Remediation and Treatment Options
Port Lands, Toronto

Prepared for

Waterfront Toronto

Final May 31, 2016

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Acronyms and Abbreviations

°C	degrees Celsius
µg/g	microgram per gram
µg/L	microgram per litre
CH2M	CH2M HILL Canada Limited
cm	centimetre
DCE	dichloroethylene
DNAPL	dense nonaqueous phase liquid
LNAPL	nonaqueous phase liquid
LTTD	low-temperature thermal desorption
m	metre
m^3	cubic metre
N/A	Not applicable
NAPL	nonaqueous phase liquid
PAHs	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PHC	petroleum hydrocarbon
RMM	risk management measure
SLRA	Screening Level Risk Assessment
TCA	trichloroethane
TCE	trichloroethylene
VC	vinyl chloride
VOCs	volatile organic chemical

Tab E. Remediation and Treatment Options

E.1 Preliminary Evaluation of Soil Treatment Alternatives for Waterfront Toronto Project

E.1.1 Background and Objectives

To reroute the mouth of the Don River through the Port Lands to improve flood protection for the City of Toronto, over 1 million cubic metres (m^3) of soil are expected to be excavated or dredged. The excavated soil will be reused as fill for the redevelopment of the Port Lands area within the project footprint, to the extent practicable. Sampling and laboratory analysis of soil along the new river route indicate the presence of contaminants such as petroleum hydrocarbons (PHCs), inorganics, and volatile organic chemicals (VOCs). Treatment to remove these contaminants to protective levels will be required before soil reuse, so soil contamination does not pose an unacceptable risk to human health or ecological receptors. The soil will also need to meet specific geotechnical criteria to be suitable for reuse.

This document presents a preliminary evaluation of potential soil treatment technologies and summarizes treatment performance standards required for reuse and potential risk management measures (RMMs). It is noted that the focus of the remediation and treatment options presented herein is on PHCs and VOCs as these are the contaminants for which remediation activities are expected to be able to reduce concentrations on a timescale in line with the project requirements. For other contaminants of concerns (COCs), such as polycyclic aromatic hydrocarbons (PAHs) and metals, limited remediation technologies are available to address these parameters and these technologies are not generally practical for short-term results. Consequently, these COCS will be mainly addressed via risk assessment, soil management or stabilization, and RMM strategies (that is, management in place) as opposed to remediation strategies geared to reducing concentrations.

E.1.2 Soil Excavation Target Areas and Characteristics

Figure 3 shows the proposed new river route through the Port Lands area (area in the dark green shading). Excavation is expected to proceed in approximately five phases. Based on the proposed river profile, the excavation depth is expected to be approximately 6 metres (m) along much of the route, increasing to approximately 10 m near the downstream portion. These depths include approximately 2 m of over excavation, intended to ensure maximum removal of potential contamination and geotechnical unsuitable soil. The depth will also provide sufficient construction depth to build the grade structures, scour protection, wetlands, and other river valley features.

Soil in the unsaturated zone will be excavated using standard excavation equipment (for example, standard off- or on-road trucks and production excavators). Depth to groundwater is generally 1 to 3 m across the Site. Soil within the saturated zone will be removed using dredging methods (either mechanical or hydraulic dredging). The dredging method may significantly impact how the dredged soil is handled, since the solids content of mechanically-dredged soil may be on the order of 30 percent, while the solids content of hydraulically-dredged soil may be on the order of 10 percent. Further discussion on the excavation methodology is provided in the Earthworks Methodology report (Tab H).

Geological cross-sections of the planned River Valley excavation (Figures 9A to 9I) suggest the soil to be excavated is predominantly fill and poorly-graded sand with lesser amounts of silt, clay, and peat. Depth to bedrock varies across the Site and is known to occur less than 10 metres below ground surface in some locations. However, bedrock is not expected to be encountered or excavated during the project. Bedrock and geology conditions are described in the Conceptual Site Model (Tab A).

Contaminants known to be present within the soil include PHCs, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), inorganics, and VOCs. Some areas of the Port Lands showed evidence of light nonaqueous phase liquid (LNAPL) and, to a lesser extent, dense nonaqueous phase liquid (DNAPL). Neither LNAPL nor DNAPL was observed at any boring or well locations during the Stage 1 field activities; however, LNAPL was observed at multiple locations during the Stage 2 field activities. Measurable LNAPL accumulations, ranging from 5 to greater than 100 centimetres (cm), were found in wells at 4 locations and a hydrocarbon sheen, indicative of potential nearby LNAPL presence, was found at 11 wells, all located at 51 Commissioners Street property during Stage 2 activities. In addition, at one location globules of nonaqueous phase liquid (NAPL) were observed to accumulate in the bottom of the bailer, an indication of DNAPL presence.

Six test pits were subsequently excavated in close proximity to wells at which LNAPL was observed to better evaluate the nature and extent of LNAPL presence. LNAPL samples tested for resemblance testing indicated that the LNAPL included motor oil range, diesel/motor oil range, and gasoline/diesel/motor oil range product. Evaluation of chromatograms for the DNAPL sample indicated that it appeared to be largely comprised of motor oil (primarily F4 organics) with some diesel product as well.

Tab A provides the maximum contaminants of concern; however, a focused review of the river valley area was completed and Table E1 provides approximate maximum concentrations. Because much of the PHC contamination spread across the properties within the Study Area laterally after being released, PHC-impacted soil is likely present at or near the top of the water table throughout most the PHC-impacted areas. This distribution is confirmed by Site data and visual observations of borings and can be used to estimate a likely minimum soil volume that requires remediation. CH2M HILL Canada Limited (CH2M) is assuming widespread PHC contamination in the Phase 1 and 3 areas, with lesser extents of contamination in the Phase 2a and Phase 2b areas (limited more to hot spots and zones).

Table E1. Approximate Maximum Concentrations in Soil for Select Parameters

Soil (µg/g)	Phase 1 (Western Greenway)	Phase 2a (Central Greenway)	Phase 2b (Lower Greenway)[a.]	Phase 3 (Upper Greenway)
PHC F1	14,700	600	165	8,800
PHC F2	16,000	4,700	6,900	2,800
PHC F3	19,500	6,400	45,000	3,300
PHC F4	6,200	7,200	44,000	3,700

Note:

[a.] Maximum concentrations listed for Phase 2b are attributable to one sample at BH109-15, which is just outside the limits of the Phase 2b area. This sample was included due to the proximity to Phase 2b and the small data set (8 samples) to base the expected PHC concentrations on. Without this sample, maximum concentrations are as follows: PHC F1 at 10 µg/g; PHC F2 at 50 µg/g; PHC F3 at 2,700 µg/g; and PHC F4 at 9,600 µg/g.

µg/g - microgram per gram

Contamination is also present in groundwater with concentrations of PHC F1 ranging from an approximate maximum of 5,000 micrograms per litre (µg/L) in Phase 1 to 103,000 µg/L in Phase 3.

Table E2. Approximate Maximum Concentrations in Groundwater for Select Parameters

Groundwater (µg/L)	Phase 1 (Western Greenway) [a]	Phase 2a (Central Greenway)	Phase 2b (Lower Greenway)	Phase 3 (Upper Greenway) [b]
PHC F1	13,400	240[2]	100[2]	103,000
PHC F2	200,000	6,600	250	15,000
PHC F3	410,000	6,600	640	4,000
PHC F4	77,000	1,400	250	250

Notes:

[a.] High concentrations of PHCs have been reported in the Phase 1 area as well as measured LNAPL of over 100 cm.

[b.] Maximum concentrations listed for F1 in Phase 2a and 2b and all fractions in Phase 3 are attributable to historical samples (2005 and 2008).

E.1.3 Soil Target Levels

Excavated soil must be treated to protective standards to prevent receptors from being exposed to unacceptable levels of contamination. Target levels for surface and subsurface soil are included in the Screening Level Risk Assessment (SLRA) (Tab B). Table E3 provides a comparison of guidelines and standards for major contaminants targeted for remediation activities, such as PHC and VOCs. As noted previously, these are the contaminants for which remediation activities are expected to be able to reduce concentrations on a timescale in line with the project requirements. S-GW3 refers to the Ontario Ministry of the Environment and Climate Change component value for the soil concentration protective of the GW3 pathway (groundwater protective of aquatic receptors in surface water).

Table E3. Preliminary Shortlist of Major Contaminants and a Comparison of Cleanup Levels
All values in µg/g

Contaminant	Table 9	Confined Fill	Free Phase Threshold	S-GW3
PHC F1	25	55	1747	745
PHC F2	10	98	2703	972
PHC F3	240	300	5761	NA
PHC F4	120	2800	6906	NA
Cis-1,2-DCE	0.05	1.9	4570	131
1,1,2,2-TCA	0.05	0.05	6660	48
TCE	0.05	0.61	4120	301
VC	0.02	0.02	6060	270

Notes:

DCE - dichloroethylene
N/A - not applicable
TCA - trichloroethane
TCE - trichloroethylene
VC - vinyl chloride

The data indicate that up to a 99 percent reduction in contaminant concentrations could be required for the soil containing the greatest degree of contamination. However, it is expected that the average concentrations of excavated material will be significantly lower than the maximum detected values.

In addition, geotechnical standards have been established for different types of soil reuse. Geotechnical standards for soil reuse are addressed in Tab D.

E.1.4 Potential Soil Treatment Methods

A variety of soil treatment methods are available to address the contaminants known to be present. The most widespread of which appear to be PHCs. Technologies to treat these organic contaminants are expected to be applied to relatively large soil volumes. However, technologies that can address metals or other contaminants may also be necessary for some soil.

The overall treatment strategy developed for the soil should be integrated with the expected excavation and dredging methods, as well as the expected reuse for the soil. Because of residual subsurface uncertainties that will remain even after final design, a flexible and adaptive soil management strategy will be essential for keeping the project on schedule and on budget. Pretreatment measures, such as dewatering or screening to remove rocks, cobbles, or debris may be also required.

Ex situ treatment methodologies were considered and the following methods appear to potentially apply:

- Excavation and offsite disposal
- Bioremediation
- Thermal desorption
- Soil washing
- Stabilization

Excavation and offsite disposal are not expected to be widely applied because of the need to reuse soil to the extent practical. This soil management approach will only be applied to limited amounts of excessively contaminated soil, such as soil impacted by DNAPL or PCBs, for which onsite treatment is neither cost-effective, nor practical.

In an ex-situ approach, where the soil in the river valley is excavated and groundwater emerges into the excavation, groundwater treatment is addressed separately through construction management techniques. At present, the approach does not incorporate additional efforts to treat or pump the water from the excavation. Standard skimming and sorbent booming to remove emerged sheen are effective methods (as shown in the following photo). Contingencies for more aggressive means such as enhanced biodegradation with dissolved oxygen spargers or fine bubble diffusion should be included.

Photo 1. Boom and Skimming Operations in Wet Excavation in Contaminated Soils

Photo 2. Skimmers Operating to Remove Floating Petroleum Products

Upland dissolved phase groundwater contamination (in the land upgradient to the future river valley) will likely remain post construction. This area is proposed to be managed through risk assessment and risk management measures, as discussed in Tab B.

In situ remediation approaches were evaluated to pretreat river valley soil before excavation. While in most circumstances the 2 to 3 years available in the schedule to pretreat areas would be sufficient to effect beneficial mass reduction, opportunities for an in situ remediation approach only apply to areas with high peat, silt, and clay composition, resulting in less certain remediation. As a result, in situ remediation was not considered further.

The following sections briefly discuss each remaining technology.

E.1.5 Bioremediation

Bioremediation is the use of biological organisms, most commonly bacteria, to degrade organic contaminants. For this project, bioremediation is most applicable to soil impacted by PHCs, particularly fractions F1 and F2. Considerable success has been achieved treating soils impacted by PHCs when this technology is properly applied.

Biopiles are one form of bioremediation that has been widely applied to soils impacted by PHCs. Biopile treatment involves treating the soil in long soil piles by creating conditions conducive to biological activity while controlling air emissions and leachate generation. Biopile treatment typically lasts from a few weeks to several months, but may last for up to a year in some cases, depending on the contaminants present and the design and operational parameters selected for the biopile. Because biodegradation rates are significantly higher at higher temperatures, this alternative can most effectively be applied during warm periods of the year or, in colder weather, may benefit from a concurrent application of heat to the soil. Heating the soil increases PHC biodegradation rates.

After excavating contaminated soil, biopile treatment may include the following steps:

- Temporarily stockpiling soil from the saturated interval to allow for drainage of entrained water, if necessary.
- Screening to remove rocks, cobbles, and debris, if significant amounts of coarse materials are present.
- Placing soil onto prepared biopile pads, in long piles up to several metres high. The pad may include an aeration and vapour extraction pipe, located down the centre of the biopile pad.
- Mixing soil with fertilizer, organic amendments, and possibly microbial amendments using either a front-end loader or specialized composting mixing equipment.
- Adding water to the pile, as needed, to achieve a moisture level in the range conducive to microbial activity
- Keeping the pile covered with an impermeable membrane to reduce air emissions and prevent excess moisture addition.
- Pulling air through the pile to promote aerobic biodegradation.
- Periodically removing the cover and mixing the pile or adding water, as needed, to promote complete aeration and biodegradation.
- Periodically testing the soil to determine when it meets the remedial standards.
- Reusing the soil after treatment has been completed.

Biopile pads are sloped to a sump that collects leachate and stormwater. Collected water is treated, or reused for moisture control, or both. If vapours are actively extracted from the biopiles, they are typically passed through granular-activated carbon to remove volatilized contaminants and odorous compounds before discharge.

It appears that sufficient space is available to construct biopile treatment. The treatment pad would likely cover substantial portions (from one quarter to one-half) of the Cousins Quay area. Cousins Quay has been identified as a potential location given the presence of a level, impermeable surface. Providing soil heating capabilities for the biopile pads to maximize biodegradation rates and minimize the soil treatment duration may facilitate achieving the target schedule of 3 months. The addition of bulking agents could also assist with biodegradation rates by improving the moisture retention capacity of the soil.

The rate and extent of biodegradation is primarily a function of the nature of the contaminants, as well as temperature. F1 and F2, the predominant PHC fractions identified in key areas, are generally biodegradable. F3s generally have lower biodegradation rates than F2s, and some F3s, such as PAHs like benzo[a]pyrene, are often very slowly degraded. F4 PHCs may not respond quickly to bioremediation treatment.

Laboratory or field pilot tests are typically conducted before full-scale implementation, to confirm the expect rates and extent of biodegradation; optimize the biopile design and operation; and confirm the length of time required within the biopile.

The cost to implement biopile treatment depends on a variety of factors, such as the volume of treated soil, the size of the treated area, the depth of excavation, the complexity of biopad construction, the required duration of treatment, and the target cleanup criteria. Including active aeration, vapour treatment, and soil heating capabilities in the pads, for example, would increase the total costs of this alternative compared with simpler applications. Published data for ex situ soil bioremediation shows the unit costs for this type of treatment can vary widely. For example, the ex situ soil bioremediation unit costs may range from as low as \$16.3 per cubic metre (m^3) to \$780/m^3. Most of the unit costs for ex situ treatment of PHC-impacted soil were less than \$130/m^3. Higher unit costs were often noted for soil with smaller volumes, which were unable to take advantage of the economies of scale realized with larger soil volumes.

Past experience suggests that order-of-magnitude unit costs to implement the simplest forms of biopile treatment may range from $45 to $85/m^3. These costs would include mobilization and demobilization, excavation, construction of the basic treatment pads, treatment, and backfilling of soil. Including dewatering, aeration and treatment of extracted vapours, soil heating capabilities into the biopile pads, and other site-specific process modifications would increase this costs for this alternative. A conservative unit cost for this technology would be approximately $85/m^3. Actual costs to implement this technology could be greater or less than this estimate. Because of the reported wide range and site-specificity of bioremediation costs, this cost should be refined through evaluations and discussions with qualified subcontractors experienced with this technology.

Photo 3. Photo of a Biopile Remediation System

E.1.6 Thermal Desorption

Thermal desorption involves the application of heat to soil under controlled conditions to accelerate volatilization of organic contaminants from soil. Organic contaminants transferred to the vapour phase are then treated using thermal oxidizers, activated carbon adsorption, or other means before discharging the treated offgas to the atmosphere. Most thermal desorbers operate at temperatures between 90 degrees Celsius (°C) to 560°C. More volatile products (such as gasoline) can be desorbed at the lower operating range, while semivolatile products (such as kerosene or diesel fuel) generally require temperatures in excess of 375°C, and relatively nonvolatile products (such as heating oil, pesticides, PCBs) require even higher temperatures. Essentially all soil types are amenable for treatment by low-temperature thermal desorption (LTTD) systems. However, different soils may require varying degrees and types of pretreatment. For example, coarse-grained soils (such as gravel and cobbles) may require crushing; fine-grained soils that are excessively cohesive (such as clay) may require shredding, wet soil will required moisture removal.

A variety of thermal desorption technologies are available. Mobile thermal treatment units, typically referred to as LTTD units, can be set up temporarily at sites for treating soils, and then demobilized once the project is completed. These units often comprise rotating steel cylinders, into which the soil is placed, followed by heating inside the vessel or within a secondary outer metal shell through gas fired burners. Vapour treatment is typically implemented using thermal oxidizer or activated carbon. Commercial mobile LTTD units that can be brought to a site, set up, and used to treat soil onsite generally have a soil treatment capacity on the order of 7 to 27 tonnes per hour. In order to provide this treatment onsite, LTTD services unit would need to be provided by a contractor with a suitable mobile Environmental Compliance Approval for this technology.

Fixed base LTTD treatment systems are available at some commercial soil reclamation facilities. These LTTD units typically have greater capacity than mobile LTTD units, as high as 160 tonnes per hour. However, no fixed base LTTD treatment systems are available in the Toronto/Ontario area. Although fixed base LTTD facilities are available in other locations, trucking large quantities of soil substantial distances from the Site for treatment and back to the Site for reuse is not consistent with sustainable soil management goals established for the project. For this reason, thermal treatment of soil at an offsite thermal treatment facility is not considered appropriate for this project.

Another thermal desorption technology developed for treating soil involves heated soil piles. In this application, contaminated soil is placed onto impermeable liners along with either metal rods, which will be electrically heated, or metals pipes, which will be heated by hot air. Impermeable liners are then used to seal the top of the piles. Heat is applied to the soil while organic vapours are withdrawn from the heated soil. Extracted vapours are treated using thermal oxidizers or activated carbon adsorption. The active heating period for this type of thermal treatment depends on the nature of the contaminant, amount of contamination present, treatment goals, soil type, and system design, but may range from a few weeks to several months.

For this project, the throughput capacity of commercial LTTD units is anticipated to be too low for the amount of soil that may require treatment for using thermal technology. However, mobile LTTD units could be potentially suitable for treating smaller quantities of LNAPL, DNAPL, or PCB-impacted soil onsite.

Thermal desorption using heated piles may be better suited for treating larger quantities of soil expected to be generated during this project. For the costing exercise, it is assumed that if thermal desorption is selected, the heated pile method would be applied.

Bench- or pilot-scale treatability studies are usually conducted to optimize the soil pile design, heating temperature, system operation and confirm length of time required for treatment and expected degree of treatment before developing full-scale design.

Costs to implement thermal desorption vary widely, depending on factors such as the type of thermal treatment unit used, soil and contaminant type, degree of contamination, treatment goal, soil moisture content, and soil volume. While costs to treat soil at a commercial soil reclamation facility with a large LTTD unit can be below $200/m^3, the costs to implement this technology onsite using a smaller mobile LTTD unit or via thermal piles may range from $200 to over $600 per m^3. The actual cost would depend on the amount of soil treated, nature and degree of contamination in the soil, required soil treatment end points, and other factors. Costs to apply thermal treatment using heated piles may be similar or less expensive, depending on the degree of treatment required and specific technology applied by the vendor. Mobile LTTD units have lower production rates and are often require to operate on a 24hr/day basis.

E.1.7 Soil Washing

Soil washing refers to a series of treatment steps that result in the removal and treatment of contaminants from soil by applying combined physical and chemical or other treatment processes. Soil washing usually involves a volume reduction process in which soil particles containing the greatest degree of contamination (usually the finest grained particles) are separated from the bulk soil, followed by treatment of the highly contaminated soil material using chemical, biological, or thermal processes. The initial step of particle separation can be accomplished using physical or chemical methods. Physical methods take advantage of differences between particle grain sizes, settling velocities in water, specific gravity, or surface chemical behaviour to separate highly contaminated soil from bulk soil containing little to no contamination. With chemical methods, soil particles are cleaned by selectively transferring the contaminants in the soil into an aqueous solution, using surfactants, solvents, acids, or alkalis.

Waterfront Toronto completed a successful soil washing pilot project in 2010; however, limited soils from the Port Lands study area were treated and effectiveness on specific contaminant concentrations needs to be further reviewed.

With physical separation methods, the highly contaminated material, which has a much lower volume than the original bulk soil volume, is treated, while the lesser contaminated bulk soil can often be reused without further remediation (although in some cases, this material may require light treatment). With chemical separation methods, the bulk soil is typically ready for reuse while the contaminated liquid generated during the washing must be adequately treated before being discharged.

Different soil washing methods can allow for capturing different size soil fractions. Physical screening methods can separate out particles down to just a few millimetres in diameter. Hydrocyclones can allow for further separation of particles to as small as 10 to 20 microns in diameter, although for soil washing remediation purposes, it is typically not necessary to separate particles down to this size. Bench-scale testing is typically conducted to determine the optimal particle separation regime for a specific application.

Soil washing systems are available with a range of throughput capabilities. Small, portable systems that can treat on the order 15 to 30 tonnes per hour can be obtained by commercial vendors. Because many soil washing systems consist of modular elements arranged to operate in series, larger capacity systems can be assembled simply by providing multiple treatment units set up in parallel, allowing for systems with capacities over 100 tonnes per hour to be implemented. This flexibility will allow the system to be sized accordingly to schedule specific production requirements and can easily be modified to accommodate short term production rate changes.

Because of the relatively large amount of soil potentially requiring treatment, soil washing may be an important pretreatment step for the project to reduce the amount soil requiring active treatment. The fine-grained portion of soil often comprises only 10 to 20 percent of the total soil mass. Therefore, the application of soil washing to all potentially contaminated soil, to reduce the volume of soil requiring subsequent treatment, followed by active treatment of the finer-grained soil containing the bulk of the contaminant mass, may be less costly and quicker than treating all soil with an active treatment process.

Costs for soil washing may vary considerably, depending on the soil volume and characteristics, type and degree of contamination, treatment processes and objectives. Typically, soil washing of smaller soil volumes has a higher unit rate cost than treatment of larger soil volumes, which may take advantage of economies of scale. Also, soil washing methods using physical separation typically have lower costs than soil washing using chemical methods. Costs for soil washing using physical methods have been reported to typically range from $65 to $180/cubic metre. However, costs for a specific application could be greater or less than this range.

Photo 4. Example of Soil Washing, Soil Screening and Water Management

E.1.8 Stabilization for Metals-Impacted Soil

Chemical stabilization via mixing a reagent into the soil has been successfully applied to soils impacted by a variety of metal contaminants. This process does not destroy the metals, but decreases their mobility and may reduce their toxicity. Stabilization chemicals most commonly applied to metals-impacted soils include reagents, such as cement, fly ash, slag, phosphorus-containing materials, clays, and other proprietary reagents. The addition of clay or pozzolans can result in permeability reduction within the areas mixed and may change the geotechnical characteristics of the soil.

For ex situ applications, conventional excavating and mixing equipment can be used to mix the soil while blending in a reagent to treat the contaminant. Very shallow soil can sometimes be mixed using equipment such as a mechanical mixing head (such as a Lange tool or with an Allu bucket), mounted to the end of a tracked excavator. The mixing process creates a relatively homogenous soil matrix, reducing peak concentrations of contaminants within the mixed zone and promoting contact with the treatment reagent. The soil mixing process results in volume swell, which results in an increase in the mixed soil volume by 10 to 15 percent or greater.

Bench-scale testing is typically conducted using various reagents and varying reagent concentrations, followed by leaching tests to determine the optimal stabilization process.

It is expected that only a relatively small subset of excavated soil would need to be treated using this process for this project. The specific metals that would need to be treated, optimal reagents, and mixing conditions would need to be further defined to determine the overall cost for this treatment element.

E.1.9 Considerations for Handling LNAPL-Impacted Soil

As noted above, LNAPL was identified at several locations during the Stage 2 field activities at 51 Commissioners Street property. Several treatment technologies described above, such as biopile and thermal treatment, are capable of treating LNAPL-impacted soil. Experience has shown that managing and treating LNAPL-impacted soil separately may allow for the most efficient treatment method to be applied, which may vary depending on the characteristics of the NAPL present in the soil. For this reason, during the soil excavation or dredging phase, separate stockpiling of LNAPL-impacted soil should be considered.

E.1.10 Overall Conceptual Treatment Approach for Contaminated Soils

To develop an order of magnitude cost estimate for treating excavated soils and maximizing the amount of soil for reuse, the following overall conceptual approach to excavating, dredging, and treating the soil is assumed:

- Soil in the unsaturated zone will be excavated using conventional excavation equipment and transported to a treatment area. Much or all of the soil will be screened with a coarse screen to remove large debris. Further pretreatment via soil washing will be conducted on this soil to minimize the amount of soil requiring active treatment.
- Soil in the unsaturated zone will be mechanically dredged, transported to a treatment area and passed through a soil washing unit designed specifically for sediment (e.g. Del-Tank system). This unit will achieve particle separation, creating a coarse soil material, which is assumed suitable for reuse without further contaminant removal, and a finer-grained material which requires further treatment.
- For both the unsaturated and saturated zone soils, the fine-grained portion separated by soil washing is assumed to be 20 percent of the soil volume.

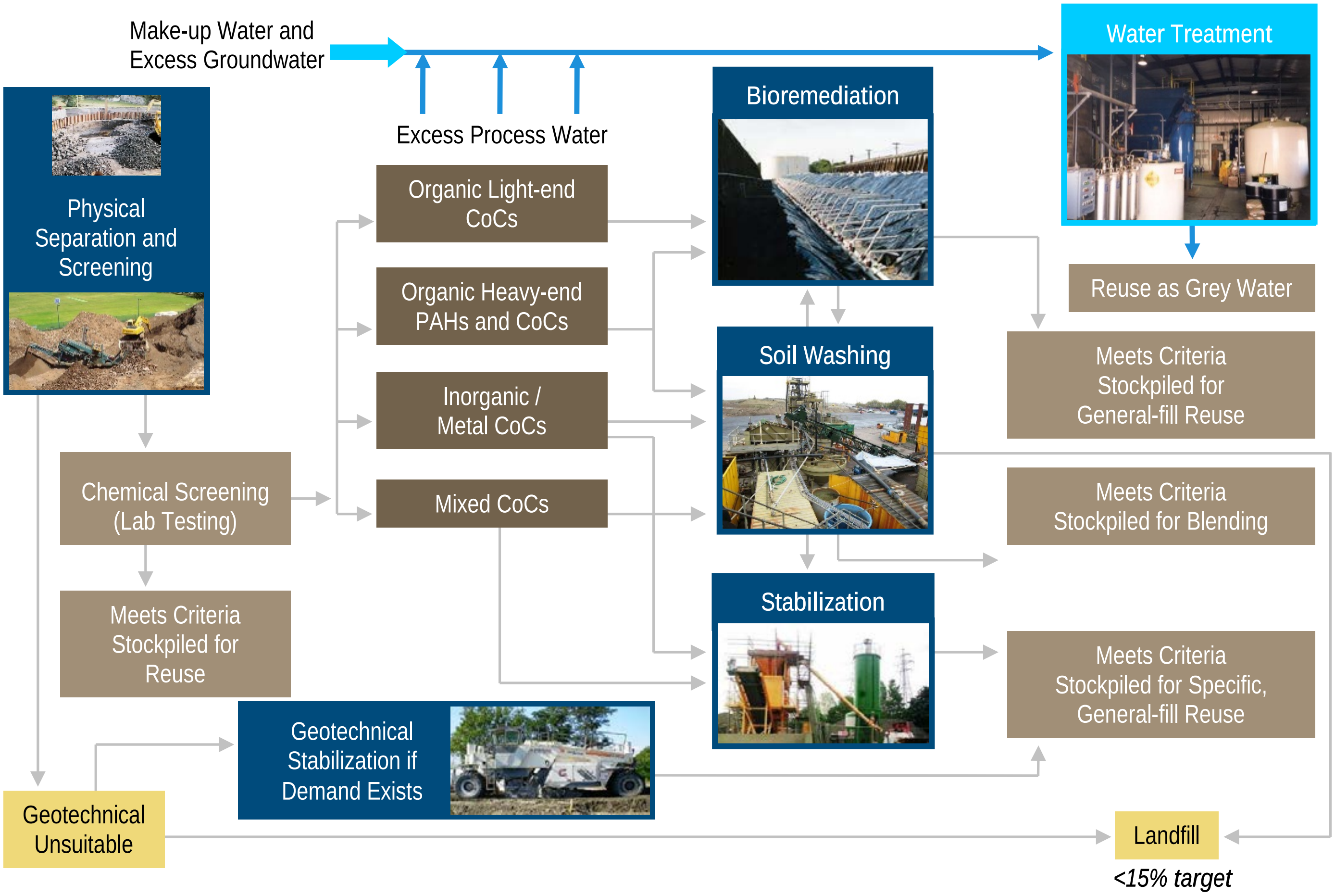

Exhibit E1. Soil Processing Schematic

- Fine-grained material separated for further treatment will be treated using biopiles, due to the lower cost of bioremediation compared to thermal treatment.
- Excavated soil contaminated by PCBs, if any, or high levels of PHC F4 will be sent for offsite disposal, since onsite treatment is impracticable. Alternatively, for F4 PHC, and if permitted through the risk assessment, soils could be reused below risk management barriers.
- Metals-contaminated soil will be treated onsite using soil washing and chemical stabilization, if required
- Some material is assumed to be untreatable and disposed of offsite

A schematic diagram of the soil treatment process is shown in Exhibit E1. Soil volumes expected to be treated using bioremediation are approximately 300,000 in situ m^3.

All key assumptions used to develop this order-of-magnitude cost estimate are subject to revision as additional information is obtained. The conceptual treatment approach may also be revised as additional information is obtained.

To better plan the required soil treatment strategy and assess the suitability and optimal conditions for key treatment technologies, the following additional steps should be implemented:

- Refine the understanding of the distribution and expected concentrations of key contaminants (ongoing).
- Develop a bench-scale and/or pilot-scale treatment program for key technologies to determine key design parameters needed for full-scale design.

- Refine the expected excavation and dredging strategies for integration with expected treatment approaches.

Further details related to these activities can be presented in a soil treatability work plan.

E.1.11 Risk Management Measures

The screening-level risk assessment and community-based risk assessment results will be used to identify risk management options suitable for implementation, given the planned redevelopment activities and future uses. The chosen risk management options will apply to all parcels within the Study Area but site-specific risk assessment for designated areas may require additional RMMs. A summary of proposed RMMs is included in Tab B. Potential exposures to soil, groundwater, and indoor air will be addressed through the implementation of RMMs.

Anticipated RMMs include the following main categories:

- Physical barriers (such as hard or fill caps, or both) to eliminate or manage risk associated with direct exposure of human and ecological receptors to impacted soils and groundwater. A 1.5-m barrier is assumed for the parkland, residential blocks and River Valley; further details are provided in Table E4. It may be possible to reduce the barrier in the River Valley so the thickness is consistent with the structural and habitat thickness requirements.
- Vapour intrusion controls to eliminate or manage risks associated with human exposure to impacted indoor air within maintained heritage buildings and future buildings.
- Administrative controls such as site-specific health and safety plans and soil management plans; these are necessary to protect construction workers and environmental receptors during construction and maintenance activities.

Table E4. Risk Management Measure Barrier Requirements

RMM Area	Thickness (m)[a]	Fill Cap Targets[b]
Existing Land Parkland	1.5 (for planting purposes 1.2 m for treed areas and 500 mm for grass areas and additional thickness to comply with 1.5 m City requirement)	Table 3 and Table 9 (30 m from shoreline), Ontario Regulation 153/04
Shoreline Fill Parkland	1.5	Table C1 (Table 2 agricultural)
Community Roadways/ Utiliducts	1.5 minus road material (approximately 750 mm)	Modified Table 3/9 (minus the eco direct contact component values [plant & org and mammals & birds])
Commercial Blocks with Heritage Structures	1.5 m (potential to reduce to 0.225 for hard cap; 0.5 for soft cap	Table 3/9, Ontario Regulation 153/04 for soft cap
Don Roadway Flood Protection Landform	1.5m (potential to reduce based on future land use)	Table 9, Ontario Regulation 153/04
River Valley Water Lot	1.5 m (potential to reduce to structural and habitat requirements from mvva varying from 1.1 to 1.8 m)	Table C2 (Provincial Sediment Quality Guideline) and Table 3/9, Ontario Regulation 153/04 for soft cap

Notes:

a. Land to be within the City of Toronto management after redevelopment will require 1.5-m barrier, i.e. parkland and roadways.

b. Generic fill cap targets are referenced in this table. Risk based targets or risk based concentrations for soil caps and soil caps under roads are provided in Tab B SLRA, Table B14, B15 and B16.

Figures