additional impacts:

The PHT S&I normal inventory of 320 Mg would be reduced to 230 Mg due to shrinkage. It would then increase to 360 Mg due to the addition of 130 Mg due to the LLDS. Therefore, 70 Mg of space would still remain in the PHT S&I tanks after the LLDS. Therefore, there is no incremental impact from this scenario.

Scenario C: SCO or VBO + Moderator Drain + LLDS

During an SCO (every 6 yrs, one planned for 2009) or VBO, the requirement is to store 430 Mg of PHT D_2O (480 Mg preferred, if possible) prior to the start of the Outage to address the 4-Unit shrinkage requirements during cool down. In addition there is a need to store the complete drain of one Moderator (345 Mg) and the drain to the low-level state of 1 PHT system (130 Mg) during the outage (see Assumption 4).

Therefore, a pre-requisite for the VBO or SCO is to increase the PHT inventory in the S&I system from 320 Mg to 430 Mg, i.e. to completely fill the S&I tanks. The 110 Mg of extra PHT inventory will have to be borrowed or accumulated from the TRF product (approximately 12 days of TRF operation).Therefore, there will be no tolerance in the S&I system to handle unit upsets (swells) before a VBO/SCO. There may be a risk of isotopic or chemistry upset if other tanks are used to accommodate any PHT swell during the preparation for a VBO/SCO.

During the VBO/SCO, the TRF will be out of operation. The S&I inventory will decrease from 430 Mg to 70 Mg due to shrinkage in 4 units and increase to 200 Mg due to the LLDS in 1 Unit. As Units are brought back up, the following space will be needed in the PHT S&I due to swell requirements:

	Space Required
4 Units down + LLDS	200 Mg
3 Units down + LLDS	290 Mg
2 Units down + LLDS	380 Mg
1 Unit Down + LLDS	470 Mg

The storage requirements caused by the swelling of the units during restart leads to inadequate storage space in the S&I system to re-start the 3rd Unit while 1 Unit is in LLDS. So, there would be a risk of Outage extension due to limited PHT storage capability (medium risk of outage extension due to D_2O storage shortfall) since the 3rd Unit cannot be started up until the LLDS in one Unit is over so that more space is freed up in S&I. Note that prior to the 2003 SCO, 480 MG of PHT grade water was requested [11], later reduced to a requirement of 430 Mg of PHT grade water available on-site. If the TRF's feed and product tanks are used for temporary storage, the productivity of the TRF will be negatively impacted and the possibility of isotopic degradation, cross-contamination will occur.

The issues with the Moderator drain are the same as those outlined for Scenario A, i.e. moderator S&I tank space needs to be cleared prior to the drain by shifting the 100 Mg of operating reserve to other storage. During the VBO/SCO, it is assumed that the Upgrader will be operating and that the recoveries would be segregated. The bounds of this particular issue are covered in Option D, below.

Scenario D: 6 or 18-Month TRF Outage (Assumption 28)

A normal, planned TRF outage is expected to be about 6 months duration and an extended TRF outage is from >6 months up to 18 months. The normal way to produce low-Ci product during a TRF outage is to segregate high-Ci and low-Ci D2O recoveries and process them separately in batches through the single IXCU and Upgrader. In a 6 month TRF outage an alternative to segregation is to store ~100 Mg (100% D2O) of PHT make-up water in the S&I tanks prior to start of the TRF Outage, and an equivalent amount of High-Ci S&I storage space at the end of the 6 month outage. The risk in this approach is a lack of PHT ready water if the outage exceeds the 6 month.

An 18 month TRF outage would require operating the Upgrader in segregated mode as the heavy water recoveries are estimated to be around 630 Mg of 100% D2O (315 Mg high Curie, 315 Mg low Curie). With the existing amount of downgraded storage space the impact on heavy water storage and inventory requirements as a result of operating the Upgrader in segregated mode is reviewed in Table 31 of AppendixD. Table 31 illustrates that the Upgrader would need to be switched from Hi-Ci to Lo-Ci feeds every 23 days beginning on day 68. In this example, for every 50 Mg batch (27% isotopic) of Low-Ci feed processed, only 20 Mg (27% isotopic) of Low-Ci product is produced, and 30 Mg (27% isotopic) of mixed–Ci flush water would be collected when switching from Hi-Ci to Lo-Ci feed. Using the schedule presented in Table 31 the volume of mixed-Ci product generated, which needs to be stored, and the extra Low-Ci products inventory required before an 18 month TRF outage can be calculated.

Also using segregation to process the downgraded water during this extended TRF outage with existing recovery storage has the following characteristics and issues:

- The system will operate in 2 parallel trains, one train consisting of a dirty & clean DG Tank collecting Hi-Ci water and the other collecting low-Ci.
- With the existing tank capacity, in this scenario, about 17-20 Mg of downgraded water has to be moved to other storage (See Table 31, Appendix D) but only once during the Outage. After this, the cycle is self repeating and no more water has to be put into other storage
- There is no flexibility for acute recoveries or high TOC conditions in the above scenario
- Filling up the Clean Tanks and feeding the Upgrader from a full Clean tank is key to this mode of operation - because this minimizes the amount of mixed-Ci water generated and optimizes segregation efficiency as compared to feeding partly-filled tanks.
- If a Clean Downgraded tank is not full and analysed (i.e. ready to feed the Upgrader), the Upgrader can go on total reflux or go on "on-line moderator Upgrading" mode to improve isotopic. This happens from time-to-time.

Another constraint is when a full Downgraded Clean Tank has TOC> 1ppm or higher conductivity than the feed specification. A full tank in this condition cannot be fed to the Upgrader and needs to be recycled through the Clean Up System. If the Dirty Tanks happen to be full, this water has to be stored in drums, totes or in the TRF Product Tanks (2x25 Mg). Such a scenario is undesirable since it can lead to potential downgrading of reactor grade water and also affect TRF receiving/shipping water to external customers.

The calculation shown in Table 31 cannot be an exact calculation as there will be the following uncertainties present in practice:

- The Upgrader feed can vary between 160 kg/h to 200 kg/h depending on the feed isotopic
- The feed isotopic is assumed to be 27% as an average, but in reality will vary from summer to winter, being lower in summer than in the winter due to ambient humidity levels

- The D2O collection rate will vary in practice, depending on maintenance activities in the Units and the weather
- Most importantly, it has been assumed that the D2O Clean Up System will work perfectly, and will not require recycling through the system to deal with high TOC levels. If this turns out to be the case, then the Upgrader may not be able to process all of the recoveries and temporary storage of downgraded water may be required in totes or drums.

During the 18-month Outage, approximately 2333 Mg (27% isotopic) of downgraded water would be processed resulting in about 180 Mg of 100% isotopic (22 flushes x 30 Mg/flush x 27% isotopic) of mixed-Ci product requiring storage. In addition, about 180 Mg (100% isotopic) of PHT make-up at < 1 Ci/kg would need to be obtained to compensate for PHT losses during this period. The mixed-Ci product can be used to displace Moderator water and thereby mitigate the growth in Moderator tritium to some extent. It is estimated that displacement by 180 Mg of mixed-Ci water will reduce Moderator concentration by about 2 Ci/kg (i.e. net growth of 4 Ci/kg instead of 6 Ci/kg during the 18 month outage).

Note that this is contingent upon the D_2O Clean-Up System working perfectly and not requiring recycling through the system to deal with high TOC levels. If this turns out to be the case, then the Upgrader may not be able to process all of the recoveries and temporary storage of downgraded water may be required. The only choice is to store the downgraded water in drums, in plastic totes or to utilize reactor-grade storage. Each of these options has its own disadvantage as outlined in the next section. If High TOC water is recovered during a period requiring segregation, there may be a need to circulate several times through the D_2O Clean-Up System. Because storage capacity has been compromised by segregation requirements, the Upgrader may have to go on total reflux because of lack of feed.

In summary, as shown in Appendix D, there is a requirement to bring in 100-200 Mg of low-Ci D_2O depending on the length of the TRF outage to provide PHT make-up, and the recovered D2O (mixed Ci) will be used to displace the High-Ci D2O from the moderator to avoid exceeding the moderator OP&P limit; its concentrations would increase at a rate of approximately 4-4.5 Ci/kg/a during this period. This in turn creates a need for storage of 100-200 Mg of high-Ci displaced moderator water, further challenging storage capacity.

Scenario E: 8-week Upgrader Outage

The current recovery tank capacity is incapable of supporting a typical Upgrader outage of 8 weeks. Based on current projections, there is a need to store approximately 237 Mg (=1540x8/52) of downgraded recoveries during this period. There is only 150 Mg of total storage capacity available in the Downgraded Dirty and Clean Tanks combined.. The only choice is to store the shortfall of 87 Mg of capacity in drums, in plastic totes or to utilize reactor-grade storage. Each of these options has its own disadvantage as outlined in the next section. However, both MOD and PHT escape will need to be compensated by make-up. Assuming 50% for each, conservatively, there will be a need for 237 x 0.5 x 0.27 = 32 Mg to be available on stand-by in the S&I tanks as a minimum for MOD make-up and 32 Mg of TRF product for PHT make-up.

Scenario F: Meeting External Business Needs

There may be a significant cost of lost opportunity due to the unavailability of storage volume to receive and store feed from external customers and return with TRF product. This has been estimated as $3 million/year.

Without additional storage space available, drums coming to the TRF from overseas cannot be emptied out into the processing streams quickly. They would continue to be stored in corridors etc., utilizing space not designed or designated for storage. This presents a housekeeping issue

as well a hazard during operation and limits the ability for Isotope Sales to pursue new business because of limited receiving and handling capability.

Summary:
Examination of the various heavy water storage scenarios as well as drum needs has identified the following issues:

- *During outages, there is not enough space in the S&I tanks for a full moderator drain. To create this space, the operating inventory held in the S&I tanks has to be moved to temporary storage or off-site.*
- *If TRF feed and products tanks are utilized then shipping and receiving of tritiated heavy water is impeded.*
- *During a 6-month TRF outage:*
  - *About 100 Mg (100%D2O) Low-Ci inventory have to be stored before the outage and an equivalent amount of empty High-Ci S&I storage space available at the end of the outage.*
  - *No flexibility in the system if downgraded water has to be recycled through the IXCU because of high TOC. This high TOC water would also have to be moved to temporary storage. Such is the situation presently where ~50 Mg of heavy water are in drums because of difficult to destroy TOC.*
  - *The mixed Curie product from the Upgrader can be used to displace Moderator water and thereby mitigate the growth in Moderator tritium to some extent. Around 100 Mg of Moderator water will require storing until the end of the outage.*
- *During an 18-month TRF Outage:*
  - *About 180 Mg (100% D2O) Low-Ci inventory needs to be stored before the outage, and an equivalent amount of empty High-Ci S&I storage space available at the end of the outage.*
  - *Around day #36, about 17-20 Mg of downgraded recovery water has to be moved into temporary storage once, either in drums or in reactor grade tanks.*
  - *There is no flexibility in the system if downgraded water has to be recycled through the IXCU because of high TOC. This water also has to be moved to temporary storage. The latter is likely to cause downgrading of reactor grade water when switching back to normal mode. It takes a long time to clear up downgraded back log due to limitations of the recovery storage and clean up systems.*
  - *The mixed-Ci product from the Upgrader can be used to displace Moderator water and thereby mitigate the growth in Moderator tritium to some extent. The Moderator S&I tanks will be almost full at the end of the TRF Outage due to holding the operating reserve, the 180 Mg of moderator displaced water from the Outage and any resin-deuteration reserve in storage.*
  - *The in-station inventory of D_2O will increase by at least 180 Mg, which will need to be processed by the TRF at the end of the Outage.*

- *Up to 180 Mg of PHT make-up will be required. This can come from the operating reserve, depending on the quality and quantity of water held in storage.*

- *During an 8-week Upgrader Outage, there is a shortfall in storage for downgraded recovery.. The only choice is to store the shortfall of 87 m^3 of capacity in drums, in plastic totes or to utilize reactor-grade storage. Each of these options has its own disadvantage.*

- *There may be a significant cost of lost opportunity due to the unavailability of storage volume to receive and store feed from external customers and return previously stored TRF product.*

7.1.2. Darlington Nuclear: Discussion of Drivers for Increasing Storage Capacity

Reactor Grade D_2O Storage

The OP&P limits on tritium concentration at Darlington are as follows:

	Moderator	***PHT***
OP&P Limit	15 Ci/kg	1.2 Ci/kg

These OP&P limits are tighter than at other Stations and make Darlington less tolerant to TRF outages. An internal administrative limit on the Moderator concentration is placed at ~13.5 Ci/kg to allow for some inaccuracy in analysis, and provide some time for corrective action. Currently (as of June 21, 2006), Darlington has an average Moderator concentration of 10.7 Ci/kg as a result of the TRF being in a planned outage for the previous 5 months. During a TRF outage, moderator concentrations are estimated to increase at about 4-4.5 Ci/kg/a, and may require partial displacement of the moderator inventory to keep concentrations under the OP&P limit.

Moderator D_2O S&I storage capacity is required to accommodate the complete drain of a poisoned moderator system during a single unit outage. A moderator D_2O drain requires the use of all moderator S&I storage (347 m^3) available. The 10 m^3 weigh tank is also reserved for contingency. Segregation of the different grades of reactor D_2O is still required during the drain. During normal operation, a 100 m^3 D_2O Supply and Inventory (S&I) moderator storage tank is used to store high isotopic (>99.98 % D_2O), high curie (>1.2 Ci/kg) reactor grade D_2O (Upgrader product) to be held as an operating reserve and for making up losses in the moderator system.

A moderator drain requires the emptying out of this operating reserve from the S&I system. In the past, it has been possible to temporarily store D_2O at Bruce A & B. With the lease of the stations to Bruce Power, this is no longer a reliable option since Bruce Power is a business competitor and is itself in the process of adding heavy water storage. AECL sites such as La Prade are not suitable for moderator water because of its tritium concentration restriction (1 Ci/kg). Also, the TDO's would be tied up for about 20 shipments (10 to transport water from Darlington and 10 shipments to bring water back) thus further impacting the capability to service external customers. An alternative method is to temporarily store the moderator make-up water in the DIOTS tanks or in drums prior to the unit outage. This method impedes the normal operation of the TRF. Assuming two Outages and Moderator drains per year the lost TRF productivity, by utilizing DIOTS to store the operating reserve, is estimated to be 40 days, that is, 11% of TRF capability.

Utilizing DIOTS or other tanks to store the operating reserve has the potential of downgrading the moderator quality water. There is OPEX that re-upgrading had cost about $1.5 million for a 3-

week Upgrader run. Downgrading of some of the moderator quality water can also lead to increase fuel burn-up.

During a Unit outage recovery rates of downgraded water are expected to increase. Any upgrader product during this period has to be returned to operating Units or held in the SUP product tanks. There is a lack of flexibility in the heavy water storage capacity during a moderator drain. If an acute recovery event occurs, filling the SUP product tanks (30 Mg), the Upgrader may have to be placed in reflux.

During an SCO (every 6 yrs, one planned for 2009) or VBO Outage, the requirement is to store 430-480 Mg of PHT D_2O prior to the start of the Outage to address the 4-Unit shrinkage requirements during cool down and in addition to store the complete drain of one Moderator (345 Mg) and the drain to the low-level state of 1 PHT system (130 Mg) during the outage (see Assumption 4).

During the SCO or VBO, the TRF is not available due to unavailability of high pressure steam, this further increases the requirement to store more Low-Ci D2O for PHT make-up as the segregation method will not be applied at the upgrader for such a short duration to recover downgraded water. As a result, all the downgraded D2O will be recovered as mixed Curie D2O. This mixed Curie D2O will need to be stored in the moderator S&I tanks if not already being occupied by the moderator drain, or stored temporarily in the DIOTS's feed tanks, or the small upgrader product tanks (2x12Mg) which can impede the upgrader operation when they are full.

During an extended TRF outage, the preferred method to recover downgraded water is to segregate and to process high-Ci and low-Ci recoveries separately. In the recent TRF outage, it has been observed that the segregation of High-Ci and Lo-Ci D_2O has not worked well. There has been some cross-contamination so that quality of the Lo-Ci water collected was poor, at a concentration of about 1-1.2 Ci/kg instead of 0.7 Ci/kg. So this water is not quite suitable for PHT make-up.

Execution of the recent SCO in 2003 has demonstrated that it would be impossible to satisfy the demand for a complete moderator drain with the existing storage capacity in the HWMB. Therefore, other temporary storage on-site (e.g. DIOTS tank or external TRF Feed Tank) would need to be utilized or water shipped off-site. During this time, the TRF would not be available to process water from Bruce, Pickering or external customers, thus compromising the ability to control reactor tritium levels or generate external revenue.

It is not clear to where this D_2O could be moved. The availability of storage at the Bruce site cannot be assumed, since they are a competitor and are also building additional storage for their own use- indicating a shortfall of storage for their own needs. The La Prade site belongs to AECL and is used to store AECL's heavy water inventory. Additionally, this was the site of an intended heavy water production facility and is only licensed for a maximum of 1 Ci/kg of tritium concentration. Furthermore, the requirements for shipment of D_2O in drums have become more restrictive recently with the requirement of overpacks. Note that although La Prade could theoretically accept PHT grade water there is a need to store 430 Mg of PHT water at DND prior to the start of an SCO and not at some external location.

A minimum inventory of PHT D_2O needs to be maintained in the PHT storage tanks to satisfy the shrinkage requirement during simultaneous cool down of all four units in the event of a four unit trip. This quantity was established to be 210 Mg as a result of a study conducted by Nuclear Safety, Heavy Water Management and the PHT group in preparation for the 1997 Vacuum Building Outage (VBO). During a 4-Unit shutdown (SCO or VBO) the total shrinkage requirement is estimated to be as much as 360 Mg.

A small quantity (typically 30 – 50 Mg) of "multi-purpose" D_2O (TRF product with an isotopic >99.98 % D_2O and <1 Ci/kg) is required to be used for deuteration of both moderator and PHT

purification systems ion-exchange resins. This is normally kept on stand-by in the 30 m^3 PHT weigh tank or in the 47 m^3 moderator storage tank, thus impacting the available capacity of the S&I system.

The initial demand to satisfy the 2003 SCO requirements was for 480 Mg of PHT quality D_2O prior to the start of the outage. This demand was later reduced to 420 Mg, due to the extended shutdown of the TRF in 2003. This requirement could only be met in 2003 by a lease of 77 Mg from AECL, a loan of 60 Mg from Bruce Power and a shipment of 40 Mg from PND. The remaining requirements were met from DND's inventory of Darlington Tritium Removal Facility product. The actual cost of the HW lease from AECL was $656,000 [29], because the HW was leased for as short a time as practicable. This heavy water was shipped without overpacks in drums. This was a one-time exception only with special permission from the Vice President of the Nuclear Waste Management Division; in the future this may not be possible. Current regulations require an overpack for each drum. Borrowing of water from Bruce Power may not be possible today. The lease of 137 Mg of D_2O today would be difficult because of the requirement of overpacks and therefore, would be much more expensive. The drums that would require to be returned (685 drums + their overpacks), would need to be stored in the interim and segregated to ensure that the same drums were to be used to return the water and hence avoid pressure testing requirements. Pressure testing of drums cost ~$250 per drum. There is an additional risk imposed on operations during drum handling and an additional administrative and engineering resource load. Overall, it is estimated that the total cost of such a lease of heavy water would be about $2.5 million.

During an unplanned, forced, moderator drain (Guaranteed Moderator Drain State) there is also storage capacity required for approximately 100 Mg since the S&I system normally stores up to 100 Mg of high curie Upgrader product for make-up. In this case, there is a high probability of downgrading of a portion of the Moderator system that could not be stored in the S&I system. The cost of the cleanup and upgrading of this water is estimated as $1.5 million [8].

Loss of Sales Revenue

Although this is not the main driver for increased storage, there are significant revenue opportunities from increased flexibility in the Darlington TRF/HW management systems. It has been previously estimated that financial benefits could exceed $9 million/year from increased sales of surplus HW and added business from improved use of the TRF and Upgrader [43].

There are contractual agreements with Bruce Power, for example, which provide ongoing revenue from detritiation. Provision of larger feed and product tanks for the TRF will allow TRF to receive and store feed from Bruce Power while the TRF is in an outage and enable previously stored product to be returned to Bruce Power. The cost of "missed opportunity" due to the TRF's inconsistent reliability has been estimated as $3 million. With the additional flexibility created by adding storage volumes, revenues have the potential to increase by $7-8 million. Therefore, there is potential net achievable benefit of $10 million.

In summary, provision of additional reactor grade storage may:

- *Eliminate the need to ship 100 Mg or more of reactor grade water off-site for temporary storage and prevent potential cross contamination and mixing of Moderator and PHT grade water. The estimated costs savings are summarized in Table 5.*

Table 5. Estimated costs savings associated with reactor grade water if additional reactor grade storage is provided		
Description	**Cost / year ($M)**	**Comment**
Ship Moderator D2O off site	0.75	1.5M once every 2 years
Downgrading D2O Event	0.33	1.5M/event 2 events in 10 years
Borrow Low Ci D2O	0.28	2.5M every SCO/VBO
Operator time lost due to shuffling drums	0.05	½ FTE (full time equivalent) / year
Cost to pressure test drums	0.05	$250/drum 200 drums/year
Total	1.46	

- *Provide additional storage capacity for TRF product which may result in significant financial benefits of up to $10 million/yr due to improved sales of detritiation services and also may avoid the need borrow or lease PHT make-up water from external sources.*
- *TRF product can be accumulated in bigger volume and help PND detritiation program by alleviating its reliance on shipping/receiving capability. (see section 8.5 for detailed discussion).*
- *The additional storage space can provide some storage relief for PND during its outages (see section 8.5 for detailed discussion)*

Downgraded D_2O Storage

Existing downgraded D_2O storage capacity in the HWMB consists of 2 x 25 m^3 downgraded dirty tanks and 2 x 50 m^3 downgraded clean tanks which also serve as the feed tanks for the Upgrader. The downgraded recovery and clean-up system configuration allows for segregation of recoveries based on tritium concentration.

The storage capacity at the Units consists of small D_2O recovery tanks (2 X 1 m^3 tanks in each unit) which are used to collect downgraded PHT and moderator D_2O. This is then pumped to the central processing area in the HWMB where the water is cleaned up in the IXCU followed by UV Oxidation, and then is sent through the Upgrader to produce reactor grade water which is used primarily for moderator make-up..

Upgrader product is stored in 2 x 12 m^3 product tanks before it is returned to the moderator system or reserved in one of the moderator or PHT S&I storage tanks for use in future moderator on-line transfers. Normally all Upgrader product is returned to the moderator system and TRF product is the source of make-up to the PHT system.

Downgraded D_2O storage capacity at Darlington is marginal at best and is inadequate to support segregated recovery during TRF outages and there is no spare capacity to deal with acute spills:

- During periods of high TOC in recovered water, the UV oxidation system imposes a restriction to Upgrader feed since the UV Oxidation system product has high conductivity and needs to be recycled to the feed tanks (2x25 Mg). This can cause the Upgrader feed to be restricted and the Upgrader to be placed into total reflux due to the limited storage capacity in the dirty tanks and the lack of on-line analysis of the clean product of the IXCU. If the TOC level in a Clean Tank is above spec, it is circulated through the UV oxidation system in a closed loop until the TOC is fully converted. This can take from 2 days to a week or longer depending on the nature of the TOC. After this, the tank contents have to be recycled through

the dirty tanks and IXCU to remove conductivity. Sometimes, for example, if a stable organic compound like ethylene glycol has been used in the reactors (for feeder inspections) then TOC is very difficult to remove. If a clean tank is locked up for feeding the SUP and the second one is on recycle through UV oxidation, it would be beneficial to have spare Clean Tank(s), which can still accept downgraded feed through the IXCU.

- During an extended TRF Outage of 6 months or up to 18 months (Assumption 28), recoveries have to be segregated so that high-Ci and low-Ci recoveries can be processed in batches through the Upgrader. This is normally the way of producing low-Ci product required for PHT loss make-up. As an option, PHT make-up water can be stored in the S&I tanks prior to start of the Outage (100 Mg for a 6-month Outage), thus avoiding the need to operate in segregated mode. With the existing downgraded storage, the Upgrader has to be cycled nominally every 23 days between processing low-Ci and high-Ci recoveries. In addition, operation in segregated mode with the existing storage necessitates the storage of about 17-20 Mg of downgraded recovery water in storage such as drums or reactor grade tanks (e.g. the TRF Product Tanks), because the Dirty Tanks cannot cope with the incoming recovery water (see calculation in Appendix D). This has occurred in the recent TRF Outage, where recovery water had to be stored in the TRF Product Tanks. Subsequently, these tanks were flushed twice with reactor grade water at 99.95% isotopic, and resulted in downgrading of the 2 batches to about 99% isotopic.

- Further evidence of shortage of storage is that backlog of downgraded water that cannot be dealt with. For example, approximately 70-80 Mg of downgraded water stored in the resin de-watering tanks has not been upgraded because downgraded storage has not been available during the recent TRF outage, yet the Upgrader has been on total reflux during this time – cost of upgrading of this water is estimated as $1 million. Hence this can be viewed as lost productivity of the Upgrader.

- During an 8-week Upgrader Outage (Assumption 17), 237 Mg of downgraded recoveries would have to be stored. The existing storage capacity of 150 m^3 would result in a *shortfall of 87 m^3* of capacity. The only option is to store this in drums, in plastic totes or to utilize reactor-grade storage. Temporary storage in drums presents a risk to personel during drum handling and challenges the existing space in the HWMB. Storing in totes has been ruled out previously due to leakage issues. Storage in reactor-grade tanks is undesirable since past history indicates the possibility of downgrading of reactor-grade water (SCR D-2003-06816, D-2003-06812).

- During a single Unit normal Outage, downgraded D2O recovery rates can be expected to increase, but the existing storage capacity is usually adequate as long as there is sufficient TRF product available to replace PHT losses, ie. the TRF and Upgrader are operating.

- During a 4-Unit Outage, such as a VBO or SCO, the TRF may be shut down if an auxiliary source of high pressure steam is not available. This situation was experienced during the 2003 SCO when high rates of moderator recoveries were experienced coincident with a TRF outage. This resulted in utilization of the 2 x 25 m^3 TRF product return tanks for storage of downgraded D_2O, storage of downgraded D_2O in 12 x 1 m^3 plastic totes and in drums The totes were procured on the understanding that they had undergone qualification via leak testing. However, while storing downgraded D_2O, leaks were experienced from 4 totes from the threaded joints near the bottom. These totes are not an approved container for tritiated D_2O. In addition, there is uncertainty about tritium absorption into the walls of the plastic totes. As a result, it has been decided that these kind of totes will not be used again for tritiated D_2O storage. A D_2O S&I storage tank was also downgraded during this period and it is thought that the downgrading was a result of activities related to transferring of the downgraded D_2O to reactor grade storage tanks

In summary, provision of additional downgraded storage will:

- *Eliminate or reduce the possibility of extensive downgrading of reactor-grade water due to cross-mixing by eliminating the need to store downgraded recoveries in reactor grade tanks*
- *Improve the capability for segregation and reduce the heavy water storage needs during an extended 18-month TRF Outage*
- *Improve the Upgrader capacity factor by allowing for circulation through the D_2O Clean Up System while still maintaining capability to feed the Upgrader , thereby improving isotopics or eliminating downgraded backlogs.*
- *Improve the capability to process TOC without impeding the entire system operation.*

7.1.3. Discussion of Drivers for Increasing Drum Storage Capacity

The drum handling requirements at DND are based on the assumption that DND will have on site on an ongoing basis ~150 drums for operational needs and on an occasional basis will require to handle an additional two ISO containers of 96 drums from external sales. Therefore, at any given time, the 350 drums will be the maximum to be handled or stored on a temporary basis. From external customers 200-300 drums/year are expected to be received, emptied and returned on an ongoing basis for the next few years in batches of 96 drums.

The HWMB was not designed for storage of drums. Temporary storage of these external drums challenges the available space in the HWMB and results in drums being stored in corridors, under stairs and in other inconvenient locations [4].

The additional drum storage space provided in Darlington will improve efficiency and safety. The personnel risks associated with handling drums will be reduced. Operational efficiency will improve due to drums not being stored in the corridors and various rooms of the HWMB, in some cases resulting in impeded access. Although difficult to quantify, these are tangible benefits.

Any drum shipped off-site has to be pressure tested to ensure its integrity. In the past, for example, drums have been shipped to Kinectrics for testing at a cost of ~$250 per drum. This will be avoided by having an on-site pressure testing facility.

7.2. Pickering Nuclear

Existing D_2O Supply & Inventory storage capacity available to support reactor unit operation and unit outages are shown in Table 6 and schematically presented in Figures 6 and 7.

Table 6. Existing Reactor Grade D_2O Storage Tanks at Pickering

Purpose	Capacity (Mg)
PHT S&I tanks	2x100
Moderator S&I Tanks	2x150
Upgrader (UPP-B) Product Tank	2x5.4
Upgrader (Sulzer-B) Product Tank	2x2.1
PIOTS Receiving Tank	1x29.8
PIOTS Shipping Tank	1x21.4
PIOTS Surge Tank	1x11.3

Eleven stainless steel tanks, with a total capacity of approximately 570 Mg are provided for storage. The two 150 Mg tanks are for moderator (MOD) heavy water and the other two 100 Mg tanks are for primary heat transport (PHT) heavy water. The MOD tanks are used for Pickering B drains (Pickering A has MOD dump tanks). The PND assumptions indicate that presently there is about 200 Mg of heavy water inventory the tanks have to hold.

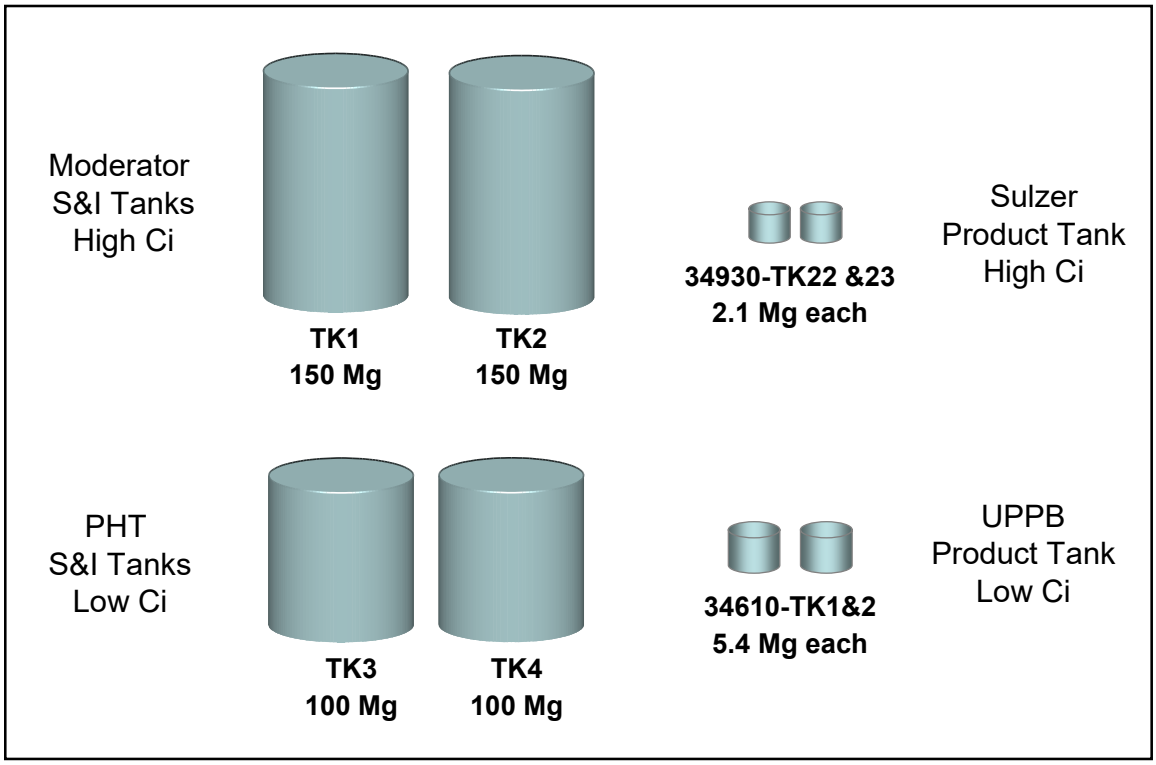

Figure 6. Visual representation of the reactor grade storage at PND.

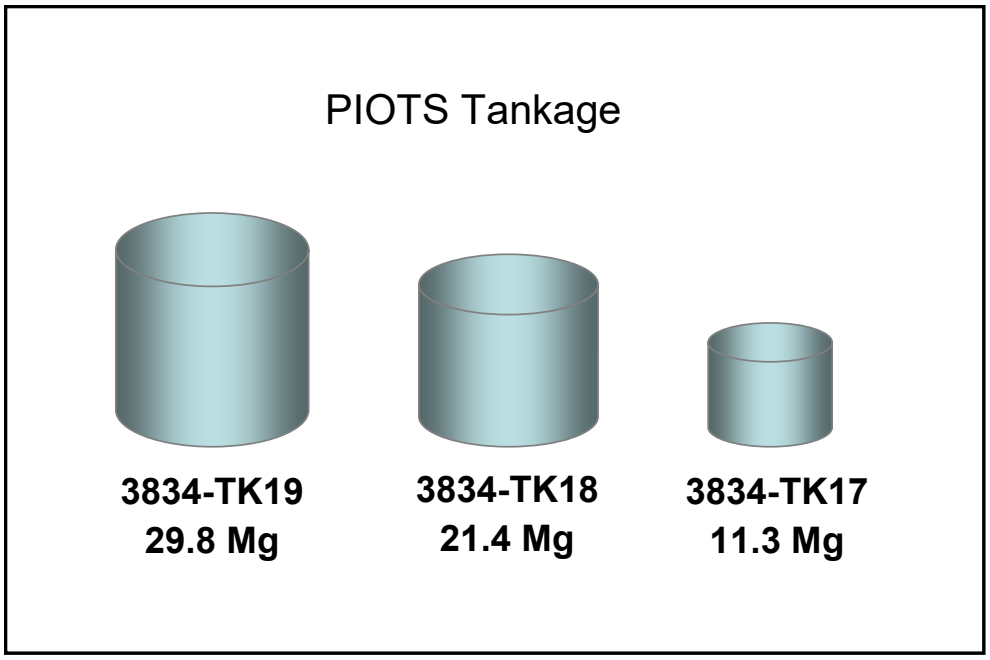

Figure 7. Visual representation of tankage storage capacity in PIOTS.

Leakage or spills of D_2O from the Primary Heat Transport (PHT) or Moderator systems are recovered by Vapour Recovery Dryers, collected from the Building Liquid Recovery System via floor drains, or collected via the various D_2O collection systems. Particularly in the Building Liquid Recovery system, “recovered”, downgraded D_2O is not only radioactive but also contaminated with emulsified oil and other organics. Oil in the recovered heavy water is a result of the usage of hydraulic fluid in the fueling machines. Note, the new reactors use pneumatically operated fuelling machines. The recovered water is normally cleaned up and upgraded to reactor grade for re-use.

Existing downgraded D_2O storage capacity at Pickering consists of 7x 6.8 m^3 D_2O recovery tanks (4 Low Curie, 3 High Curie) at the IXCU that are used to collect downgraded PHT and moderator D_2O. The recovered water is then processed at the IXCU with the product water being stored in 2x5.5 m^3 tanks ready to be processed through the Upgrader. There are nine 50 m^3 feed tanks in the UPP (5 in UPP-A and 4 in UPP-B) and five feed tanks at Sulzer-A and Sulzer-B, 1 x 1 m^3 and 4x15 m^3, respectively.. Sulzer-A and UPP-A are no longer in service. However, the UPP-A feed tanks are currently utilized to vent off volatile organic carbon from downgraded water containing less than 5 Ci/kg tritium. Furthermore, these feed tanks are made of carbon steel, which are not suitable for long-term storage of D2O. Table 10 summarizes the existing storage capacity for downgraded D2O at PND while Figure 8 presents the tankage visually.

Table 7. Existing Storage Tank and Capacity for Downgraded D_2O at Pickering

Purpose	Capacity (Mg)
D2O Recovery Tanks (at IXCU) – High Curie Oily	2.3
D_2O Recovery Tanks (at IXCU) - High Curie	3x6.8
D2O Recovery Tank (at IXCU) – Low Curie Oily	2.3
D_2O Recovery Tanks (at IXCU) - Low Curie	4x6.8
IXCU Product Tanks – High Curie	2x2.7
IXCU Product Tanks – Low Curie	2x5.5
UPPB Feed Tanks	4x50
Sulzer B Feed Tanks	4x15

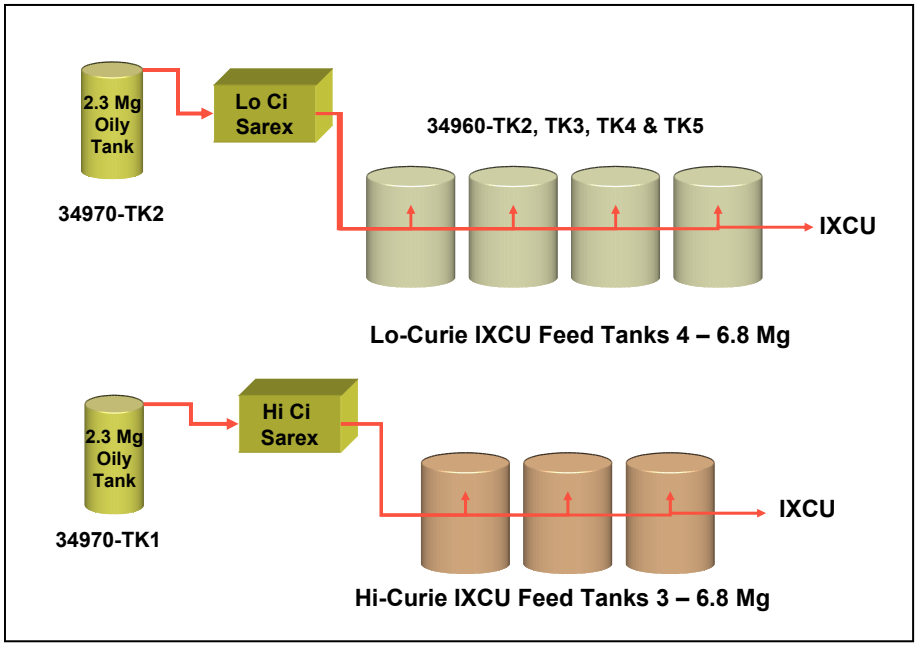

Figure 8. Visual representation of the storage capacity at the front end of the IXCU process.

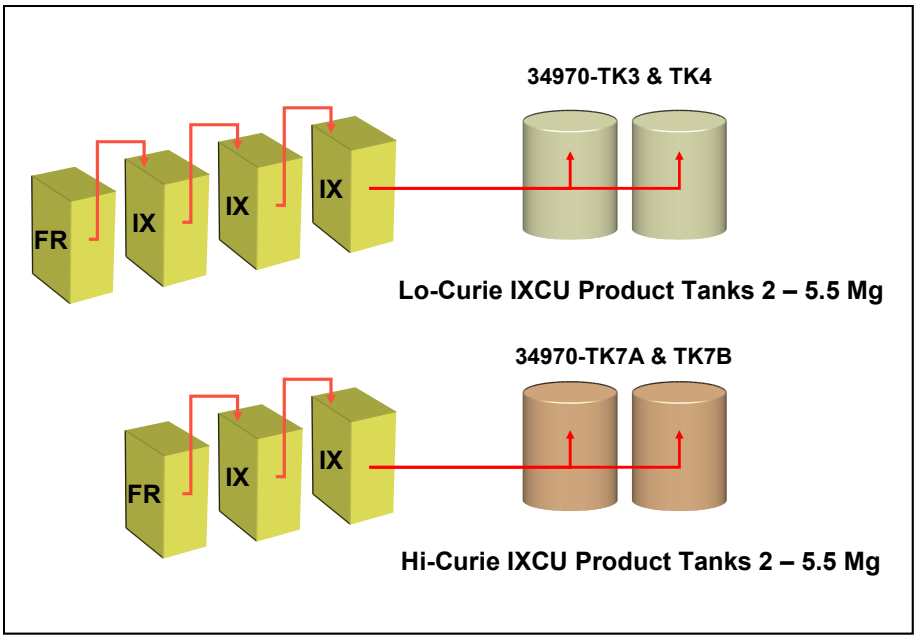

Figure 9. Visual representation of the storage capacity at the back end of the IXCU process.

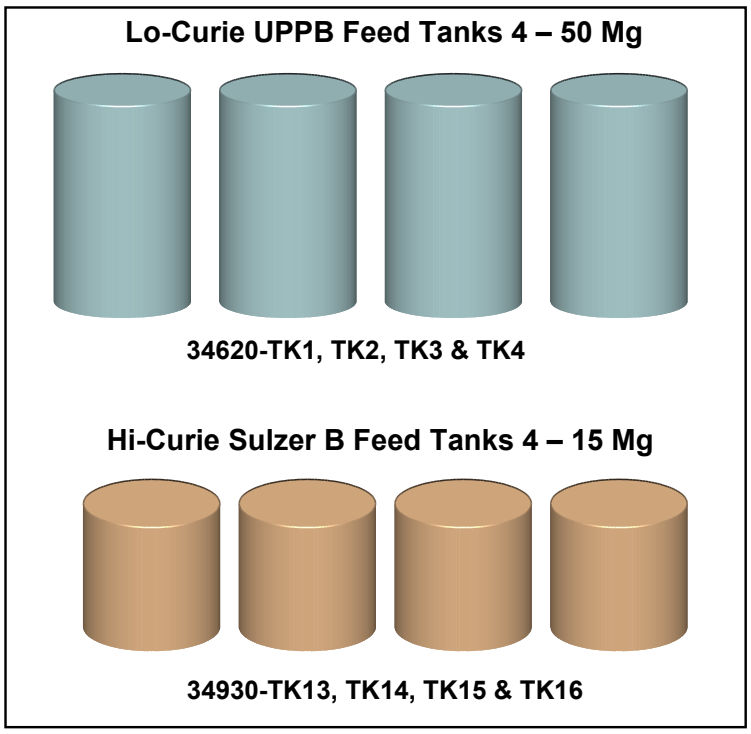

Figure 10. Visual representation of the storage capacity to the Upgraders.

Product from the UPP-B and Sulzer-B upgraders are stored in 2x5.4 and 2x2.1 Mg product tanks, respectively, (see Table 8) before being returned to the moderator system or reserved in one of the moderator or PHT S&I storage tanks for use in future moderator on-line transfers. Normally all Upgrader product is returned to the moderator system and TRF product is the source of make-up to the PHT system.

7.2.1. PND Storage Requirements during Normal and Outage Situations

D_2O storage requirements are driven by several different demands. These demands include HW storage capacity to support the reactors during normal operation and during outages; make-up water for system losses, water for detritiation, water for improvement of system isotopics and water drained from systems undergoing maintenance. An additional demand on the storage capacity is made by the need to segregate heavy water of varying qualities.

Various scenarios are examined and the heavy storage needs identified. The scenarios examined are:

- Normal Operations
- PNDB Outage plus a moderator drain
- PNDA Outage plus a moderator drain
- Very Low Level Drain State PHT system
- PNDB Outage plus a moderator drain and a VLLDS for the PHT system
- PNDA Outage plus a moderator drain and a VLLDS for the PHT system
- 6 month TRF outage
- 4 week Upgrader outage

Normal Operation

Presently, the existing reactor grade heavy water inventory in the PND S&I tanks is approximately 200 Mg of various qualities. The operating manual defines the following minimum reactor grade water to be held in Storage and Inventory for operating system makeup:

- 33 Mg PHT make-up
- 20 Mg high Curie for Moderator make-up

The state (quality) of the remaining reactor grade water is dependent on the needs of the station; for example, TRF product for PHT make-up and low Curie product for detritiation and isotopic improvement.

During normal operations there is adequate S&I heavy water storage at PND. On-line detritiation, which bleeds high Curie Moderator water out of the running unit and feeds low Curie water, can be performed with no additional reactor grade storage requirements. During the period of on-line detritiation, because high Curie is fed to the S&I tanks through the high Curie side (TK1/TK2) and low Curie fed from the low Curie side (TK3/TK4), upgrader product cannot be received. On-line detritiation using a 90 Mg swap can be performed over a 48 hr time period [12]. Segregation by Curie content is performed by sending Sulzer product to the high Curie TK2 tank, TRF product to the low Curie TK3 tanks and UPPB product to the low Curie TK4 tank.

During normal operations the Clean Up System (IXCU) suffers from the following:

- Not enough storage capacity to contain existing recovery rates (see calculations in Appendix C) leading to:
    - High drum usage (3000 drums scattered throughout the station)
    - Contamination of relatively clean vapour recovery water with oil
- Not enough segregation capacity for efficient use of the IXCU system as a result of:
    - Downgraded D2O containing oil from fuelling machines
    - Downgraded D2O containing high “total organic carbon” (TOC) from lubricants used in the inspections of reactor components and organic solvents in reactor building

- Inability to clean drums leads to using dirty drums to collect clean water

Oil leaking from fuelling machines leads to an oily water inventory which is beyond the present storage capacity and decanting capabilities. When the oily tank is full, the waters are transferred to tanks that are designated to contain only clean water, thereby making these tanks oily as well. As a result, the IXCU cannot run as efficiently as originally designed since oily water requires more passes through the charcoal and ion exchange columns.

The increase in inspections of feeders and other reactor components uses a lot of organic compounds. Solvents used in the reactor building are often of an organic nature, which causes the recovered water to contain high amounts of organic carbon; this TOC is difficult to remove.

The upgraders have a specification (<1 ppm) on TOC to prevent degradation of the upgrader. PND has been unable to achieve this target due to the high oil and TOC in the downgraded heavy water.

PNDB outage plus Moderator drain

During a Moderator drain 250 Mg of Gd (gadolinium) containing reactor grade water requires to be stored in the S&I system. In order to do this both S&I TK1 and TK2 (300 Mg total) need to be emptied prior to the outage to accommodate the gadolinium containing Moderator water. The existing high Curie inventory in TK1 or TK2, will have to be converted to low Curie via the TRF to be moved to the low Curie tanks (TK3/TK4). Once tanks TK1 and TK2 are occupied by the drained Moderator water, they are isolated from the other reactor grade water due to the gadolinium making the remaining free volume of 50 Mg in TK2 unusable. This leaves the 200 Mg of the low Curie tanks (TK3 and TK4) as available space.

The existing inventory of 200 Mg will occupy both TK3 and TK4 leaving no space for receiving the products of the two Upgraders (low and high Curie) with the likely possibility that the Upgraders may be placed into a reflux mode. Under this scenario there is a possibility of mixing TRF product with UPPB Upgrader product. In mixing the UPPB and TRF product the effectiveness of TRF product to maintain or lower PHT tritium concentrations is reduced due to the larger tritium concentration of the combined waters

The Sulzer product (medium Curie) can be stored in PIOTS tank TK18 for shipment to the TRF. Approximately 16 Mg of high Curie product is expected during a 30 day period, see Appendix C. Since TK18 can hold around 21 Mg the expectation is that the Sulzer upgrader will not require being placed into reflux. If the tank approaches the full state then a shipment of water to the TRF will be required.

In this scenario UPPB product, estimated at ~28 Mg during the outage period (see Appendix C), cannot be accommodated in TK3 or TK4. The upgrader product is either placed in PIOTS TK19 (capacity of 29 Mg) or UPPB is placed into reflux. If the PIOTS tank is utilized receipt of TRF product is not possible.

If the TRF is down during this outage scenario then the situation described is aggravated further as the TRF may not be in a position to receive water.

No detritiation of other units are possible during this scenario as there is no space to receive the high Curie water. There is a lack of flexibility in the overall S&I storage system under this scenario. Any additional requirements of the heavy water system would require operator work arounds. Segregation of the different qualities of heavy water is difficult.

Offline detritiation of the unit in the outage mode can be performed during this scenario. Since a minimum of 53 Mg must be kept in TK3 and TK4 the largest swap size for detritiation would be in the order of 140 Mg.

PNDA outage plus Moderator drain

PNDA have Moderator dump tanks thereby eliminating the need to use S&I TK1 and TK2 to store the moderator water. Detritiation via bulk swap (offline) is possible during this time period. Space is available in S&I high Curie tank (TK2) and the low Curie tanks (TK3 and/or TK4) to receive low and high Curie Upgrader product during this time period.

Very Low Level Drain State of PHT System

In this scenario 100 Mg of low Curie S&I storage will be required. Tank TK3 will require emptying as it will hold the 100 Mg of lithiated PHT water. TK4 will contain the required low Curie make-up plus any other low Curie water. Any TRF product being held in TK3 will have to be mixed with UPPB product in TK4 reducing the effectiveness of the TRF product in maintaining or lowering PHT tritium. Low Curie water in excess of 100 Mg will require additional storage. Low Curie upgrader product during this time (calculated to be ~28 Mg, CB) cannot be stored in TK3 or TK4 and can either be stored in PIOTS or in TK2. Storage in PIOTS will limit shipping and receiving of heavy water to and from the TRF. Storing the low Curie product in the high Curie tank will defeat the segregation philosophy and make it unusable for the PHT system but can be utilized for detritiation.

PNDB Outage plus a moderator drain and a Low Level Drain State (VLLDS) for the PHT system

The heavy water storage system is the most stressed under this scenario. In the case of a PNDB unit moderator drain the total storage requirement on the S&I system is 350 Mg (250 Mg for the Moderator and 100 Mg for the PHT system). The S&I high Curie tanks (TK1 and TK2) will be occupied and isolated while TK3 will have 100 Mg of lithiated heavy water from the PHT system. Any high Curie water in tanks TK1 and TK2 will have to be relocated prior to the outage as will any low Curie water in TK3. With approximately 200 Mg of heavy water in the S&I system prior to the outage, 100 Mg will be kept in TK4 and the other 100 Mg will require additional storage.

If the PIOTS tanks are utilized to provide some of the necessary storage then no shipping or receiving to the TRF is possible. Even with these tanks additional storage for ~50 Mg of heavy water will be required either externally or internally.

Because of the full utilization of the S&I tanks UPPB and Sulzer upgraders will be required to be placed into reflux. During a 40 day outage the systems are expected to be drained for 30 days meaning that ~127 Mg of low Curie and ~69 Mg high Curie downgraded water will be generated (no acute downgraded events assumed) which will require storage at IXCU, see Appendix C for calculation. The Upgrader feed tanks (200 Mg – UPPB and 60 Mg – Sulzer) would have enough storage capacity to accommodate the downgraded collection.

Offline detritiation is limited to ~40 Mg volume swap; the remaining water in TK4 that is not required for makeup.

There is no flexibility in the S&I system during this scenario. IXCU may also backup because the Upgraders are in reflux mode. If an acute downgraded event occurs there is no choice but to utilize drums.

PNDA Outage plus a moderator drain and a Low Level Drain State (VLLDS) for the PHT system

The moderator dump tanks of PNDA makes this scenario less stressfull on the S&I system. TK1 can now be utilized for offline detritiation (~100 Mg); that is, receive 100 Mg of PNDA moderator water. Low curie, TRF product, water stored in TK3 can be used with any high Curie water in

TK2 to produce the swap volume. TK3 once drained can hold the 100 Mg of lithiated PHT water. TK4 will hold UPPB product.

There will be no flexibility in the S&I system to hold Upgrader product during this period (~28 Mg low Curie and ~16 Mg high Curie). If the PIOTS tanks are utilized there will be no ability to ship or receive to the TRF. If PIOTS are not utilized the Upgraders may have to be placed into reflux placing the additional storage requirements on IXCU (127 Mg fluid of low Curie and 69 Mg fluid D2O of high Curie, see Appendix C). The Upgrader feed tanks (200 Mg – UPPB and 60 Mg – Sulzer) would have enough storage capacity to accommodate the downgraded collection.

6 month TRF outage

During a 6 month TRF outage PND requires at minimum make-up water (-15 Mg [1]) for PHT system losses. This PHT loss make-up would have to be brought in prior to the TRF outage. Any detritiation performed during this time period will require ~100 Mg of low Curie water availability in the S&I system. The heavy water in the S&I will require managing prior to the TRF outage to insure enough low Curie water is available.

Offline detritiation, performed during a scheduled Unit outage, is less flexible in scheduling than online detritiation; hence, during a 6 month TRF outage detritiation is most likely to be performed online.

Present TRF feed and product storage capacity at DND may make preparation for the outage difficult.

4 week Upgrader outage

During a 4 week Upgrader outage there will be a need to store recovered downgraded water. Appendix C estimates that 127 Mg of low Curie downgraded water would be required to be stored if UPPB was in an outage situation and 69 Mg of high Curie downgraded water if Sulzer was in an outage. UPPB has feed tank storage capacity of 200 Mg hence a 4 week outage would not be an issue. Sulzer has 60 Mg of storage capacity on the feed size. A Sulzer outage would most likely lead to a situation where drums would have to be utilized to hold the extra water that the feed tanks could not contain.

Any water in the upgrader feed tanks will require processing prior to the outage to maximize the storage capability during the outage.

Any acute recovery events during an Upgrader outage will most likely lead to drumming of heavy water.

Summary

The review of heavy water storage needs under various scenarios has identified the following issues:

- *a lack of flexibility in the Storage and Inventory system to accommodate the needs of operating units during system drains (Moderator, PHT)*
- *little tolerance in PND Heavy Water System to handle erratic TRF performance when preparing for moderator/PHT drains*
- *insufficient storage capacity in S&I to accommodate a simultaneous PNDB moderator and PHT VLLDS drain situation*
- *insufficient storage capacity for downgraded water recovery rates*

•insufficient storage capacity at the Clean Up system to handle the high oil and high TOC water recovery rates resulting in a poorer performance of the Ion Exchange Clean-Up System

•Inability to clean contaminated drums resulting in further downgrading of relatively clean recovery water

•large number of drums occupying station real estate (>3000) as a result of inadequate storage capacity at IXCU

•difficulty in adhering to segregation philosophy of different quality waters due to insufficient storage (on occasion applies to S&I but generally to IXCU)

7.3. Discussion of Drivers for Increasing S&I Storage Capacity

One of the driving arguments for increasing S&I storage capacity at PND is the ability to detritiate the units more effectively through the off-line detritiation technique. Section 2.1 and Appendix A discuss and review the two methods of detritiation: online and offline. Appendix A demonstrates that offline detritiation is indeed more effective. For similar 100 Mg swaps of 1 Ci/kg water into a moderator with a tritium concentration of 17 Ci/kg the resulting tritium concentration at the end of the swap is 11.3 Ci/kg for offline and 12.2 Ci/kg for online. The cause of this difference is the mixing of the swap and moderator waters while the online detritiation is proceeding. This mixing leads to some of the swap water being bled out with the moderator water resulting in a less effective detritiation effort. In either technique large volume swaps are more effective than small volume swaps. PND in its present detritiation plan [12] calls for large on-line swaps of 90 Mg along with an off-line swap of 80 Mg.

PNDB can be detritiated via either technique while PNDA because of logic control issues can only be detritiated via the off-line technique [30]. OPEX indicates that on-line detritiation of PNDB units is restricted to the quiet periods such as weekends or on overtime. PNDA (Units 1 and 4) have only recently began operating again (P1 – Nov 2005, P4 – Sept 2003) since being layed up in 1997. Their average tritium concentration at the beginning of 2006 was 8.35 Ci/kg [12]. Review of the 2004 Heavy Water Management report [1] shows that since 1997, when PNDA was layed up, the tritium concentrations in the PNDB units have been steadily climbing while the isotopics steadily declining. In January 2006 the average moderator tritium concentration for PNDB was 17.0 Ci/kg (target 10 Ci/kg) while the average isotopic was at 99.88% (target 99.94%) [12]. The OP&P limit for the tritium concentration at PND is 25 Ci/kg. What is clear from this report is that detritiation has not been performed often enough. PND Common Services indicates that on average there has been a 187 Mg shortfall in shipments of water to the TRF for detritiation; Appendix Q breakdowns the shortfall over the years. Such a shortfall would help in explaining the trends presented in the Heavy Water Report.

This shortfall and therefore difficulties in executing detritiation over the years are attributed to a host of reasons [30]:

1. Extended TRF outages (2003 and 2006) limiting the amount of TRF product
2. Moderator S&I tank (TK1) occupied with Gd containing water, a result of a previous detritiation effort via the off-line technique
3. Before 2002, D2O from the Unit 4 shutdown was stored in S&I tanks to allow maintenance preventing on-line detritiation of PND-B units for 13 months
4. Procedural issues with safe execution of on-line swaps. Resolution took 6 to 9 months.
5. Planning/resource/schedule/co-ordination problems in shipment of heavy water to and from the TRF

6. Can only be performed during quiet times (weekends or by utilizing overtime)

The above points reinforce some of the present issues with the heavy water storage system: a lack of storage (items 2 and 3) and a lack of TRF reliability (item 1). Other items (4, 5 and 6) appear not to be associated with a lack of storage.

Item 1 is an indication of a lack of sufficient storage to deal with the uncertain TRF performance. However, the lack of TRF reliability can be addressed in a number of ways. One, the reliability of the TRF itself can be improved or two, heavy water TRF product buffers (requiring extra storage) can be built up at DND, PND or both. If a buffer is to be available at Pickering then additional storage capacity at S&I is required. OPG solutions to mitigate TRF reliability are discussed in section 8.5 “Heavy Water Storage at OPG” which argues additional storage at DND can aid Pickering in dealing with an unreliable TRF without adding extra S&I storage at PND.

Item 2 is discussed further because it highlights other issues pertaining to off-line detritiations and IXCU. A PND-B operating unit is shut down by poisoning the moderator with gadolinium (Gd). In the case of an off-line detritiation the moderator water is over poisoned to compensate for the lack of Gd in the swap water. The moderator water when drained must be segregated because the Gd in the water can precipitate and form a gel-like material when the pH of the moderator water goes alkaline as it mixes with the PHT lithiated water. The precipitate can plug up system process lines, valves and tanks. [It is highlighted that PND-A does not suffer from this issue because it does not poison the moderator for shutdown although on occasion Boron is used.] The net effect of a PND-B moderator drain is to occupy the two 150 Mg MOD S&I tanks as previously discussed in section 7.2.1. The volume of Gd containing moderator water left in S&I after the swap cannot be shipped to the TRF until the Gd is removed; such was the case in the event that left Gd containing water in TK1 (item 2). The water would have been sent to IXCU to remove the Gd but the IXCU is overtaxed (see section 7.4 below) and could not handle this water. Furthermore, during cleanup the good isotopic water would be downgraded and then upgraded again through the Sulzer upgrader wasting energy, resources and money. The result was the Gd containing moderator water remained in TK1 and impeded S&I utilization because of the need to segregate this water from the rest of the reactor grade water. To address this issue an engineering change (EC 88224) was initiated and recently completed. The EC resulted in the addition of a permanent ion exchange clean up system to the moderator S&I tanks (TK1 and TK2). This change now permits Gd containing water to be cleaned at S&I prior to sending to the TRF. Thus, the impediment to S&I utilization by this scenario cannot occur again because of the permanent ion exchange clean up system at S&I.

On-line detritiation does not suffer from the problem presented in item 2 as no Gd is present.

The previous off-line detritiation uncovered complexities associated with the off-line technique:

- Detritiations must be completed within 5 days in order not to threaten the outage schedule. A complete moderator drain and refill can take up to 8 days to complete.
- Must be approved by the CNSC since the Gd content in the water returned to the moderator must be controlled.
- The mixing conditions have to be frequently monitored to prevent undesired flux tilts. Monitoring involves frequent sampling through the swap process to ensure reactor safety. More chemicals will be required and more waste will be generated.

Item 3, although it is illustrative of a lack of storage capacity, is outside the scope of this study; nonetheless, it is a reality. Refurbishment activities, as was the case with Unit 4, are not normal operation or scheduled maintenance outages. If future refurbishment activities take place at PND this will require additional heavy water storage as the present S&I system does not have sufficient capacity.

To summarize thus far, the inability to detritiate or improve moderator isotopics effectively over the last 10 years at PNDB cannot be solely tied to a lack of storage capacity at S&I. In times where a lack of storage capacity has caused stress to the S&I system other solutions are possible (improve TRF reliability) (section 8.5) or are not in the scope of this study (refurbishment).

Operational Performance Reporting was approached to determine if a lack of heavy water storage had impacted outages either in scheduling or duration; the response was that to date there had been no impacts [34].

When reviewing the demands on the heavy water storage at S&I during a simultaneous moderator drain and a VLLDS PHT drain it is clear additional storage is required. Assumption #4 indicates that in the long term such a scenario is expected. However, to date such a scenario has not occurred although the schedule for outage P671 shows an overlap of one day during which time the moderator is nearing the end of a refill while a PHT drain is set to begin [47]. Common Services has asked DND to withhold 100 Mg of TRF product in order to accommodate this scenario [49]. Again, in the case of PND-A the scenario is different because of the moderator dump tanks to accommodate the drain.

Presently, for PND-B a simultaneous Mod and VLLDS PHT drain of the same Unit cannot be performed within a 40 day outage because of heat sink issues [44]. As OPG moves to a 40 day outage schedule, Outages [44] indicates that the simultaneous drain of the two systems, for the same unit, is possible once the heat sink issue is resolved. In the present outage template a moderator drain will not occur in the same window as a PHT drain [44]. There is no clear indication that in the future there will be a simultaneous drain of two systems thus the need for additional S&I storage driven by this scenario is in question. On the other hand, by not increasing S&I storage, the availability to perform simultaneous drains is severely restricted.

Additional information from Outages [50] indicates two outages per year for PND-B and one outage per year for PND-A. However, according to the approved schedule every outage does not have a moderator drain associated with it. For PND-B one moderator drain per year is planned which means only one offline detritiation opportunity per year. Additionally, no PHT LLDS are presently planned for PND-B beyond 2007.

This study deals with planned scenarios but in operating nuclear plants there are unplanned scenarios, such as, outage P751 which originally was planned for 40 days but now extended to 55 days. Since the state of heavy water storage capacity is always in flux it is difficult to say with certainty what will be the future needs suffice to say that PND does not have a great deal of flexibility in its S&I storage which increases the risk of operator workarounds during unplanned scenarios. Common Services indicates the time spent on operator workarounds is equal to 2 full time equivalent positions [Appendix Q].

In summary, the lack of sufficient S&I storage has impacted PND at present. Had sufficient storage been available the Gd contaminated water would not have impacted detritiation of PND units. Had sufficient S&I storage been present the water from Unit 4 (undergoing reburbishment) would not have impacted detritiation. Had sufficient S&I storage with detritiated water been available the extended TRF outages would not have impacted PND. However, a permanent IX clean up system attached to S&I MOD tanks eliminates the Gd problem. Unless PND goes forward with future refurbishments there will be no S&I storage impacts from such activities in the future; and increased storage at DND would be more beneficial to OPG in dealing with TRF outages than increased storage at PND (section 8.5). PND under the various scenarios utilizing heavy water storage (section 7.2.1) does suffer from a lack of flexibility in the system; however, it has dealt with this most of its operational life. Section 8.5 discusses how adding more storage at DND will help mitigate storage issues at PND. Section 9 indicates that increased S&I storage will require until late 2010 to implement. By 2014 most of PND-B units may be shutdown and the requirement on the S&I system will greatly diminish.

At present, the case for additional S&I storage at PND is not clearcut. Add to this the limited lifespan remaining in the station (all 4 PNDB units shutdown by 2016 with three units in 2014) with the expected implementation date for additional storage of 2010 (see section 9) leads the study to recommend not adding additional tankage for S&I at PND. Section 8.4 outlines the risks associated with this recommendation. These risks can be mitigated by going forward with the storage recommendations at DND. The remainder of this section captures some of the costs associated with high tritium concentrations and low isotopics in the moderator.

The above recommendation must be reconsidered if OPG decides to refurbish the operating units at PND. Presently, OPG under directions of the Government of Ontario is investigating new build or refurbishment of existing units. During refurbishment, systems will be drained for extended periods of time which, if no additional storage is provided, will utilize the present S&I system and will significantly impact operations, tritium concentrations, moderator isotopics and potentially outages at PND.

Costs Associated with High Tritium Concentrations and Low Isotopics in PND Moderators

The higher than target tritium concentrations in the moderators have an impact; specifically, the high tritium concentrations in PNDB units are:

- in conflict with OPG's ALARA philosophy (~733 Curies emitted to the air per (Ci/kg) increase in moderator tritium concentrations) ,
- impacting worker dose, and
- sending the wrong message to the public and regulatory body.

References [32, 41] provide a relationship for total dose as a function of PHT and Moderator tritium concentrations associated with PND-B,

Dose (rem/a) = 100 x PHT (Ci/kg) + 4 x MOD (Ci/kg)

and for PND-A,

Dose (rem/a) = 200 PHT (Ci/kg) + 20 MOD (Ci/kg)

Presently, PND average PHT concentration is 1.1 Ci/kg and 17 Ci/kg [35] for the Moderator. At a value of $25,000 per rem [33] the increased cost, associated with dose, to operate the PNDB moderators above the target concentration is 0.1M$/annum/(Ci/kg above the target); that is, operating with the PND-B units at the present tritium concentration versus the target values results in a cost associated with dose of 0.7 M$/a. PNDA at present is near the target tritium concentration. Appendix A refines this cost, calculating what the costs savings to PND would be if additional storage at S&I was implemented. The savings, due to dose reduction, would be $2.5M over the remaining life of PND.

Environmentally there is no direct cost associated to tritium emissions but it is likely to impact public and regulatory opinion. Tritium emissions to air increase at approximately 730 Curies per annum per Ci/kg increase in average tritium concentration in the PNDB moderators [1].

Presently, moderator isotopics are lower than target values. Low isotopics increase fuel burn-up resulting in higher fuel costs. For PND [51] the cost of system isotopic on fuel burn-up is ~37.9 k$/0.01% isotopic/unit/a. Presently PND-B average isotopic is 99.88% [12]; the target is 99.94% [12]. The cost to PND of the lower than target moderator isotopics is estimated to be (99.94-99.88) x 39 x 4 = $936,000/a. Appendix A refines this cost, calculating what the costs savings to PND would be if additional storage at S&I was implemented. The savings, due to improved isotopics, would be $0.71M over the remaining life of PND.

The low isotopics at PND-B is linked to the lack of detritiation of the units; however, it is pointed out that it is not because of lack of TRF product as system isotopics are improved via the upgraders and not the TRF. Much like in the case of detritiation discussed previously, isotopic improvement is most effective when employing large volume swaps, see Appendices A and B for example calculations. This swapping of large volumes of moderator water is done during detritiation. In other words, if you have the capability to swap large volumes of moderator water it is most efficient to increase isotopics while simultaneously detritiating. Because detritiation of the PND-B was limited over the past ten years the isotopics in the PND-B units have suffered which has resulted in greater costs due to enhanced fuel burnup.

7.4. Discussion of Drivers for Increased Storage Capacity at IXCU and Drum Cleaning Capabilities

The previous study [4] indicated the need for additional downgraded D_2O storage capacity to address segregation requirements of PHT and moderator recoveries (oily and non-oily) and to reduce the number of drums at PND. This segregation is required to ensure that the UPPB Upgrader can be used to produce low curie D_2O suitable for use as PHT make-up, in the event of an extended, unplanned shutdown of the TRF.

Presently, the IXCU system at PND is suffering from the following symptoms:

- increased usage of drums and number of drums (presently over 3000 drums),
- slower throughput in the processing of the dirty, downgraded, water, (150 kg/hr versus capability of around 400 kg/hr)
- difficulty in meeting Upgraders feed water specifications (TOC > 1 ppm typically 3 to 4 ppm),
- degradation of upgrader throughput, particularly UPPB, due to higher TOC in feedwater provided by IXCU system,
- oil contamination of all feed tanks to the IXCU.
- difficulty in segregating dirty, downgraded water.
- loss of heavy water inventory into drums and UPPA. Approximately 190 Mgs D2O of dirty downgraded water occupy drums and tanks in the UPPA (no longer operational) waiting to be cleaned and upgraded.

These symptoms are indicative of an overloaded, overtaxed IXCU. The cause of the overload is inadequate storage capacity in the feed tanks. Appendix C, utilizing historical recovery rates and operational experience from Common Services, calculates the required tank sizes. The calculated sizes for the required tanks support the statement that there is inadequate storage capacity in the Clean Up system. The calculations illustrate an inconsistency in the holding capacity among the tanks utilized for each quality of water (oily low and high Curie, non-oily low and high Curie). For example, the low Curie oily tank has a holding capacity for a quarter of a week of generation while the non-oily, high Curie can hold a week's worth of downgraded water. The lack of appropriate storage heavily restricts the ability to segregate the downgraded water slowing down processing throughput. The slower processing throughput further backs up the Clean Up system requiring greater storage capacity. The lower processing rates for downgraded water versus design are attributable to:

1. High levels of oil in the downgraded water; an unavoidable result of using hydraulic fluid in the fueling machines.
2. High TOC in downgraded water [45]. Possibly a direct result of the solvents and lubricants utilized during outages or of oil contamination of all IXCU feed tanks.
3. Oil contamination of all IXCU feed tanks as a result of incompatibility of the heavy water storage capacity with the downgraded water generation and the IXCU processing throughput.

4. Lack of drum cleaning capability leading to re-use of oil contaminated drums leading to the cross contamination of relatively clean water with oily water.
5. Inadequate oil decanting/removal system.

The first item is unavoidable at PND and deficiencies at IXCU will have to be addressed to deal with it. The second item requires changes in the solvents and lubricants used during outages; this may not be possible. The third item can on occasion be addressed by cleaning the tanks. The fourth item requires a drum cleaning facility that PND or DND is lacking. Lastly, the fifth item can only be addressed by additional storage capacity.

The unavoidability of items 1 and possibly 2 drives the need to increase storage capacity at IXCU for downgraded water. To prevent spreading of oil/TOC contamination through the re-utilization of dirty drums a drum cleaning facility is essential. A drum cleaning facility would have the additional benefit of preventing further buildup of drums while, potentially, reducing the total number of drums. Hence the study recommends additional storage at IXCU and the placement of a drum cleaning facility at PND.

From PND Assumption # 5 a drum cleaning facility is required to be able to process a minimum of 10 drums/day. This number is consistent with the derived recovery rates calculated in Appendix C (7 drums for non-oily downgraded water and 3 drums for oily downgraded water). Additional throughput for the drum cleaning facility is placed upon it by the desire to have the historical number of drums (~2000) cleaned either for re-use or disposal.

Over the years the following actions have taken place to deal with the symptoms experienced by the IXCU system:

- Addition of a UV Oxidation system at IXCU. The system is presently being tested. This system once installed will aid in reducing the TOC in the Upgrader feed water. Common Services Operations suggests the system may not be sufficient for the following reasons: the very high TOC at PND; has to serve both the high and low Curie trains and the process rate is too slow [46]. There is a possibility that the UV system may increase water residence time within IXCU.
- Use of additional charcoal columns [45].
- TOC sampling on recovery from units to allow segregation [45].
- Flushing of heavily contaminated tanks (0-3496-TK1 and 018-3496-TK6/7) to 0-3497-TK1/2 [45]
- Cleaning of oily IXCU feed tanks [26]; recently completed.
- Purchase of additional drums.
- Additional Clean Up process utilizing UPPA feed tanks for volatile carbons that are difficult to remove via the IXCU charcoal columns. UPPA tanks in conjunction with a temporary IXCU system is used to circulate the high TOC water (5 ppm) to reduce the TOC down to 3 ppm. Prior circulating the high TOC water is left to sit in the tanks. It is believed that the venting of the tanks naturally allows the volatile TOC to dissipate [53].
- Two campaigns utilizing external contractors to clean the segregated high TOC, high oil water: Pacific Nuclear and presently, Westinghouse.

The above actions have resulted in the following non-recoverable costs to OPG.

- 2000 more drums at PND than required (PND Assumption 3 & 5). Presently, closed top stainless steel drums can be purchased for $800 [52]. In the past drums have been purchased from AECL at $500 [52]. Thus, 2000 extra drums represent an additional cost of 1 to 1.6 M$.
- Extra handling of these extra drums is estimated to cost $360,000[1].

[1] 3 hrs/drum x $60/man x 2000 = $360,000 [30]

- Installation of a UV Oxidation System at a cost of approximately $2 million [48]
- Clean up of all the oily IXCU feed tanks, presently underway, is estimated to cost $105,000 [26].
- Cleaning up of segregated high TOC/oily water - $350,000 (Pacific Nuclear) and $700,000 (Westinghouse)
- A significant amount of high TOC/oily water has been segregated (not been utilized for operations) (~190 Mg D2O). If not for the shutdown of Units 2 and 3 PND would have obtained replacement water from external sources. The shutdown units provided HW management at PND with the required replacement water.

Intangibles or potential future costs are captured in the Table below.

Table 8. Potential Future Costs due to Insufficient Storage at PND IXCU

Description	Cost ($/yr)	Comments
Continued degradation of UPP packing with the potential that the Upgrader will no longer meet station demands. Pickering Common Services estimates that by 2010 the UPPB upgrader will no longer be able to meet the operational needs	Potentially millions of dollars after 2010.	See Appendix Q. PND will have various options to deal with this: purchase of external upgrading services, cleaning the upgrader packing (if deemed to be the problem), repacking the upgrader or building a new upgrader.
Additional efforts by Common Services to meet operational requirements; that is, operator workarounds	264,000	2 FTE per yr at 1650 hrs/yr at $80/h (OT rate)
Replacement of 'lost' water due to the inability to process the oily water. Assumes 10% of oily drums unprocessable.	28,700	0.1x2.7drums/day x 365 days/yr x 230 kg/drum x 0.23 (isotopic) x 5.5 cents/day/kg x 0.01 $/cent
Purchase of more drums	14,000	20 drums/yr x $700/drum
More external contracts to clean up segregated high TOC/oily water	350,000	$700,000 (Westinghouse campaign)/2yr
Cleaning of oily IXCU tanks	52,500	$105,000 (present clean up campaign) every 2 yrs.
Disposal of drums	9,200	Drums disposed as solid waste (internal sludge solidified in-situ) 0.23 m3 x 10 drums/yr x $4000/m3 (cost to external OPG customers)
Total	*718,400*	*Excludes potential costs associated with Upgraders*

8. Options to Address OPG's Long Term Heavy Water Storage and Drum Handling Requirements

The collected information (strategy documents, OPEX, outage schedules, system flowsheets, notes of meetings etc.) was scrutinized in order to understand present heavy water management practices and resources. The future needs as defined by the assumptions were compared to the present practices and resources. Where deficiencies presented themselves heavy water storage options are defined to address the deficiencies. Criteria were defined to aid in judging potential heavy water storage options. These criteria are presented below.

Potential options, exclusive of the maintaining status-quo option, are judged by applying the following criteria.

- Are all the requirements outlined in the assumptions met?
- Is it flexible; that is, does the option provide a flexible storage system which can be adapted for differing requirements from time to time while still preserving the principle of segregation based on isotopic and tritium content of heavy water?
- Is the additional storage defined by the option the minimum required to address the requirements?
- Are the functional requirements met for segregation of D2O based on:

    a) isotopic concentration –e.g. reactor grade vs downgraded.
    b) tritium content – Low tritium for PHT make-up vs high tritium for moderator.
    c) system chemistry – for example, lithiated PHT D2O cannot be sent to the moderator system since this would pose a risk of Gd precipitation.

- Are impacts to operations during implementation minimized; that is, will it require a unit(s) shutdown?
- Are OPG operational and design philosophies maintained (segregation, ALARA, etc.)?
- Is it the most cost efficient?
- Are there impediments preventing implementation?
- Do the risks and cons exceed the benefits and pros?
- Does it meet the physical constraints of the sites?
- Does it allow for easy tie-ins to existing heavy water and supporting systems (i.e. consider the ease of connecting to existing services or use of existing services).

The developed options are further scrutinized in order to select a preferred option. The preferred option for DND and PND is judged on:

- Is it the benefit maximized for the cost expended?
- Based on the operational life of the station is there sufficient time for cost recovery?
- Are the risks associated with the preferred option less than the other options?
- Do the pros of the preferred option outweigh the cons?

8.1. Heavy Water Storage Options at DND

Within this section the heavy water storage and drum handling options for DND are presented and discussed. The heavy water storage and drum issues at DND reviewed in Section 7 involved three systems; Storage and Inventory (reactor grade water), Ion Exchange Clean-Up (downgraded water recovery and Upgrading) and the Tritium Removal Facility (detritiation of OPG reactor grade water). All three systems are housed in the Heavy Water Management Building at Darlington. The previous section examined the issues and demonstrated that increasing storage capacity for heavy water will benefit Darlington and OPG. The vision of a drumless Darlington station has not been the case and will not be the case so physical space is required to meet the needs of handling drums.

Two options have been identified for Darlington; one, maintain the status quo and two, meet all the requirements of the three systems identified above. Option two, requires a building addition to the existing Heavy Water Management Building to house 400 m^3 of additional heavy water storage.

Other possibilities were examined in which additional heavy water storage could be provided within the existing station structures bypassing the need for a building extension. Once a building extension or new building is required, the incremental costs associated with the heavy water tanks are minor and the various options of providing additional storage for only one or two systems were deemed unnecessary.

Prior to presenting the two viable options a discussion ensues as to how space available within the pre-existing structures was deemed inadequate for meeting the needs of additional heavy water storage defined in previous sections of this report. This is followed by presentation of the two options where the various pros, cons and risks are identified and a recommendation is made to proceed with one of the options.

Provision of Additional Storage at each Unit and in the Off Gas Management System Room

Basis: ***Provide one 50 m^3 tank located at each Reactor Unit (provide 4x50 m^3 tanks in total) supplemented by additional storage in the Off Gas Management Room***

Following a walkdown, it has been noted that there is space available at each Unit to install a 50 m^3 tank. This would enable inventory of PHT water to be stored close to the Units and thereby meet the requirements of shrink and swell of the PHT system during cool down and heating up. This will also resolve the issue of increasing the transfer rate of PHT D_2O from the HWMB to the Unit (a project to implement this is being considered).

Addition of storage at the Units will free up approx. 200 m^3 of available space in the PHT S&I tanks to be used for other purposes. *However, the existing PHT tanks, 0-38110-TK7 to 0-38110-TK10 are built to ASME Section VIII (CSA Class 6).* Therefore, these tanks cannot be used to store moderator drains or high-Ci Upgrader product. They can only be used for storing low-Ci Upgrader product and TRF Product.

The 4 new storage tanks at the Units would be connected to the inter-unit reactor grade header and would be dedicated to storing PHT water alone *(see Assumption 20: the system will maintain the current mode of operation)*. Therefore, there is no flexibility in usage of the additional tanks in this design. In addition, installation of these tanks could only be performed during unit outages and would present a risk of outage extension.

In conclusion, additional tanks at each Unit would not meet the additional storage requirements.

Basis: **Locate Additional Tanks in the Off Gas Management System (OGMS) Room**

This site has the advantage that all services are currently available in this Room, and the floor drains in the Room are also connected to the D_2O Collection System. Furthermore, the walls of the room are adjacent to the S&I tank room and appear to be seismically qualified, at least on one side. However, the OGMS Room currently contains 4 large, vertical Carbon Steel Tanks (<. 2m diameter) containing activated charcoal. The Off Gas Management System (OGMS) equipment contained in the HWMB is no longer required and is intended to be permanently removed from service and declared redundant. These tanks would have to be dismantled, removed and sent to the Bruce Waste Management Site or scrapped for disposal, if they are contamination free, in order to free up space for the new tanks. The dismantling and disposal of the existing tanks from within the HWMB has never been attempted previously. The risks associated with such an activity are presently unknown.

This option is judged to be not feasible for the following reasons:

- This room is approx 7m x 16m and is only accessible via a stairwell and through a small hatch (2.2m x 2m) in the ceiling (94m El). To access this hatch would require removing a section of concrete floor from the 100m El and removing the steel ceiling and I-beams below this floor.

- A seismically qualified pit would need to be constructed in this room [9], further reducing the available space. Seismically qualifying the room, located in the middle of the HWMB, is not feasible because it would require re-evaluation and assessment of the foundation design, reinforcement to current standards where required and construction of a seismic pit.

- Most importantly, the OGMS room could only accommodate a 100 m^3 tank or about 8 x 20 m^3 tanks. These tanks are too large to be moved into the OGMS room through the access hatch. The tank sections would have to be prefabricated then welded piece by piece in-situ. Such a fabrication and testing process is not permitted as per the requirements of the ASME Section III code.

- Moving tanks in and out of this room would cause a significant disruption to ongoing operations and would essentially make the truck loading bay at El 100m inaccessible for about 6 months.

- If prefabricated and assembled tanks are to be moved into this room, then they would be restricted to about 1.6 m diameter and a capacity of about 10 m^3 per tank. At the most, 8-10 tanks could be moved into place in this room, i.e. a maximum of 100 m^3 capacity would be provided.

Hence, the provision of additional bulk storage in the OGMS room is judged to be not a viable option leaving only the possibility of installing 4 x 50 m^3 tanks in the Units. This leaves the following requirements unmet because of lack of flexibility in this design:

Capacity m^3	**Purpose**
2 x 50 m^3	TRF Feed Tank/Moderator Drain Tank
2 x 50 m^3	Downgraded Dirty Tank/Drum Emptying Tank
2 x 50 m^3	Downgraded Clean Tanks

Also, the requirement for additional storage area for drums is not addressed .

On this basis, locating additional heavy water storage or space for drums in pre-existing structures is deemed inadequate and options arising from this are not developed further.

8.1.1. Option 1:Maintain Status Quo

This is the “Do Nothing” option. Therefore, in this option, Darlington will carry on with “business as usual” and undertake contingency measures during planned or forced outages, such as those taken in the past to resolve the shortage of storage (for example, during the 2003 SCO). In order to avoid implementing similar contingency measures during the 2009 SCO, the implementation schedule outlined in this report would have to be fast tracked by OPG to place early orders for long lead items, obtaining quick project approval and starting detailed design quickly.

- ***Pros***

The obvious advantage of adopting this course of action for the future is that there are no incremental expenditures of capital involved and no implementation required, that is, continue operating in the same manner

- ***Cons***

The cons or negatives have been identified and discussed in the previous sections 7.1.2 and 7.1.3 and are only summarized here.

- Cannot support a moderator drain without associated cost of using DIOTS or offsite storage
- Cannot support SCO/VBO w/LLD
- Risk of downgrading moderator grade D2O
- Lack of flexibility and storage in the event of an unplanned outage
- Difficulty in dealing with high TOC events
- Increased planning and scheduling for water movement
- Inefficient use of Operators to move drums
- Inadequate space for storing drums
- Inefficient use of the TRF
- Inability to meet contractual detritiation obligations
- Continue to send drums off site for pressure testing
- Limited ability to pursue potential external sales

- ***Risks***

The risks to DND and OPG by maintaining the status quo at DND are associated with the Cons listed above.

- Risk of lack of available offsite storage
- Risk of outage extension during SCO/VBO
- Increased risk of downgrading D2O
- No flexibility in the system to deal with risk of upsets during an outage
- Drum storage issues getting worse due to increased drumming at the station
- Increase risk of health and safety issues related to drum handling
- Costs incurred to borrow Low Ci D2O
- Continued increase in OPG tritium concentrations possibly exceeding OP&P limits

The estimated cost to DND of maintaining the status quo is $1.46 million/yr together with the risk of losing up to $10 million/yr of external business, see Table 5 and section 7.1.2.

8.2. Option 2 Additional Storage in an extension to the Heavy Water Management Building – PREFERRED OPTION

The study recommends this option for DND as it meets all the requirements identified by the Project, provides flexibility and will lead to improved efficiency. The option is to build a 12x12m^2 extension to the West end of the HWMB to house four 100 Mg, class 3 tanks and 12x14 m^2 of space to house drums and a drum pressure testing facility. Each 100 Mg tank is to be subdivided

into two internal compartments of 50 Mg capacity each. Drum cleaning services is recommended to be performed by PND, see section discussing PND options and section 8.5.

Each 100 m^3 capacity double-tank is 4.25 m in diameter and 8.5 m long. Therefore, a total of 8 x 50 m^3 is provided to be allocated as follows:

Table 9. Recommended additional heavy water storage capacity at DND

Tag No.	Capacity m^3	Purpose
TK1-A,B	2 x 50	TRF Feed Tank/Moderator Drain Tank
TK2-A,B	2 x 50	TRF Product Tank/Upgrader Product tank
TK3-A,B	2 x 50	Downgraded Dirty Tank/Drum Emptying Tank
TK4-A,B	2 x 50	Downgraded Clean Tanks

The recommended additional storage provides a flexible design which meets the functional requirements of HW storage as well as maintaining the required segregation in terms of isotopic, chemistry and tritium concentration.

The additional reactor grade storage tanks, TK1-A,B and TK2-A,B will provide storage for a total of 220 Mg of D_2O due to the specific gravity of heavy water. In addition, all of the tanks will be provided with a volumetric design margin of 10% so that they are only filled to a nominal 90% of capacity.

A summary of the existing and proposed additional storage capacity is shown in Tables 9 and 10 below:

Table 10. Existing and Proposed Additional Reactor Grade Storage Capacity at DND

Existing Reactor Grade D_2O Storage Tanks		***Proposed Additional Reactor Grade Storage***	
Purpose	**Capacity: m^3**	**Purpose**	**Capacity: m^3**
PHT S&I tanks	4x100	TRF Feed Tank/Moderator Drain Tank, TK1-A,B	2 x 50
PHT Weigh Tank	1x30	TRF Product Tank/ Upgrader Product tank, TK2-A,B	2 x 50
Moderator S&I Tanks	3x100		
Moderator Storage	1x47		
Moderator Weigh Tank	1x10		
Upgrader Product Tank	2x12		
Upgrader On-Line Feed Tk	1x9		
TRF Feed Day Tanks	2x10		
TRF Product Day Tanks	2x10		
TRF Product Return Tanks	2x25		
TRF External Feed Tank	1x57		

TK1-A,B and TK2-A,B are provided for storing reactor grade D_2O while TK3-A,B and TK4-A,B are allocated to storing downgraded D_2O.

For TK1 and TK2, the full 100 m^3 capacity is available to be used for either assigned duty if required, e.g. for TK1-A,B, 100 m^3 could be made available for moderator drains or could be scheduled to store external TRF feed during normal operation of the Station .

TK2-A,B during normal operation would allow for the segregation of reactor grade TRF product and Upgrader Product based on tritium concentration, hence allowing TRF product to be sent to the PHT system and the Upgrader product to be sent to the Moderator system. During an outage requiring a PHT drain, these tanks could be utilized for storing up to 100 m^3 of PHT water temporarily.

Table 11. Existing and Proposed Additional Downgraded D2O Storage Capacity at DND

Existing Downgraded D_2O Storage Tanks		***Proposed Additional Downgraded D_2O Storage Tanks***	
Purpose	**Capacity: m^3**	**Purpose**	**Capacity: m^3**
Downgraded Dirty Tanks	2x25	Downgraded Dirty Tanks, TK3-A,B	2 x 50
Downgraded Clean Tanks	2x50	Downgraded Clean Tanks/ Downgraded D_2O from Emptied Drums, TK4-A,B	2 x 50

TK3-A,B and TK4-A,B arrangement allows for segregation of downgraded dirty and clean D_2O based on tritium concentrations. In addition, TK3-A,B can also be used to store the contents of drums which may be emptied into either tank based on tritium content. If the drums are known to contain clean D_2O, then they could be emptied into TK4-A,B. In the proposed design, there is more Clean Downgraded Tank Capacity than Dirty Downgraded Tank Capacity. The reason for this is that during a TRF or Upgrader Outage, we need to store some or all of the recoveries. During this time, the IXCU can keep operating to produce clean downgraded water stored and ready for processing once the Outage is completed.

Appendix D demonstrates how the additional tankage can be utilized during the following scenarios: 18 month TRF outage, SCO and outage with moderator and PHT drain. In particular, during an 18 month TRF outage the additional tankage will reduce the number of flushes required after high Curie downgraded water processing resulting in ~120 Mg less of mixed Curie water generation with an equivalent reduction in the amount of PHT ready water required prior to the outage.

The primary functional interface requirements are:

To receive D_2O from and supply D_2O to the following systems:

(1) D_2O Upgrader (38430)
(2) D_2O Clean-up System
(3) D_2O Collection System
(4) Moderator System (32100)
(5) PHT System
(6) Tritium Removal Facility (39000)

Seismic Qualification Requirements

The level of seismic qualification required for the additional storage will only be finalized once the CNSC classification approval process is completed. This approval is usually sought during the detailed design phase.

For the existing systems, most of the storage tanks are in a tank pit that is seismically qualified to contain a spill following an earthquake. It is very likely that the same level of requirement will be imposed for equipment that performs a similar, but increased capacity, function. It is reasonable to expect that either the new equipment will itself need to be seismically qualified or a similar alternative pit type arrangement will need to be provided. Currently, the pit housing the S&I tanks is qualified to DBE category 'A', which means that it will not incur increased leakage during and following a seismic event. The piping in the D_2O management building is not seismically qualified. The additional storage recommended for this study will be assumed to have the same seismic requirements [9].

S&I Tank Requirements

- All storage tanks added must have level instrumentation that displays on the HWMB Control Computer System
- All existing S& I level and weight instrumentation should also be displayed on the HWMB Control Computer System
- The building that houses this facility must tie-in to the existing HWMB D_2O liquid recovery system or have its own liquid recovery system.
- The building that houses this facility must tie-in to the existing HWMB D_2O ventilation system or have its own ventilation system.
- The storage tanks added must tie-in to the existing HWMB D_2O vent and cover gas system or have its own D_2O vent and cover gas system.
- An equipment vent dryer is required if the facility is to be housed in a new building.
- Tritium monitors are required to be located strategically in the building.
- New PHT S&I transfer pumps are to be installed with a design flow rate of 8 l/s and the same head capacity requirements as the existing units
- The storage tanks will have associated valves and pumps to transfer D_2O as required to their respective tie-in systems. Capability to transfer water from existing tanks to the new storage tanks and from the new storage tanks to existing tanks is required.
- The existing pit where the D_2O S&I storage tanks are housed is seismically qualified. Consideration of seismic qualification requirements for the additional storage area is required, since some of the new tanks will be used for storage of high tritium D_2O.
- A radiological dose assessment will be required to cover loss of the complete inventory of these tanks, similar to what was completed as part of the original design of the D_2O S&I system.

- ***Pros***

The pros of moving forward with this option are:

- Supports Moderator drains and eliminates the need for off-site shipments during planned moderator drains
- Avoids Outage extension due to limited PHT storage capability
- Creates the flexibility and storage requirements to meet the requirements of an unplanned outage and operational upsets during an outage
- Able to support VBO/SCO with LLD
- Provides sufficient downgraded storage to minimize the risk of downgrading D2O
- Avoids increasing PHT tritium concentration by being able to segregate PHT and moderator recoveries during extended TRF outages.
- Minimize the risk of having to borrow Low Curie D2O

- Improves the storage capacity available to manage an acute leak event resulting in high recovery rates for a short period
- Improves ability to empty drums from outside customers quicker so drums can be returned sooner and more space available for more drum shipments
- Ability to pressure test drums in house on as needed basis
- Minimize health and safety issues related to drum handling
- Improve operator efficiencies
- Increases flexibility in the TRF to:
    - Help meet contractual detritiation obligations
    - Allows Isotope Sales to pursue new business opportunities
    - Increase the efficiency of the TRF
    - Allow OPG to meet tritium concentration OP&P limits
- Permit cost recovery through increased D2O external services
- Additional storage space can provide some relief for PND during its outages mitigating some of the storage issues at PND, see section 8.5

- ***Cons***

- There is a significant capital expenditure of $27 million, see section 9
- It is estimated to require 4 years to install and commission

- ***Risks***

- *Failure to recover cost of investment* - The benefits from execution of this project are made up of some items where the benefits are quantifiable and also other items where the benefits are more intangible. For example, there will be operational improvements and increased efficiencies as a result of installing additional storage. The con of investing about $27 million in additional storage facilities can be weighed against the potential revenue from improved external sales alone. This indicates a payback period of about 3 years, which is favourable. Therefore, the risk of the additional sales benefits not materializing should be evaluated.

- *Higher costs due to discovery work during detailed design* - This risk has been mitigated by including a 25% contingency in the overall estimate. However, there still remains a risk that some discovery work during detailed design or execution of the project will result in an increase in the estimated cost.

- *Unreliable TRF* - The rate of return on investment through external sales is dependent on the TRF operating reliability as per the operational plan. Although increased heavy water storage will mitigate the effects of an unreliable TRF, a period of reliable TRF operations is required once the extra storage is in place in order to create the necessary low Curie heavy water buffers.

- *During construction and commissioning there is a potential to disrupt HWMB operations.*

In summary, provision of additional reactor grade storage will:

- *Eliminate the need to ship 100 Mg or more of reactor grade water off-site for temporary storage during a complete Moderator drain and prevent potential cross contamination and mixing of Moderator and PHT grade water*

- *Provide additional storage capacity for TRF feed and product to support OPG detritiation needs*

- *Provide additional storage capacity for TRF product with potential for significant financial benefits due to improved sales of detritiation services and avoiding the need to borrow or lease PHT make-up water from external sources. With the additional flexibility created by adding storage volumes, revenues have the potential to increase by $7-8 million. Therefore, there is potential net achievable benefit of $10 million.*

- *Provide additional storage capacity for TRF feed and product with the potential to mitigate the reactor grade storage requirements at PND during its outages.*

Provision of additional downgraded storage will:

- *Eliminate the need to store downgraded water in reactor grade storage tanks and thereby eliminate the possibility of extensive downgrading of reactor-grade water due to cross-mixing, thus allowing isotopics to improve by better utilization of the Upgrader*

- *Improve the capability for segregation, produce less mixed-Ci water and reduce the need for storage by more than 100 Mg during an extended TRF Outage*

- *Improve the Upgrader capacity factor by allowing for recirculation through the D_2O Clean Up System while still maintaining capability to feed the Upgrader*

The additional drum storage space provided in Darlington will improve efficiency and safety. An on-site pressure testing facility will improve the ability to ship drums off-site.

8.2.1. Possible Locations of Additional Storage

The above arrangement is expected to provide the required flexibility while reducing costs compared to dedicating 750 m^3 of additional storage to specific duties as recommended in the previous report[4].

There are various sites for locating the additional tanks in the vicinity of the HWMB

Location A: New Extension to the Heavy Water Management Building (HWMB) – preferred location

An extension to the HWMB would be constructed to the west of this building. This will be an industrial building with approximate floor area of 12m by 26m, see Appendix F for sketches of the proposed extension building extension.

The design of the building will be such that ISO Container and drum unloading will be on the ground floor so that trucks could park by the loading door.

The required area for building extension shall include the dismantling of the existing truck loading bay and its loading deck/receiving area housing/office. The loading bay would be filled in and leveled. A new truck receiving door shall be built on the receiving bay. Also the docking/receiving/drums loading bay shall be provided with a ramp to allow a forklift to access the truck and lift out a palleted drum from an opened ISGHWP container.

During construction of the HWMB extension, the existing loading dock would be unavailable for receiving ISO containers and unloading of drums from ISGHWP customers. During this period, it

is recommended that as a temporary measure, ISO container unloading should be performed in the TDO loading/unloading bay. This would need to be scheduled and planned so that it does not interfere with the arrival of TDO shipments.

The building height on the receiving/drum loading areas shall be restricted a few feet below the fresh air intake louver (107.8m El.) on the adjacent building, but beyond the louver, the building height shall be constructed to house the tall vertical tanks.

The existing S&I tanks in the HWMB are currently below grade and are gravity fed from the Units, due to design constraints. If new tanks are built above the ground, the ability to pump D_2O from the station to the new tanks would need to be confirmed.

The bottom section of the proposed HWMB extension would form a seismically qualified, leak tight enclosure, constructed from reinforced concrete of the appropriate thickness. This is intended to contain the entire inventory of the storage tanks in case the tanks were to rupture and release their contents into the building. It is expected that this seismically qualified section would be approximately 12m by 12m by about 4-6 m high. The pumps associated with these storage tanks would be located outside of this area, in an adjacent, existing room of the HWMB to make maintenance access easier and to prevent submersion in the event of loss of D2O containment.

It has been determined that no building can be within 9m of the fuel oil tanks for the Auxiliary Steam Generators which are located to the west of the HWMB [10]. The current proposal for the HWMB extension is located approx 24m from the fuel tanks so this will not be an issue

Construction Issues

There are existing services buried underground in the area where the HWMB extension is proposed. A walkdown was conducted and the following are the preliminary findings.

There are buried services which would add to the construction costs. Concerns are regarding a helium supply line, pressure switch indication cable to the helium supply tank, fire lines, storm sewer lines, roof drains, buried electrical cables to supply the temporary trailers across the road, and station ground cables.

An existing storm drain running down the middle of the proposed extension site would have to be re-routed. There are electrical power lines running west of the HWMB to the trailers. These would also need to be re-routed.

The details of these services are found in drawing NK38-D1H-10249-1343 which indicates the specific helium piping, fire lines, roof drains, and storm sewer lines. If further digging was required, there are buried lines under the middle of the road for steam, condensate return, air, and water that need to be addressed.

Detail of Helium Supply can be shown on drawings:
NK38-D1S-57500-0030
NK38-D1S-67554-0001
NK38-D2S-67554-5002

Standby Generator Equipment does not appear to be a problem but the following drawings show the service locations:
NK38-D0S-57500-0018 cable duct to storage tanks
NK38-D0S-57500-0004 tunnels servicing SG's 1&2
NK38-D1H-10249-1342 SG oil storage tank oil and fire water lines

Station Grounding

NK38-D0S-57684-0002 D_2O Bld 87 el
NK38-D0S-57684-0004 D_2O Bld 100 el
NK38-D0S-57600-0002 site layout

Telephone
NK38-D5F-57304-0265 site layout shows no trunk cables but the walk down observed a phone on the wall of the loading dock building and lines buried under the road to service the temporary trailers.

Lighting
NK38-D0S-56102-0051 street lights with wiring across the road so it is not a problem
NK38-D0S-56184-0003 el 100 lighting for inside and outside D_2O management Bld

Truck Ramp Snow Melting
NK38-D0S-56384-0001 heating cable layout
NK38-D2S-53348-0001 600 volt panel

Temporary Trailer Wiring

This would likely require a more detailed field walk down to determine the location of telephone wiring. However, at this time it was observed from the previous walk down that there are 5 conduits trenched under the road to service the temporary trailers fed from the D_2O management building. The conduits would contain electrical power, LAN connection, and telephone.

Pros

There are many advantages to Location A, which will make it the lowest cost location of all that are considered here. Besides being the lowest cost feasible option, it has also operational advantages being in the vicinity of the HWMB. For example, services for the extension can also be extended from the existing services in the HWMB, particularly for D_2O Collection, ventilation, stack monitoring, etc. Personnel working in the HWMB will find it easy and efficient to carry out required duties in the extension. Movement of heavy water will require minimal holdup in piping, and the philosophy of centralized Heavy Water Management will be maintained. Overall, this is judged to be the most effective location for the additional storage to be provided at Darlington.

Cons

The available space is constrained by the roadway to the west and the HWMB to the East. However, it has been demonstrated that the requirements for additional Heavy Water storage can be met in this location, both for ongoing operational needs but also for the SCO, VBO outages, for an 18 month TRF outage and for an 8 week Upgrader outage. The requirements imposed by life extension or retubing of the reactors are not part of the Scope of this study. However, their impact is being considered below and a means of accommodating these requirements is discussed.

Location B: Locate Tanks in a New Building east of Unit 4

In this site, a new building would be constructed east of Unit 4 to house the additional storage tanks as well as to provide a drum unloading and storage facility for drums received by ISG from offshore.

Tie-ins from this building would be provided to the inter-unit reactor grade D_2O header. The use of the existing header would avoid the installation of additional piping to cover the large distance from this location to the HWMB. Similarly, there is a downgraded header which could be utilized for transporting downgraded water to the HWMB.

Pros

An advantage of this location is that there will be room to expand easily to take care of future needs for storage, e.g. for re-tubing. The space is not as restricted as in the other two options. It is also possible that at this new location, fewer services are buried underground than in the proposed Location A near the HWMB.

Cons

There are many significant disadvantages to this location rendering it undesirable, both for supporting ongoing HWMB operations and for future life extension needs. Stored D_2O transported in the headers crossing all 4 Units make the Units more vulnerable to an operator error leading to downgrading or cross-contamination. Such a possibility is eliminated if the storage is located next to the HWMB. To avoid cross-contamination, four new headers, running the length of the 4 Units may be needed. This would add significantly to project costs.

In addition, it would not be feasible to provide additional feed storage to the IXCU from this location. To facilitate recycling when required, these storage tanks should be close to the IXCU (this is required as per Assumption 15). The amount of holdup in the piping makes recycling from the IXCU impractical. Larger feed tanks for the TRF should also be located close to the TRF ideally, in order to avoid dilution of the feed tritium concentration via the reactor-grade headers.

Services provided in the HWMB – e.g. ventilation, stack monitoring etc cannot be shared increasing the cost of the new building as compared to the HWMB extension.

The large distance from the HWMB will also consume more operator time in traveling back and forth when required consuming additional human resources.

It is not clear whether all of the various grades of D_2O could be transported economically from east of the reactor building to the HWMB. For example, D_2O received from off-shore by ISGHWP, may be at a lower concentration than the PHT or Moderator D_2O at Darlington. Thus it could not be transferred via the reactor grade header and may be too high in concentration to transport via the downgraded header. Hence, segregation of D_2O would be compromised by this location. Downgrading of reactor grade water is not an option. An alternative is to build a new header crossing all 4 units. Retrofitting of this header with its supports is expected to be very expensive and disruptive. Seismic qualification of the piping will likely be a requirement.

Therefore, the study concludes that the new extension to the HWMB, Location A, represents a more economical and less disruptive option.

8.3. Consideration of Reactor Life Extension or Reactor Re-tubing

Although consideration of Life Extension of DND units is not within the scope of this study, it is anticipated that the Government of Ontario may make a decision on refurbishment of existing reactors within the lifetime of this project. This could result in a quick change of direction for this project. Therefore, the impacts of life extension have been considered here and a possible location of the additional storage that would be required has been identified.

During the re-tubing of a Unit, it is expected that the Moderator and PHT will need to be drained, causing an additional storage need for 750 m^3 of heavy water over and above the requirements outlined in this study. The current footprint available for the HWMB extension is constrained. There are two options for accommodating the 750 m^3 of heavy water storage required for re-tubing of a reactor:

- Design and build the HWMB extension with a lower basement level approximately 9 m below grade. This additional level will then be designed to house tanks capable of storing 750 m^3 of heavy water, say in 4 tanks of 200 m^3 each. It is more cost effective to plan and include the space requirements for the storage needs associated with Life Extension during the implementation of the present project. This would require a space approximately 29m long, 10m wide and 10m deep. This is proposed to be located below grade, directly below the proposed HWMB extension. In order to enable access to the underground space for future installation of tanks, a removable 6.5m by 6.5m hatch should be considered in the design, to be provided at ground level in front of the drum handling area. However, it is anticipated that modifying the scope of the current project to accommodate life extension requirements may complicate and possibly delay the approvals process for the project.

- Build the future storage tanks for life extension of DNGS directly to the South of the proposed extension to the HWMB. This would require the relocation of some existing gas services being supplied from this area (liquid nitrogen, helium). The tanks would be located 3-4 m below ground level, so that a seismically qualified pit would be available to contain the contents of the tanks in case of a leak.

At this time, a cost estimate of the full basement is out of the scope of this study. However, any future assessment of utilizing the proposed site to accommodate life extension must consider the following issues:

- The possibility of being below the water table and the need to address waterproofing .
- The construction of a reinforced concrete pit may become more complicated and more costly.
- The need to conduct soil characterization. The nature of the soil can significantly impact excavation machine requirements and progress.
- Potential soil contamination (radionuclides, chemicals, metals) requiring the soil to be shipped off-site at a significant cost. This issue cannot be addressed until soil characterization is completed.
- How far away from the existing wall foundation can the pit be built without affecting the soundness of the existing building structures and wall footing clearance? This requires the assessment of a civil engineer.

8.4. Heavy Water Storage Options at PND

PND issues involve two of the HW systems, Clean up (IXCU) and 'Storage and Inventory'. Although the issues with drums fall under the IXCU it also can stand on its own. Various storage options present themselves for PND but only one addresses all the requirements defined by the assumptions. A significant factor in the assessments of options for PND is the remaining lifetime of the PND-B units that are scheduled to begin shutdown as early as 2014 and end by 2016. Any defined option has to be balanced out by the anticipated date of implementation, the estimated cost, the potential savings to PND within the remaining lifetime of PND-B or the potential risks associated with not implementing the recommended option. The announcement made by the provincial government, near the end of this study, that life extension at PND is under consideration may alter the considerations given to the recommendation made.

8.4.1. Option 1 – Maintain Status Quo

With this option business as usual continues. In this option all the deficiencies in the heavy water management system are known and Common Services will continue to find ways to work around them, as they have so far. There will continue to be cost penalties associated with this option some quantifiable and others not. The quantifiable costs resulting from the system deficiencies have been previously discussed.

- ***Pros***

With this course of action there are no additional expenditures of capital or resources.

- ***Cons***

All shortcomings covered previously in this report will continue with potential to further aggravate the situation:

- Little tolerance at PND to deal with erratic TRF performance which impacted its detritiation performance.
- The moderator tritium concentrations will, most likely, continue to be above target resulting in higher tritium emissions to the environment and higher worker dose.
- The system isotopics will, most likely, continue to be low resulting in larger fuel burn-up.
- Limited flexibility in dealing with competing heavy water requirements negatively impacting the segregation philosophy for different quality waters.
- Overlapping Moderator drain (PND-B) and PHT VLLDS, regardless of the length of the outage, cannot be accommodated without operator work-arounds and the shipment of heavy water offsite.
- Drum numbers at PND will continue to climb further clogging station real estate and increasing the risk to health and safety of workers.
- Large number of drums will continue to attract CNSC attention with potential direct impact to operations.
- The ability to segregate oily downgraded water from non-oily downgraded water will continue to be limited, defeating the efforts of the present campaign to clean up IXCU feed tanks of oil.

- Clean up system throughput, expected to go up when the oily feed tanks are cleaned, will again become contaminated reducing IXCU processing throughput.
- Upgrader performance, particularly UPPB, will continue to degrade.

- ***Risks***

The risks associated with this option are:

- Use of non-standard procedures (work-arounds) to maneuver existing S&I inventories to accommodate a simultaneous moderator drain and VLLDS from a single unit can increase PND operational risks such as:
  - Outage duration can be extended by at least the number of days overlapped between moderator drain and PHT VLLDS, if an alternate mitigating method is not found or acceptable. The cost penalty of an outage delay can be as high as $1M/day per unit;
  - Possibility in downgrading valuable TRF product by mixing with lower grade PHT product or Sulzer product.
  - Possibility that there is no available direct storage for one or both upgraders' product, and will have to resort to using drums or placing upgraders into reflux. This can increase labour costs, negatively impact housekeeping worker safety and ALARA.
- Use of non-standard procedures to deal with the limited flexibility in the S&I system may lead to outage delays ($1M/day) or downgrading of TRF or UPPB product.
- Tritium concentration OP&P limits for the moderator may be exceeded.
- Degradation of the Upgraders, to the point they can no longer meet operational requirements – potential cost in the millions of dollars to address shortcomings [Appendix Q, 54].
- Further overtaxing of the IXCU to the point that:
  - Drums become an unmanageable problem
  - Operational demands for upgraded clean water not met without external heavy water

The estimated cost to PND of maintaining the status quo is $0.72 million/yr, see Table 8, section 7.4. This cost excludes the potential millions of dollars per year costs that is anticipated due to the continued degradation of the UPPB Upgrader.

Based on the potential costs associated with the major risks this course of action is not recommended.

8.4.2. Option 2 – Increased S&I storage, increased IXCU storage and Drum Facility –

This option addresses all the requirements defined by the PND Assumptions. The requirements are driven by deficiencies in three areas: drum handling, clean up system and the Storage & Inventory system. How the option addresses the three areas is discussed. The Pros and Cons, benefits and risks of implementing the option are presented. Appendix C – Rationalization for Storage Options at PND demonstrates how the recommended storage capacity increase addresses the needs defined by the PND Assumptions.

- ***Drum Cleaning Facility***

This option provides PND with a much needed drum cleaning facility. The recommendation is for this drum cleaning facility to service both PND and DND as Darlington's drum needs are one-tenth that of PND [PND Assumption 5 and DND Assumption 3].

Appendix E summarizes the nature of dirty drums and the different levels of cleanliness of drums required by the intended end use. A drum cleaning facility can be purchased as a complete automated unit from a drum cleaning equipment supplier. The general features of a drum cleaning facility for PND are similar as that supplied by the equipment supplier, what varies maybe the nature of the cleaning solution. The minimum cleaning approach would be to use pressurized hot water or steam.

An example of drum cleaning equipment is Model DW55 from Drumbeaters of America; it has the capability to process 30 drums/day. The facility can be self-enclosed and ventilated, eliminating the need for a separate fumehood. In removing the drum bungs in preparation for cleaning a separate, articulated, trunk line can be made available as local ventilation.

The recommended location for a drum cleaning facility is at elevation 254' in the Service Area. The location is presently identified as the 'Liquid Radioactive Waste Facility' in drawing NK30-DFA-24000-0003-R19. In the aforementioned drawing the location is defined by Lines 189 and 191 and Rows O and Qy; see Appendix G – Proposed Location of Drum Cleaning Facility. The area has sufficient space to accommodate the number of drums to be processed that day plus the previous day's cleaned drum allotment.

The proposed location for the drum cleaning facility is next to D2O drum storage facilitating the movement of drums to and from the cleaning facility. Additionally, for drums requiring disposal the facility is close to the solid waste handling area. Also, the location has many of the required services (power, instrument air, active drain liquid drain).

- ***Increased Storage at IXCU***

Table 12 captures the proposed increase in storage capacity at IXCU. The largest change is in the storage capacity for oily downgraded water (low and high Curie) from the present two tanks of 2.3 m^3 for low and high Curie. This represents a significant increase but historical data supports the recommended change, see Appendix C. Additional storage capacity of 16 Mg is recommended for the low Curie and high Curie, oily, recovered water.

Table 12. Recommended Additional Storage Capacity at PND IXCU

Purpose	Capacity (Mg)
Low-Ci, oily, water	16
Low-Ci vapour recovery	46
High-Ci, oily, water	16
High-Ci vapour recovery	19

For non-oily, low Curie, downgraded water an additional 46 Mg of storage capacity is recommended. While 19 Mg of additional storage for the non-oily, high Curie, downgraded water is considered sufficient.

The proposed additional storage capacities are calculated quantities from the rates of downgraded water production. Appendix C presents the appropriate calculations substantiating

the recommended increases in storage proposed in Table 12. The recommended increase in storage capacity provides contingency for acute recovery rates. A preliminary review of architectural drawings indicates the 50 m^3 tank proposed by ECN 963 may not fit through the corridors and corners so a 46 Mg tank may also have difficulty fitting. ECN 963 was a previous engineering change package that proposed additional storage tanks for IXCU. Solutions to this potential dilemma are: using two smaller tanks (sitting vertically) with the same overall capacity, building the tank in-situ or scaling down the size requirements. As Appendix C illustrates the sizing of the tanks was driven by consistency in capacity among the various holding tanks and their ability to handle acute recovery events. An arbitrary period of 2 weeks of holding capacity under acute conditions was chosen to allow flexibility in the system. This flexibility can be relaxed by 10% (~7 Mg) if needed in order to permit a tank in the proposed location.

The increased storage is proposed to be located in the area previously recommended by ECN 963. This area is next to IXCU at the 274' location in the Reactor Auxiliary Bay (RAB) east of Unit 1 in Pickering A. The closeness of the tanks to IXCU is a strong positive. Appendix H shows the proposed location of the additional tanks. The area is defined on drawing NA44-06-21002-00058 by lines H and O and rows 8 and 10.

The Pickering A RAB structure was assessed to be seismically adequate [22]. The impact of additional reinforcements required to deal with the extra weight of the tanks may require further seismic assessments resulting in extra costs. Detailed design will indicate the necessary reinforcements required.

Appendix M identifies potential installation risks in adding tanks to this area.

- ***Increased Storage at S&I***

The existing S&I storage capacity is

Table 13. Existing Reactor Grade D2O Storage at PND

Purpose	Capacity (m^3)
PHT	2x100
Moderator	2x150
UPPB upgrader (low-Ci) product	2x5.5
Sulzer upgrader (high-Ci) product	2x2.1
PIOTS receiving	1x29.8
PIOTS shipping	1x21.4
PIOTS surge	1x11.3

The total capacity of the system is 570 m^3.

The following additional storage capacity is proposed, see Table 14. It is recommended that two 100 Mg capacity, class 3, tanks be subdivided into 50 Mg capacity tanks and interconnected to the PHT and Moderator S&I tanks utilizing a double block and bleed arrangement. The double block and bleed arrangement will provide maximum flexibility in the utilization of the storage space while preventing cross-contamination. Appendix C demonstrates how the added tankage provides the flexibility needed at S&I to accommodate a simultaneous moderator and VLLDS PHT drain.

Table 14. Additional Tanks and Capacity for Reactor Grade D2O Storage at PND

Purpose	Capacity (Mg)
Moderator/PHT	2x50 (as one 100 Mg unit)
Moderator/PHT	2x50 (as one 100 Mg unit)

It is proposed to place the additional S&I tanks in room S668, located on elevation 277'-4" and currently containing obsolete HVAC equipment (reference drawing NK30-D5A-24000-0053). This is the recommended location for additional S&I tanks. The HVAC equipment enclosure is constructed on top of the Solid Waste Handling Facility. The facility was constructed to the following seismic requirement [20]:

"Except for the siding on the South side, the building structure does not need to be seismically qualified. The south wall siding shall be seismically qualified for design basis earthquake (DBE) [19]. The structure shall not produce negative impact on the seismic capability of the pressure relief duct (PRD)."

Appendix I is a sketch of the proposed additional S&I tank location within the HVAC room. This room has sufficient space to accommodate even more tanks. Presently the area is Zone 2. The equipment within the room is not commissioned and is expected to be non-radioactive. The equipment will require removal and scrapping. It is anticipated that after scanning for radioisotopes that it will be confirmed to be non-radioactive and can be disposed of to conventional land fill.

To facilitate the movement of the removed equipment and insertion of the S&I tanks removal of a portion of the 'seismic' south wall is envisioned. The south wall being an external wall facilitates removal of part of the wall. Reinforcement of the floor to accommodate the additional weight and meet seismic requirements is expected. Reinforcement of the floor is expected to be difficult due to the present floor having been built approximately 4 feet higher than the old roof; that is, there exist a crawl space of approximately 3 to 4 feet in height between the old roof and the new floor.

Any work performed in this location will require a Green person or rezoning during the course of construction.

<u>Optional Location for S&I tanks – UPPA</u>

The UPPA Upgrader is no longer in operation. All the equipment in the area except for certain piping and feed tanks is no longer in use. The area is defined in reference drawing NA44-EMG-34600-0004 by lines A to D and columns 1 to 4. Appendix J is a sketch of the proposed tank locations. The location could accommodate even more tanks if required.

The design manual [21] does not stipulate any seismic requirements. Also the building is not in the seismic success path evaluated in reference 22. Because S&I tanks are part of the D2O Safety System as described in the previous sections a seismically qualified dyke will be required to surround the tanks. Additional seismic assessments to be performed during the design phase are viewed as less onerous than for the Obsolete HVAC area because the tanks would be located on grade level. The appropriate seismic response spectra for this area are documented in references 22 and 23.

This location is a significantly distant from the present S&I tanks. Pipes connecting to the main heavy water S&I headers in the station will likely be required to be seismically qualified to DBE A. Flow diagram NK30 F0H 38210 0001 and Design Manual NK30-38210 for D2O Supply System indicate:

- The D2O supply system is seismically qualified for a DBE category A
- Seismic qualification DBE category A shown on equipment data sheets (tanks and relief valves) in the design manual.
- System Classification List for CNSC approval of Code Classification also shows system and tanks to seismic qualification DBE A

The location of the UPPA site versus present S&I tanks and the higher costs (~2.5 M$ versus HVAC room) associated with this option led to the HVAC room being chosen as the preferred location.

- ***Pros of Implementing PND Option 2***

Implementation of this option have the following pros:

Drums

- Reduction in the number of drums at PND
- Improved operations at IXCU by balancing the downgraded water creation rates, processing rates and feed storage,
- Reduction in the number of drums purchase,
- Freeing up of station floor station presently occupied by drums
- Ability to adhere to segregation philosophy for different quality waters
- Clean drums available to deal with acute recovery events or to temporarily store reactor grade water

IXCU Storage

- Reduce the number of drums.
- Improve or slow down the rate of deterioration of the performance of the upgraders and this may benefit OPG in considering PND's life extension.
- Improve overall water management by allowing recovered water to return to the units within its normal cycle instead of storing in drums which make the inventory not readily available. This may also reduce or eliminate the need to purchase or borrow further water inventory to replenish water being stored in drums.
- IXCU will have the required flexibility to support various operational and outage scenarios, including acute recoveries.
- Permit segregation of the different qualities of downgraded water to be processed effectively.
- Handle the variation in downgraded heavy water production rates.
- Reduce the number of drums being recycled for collecting downgraded dirty water by allowing more drums to be emptied. Emptying more drums, cleaning them and recycling them quicker will reduce the total number of drums.
- Less drums will reduce dose to workers and the risk of injury to workers.

S&I

- Reduction in tritium concentration in moderators
- Increase in isotopics in moderators
- Detritiation of PND-B can easily be performed via bulk swap during a unit outage and moderator drain,
- Receive TRF product at any time,
- Ship heavy water to the TRF at any time,
- Enhancement of moderator isotopics,

- Accomodation for moderator drains and a VLLDS PHT drain from two units (Pickering A and Pickering B)
- Flexibility in storage system to handle unplanned events
- Permit the segregation of different quality waters
- Improve the ability to handle erratic TRF performance even 18 month outages

The proposed 50 Mg capacity tanks are the same capacity as the TRF's bottom product tanks. This similarity in tank capacities means that two of the four 50 Mg capacity tanks can be utilized as transitional tanks to support shipment between TRF and PND, thus, minimizing the risk of mixing other products from PND or of downgrading the received TRF products. The stored TRF product can be utilized to support PND detritiation program or even external sales.

- ***Cons of Implementing PND Option 2***

The maximum expenditure of capital, approximately $23 million, is with this option.

With an estimated end date for the execution of this option of late 2010 (see costing Section 9) and with the first PND Units reaching end of life 2014 (no life extension considered) there is a short time frame for a return on investment. Additionally, by the end of the estimated project completion date of late 2010, PND will have dealt with all the aforementioned shortcomings for most of its operational life. As the units are retired the demands on the heavy water management system, from an operational point of view, will decrease; however, they may be a need to hold the heavy water from the shut down units.

<u>Drums</u>

Additional resources will be required to operate the drum cleaning facility. Automated drum cleaners are available but still require drums be manually placed into the drum cleaner and then taken out. Day to day maintenance of the drum cleaning facility will be required (extraction of oil from collection tanks, filter changes, washing solution changes, movement of dirty drums in and clean drums out of drum cleaning facility. Shipping of dirty and clean drums between PND and DND will require resources for the physical shipment and for tracking. OPG finance suggests to cover the above a cost of $50/drum be utilized; thus, for 10 drums per day x 365 days = $182,500 (see Appendix Q).

There will be potential tritium emissions to the environment which will require managing.

A drum cleaning facility will require removal of pre-existing equipment. The cost for removal of the old equipment (estimated to be ~160 k$) is higher than the drum cleaning equipment (<100 k$). The emptied room will require: an exhaust line to a chiller or dryer because of the presence of tritiated water vapour, local monitoring due to the potentially high MPCa of tritium within the drums and a shower station.

<u>IXCU storage</u>

The negatives in increasing storage capacity for IXCU are:

- Costs to remove existing equipment (~840 k$)
- Seismic assessment required
- Reinforcement of pre-existing structures needed
- Significant capital expenditure (~11 M$)

S&I Storage

In order to increase the S&I storage significant capital expenditures have to be incurred (~13 M$). The costs will not only include equipment and materials but the need for structural reinforcements of existing structures. Major interruptions to the operations, such as, an outage of the generating units are not foreseen.

- ***Risks***

The single largest risk in implementing this option is financial, approximately $23 million, which isrecoverable if PND receives a life extension. Expenditures associated with adding a drum cleaning equipment and extra storage at IXCU has some strong quantifiable cost savings and will mitigate the major risk to the systems (Upgraders). The cost savings associated with dose and isotopics although significant may be achievable without increasing S&I tank capacity.

Drums

The manufacturer [28] assures that the typical dirty drums created at the station can be cleaned by their equipment with their recommended cleaning approach. However, given the additional considerations that dirty drums at the nuclear station present, such as, radionuclides, MISA and MOE discharge restrictions and active liquid drain constraints, the cleaning solution ultimately utilized may not be that recommended by the drum cleaning equipment manufacturer. The impact of this might be less than ideal drum cleaning or additional equipment to process the wash water (eg. reverse osmosis for salt removal).

To overcome this risk a staged approach is recommended. The first stage would involve quantitatively defining a typical dirty drum and creating surrogate dirty drums (no radionuclides). The surrogate dirty drums would be shipped to the drum cleaning equipment supplier for cleaning at their facility utilizing a variety of cleaning solutions. The information gained from the exercise would define the nature of the drum cleaning facility waste stream and the anticipated level of cleanliness achieved by the various cleaning solutions. This information supplemented by operational experience from the petrochemical, food and bio-medical industries would constitute stage two. In the third stage the information gained through stages 1 and 2 will be utilized by the design team to tailor fit a drum cleaning facility to meet the needs of the nuclear station. Failure to do this will increase the risk that any drum cleaning equipment purchased which satisfies the effluent discharge criteria might not effectively clean the drums.

Storage at IXCU and S&I

The recommended increase in S&I storage volume and the benefits gained from it are contingent on having an efficient, well-managed TDO transportation system. Detritiation of nuclear stations outside of DND is dependent on the shipments of TRF feed and product from DND via the TDO transportation system; it is critical that sufficient TDO packages, trailers and resources be available. A factor in the inability to detritiate PND-B has been resource issues with the TDO transportation packages; this should be examined. Once the buffer heavy water volumes of TRF product have been created the dependence on the TDO transportation and an unreliable TRF is reduced.

If segregation of the different qualities of water is not practiced then adding more storage to the feed tanks at IXCU will not change the present situation except to have more oily tanks. If IXCU encounters downgraded heavy water it cannot clean, the usage of drums to store this water is anticipated leading to similar problems faced today. The recommendation for no additional storage at IXCU with a drum cleaning facility is based on the fact that the majority of drums are

presently dirty. If no drum cleaning is available then the segregation of different water varieties will not be possible. The net effect of the inability to segregate would be to contaminate the new tanks returning the present situation but on a larger scale. Conversely, segregation could be practiced with additional storage by buying new drums further exacerbating the present drum problem.

There is a risk that improvements in the TOC contamination of the upgrader feed may not materialize even after having increased the storage capacity at IXCU.

Seismic assessment during design phase may identify the need for additional reinforcements and further costs.

The Engineering Design Guide [19] indicates the D2O Supply System (SCI 38200) has to be DBE "A" qualified. This means the D2O Supply System has to be seismically qualified to the extent that there will be no loss of inventory from the bulk storage tanks. Reinforcement of floors to support the additional weight of the tank and water will not be sufficient. A seismic assessment will be required to be performed during the design phase to insure the seismic integrity of the system. Although a seismically qualified dyke surrounding the D2O supply system would satisfy the requirement, the impact of surrounding structures on the integrity of the dyke during a seismic event will have to be examined. The impact of this might be additional costs above those discussed in the Costing Section.

8.4.3. Option 3 – Drum Facility with increased storage at IXCU – PREFERRED OPTION

The study does not recommend increased storage for S&I. The rationale for this has been presented in section 7.3. This option considers additional storage at IXCU and the addition of a drum cleaning facility (DCF).

- ***Pros and Cons of Implementing PND Option 3***

The Pros and Cons of a Drum Facility and increased IXCU have been presented in Option 2. *However, it is strongly recommended that no additional storage at IXCU be added unless a Drum Cleaning Facility is installed.* This recommendation is made for the following reasons:

- A lack of drum cleaning equipment will continue to lead to situations where oil contamination of "clean" water will occur increasing the risk of contaminating the increased IXCU storage capacity. This scenario returns PND to the present situation but with larger storage capacity.
- The issues with IXCU are storage and drum cleaning, they are intimately tied they should be addressed as such to maximize the benefits.

- ***Risks***

Outside of the risks outlined in Option 2 there is the financial risk of failing to recover the $12.7M expenditure.

8.4.4. Additional Considerations for dealing with Storage Requirements at PND

Although not part of the scope of this work the following options should be given consideration:

- Improvements to the PND Clean Up system,
- Use of the Heavy Water from PND-A laid-up Units 2 and 3.

This study examines adding extra storage capacity to address the issues in the Clean Up System. The recommended additional storage addresses the slower throughput of the Clean Up System due to the high levels of oil and volatile organics. It addresses this by balancing the storage capacity of the feed tanks with the present throughput of the system. Consideration should be given to improving the throughput capabilities of the IXCU. The cost of such an improvement may remove or significantly reduce the need for additional storage at IXCU while simultaneously improving the quality of the water fed to the Upgraders.

The heavy water (hundreds of Mg) removed from laid-up units 2 and 3 of PND-A is available for use. OPG should consider utilization of this inventory of heavy water. Usage of this water can benefit OPG in many ways:

- As feed for the TRF. If TRF is lacking product the heavy water can be shipped to TRF for detritiation and the product returned to the same tanks.
- As a huge reservoir of TRF product (built up over time) available for use by PND, DND or IS&HWP for detritiation, loss make-up or external sales. This is dependent on resolving issues with filling and emptying TDO packages at PND.
- Eliminate the need for additional S&I storage capacity. If the tanks into which Unit's 2 and 3 moderator and PHT water will be stored at are interconnected to the S&I headers they can become additional S&I tanks.

Utilization of this water in the fashion presented will give the heavy water management system more flexibility by having a large reservoir of reactor grade water, as additional product and feed tanks for the TRF and allowing the overall system to withstand a prolonged TRF outage.

A drum cleaning facility on its own has minimum impact on the overall PND Heavy Water management system. As such, drum cleaning was not considered as its own option. Drum cleaning will improve to some extent downgraded water segregation; however, the overall drum problem at PND will still be present if the Clean Up system does not allow emptying of the drums. Only by emptying and stacking the drums will less real estate be used for drum storage. Disposal of the drums given the cost associated with them is not an option although resale, if a customer could be found, would be an option.

8.5. Heavy Storage and Drum Cleaning Options for OPG

In previous sections options for heavy water storage and drum cleaning have been presented for PND and DND. Here the options are discussed as to an OPG solution. In discussing an OPG solution the following assumptions are made:

- PIOTS at PND will always be available except possibly during outages with system drains,
- Resources required to fill and empty TDO packages will be available at PND and DND,
- Resources for the transportation of drums between PND and DND are available,
- Transportation officers for TDO packages will be available at PND and DND,
- TDO shipment may increase to a range of 3 to 7 shipments per week during times of need,
- 10 Mg of heavy water per TDO shipment,
- The additional storage at DND will be available when DND is not in an outage situation.

Drum Cleaning Facility:

Drums are utilized throughout OPG to temporarily store and move heavy water. PND has the largest number of drums within a station and more importantly a large number of dirty drums. PND, as discussed previously, has a strong need for a drum cleaning facility. The study has recommended that a drum cleaning facility be located at PND to address their needs and DND's. Dirty drums at DND don't have to contend with oil as does PND. In discussions with the stakeholders at DND and PND it has been determined that DND will generate 1/10th the number of dirty drums that PND will. On this basis the drum cleaning facility has been recommended to be at PND serving OPG as a whole. The facility will have sufficient capacity to deal with PND and DND's drum cleaning needs.

Heavy Water Storage:

This study recommends the installation of additional reactor grade heavy water storage at DND but not PND, see the sections 7.1 and 7.2. Although additional heavy water storage at PND's S&I is not recommended, the study realized that the additional storage installed in DND can mitigate heavy water S&I storage issues at PND, and below is the explanation.

The basis for the mitigation is allowing some of PND's present D2O inventory to be temporally relocated to the extra capacity installed at DND to support PND's operation when circumstances arise. Section 7.2 has revealed various extra reactor grade heavy water storage needs at PND S&I tanks during normal and outage situations. Assuming the nominal D2O inventory in PND S&I tanks is about 200Mg (150Mg Lo-Ci & 50Mg Hi-Ci), the table below summarizes the needs:

Table 15. Extra S&I Storage Requirements at PND for various Scenarios

Scenarios	Hi-Curie (In addition of Tk1 & 2)	Lo-Curie (In addition of Tk 3 & 4)
1. Normal Operation	0	0
2. PB Moderator Drain	>30Mg (mod make-up) + >14Mg (Sulzer Product)	0
3. PA Moderator Drain	0	0
4. VLLDS	0	>50 to 100Mg (PHT make-up) (Note: PHT make-up may be temporally stored in Tk1 & 2 if required)
5. PB Mod Drain + VLLDS	>30Mg (mod make-up) + >14Mg (Sulzer Product)	>28Mg (UPP Product) + >50 to 100Mg (PHT make-up)
6. PA Mod Drain + VLLDS		>28Mg (UPP Product) + >50 to 100Mg (PHT make-up) (Note: PHT make-up may be temporally stored in Tk1 & 2 if required).
7. 6 month TRF outage	0	0

A study of the above table reveals that scenario #5 is the worst scenario, but it is unlikely to occur in a 40-days outage. However, even with scenario #5, if 50Mg of Lo-Curie D2O and ~ 50Mg of Hi-Curie D2O can be relocated to DND so that both Tk1 & 2 are emptied for the moderator drain, and one of the Lo-Curie Tank 1 or 2 is emptied out for the VLLDS, then a PB moderator drain and a VLLDS can occur simultaneously without impacting outage schedule. The most likely and frequent scenario is scenario #2 which can occur twice a year. In this scenario, if about 50Mg of Hi-Curie D2O can be shipped to DND, and returned as TRF product, then a moderator drain and an off-line detritiation can be performed in the same outage

The other side of the equation to this approach is DND's availability and capability to receive D2O from PND for temporary storage. Table 16 below summarizes the extra capacity (after the new addition of 400Mg of storage capacity – DND Option 2) that can be available at DND to support PND under each of the DND's scenarios discussed in section 7.1, with the following assumptions:

- Nominal D2O inventory in DND's S&I tanks is 390Mg (290Mg of Lo-Curie D2O, and 100Mg Hi-Curie D2O),
- 100Mg of the additional 400Mg storage space is always reserved for the downgraded water process;
- 100Mg of the additional 400Mg storage space is normally assigned to support DIOTS, but can used for temporary storage as required.
- Only the new tanks or the existing Hi-Curie tanks can be used to temporally store PND's water.

Table 16. Extra S&I Storage Available at DND under DND Option 2

Scenarios	New Storage (Total Capacity = 200Mg)	Hi-Ci (Total capacity = 400Mg)	Lo-Ci (Total capacity = 400Mg)
1.) Normal Operation	200Mg	300Mg	110Mg
2.) Moderator Drain	100Mg	0	110Mg
3.) Moderator Drain + LLDS	50Mg	0	10Mg
4.) SCO/VBO + Moderator Drain + LLDS	0	0	30Mg
5.) 6 month TRF outage	100	300	10
6.) 18 month TRF outage	140	300	50

Examination of Table 16 indicates that only scenario #4 prevents temporary storage of PND's water. However, this scenario occurs only once every 6 years, and is a planned outage. Therefore, it is predicted that under normal circumstances, the additional tanks installed at DND will have no difficulty temporarily storing 50Mg to 100Mg of PND's water.

When temporary storage is not required, this additional storage space plus the 50Mg already assigned for DIOTS can be used to accumulate TRF product to support ongoing PND's detritiation program or external sales.

9. Cost Estimates for Implementation of Options

Costs for the implementation of the various options have been developed. In order to develop the costs assumptions, presented below, have been made.

9.1. General Assumptions:

- All cost estimates given in 2006 dollars.
- Cost estimates subject to applicable taxes, duties, shipping costs, and fluctuations in supplier prices and labour rates.
- Costs associated with work at the site are included in cost estimate.
- Components are assumed to be designed, fabricated, and tested in accordance with the requirements of CSA N285.0/ASME Section III, and in compliance with Canadian Standards Association Quality Assurance Program CSA-Z 299.3, or equivalent.

9.2. Assumptions Associated with Drum Cleaning facility (DCF), Drum Pressure Testing facility (DPTF) and Additional HW storage:

General:

- Cost estimate for Drum Cleaning application is based on commercial equipment, and not to any pressure vessel code requirements.
- Cost estimate assumes coolant water activity is less than 2 Ci/kg. Therefore, treated water activity is also assumed to be less than 2 Ci/kg.

Heavy Water Tanks and Equipment:

- Cost estimate based on 304L or 316L stainless steel tanks which can withstand the following design parameters: Pressure = 200 kPa; Temperature = 38°C.
- All tanks are per CSA N285.0, Class 3
- Tanks located within containment dyke, seismically qualified (DBE.A)
- All tanks based on a volumetric design margin of 10% so they are only filled to 90% of capactiy eg. Defining a 100 m^3 storage tank implies the tank is capable of holding 110 m^3 or 110 Mg of HW (specific density of D2O – 1.1)

Piping, Valves, Hangers and Supports:

- Cost estimate based on Class 3, 304 or 316 stainless steel for Heavy Water Tanks piping.
- Cost estimate based on Class 3, 304 or 316 stainless steel valves
- Cost estimate based on Class 3, carbon steel hangers and supports.

Utilities:

- Cost estimate based on carbon steel materials for utility piping designed to the following parameters: Pressure = 200 kPa; Temperature = 38°C.

9.3. Cost Estimating Methodology

A bottom-up budget cost estimate has been developed with consideration of each individual component and task.

The hourly rates for various categories have been assumed as follows:

(1) trades $ 80 per hour
(2) engineers $100 per hour
(3) project manager $ 140 per hour

All engineering administration support costs have been included in the above rates.

Budget cost estimates for the time required to complete each item listed in the activities, are based on past OPG design and installation experience. A few cost estimates for removing and cleanup of existing equipment in rooms for installation of the storage tanks are provided by OPG [36, 37]. OPG has also provided some budget cost estimates on the total labour hours required to complete the conceptual installation [38].

All major equipment budget cost estimates have been obtained from equipment suppliers. Minor items are based on past experiences. Instrumentation, controls and electrical cost estimates are based on assuming 25% of mechanical costs as standard practice.

OPG Projects cost is the cost associated with Projects and Modifications carrying the recommended options for PND and DND through to completion. This cost has been developed with the help of OPG Projects and Modifications team. The total estimated project cost of 2.57 M$ has been split between PND and DND. If, for example, DND option proceeds but none of the PND options go forward then the full amount is envisioned transferred to DND; that is, OPG projects costs for DND would go up an additional 2.57/2 = 1.287 M$.

OPG Contract Management represents OPG's cost to manage the various trades; it is a percentage of the estimated trade labour costs. Similarly, Field Engineering costs are in addition to the Contract Management portion; it also is applied to the cost of associated with utilization of various trades.

The contingency of 25% for this stage of the project is intended to cover design and installation changes to take the project to completion. This contingency is not expected to cover major changes in the project scope. The contingency does not cover the implementation risks identified in the report and highlighted below.

9.4. Major Risks to Cost Estimates

The following risks are identified that can significantly impact estimated costs:

- Limited labour force. With major work moving forward in the Canadian Nuclear Industry the labour required to perform some of the work associated with this project may be in short supply potentially delaying the project and affecting costs.

- Meeting seismic requirements. The costs covers seismic analysis associated with implementation of the various options. Additional discoveries during the seismic analysis phase may require further reinforcements with potential schedule delay and cost increases.
- Unforeseen CNSC requirements or above normal level of effort for regulatory matters typically expected with this type of work.
- Discoveries during a geotechnical analysis of the soil may impact implementation of DND option.
- Escalation of costs (materials and labour).

9.5. Project Schedules

The schedules presented here are a projection of the various stages of the heavy water project. This schedules covers all the preferred options for PND and DND.

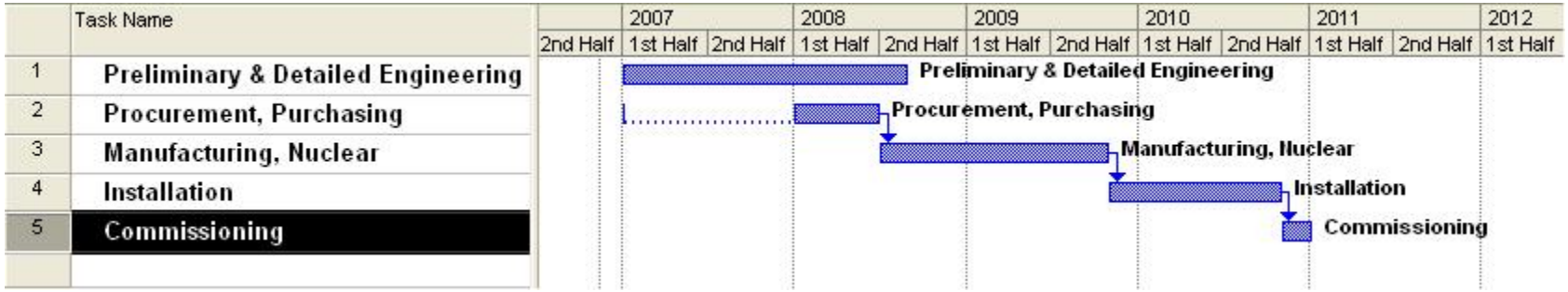

Figure 11. Estimated Schedule for the Implementation of Preferred Option at DND.

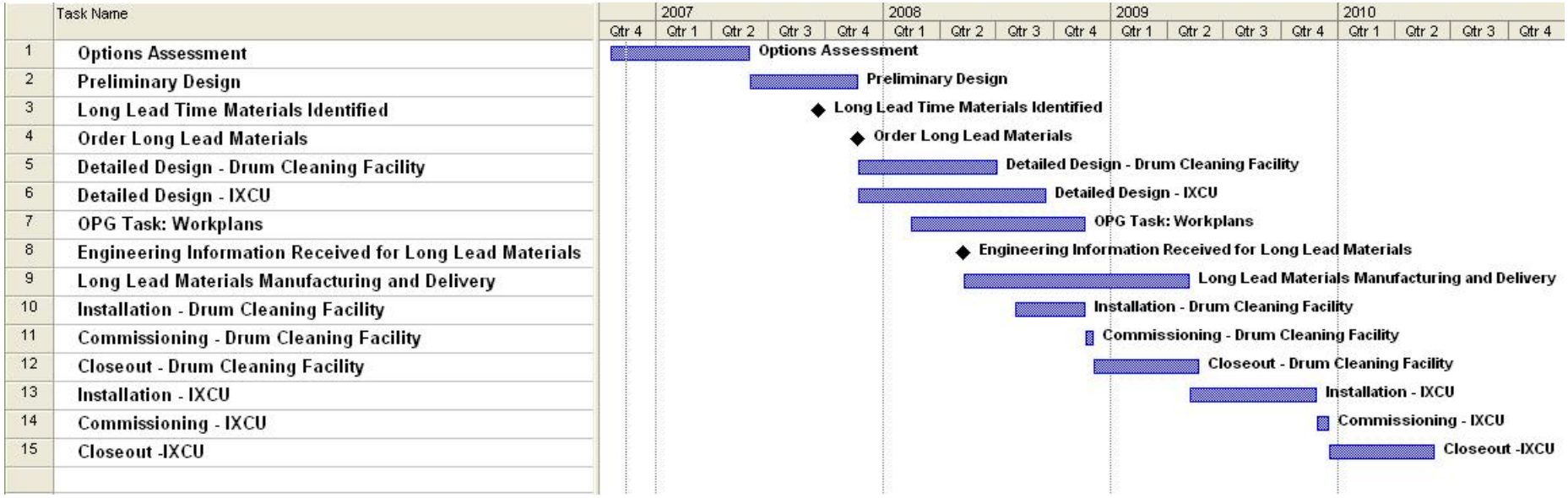

Figure 12. Estimated Schedule for the Implementation of Preferred Option at PND

9.6. Costs of Implementation of DND Preferred Option

Table 17. DND Cost of Preferred Option.

A. Bulk Storage	**Estimated Cost (M$)**
Equipment and Materials	4.60
Installation	3.16
Engineering	1.82
Subtotal	***9.58***
B. HWMB Building Extension	
Materials	1.45
Engineering	0.15
Labour	2.56
Site Preparation (movement of existing services, temporary services)	2.90
Subtotal	***7.06***
C. Drum Pressure Testing	
Materials	0.013
Labour	0.064
Subtotal	***0.077***
Subtotal A+B+C	16.72
OPG Projects	1.29
Contract Management (15% of Trades)	1.20
Field Engineering (15% of Trades)	1.20
Contingency (25%)	4.17
Cost of Borrowing	2.47
Total	**27.05**

9.7. Costs of Implementation of Various PND Options

Table 18. Estimated Costs of PND Option 2 - Drum Cleaning, Bulk Storage in IXCU and S&I

Drum Pressure Cleaning	**Estimated Cost (M$)**
Drum Cleaning Definition and Testing	0.05
Equipment and Materials	0.125
Installation	0.264
Site Preparation (removal of equipment)	0.160
Subtotal	***0.599***
Bulk Storage (IXCU)	
Equipment and Materials	2.23
Installation	1.82
Site Preparation	
Removal of Equipment	0.84
Building Reinforcement	
Materials	0.10
Labour	0.27
Subtotal	***5.26***
Bulk Storage (S&I) – HVAC room 277'	
Equipment and Materials	2.42
Installation	2.76
Site Preparation	
Removal of Equipment	0.63
Building Reinforcement	
Materials	0.20
Labour	0.34
Subtotal	***6.35***
Engineering	1.99
Subtotal	***14.20***
OPG Projects	1.29
Contract Management (15% of Trades)	1.07
Field Engineering (15% of Trades)	1.07
Contingency (25%)	3.55
Cost of Borrowing	2.13
Total	**23.31**

Table 19. Estimated Costs for the Implementation of PND Option 3 (Preferred Option)-

Drum Pressure Cleaning	**Estimated Cost (M$)**
Drum Cleaning Definition and Testing	0.05
Equipment and Materials	0.125
Installation	0.264
Site Preparation (removal of equipment)	0.160
Subtotal	***0.599***
Bulk Storage (IXCU)	
Equipment and Materials	2.23
Installation	1.82
Site Preparation	
Removal of Equipment	0.84
Building Reinforcement	
Materials	0.10
Labour	0.27
Subtotal	***5.26***
Engineering	1.39
Total	**7.25**
OPG Projects	1.29
Contract Management (15% of Trades)	0.51
Field Engineering (15% of Trades)	0.51
Contingency (25%)	1.81
Cost of Borrowing	1.17
Total	**12.54**

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11. APPENDIX A – On-line versus Off-line Detritiation

Two approaches to detritiation are practiced: on-line (bleed and feed) and off-line (moderator swap). The on-line detritiation technique involves replacing of a volume of high Curie moderator water with an equal amount of low Curie (maybe higher isotopic) water while the Unit is operating. Off-line detritiation also replaces high Curie with low Curie water but it is performed during an outage when a Unit moderator has been drained. These techniques perform the same function, that is, replace high Curie heavy water with low Curie heavy water. Each technique has its pros and cons as highlighted in section 2.1.

Off-line detritiation is dilution (in the case of tritium) or enhancement (in the case of isotopics) by bulk volume replacement. Assume a volume Vo of tritium reduced or isotopically rich heavy water is replaced in a Moderator volume of Vm. The resulting tritium concentration is,

$$C_o = \frac{\left(C_i(V_m - V_o) + C_r V_o\right)}{V_m}$$

Where Ci, Co and Cr are the tritium concentrations in the moderator prior to the swap, after the swap and in the water used for the swap respectively. For example, if the Ci = 17 Ci/kg and Cr = 1 Ci/kg and a 100 Mg swap is done at PND-B where Vm = 280 Mg the resulting Co is 11.3 Ci/kg. A similar relationship exists for the improvement in isotopic where the tritium concentrations in the equations are replaced by the respective isotopic ratios.

On-line swapping final tritium concentration is determined by solving the simple ordinary differential equation,

$$V_m \frac{dC_m}{dt} = F(C_r - C_m) + T$$

where Cm is the tritium concentration in the moderator (Ci/Mg) , F the flow rate of water into the moderator during the on-line swap(Mg/hr) and T the rate of tritium production (3.5 Ci/annum at PND. During the course of a on-line swap it is assumed T is zero. Using the same values as in the off-line swap yields a tritium concentration in the moderator after an online 100 Mg swap of 12.2 Ci/kg. Online swapping is less effective because as the TRF water is fed into the moderator it dilutes the tritium concentration in the moderator. The result is a decreasing tritium concentration in the heavy water bled out. With offline detritiation the extracted water has a constant tritium concentration. Furthermore, the online technique results in a less efficient utilization of the TRF because the TRF feed concentration decreases with time. In contrast, offline detritiation results in a constant tritium concentration in the TRF feed.

12. APPENDIX B - Calculations in Cost Savings in Dose and Fuel Cost through the implementation of Option 2 for PND

Tables 20 to 24 in the following pages defines what the tritium concentrations, the isotopic levels and what their associated cost savings would be in the PND units if PND implements option 2 (see section 8.4). These tritium concentration and isotopic values are compared to the situation if PND maintains the status quo. In calculating the tables the following assumptions have been made.

1. All units start at 17 Ci/kg and 99.88% isotopic
2. Rate of tritium growth is 3.5 Ci/kg/unit
3. Based on the 5 year plan the average water shipment to the TRF from PND is 629 Mg (ref C. Foster)
4. In the status quo scenario there will be an average shortfall of 187 Mg [Appendix Q]; thus without S&I increased storage the available water for detritiation is 629-187 Mg = 442 Mg.
5. PNDA can only be detritiated by volume swap during an outage which is taken to be every two years for a given unit.
6. PNDB units can be detriated via offline or online bulk swaps. At every outage a bulk, offline, swap is performed. During years of non-outage the heavy water swap is taken to be via the online technique.
7. In order to exceed the tritium growth a minimum swap size of 120 Mg is taken for PNDA detritiation leaving 442-120 = 322 Mg for detritiation of PNDB.
8. The water used for the volume swap is considered to have a 1 Ci/kg tritium concentration and an isotopic of 99.94%.
9. The water available to detritiate PNDB units 5 to 8 is 442-120=322 Mg; averaged over 4 units this becomes this becomes 322/4~80 Mg until 2015 when 3 PNDB units are down then the swap size is 100 Mg.
10. With increased S&I storage there is no shortfall which allows for an average swap size of 629/4 ~ 126 Mg for all units.
11. When the 3 PND-B units are down the swap size for the remaining units is taken to be 150 Mg.
12. The dose associated with the tritium concentration for PNDA (all four units) is DA (rem/annum) = 200 PHT (Ci/kg) + 20 MOD (Ci/kg) (Ontario Hydro Report CNS-IR-03850-1, 1980)
13. The dose associated with the tritium concentration for PNDB (all four units) is DB (rem/annum) = 100 PHT (Ci/kg) + 4 MOD (Ci/kg) (Ontario Hydro Report CNS-IR-03850-1, 1980)
14. Cost associated with dose is $25,000 per rem (J. Wigglesworth, June 9, 2006)
15. Average fuel cost for PND is $37940/0.01%isotopic/unit/annum (F. Fusca, Sept 13, weighted average values)

The schedule for outages is,

Table 20. Heavy Water Swap Schedule for Dose/Fuel Burnup Costs Calculations

	year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
	Unit																			
PNDB	5		OFF	ON	OFF	ON	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
	6		OFF	ON	OFF	ON	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
	7		ON	OFF	ON	OFF	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
	8		ON	OFF	ON	OFF	ON	offline	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
PNDA	1		OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	SD	SD	SD
	4		none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	OFF	none	SD
Notes						3 units PND-B shutdown		last PND-B unit shutdown									1 PNDA unit shutdown		2nd PNDA unit shutdown	
		OFF refers to offline detritiation																		
		ON refers to online detritiation																		
		SD means the unit has been shutdown																		

A moderator drain is assumed during every PND outage although the present outage schedule does not support this.

Table 21. Calculated Tritium Concentrations (Ci/kg) using Swap Schedule defined in Table 20.

OPTION 2 - Increased S&I storage NO SHORTFALL

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Unit																			
5	17	13.3	12.34	10.74	10.7	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
6	17	13.3	12.34	10.74	10.7	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
7	17	14.7	12.04	11.54	10.3	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
8	17	14.7	12.04	11.54	10.3	9.94	8.65	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
1	17	13.3	16.8	13.2	16.7	11.79	15.29	11.14	14.64	10.83	14.33	10.69	14.19	10.62	14.12	10.59	SD	SD	SD
4	17	20.5	15.23	18.73	14.25	17.75	12.28	15.78	11.36	14.86	10.94	14.44	10.74	14.24	10.65	14.15	10.61	14.11	SD

OPTION 1 - STATUS QUO, SHORTFALL

year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Unit																			
5	17	15.93	15.72	15.01	15.03	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
6	17	15.93	15.72	15.01	15.03	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
7	17	16.52	15.59	15.46	15.37	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
8	17	16.52	15.59	15.46	15.37	14.55	13.21	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
1	17	13.65	17.15	13.73	17.23	12.04	15.54	11.25	14.75	11.07	14.57	10.8	14.3	10.68	14.18	10.62	SD	SD	SD
4	17	20.5	15.64	19.14	14.87	18.37	12.56	16.06	11.49	14.99	11	14.5	10.77	14.27	10.66	14.16	10.61	14.11	SD

The tritium concentrations are calculated by solving the two equations presented in Appendix A . The generation of tritium over one year is included in the above calculations.

Table 22. Calculated Moderator Isotopics following Swap Schedule of Table 20

OPTION 2 - Increased S&I storage NO SHORTFALL

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Unit													
5	99.88	99.907	99.919	99.928	99.932	SD	SD	SD	SD	SD	SD	SD	SD
6	99.88	99.907	99.919	99.928	99.932	SD	SD	SD	SD	SD	SD	SD	SD
7	99.88	99.902	99.919	99.927	99.933	SD	SD	SD	SD	SD	SD	SD	SD
8	99.88	99.902	99.919	99.927	99.933	99.936	99.938	SD	SD	SD	SD	SD	SD
1	99.88	99.907	99.907	99.922	99.922	99.932	99.932	99.936	99.936	99.938	99.938	99.939	99.939
4	99.88	99.88	99.907	99.907	99.922	99.922	99.932	99.932	99.936	99.936	99.938	99.938	99.939

OPTION 1 - STATUS QUO, SHORTFALL

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Unit													
5	99.88	99.897	99.908	99.917	99.923	SD	SD	SD	SD	SD	SD	SD	SD
6	99.88	99.897	99.908	99.917	99.923	SD	SD	SD	SD	SD	SD	SD	SD
7	99.88	99.895	99.908	99.916	99.923	SD	SD	SD	SD	SD	SD	SD	SD
8	99.88	99.895	99.908	99.916	99.923	99.928	99.932	SD	SD	SD	SD	SD	SD
1	99.88	99.906	99.906	99.921	99.921	99.931	99.931	99.936	99.936	99.938	99.938	99.939	99.939
4	99.88	99.88	99.906	99.906	99.921	99.921	99.931	99.931	99.936	99.936	99.938	99.938	99.939

The costs savings associated with implementing Option 2 versus maintaining the status quo is presented in the subsequent tables. For a given year the difference between the two options is utilized to calculate the savings. For example, taking the year 2011 for unit 5, Table 21 gives calculates a tritium value of 15.93 Ci/kg for Option 1 and 13.3 Ci/kg for Option 2. The savings due to dose is calculated utilizing equation of assumption 13 for the two cases, subtracting the difference and dividing by four (the equation applies to all of PNDB); that is, (15.93-13.3)x$25,000=$65,750. Similar type of calculation follows for the savings associated with fuel savings utilizing the calculated isotopic values.

Table 23. Calculated Costs Associated with Dose

physical year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Unit																
5	-$65,750	-$84,500	-$106,750	-$108,250	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
6	-$65,750	-$84,500	-$106,750	-$108,250	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
7	-$45,500	-$88,750	-$98,000	-$126,750	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
8	-$45,500	-$88,750	-$98,000	-$126,750	-$115,250	-$114,000	SD	SD	SD	SD	SD	SD	SD	SD	SD	SD
1	-$43,750	-$43,750	-$66,250	-$66,250	-$31,250	-$31,250	-$13,750	-$13,750	-$30,000	-$30,000	-$13,750	-$13,750	-$7,500	-$7,500	-$3,750	SD
4	$0	-$51,250	-$51,250	-$77,500	-$77,500	-$35,000	-$35,000	-$16,250	-$16,250	-$7,500	-$7,500	-$3,750	-$3,750	-$1,250	-$1,250	$0
subtotal	**-$266,250**	**-$441,500**	**-$527,000**	**-$613,750**	**-$224,000**	**-$180,250**	**-$48,750**	**-$30,000**	**-$46,250**	**-$37,500**	**-$21,250**	**-$17,500**	**-$11,250**	**-$8,750**	**-$5,000**	**$0**

Total costs associated with dose due to shortfall in TRF shipments **-$2,479,000**

Table 24. Calculated Costs Associated with Fuel Burn

physical year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Unit												
5	-$37,940.00	-$41,734.00	-$41,734.00	-$34,146.00	SD	SD	SD	SD	SD	SD	SD	SD
6	-$37,940.00	-$41,734.00	-$41,734.00	-$34,146.00	SD	SD	SD	SD	SD	SD	SD	SD
7	-$26,558.00	-$41,734.00	-$41,734.00	-$37,940.00	SD	SD	SD	SD	SD	SD	SD	SD
8	-$26,558.00	-$41,734.00	-$41,734.00	-$37,940.00	-$30,352.00	-$22,764.00	SD	SD	SD	SD	SD	SD
1	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
4	$0.00	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	-$3,794.00	$0.00	$0.00	$0.00	$0.00	$0.00
subtotal	**($132,790.00)**	**($174,524.00)**	**($174,524.00)**	**($151,760.00)**	**($37,940.00)**	**($30,352.00)**	**($3,794.00)**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**

Total costs associated with fuel costs due to shortfall in TRF shipments **($705,684.00)**

13. APPENDIX C - Rationale for Storage Needs at PND

Rationale for Additional S& I Storage

Allowing for flexibility during the period of highest storage demand will accommodate other station needs during normal operations. The highest demand for reactor grade water storage is during an outage under the following scenario: 1 unit moderator drain, 1 unit PHT drain to a very low level drain state (VLLDS) and a 6 month TRF outage with 5 operational units. The upgraders continue to operate during this time period. The outage is for 40 days.
The amount of heavy water in the PND system at the time of this report is captured in the Table 25.

Table 25. Heavy Water in the PND system

Purpose	**Volume (Mg)**
High Curie Mod/D2O/TRF make-up#	53
PHT ready water#	138
TRF product scheduled for return	20
Recoverable water from UPPA + drums $	190
To be returned to U2/U3 $	(200)
Total	**201**
# - PND D2O Management Summary – April 3, 2006	
$ - PND assumptions	

PND Assumption 4 requires storage capacity for a simultaneous Moderator drain (250 Mg) and a very low level drain state (VLLDS) drain of the PHT system (100 Mg). The combined volume of heavy water requiring storage is 201+250+100 = 551 Mg.

At present there exists two 100 m^3 PHT S&I tanks and two 150 m^3 S&I tanks for moderator ready water. The total storage volume for the S&I tanks is 500 m^3 insufficient to house the 551 Mg. Thus, accommodation of this scenario requires additional S&I storage.

Adding two new S&I tanks of 100 m^3 (split 50/50) will increase the storage capabilities to the point the above scenario can be accommodated. Additionally, separating the tanks with double block and bleed piping and valve arrangement will gave the new S&I more flexibility by making them open to storing PHT or Moderator water. With the addition of these two new tanks (TK-5A/B, TK-6A/B) the storage utilization during the outage, both moderator and PHT (VLLDS) drained, is expected to look like that presented in Table 26.

Table 26. Distribution of Different Qualities of Reactor Grade Water during Combined Moderator and VLLDS PHT drain Scenario

Type	Volume	Comments	TK1	TK2	TK3	TK4	TK5 A/B	TK6 A/B
			150	150	100	100	50/50	50/50
Low Curie	138	UPPB Product			100		38	
High Curie	53	Sulzer Product						43*
TRF	20	PHT ready					20	
Drums/UPPA	190							
P2/P3 Water	(200)	Return to P2/P3						
PHT Drain	100	Lithiated				100		
Mod Drain	250	Gd bearing	100	150				
Sum			***100***	***150***	***100***	***100***	***58***	***43***
* - 10 Mg has been subtracted to capture the net movement of water to P2/P3 after the water from UPPA/drums is accounted for								

With additional tank storage volumes an off-line Moderator swap of 100 to 150 Mg is easily accommodated. Water for the 100 Mg swap would be pulled in from the UPPB product in TK3. On-line detritiation of the other units would not be conducted during this time period but would be possible when the PND station outage was over. At the end of the outage 350 m^3 of free space would be available. If a swap of 150 Mg is desired an additional 50 Mg would be required to be brought in from the TRF (or P2/P3) and located in the empty 50 Mg of TK6. A permanent modification (EC #88224), allowing for the removal of Gd from either TK1 or TK2 has now being implemented. This change allows the Gd to be removed in-situ permitting the direct shipment of this heavy water to the TRF without having to go through the Clean up system.

Rationale for Increased Storage at IXCU

The following assumptions are taken in calculating the required additional feed tank storage for the High and Low Curie clean up systems.

- The ratio of oily downgraded water to the total downgraded water is 0.25[2]. This value is consistent with operational data [42].
- The ratio of high Curie downgraded to total downgraded water is taken as 0.35 [2][3] .
- Recovery rate for low Curie water is 1247 Mg fl/a [2], only 2 units operating at PND-A. It includes a 20% contingency to cover variability in recoveries. Pickering CS Operations[4] indicates the OPEX does not support a 42% isotopic for the recovered water from PND-A used in reference 2. PND CS Operations suggests an isotopic more in range of 20 to 25%. The same isotopic as PND-B (23%) is utilized for PND-A. An additional 30% is added to capture acute recovery events. The modified recovery rate for low Curie water is 1528x1.5/1.2 = 1910 Mg fl/a..

[2] Meeting February 6, 2006 Project Building A
[3] Consistent with calculated average of IXCU drum processing performance for period January 2005 to March 2006
[4] Meeting June 8, 2006, F. Drepaul office

- Recover rate for high Curie water is 823 Mg fl/a [2] modified as indicated in previous bullet, only 2 units operating at PND-A It includes a 20% contingency to cover variability in recoveries. An additional 30% is added to capture acute recovery events. Thus the recovery rate for high Curie water used for calculation purposes is 823x1.5/1.2 = 1029 Mg fl/a.

- The upgrading capacity for UPPB is 224 kg/hr [2], operating at 80% capacity. PND assumption 29 indicates the UPPB present throughput is 150 kg/hr.

- The upgrading capacity for Sulzer (Moderator) is 120 kg/hr [2], operating at 80% capacity. PND assumption 29 indicates the Sulzer throughput is presently 110 kg/hr.

- Approximately 20% of all downgraded water is drummed[5]

Table 27 presents the calculated heavy recoveries estimated from the above information; for example, low Curie oily is 0.25x1910=478 Mg fl/a. Because all oily water once it is processed enters the Low Curie, non-oily, train it's recovery rate is added to the calculated non-oily recovery rate.

Table 27. Estimated Heavy Water Recoveries

Water quality	Annual recovery (Mg fl/a)	Weekly recovery (Mg fl/wk)	Weekly recovery drummed (Mg fl/wk)	# of drums utilized per week
Low Curie, oily	478	9.2	1.8	9
Low Curie, non-oily	1432	27.5+9.2 = 36.7	7.3	37
High Curie, oily	257	5	1	5
High Curie, non-oily	772	14.9 +5 = 19.9	4	20

The present tank capacity at the IX Clean Up system is shown in Table 28

Table 28. Feed Tank Capacity at the IX Clean Up System

Water quality	Capacity (Mg)
Low Curie, oily	2.3
Low Curie, non-oily	27.2 (4 x 6.8)
High Curie, oily	2.3
High Curie, non-oily	20.4 (3 x 6.8)

Examination of Tables 27and 28 reveals the following;

- there is about 1/4 of a week holding capacity for low Curie, oily
- there is about 1/2 of a week holding capacity for high Curie, oily

[5] IXCU drum processing performance for period January 2005 to March 2006

- there is about 3/4 of a week of holding capacity for low Curie, non-oily
- there is about 1 week of holding capacity for high Curie, non-oily

To be consistent it is recommended that all tanks hold sufficient capacity to accommodate recovery for a similar period of time. To provide flexibility to IXCU for maintenance and to prevent buildup of drums a period of 2 weeks is arbitrarily chosen. Table 29 presents the recommended increase in storage capacity for the IX Clean Up System. For example, low Curie, oily for a two week period would require 2x9.2 = 18.4 Mg capacity. Subtracting the present capacity of 2.3 yields, 18.4-2.3 = 16.1.

Table 29. Recommended increase in Feed Tank Capacity at the Clean Up System

Water quality	**Capacity (Mg)**
Low Curie, oily	16
Low Curie, non-oily	46
High Curie, oily	8
High Curie, non-oily	19
Capacity has been round off to the nearest whole number	

Common Services OPEX [Appendix L] indicates the oily, high Curie, recoveries are larger than the above calculations suggests, the recommendation is to make the oily, high Curie, tank equivalent in size to the oily, non-Curie. Based on this OPEX the low Curie and high Curie, oily, tanks are recommended to be of 16 Mg capacity.

Requirements during Upgrader Outage

During Upgrader outage of one month (PND Assumption # 28) there will continue to be a need to store recovered water. Table 30 summarizes the monthly recoveries anticipated during the outage.

Table 30. Proposed IXCU Volumes compared to Water Recovery during an Upgrader Outage of 1 Month

Purpose	**Upgrader Feed Tank Capacity (Mg)**	**Recovered volume (Mg)@**
Low Curie (yearly recovered water 1524 Mg)	200	127
High Curie (yearly recovered water 828 Mg)	60	69
@ - calculated using the lower estimated recovery (20% contingency vs 50%) and not the higher recovery rates used in the above calculation. In the event the recovery rates are acute during the upgrader outage there is still ample storage for UPPB while falling short for the Sulzer unit; not all the recovered high Curie water would be processed. Storage in the IXCU feed tanks and possibly drums may will be required.		

No additional storage to accommodate an Upgrader outage is recommended.

An operating UV oxidation system is expected to deal with the high TOC water and hence eliminating the need for additional storage volume for high TOC water as identified in Kinectrics report K-011043-001.

It is anticipated that the IXCU will function more efficiently and increase its throughput if the additional storage defined above is introduced at IXCU.

14. APPENDIX D - Tank Utilization at DND with Additional Storage

TRF Outage of 18 Months No Additional Storage

2003, 2004 Average Recoveries, 100% D2O = 75 Mg/U/a

Total = 300 Mg/a for 4 Units or 1111 Mg/a at 27% isotopic [10]

Previously, 20-30% of recoveries were assumed to be from Moderator system. Now, from 2005 onwards, Moderator is leaking more and 50% of recoveries are estimated to be from the Moderator.

Therefore, total recoveries will be higher = 1111 x0.7/0.5 = **1555 Mg/a**, or 4.3 Mg/d feed to the Upgrader . This is within the capability of the Upgrader.

PHT & MOD Recoveries

In an 18 month TRF outage the Upgrader will be required to operate in a segregated mode, that is, process the high and low Curie water independently versus the mixed mode operation when the TRF is operating. Operating in this mode requires utilization of some of the low Curie downgraded water (30 Mg at 27% isotopic) to flush the Upgrader of the high Curie water in the system. This downgraded low Curie water is effectively lost to the PHT system, requires additional high Curie S&I storage and results in the need to store an equivalent 100% D2O amount of <1Ci/kg heavy water prior to the TRF outage (30 x 27% = 8.1 Mg 100%D2O). The less number of flushes required the less pressure there is on heavy water storage requirements, downgraded and reactor grade. Below the schedule describing how the Upgrader would be operated during the extended TRF outage is presented and the amount of mixed Curie, flush, water is calculated.

Presently the DND HW storage system has,
2x25 Mg of Dirty Downgraded Tanks
2x50 Mg of Clean Downgraded Tanks.

During the TRF Outage, the MOD recoveries will be cleaned up utilizing one set of dirty/clean tanks and the PHT recoveries the other set. When one of the 50 m^3 Upgrader feed tank becomes full with either high or low Curie water then the Upgrader processes that water while the other 50 m^3 feed tank is filled with the opposing Curie downgraded water. This cycle continues until the TRF outage is over. An outage of 18 months (548 days) results in having to process 1555x1.5 = 2333 Mg of downgraded water. The Upgrader can process at 5 Mg/d thus 50 Mg would require 10 days to process. The rate of downgraded water generation is slower (4.3 Mg/d) which results in having to store 17 Mg of high Curie downgraded water in the TRF product tank or drums in order to set up the processing schedule presented in Table 31.

DND indicates that a flushing of the Upgrader after processing high Curie water will require ~30 Mg of low Curie downgraded water. Table 31 presents the schedule under Option 1, that is, maintaining the status quo; no additional heavy water storage provided. The calculations shown in Table 31 indicate that ~170 Mg (100%D2O) of mixed Curie heavy water will be created requiring a similar quantity of <1 Ci/kg water prior to the start of the TRF outage. Additionally, this 170 Mg will be required to be stored in the high Curie S&I tanks.

After day 44 the schedule repeats itself until the end of the 18 month TRF outage. The switching between high and low Curie processing is done after every 23 days.

The total value processed is 2200 Mg with 67 Mg still left to process at the end of the TRF outage. Add to this 17 Mg of high Curie water stored again and a total of 2200+67+17 = 2274 of downgraded water has been processed. The difference between this number and the 2333 Mg is due to the rounding off error.

Table 31. Downgraded water, segregated processing with existing storage; that is, maintaining the status quo.

Dirty Tanks: 2x25 m3								
Clean Tanks: 2x50 m3								
Collection Rate	**2.1 Mg/d Hi-Ci, 2.1 Mg/d Lo-Ci**							
Upgrader Throughput			**5 Mg/d**					
Day #	**Hi-Ci Dirty Inv**	**Lo-Ci Dirty Inv**	**Hi-Ci Clean Inv**	**Lo-Ci Clean Inv**	**Hi/Mixed Ci UG Prod**	**Lo-Ci UG Prod**	**Total Collected + Processed = Daysx4.2**	
0	0	0	0	0	0	0		
24	0	0	50	50	0	0	100	
34	21	21	50	**0**	0	50	142	Lo-Ci clean Tk locked out for processing
36	25	0	**40**	25	10	50	150	See Note 1; Hi-Ci clean Tk locked out for processing
44	25	0	**0**	42	50	50	184	See Note 1; Hi-Ci clean Tk locked out for processing
48	0	0	33	50	50	50	200	
58	4	21	50	**0**	**80**	70	242	Lo-Ci clean Tk locked out for processing
68	25	0	**0**	42	130	70	284	Hi-Ci clean Tk locked out for processing
72	0	0	33	50	130	70	300	
82	4	21	50	**0**	**160**	90	342	Lo-Ci clean Tk locked out for processing
92	25	0	**0**	42	210	90	384	Hi-Ci clean Tk locked out for processing
96	0	0	33	50	210	90	400	
pattern from day 72 to 96 repeats itself until end of outage								
Note 1	On day 36, the Hi-Ci Dirty Tank is full and cannot accept more recoveries.							
	Between days 36-44, 17 Mg of Hi-Ci recoveries have to be stored in TRF Product Tank, drums, etc.							
	Total includes 17 Mg which is in Other Storage							
	Full tank is locked up and being fed to Upgrader in next 10 days							
	Flush occurred, & 30Mg Lo-Ci product converted to mixed-Ci product due to switching							

TRF 18 month Outage with Additional Storage – DND Option 2

Table 32 presents a similar schedule to Table 31 but for the case where DND implements Option 2; 400 Mg of additional heavy water storage.

The table illustrates that the pattern between days 184 and 256 repeats itself at 72 day intervals. This repeating pattern continues until the end of the outage (~day 550). The following observation are made from the schedule:

- Before day 200 only two (2) low Curie flushes are required,
- After day 200, flush occurs every 72 days.
- For a 6 month TRF outage this means 2x30x0.27=16Mg (100% D2O) of mixed Curie product requiring storage and an additional 16 Mg of PHT grade water required prior to the outage.
- For an 18 month TRF outage this schedule leads to `~7 flushes (7x30x0.27 = 57 Mg of 100%D2O) producing 57 Mg of mixed Curie D2O requiring storage and and additional 57 Mg of PHT grade water required prior to the outage.

It is noted that the additional storage reduces the overall quantity of mixed Curie water generated because of Upgrader flushing (170 Mg – Option 1, 57 Mg – Option 2). The amount of PHT grade water required prior to the outage is also reduced when additional storage is available.

Note that throughout the outage 50 Mg of storage space, Tk(2), is always available to deal with high TOC events.

Table 32. Downgraded segregated processing with additional storage – DND Option 2

Collection Rate	**2.1 Mg/d Hi-Ci, 2.1 Mg/d Lo-Ci**										
Upgrader Throughput			**5 Mg/d**								
Day #	**Hi-Ci Dirty Inv(1) (25Mg)**	**Hi-Ci Dirty Inv(2) (50Mg)**	**Hi-Ci Clean Inv (1)**	**Hi-Ci Clean Inv (2)**		**Lo-Ci Dirty Inv(1) (25Mg)**	**Lo-Ci Dirty Inv(2) (50Mg)**	**Lo-Ci Clean Inv (1)**	**Lo-Ci Clean Inv (2)**	**Hi/Mx-Ci UG Prod**	**Lo-Ci UG Prod**	**Total Collected and Processed = Daysx4.2**
0	0	0	0	0		0	0	0	0	**0**	**0**	
24	0	0	50	0		0	0	50	0	**0**	**0**	101
34	0	0	50	21		0	0	0	21	**0**	**50**	143
49	1	0	50	50		1	0	0	50	**0**	**50**	206
59	22	0	50	50		0	0	22	0	**0**	**100**	248
69	25	17	0	50		0	0	43	0	**50**	**100**	290
79	18	0	50	0		0	0	50	14	**100**	**100**	332
89	0	0	0	39		0	0	50	35	**150**	**100**	374
99	0	0	10	50		6	0	0	50	**180**	**120**	416
109	0	0	31	50		0	0	27	0	**180**	**170**	458
119	2	0	50	50		0	0	0	0	**180**	**197**	500
129	23	0	50	0		0	0	48	0	**230**	**197**	542
139	0	0	0	44		0	0	50	19	**280**	**197**	584
149	0	0	15	50		0	0	0	40	**310**	**217**	626
154	0	0	25	50		0	0	0	50	**310**	**217**	647
164	0	0	46	50		0	0	21	0	**310**	**267**	689
174	15	0	50	0		0	0	42	0	**360**	**267**	731
184	0	0	0	36		0	0	50	13	**410**	**267**	773
191	0	0	0	50		0	0	50	27	**410**	**267**	802
201	0	0	21	0		0	0	50	48	**460**	**267**	844
211	0	0	42	0		19	0	0	50	**490**	**287**	886
221	0	0	50	13		0	0	40	0	**490**	**337**	928
226	0	0	50	23		0	0	50	0	**490**	**337**	949
236	0	0	50	44		0	0	0	21	**490**	**387**	991
246	15	0	0	50		0	0	0	42	**540**	**387**	1033
256	0	0	36	0		0	0	13	50	**590**	**387**	1075
262	0	0	50	0		0	0	27	50	**590**	**387**	1100
	Period require Lo-Ci flushing											

Observations:
1. Before Day 200, only 2 flushes are req'd;
2. After Day 200, flush repeats every 72 days (ref: Note on day#256) until outage ends
3. Therefore, for 6 months TRF outage, only 2 flushes need to be performed. So, Lo-Ci water needs to stored = 60Mg x 27% = 15Mg;
4. For 18 mths TRF outage, there will be 2 flushes before day 200, & about 5 flushes from day 200 to day 550. Total 7 flushes req'd. So, Lo-Ci water needs to be stored = 210Mg x 27% = 60Mg
5. 50Mg Dirty Tk(2) will always be available on each stream to deal with Hi-TOC.

Tank Utilization with Additional Storage during non-TRF outages – DND Option 2

Tables 33 and 34 illustrate how the heavy water would be distributed among the present heavy water storage tanks and the new tanks under the following scenarios: SCO outage and normal

outage with MOD and PHT drain. Refer to sections 7.1.1 and 7.1.2 for understanding of the heavy water storage needs during various Scenarios.

Table 33. DND Tank Inventories during Normal Operation and SCO Outages with Additional Storage – DND Option 2

Tank	Volume (m3)	Content prior to SCO Outage (Mg)	PHT Content During SCO Outage (Mg)	MOD Content Added During Outage (Mg)	Spare Capacity Available (Mg)	Comment
PHT-1	100	100	40		0	During SCO Outage, 360 Mg removed due to shrinkage, 130 Mg added due to LLD of 1 Unit
PHT-2	100	100	30		0	
PHT-3	100	100	70		0	
PHT-4	100	100	60		0	
PHT Weigh Tank	37	30			0	
MOD-1	100	0		100	0	
MOD-2	100	0		100	0	
MOD-3	100	0		100	0	
MOD-4	47	0		47	0	
MOD Weigh Tk	10					
TK1-A	50	50		50	50	MOD Operating Reserve
TK1-B	50	50		50	50	MOD Operating Reserve
TK2-A	50	0		0	50	Contingency
TK2-B	50	0		0	50	Contingency
Total	**994**	**530**	**200**	**447**	**200**	

Table 34. DND Tank Inventories during Normal Operation and Normal Outages with Additional Storage – DND Option 2

Tank	Volume (m3)	Content prior to Outage (Mg)	PHT Content Added during Outage (Mg)	MOD Content Added During Outage (Mg)	Spare Capacity Available (Mg)	Comment
PHT-1	100	100				
PHT-2	100	100				
PHT-3	100	20	80			
PHT-4	100	100				100 Mg reserve for PHT make-up during TRF Outage
PHT Weigh Tk	37				37	
MOD-1	100			100		
MOD-2	100			100		
MOD-3	100	80			20	80 Mg OPGN operating Reserve
MOD-4	47	25			22	25 Mg for Upgrader Outage of 6 weeks
MOD Weigh Tk	10				10	
TK1-A	50		50		0	
TK1-B	50			50		
TK2-A	50			50		
TK2-B	50			47	3	
Total	**994**	**425**	**130**	**347**	**92**	

Upgrader Outage of 8 Weeks with Additional Storage

Need to store downgraded recoveries during this period.

i.e. 1540x8/52 = 237 Mg of fluid will need to be stored. This can be cleaned up and stored in the Downgraded Clean Tanks. There is not enough capacity just in the Clean Tanks for this. Therefore, 37 Mg will be stored in the Dirty Tanks and 200 Mg in the Clean tanks; Table 35 illustrates this visually.

During this period, it is assumed that the TRF is working and PHT make-up is not an issue and is available.

Table 35. DND Downgraded Inventories during 8 week Upgrader Outage with Additional Storage – DND Option 2.

Tank	Volume (m3)	Content prior to Outage (Mg)	Mixed Content Added during Outage (Mg)	Spare Capacity Available (Mg)	Comment
DG Dirty	25	25			
DG Dirty	25	12		13	
DG Clean	50		50		
DG Clean	50		50		
TK3-A Dirty	50			50	
TK3-B Dirty	50			50	
TK4-A Clean	50		50		
TK4-B Clean	50		50		

15. APPENDIX E - Drum Cleaning

Drums are used at the nuclear stations for the movement of downgraded heavy water from collections points to the clean up systems and subsequent upgrading to reactor grade water. Additionally, drums may are used to store reactor grade water during times of need Typical drums utilized are stainless steel in nature with 2 and ¾ inch bungs. The following conditions typify the drums requiring cleaning:

- Only the internal surfaces of the drum are required to be cleaned
- Drums are empty minus a heel of no more than 100 ml of heavy water
- Residual tritium present within drum
- Oil film within drum possible
- Volatile organics carbons within drum possible
- Soil, particulates and dissolved impurities within drum possible
- Hydrocarbon , oil, heel is possible (oil presence at PND is due to the use of hydraulically operated fueling machines)

Carbon steel drums, with epoxy coatings, are the exception. Drums containing fission products, activated particles, metal fillings, corrosion products and large objects are considered the exception and will be dealt with separately.

Drums once cleaned will be re-utilized to collect downgraded (oily and non-oily) heavy water or store reactor grade water. Five (5%) percent of the drums containing historical contaminated heavy water will, upon emptying, contain: sludge, oil, charcoal, resins and maybe silica sediment. In some cases the sludge maybe 5 to 6 inches deep.

IP2 drums, utilized for external sales of heavy water, will require pressure testing to 5 psig.

The end use of cleaned drums are:

1. Disposal to waste site (less stringent of cleaning criteria)
2. Re-use for oily, downgraded, heavy water (less stringent of cleaning criteria)
3. Re-use for non-oily, downgraded, heavy water (higher level of cleanliness)
4. Re-use for reactor grade heavy water storage (highest level of cleanliness)

Disposal to the Western Waste Management Facility has to satisfy the criteria imposed by the Waste Management. The criteria require that no free liquid be present in the drum while restricting the level of radioactive contamination. An oil film on the internal surfaces will not be a deterrent to disposal and neither will it be a deterrent to re-issue of this drum for oily, downgraded, heavy water. Use of drums to transfer, non-oily, downgraded heavy water is not expected to be significantly impacted by a fine oil film on the inner drum surfaces. The highest level of cleanliness is reserved for temporary storage of reactor grade water. Here no oil film is desired as are no particulates or VOC.

Review of methodologies used by drum cleaning equipment suppliers indicates the use of detergents, surfactants, caustic or acidic media for effective cleaning of drums. The use of surfactants to emulsify the oils is unavoidable. Drum cleaning is used extensively in the pharmaceutical, food and petroleum industries. The petroleum industry is expected to be the most similar to the situation at Pickering as they deal with heavy crude oils and ragging (the presence of ultra fine particles). Drum cleaning equipment developed specifically for the petroleum industry uses a proprietary surfactant with salt water (specifically sea water) to perform the cleaning [28].

Bruce Power at one time had drum cleaning capabilities which utilized an industrial cleaner and in some situations hydrochloric acid (rust removal)[6].

The choice of drum cleaning approaches at PND will be dependent on level of cleanliness sought and the disposal pathways of cleaning solutions. The equipment in the market is general enough to utilize different cleaning solutions (surfactants, pressurized hot water etc). What the drum cleaning equipment supplier may not guarantee is the effectiveness of the drum cleaning if their approach (ie. cleaning solutions) are not utilized.

[6] Ontario Hydro procedure , "Active Drum Cleaning" CVP-78130-1

16. APPENDIX F – Sketches of Proposed HWMB extension at DND

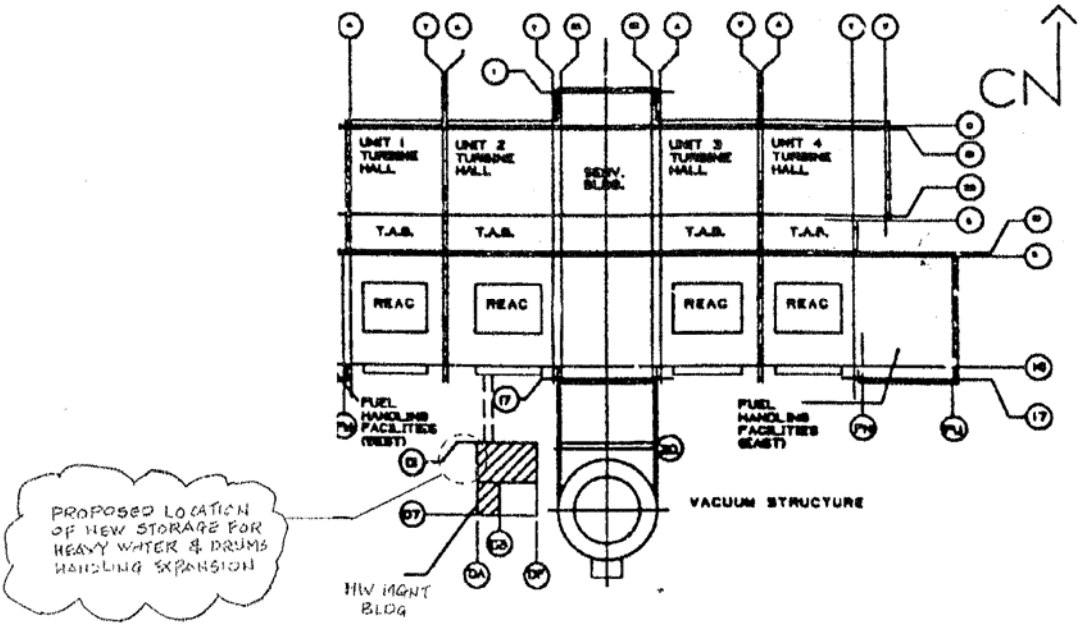


Figure 13. Sketch illustrating site location of proposed Heavy Water Management Building extension.

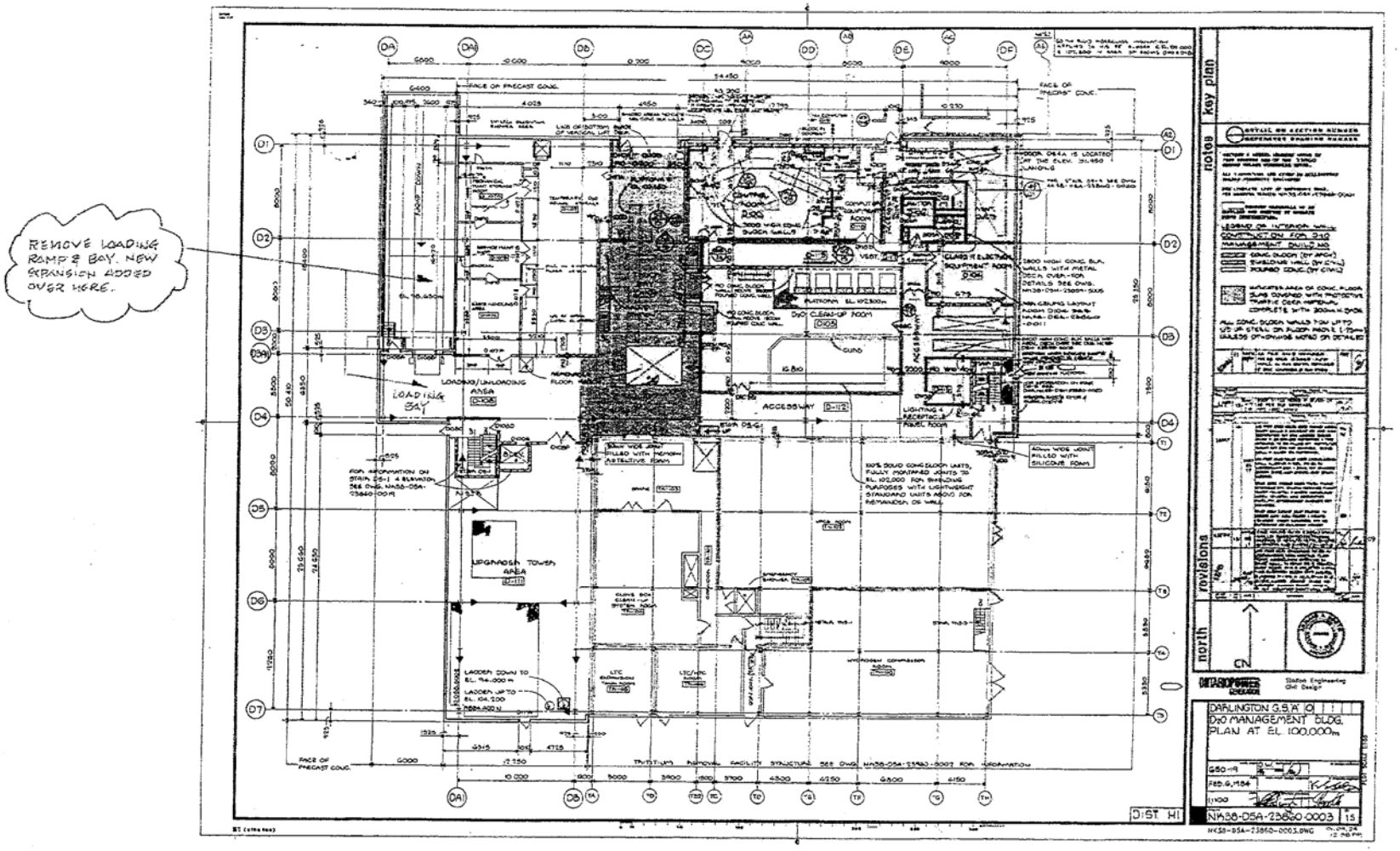


Figure 14. Detailed sketch illustrating changes to present Heavy Water Management Building.

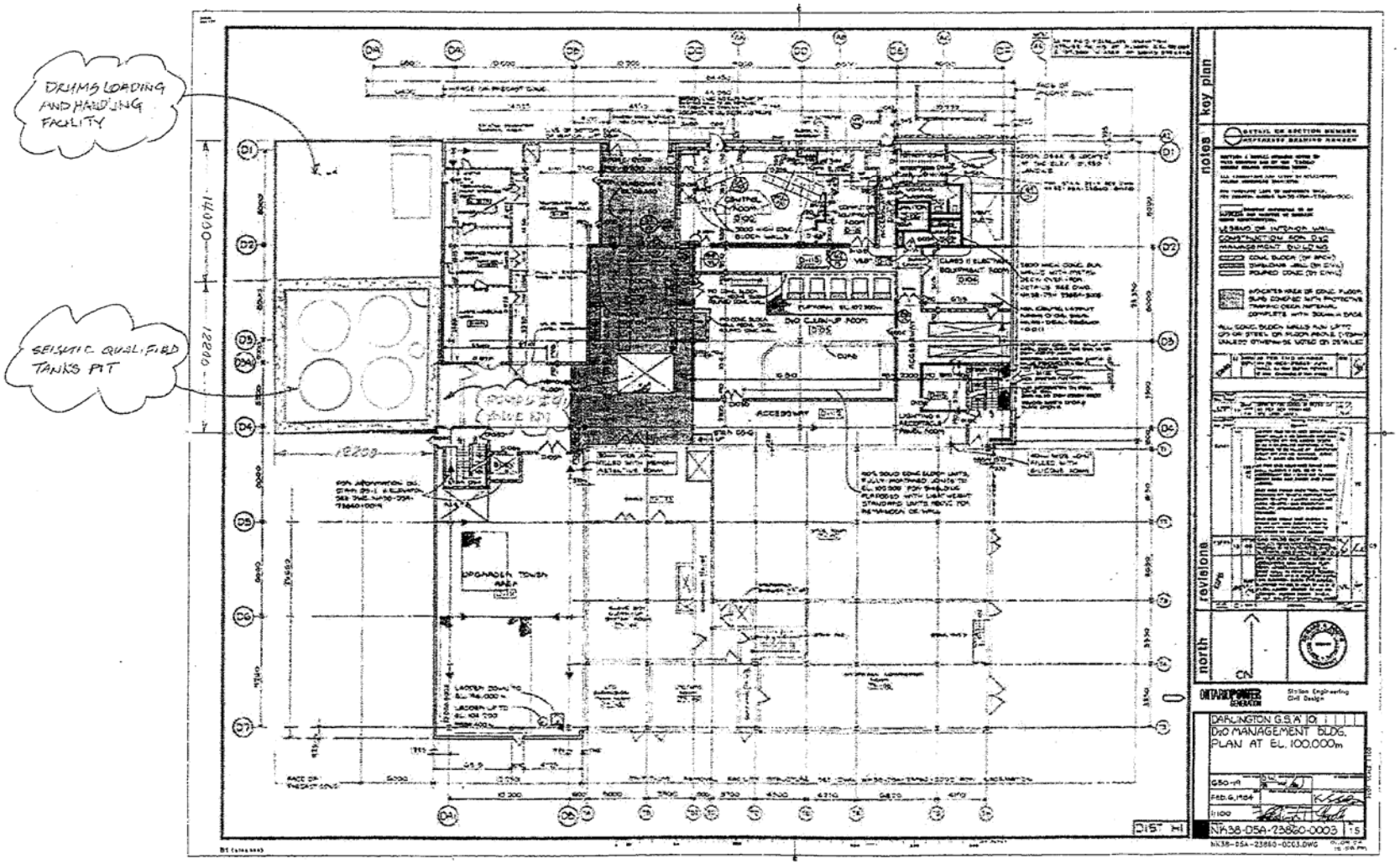


Figure 15. Sketch illustrating size of extension to Heavy Water Management Building and the location of the additional heavy water storage tanks and new drum loading and handling facility.

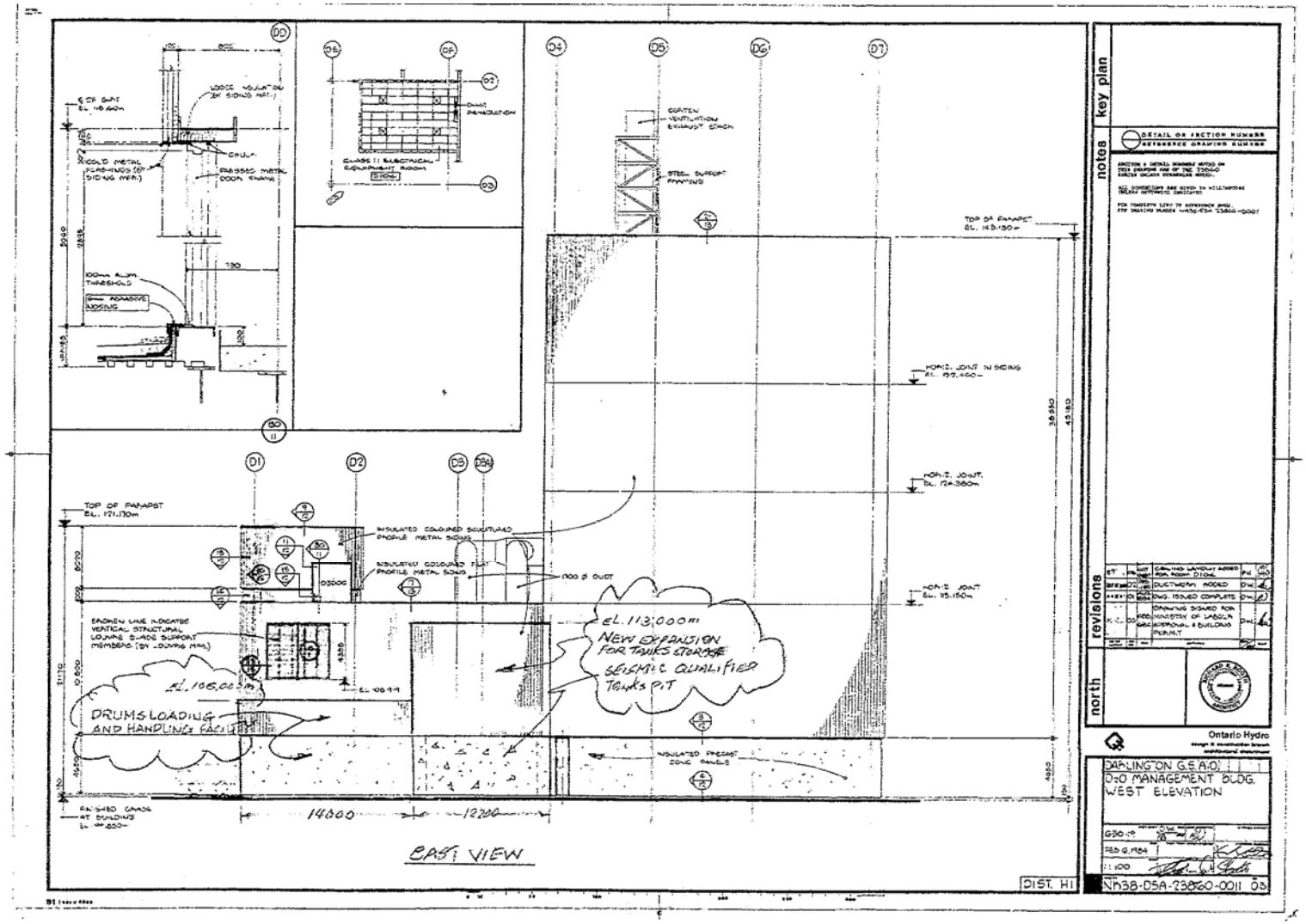


Figure 16. Sketch illustrating east view of proposed extension to Heavy Water Management Building.

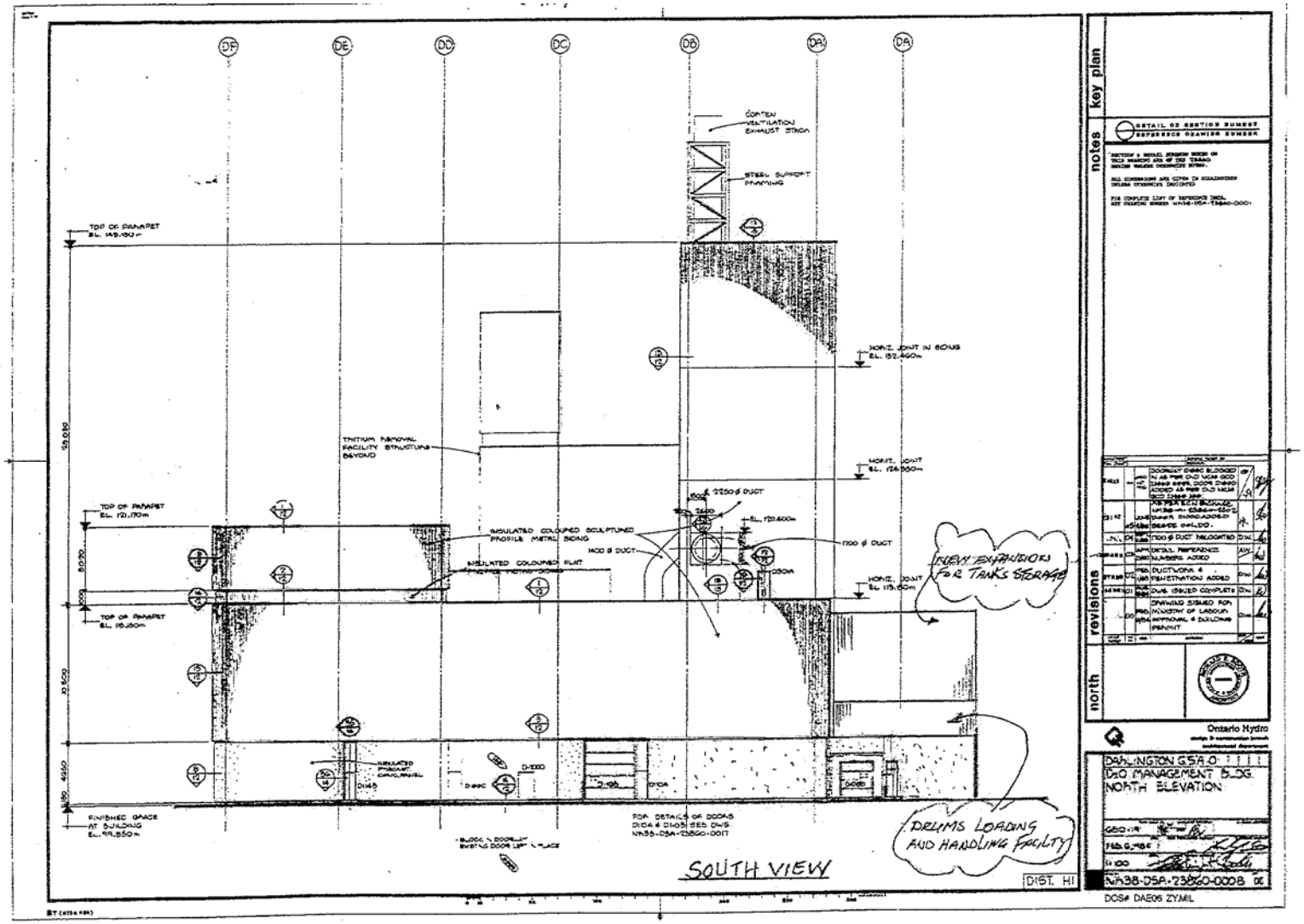


Figure 17. Sketch illustrating south view of proposed extension to Heavy Water Management Building.

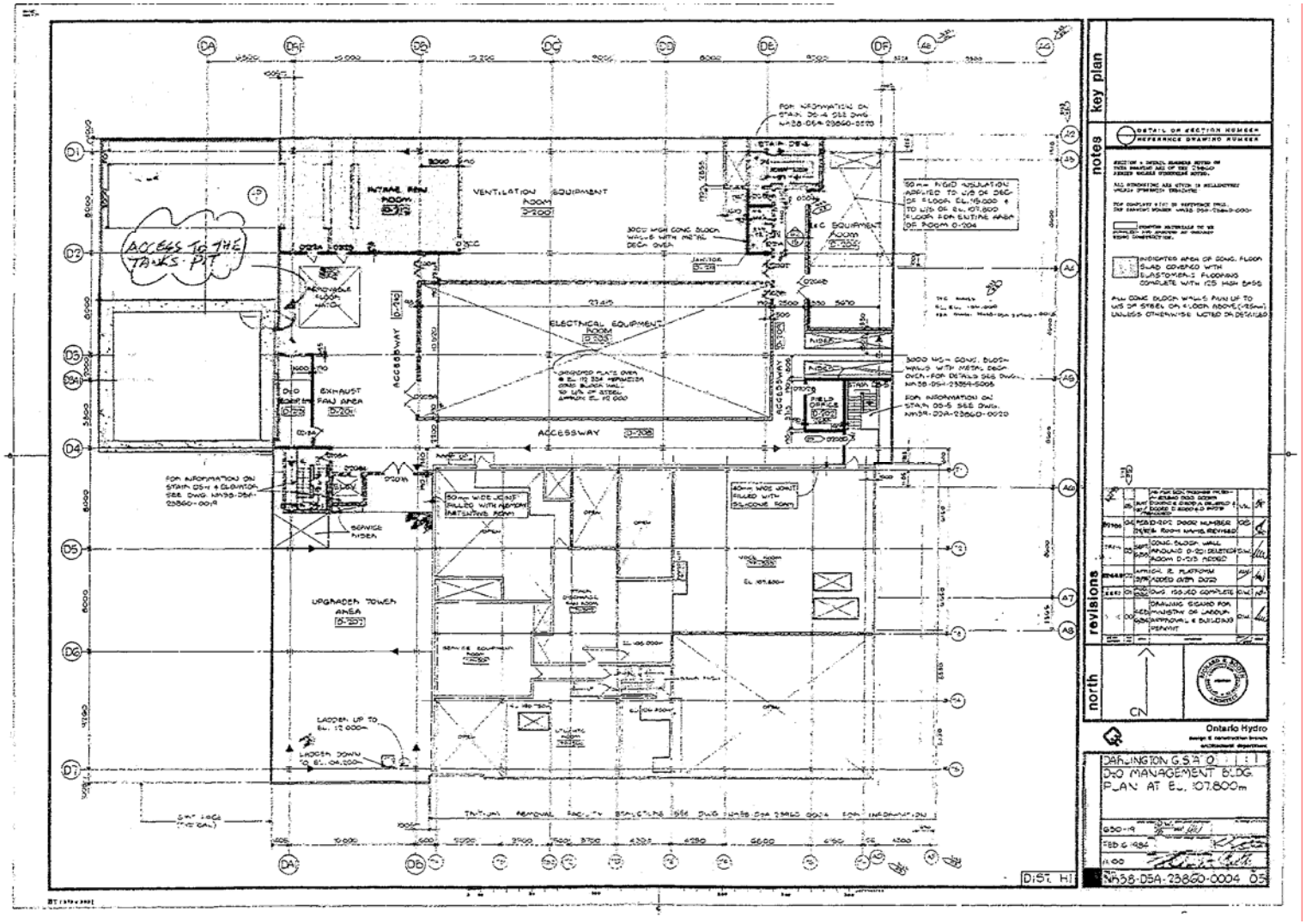
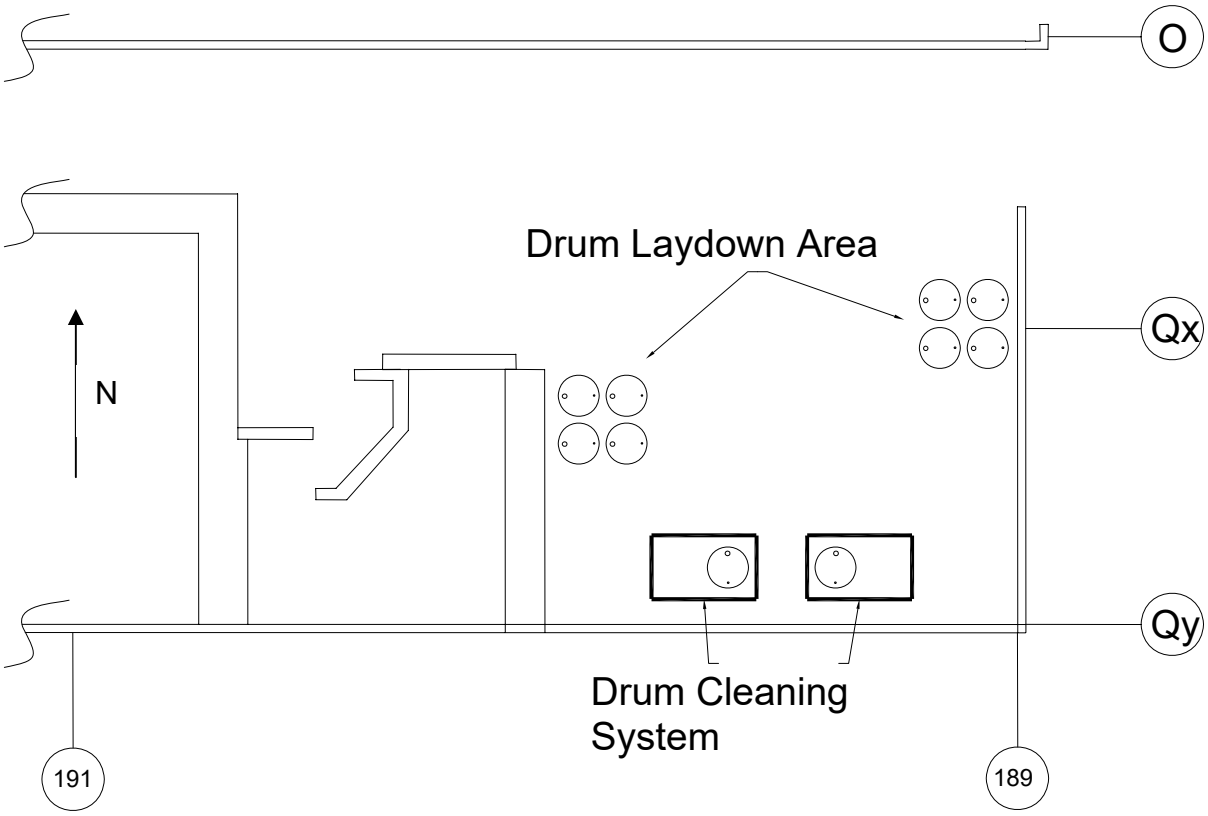
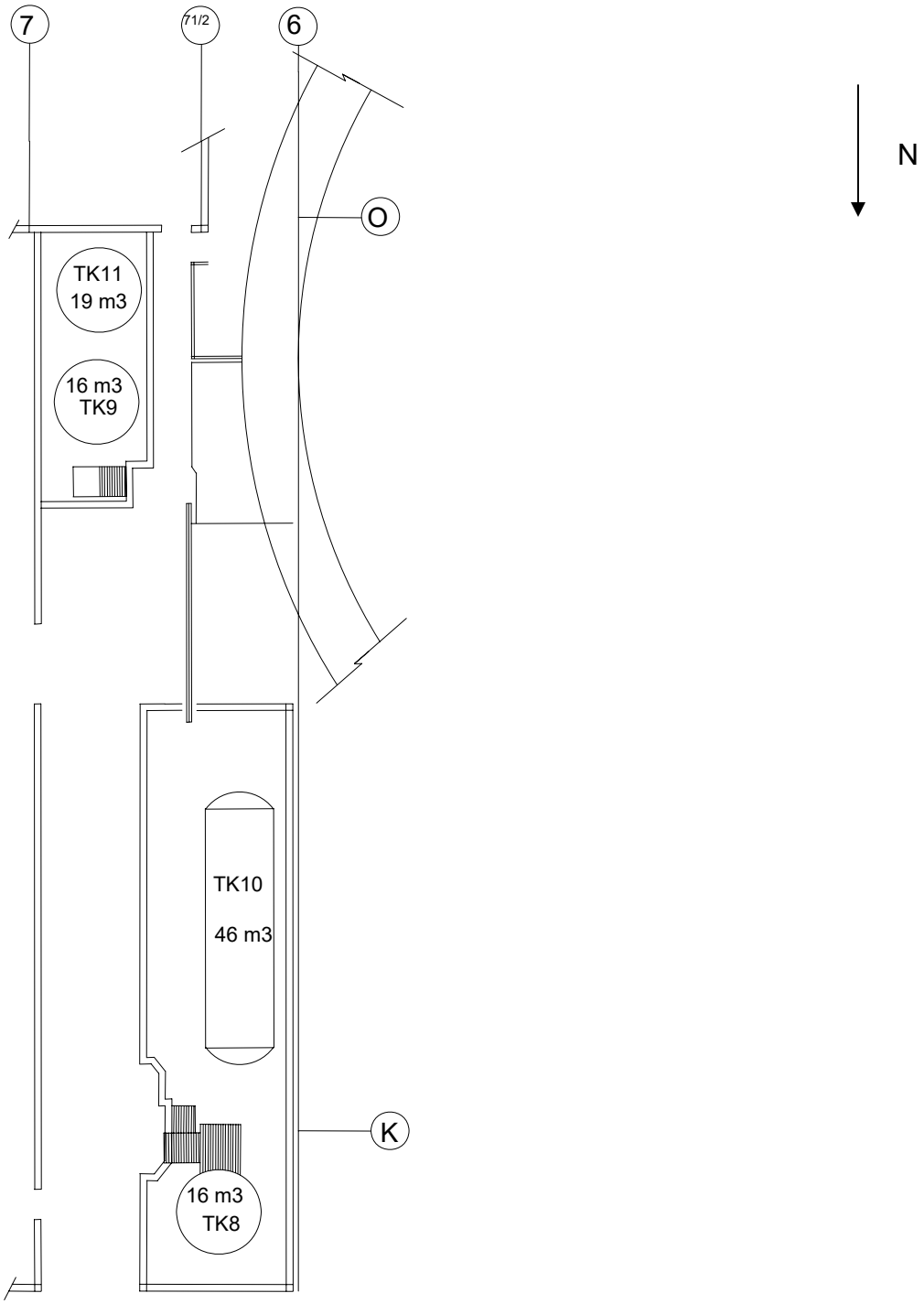


Figure 18. Sketch illustrating access to tank pit from present Heavy Water Management Building to proposed extension.

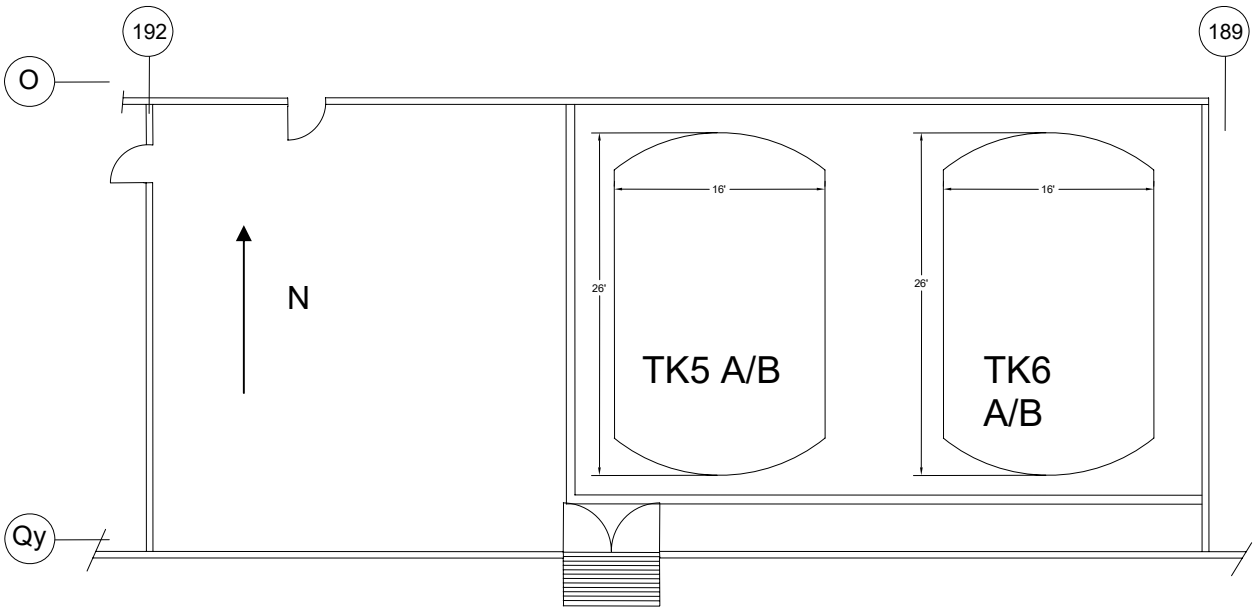
17. APPENDIX G – Sketch of Proposed Location of Drum Cleaning Facility at PND



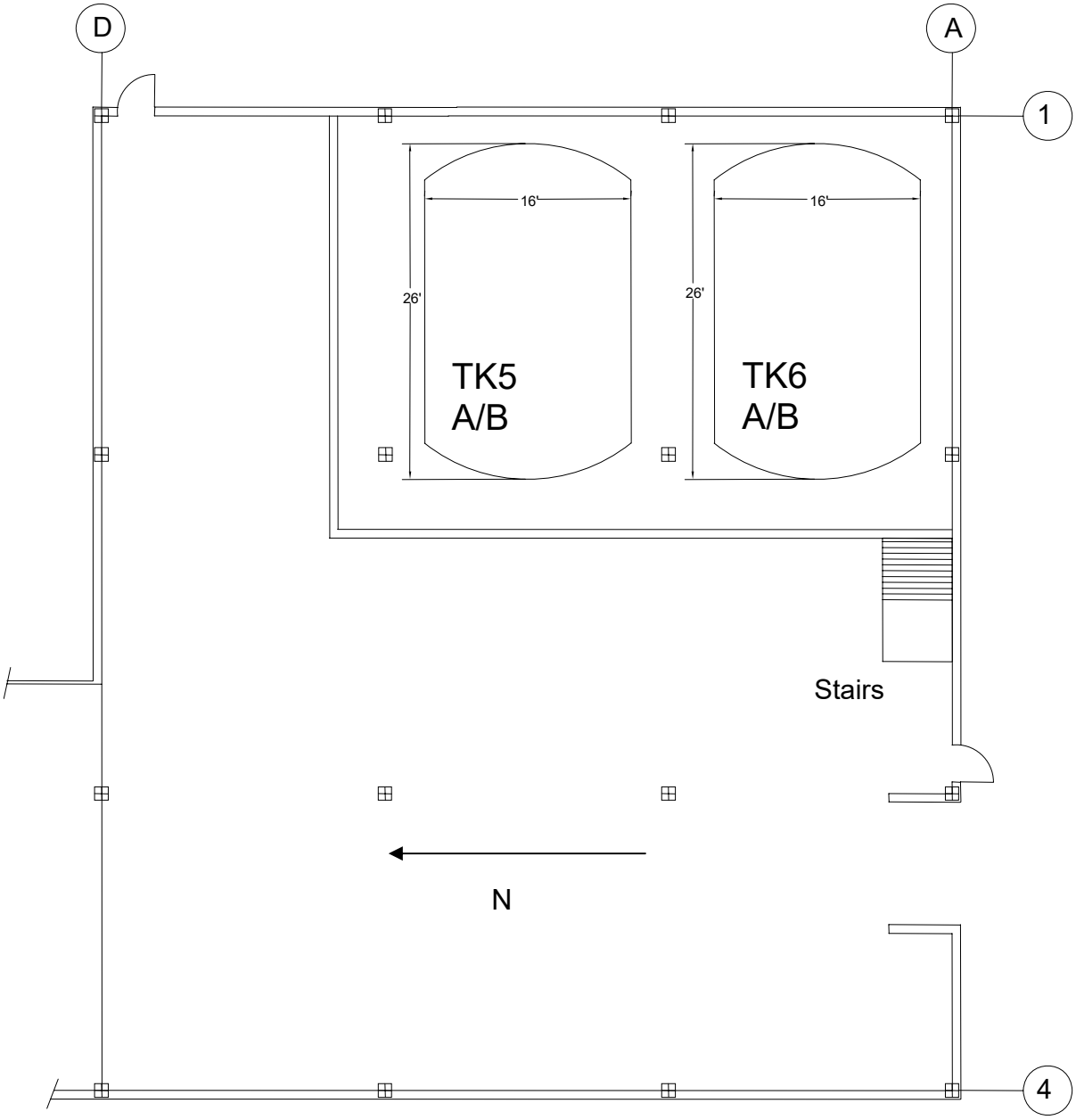
18. APPENDIX H – Sketch of Proposed Location of IXCU Additional Storage at PND



19. APPENDIX I – Sketch of Proposed Location of Additional Storage S&I Storage at PND: HVAC Room



20. APPENDIX J – Sketch of Proposed Location for Additional S&I Storage at PND – UPPA



21. APPENDIX K – DND Plant Walkdowns and Interviews

At least two walkdowns of the TRF/HWMB were conducted to review the current layout of equipment and explore possible locations for new tankage and drum handling/cleaning facility. Following the first walkdown, a meeting was held with attendees to review the walkdown and discuss any further D_2O storage and drum handling issues.

WALKDOWN

1) Access way (D112)

This access way sometimes is full with heavy water drums arriving from overseas sources, e.g. Japan. Drums have to be stored here since every other available space is deemed to be used up. This is creating an access hazard.

2) D_2O Clean-Up Room (D103)
   a) This room housed the D_2O Clean-Up IXCU equipment and TK12/13 tanks. Drums in this room are currently all from DND. This room is fully occupied. There is no additional space available for any other use.

3) Drum Handling Room (D107)
   a) Drums are filled in this area for external sales.
   b) The UV equipment is set up in this room.
      i) One of the operational issues is that after water has been treated by the UV system it may need to go back to the downgraded dirty tanks for re-processing through the IX columns to remove impurities that are created during the UV oxidation process. This can cause a bottle neck in the system if space is not available.
      ii) A small separate IX column dedicated to this process could eliminate this issue (this is outside the scope of this project)
   c) Fume hood and emergency shower and eye washer basin is also available in this room.
   d) There is a possible space available for drum cleaning up equipment to be located in this room, next to the door, leading to the loading bay.
   e) There may be other areas in this room for drum cleaning equipment, but it involves relocating some equipment.
   f) There is a mechanical storage room within this room, which can be used for housing the drum cleaning equipment, if this room is available.

4) Loading/Unloading area (D108)
   a) This area is always used for drum holdup storage, which blocks normal access loading/unloading purpose.

5) Upgrader Tower Area (D111)
   a) This area housed the upgrader towers, there is a small space accessible inside this area, which is required for access and maintenance purpose.
   b) This space is currently used for temporary drums storage use.

6) Access way (D021)
   a) This area is also fully loaded with temporary drums.

7) Off Gas Recombiner area (010)
   a) This room is very small, and very little practical use. This room is not in service.

8) D_2O Supply Tanks Area (D001)
   a) These are seismic qualified tank floor. There is no more room for any additional use.

9) Off Gas charcoal tanks basement, El 87m (D002)

a) This room approx 7m x 16m and is only accessible via a stairwell and through a small hatch (2.2m x 2m) in the ceiling (94m El). To access this hatch would also require removing a section of concrete floor from the 100m El and removing the steel ceiling and I-beams below this floor.
b) There may be room for one 100 to 150 m^3 tank. But it would be costly to dismantle and remove the existing carbon steel tanks and costly to install new tanks. New tanks must be prefabricated then re-installed and welded piece by piece in-situ since this room is not accessible for a complete tank assembly due to the small access way. This also means that this area can not be used for Class 3 tanks due to the fabrication and testing requirements of class 3 tanks. Working conditions would be difficult and it may be hard to find a manufacturer willing to do it. Also need to check with civil about the floor design loading.

10) Extension of the West end of the HWMB next to the Loading/Unloading Bay
a) This area provides a possible extension to the existing HWMB. The required area for building extension must include the dismantling of the existing truck loading bay and its loading deck/receiving area housing/office.
b) For new truck receiving door, the door front shall be facing at angle (approx 30 to 40 degree to north) to ease truck decking with the receiving bay. Also the decking/receiving/drums loading bay shall be provided with hydraulic lifting platform/or lifting devices to haul the ISO from the truck to the receiving floor.
c) The building height on the receiving/drum loading areas shall be restricted a few feet below the fresh air intake louver (107.8m El.) on the adjacent building, but beyond the louver, the building height shall be constructed to house the tall vertical tanks.
d) The number of the tanks to be determined upon the confirmed total storage requirements from DNGS.
e) S&I tanks are currently below grade and gravity fed from the plant, due to design constraints. If new tanks are built above ground we would need to confirm the ability to pump D_2O from the station to the new tanks.
f) Installing new tanks below grade would require extensive excavation immediately next to the current HWMB foundation. Construction issues would have to be further investigated.

MEETING

The notes of the meeting are as follows:

2) PHT D_2O storage requirements.
a) With all units running 210Mg of HT quality D_2O required to be in storage.
b) Can this D_2O be stored at each unit, i.e. 55 Mg storage tank at each unit?

3) Project scope reviewed
a) Aileen Sullivan has the action to confirm whether the D_2O storage requirements to support SCO (2008 and/or future SCOs) are included in the scope of the project, and to provide the rationale and valid data to support this requirement for each SCO.
b) Mario has confirmed that Station Life Extension and Decommissioning are not part of the scope of this project.
c) Is Re-Tube considered Life Extension or is it part of the DND plan to meet expected plant life?
i) DND is planning on completing Re-tube in 10 to 12 years. DND personnel believe that D_2O storage requirements to accommodate the Re-Tube of 1 unit at a time should be considered as part of the scope of this project. This requirement is approx. 700 Mg (plus the requirements to keep 3 other units running)

22. APPENDIX L - Meeting with Common Services Operations

Attendees:
CS OPS: F.Drepaul (for D.Topolnisky); G.Kaulessar; G.Walker
Projects: E.Wong; T.Leung
Kinectrics: A.Antoniazzi
Sponsor: C.Foster

Date: June 8, 2006

Hi-Lites:
1. Additional IXCU Tanks:
a. Obtained agreement that the increased capacity at IXCU for Low Ci (both oily & non-oily) are adequate;
b. G.Kaulessar advised the project that the additional capacity proposed at IXCU for Hi Ci (both oily & non-oily) are inadequate. He indicated that the information from N-REP-03861-10000 "Upgrading Capability in OPGN" used by Kinectrics to calculate the additional capacity is too conservative, and did not take into consideration the following OPEX, even though such OPEX were not documented. His advise is to use the OPEX to further increase Hi-Ci capacity by 30%.
* The "acute" (either volumetrically & qualitatively) water recovered are normally drummed, and were not documented as part of the present total annual water recovered.
* The % isotopic in the recovered water is recently at 20% to 25% vs 33% as indicated in the report.
* Presently, drumming of downgraded Hi-Ci water will start to occur if Sulzer is shutdown by 1 wk. This indicates more leakage is occurring from the moderator than what was indicated in previous reports.
c. Discussed various cost benefits & justification for the additional tankage at IXCU, and obtained consensus that enough "quantitative" information are available.
2. New Drum Cleaning Facility:
a. Discussed various cost benefits & justification for the new Drum Cleaning Facility at PND, and obtained consensus that enough "quantitative" information are available.
3. Additional S&I Tanks:
a. CS Ops agreed that the "quantitative" cost justifications for new S&I tanks are not readily available, and project may have to use the "qualitative" reasoning as business drivers.
b. Following potential cost benefits were discussed, but are inconclusive as to whether they can be used as business driver(s):
* The benefits in shortening outages with the capability to simultaneously drain the moderator & PHT from the same unit are indeterminable as this scenario had never been tried, and may not be feasible due to heat sink concerns.
* Similarly, the benefits to shorten outages with the capability to simultaneously drain the moderator from a PB unit & PHT drain from a PA unit are indeterminable as this scenario had never been tried.
* The present mode of detritiation using on-line swap is inefficient & costly, and the station is always firefighting to keep the tritium level in all its units to be within spec. This is because on-line swap can only be performed in quiet mode, usually over week ends or utilize overtime. There will be certain amount of OM&A savings if this is changed to off-line swap.
* The additional tanks will provide the flexibility to perform

off-line swap. The cost benefit can be from OM&A savings as mentioned above, ALARA & fuel burn-up. However, calculations of the ALARA savings from reduction of tritium level inside the reactor are not available yet, and the savings from fuel burn-up due to improved isotope are still required to be calculated.
(Note: CS OPS also indicated that with the additional tanks, the off-line swap can be achieved within the "40 days outage", which otherwise will not be achievable.)

Actions:
1. Issue email & obtain agreement from G.Kaulessar to document the revise assumptions for Hi Ci downgraded water.
* Actioned: A.Antoniazzi TCD=June 13, 06
2. Provide historical yearly consumption rate for resin & NUPAC.
* Actioned: G.Walker TCD=June 13, 06
3. Provide upgraders' unit cost (ie: $/Kg-fluid processed) so that the reduction of upgraders' efficiency can be used to calculate cost benefit.
* Actioned: G.Walker TCD=June 13, 06
4. Provide unit cost benefit from detritiation via ALARA & emission (ie: $ savings to production/outage per Ci/Kg reduction) .
* Actioned: F.Drepaul TCD=June 13, 06

23. APPENDIX M – PND Walkdown Notes

The following are locations within PND review as potential locations for additional tank storage and drum cleaning facilities. The notes are a summary of walkdowns performed on April 7, 2006 and April 25, 2006.

1st Location (potential tank storage):

'Obsoleted' HVAC Rm –274' behind south CM Shop
Area approximately defined by rows O and Qy and lines 189 to 192 on drawing NK30-D5A-24000-0053 (35 x 84 sq. ft, height ~17.5 ft)

- Full of specially constructed HV systems to be removed. It can be done in small sections using present door otherwise one wall will required opening.
- Equipment removal (paperwork) should be easy because never commissioned
- Will need reinforcement to floor and structure to accommodate extra HW storage
- Small heating/ventilation will be required (add/or modify to provide coverage for room)
- Will have to temporarily remove bean by double door to have equipment access
- Active drainage system available for this area and the area below
- 7' wide door
- tank(s) will require to be laid on side
- south wall can be removed for tank access
- up to 3 100 m^3 tanks could be accommodated

2nd Location - Insulation shop – 274' (potential tank storage). Area is east of the present S&I tank locations in Reactor Auxiliary Bay near Unit 5. In reference drawing NK30-DFA-22000-0006 the area is defined by lines L to O and columns 184 and 191.

- next to S&I tanks
- have to investigate floor loadings and structure requirements
- present equipment easy to remove, very little fixed equipment
- active drainage required?
- have to add wall to separate from office side
- one 100 m3 could be accommodate on its side

3rd location - Visited S&I tanks on 254' elevation.

- 2 x 150 Mg
- 2 x100 Mg

4th location (potential drum facility) - PIOTS and Solid Waste Handling

- power available
- remove present system, not used
- is their active drain?
- Excellent place for drum facility
- Air available
- Door available to separate from solid waste handling
- Obtain dimensions from drawings

5th Location - Space below HVAC shop

- Ceiling will require reinforcement

- No trucks drive in
- What is below floor?
- What is present floor loading capacity?

6th Location - Decontamination Shops (N&S) (possible drum facility)

- Jay Joyce (ext 5332) contact person
- Approved for 0.5M$ in modifications
- Runs 7 days wk with overtime to keep up
- Would need a separate work group for drums
- Extension to RV shop
- Space utilization varies but significant activity
- Not a practical place for drum facility

9th Location - Area by NUPAC (potential tank(s) location)

- Below IXCU
- Slur pump out - have to maintain access
- HX501 location need to leave room for maintenance and replacement of components
- Has bay doors to let tanks in
- At ground level
- Have to move resin container (NUPAC?) back away from bay doors to free up space
- Intake channel underneath where is it? Need drawings
- Possible to locate a 100m3 tank in this location with little modifications
- Active drainage?

10th Location - IXCU (potential tank location) – 274'

- ECN 963 was set to go in 1991, project ~3/4 done, tanks no longer available, all documentation not present, package outdated and has to be re-done
- 2x19 m^3, 1x50 m^3 and 1x25 m^3 tanks were to go in
- floor loading needs to be looked at
- good site
- area approximately defined by lines H and O and 8 and 10 on drawing NA44-06-21002-0058

Risks:

- Possible interferences for ECN 963 recommended tanks 018-34970-TK-9 and 018-34960 TK11
    - Fire hose cabinet (1-71410-FHC 62) [would be blocked by proposed TK9]
    - Door 0-24165-RAB 204 [would be blocked by proposed TK11]
    - Piping and Valves belonging to SCI 34970 [would be blocked by proposed TK9]
    - Existing 6" pipe at running from between 0-34970-TK3 and TK4 through the walls east of the proposed TK9
    - Tygon hoses (for venting) that are tied onto the aforementioned 6" pipe
    - Existing D2O Transfer Lines at 286'-6" [north of proposed TK9]
    - Fume Hood, (not shown on drawings), located north of double doors leading into the IXCU room.
    - The corridor between the Reactor building and the west wall of the IXCU and Resin deuteration area is a seismic route, marked on the floor with grey paint
        - The proposed tank location for TK 8 and TK 10 will sit right on top of the seismic route
            - Not a big issue, since drawings will only show the seismic route as a straight line leading out the door at Line O-8. We can just

repaint the seismic route after the installation and move it over for about 1 to 1.5 feet.

- Possible interferences for ECN 963 recommended tanks 018-34970-TK-8 and 018-34960 TK10
    - TK 10 is 34'-2" in length. It may have difficulty clearing the corners of the corridor.
    - The location of proposed tanks is currently taken up by drums to be processed by IXCU, forklifts, and a Herfurth monitor. We would need to find an alternate location for these in order to use this space.
    - 018-34970-TK8 is right beside MCCs.
        - Must have reviews to make sure any accident scenario at the tanks will not impact the MCCs
        - During the transport of tanks into their proposed locations (especially TK10), care must be taken to not hit the MCCs

Other Installation Risks Identified

- The closest hatch is at Unit 1, 274', the crane can lift up to 30 tonnes at Grid H22
- A lifting beam (adjustable) maybe required to lift tanks horizontally from 254' to 274'
- To move tanks from the horizontal position to the vertical position (as required) a lifting beam and hoist may need to be installed on 274' at each tank location.
- May not have the clearance to lift into the vertical position for the proposed TK 8 and TK 9
- Depending on the weight of the tanks, the floor on-route [from the hatch the to the IXCU area] may have to be reinforced
    - The floor on-route may be peeled if the tanks are too heavy
        - May need a ¼" plate on the floor to prevent floor peeling
- Reinforcement of the floor of 274' at IXCU is required
    - Scaffolding is required at 254' to reinforce the floor of 274' (increased costs)
- Work area may interfere the Equipment cage belonging to John Weigand's group and the NUPAC tank (collects spent resin)
        - Need to coordinate work activities with Maintenance and Operations
- The location of TK8 is currently in the Zone 2 area [boundary at K-line]. If ECN 0963 were to be installed, Zone 3 will have to be extended to between the H-Line and the K-Line.
        - Need Radiation Protection's concurrence

11th Location - Off Gas Building (potential tank location)

Located in the unzoned area at elevation 254'. The building has never been commissioned. The reference drawing is NK30-DFH-79320-00001.

- pipes already running from U2 to off gas building via vacuum building
- piping maybe carbon steel will need upgrading to stainless steel
- building not being used
- non-radioactive building in unzoned space
- 7 carbon steel tanks presently in there need to be removed
- wall will require breaking to move tanks in
- heating and ventilation appear present
- floor drains appear to go to a ditch in the surrounding yard.
- Could probably place 1x150Mg tank
- Ground floor no problem with loading
- Non-operational area, least impact

Additional Notes: Earthquake loading was never considered according to Design Manual NK30-291000 (Off-gases Building and Service Duct, 1977). Some minimal earthquake resistance is considered to exist.

General discussions while in Off Gas Building

East Annex discussed
- Ventilation problems
- FM want the area
- IMS using part of it

West Annex discussed
- U2&U3 staging area
- Heavily utilized
- Two active drain tanks

Drum Facility
- Drum cleaning makes sense to have on 274'. Most drums handled in 274'.

Visit to drum storage area

Most dirty drums contaminated by maintenance, operations. Drum cleaning facility would not have alleviated most of the dirty drum/water problem.
IXCU problem – inability to handle high Toc, detergents

12th Location - UPPA/UPPB (potential storage tank location)

- 5x50Mg carbon steel tanks for dirty, downgraded water
- floor area may need reinforcement
- will need containment dike
- first impression – last option for additional tank storage
- UPPA area asbestos present
- Has active drainage
- Services, power, heating /ventilation available, also stack monitor

24. APPENDIX N – PND Stakeholder Meeting Notes

Date: April 11, 2006
Time: 9:30 am
Location B2 Projects Building PND
Attendees: James Bryant, Ghaman Kaulessar, Glenn Walker, Armando Antoniazzi, Edmond Wong, Tracy Leung

General comment was provided that Pickering not doing well managing its heavy water inventories due to the lack of storage and drum cleaning facilities. With Units 2 and 3 shutdown, operationally managing the heavy water anticipated to be easier but there is still the need to accommodate the heavy water.

There are three areas in HW management that need help: IXCU, S&I and drums.

A past engineering change notice, ECN 963, went into great detail into these heavy water management problems. The ECN 963 package was ready for field execution. It is the general feeling of Operations and Engineering that the recommended heavy water storage volumes outlined in ECN 963 for the IXCU would, if implemented, be sufficient to address their needs (one – 50 Mg, one – 25 Mg, two – 19 Mg). In the period of 1993 to 1995 because of priority setting and financial restrictions the ECN was cancelled.

There are now over 3000 drums at PND. The lack of HW storage capacity at the IXCU has led to an increasing number of drums being utilized for downgraded, dirty, water. Additionally, the lack of HW storage at the IXCU prevents the proper segregation of oily downgraded water from vapour recovery water subsequently reducing the throughput of the IXCU system. The slower throughput of the IXCU system further exacerbates the storage problem resulting in additional storage utilizing drums; at times dirty drums. The lack of drum cleaning services results in the re-usage of dirty oily drums for storage of downgraded vapour recovery. The reduced throughput of the IXCU, due to the need to process downgraded oily water, limits maintenance on the IXCU feed, storage, tanks. Having never been cleaned all the IXCU feed tanks are oily. Even if the one of the tanks was cleaned the lack of storage will inevitably lead to oily HW been pumped into the clean tank. This inability to segregate downgraded oily water from vapour recovery water results in poorer performance of the IXCU system, lost revenue by having to clean oily vapour recovery water, increased labour and worker dose associated with drumming and efforts to find storage were ever possible, inability to perform system maintenance which will ultimately force an unscheduled system shutdown, and threatening the performance of the upgrader. The high TOC water entering the upgrader leads to the degradation of the upgrader packing and subsequently the efficiency. The upgrader packing is very expensive to the extent it was suggested that a whole new upgrader be built.

Oily water at Pickering is inevitable because of oil used in the fuelling machines.

The collapse of 0-34970-TK1 (Hi-Ci oily tank 2.3 Mg) is attributed to the plugging of the vent system by charcoal and resin (P-2006-01032). The contribution factor was the inability to perform maintenance on the system due to the lack of storage capacity. (*is this correct?)*

IXCU is capable of processing at 400 kg/hr versus the present rate of ~150kg/hr (*confirm both numbers*). The lower processing rate is due to the oily nature of the feed water which consumes resin and charcoal at a much higher rate.

In 1991 PND was restricted to a 6 month operating license. The #5 item on the list of reasons why was the number of drums at the station. The lack of storage at IXCU is one of the reasons why there exists a large number of drums. A report which looked at the minimization of HW

drumming at PND-A was identified, CNS-IR-38000-14, 1987. Drum cleaning is essential in order to prevent vapour-recovery water from becoming oily when the lack of storage at IXCU forces usage of drums for storage. This has happened where downgraded, non-oily, water has been placed into oily tanks. The result is the extra processing time and materials costs for removal oil from the HW which wasn't there when collected.

It was indicated that a drum cleaning capable of processing 10 drums/day would be sufficient for PND needs. PND envisions a drum inventory of about 1000/yr will be required for operational needs.

Contact Jack Page for information on dose to station personnel from drums.

Glen Walker can provide information of HW recovery rates.

Storage and Inventory has three objectives: one, water make-up for units; two, maintain quality (tritium and isotopic) and three, support outages. The systems have been designed to hold HW from 1 unit's PHT and 1 unit's Moderator. The system was not designed to support outage and normal operations concurrently.

To date there has been no impact on outages in terms of delay or extension because work arounds when there is a lack of S&I storage but other activities have suffered; for example, maintenance and TRF shipments. Two years ago the lack of S&I storage came close to postponing an outage. Valves passing increases storage to S&I tanks.

Three outages per year is expected to be case for the future with moderator drain and simultaneous HT drain to LLDS.

A simultaneous moderator and heat transport drain and the requirement to distribute water among S&I tanks, because of the lack of storage, to accommodate the needs increases the risk of mixing gallodinium containing moderator water and lithium containing heat transport water. The result of the mixing would lead to the production of a polymer which would plug up equipment and pipes.

Storage of PHT HW from Unit 2 and 3 in spent resin tanks unlikely because of potential for leaks and no means of monitoring. The result is this water will have to be accommodated somewhere (~280 Mg)

TDO shipments cost around $2500 per shipment. PND targets for TDO shipments is 3 shipments out and three shipments in per week. This target cannot be met during an outage because of lack of S&I storage.

Maximum benefit to worker dose and associated cost is the detritiation of the HT system because this is where the majority of the leaks arise from.

The administrative limit for PHT ready water on stand-by is 33 Mg (assumes a certain size gross leak plus normal leakage)

Recovery of HW presently in drums is estimated to be about 160 Mg while from UPPA around 30 Mg.

A low level drain state (LLDS) for the HT system requires about 100 Mg of storage and from a moderator system around 250 Mg.

There is no capacity in Unit 3 for storage but some capacity in Unit 2 (~95 Mg).

It was pointed out that doing a total volume of the water presently in the system and looking at the available storage volume leads to the erroneous conclusion that enough storage space is available. The reason for the incorrect conclusion is attributed to ignoring the fact that the HW with in the storage system is not all of the same quality (reactor grade, HT grade, Gd containing moderator HW, Li containing PHT HW). For example, once a storage tank is filled with Gd containing moderator HW the space is no longer available for usage. Or if HT ready water occupies 30% of the volume it can no longer be used for moderator water storage.

25. APPENDIX O – Seismic Requirements of Various Systems at PND

Below are the seismic requirements identified [39] during a preliminary review. A list of reference documents that govern the seismic qualification of systems, structures and components in Pickering A and B are also included at the end of the summary.

(1) East of D2O Supply Tanks (PB)
Elevation: 254'-0" (tanks are 20 ft in height)
Potential Tank Area: The area east of the supply tanks. [Line L to Line O, Between column 184 and column 185]
Note: The area cannot be impeding the D2O tankers that will come in through the loading area S559.
Reference Drawing: NK30-DFA-22000-0005

This location is in the PB Reactor Auxiliary Bay. According to [R-12] and [R-13], the RAB structure was deemed seismically adequate.
Seismic demand response spectra for PB are documented in Ref. [R-11].

(2) Ventilation Equipment Room (PB)
Elevation: 277'-4"
Potential Tank Area: Room S668
Note: Currently containing obsolete HVAC equipment
Reference Drawing: NK30-D5A-24000-0053

This ventilation equipment enclosure is constructed on top of the solid waste handling facility, which was constructed to the following seismic requirements:
Ref.: Design Manual NK30-24000, Addition to Service Wing for Solid Waste Handling Facility. Section 5.0 Seismic Requirements:
Except for the siding on the South side, the building structure does not need to be seismically qualified. The south wall siding shall be seismically qualified for design basis earthquake (DBE) [R-11]. The structure shall not produce negative impact on the seismic capability of the pressure relief duct (PRD).

Seismic demand response spectra for PB are documented in Ref. [R-11].

(3) IXCU Area (PA)
Elevation: 274'-0"
Potential Tank Area: East of unit 1, IXCU Footprint [Between Lines H and K to Line O, column 6 to Column 9]
Note: Cancelled ECN 0963
Reference Drawing: NA44-0G-21002-00058

This location is in the PA Reactor Auxiliary Bay (RAB).
According to [R-3], the PA RAB structure was assessed to be to be seismically adequate. It should be noted that masonry walls (a typical seismic liability) in the vicinity of any structures, systems or components (SSC's) on the success path were evaluated and upgraded if necessary. The same needs to be followed for new SSC's. Seismic demand for PA is characterized by the floor response spectra in Ref. [R-6] and [R-3].

(4) UPP- A (PA)
Elevation: 274'-0"
Potential Tank Area: Line A to D, Columns 1 to 4

Note: All equipment in UPPA, with the exception of certain piping and feed tanks, are not in use, and can be removed.
Reference Drawing: NA44-EMG-34600-00004

Ref. Design Manual NA44-29800, Heavy Water Upgrade Plant Building, Nov. 1971.
This design manual does not stipulate any seismic requirements.
The building is not on the success path evaluated in Ref. [R-3].
Seismic demand response spectra for PA are documented in Ref.
[R-6] and [R-3].

(5) Off-Gas Building (PB)
Elevation: 254'-0" (outside the plant)
Potential Tank Area: Entire Building
Note: This building has never been commissioned.
Reference Drawing: NK30-DFH-79320-00001

According to Design Manual NK30-29100 (Off-Gasses Building and Service Duct, April 1977), earthquake loading was considered in design.
No details are available on the extent or the level of seismic loading and according to Operations, the building was never commissioned. It would be conservative to assume that the building has some inherent minimal earthquake resistance (as per the National Building code at the time,1965). But since the building was never commissioned, seismic evaluation will have to be conducted based on PB DBE according to Ref.
[R-11].

References

[R-1] Control of Unsecured Equipment in Seismically Qualified Areas, OPG-N Procedure N-PROC-MA-0031.
Pickering A
[R-2] Engineering Direction on Evaluation Methodology for Seismic Impact of Plant Modifications, NA44-CORR-03652-0073548, January 30, 2004.
[R-3] Seismic Assessment of Pickering 'A' Nuclear Generating Station, NA44-REP-02004-0073, Feb. 1998.
[R-4] Administrative Controls for Seismic Qualification, NA44-REP-03650-00002.
[R-5] Seismic Capacity Preservation, Pickering 'A' Return to Service, AECL Implementation Guide No. 44RS-03650-IG-002 R02, December 2000.
[R-6] Floor Response Spectra (FRS), Pickering 'A' Return to Service, AECL Implementation Guide No. 44RS-20090-IG-001 R01, April 1999.
[R-7] Pickering A Safety Report, Section 2 Design Criteria, Subsection 2.3: Seismic Qualification and Classification,
NA44-SR-01320-00001 R11, July 2003.
[R-8] Control of Unsecured Equipment in Seismically Qualified Areas, OPG-N Procedure N-PROC-MA-0031.
[R-9] Abnormal Incident Manual, Common Mode Events, NA44-014-09013-6.
Pickering B
[R-10] Pickering B Safety Report, Section 2 Design Criteria, Subsection 2.3: Seismic Qualification and Classification,
NK30-SR-01320-00002 R01, June 2003.
[R-11] Safety Systems Engineering Design Guide No.
DG-30-68000-2, Pickering G.S. 'B' Seismic Qualification of Safety Related Systems.
[R-12] Safety Systems Engineering Design Guide Supplement No.
DG-30-68000-006, Pickering G.S. 'B' Seismic Qualification of Safety Related Systems: Reactor Auxiliary Bay Structure/2/21441/21451, Oct.
1980.
[R-13] Email from. C. Alexander to P.J. Armstrong Re: PB Seismically Qualified Structures, NK30-CORR-67100-0084852

Additional information on seismic systems [40].

If the modification is part of 38210 system, then the system shall be seismically qualified to meet (1) and (2). If modification involves containment penetration, then the lines and valves must also be seismically qualified to maintain contain boundary integrity. The services (e.g. instrument air, power for MV) to operate a seismically qualified valve during or after a seismic event must also be seismically qualified.

1. Engineering Design Guide DG-30-68000-2 Seismic Qualification of Safety Related Systems specifies:

* 38200 D2O Supply System qualified to DBE "A".
* Note 13 stated "The D2O supply system is to be seismically qualified only to the extent that there will be no loss of inventory from the bulk storage tanks."

2. Flow diagram NK30 FDH 38210 0001 and Design Manual NK30-38210 for D2O Supply System state:

* The D2O supply system is seismically qualified for a DBE Category A.
* Equipment Data Sheets (tanks and relief valves) in the design manual also show seismic qualification to DBE A.
* System Classification List for CNSC approval of Code Classification also shows system and tanks to seismic qualification DBE A.
* Notes on piping drawings do not specifically state seismic requirements. If the relief valves are seismically qualified, it is most likely that the piping is also seismically qualified.

3. 34960 - D2O Transfer System:

* Flow diagram NK30-FFH-34960-0001 marked seismic requirements for specific section (containment penetration) of the drawing.
* Design manual NK30-34960 states D2O transfer lines that penetrates RB wall and containment are seismically qualified to DBE A, isolation valves seismically qualified to DBE B.

4. 34970 - Moderator D2O Ion Exchange Cleanup System:

* No seismic requirements marked on flow diagramNK30-FFH-34970-0001. No seismic requirements stated in design manual NK30-34970.
* Equipment data sheet for strainer in design manual stated seismic qualification not required.

5. 38340 - 30TF-38340 Pickering Incoming/outgoing D2O Transfer System (PIOTS)

* Design Manual 30TF-38340 stated PIOT system is not seismically qualified.
* Seismically qualified dike is provided around tanks and pumps to contain a limited spill of tritiated D2O, but not a full tank.
* PIOTS tanks's supports are designed to withstand seismic loads equivalent to DBE A to prevent toppling of the tanks in the seismically qualified dike.
* PIOTS tank room wall are designed to withstand DBE A.
* Pickering B containment isolating valves are seismically qualified to DBE A or B.
* Pickering A containment isolating valves are NOT seismically qualified.

26. APPENDIX P – Personal Communications Emails

EMAIL 1.

From: BREMNER Shawn -NUCLEAR [shawn.bremner@opg.com]
Sent: Friday, May 19, 2006 2:28 PM
To: ANTONIAZZI Armando; LEE David Tw -DARLINGTON; SOOD Sav -DARLINGTON
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR; THAM Stephanie -NUCLEAR
Subject: SG fuel storage tanks
FYI

Dragana has done some research and determined that no building can be within 9m of the SG tanks, our current proposal is approx 24m from the fuel tanks so this will not be an issue. Dragana will issue an official memo by May 30th (she is on holidays next week)

Cheers
Shawn Bremner - OPG PNGS
Design Projects
905-839-1151 ext 2070
Pager 416-237-2802

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EMAIL 2.

From: WONG Edmond -NUCLEAR [edmond.wong@opg.com]
Sent: Friday, June 16, 2006 4:31 PM
To: ANTONIAZZI Armando
Cc: LEUNG Tracy -NUCLEAR; BREMNER Shawn -NUCLEAR; THAM Stephanie -NUCLEAR
Subject: Reasons for Lack of De-Tritiation Effort in PND.

Armando,

Here are some of the reasons Glenn gave me in regard to why PND was having problem to execute the "on-line" de-trit plan in the last few years....

1. Extended TRF outage (ie: in Y2003) & now;
2. S&I tanks occupied by moderator drains in PB units in the last few yrs preventing on-line swap; generally last about 6 wks per outage;
3. Before 2002, U4 moderator D2Or stored in S&I tanks to allow maintenance works to support PARTS. This lasted 18 mths, and prevented on-line swap.
4. There were some procedure issues that prevented "on-line swap" to be executed safely. This resolution took about 6 to 9 mths;
5. At times, there were planning (IOP) / resource (OPS & inventory) / schedule / co-ordination problems that prevented on-line swap;

I am a little troubled by what Sav said that DND has only 1 viable option to resolve the charter's objectives. I imagine other people could be troubled too. Example, just off the cuff, why can't the status quo of drumming or using external storage to support outages (such as SCO/VBO which occur every 6 yrs) as viable options, if it is cost effective.

Edmond

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EMAIL 3.

From: WONG Edmond -NUCLEAR [edmond.wong@opg.com]
Sent: Thursday, June 08, 2006 6:25 PM
To: TOPOLNISKY Dave -PICKERING; DREPAUL Fred -PICKERING; KAULESSAR Ghaman -PICKERING; ANTONIAZZI Armando; THAM Stephanie -NUCLEAR; LEUNG Tracy -NUCLEAR; FOSTER Charles -NUCLEAR; CORNACCHIA Mario -NUCLEAR; WALKER Glenn -PICKERING
Subject: Minutes & Actions: PND D2O Project - Cost Benefits

Attendees:
CS OPS: F.Drepaul (for D.Topolnisky); G.Kaulessar; G.Walker
Projects: E.Wong; T.Leung
Kinectrics: A.Antoniazzi
Sponsor: C.Foster

Date: June 8, 2006

Hi-Lites:
1. Additional IXCU Tanks:
a. Obtained agreement that the increased capacity at IXCU for Low Ci (both oily & non-oily) are adequate;
b. G.Kaulessar advised the project that the additional capacity proposed at IXCU for Hi Ci (both oily & non-oily) are inadequate. He indicated that the information from N-REP-03861-10000 "Upgrading Capability in OPGN" used by Kinectrics to calculate the additional capacity is too conservative, and did not take into consideration the following OPEX, even though such OPEX were not documented. His advise is to use the OPEX to further increase Hi-Ci capacity by 30%.
* The "acute" (either volumetrically & qualitatively) water recovered are normally drummed, and were not documented as part of the present total annual water recovered.
* The % isotopic in the recovered water is recently at 20% to 25% vs 33% as indicated in the report.
* Presently, drumming of downgraded Hi-Ci water will start to occur if Sulzer is shutdown by 1 wk. This indicates more leakage is occurring from the moderator than what was indicated in previous reports.
c. Discussed various cost benefits & justification for the additional tankage at IXCU, and obtained consensus that enough "quantitative" information are available.
2. New Drum Cleaning Facility:
a. Discussed various cost benefits & justification for the new Drum Cleaning Facility at PND, and obtained consensus that enough "quantitative" information are available.
3. Additional S&I Tanks:
a. CS Ops agreed that the "quantitative" cost justifications for new S&I tanks are not readily available, and project may have to use the "qualitative" reasoning as business drivers.
b. Following potential cost benefits were discussed, but are inconclusive as to whether they can be used as business driver(s):
* The benefits in shortening outages with the capability to simultaneously drain the moderator & PHT from the same unit are indeterminable as this scenario had never been tried, and may not be feasible due to heat sink concerns.
* Similarly, the benefits to shorten outages with the capability to simultaneously drain the moderator from a PB unit & PHT drain from a PA unit are indeterminable as this scenario had never been tried.
* The present mode of detritiation using on-line swap is

inefficient & costly, and the station is always firefighting to keep the tritium level in all its units to be within spec. This is because on-line swap can only be performed in quiet mode, usually over week ends or utilize overtime. There will be certain amount of OM&A savings if this is changed to off-line swap.

* The additional tanks will provide the flexibility to perform off-line swap. The cost benefit can be from OM&A savings as mentioned above, ALARA & fuel burn-up. However, calculations of the ALARA savings from reduction of tritium level inside the reactor are not available yet, and the savings from fuel burn-up due to improved isotope are still required to be calculated.

(Note: CS OPS also indicated that with the additional tanks, the off-line swap can be achieved within the "40 days outage", which otherwise will not be achievable.)

Actions:

1. Issue email & obtain agreement from G.Kaulessar to document the revise assumptions for Hi Ci downgraded water.
* Actioned: A.Antoniazzi TCD=June 13, 06
2. Provide historical yearly consumption rate for resin & NUPAC.
* Actioned: G.Walker TCD=June 13, 06
3. Provide upgraders' unit cost (ie: $/Kg-fluid processed) so that the reduction of upgraders' efficiency can be used to calculate cost benefit.
* Actioned: G.Walker TCD=June 13, 06
4. Provide unit cost benefit from detritiation via ALARA & emission (ie: $ savings to production/outage per Ci/Kg reduction) .
* Actioned: F.Drepaul TCD=June 13, 06

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EMAIL 4.

From: WIGGLESWORTH J J -NUCLEAR [john.wigglesworth@opg.com]
Sent: Friday, June 09, 2006 11:23 AM
To: ANTONIAZZI Armando
Cc: DREPAUL Fred -PICKERING
Subject: RE: questions pertaining to tritium emissions from nuclear stations

Currently < 20 % of outage dose is attributed to internal tritium uptakes. The recommended monetary value for a rem saved is now $25,000 (#3 below).

The other part is complicated to explain. The Heat Transport system is a high pressure high temperature system which leads to more leaks as opposed to the lower temperature lower pressure moderator system. The Curie content in the HT is ~ 1.15 Ci/kg vs ~ 18.5 Ci/kg moderator systems. Our cold fingers give us approximate values of the %HT in the stack which is drawing on the air in accessible areas of the Reactor Buildings. Although are emissions are vary low the % of HT D2O going out to atmosphere is 96 %. During outages work is completed on both systems in a ratio of 90 % HT systems to 10 % moderator work. We assume that 90 - 95 % of our uptakes are due to HT system Curie content.

If 30 Megagrams (~ capacity of 6 boilers) of 1.1 Ci/kg Heat Transport D2O is replaced by 0.5 Ci/kg D2O this will reduce the net Curie content in the Heat Transport by 10%. This would save ~ 2.5 rem over the next year which is a net savings of $62,500 for the one outage. Since two outages occur per year this would save $125,000.

Outage dose is in the range of 20 to 30 rem for each of the past few outages.

Hope this helps, John.

-----Original Message-----
From: ANTONIAZZI Armando [mailto:Armando.Antoniazzi@kinectrics.com]
Sent: Thursday, June 01, 2006 11:46 AM
To: WIGGLESWORTH J J -NUCLEAR
Subject: FW: questions pertaining to tritium emissions from nuclear stations

John,

I have not heard from you on my original inquiry, see below. Should I address the questions I posed to you to someone else?

Thanks for your help.

Armando

Dr. Armando B. Antoniazzi
Nuclear Waste and Tritium Solutions
Kinectrics Inc.
800 Kipling Ave
Toronto, Ontario
Canada M8Z 6C4

ph: 416-207-6000 ext 6680
fax: 416-207-6094

email: armando.antoniazzi@kinectrics.com

-----Original Message-----
From: ANTONIAZZI Armando
Sent: Thursday, May 18, 2006 5:13 PM
To: 'WIGGLESWORTH J J -NUCLEAR'
Cc: 'LEUNG Tracy -NUCLEAR'; WONG Edmond -NUCLEAR; 'BREMNER Shawn -NUCLEAR'
Subject: RE: questions pertaining to tritium emissions from nuclear stations

John,

Could you answer some further questions?

During an outage dosage to personnel is estimated and eventually actual doses are measured. In general most of the dose is associated with tritium; is this correct? Is there a relationship utilized to calculate anticipated worker tritium dose that ties the dose to the tritium levels in the PHT and/or moderator systems. I know you can calculate the dose to a person from the MPC of tritium in the work area. Is there a tie to the Ci/kg in the PHT or Moderator system.

Specifically, I am looking to utilize the cost provided in #3 below. I would like to estimate the cost associated with worker dose (tritium related) received during outage work and whether that dose can be correlated with the tritium concentration in the operating systems. Also, what is the average total dose of all personnel(tritium related) during outages?

Help on this would be appreciated. Thank-you.

Armando

Dr. Armando B. Antoniazzi
Nuclear Waste and Tritium Solutions
Kinectrics Inc.
800 Kipling Ave
Toronto, Ontario
Canada M8Z 6C4

ph: 416-207-6000 ext 6680
fax: 416-207-6094
email: armando.antoniazzi@kinectrics.com

-----Original Message-----
From: WIGGLESWORTH J J -NUCLEAR [mailto:john.wigglesworth@opg.com]
Sent: Monday, April 10, 2006 10:51 AM
To: ANTONIAZZI Armando
Subject: RE: questions pertaining to tritium emissions from nuclear stations

#3. $10,000 / rem.

#4. Related to health effects of radiation and replacement cost for another worker to be trained up if the first worker approaches a dose limit and is restricted from doing radioactive work.

John.

-----Original Message-----
From: ANTONIAZZI Armando [mailto:Armando.Antoniazzi@kinectrics.com]
Sent: Friday, March 31, 2006 7:24 AM
To: WIGGLESWORTH J J -NUCLEAR
Cc: THAM Stephanie -NUCLEAR; WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: questions pertaining to tritium emissions from nuclear stations

John,

My name is Armando Antoniazzi and I work for Kinectrics. We have been contracted by OPG to examine the options for heavy water storage and drum handling. Would you be able to answer questions related to those issues that lead to tritium emissions to the environment and to worker dose. Specifically,

1. What is financial impact to OPG of increase or decrease in tritium emissions?
2. What is non-financial impact to OPG of increase or decrease in tritium emissions?
3. What is the dollar value associated with dose?
4. Is this value related to lost worker hours or health?

I will follow up with a telephone call to you.

Thank-you for your time.

Armando

Dr. Armando Antoniazzi

Nuclear Waste and Tritium Solutions

Kinectrics Inc.

800 Kipling Ave

Toronto, Ontario M8Z 6C4

ph: 416-207-6000 ext. 6680

email: armando.antoniazzi@kinectrics.com

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EMAIL 5.

From: ALY Nasser -NUCLEAR [nasser.aly@opg.com]
Sent: Friday, May 19, 2006 3:19 PM
To: WONG Dominic -NUCLEAR
Cc: LEUNG Tracy -NUCLEAR; WONG Edmond -NUCLEAR; ANTONIAZZI Armando
Subject: Preliminary Seismic review of Potential Locations for D2O Tank Installation

Dominic,

As discussed during the project meeting, I conducted a preliminary review on the seismic requirements for potential locations for D2O storage tanks (locations identified in an email by Tracy, attached below). The findings are summarized below. A list of reference documents that govern the seismic qualification of systems, strcutres and components in Pickering A and B are also included at the end of the summary. This information should assist Kinectrics with their conceptual/costing study.

(1) East of D2O Supply Tanks (PB)
Elevation: 254'-0" (tanks are 20 ft in height)
Potential Tank Area: The area east of the supply tanks. [Line L to Line O, Between column 184 and column 185]
Note: The area cannot be impeding the D2O tankers that will come in through the loading area S559.
Reference Drawing: NK30-DFA-22000-0005

This location is in the PB Reactor Auxiliary Bay. According to [R-12] and [R-13], the RAB structure was deemed seismically adequate.
Seismic demand response spectra for PB are documented in Ref. [R-11].

(2) Ventilation Equipment Room (PB)
Elevation: 277'-4"
Potential Tank Area: Room S668
Note: Currently containing obsolete HVAC equipment
Reference Drawing: NK30-D5A-24000-0053

This ventilation equipment enclosure is constructed on top of the solid waste handling facility, which was constructed to the following seismic requirements:
Ref.: Design Manual NK30-24000, Addition to Service Wing for Solid Waste Handling Facility. Section 5.0 Seismic Requirements:
Except for the siding on the South side, the building structure does not need to be seismically qualified. The south wall siding shall be seismically qualified for design basis earthquake (DBE) [R-11]. The structure shall not produce negative impact on the seismic capability of the pressure relief duct (PRD).

Seismic demand response spectra for PB are documented in Ref. [R-11].

(3) IXCU Area (PA)
Elevation: 274'-0"
Potential Tank Area: East of unit 1, IXCU Footprint [Between Lines H and K to Line O, column 6 to Column 9]
Note: Cancelled ECN 0963
Reference Drawing: NA44-0G-21002-00058

This location is in the PA Reactor Auxiliary Bay (RAB).

According to [R-3], the PA RAB structure was assessed to be to be seismically adequate. It should be noted that masonry walls (a typical seismic liability) in the vicinity of any structures, systems or components (SSC's) on the success path were evaluated and upgraded if necessary. The same needs to be followed for new SSC's. Seismic demand for PA is characterized by the floor response spectra in Ref. [R-6] and [R-3].

(4) UPP- A (PA)
Elevation: 274'-0"
Potential Tank Area: Line A to D, Columns 1 to 4
Note: All equipment in UPPA, with the exception of certain piping and feed tanks, are not in use, and can be removed.
Reference Drawing: NA44-EMG-34600-00004

Ref. Design Manual NA44-29800, Heavy Water Upgrade Plant Building, Nov. 1971.
This design manual does not stipulate any seismic requirements.
The building is not on the success path evaluated in Ref. [R-3].
Seismic demand response spectra for PA are documented in Ref.
[R-6] and [R-3].

(5) Off-Gas Building (PB)
Elevation: 254'-0" (outside the plant)
Potential Tank Area: Entire Building
Note: This building has never been commissioned.
Reference Drawing: NK30-DFH-79320-00001

According to Design Manual NK30-29100 (Off-Gasses Building and Service Duct, April 1977), earthquake loading was considered in design.
No details are available on the extent or the level of seismic loading and according to Operations, the building was never commissioned. It would be conservative to assume that the building has some inherent minimal earthquake resistance (as per the National Building code at the time,1965). But since the building was never commissioned, seismic evaluation will have to be conducted based on PB DBE according to Ref.
[R-11]. It is noted that earlier effort pointed to total lack of seismic resistance for this building, however, further investigation concludes some seismic strength exists as mentioned above.

References

[R-1] Control of Unsecured Equipment in Seismically Qualified Areas, OPG-N Procedure N-PROC-MA-0031.

Pickering A

[R-2] Engineering Direction on Evaluation Methodology for Seismic Impact of Plant Modifications, NA44-CORR-03652-0073548, January 30, 2004.

[R-3] Seismic Assessment of Pickering 'A' Nuclear Generating Station, NA44-REP-02004-0073, Feb. 1998.

[R-4] Administrative Controls for Seismic Qualification, NA44-REP-03650-00002.

[R-5] Seismic Capacity Preservation, Pickering 'A' Return to Service, AECL Implementation Guide No. 44RS-03650-IG-002 R02, December 2000.

[R-6] Floor Response Spectra (FRS), Pickering 'A' Return to Service, AECL Implementation Guide No. 44RS-20090-IG-001 R01, April 1999.

[R-7] Pickering A Safety Report, Section 2 Design Criteria, Subsection 2.3: Seismic Qualification and Classification,
NA44-SR-01320-00001 R11, July 2003.

[R-8] Control of Unsecured Equipment in Seismically Qualified Areas, OPG-N Procedure N-PROC-MA-0031.

[R-9] Abnormal Incident Manual, Common Mode Events, NA44-014-09013-6.

Pickering B

[R-10] Pickering B Safety Report, Section 2 Design Criteria, Subsection 2.3: Seismic Qualification and Classification,
NK30-SR-01320-00002 R01, June 2003.
[R-11] Safety Systems Engineering Design Guide No.
DG-30-68000-2, Pickering G.S. 'B' Seismic Qualification of Safety Related Systems.
[R-12] Safety Systems Engineering Design Guide Supplement No.
DG-30-68000-006, Pickering G.S. 'B' Seismic Qualification of Safety Related Systems: Reactor Auxiliary Bay Structure/2/21441/21451, Oct.
1980.
[R-13] Email from. C. Alexander to P.J. Armstrong Re: PB Seismically Qualified Structures, NK30-CORR-67100-0084852

Regards,

Nasser Aly, M.Eng., P.Eng., P.E.
Senior Design Engineer
Engineering Services Division
Ontario Power Generation - Nuclear
889 Brock Road, Pickering, Ontario Canada L1W 3J2
T. 905.839.6746 x. 5216
E. nasser.aly@opg.com
OPG Building Code P82 5D1
Internal 702+5216

-----Original Message-----
From: LEUNG Tracy -NUCLEAR
Sent: Tuesday, May 09, 2006 2:55 PM
To: WONG Dominic -NUCLEAR
Cc: WONG Edmond -NUCLEAR; BREMNER Shawn -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: Re: Potential Locations for D2O Tank Installation

Dominic,
As per our conversation today, you need a list of proposed locations to speak to the Structural Analysis expert about the seismic issues that the D2O storage project may encounter. Here is the list, and the reference drawings for the locations. Please contact me if you need more information. Thanks.
1. East of D2O Supply Tanks
Elevation: 254'-0" (tanks are 20 ft in height)
Potential Tank Area: The area east of the supply tanks. [Line L to Line O, Between column 184 and column 185]
Note: The area cannot be impeding the D2O tankers that will come in through the loading area S559.
Reference Drawing: NK30-DFA-22000-0005
Drawing Link:
http://passport.opg.com:80/pjserv/servlet/com.iint.pjserv.servlets.PJBrowserServices?ConfigSection=PNDB&PanelID=TIMC010&PanelKeyData=P%20%20DRAWARC%20NK30-DFA-22000-0005%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20&ShortCut=Y
2. Ventilation Equipment Room
Elevation: 277'-4"
Potential Tank Area: Room S668
Note: Currently containing obsolete HVAC equipment
Reference Drawing: NK30-D5A-24000-0053
Drawing Link:

http://passport.opg.com:80/pjserv/servlet/com.iint.pjserv.servlets.PJBro
wserServices?ConfigSection=PNDB&PanelID=TIMC010&PanelKeyData=P%20%20DRAW
ARC%20NK30-D5A-24000-
0053%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%2
0%20%20%20%20&ShortCut=Y

3. IXCU Area
Elevation: 274'-0"
Potential Tank Area: East of unit 1, IXCU Footprint [Between Lines H and K to Line O, column 6 to Column 9]
Note: Cancelled ECN 0963
Reference Drawing: NA44-0G-21002-00058
Drawing Link:

http://passport.opg.com:80/pjserv/servlet/com.iint.pjserv.servlets.PJBro
wserServices?ConfigSection=PNDB&PanelID=TIMC010&PanelKeyData=P%20%20DRAW
LOC%20NA44-0G-21002-
00058%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%2
0%20%20%20%20&ShortCut=Y

4. UPP-A
Elevation: 274'-0"
Potential Tank Area: Line A to D, Columns 1 to 4
Note: All equipment in UPPA, with the exception of certain piping and feed tanks, are not in use, and can be removed.
Reference Drawing: NA44-EMG-34600-00004
Drawing Link:

http://passport.opg.com:80/pjserv/servlet/com.iint.pjserv.servlets.PJBro
wserServices?ConfigSection=PNDB&PanelID=TIMC010&PanelKeyData=P%20%20DRAW
MAD%20NA44-EMG-34600-
00004%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%
20%20%20%20&ShortCut=Y

5. Off-Gas Building
Elevation: 254'-0" (outside the plant)
Potential Tank Area: Entire Building
Note: This building has never been commissioned.
Reference Drawing: NK30-DFH-79320-00001
Drawing Link:

http://passport.opg.com:80/pjserv/servlet/com.iint.pjserv.servlets.PJBro
wserServices?ConfigSection=PNDB&PanelID=TIMC010&PanelKeyData=P%20%20DRAW
MAD%20NK30-DFH-79320-
0001%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%20%2
0%20%20%20%20&ShortCut=Y

Tracy Leung
Assistant Technical Officer
Design Projects, Pickering A
Phone No.: (905) 839-1151 ext. 2767
Pager: 416-390-4746

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EMAIL 6.

From: LEUNG Tracy -NUCLEAR [tracy.leung@opg.com]
Sent: Tuesday, May 30, 2006 3:10 PM
To: ANTONIAZZI Armando
Subject: FW: Review of Seismic Requirements for D2O Storage and Transfer Systems

Tracy Leung
Assistant Technical Officer
Design Projects, Pickering A
Phone No.: (905) 839-1151 ext. 2767
Pager: 416-390-4746

-----Original Message-----
From: WONG Dominic -NUCLEAR
Sent: Tuesday, May 30, 2006 2:23 PM
To: LEUNG Tracy -NUCLEAR
Cc: WONG Edmond -NUCLEAR
Subject: Review of Seismic Requirements for D2O Storage and Transfer Systems

The following is a review of the seismic requirements of various systems.

If the modification is part of 38210 system, then the system shall be seismically qualified to meet (1) and (2). If modification involves containment penetration, then the lines and valves must also be seismically qualified to maintain contain boundary integrity. The services (e.g. instrument air, power for MV) to operate a seismically qualified valve during or after a seismic event must also be seismically qualified.

1. Engineering Design Guide DG-30-68000-2 Seismic Qualification of Safety Related Systems specifies:
* 38200 D2O Supply System qualified to DBE "A".
* Note 13 stated "The D2O supply system is to be seismically qualified only to the extent that there will be no loss of inventory from the bulk storage tanks."

2. Flow diagram NK30 FDH 38210 0001 and Design Manual NK30-38210 for D2O Supply System state:
* The D2O supply system is seismically qualified for a DBE Category A.
* Equipment Data Sheets (tanks and relief valves) in the design manual also show seismic qualification to DBE A.
* System Classification List for CNSC approval of Code Classification also shows system and tanks to seismic qualification DBE A.
* Notes on piping drawings do not specifically state seismic requirements. If the relief valves are seismically qualified, it is most likely that the piping is also seismically qualified.

3. 34960 - D2O Transfer System:
* Flow diagram NK30-FFH-34960-0001 marked seismic requirements for specific section (containment penetration) of the drawing.
* Design manual NK30-34960 states D2O transfer lines that penetrates RB wall and containment are seismically qualified to DBE A, isolation valves seismically qualified to DBE B.

4. 34970 - Moderator D2O Ion Exchange Cleanup System:
* No seismic requirements marked on flow diagramNK30-FFH-34970-0001. No seismic requirements stated in design manual NK30-34970.
* Equipment data sheet for strainer in design manual stated seismic qualification not required.

5. 38340 - 30TF-38340 Pickering Incoming/outgoing D2O Transfer System (PIOTS)
* Design Manual 30TF-38340 stated PIOT system is not seismically qualified.
* Seismically qualified dike is provided around tanks and pumps to contain a limited spill of tritiated D2O, but not a full tank.
* PIOTS tanks's supports are designed to withstand seismic loads equivalent to DBE A to prevent toppling of the tanks in the seismically qualified dike.
* PIOTS tank room wall are designed to withstand DBE A.
* Pickering B containment isolating valves are seismically qualified to DBE A or B.
* Pickering A containment isolating valves are NOT seismically qualified.

Dominic.

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EMAIL 7.

From: LEUNG Tracy -NUCLEAR [tracy.leung@opg.com]
Sent: Thursday, May 25, 2006 8:54 AM
To: ANTONIAZZI Armando; KAULESSAR Ghaman -PICKERING
Cc: THAM Stephanie -NUCLEAR; WONG Edmond -NUCLEAR; BREMNER Shawn -NUCLEAR
Subject: FW: D2O Storage - FLR Losses

Armando and Ghaman,

FYI, info from Operational Performance Reporting. Thanks.

Tracy Leung
Assistant Technical Officer
Design Projects, Pickering A
Phone No.: (905) 839-1151 ext. 2767
Pager: 416-390-4746

-----Original Message-----
From: WONG Edmond -NUCLEAR
Sent: Thursday, May 25, 2006 8:48 AM
To: LEUNG Tracy -NUCLEAR
Subject: RE: D2O Storage - FLR Losses

Tracy,
Pls forward to Armando & Ghaman, & cc Stephanie.
Thx.. Edmond

Tracy Leung
Assistant Technical Officer
Design Projects, Pickering A
Phone No.: (905) 839-1151 ext. 2767
Pager: 416-390-4746

-----Original Message-----
From: SWANN Brenda -CORP FINANCE
Sent: Wednesday, May 24, 2006 3:23 PM
To: LEUNG Tracy -NUCLEAR
Cc: NOONAN Karen -CORP FINANCE
Subject: D2O Storage - FLR Losses

Tracy,

I spoke with a couple of engineers (& the station generation contact) regarding your query as to whether we have had outages or extensions due to lack of D2O storage. The concensus is that it would be highly unlikely that we would have outage or outage extension as a result of this.

To verify that, I checked our NUGEN database for the past 3 years and there are no charges against the USIs you provided.

Sorry I wasn't able to help.

Thx/Brenda

Brenda Swann
Cost & Schedule Analyst
Operational Performance Reporting

Phone: 702-4099
Bell Line: (905) 839-6746 x 4099
*: brenda.swann@opg.com

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EMAIL 8.

MessageFrom: WALKER Glenn -PICKERING [glenn.walker@opg.com]
Sent: Friday, August 11, 2006 9:38 AM
To: WONG Edmond -NUCLEAR; ANTONIAZZI Armando
Cc: LEUNG Tracy -NUCLEAR
Subject: RE: S&I

You could install valves and probably some piping that would allow a transfer but consider the following. If we had high curie water in TK1 that was being sent to the TRF or as in our current situation with gad in TK1, why would we you want to contaminate good lower ci water? Another point which I missed. Let's assume we are receiving TRF product. We are placing it in TK3 because we like to segregate by Ci content, and we are using TK4 for UPP product storage. In order to accommodate the swap using higher Ci water, we now need to transfer TK3 containing TRF product into TK4 with the Upgrader product, (assuming there is sufficient room in TK4). You've now reduced the effectiveness of TRF product for the purpose of maintaining/lowering PHT tritium. With additional storage this wouldn't be a concern. This condition will also exist when HT drains are performed, as will be the case for U7. We need TK3 empty to accept HT drain water. TK4 will contain UPP product so I have asked TRF to withhold 100+ Mgs of TRF product. (I know the 40 day outages preclude HT drains and you can't accommodate for all scenarios, but in my 14 years in this position I have scene things change quickly. Discovery work during outages can require draining on very short notice).

I apologize if I seem a little short. I struggle with these types of issues on a regular basis and I'm not getting a warm fuzzy feeling that we are going to get what we feel we need. Oh well, only 1377 more days to go!

Glenn

-----Original Message-----
From: WONG Edmond -NUCLEAR
Sent: Friday, August 11, 2006 8:32 AM
To: WALKER Glenn -PICKERING; 'ANTONIAZZI Armando'
Cc: LEUNG Tracy -NUCLEAR
Subject: RE: S&I

Glenn,

I am not cleared whether the root cause of this problem ----a “valve configuration” issue or “tankage issue”? Please elaborate.

Edmond

-----Original Message-----
From: WALKER Glenn -PICKERING
Sent: Friday, August 11, 2006 8:26 AM
To: 'ANTONIAZZI Armando'
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: RE: S&I

This prevents us from transferring any upgrader product into any of the S&I Tanks and have in past been required to place an upgrader on Total Reflux. This in turn can lead to increased

backlog in IXCU. Frequently we will use Moderator Upgrader product for swaps as the tritium concentration is considerably lower compared to the units. This means we are putting Hi Ci water into the low Ci side of S&I. This doesn't impact operations but does increase the risk of potentially contaminating the HT make-up.

Glenn

-----Original Message-----
From: ANTONIAZZI Armando [mailto:Armando.Antoniazzi@kinectrics.com]
Sent: Thursday, August 10, 2006 4:37 PM
To: WALKER Glenn -PICKERING
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: S&I

Glenn,

Another point requiring clarification. One of Ghaman's comments was that during an on-line or off-line moderator swap PND can only feed from the low Ci side (TK3/4) and receive into HiCi (TK1/2) side of S&I. Can you explain to me how this impacts Operations during a swap.

Thanks,

Armando

Dr. Armando B. Antoniazzi

Nuclear Waste and Tritium Solutions

Kinectrics Inc.

800 Kipling Ave

Toronto, Ontario

Canada M8Z 6C4

ph: 416-207-6000 ext 6680

fax: 416-207-6094

email: armando.antoniazzi@kinectrics.com

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Kinectrics Inc. 800 Kipling Avenue, Toronto, Ontario, Canada M8Z 6C4

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EMAIL 9.

From: LEUNG Tracy -NUCLEAR [tracy.leung@opg.com]
Sent: Tuesday, October 10, 2006 4:15 PM
To: ANTONIAZZI Armando
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: Re: Outage info confirmation

Armando,

From information on both the Pickering A and Pickering B outage websites, your original assumptions were correct.

For Pickering B: Assume two outages per year. Each unit will go into outage every other year.

For Pickering A: Assume one outage per each. Each of unit 1 and unit 4 will go into outage every other year.

For Pickering A, there's no indication that PHT drains are performed. However, PHT system maintenance is required every year. There's also a bleed cooler inspection call-up every ten years. In either cases, I do not believe that the entire system needs to be drained. This probably needs confirmation from Glenn Walker or James Bryant.

For Pickering B, I've found the following information from the Outage website. Moderator drains are not schedule in every outage, nor are they scheduled with PHT drains for outages past 2007. Please see the following:

Copied from File "PB 2006 June Tri-annual Review Outage Overview APPROVED Web Copy 04 August 2006" Posted on OPG Outage website (Aug 23, 2006, 2:19 pm)

Miscellaneous
Project #
P671
P751
P761
P881
P871
P951
P961
P1081
VBO
P1051
P1061
P1071

P1072
P1151
P1161
P1281
P1271

Moderator Drain

Yes
No
Yes
Yes
No
Yes
No
No
Pick "A"
None
None
None
TBD
No
TBD
TBD
TBD

HP Service Water Outage

Yes
Yes
Yes
Yes
None
None
None
None
Pick "A"
None
None
None
TBD
TBD
TBD

LP Service Water Outage

Pick "A"
None
None
None
TBD
TBD
TBD

Electrical Mtce

Type C/D
Type E
Type E
Type E
Type E
Type F
Type F
Type F
Pick "A"
None
None
None
Type F
??
??

PHT Low Level Drain State

2 Loops
2 Loops
South Loop
None
None
None
None
None
Pick "A"
None
None
None
None
TBD
TBD

PHT Quadrant Mtce - Major (11 days)

All
Minor
NE & SE
NE & SE

NE & SE
NW & SW
NW & SW
NW & SW
Pick "A"
None
None
None
NW & SW
NE & SE
NE & SE

PHT Quadrant Mtce - Minor (6 days)

All
All
NW & SW
NW & SW
NW & SW
NE & SE
NE & SE
NE & SE
Pick "A"
None
None
None
NE & SE
NW & SW
NW & SW

Shutdown Cooling Loop

All
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
Pick "A"
None
None
None
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4
SDC Loop 1,2,3,4

Please let me know if you need additional information. Thanks.

Tracy Leung
Assistant Technical Officer
Design Projects, Pickering A
Phone No.: (905) 839-1151 ext. 2767
Pager: 416-390-4746

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EMAIL 10.

From: WONG Edmond -NUCLEAR [edmond.wong@opg.com]
Sent: Wednesday, September 13, 2006 9:07 AM
To: ANTONIAZZI Armando; BREMNER Shawn -NUCLEAR; THAM Stephanie -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: FW: Fuel Burnup Savings

Fyi....

-----Original Message-----
From: FUSCA Frank
Sent: Wednesday, September 13, 2006 8:39 AM
To: WONG Edmond -NUCLEAR
Cc: LEUNG Tracy -NUCLEAR; FUREY Patrick -NUCLEAR; KALYANAM Kaly -NUCLEAR
Subject: RE: Fuel Burnup Savings

Hi Edmond,

The fuel burnup savings for PN are shown in the table below:

PNA and PNB System Isotopic Marginal Fuel Cost Savings

Year	Marginal Fuel Savings (k$/0.01%/Unit/a)			
	PNA	PNB		
	Mod	PHT	Mod	PHT
2006	33.81	0.94	40.09	1.12
2007	32.99	0.92	39.12	1.09
2008	33.55	0.94	39.78	1.11
2009	34.22	0.96	40.58	1.13
2010	34.22	0.96	40.58	1.13

These data are based on a Capacity Factor of 80% for the PN generating Units. The Nuclear Finished Fuel Prices are from 2005 and have not been updated for 2006. This may cause a little variance in the numbers. Like in the DND report, the above Fuel Burnup Savings for PNA and PNB are the dollar savings in the finished fuel costs only and do not include cost savings resulting from irradiated (spent) fuel handling, storage, disposal, decreased fueling operations, etc.
Please let me know if you have any questions. Thanks, Frank

-----Original Message-----
From: WONG Edmond -NUCLEAR
Sent: Tuesday, September 12, 2006 12:53 PM
To: FUSCA Frank
Cc: LEUNG Tracy -NUCLEAR
Subject: Fuel Burnup Savings

Frank,

We are in the conceptual phase of D2O Storage Project, and is trying to justify the expense by crediting additional D2O storage can improve isotopes & thus can save $ via the fuel burnup savings.

In your recent << OLE Object: Forms.HTML:Hidden.1 >> << OLE Object: Forms.HTML:Hidden.1 >> << OLE Object: Forms.HTML:Hidden.1 >> N-REP-03861-10001 <javascript:showDoc(%220%22,576,%22a0%22);>

"Comparison Of The Present And Proposed Upgrading And Detritiation Strategies At DND", you had shown some fuel burnup savings data from DND. I am wondering whether you can provide us with similar data from PND for each 0.01% isotope improvement in each of PND's moderator & PHT systems.

Thx.. Edmond

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EMAIL 11.

From: WESTON E H -PICKERING [e.weston@opg.com]
Sent: Friday, June 16, 2006 1:09 PM
To: WONG Edmond -NUCLEAR; WOODS Steve -PICKERING
Cc: THAM Stephanie -NUCLEAR; ANTONIAZZI Armando; LEUNG Tracy -NUCLEAR; BREMNER Shawn -NUCLEAR
Subject: RE: LLDS in 40 days outage.

Correct

> -----Original Message-----
> From: WONG Edmond -NUCLEAR
> Sent: Friday, June 16, 2006 11:52 AM
> To: WESTON E H -PICKERING; WOODS Steve -PICKERING
> Cc: THAM Stephanie -NUCLEAR; 'ANTONIAZZI Armando'; LEUNG Tracy
> -NUCLEAR; BREMNER Shawn -NUCLEAR
> Subject: RE: LLDS in 40 days outage.
>
> For 3-ways communication.....
>
> Your reply indicated to me that
> * With the present outage template, a moderator drain can
> occur within the 40 days outage window, but a PHT LLD will not occur
> in the same window.
> * In the future, there may be a chance that PHT LLD can
> occur together with a moderator drain within the 40 days outage window
> when a new alternate heatsink procedure is approved (at least 1 yr
> away).
>
> Thanks,
> Edmond
>
> -----Original Message-----
> From: WESTON E H -PICKERING
> Sent: Friday, June 16, 2006 11:35 AM
> To: WONG Edmond -NUCLEAR; WOODS Steve -PICKERING
> Cc: THAM Stephanie -NUCLEAR
> Subject: RE: LLDS in 40 days outage.
>
> Correct...Per our discussion, the current 40 Day Outage Template
> Does Not include a LLD, however, a Mod Drain may or may not be
> included depending on specific Unit Moderator Maintenance
> requirements.....NOTE: The currently approved Heat Sink (HS #9)
> supporting LLD, can only be credited after Day 38. In a Standard 40
> Day Outage , this obviously doesn't fit. Reactor Safety is
> reviewing alternate Heat Sink configurations /entry conditions
> specific to LLD which, if approved, may change the conditions as
> stated above... (Recommendations/approvals at least 1 year
> away)...Hope this helps
>
> -----Original Message-----
> From: WONG Edmond -NUCLEAR
> Sent: Wednesday, June 14, 2006 2:27 PM
> To: WESTON E H -PICKERING; WOODS Steve
> -PICKERING

> Cc: THAM Stephanie -NUCLEAR
> Subject: LLDS in 40 days outage.
>
> Herb,
>
> As I explained to you earlier that the "D2O Project" was advised to
> consider additional S&I Tanks storage capacity in PND's to accommodate
> an outage scenario that drains both moderator
> & PHT to low level (LLDS) from the same unit. After our discussion,
> please confirm my understanding is correct that the present "40 days
> outage" template does not include a LLDS scenario as this will require
> longer (>40 days) outage duration to achieve.
>
> Thanks.
>
> Edmond

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EMAIL 12.

MessageFrom: WALKER Glenn -PICKERING [glenn.walker@opg.com]
Sent: Thursday, August 10, 2006 11:47 AM
To: ANTONIAZZI Armando
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: RE: UPPA tanks and high TOC

You're right, the questions are all inter-related. I hope my response answers your questions without confusing the issue. Let me know if further explanation is required.

Glenn
-----Original Message-----
From: ANTONIAZZI Armando [mailto:Armando.Antoniazzi@kinectrics.com]
Sent: Thursday, August 10, 2006 10:54 AM
To: WALKER Glenn -PICKERING
Cc: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Subject: UPPA tanks and high TOC

Glenn,

I am revising our report and I need a clarification on the use of UPPA tanks. In our original report of 2004 we noted that,

"The TOC spec of 1 ppm required by the Upgraders and the TRF is difficult to achieve with the IXCU. Normally the TOC level can be reduced to about 3-4ppm. Even for this, the UPPA storage tanks are utilized together with a temporary IXCU on recirculation to bring the TOC levels down from 5ppm to 3ppm."

I gather, as our previous report states, the 5ppm water sits in the UPPA tank(s) allowing venting of volatile TOC prior to using a temporary IXCU to clean up this water. The further clean up is needed because of rust, conductivity, pH issues arising from the usage of the carbon steel UPPA tanks. This information came from a meeting with you.

Can you clarify for me several things:

1.. Is the procedure described above in addition to the use of external contractors (Pacific Nuclear, Westinghouse) to clean the water; that is, PND personnel perform the above work using some of the UPPA tanks and the external contractors deal with the really high TOC water in other UPPA tanks? This procedure is how Pickering has been attempting to deal with the high TOC water. It was our intention to clean up the really high TOC water ourselves but in the last 6 months or so the use of Westinghouse has been developed, so yes the procedure will be in addition to the use of external contractors. (The value of 5 ppm is somewhat low. We typically deal with water which is several times higher than that.)

2.. Are the UPPA tanks used strictly for storage of low Curie (high TOC) water awaiting some future treatment or a combination of storage and additional IXCU help as described above? We initially were using UPP-A tanks strictly as storage for the high TOC water. One tank contained some low curie high TOC water which we were able to clean up at over a period of time at IXCU. Our plan was to then use temporary columns and UV oxidation to pass the water from one tank to the empty tank eliminating the need to recirculate the water. Constant TOC problems with our recovery water have however continually forced use to send water to UPP-A for recirculating through the temporary columns and take the pressure off IXCU. As such we haven't had the opportunity to deal with the water Westinghouse has been looking at. As for the term low Curie, that depends on how you look at it. We normally consider water which is < 2 Ci/Kg as low curie water. All the water we have been processing, (other than that original low Ci tank mentioned above), has been > 2 Ci/kg but relatively low in comparison to the units. Most of the water has been between 2 and 5 Ci/kg, good for detriatiation purposes once upgraded.

3.. Venting off volatile TOC can be done in any vented vessel but the UPPA tanks are (were?) used to do this because of the limited storage capacity at IXCU? Yes, without the use of UPP, IXCU would be shutdown and unable to accept water from the units, (forcing the units to drum).

The questions deal with the same issues but looked from different perspectives.

Thanks,

Armando

Dr. Armando B. Antoniazzi

Nuclear Waste and Tritium Solutions

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800 Kipling Ave

Toronto, Ontario

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email: armando.antoniazzi@kinectrics.com

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EMAIL 13.

MessageFrom: WONG Edmond -NUCLEAR [edmond.wong@opg.com]
Sent: Friday, September 22, 2006 6:21 PM
To: JAHANGIR Nimun -PICKERING; LEUNG Tracy -NUCLEAR
Cc: KAULESSAR Ghaman -PICKERING; THAM Stephanie -NUCLEAR; BREMNER Shawn -NUCLEAR; TOPOLNISKY Dave -PICKERING; ANTONIAZZI Armando
Subject: RE: Upgrader degradation Improvement mechanism

Nimun, Ghaman,

This is to document your conclusion that the natural degradation rate for the upgraders is around 15% to 17% when calculation is based on the “do-nothing” option (note: the 25% normal degradation rate previously provided was based after the exclusion of UV improvement).

The 35% improvement of upgraders rate of degradation after installing UV is also calculated based on “do-nothing” option. Therefore, the resultant from the normal degradation (15%) and the improvement from UV (35%) yields a net improvement to the degradation rate of 50% by IXCU alone.

The technical justification for this rate of improvement by IXCU alone has been provided below.

Edmond

-----Original Message-----
From: JAHANGIR Nimun -PICKERING
Sent: Friday, September 22, 2006 1:28 PM
To: WONG Edmond -NUCLEAR; LEUNG Tracy -NUCLEAR
Cc: KAULESSAR Ghaman -PICKERING; THAM Stephanie -NUCLEAR; BREMNER Shawn -NUCLEAR; TOPOLNISKY Dave -PICKERING
Subject: RE: Upgrader degradation Improvement mechanism

Hi :

Attached is the response of the actions from the minutes of the Meeting held on September 20 th.

Please also find the explanation on how & what contribute to the improvement on the “rate of degradation” of the upgraders packing after installing the IXCU tanks.

· As calculated (Kinterics report), IXCU is grossly undersized for incoming recoveries.

· Currently, oil decanting/removal process is in adequate

· With one UV unit servicing both Hi Ci/ Low Ci trains, there is not enough tank space to allow further TOC reduction for the current 3 ppm to 1 ppm. In other words, the UV unit will increase the residence time of water in IXCU. The benefit of the UV unit is to ensure we meet the TOC spec; less usage of charcoal and possibly reducing the TOC from 3 ppm to 1 ppm. Additional feed tank will allow for the additional residence time to clean up water down to TOC = 1 ppm via the UV unit.

· One of the major benefits of the increased tankage is the improvement of the oil removal process in IXCU. Currently this process is grossly inadequate and consequently oil from IXCU is shipped to the upgrader feed tanks (UPP/Sulzer feed tanks currently contain oil). This oil is eventually fed to the distribution columns and gradually coats the packing.

Thanks

Nimun A Jahangir
Common Services - Engineering
Ontario Power Generation
Tel: 905 839 1151 X 6041
Pager: 416 541 2387

-----Original Message-----
From: WONG Edmond -NUCLEAR
Sent: Thursday, September 21, 2006 9:09 AM
To: 'Nimun Akhter Jahangir'; KAULESSAR Ghaman -PICKERING
Cc: LEUNG Tracy -NUCLEAR; THAM Stephanie -NUCLEAR; BREMNER Shawn -NUCLEAR; 'ANTONIAZZI Armando'
Subject: Upgrader degradation Improvement mechanism

Ghaman, Nimun,

Per my phone message this morning. Please provide some explanation on how & what contribute to the improvement on the “rate of degradation” of the upgraders packing after installing the IXCU tanks. Since we are using this as a cost benefit, we need to explain in both the report & BCS, what the mechanism is causing such an improvement. Note: The success of such improvement may even require to be listed as an item in the PIR “Post Installation Review” section in the BCS, & be tested after the project is complete.

Your latest instructions & tables indicated that the rate of degradation of upgraders packing will be improved by 35% after UV Oxidation System is installed, 40% after IXCU tanks are installed, and final 25% will remain as natural degradation.

We understand how UV can improve the rate of degradation by reducing or maintaining the TOC of the feed stock to the upgraders to about 1 ppm from nominal 3 to 5 ppm. However, we don't understand via what mechanism can IXCU contribute to such improvement of up to 40% (note: this improvement is even better than UV).

Edmond

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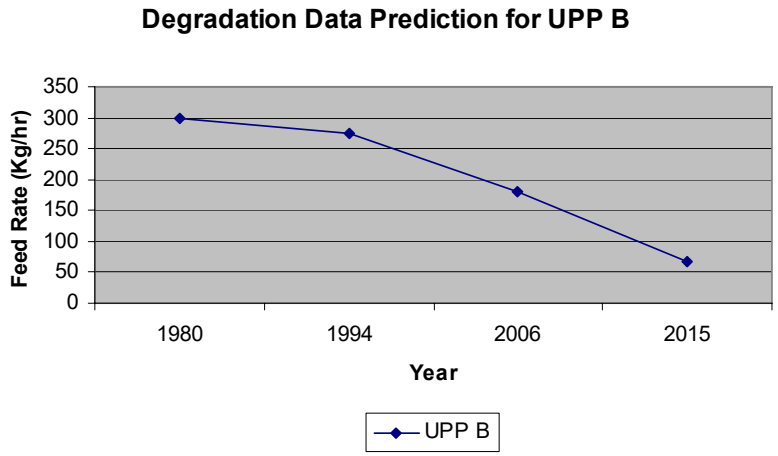
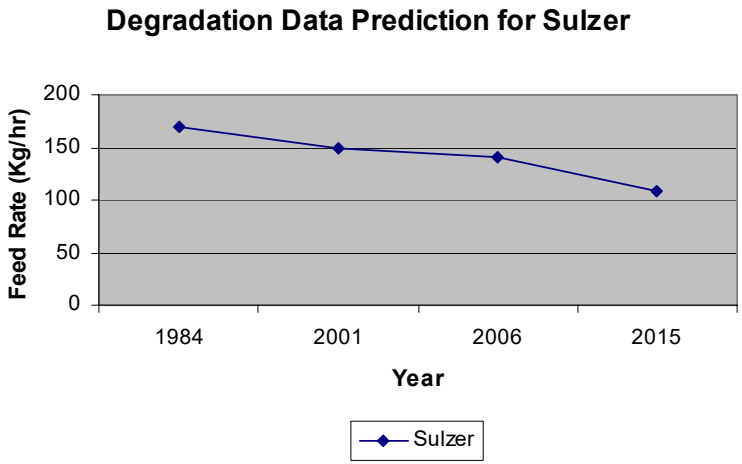
27. APPENDIX Q – Cost Justification Information from PND Common Services Engineering

Action No.	Item Description	Information
1	Disposal of Drums : No of Drums	Approximately 10 drums /year
2	Solid Content from Drums	Approximately 2" – 5" from the bottom 1.) Pls provide # of drums that contain such contents = Approximately **100** 2.) Project will use 3.5" of average content per drum. Pls confirm acceptance of this assumption. **OK**
3	Degradation Data of Upgraders	Predicting future performance is not simply linear progression. Feed performance due to packing degradation worsens at a faster rate from a certain point.


Degradation Data Prediction for UPP B
Feed Rate (Kg/hr)
350
300
250
200
150
100
50
0
1980
1994
2006
2015
Year
UPP B


Degradation Data Prediction for Sulzer
Feed Rate (Kg/hr)
200
150
100
50
0
1984
2001
2006
2015
Year
Sulzer

As per minutes….

1.) Pls predict a date for packing replacement =

UPP B : At the End of 2014

Sulzer B : At the end of 2019

[See the table below for clarification]

2.) Pls predict a date that upgrader can no longer sustain normal operation, and provide mitigate actions & associated costs req'd at that point.

UPP B: End of 2008

Sulzer B; End of 2017

Mitigate Action Required: Buying Upgrading Services

Cost Required: Please see the table below.

UPPB

year	Projected Feed rate	External Upgrading Cost
2006	180	-3942000
2007	167.52	-2302128
2008	155.04	-662256
2009	142.56	977616
2010	130.08	2617488
2011	117.6	4257360
2012	105.12	5897232
2013	92.64	7537104
2014	80.16	9176976
2015	67.68	10816848

Sulzer

year	Projected Feed rate	External Upgrading Cost
2006	140	-5256000
2007	136.51752	-4798402.128
2008	133.03504	-4340804.256
2009	129.55256	-3883206.384
2010	126.07008	-3425608.512
2011	122.5876	-2968010.64
2012	119.10512	-2510412.768
2013	115.62264	-2052814.896
2014	112.14016	-1595217.024
2015	108.65768	-1137619.152
2016	105.1752	-680021.28
2017	101.69272	-222423.408
2018	98.21024	235174.464
2019	94.72776	692772.336
2020	91.24528	1150370.208
2021	87.7628	1607968.08
2022	84.28032	2065565.952
2023	80.79784	2523163.824
2024	77.31536	2980761.696
2025	73.83288	3438359.568
2026	70.3504	3895957.44

Reference Data :

1. Required Feed Rate : 150 Kg/hr (UPPB) ; 100 Kg/hr (Sulzer)
2. Per Kinterics Report, Packing Replacement is $10M
3. External Upgrading Cost is $15/kg (Per Charles Foster)

<table>
<tr><td>4</td><td>TRF allotment and actual usage of TRF product</td><td>See Attached E-mail from Charles Foster

TRF Info rptSummByYearA.rtf

Per minutes…
1). Pls clarify what were the gaps from past yrs due to lack of storage.
<table><tr><th>Year</th><th>Gaps due to Lack Of Storage (Kg)</th></tr><tr><td>2001</td><td>55100</td></tr><tr><td>2002</td><td>372513</td></tr><tr><td>2003</td><td>167254</td></tr><tr><td>2004</td><td>215824</td></tr><tr><td>2005</td><td>125310</td></tr></table>
2). Since project does not know what allotment are expected by PND from TRF beyond 2011, Pls provide prediction of what this gap will be between 2011 to end of life.
Predicted Avergae Gap per Year : 187200.2 kg</td></tr>
<tr><td>6</td><td>Upgrader Reflux Costs</td><td>Reflux Cost for Sulzer : $20,000 /day
Reflux Cost for UPP : $24,000 /day</td></tr>
<tr><td>7</td><td>Duration of Upgrader Reflux</td><td><table><tr><th>Year</th><th>2004</th><th>2005</th><th>2006</th></tr><tr><td>UPP</td><td>7</td><td>15</td><td>22</td></tr><tr><td>Sulzer</td><td>5</td><td>9</td><td>0</td></tr></table></td></tr>
</table>

		Days on total reflux due to Bottom product can not be sent to S& I system. confirm following calculations are acceptable = OK 1.) For UPP Reflux cost = 15 days average per yr x $24K/day ; 2.) For Sulzer Reflux cost = 5 days average per yr x $20K/day
8	External D2O Storage Costs	Cost born Internally
9	High Stack Losses	See Attached E-mail from Steve Dickson FW: PND H3 Emissions

K-012667