RESTORATION OF CELLS 1 AND 3 OF SECTOR 103 OF THE MONTRÉAL HARBOUR – SELECTED INTERVENTION SCENARIO

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ABSTRACT

Three scenarios were developed to evaluate the most suitable method to restore contaminated sediments. The scenario recommending their dredging followed by their terrestrial management was selected. This scenario allows application of mitigation as well as the use of specialized technologies to minimize the impacts produced throughout the dredging phase. The terrestrial management of the dredged material will be completed on the Partner's properties and include drying within a storage basin or on a drying pad (successive thin layers drying). All the sediments coming out of cell 1 (≈20 000 m^3 *in situ*) will be biotreated while those from cell 3 (≈21 000 m^3) will be buried off-site in a maximum security level cell as they are characterized by a high level mixed contamination (organic and inorganic).

RÉSUMÉ

Trois scénarios d'intervention ont été développés pour évaluer la meilleure méthode de restauration des sédiments contaminés. Parmi ces scénarios, celui préconisant le dragage des sédiments suivi d'une gestion terrestre a été choisi. Ce scénario prévoit le déploiement de mesures de mitigation et d'outils technologiques permettant la minimisation des impacts tout au long du dragage. La gestion terrestre s'effectuera sur les propriétés des partenaires et comprendra l'assèchement passif des sédiments dans un bassin ou sur une surface d'assèchement (assèchement successif en couche mince). Tous les sédiments de la cellule 1 (± 20 000 m^3 *in situ*) seront biotraités tandis que ceux de la cellule 3 (± 21 000 m^3 *in situ*), présentant une contamination mixte (organique et inorganique) élevée, seront enfouis à l'intérieur d'une cellule à sécurité maximale hors-site.

1. INTRODUCTION

Within the context of its *St. Lawrence Action Plan* launched in 1988, Environment Canada completed a series of sediment environmental characterization in the ports of Montréal, Trois-Rivières and Québec, between 1989 and 1993. The study for the Port of Montréal (Environnement Illimité, 1990) outlined 3 priority zones including the Sector 103, where contaminants were found significantly exceeding the Toxic Effect Level (TEL) criteria for the sediment quality of the St. Lawrence River (EC/MENV, 1992).

Sector 103 of the Montréal Harbour is located on the North bank of the St. Lawrence River, approximately 15 km downstream of downtown Montréal (figure 1). This sector has been the site of intensive industrial activities since the beginning of the 20th century, including oil and metal refining.

The aquatic zone of Sector 103 includes two bays (figure 2), the South and the North, each of them being characterized by a particular contamination: the South bay, composed of cells 1 and 2, contains essentially organic contaminants (Petroleum Hydrocarbons (PH) and Polycyclic Aromatic Hydrocarbons (PAHs) while the North bay (cell 3) is characterized by a mixed contamination (organic: PH and PAHs and inorganic: As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn).

Following the conclusions of numerous studies mandated so far to asses the contaminated sediments of Sector 103, the Restoration Group (Montréal Port Authority, Noranda – CCR Refinery, Imperial Oil and Shell Canada) and Environment Canada agreed to develop a restoration project for cells 1 and 3 (Dessau-Soprin, 2002). The restoration of cell 2 is excluded of the Project because 1) the contamination level is low (in comparison with the one of cells 1 and 3), 2) the ecotoxicologic risk is low to moderate (Triad approach), 3) the dredging effort required would be major and 4) the extra cost required would be significant.

2. CONTAMINATED SEDIMENTS CHARACTERISTICS

An exhaustive study was completed during the fall of 1994 by Geophysics GPR International (1995) to assess the physicochemical characteristics of the sediments (contaminant concentrations, granulometry, thickness, volume, bathymetry, etc.). A list of the most pertinent information regarding the restoration work is summarized in Table 1.

The contaminated sediment layer is described by GPR as a blackish gelatinous sludge presenting a strong petroleum odour and overlays unconsolidated material (clay, silty clay, till) or the bedrock (at the cell 2 location as well as at the offshore limit of cells 1 and 3).

3. ESTORATION SCENARIOS DEVELOMENT

The general approach used to define the selected restoration scenario consisted in focusing from general solutions toward detailed conceivable scenarios, in regards to the projects constraints (budget, wharfs activities, legal constraints, etc.), as shown in the following scheme:

General intervention approach (GIA) → Intervention modes (IM) → IM selection → Conceivable technical options → Scenarios development → Scenario selection

As an example of GIA, a decision had to be made as to whether the contaminated sediments would be left in place or extracted, and where the sediments would finally be managed, if extracted. The IM are more defined solutions than GIA are, and consider the arrangement of one or more stages, leading to an organized intervention sequence combining general concepts (e.g. *in-situ* capping or restoration, usage restriction of the bays, dredging, pre-treatment/treatment, disposal: upland, aquatic or out of the site, etc.). Finally, the scenarios developed are an organisation of the selected technical options given the selected IM. For each scenario, every step is sufficiently developed (drawings, quantity estimation, performance, schedule, cost, etc.) to enable the selection of one scenario. For the current Project, 3 scenarios were developed:

Scenario 1: mechanical dredging, drying, biotreatment (cell 1 only) and off-site disposal of the sediments, according to their contamination level;

Scenario 2: idem to scenario 1 except that cell 3 sediments are also biotreated prior to their disposal;

Scenario 3: mechanical dredging, drying, biotreatment and disposal of cell 1 sediments, according to their contamination level. For cell 3 sediments:

A) mechanical dredging, hydro-mechanical and physicochemical treatment and off-site disposal of the treated and the concentrate materials, according to their contamination level ; or

B) mechanical dredging, drying, off-site stabilization/fixation and disposal, according to the contamination level.

4. SELECTED SCENARIO DESCRIPTION

The selected scenario was chosen using a multi-criteria grid which enabled comparison between the 3 scenarios, using the following 5 criteria:

- **Final management:** reduction of the contamination level or the volume to be buried, long term transfer potential of contaminants to the environment, etc.;
- **Minimization of short term impacts:** noise, odours, circulation, air and water quality, etc.;
- **Technical reliability:** overall technologies considered;
- **Reliability of the cost estimate:** based on the volatility or the accuracy of key budget activities (e.g. sediments treatment or disposal;
- **Economical advantage:** total estimated cost.

Based on the results of the multi-criteria analysis, it was more advantageous to follow Scenario 1.

4.1 Sediments dredging and transportation

The sediments will be mechanically dredged using a small environmental dredging system such as the one developed by Cable Arm inc. The advantages of such a system, compared to conventional ones, are: minimization of the sediment resuspension, a neat and precise dredged surface, high precision positioning and reduced overdredging. The estimated dredging rate of such equipment is 500 m^3/day, leading to a dredging duration of ≈40 days for each cell. The planned sequence will start with the cell 3 dredging (April-May) followed by the cell 1 (May-June). This proposed sequence will minimize the impacts (noise and odours) on the Richard street sector (adjacent to cell 3) and reduce the volume of sediment to be stored during the dredging of cell 1.

The dredged material will be deposited in a barge and unloaded into waterproof containers mounted on trucks, with the use of a long-stick / long-boom hydraulic excavator working from wharf 102 (cell 1) or wharf 104 (cell 3). The sediments will be brought to one of the following management sites: Imperial Oil (cell 1) and Shell Refinery (cell 3), using private roads (figure 1). At each unloading location (wharfs 102 and 104), a truck cleaning pad will be built to minimize sediment drops on the transportation paths used by the trucks.

4.2 Special mitigation measures while dredging

Weighted silt curtains with equilibrium windows will be deployed during the dredging activities to confine the contaminated sediments within the working area. They will be of variable height to match the variable bathymetric surface of the bays. The silt curtains layout will follow the limits of cells 1 and 3 (figure 2). Cables with floats will be stretched between wharfs 102 and 103, while dredging cell 1, and between wharfs 103 and 105, while dredging cell 3. The stretch limit joining wharfs 102-103-105 is located at the shear zone limit between the bays and the river, as measured by Environnement Illimité (1997) during the current study conducted in the Sector 103. At these locations, the expected current will be in the range of 50 cm/s. An intermediate silt curtain will also be installed at the cell 1 and 2 delimitation.

During their dredging, the sediments are likely to produce an oil film at the water surface due to their high petroleum concentration (table 1). This phenomenon was observed while extracting 36 m^3 of sediment from cell 1 in 2001, for a pilot scale drying and biotreatment test (Dessau-Soprin, 2003a), and was recorded occasionally in the 1990s in cell 3, when some sediments and oil were occasionally brought to the surface by oil tankers leaving wharf 103. To contain the oil film, the dredged area will be surrounded by oil booms. The contained surface will be kept as small as possible to minimize the organic compounds emission rate as well as the petroleum odours. The oil film will be taken off the water surface using a surface oil skimmer combined with an oily water separator. The separator outflow will be redirected to the confined zone or to the municipal sewer, depending upon the water quality. On the other hand, a recycling firm will handle the accumulated oil.

4.3 Sediments management

4.3.1 Cell 1

The selected site for the management of the cell 1 sediments is located on the West side of Notre-Dame Street and is part of the former Imperial Oil refinery, currently being dismantled (figure 1). As mentioned previously, the selected scenario recommends the drying, biotreatment and the disposal of the cell 1 sediments.

To enable their biotreatability, the sediments must be dried to a certain %Humidity, estimated at 25 % (Dessau-Soprin, 2003a). Numerous drying methods were considered (air surface exposure, passive or induced (vacuum) drainage, mechanical drying (centrifugation, band or press filters), etc.), but experience gained from previous projects with materials showing a strong petroleum contamination (mostly oily sludge) showed that the passive techniques were the most efficient (easy to use, reduced costs and time), especially when the material is fine grained (cell 1: 67.7 % silt and clay).

A pilot scale drying test was conducted in 2001 to validate the efficiency of two passive techniques: air surface exposure and drainage (Dessau-Soprin, 2003a). For this purpose, a 36 m^3 basin was built using concrete blocks waterproofed using 2 bituminous membranes layers (the exposed one being aluminium coated). On the bottom of the basin, a drainage system (slotted interconnected PVC pipes) was installed within a filtering sand bed covered by a geotextile suitable for the sediment granulometry (SOLMAX SX90T, filtration opening: 600 microns, permittivity: 0.07 sec^{-1}). The drainage system was directed to a sump well, recording the volume of drained water and enabling its sampling.

For the first 8 days of drying (June 7^{th} to 15^{th} 2001), the average water content (w) decrease was –4.4 % (83.9 % to 79.5 %). Considering the volume of water pumped out and the estimated volume of water required to saturate the filtration sand (total of ± 240 L), the drained water represents a decrease of w equal to –0.91 % (for a density of 1 475 kg/m^3). Thus, the drainage was only responsible for 20 % of the total drying (it was 5 time less efficient than the surface drying was). The drainage potential is probably lowered by the high fines percentage (67.7 % silt and clay) but mostly because of the gelatinous texture of the sediment, caused by the petroleum products which probably entrap the pore water.

During the first 2 months of the test, the average drying rate (Δ%Humidity/Δt) was -0.135 %/day, thus requiring approximately 185 days to dry the sediments from 50 % (considering an increase of ≈5 % induced during the dredging) to 25 % (required for the biotreatment). However, this drying rate presupposes a continuous removal of the crust at the surface, as was carried out during the test. This was necessary because as soon as the crust thickness reaches ≈150-200 mm, the surface drying almost stops.

At the end of the drying test in the basin (August 8^{th}), the sediments were moved to an asphalt paved surface and spread to form a thin layer (300 mm). The measured drying rate was -1.14 %/day, 8.8 times faster than the drying rate measured within the basin. In this way, the sediments could be dried in 22 days to reach the required %Humidity. However, the difference between the two measured drying rates is directly related to the exposed surface. In the basin, the exposed surface was 17.9 m^2 (3.66 m x 4.88 m) while it was 120 m^2 when spread to form a thin layer (36 m^3 / 0.3 m = 120 m^2), leading to a surface ratio of 6.7 between the two methods.

Considering these results, Imperial Oil decided to proceed with the drying of the cell 1 sediments using the thin layer technique. The designed management facilities for the cell 1 sediments include the construction of a temporary basin to stock most of them as well as a multi-cycle temporary thin layer drying pad.

Imperial Oil required that the sediments dry during the first summer (June-July-August, or ≈90 days), in order to start the biotreatment as soon as possible. The drying pad has to be designed accordingly. Assuming that the %Humidity will be ≈50 %, the total volume to be dried will be 23 000 m^3. Considering that every drying cycle (300 mm thickness) will last for ≈20 days (the drying rate estimated previously could certainly be maximized using farm equipment to turn over the sediments, as soon as the 150 mm crust has formed at the surface), each cycle has to dry ≈5 100 m^3, thus the designed drying pad surface must cover 17 000 m^2 (130 m x 130 m). The pad will be paved with asphalt and a 2 % outward slope will redirect the runoff (drainage and rainfall) toward peripheral sumps. The water from the sumps will be pumped into reservoirs, characterized and managed (including the treatment, if necessary, using appropriate technology) according to the contamination level. As soon as a drying cycle will be completed, the sediments will be sent to the biotreatment facilities.

A total volume of ≈13 000 m^3 is required for the storage basin, since 10 200 m^3 (2 drying cycles) will be sent directly to the drying pad during the dredging period (≈40 days). The basin will be built within 2 former tank areas. The actual perimeter dikes will be restored (enlarged), truck ramps installed and membranes laid to avoid contamination migration. The runoff, which will naturally accumulate in mass excavation scars, will be characterized and managed according to the contamination level, including treatment with appropriate technology if necessary.

The biotreatment pad will be conventional design, similar to those presently in operation by Imperial Oil: impermeable surface, venting and water pipes, pumps and air blowers, impermeable membrane cover, air and water treatment facilities, etc. During the pilot scale biotreatment test completed during the summers of 2001 and 2002 (Dessau-

Soprin, 2003a), PH concentration variations (at t_0, [PH] = 21 000 mg/kg, or 3 times the average cell 1 concentration) were monitored to evaluate if biotreatment of the sediments could be achieved. The result showed that the degradation reaction is almost inhibited until the %Humidity reaches ≈25 %. From that point, the reaction was relatively fast (79 mg/kg/day), with a calculated first order degradation rate half-life of 120 days. However, as soon as the PH concentration reached ≈4 900 mg/kg, the degradation rate significantly decreased and it took the entire 2002 summer to reach a concentration of 3 500 mg/kg (Québec's Level C criterion, limit for commercial and industrial lands). No nutrients were added since the C:N:P ratio was considered sufficient (100:1:4), based on a carbon mineralization test performed in the laboratory. Considering the contamination level of the sediments (average PH concentration of 6 700 mg/kg), most of the concentrations should be lowered below the C criterion within one complete biotreatment season.

According to the regulation and the contamination level expected (< C criteria for all of the parameters), the biotreated sediments could either be used as daily cover in a landfill or reused on the Imperial Oil property, if the residual contamination level does not increase the Imperial Oil site contamination background.

4.3.2 Cell 3

Sediments from cell 3 will be managed on the Shell refinery property, located West of Sherbrooke Street (figure 1). As previously mentioned, the selected scenario recommended the drying and the disposal (burial) of these sediments, without any treatment to decrease the contamination level.

To comply with the Provincial soil burial regulation (Québec Environment Quality Act, *Regulation respecting the burial of contaminated soils*), the cell 3 sediments must be dried prior to sending them to the high security burial sites. This requirement allows their placement (compaction) within the burial cell, and the sites generally request that the sediments be so called «shovelable». A fist attempt to estimate the drying level of «shovelable» sediment was done using the results of a slump test (CSA, 2001) performed on the cell 1 sediments in 2001 (Dessau-Soprin, 2003a), during the pilot scale drying test. The slump test results showed good correlation between the water content (w) and the slump height (R^2 = 0.92). For a w = 84 %, the slump height was 250 mm (over a normalized cylinder of 300 mm) while it was only 60 mm at w = 72 % (the sediments were hard to pull out of the cylinder). For a w = 75 %, the sediments were qualified «shovelable», even if they were still viscous and sticky, due to the high level of petroleum products and the fines fraction in the sediment. In such conditions, the sediment could not be compacted using conventional machinery and the slump test in not appropriate to evaluate the minimum water content required for their burial. Based on visual estimations, it is assumed that the cell 3 sediments have to be dried up to w = 43 % (%Humidity = 30 %) prior to their burial.

The suitable drying technique for the cell 3 sediments was evaluated using the same logic as for those of the cell 1. However, because of the limited space on the Shell and Noranda properties (both responsible for the cell 3 sediments management), the thin layer drying technique was discarded and the sediments will have to be dried within the storage basin (no drying pad). The surface desiccation crust will have to be taken off periodically using a long-boom/long-stick hydraulic excavator working on the top of the perimeter dikes and inner ramps. Also, to accelerate the drying rate, special adapted machinery (e.g. trenchers) as well as excavators could be used to drain out the water. However, despite these measures to speed up the drying rate, it is expected that the sediments will not be completely dried during the first summer.

The basin will have a storage volume of ≈24 000 m^3, assuming that the sediments %Humidity will be ≈50 %. The basin will be constructed within 2 former tank areas. The actual perimeter dikes will be restored (enlarged) and inner and unloading ramps installed to allow for access to most of the basin surface. Membranes will be laid on the bottom and the sides to avoid contamination migration. The drainage and rainfall water will be intercepted and redirected toward a temporary storage basin. The water will be characterized and managed according to its contamination level, which could include treatment at the Shell refinery water treatment plant, if necessary.

In accordance with the burial regulation, the dried sediments will be disposed of in a privately owned maximum security level burial cell. No treatment is planned, even if the contamination level of 3 parameters (PH, Cu and Se) exceeds the treatment obligation standards of the regulation (PH: 10 000 mg/kg, Cu: 2 500 mg/kg and Se: 50 mg/kg), because no treatment plant is actually available to extract 90 % (efficiency standard) of the contamination of all the exceeded parameters. As an interesting technical point, a biotreatability test was performed with the cell 3 sediments with good results (half-life: 115 days), even with the high concentration in heavy metals (Dessau-Soprin, 2003b).

4.4 Cost estimate

The overall cost estimation for the Project is 7.3 M CAN$, of which approximately 3.1 M CAN$ is for the restoration of cell 1 while 4.2 M $CAN would be required by cell 3 . The main budgetary activities are (cost importance decreasing): 1) sediments treatment and/or disposal, 2) facilities preparation, 3) sediments dredging, 4) quality control and environmental management, and 5) sediments drying activities.

4.5 Anticipated impacts

The Project's environmental impact study actually under completion identified the following temporary impacts:

Noise: No significant impacts will be produced during the construction of the management facilities and the consequent drying activities, considering the locations where these activities will be performed. The estimated noise level from dredging activities will remain below the Québec Ministry of transportation building site standards ($L_{10\%}$ = 75 dB(A));

<u>Traffic Circulation:</u> No anticipated impacts since sediments transportation will be done on private roads. Traffic lights already exist where they cross Notre-Dame and Sherbrooke Streets;

<u>Water quality:</u> In regards to the mitigation measures deployed during the dredging (silt curtains, oil booms and surface skimmer) and the environmental dredge proposed, no significant impacts are expected outside the confined zone. The water management scheme developed for the Project ensures the characterization of the water (mostly runoff) and its treatment (if necessary) to comply with Municipal standards for surface or sewer water ;

<u>Air quality (chemical):</u> According to the maximum organic compound emission rate measured during the pilot scale drying test (Dessau-Soprin, 2003a), the BTEX (Benzene, Toluene, Ethylbenzene and Xylenes) concentrations will remain far below the Municipal standards at the property limits. As well, the total organic compound emission rate produced by the basins and the drying pad facilities will respect the Municipal standard of 5 kg/hr (per facility).

<u>Air quality (odours):</u> An odour dispersion modeling of freshly dredged sediments indicated that the odours generated throughout the Project should be limited to a few hours, mostly generated at night (between 20h00 and 06h00) and during the months of May and June (Dessau-Soprin, 2003c). However, the model could not take into account the odours that are likely to be produced by the oil film and the release of entrapped degradation gas while dredging the sediments, which could temporary impact the nearby residential sector (Richard street). To minimize this temporary impact, the dredging activity in this area (cell 3) will be done in April and May (reduced outdoor activities) and the exposed surface of the oil film will be kept as small as possible using oil booms and a surface skimmer.

Considering the above information, the anticipated impacts of the Projects should be very limited.

5. CONCLUSION

After having invested roughly 1 M CAN$ in various studies since 1994, the Restoration Group has made an important step forward with their intent to restore the contaminated sediments in cells 1 and 3 of Sector 103 of the Montréal harbour.

Based on the particular constraints of the Project, numerous intervention modes and their associated conceivable technical options were evaluated to develop 3 scenarios, one of which was finally retained. The selected scenario proposes the mechanical dredging of the sediments, their drying, biotreatment (only for that of cell 1) and disposal off-site, according to the contamination level. Overall, approximately 50 % of the total dredged volume will be restored to a level enabling their potential reuse on the Imperial Oil property or their recycling as daily cover in a landfill. The remaining 50 % will not be treated due to the absence of technology able to efficiently handle the mixed contamination of the cell 3. The overall cost estimation for the Project is 7.3 M CAN$.

The numerous pertinent studies completed on the particular issues of Sector 103 enabled to design the sediment management facilities as well as to anticipate the use of mitigation measures / adapted devices to minimize the temporary impacts of the Project. The overall anticipated impacts of the restoration Project should be very limited, the most important being the odours.

Table 1. Physicochemical characteristics of the sediments

Parameter	Unit	Cell 1	Cell 3
Geometric characteristics[1]			
Dredging surface	m^2	15 525	16 600
Volume	m^3	19 975	20 750
Thickness	m	1.29	1.25
Physical properties			
%Humidity (W_{H2O}/W_{total})	%	44.3	47.0
Water content, w (W_{H2O}/W_{solids})	%	79.5	88.7
Gravel	%	1.4	1.7
Sand	%	30.9	34.9
Silt	%	59.7	55.3
Clay	%	8.0	8.1
Chemical properties			
Arsenic (As)	mg/kg	6.5	77
Cadmium (Cd)	mg/kg	2.3	2.8
Chromium (Cr)	mg/kg	111.9	764
Copper (Cu)	mg/kg	165.6	4 770
Mercury (Hg)	mg/kg	1.1	1.3
Nickel (Ni)	mg/kg	41.8	623
Lead (Pb)	mg/kg	131.0	158
Selenium (Se)	mg/kg	5.8	195
Zinc (Zn)	mg/kg	412.7	654
Petroleum Hydrocarbons (PH)[2]	mg/kg	6 703	11 762
Major PAHs			
Phenanthrene	mg/kg	15.0	24.6
Chrysene	mg/kg	3.0	2.7
Benzo(a)anthracene	mg/kg	3.6	4.8
Benzo(a)pyrène	mg/kg	2.0	1.7
Benzo(ghi)perylene	mg/kg	1.2	1.6
Total PCBs	mg/kg	0.5	2.6

[1]Including sedimentation (1 cm/yr) and overdredging (15 cm)
[2]PH C_{10}-C_{50} equivalent, considering 70 % of the Oil & Mineral Greases concentration

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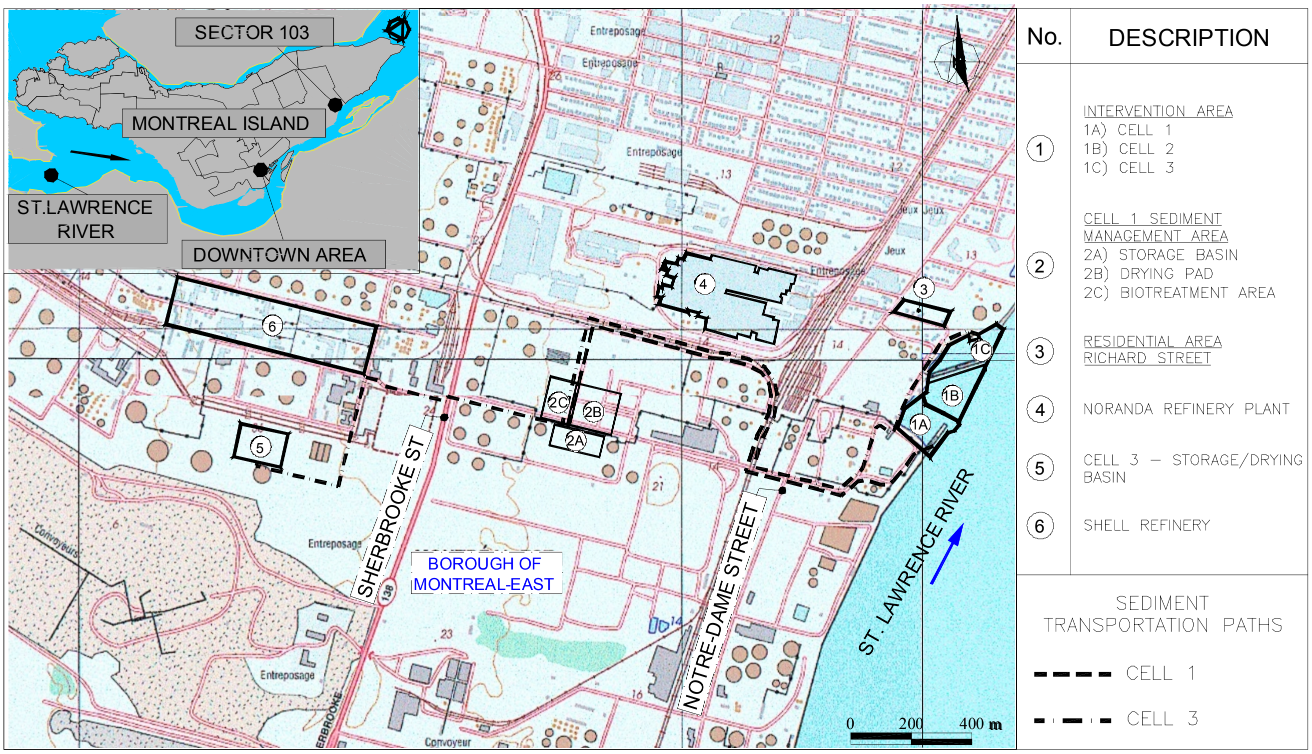

Figure 1 : Sector 103 of the Montreal Harbour - General location map

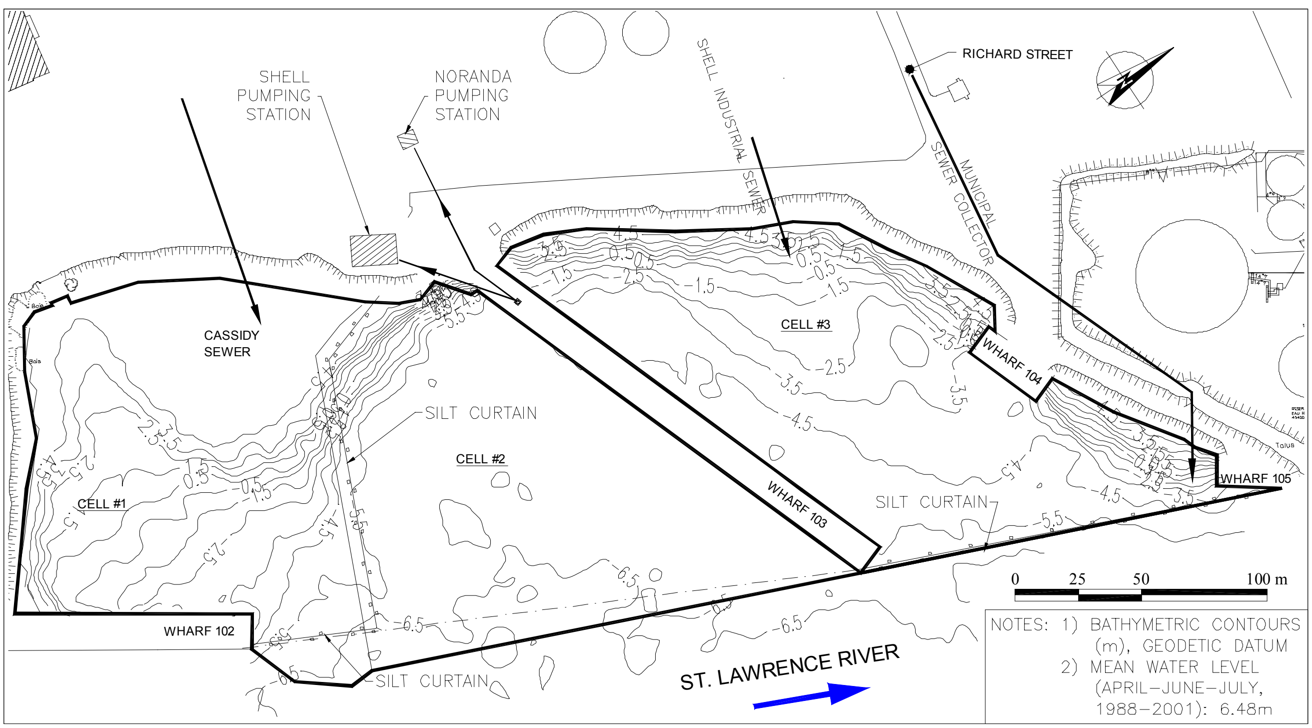

Figure 2 : Sector 103 of the Montreal Harbour - Intervention sector