DREDGING UP THE PAST

– REMOVAL OF HISTORIC LOW-LEVEL RADIOACTIVE SEDIMENT FROM THE PORT HOPE HARBOUR

Glenn Case [1], Mark Kolberg[2]

[1] Atomic Energy of Canada Limited, Port Hope, Ontario, Canada

[2] Baird, Oakville, Ontario, Canada

ABSTRACT

Port Hope is located on the northern shore of Lake Ontario at the confluence of the Ganaraska River and has existed as a Port of Entry since at least 1819. Once operated as a major Lake Ontario port, through periods of vibrant industrial growth, it is now a recreational anchorage for the local yacht club.

The history of the Port Hope harbour from the early 1800s to today is typical of other small-town ports along Lake Ontario that have experienced growth and decline in direct relation to Great Lake shipping volumes and the shift in industry and commerce to larger urban areas. However, in the case of the Port Hope harbour, the presence of low-level radioactive sediment, resulting from a former radium and uranium refinery that operated alongside the harbour, currently limits redevelopment and revitalization opportunities.

The presence of low-level radioactive waste is not limited to only harbour sediments. Several other on-land locations within the community are also affected by the low-level radioactive waste management practices of the past. To address these situations, the Port Hope Area Initiative project is currently underway to implement a local, safe, long-term waste management solution. The Port Hope Area Initiative is a community initiated undertaking that will result in the consolidation of an estimated 1.2 million cubic metres of the low-level radioactive waste from the various sites in Port Hope into a new engineered above ground long-term waste management facility. The remedial cleanup of the estimated 120,000 cubic metres of contaminated sediments from the Port Hope harbour is one of the more challenging components of the Initiative.

This paper demonstrates how the historical development of the harbour over the past 200 years, the nature and extent of the contaminated sediments, and Municipality of Port Hope's desires for future redevelopment of the waterfront area have all played a role in the design of the remedial cleanup plan for the Port Hope harbour.

1. HISTORICAL DEVELOPMENT

Port Hope was a Port of Entry as early as 1819; however, no effort was made to construct a wharf or harbour until 1829. Initially, passengers and goods were ferried to shore by smaller boats that would act as shuttles between the larger lake boats and the mainland. In 1829, the Port Hope Harbour and Wharf Company was created. Once it acquired sufficient funds, the company started work on the creation of a harbour in 1832.

The harbour consisted of parallel wooden wharves that extended approximately 180 metres out into Lake Ontario on the east side and 150 metres on the west side. By 1851, these wharves were

in a poor state of repair, so the Town of Port Hope acquired the harbour from the Port Hope Harbour and Wharf Company and vested its interest in Commissioners acting as trustees for the benefit of the Town Council. The Commissioners immediately took steps to repair and enlarge the harbour to attract a new railroad that would connect the town to points to the north (see Figure 1).

The work of the Commissioners would result in an improved harbour extending over 2 hectares in size and projecting over 360 metres into Lake Ontario and 250 metres along the shoreline. The harbour would subsequently be reconstructed to include a Turning Basin, an Approach Channel and protective breakwalls. The Turning Basin walls were built in the mid 1800s as squared timber cribs set on rock or hard till and filled with large field stone ballast. With the exception of the concrete copewalls, these walls have remained essentially unaltered since that time.

Figure 1: Historic Photo of Port Hope Harbour Area Looking North from Eastern Spit (Pre-1900)

The Centre Pier was constructed during the later 1800s to service the needs of the local lumber industry -- and to provide additional docking space and areas for coal storage and servicing facilities for the heavy lake vessel traffic in and out of the port (see Figure 2). Commencing in the early 1930s, interlocking steel sheet piling and anchorage points were used to construct new harbour walls rather than timber cribs.

Although a significant proportion of the harbour construction work was completed by the early 1900s, the current harbour configuration was not attained until 1953. Under the current configuration, the harbour comprises the Outer Harbour between the entrance breakwaters, an Approach Channel 40 metres wide by 305 metres long, providing access to a Turning Basin measuring 195 metres by 135 metres. The harbour no longer receives commercial traffic and is best described as a recreational harbour that serves as a boat mooring facility for the Port Hope Yacht Club. Figure 3 presents an aerial photo of the habour area taken in the spring of 2010.

Figure 2: Historic Aerial Photo of Port Hope Habour Area (1923)

Figure 3: Aerial Photo Port Hope Harbour (2010)

2. ELDORADO GOLD MINES OPERATIONS

In 1932, a radium refinery was established by Eldorado Gold Mines Limited on the west side of the Port Hope Harbour Turning Basin (Figure 4). This site was reportedly selected because of the availability of an existing building, access to major railway lines for the delivery of raw materials and ore feedstock, and an eager and willing workforce looking for work during the Depression.

The feedstock for the refinery was primarily pitchblende ore from Eldorado's Port Radium mine site in the Northwest Territories. Due to the remote location of the Port Radium mine, the pitchblende ore was shipped directly to the plant in Port Hope for refining rather than conducting the extraction process at the mine site. The first radium concentrates were produced in 1933 and, during the period of 1933 to 1942, recovery of radium from pitchblende ore was the primary focus of the plant. The extraction process required large quantities of chemicals to be mixed with the pitchblende ore to yield "gram quantities" of radium-226. As a result, large quantities of residues (tailings) were produced by the refining process.

Because the pitchblende ore from the Port Radium mine site was rich in other elements such as uranium, copper, cobalt, antimony, lead, nickel and arsenic, the processing residues held potential for future use and were stored on the plant site and other locations in the town for further potential processing. During the period from 1942 to 1954, operations at the plant site shifted from radium to uranium refining as the market for radium decreased and the need for uranium increased.

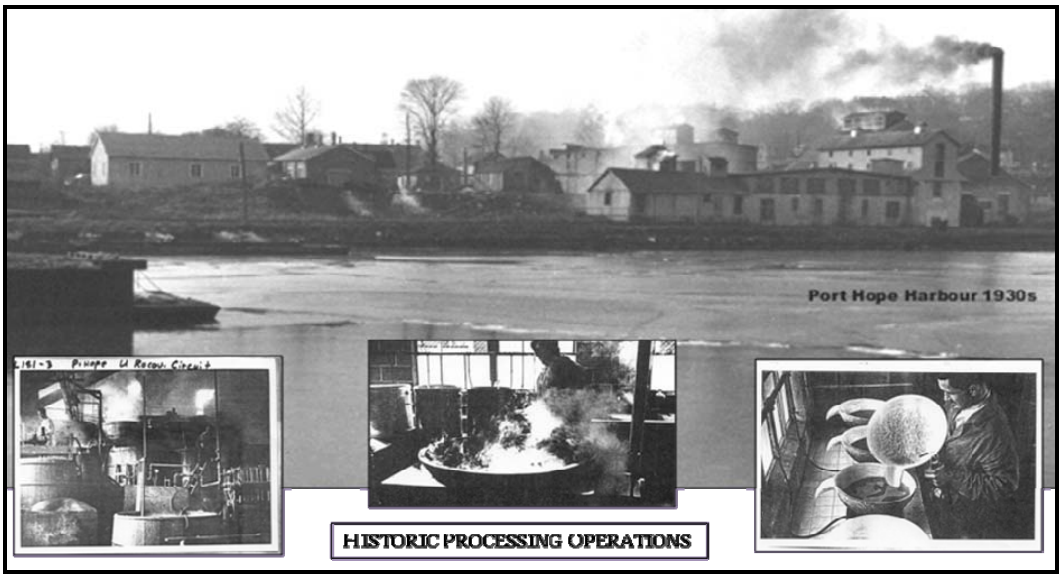

Figure 4: Port Hope Harbour 1930s, looking at West Side of Turning Basin

3. DISCOVERY OF RADIOACTIVELY CONTAMINATED SITES IN PORT HOPE

In 1975, elevated radon gas levels in private and public buildings were discovered, along with radium-contaminated soil and radioactively-contaminated building materials that had been salvaged from the former radium and uranium refining operations. The residues from the refining of the pitchblende ore contained a number of primary Contaminants Of Potential Concern (COPCs), most notably: arsenic; antimony; cadmium; cobalt; lead; nickel; uranium; radium-226; thorium-230; and the thorium-232 decay series.

In addition to five designated process residue storage sites employed by Eldorado during the period from 1932 to 1988, large and small areas within the Town of Port Hope became contaminated in a variety of ways, including:

i) spillage of wastes or residues during transport to the waste management sites;

ii) unrecorded, unmonitored, or unauthorized diversion of contaminated fill, building material and reclaimed materials to sites within the town;

iii) off-site transport from the Monkey Mountain Site due to wind and water erosion; and

iv) contamination at temporary storage locations while awaiting shipment for secondary metal recovery.

In February 1976, the Minister of Energy, Mines and Resources announced the formation of a Federal-Provincial Task Force on Radioactivity. The role of the Task Force was to expedite the

cleanup of radioactive contamination in the Town of Port Hope and to assist the Atomic Energy Control Board (AECB) in assessing the significance of such radioactive contamination in other locations in Canada (e.g., Elliot Lake, Bancroft, and Uranium City, Saskatchewan).

During the period of 1976 to 1981, a large-scale investigative and remedial action program was conducted in Port Hope under the direction of the AECB. This program involved the removal of more than 100,000 tonnes of radioactively-contaminated soil from over 400 properties and transfer to a waste management facility at Atomic Energy Canada Limited's Chalk River Laboratories. Remedial work was suspended in 1981 when the Chalk River site was filled to capacity and an alternate waste management location was needed for the remaining wastes.

For the next 20 years, a province-wide search was undertaken by Eldorado and a Federal Siting Task Force -- formed to find a willing host for the remaining low-level radioactive wastes that had resulted from the former Eldorado refining and conversion operations. These wastes were located in ravines, under roadways, at the Welcome and Port Granby Waste Management facilities, within the former Port Hope municipal landfill site, and in the Port Hope Harbour Turning Basin and Approach Channel.

By the conclusion of the investigative work by the Siting Task Force in 1996, a willing host and long-term solution for the Port Hope area wastes was not found.

4. PORT HOPE AREA INITIATIVE (PHAI)

Following the unsuccessful attempt to find a willing host community in the Province of Ontario, the three communities in which the former Eldorado historic wastes are located (Town of Port Hope, Township of Hope and Municipality of Clarington) developed conceptual plans for the construction of long-term waste management facilities (LTWMFs) within their individual communities. These plans formed the basis of the October 2000 Memorandum of Understanding (MOU) between these three communities and the Federal Government, as represented by Natural Resources Canada (NRCan). The MOU was subsequently formalized in a Legal Agreement signed by the three municipalities and NRCan.

The legal agreement set out the various terms and conditions under which the projects would take place, including: compliance with the federal environmental assessment process; the sources and types of wastes to be accommodated in the new LTWMFs; the basis for the cleanup criteria to be applied at the various waste sites; the need for cooperation and consultation between the various parties to the agreement; and financial support for the three municipalities in which the wastes are located.

Through this legal agreement, the Port Hope Area Initiative (PHAI) was created, comprised of the Port Hope and Port Granby Projects.

The Port Hope Project is a community-initiated environmental remediation project designed for the cleanup and safe, local, long-term management of the historic low-level radioactive waste and specified legacy industrial waste in the Municipality of Port Hope. Through the Port Hope Project, a new LTWMF will be built at the site of the closed Welcome Waste Management Facility (WMF) and an adjacent property. Existing waste at the Welcome WMF will be excavated and placed into a new, engineered above-ground mound. Other historic low-level radioactive waste from various sites in the urban area of Port Hope, including the Port Hope Harbour, will be excavated and safety transported to the new LTWMF.

The facility has been designed to manage a capacity of almost 2 million cubic metres (m^3) of contaminated waste (including contingencies and daily cover material) from within the Municipality of Port Hope – safely and for hundreds of years.

Figure 5 depicts the major waste locations that currently remain in the urban area of Port Hope and are the focus of the PHAI and the Long-Term Waste Management Project.

Figure 5: Major Historic Low-Level Radioactive Waste Sites in Ward 1 of Port Hope

5. PORT HOPE HARBOUR CONTAMINATED SEDIMENT

Surveys of radioactivity conducted in the vicinity of the harbor -- including its sediments -- during the 1970s and early 1980s identified the presence of historic low-level radioactive waste. With respect to the Port Hope Harbour, it is probable that the accumulation of this historic waste started with the commissioning of the radium refinery and resulted from direct deposition of chemical wastes in the 1930s and 1940s, discharges of aqueous process effluent, discharge of plant-site runoff, accidental spills due to plant process upsets, operating water discharges, groundwater movement and other waste management practices on the former Eldorado plant site.

Contamination in the harbour exists in a naturally-accumulated sediment layer overlying the till and bedrock throughout the Turning Basin and Approach Channel and in a portion of the Outer Harbour. The sediment is typically comprised of silty organics, soft silts and clays underlain by hard till or bedrock. The thickness of the contamination varies across the site and extends to as much as 3.5 metres deep in the Turning Basin and 7 metres in the Approach Channel and Outer Harbour.

Table 1 presents a summary of typical and maximum contaminant concentrations measured in the Port Hope Harbour Sediments.

Table 1: Typical and Maximum Contaminant Concentrations for Port Hope Harbour Sediments

Contaminant	Units	Typical	Maximum
Radium-226	Bq/g	41	380
Uranium	ppm	1,736	17,620
Arsenic	ppm	1,093	10,500
Barium	ppm	240	670
Copper	ppm	474	2,400
Lead	ppm	5,532	61,700

6. SEDIMENT CLEANUP CRITERIA

A field and laboratory study was conducted by SENES-Golder in 2002 to derive site-specific cleanup criteria for the contaminated sediment in the Port Hope Harbour. These criteria were developed based on the protection of aquatic biota, with emphasis on the benthic invertebrates inhabiting the bottom, on or within the contaminated sediments. The recommended toxicity-based sediment criteria were arsenic at 375 ug/g, lead at 2500 ug/g, uranium at 1100 ug/g and copper at 400 ug/g.

SENES-Golder determined that the application of these criteria would also protect against chronic toxicity of the other COPCs associated with the harbour sediment, including radioactive constituents. However, based upon the objectives of the PHAI, it was recommended that, rather than apply these site-specific criteria, the more stringent criteria applicable to residential soils be applied for Ra-226, Th-230, and uranium instead. This would ensure that, if harbour sediments were ever dredged again in the future after completion of the PHAI, no historic low-level radioactive waste would be present that could require special management due to its radioactivity. If, in the future, non-radioactive COPCs were to be present above residential or commercial/industrial criteria, these sediments could be managed without concern for radioactivity.

Although cleanup criteria have been developed for the cleanup of contaminated harbour sediments, the apparent variability of the contamination distribution -- and impracticality of attempting to segregate the contaminated and non-contaminated sediment -- has led to the design whereby the remedial cleanup of the Turning Basin and Approach Channel is based upon the removal of the accessible sediment above the bedrock or till. With this approach, the estimated quantity of material to be dredged is 120,000 m^3.

7. CONTAMINATED SEDIMENT REMOVAL STRATEGY

Over the past 20 years, a variety of remediation strategies has been proposed to address the Port Hope contaminated harbour sediment. The options range from excavation *in-the-dry* (whereby all the water in the Turning Basin and Approach Channel would be pumped out to allow conventional construction equipment to work *in-the-dry* and excavate the sediment) to *in situ*

management, whereby the entire Turning Basin and Approach Channel would be in-filled with clean soil and the impacted sediment left in place.

Following a thorough review of various options, conducted during the environmental assessment process, the proposed method of contaminated sediment removal is by dredging (see Figure 6). The sediment from the dredge will then be pumped as a sediment-water slurry mixture into geosynthetic containment tubes to dewater the mixture.

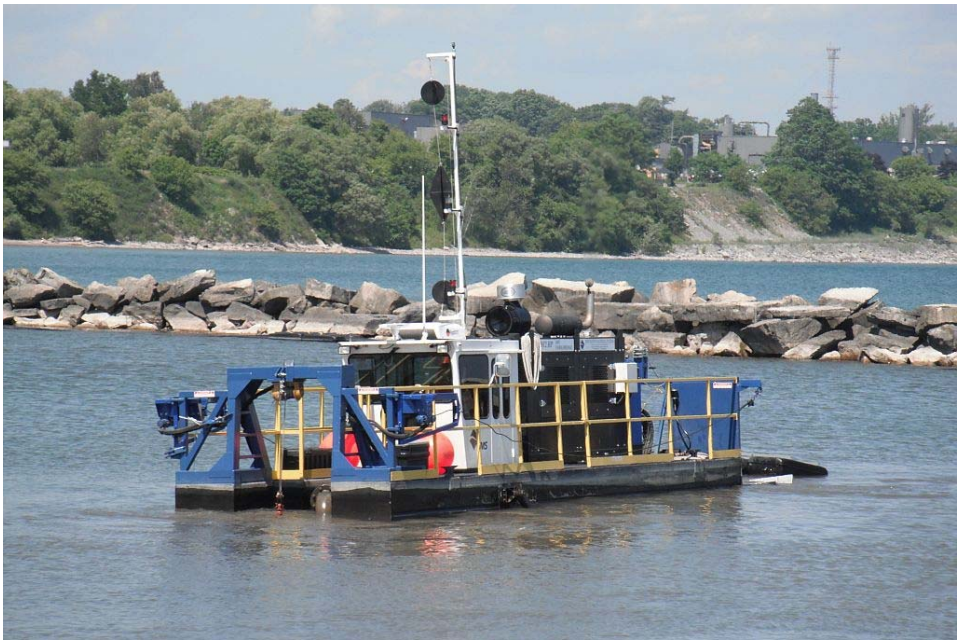

Figure 6: Conventional Hydraulic Dredge

During the dredging design development, the Port Hope Clean-up Criteria for Ra-226, arsenic and uranium were used to evaluate additional samples taken from the Outer Harbour and delineate the extent of the Outer Harbour remediation dredge area.

Dredging of the Harbour will proceed through a two-stage dredging program to achieve effective control of residuals. During the first stage (production dredging) the work will focus on removing the bulk of the material to be dredged to hard bottom. Following the first stage production dredging, a sufficient period of time will elapse to allow re-suspended material to settle before the second stage dredging (cleanup dredging passes). The second stage cleanup dredging will remove residual material left following the first stage (production) dredging.

For the production dredging, the specific type of dredging equipment has not been specified thereby allowing potential contractors to propose what they recommend to be the most effective equipment to meet the project objectives, specified performance standards, site-specific constraints and environmental and health and safety requirements while at the same time being able to reduce resuspension, deal with debris in the dredge material and the requirement to dredge to hard bottom and to deliver the dredge material hydraulically to the Centre Pier for dewatering within the geosynthetic tubes. The dredge rate will be primarily governed by the rate of chemical conditioning and dewatering.

Selection of the appropriate and effective environmental dredging equipment will be based on the following key factors:

- Debris and loose rock in sediment to be removed. Debris in the Harbour sediment has been identified by sonar survey. A pre-dredging survey will be undertaken to identify objects requiring removal prior to dredging;
- Hard, sloping and uneven bottom below the sediment that is to be removed. Approximately 90 boreholes were used to define the elevation and characteristics of the underlying bedrock or hard material, the thickness of the sediment and the physical parameters of the sediment;
- Hydraulic delivery of dredge sediment slurry to be compatible with geosynthetic tubes to be used for dewatering;
- Sediment resuspension control;
- Thin lift removal of residuals; and
- Residual sediment meeting performance standard.

Control of resuspensed material will be through the use of the fixed structural barrier that fully encloses the opening of the harbour (i.e., temporary wave attenuator). Current plans call for the isolation of the harbour from the Ganaraska River mouth and Lake Ontario during the remedial work by installing a cellular steel sheet pile temporary wave attenuator in the Outer Harbour. A turbidity curtain will also be employed on the work side of the wave attenuator. This isolation is necessary to protect the work area from wave action and prevent the release of potentially impacted suspended sediments to Lake Ontario and the Ganaraska River during the dredging operation. Installation of this barrier will also prevent fish from entering the dredging area during the annual fish spawns that occur during the spring and fall of the year.

The specifications for the work require the use of a computerized dredge guidance system to provide precise control of the dredging both in the vertical and horizontal planes.

Due to the hard bottom, the dredge will not be able to perform a cleanup pass that involves overdredging of a thin layer of underlying clean sediment. The contract specifications require the use of a plain suction or pneumatic dredge or specialty dredgehead to complete up to two cleanup dredging passes to remove residuals on the harbour bottom. The first cleanup dredging pass must provide 100 percent coverage of the harbour bottom area.

Following the dredging, the harbour will be surveyed using precisely coregistered bathymetry and properly corrected backscatter from a multibeam echosounder system to quantify the volume of residuals remaining on the harbour bottom. The harbour bottom will also be sampled according to the Remedial Verification Standard Operating Procedure (RVSOP) developed specifically for the Port Hope Harbour remediation project.

Where the criteria are met after the first cleanup pass, a second cleanup pass will not be required, and the area will be considered to have met the cleanup requirements. Where the criteria have not been met for one or more of the COPCs, a second cleanup pass will be required for those areas not meeting the criteria. The second cleanup dredging pass will provide 100 percent coverage of the harbour bottom areas requiring a second pass. Re-sampling and analysis will be required after the second cleanup pass only for those areas for which additional dredging was undertaken. The entire harbour bottom will be surveyed again using precisely coregistered bathymetry and properly corrected backscatter from a multibeam echosounder system.

Bench scale investigations involving Port Hope harbour sediments demonstrated that the sediment-water slurry can be successfully mixed with polymers to promote flocculation and consolidation of the sediment within containment tubes.

Figure 7 presents a picture of the consolidated sediment in the bench scale containment bag and the form of collected sediment that will make it amenable for placement into standard haulage vehicles for transportation to the off-site long-term waste management facility.

Figure 7: Bench Scale Test of Polymer Additive and Sediment Containment Bag Dewatering System

The Centre Pier property will be used as the dewatering site and lined sediment dewatering areas constructed. Dewatering of the sediment within the containment tubes will take place within the dewatering areas and the drained water will be collected and treated prior to discharge back into the harbour. Once the sediment has dewatered to an acceptable solids content (e.g., >50%), the containment tubes will be broken open and the contaminated sediment loaded into dedicated dump trucks for transport to the LTWMF. Odours and dust associated with the sediment will be monitored and appropriately managed to prevent off-site impacts.

Figure 8 illustrates the three primary steps in the use of sediment dewatering tubes: filling, dewatering and material removal.

Filling **Dewatering** **Sediment Removal**

Figure 8: Three Basic Steps in Use of Sediment Dewatering Tubes

8. VERIFICATION OF SUCCESSFUL SEDIMENT REMOVAL

All dredging operations normally leave some of the material behind due to resuspension and residuals. The surfaces of the till and bedrock underlying the Harbour sediment are not uniformly smooth and exhibit natural irregularities, fissures and depressions that will practically result in some amount of residual material. At Port Hope, residuals will be below any reasonable future dredging depth for the harbour.

Cleanup criteria have been established to meet the remediation project goals and objectives. Performance standards are required to measure the success in achieving compliance with the cleanup criteria and the Harbour remediation objectives. Verification of compliance with the cleanup criteria will be undertaken in accordance with the RVSOP. Due to the hard substrate below the contaminated sediment, the challenge has been to set performance standards in terms of low residual surface concentration that are attainable in an operationally efficient manner. The RVSOP presents the Port Hope Cleanup Criteria as the acceptance criteria for removal of residuals and completion of dredging. The RVSOP assumes that some residual sediment will remain following the completion of the initial cleanup dredging pass and that the residuals could contain concentrations of COPCs that exceed the remediation target criteria. The intent of the verification sampling program is to assess whether the sediment clean-up objectives established for the remediation project have been met and provides the appropriate sample collection methods and the required laboratory analyses. The RVSOP provides a detailed description of the sampling methods, the number of samples required, and the analytical methods and limits to be used.

9. PRE-SEDIMENT REMOVAL ENABLING ACTIVITIES

As noted previously, the Port Hope Harbour has undergone many upgrades over the past 200 years, resulting in walls of various construction types and other supporting structures that will present challenges for the remediation work (e.g., steel sheet pile with uncertain toe embedment conditions, tie-backs, deadheads, wooden cribbing, stone ballast, concrete cope walls, etc.).

The design of the harbour remediation strategy has involved careful examination of the integrity and stability of the existing harbour walls, revealing that the removal to bedrock, or hard till, of the sediment located adjacent to the walls could compromise the wall structures. To address this concern, a harbour wall condition assessment was conducted during the summer of 2010 on over 1,800 metres of existing harbour wall structures which could be impacted by the dredging operation. The physical appearance and integrity of these walls were characterized (i.e., timber crib, steel sheet pile) as part of this study (see Figure 9).

Figure 9: Harbour Wall Condition Assessment Activities

Based on the results of this condition assessment, and the required depth of sediment removal to bedrock or hard till, a series of optional concepts for the repair, rehabilitation or replacement of specific sections of harbour walls potentially impacted by the dredging were developed. These concepts took the following factors into consideration:

- shift in harbour use from commercial traffic to recreational boating;
- pedestrian and light vehicle loadings rather than heavy industrial along specified wall perimeters;
- depth of small pleasure craft (sail and power) less than 3 metres below chart datum;
- depth of visiting larger vessels such as tall ships, less that 5 metres below chart datum; and
- alongside moorings versus floating docks.

Discussions with harbour area stakeholders (Port Hope Yacht Club, Municipality of Port Hope, Port Hope Harbour Commission, Department of Fisheries and Oceans, and Cameco Corporation) were conducted and various scenarios presented on potential rehabilitation strategies for the harbour walls affected by the sediment dredging, as well as on-land soil remediation work planned for sites adjacent to the harbour.

Based upon these discussions, a wall rehabilitation program involving the installation of new steel sheet pile walls, and stabilization of existing walls through the placement of new stone revetments in front of selected existing walls, was agreed as the preferred concept in principle. Aspects considered during these discussions included maintenance of an acceptable Approach Channel entrance width, maintenance of recreational craft alongside wall moorings, allowance for potential larger draft vessels alongside wall moorings, reduction in wave action in the Approach Channel and wave agitation in the Turning Basin, provision of a heavy lift area to position a crane to place boats in the water in spring and remove from the water in the fall, and optimization of fish habitat following removal of the contaminated harbour sediments.

The final wall rehabilitation plan includes the removal of 270 lineal metres of contaminated timber cribs (up to 4 m below chart datum) and the construction of approximately 1760 m of new harbour wall, including:

- 150 m - new river bank stone revetment;
- 200 m - remediated timber crib/ concrete cope wall;
- 180 m - replacement of existing tie rods and anchor blocks for existing SSP wall;
- 180 m - new combination pipe pile steel sheet pile wall (up to 9 m below chart datum);
- 350 m - new steel sheet pile wall (typically 3 to 6 m below chart datum);
- 700 m - new stone revetment.

Figure 10 illustrates a schematic cross-section of the Approach Channel depicting the new combination steel pipe pile sheet pile wall along the Centre Pier side, and new stone revetment along the Queens Wharf wall.

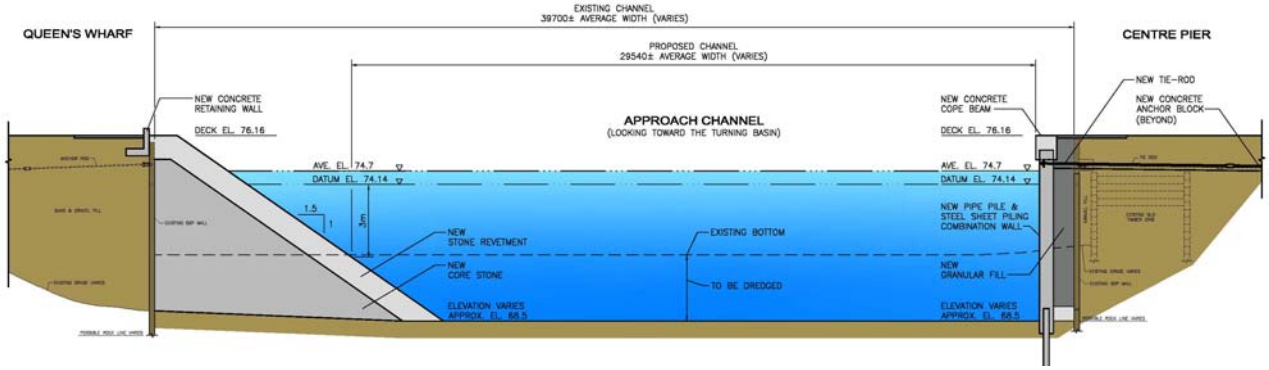

Figure 10: Typical Section through Approach Channel Following Wall Rehabilitation Looking North

It has been determined that the Port Hope Yacht Club will be relocated and the harbour will be closed for the duration of the project. Temporary facilities will be provided so that the existing Cameco intake, discharges and outfalls will remain functional for the duration of the Harbour remediation work.

10. CONCLUSION

Since its original development in 1832, under the direction of the Port Hope Harbour and Wharf Company, the Port Hope Harbour has undergone many changes and reconfigurations. Once serving as a bustling port on Lake Ontario serving the shipping needs of local commerce and trade, it now serves as a recreational anchorage for the Port Hope Yacht Club.

The lack of an appropriate waste management site to receive the existing low-level, radioactively-contaminated sediment (resulting from former radium and uranium refining operations adjacent to the harbour) has precluded harbour remediation for more than 30 years.

The PHAI's Port Hope Project – including the development of a new, long-term waste management facility – now provides an opportunity to address this impacted sediment. But this cleanup is far from a conventional dredging operation. It will require unique and specific expertise, training and equipment – and will present unique challenges. Based on the nature and large volume of the sediment to be removed, the remediation work must include:

- radiological protection for workers and the environment during the work;
- structural assessment and rehabilitation of the harbour walls that could be structurally compromised by dredging to bedrock or hard till;
- special procedures for the dewatering and management of radioactively contaminated sediments; and
- implementation of socio-economic mitigation measures to address the temporary relocation of the Harbour's tenant, the Port Hope Yacht Club.

What may have appeared, back in the late 1990's, as a simple line-item – the removal of 120,000 cubic metres of contaminated sediment from the Port Hope Harbour – has, through comprehensive environmental assessment and detailed engineering design processes, evolved into a highly complex and unprecedented undertaking. As the PHAI dredges up the past, it will also be making history.