Alternatives Evaluation
West, Seep 2, and Seep 1 CKD Areas
Revision 0.0 – July 31, 2009
Little Traverse Bay CKD Release Site
Emmet County, Michigan

Prepared for CMS Land Company and CMS Capital, LLC
U.S. EPA Docket No. VW-05-C-810

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1.0 Introduction

1.1 Report Purpose and Organization

This Alternatives Evaluation report (AE or AE Report) has been prepared for the West Cement Kiln Dust (CKD) Area, Pine Court Seep area, Seep 2 (including Guard Rail) CKD Area, and Seep 1 CKD Area (collectively referred to as Site) at the Little Traverse Bay CKD Release Site in Emmet County, Michigan. This AE Report has been completed pursuant to Section VIII of the February 22, 2005 Administrative Order on Consent (AOC), Docket No. VW-05-C-810, between the United States Environmental Protection Agency (U.S. EPA) and CMS Land Company and CMS Capital, LLC (referred to collectively as CMS). The AOC was issued under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended (CERCLA) 42 U.S.C. §§ 9604, 9606 (a) and 9607 to address conditions that constituted a threat based on factors set forth in the National Oil and Hazardous Substances Pollution Contingency Plan, as amended (NCP), 40CFR § 300. The work performed at the Site and this AE are to be consistent with the NCP.

The purpose of this AE Report is to evaluate potential remedial action alternatives that provide a range of protection for human health and the environment and a range of feasibility and potential costs. This evaluation addresses the requirements and scope for evaluating alternatives for long-term remedy selection contained in the AOC, as described in Section VIII, Paragraph 15, Subsection X and will enable decision-makers to review the selection of an appropriate long-term remedy for the Site. The preparation of this report also fulfills the requirements for development, screening, and evaluation of remedial alternatives and for preparation of a draft feasibility study report as outlined in Section 6.2.1: Draft Feasibility Report, of the *Final Approved Removal Action Work Plan,* (Work Plan) (Barr, 2005).

This AE Report is also intended to be consistent with the State of Michigan Administrative Rules for Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act (NREPA, 1994 PA 451), specifically Rule 530 (R 299.5530), which provides guidelines for a feasibility study for department approval, Rule 607 (R 299.5603), which includes a list of evaluation criteria for selection of a remedial action, and Rule 705 (R 299.5705) Part 7, which provides rules applicable to Interim Response Actions Designed to Meet Cleanup Criteria (IRDC).

1.1.1 Scope

The scope of the AE Report, as defined in the Work Plan, is to evaluate alternative response actions that build on the investigation results and that pursue the following goals:

- Preventing unacceptable exposures to surface waters and sediment impacted by CKD waste material;
- Preventing discharge of groundwater containing hazardous substances at concentrations above state criteria to surface waters of the State;
- Preventing unacceptable risk from human direct contact with CKD waste material;
- Preventing exacerbation, new releases, and unacceptable exposure to CKD waste material; and
- Ensuring that any other unacceptable exposures are adequately addressed.

The scope of this AE Report includes:

- A brief summary of the conceptual site models and identification and quantification of affected media.
- A summary of implemented interim response actions (IR) at the Site.
- Remedial action objectives (RAOs) for affected media.
- A summary of the development of general response actions and the identification, screening, and documentation of remedial technologies for affected media.
- A summary of the screening of process options or combination of process options on the basis of effectiveness (short-term and long-term), implementability, and cost.
- Assemblage of remedial technologies and process options into combinations, each of which addresses all affected media.
- A summary of the development and detailed analysis of retained alternatives against a set of nine evaluation criteria identified in the National Contingency Plan (NCP).

- A comparative analysis of alternatives using the same nine criteria.

The scope outlined above is consistent with the U.S. EPA guidance for feasibility studies (U.S. EPA, 1988). The format has been streamlined, where appropriate, consistent with a suggested outline provided to CMS by the U.S. EPA (facsimile transmission from Diana Mally (EPA) to CMS on November 26, 2006). Compliance with this guidance maintains consistency with the NCP. This AE Report is intended to provide the basis for remedy selection and subsequent approval in accordance with the AOC.

1.1.2 Organization

This AE Report is organized into four sections:

- Section 1.0 includes a description of the purpose of the report and provides a brief summary of the background information, including the conceptual site models and IR.
- Section 2.0 summarizes the development of the RAOs for soil, groundwater, and surface water at the Site, and provides the identification and screening of potential remedial technologies and process options.
- Section 3.0 contains the development and screening of comprehensive remedial alternatives.
- Section 4.0 provides detailed and comparative analyses of the developed alternatives.

1.2 Background Information

A detailed summary of the Site background information, including the remedial investigation (RI) work performed under the Work Plan, the nature and extent of contamination, and the site conceptual model is included in the Removal Action Investigation/Remedial Investigation Report, West, Seep 2 and Seep 1 CKD Areas (Barr, 2009a) (referred to here as RI Report), that has been submitted to the U.S. EPA. Therefore, only a brief summary of the Site background information is included in this AE Report.

1.2.1 Site Location

The Little Traverse Bay (LTB) CKD Release Site is located along five miles of shoreline on Little Traverse Bay of Lake Michigan. The Site is approximately five miles west of the City of Petoskey, and located in Resort Township, Emmet County, Michigan (Township 34N, Range 6W, Sections 2 through 10). The West CKD Area, Pine Court Seep area, Guard Rail Seep area, Seep 2 CKD Area, and Seep 1 CKD Area (the focus of this AE) are located on the central portion of the LTB CKD Release Site as shown on Figure 1-1.

1.2.2 Site Description

The Site is currently a multi-use area with mixed residential, commercial, open space, and recreational (golf course) land uses and is currently owned by a combination of private property owners (primarily residences or open lots), Bay Harbor Golf Club, Inc. (golf course), and Bay Harbor Company (roads, commercial, and undeveloped/open space). The Site includes CKD piles which are bordered by Lake Michigan on the north, a Bay Harbor marina complex to the east, and residential areas to the south and west. The Site is described in greater detail in Section 1.3.2 of the RI Report.

1.2.3 Site History

The LTB CKD Release Site is located on a former limestone mining and cement manufacturing plant operated by the Penn-Dixie Company from approximately 1870 through 1980. CKD was stockpiled on the Site from approximately 1921 to 1980 (NTH, 1994). Bay Resort Properties Limited Partnership (Partnership) purchased the property in stages beginning in the late 1980s and completing in the 1990s. The Partnership developed the property in December 1995 into a golf course with residential units adjacent to the CKD footprint. The Site CKD piles were contoured to enhance precipitation runoff and covered to provide for use as a golf course. Site history is described in greater detail in Section 1.3.3 of the RI Report.

1.2.4 Nature and Extent of Contamination

The source of high-pH leachate impacts at the Site are three CKD piles placed at the West CKD Area, Seep 2 CKD Area (including Pine Court Seep area and Guard Rail Seep area), and Seep 1 CKD Area. CKD is a by-product of Portland cement production and is a particulate mixture of partially calcined and unreacted raw limestone feed, clinker dust, and fuel ash, enriched with alkali sulfates, halides, and other volatile inorganic materials. The location and extent of the CKD piles are shown on Figures 1-1 and 1-2, and in-place volume estimates are summarized in Table 1.

The footprint and volume of CKD located within the West CKD Area is estimated to be approximately 5.4 acres and 100,000 cubic yards (CY), respectively. The thickness of CKD varies from 0 to 33 feet, with the thickest CKD located near borehole B3001 (see Figure 4-1a of the RI Report for boring locations). An estimated 15 percent of this material may be saturated during high groundwater conditions based on the evaluation of geophysical and borehole data collected as part of the RI.

The footprint and volume of CKD located within the Seep 2 CKD Area (including Pine Court Seep area and Guard Rail Seep area) is estimated to be approximately 34.8 acres and 1.1 million CY, respectively. The thickness of CKD varies from 0 to 63 feet, with the thickest CKD located near boreholes B2022, B2021, and B2005 (see Figure 4-1b of the RI soil boring locations). Less than approximately two percent of this material is estimated to be located below the regional groundwater table during high groundwater conditions based on the evaluation of geophysical and borehole data collected as part of the RI.

The footprint and volume of CKD located within the Seep 1 CKD Area is estimated to be approximately 15.5 acres and 550,000 CY, respectively. The thickness of CKD varies from 0 to 56 feet, with the thickest CKD located near boreholes B1022, and B1024 (see Figure 4-1c of the RI Report for boring locations). Approximately one percent of this material is estimated to be located below the regional groundwater table, based on the evaluation of geophysical and borehole data collected as part of the RI.

Analytical data for Site samples were evaluated against potentially applicable criteria to identify Site Contaminants of Concern (COCs). Data for groundwater and unconsolidated material samples (non-CKD and CKD) were compared to Part 201 Generic Cleanup Criteria. Analytical data for surface water samples were compared to potentially applicable Part 31 surface water criteria; however, the data collected only sporadically and inconsistently exceeded potentially applicable Part 31 criteria and these data could not be correlated to the seep areas. As a result, CMS requested in a letter dated January 31, 2007 that surface water sampling requirements pursuant to Section 4.2.5.2 of the Work Plan be eliminated and the U.S. EPA approved this request in an email dated May 11, 2007.

The following criteria were exceeded by potential Site COCs in groundwater and/or unconsolidated materials (including non-CKD and CKD).

Groundwater (monitoring well samples):

Residential Drinking Water Criteria	chloride, sum of potential nitrogen sources, ammonia nitrogen as N, TDS, sulfate, pH, aluminum, arsenic, barium, beryllium, chromium, iron, lead, magnesium, manganese, mercury, nickel, selenium, sodium, thallium, vanadium, bis(2-ethylhexyl)phthalate
Groundwater Surface Water Interface Criteria	chloride, % ammonia that will become NH_3 in surface water, TDS, pH, antimony, arsenic, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, zinc

Unconsolidated Materials (non-CKD and CKD):

Drinking Water Protection Criteria	sum of potential nitrogen sources, total phosphorus, sulfate, aluminum, arsenic, chromium, iron, lead, magnesium, manganese, sodium, thallium
Groundwater Surface Water Interface Protection Criteria	chromium, selenium, manganese
Direct Contact Criteria	chloride, arsenic

The ubiquitous nature of some potential COCs (e.g., aluminum, iron, manganese, etc.) in groundwater suggests that some potential COCs are naturally occurring or both naturally occurring and associated with CKD. Groundwater and unconsolidated material potential COC exceedances for each CKD area are presented in Section 5.0 of the RI Report. Exceedances in groundwater monitoring well samples are shown on Figure 5-1a to Figure 5-1c through Figure 5-18a to Figure 5-18c of the RI Report and discussed in Section 2.2.3 of this report.

1.2.5 Contaminant Fate and Transport

Contaminants present in the CKD have the potential to impact human health and the environment through direct contact with the CKD, by physical migration of the CKD (runoff or wind erosion), or by migration of contaminants in leachate derived from water contact with CKD. Direct contact with CKD and physical migration of CKD are not relevant potential exposure pathways based on existing Site conditions. Because the CKD at the Site is covered, there is presently no potential for direct contact with the CKD. It is possible that CKD exposed by erosion of the soil cover may allow air or surface water to become a relevant route of contaminant migration. However, inspection of the Site during the RI has shown that the soil cover placed over the CKD during golf course development is effectively preventing erosion, thereby mitigating this potential exposure pathway.

Migration of contaminants derived from water contact with CKD is a relevant potential exposure pathway for existing Site conditions. Water that infiltrates through the CKD or groundwater that passes through the CKD below the water table seasonally migrates in the direction of Lake Michigan. Water that has come into contact with the CKD (leachate) can transport some contaminants and may impact the surface water. Prior to IR actions (e.g., operation of the beach collection drains) impacts to the pH of surface water adjacent to the Site CKD areas were documented during three targeted shoreline water quality survey events, as described in Section 3.1.4.1 of the RI Report. The results from these surveys indicate that the high pH in the CKD leachate historically migrated via groundwater to the surface water of Lake Michigan. The migration of other contaminants in CKD leachate, such as metals and inorganic compounds, may be attenuated by numerous mechanisms, including physical (dilution via differential permeability, dispersion, and diffusion) and chemical (adsorption, chemical reactions, and precipitation) processes, as discussed in Sections 6.2 and 7.1 of the RI Report. Any metals and inorganic compounds not addressed by remedy construction or otherwise attenuating below surface water criteria will be included in the compliance monitoring plan required by State law.

Groundwater models have been developed for the West CKD Area, Seep 2 CKD Area (including Guard Rail Seep area and Pine Court Seep area), and the Seep 1 CKD Area to help describe and quantify the flow of the groundwater. These models are described in detail in the groundwater modeling report (Barr, 2009b). Groundwater flow results at each seep area are summarized in Appendix B.

Section 7.1 of the RI Report outlines the prevalence of potential COCs, their characteristics, distribution at the Site, and the potential attenuation processes which will control their concentrations along a groundwater flow path.

1.3 Interim Response Actions

This section summarizes the status of the IR actions performed at the Site. IR actions carried out at the Site include both leachate migration control and leachate generation control activities.

1.3.1 Current Status of Interim Response Actions

Figures 4-1, 4-2, and 4-3 show existing conditions at the West CKD Area, Seep 2 CKD Area (including Pine Court Seep area and Guard Rail Seep area), and Seep 1 CKD Area, respectively, based on the IR actions implemented through May 2009.

1.3.1.1 West CKD Area

The IR activities in place or performed at West CKD Area are as follows:

- Leachate Migration Controls
  - The West CKD East Leachate Collection System (West CKD east beach drain) was installed and operated beginning December 22, 2005.
  - The West CKD West Leachate Collection System (West CKD west beach drain) was installed and operated beginning May 22, 2006. This beach drain was augmented by

extending the drain 75 feet west in October 2006. The entire length of the West CKD west beach drain was operated from October 18, 2006 through January 5, 2009 at which time it was temporarily removed during beach CKD/soil excavation activities.

- Installation of modified low permeability backfill downgradient of the West CKD beach drains was completed April 8, 2009.
- Beach drains were reconstructed and operation resumed in May 2009.

- Leachate Generation Controls

  - 12,435 tons of CKD-impacted soil removal from the West CKD Area beach was completed February 5, 2009.

1.3.1.2 Pine Court Seep Area

The IR activities in place or performed at the Pine Court Seep area are as follows:

- Leachate Migration Controls

  - The Pine Court Seep area East Leachate Collection System (Pine Court east beach drain) was installed and operated from December 22, 2005 through June 23, 2006.
  - The Pine Court Seep area West Leachate Collection System (Pine Court west beach drain) was installed and operated from December 22, 2005 through July 12, 2006.
  - The Pine Court Seep area Carbon Dioxide (CO_2) Pilot Injection System was installed in the Pine Court Seep area east beach drain and operated beginning June 29, 2006. The CO_2 System was augmented to a “three tube” configuration on December 16, 2006 to target locations with recurring lake pH values greater than 9.0 s.u. This system was somewhat effective in reducing pH in the Pine Court Seep area; however, delivery of CO_2 to the trench was unable to completely control the high flow rate of moderately elevated pH in certain areas of the shoreline. As a result, CMS requested that the CO_2 Pilot Injection System be terminated in a letter dated February 13, 2009 and the U.S. EPA approved this request in a letter dated April 8, 2009.
  - The Seep 2 CKD Area Targeted Leachate Collection Pilot System (TLC System) was installed and operated beginning May 30, 2008 with collection from S2RW-1. The TLC System was expanded to include collection from S2RW-4 and S2RW-5. Operation of the modified system began April 30, 2009.

- The Pine Court Seep area beach collection drain was modified in April 2009 to include a temporary aboveground discharge line routed to frac tanks and a tanker load-out area. The temporary system was constructed to make possible collection of Pine Court Seep area leachate without mixing moderate pH Pine Court Seep area leachate with higher pH leachate from other seep areas. Collection from the Pine Court Seep area east and west drains resumed April 30, 2009.

1.3.1.3 Seep 2 CKD/Guard Rail Seep Area

The IR activities in place or performed at the Seep 2 CKD Area/Guard Rail Seep area are as follows:

- Leachate Migration Controls
  - Continued operation of the Edge Drain Leachate Collection System (Edge Drain).
  - The Seep 2 Leachate Collection System (Seep 2 beach collection drain) was installed and operated beginning October 10, 2005.
  - The Guard Rail Leachate Collection System (Guard Rail beach collection drain) was installed and operated beginning October 10, 2005.

1.3.1.4 Seep 1 CKD Area

The IR activities in place or performed at the Seep 1 CKD Area are as follows:

- Leachate Migration Controls
  - The Seep 1 CKD Area West Leachate Collection System (Seep 1 CKD Area west beach collection drain) was installed operated beginning October 10, 2005.
  - The Seep 1 CKD Area East Leachate Collection System (Seep 1 CKD Area east beach drain) was installed and operated beginning in April 2006.
  - Installation of a slurry wall vertical barrier downgradient of the Seep 1 CKD Area east beach collection drain was completed October 11, 2008.

1.3.2 Effectiveness of Interim Response Actions

The effectiveness of the IR at protecting human health and the environment is evaluated through the following three lines of evidence: (1) effectiveness monitoring – lakeshore pH control; (2) mercury flux analysis; and (3) surface water quality data. The review of these three lines of evidence leads to the following general conclusions:

- The West CKD East and Seep 1 CKD West beach collection drains are highly effective at protecting human health and safety and the environment.

- The Seep 2 CKD Area (including Guard Rail Seep area) beach collection drains, in conjunction with operation of the Edge Drain, are highly effective at protecting human health and the environment.

- The West CKD Area West beach collection drain, in conjunction with removal of CKD from the beach and installation of modified low-permeability backfill downgradient of the beach collection drain, is expected to be highly effective at protecting human health and safety and the environment.

- The Seep 1 CKD Area East beach collection drain, in conjunction with the slurry wall vertical barrier, is expected to be highly effective at protecting human health and safety and the environment.

- The impact of the existing TLC System related to protection of human health and the environment at the lakeshore has been documented (Barr, 2008b). The existing TLC system operation appears to be having a positive effect on pH in shallow wells west of the TLC area (e.g., in the vicinity of borehole B2025) and within approximately 500 feet. However, the same positive effect is not yet observed in deep wells, wells further to the west of the Pine Court Seep area, or in wells to the north of the TLC area. Continued operation of the existing TLC System is expected to allow the positive effects of the leachate collection, as demonstrated in well W2226, to manifest themselves in wells further to the west and north.

- The Pine Court Seep area beach collection drains are expected to be highly effective at protecting human health and safety and the environment.

1.3.2.1 Effectiveness Monitoring – Lakeshore pH Control

The first line of evidence of the effectiveness of the IR actions is from effectiveness monitoring of lakeshore pH control. Effectiveness monitoring has been conducted and evaluated at the Site subsequent to construction of the Interim Leachate Recovery System (ILRS) also referred to as the leachate collection system. Lakeshore pH readings greater than 9.0 s.u. have been recorded in surface water during this effectiveness monitoring. The results show a significant improvement of lakeshore conditions relative to the initial targeted shoreline survey. This improvement demonstrates that the IR is generally effective at controlling pH in the lake. Also, the occasional and low-level pH exceedances (e.g., pH excursions) observed do not pose a threat to human health and safety or the environment.

1.3.2.1.1 West CKD Area Effectiveness Monitoring

A total of 1,807 effectiveness monitoring data points have been measured and recorded. Since the completion of the augmentation work in April of 2009, there have been no pH exceedances in the West CKD Area during the April and May 2009 effectiveness monitoring events.

1.3.2.1.2 Pine Court Seep Area

A total of 1,058 effectiveness monitoring points have been collected in the Pine Court Seep area. Only 21 of these data points exceeded the pH goal of 9.0 (ranging from 9.14 to 9.87 s.u.) through 2007. Due to the inability of the CO_2 system to effectively control the pH, leachate collection was resumed at Pine Court Seep area in May 2009. Only one exceedance was noted in the effectiveness monitoring that occurred after leachate collection was resumed in May 2009. The occasional pH excursions do not pose any threat to public health and safety or the environment.

1.3.2.1.3 Seep 2 CKD Area (including Guard Rail Seep area)

Seep 2 CKD Area (including Guard Rail Seep area) effectiveness monitoring has been conducted since October 2005 and a total of 809 lakeshore pH samples have been collected. A total of four samples exceeded a pH of 9.0, resulting in 99% of the samples meeting 9.0. Maximum lakeshore pH measurements in 2006 and 2007 were 9.19 and <9.0, respectively. Maximum pool pH measurements in 2006 and 2007 were 9.33, and <9.0, respectively. Excluded from the effectiveness monitoring are three pools measured on October 18, 2006 at the western end of the Seep 2 CKD Area beach collection drain which exceeded a pH of 9.0. The three pools were determined to be related to a construction defect at the Seep 2 CKD Area Manhole which was corrected. For all other lakeshore and pool measurements, the only excursions of pH in the lakeshore were at Seep 2 CKD Area on October 5, 2006. The pH readings ranged from 9 to 9.19 with specific conductance values at or below that expected for the lake. As such, these lakeshore pH excursions were potentially due to localized algal influence since specific conductivities were below 300 micromhos.

1.3.2.1.4 Seep 1 CKD Area

The Seep 1 CKD Area beach collection drains became operational on October 10, 2005. Initially, the east 200 feet of the collection drain contained pH measurements less than 9 and, therefore, the isolation valve remained closed for this section. In approximately April 2006, pH levels increased in this section of the collection drain to >9.0 and IR collection began.

A total of 1,401 pH measurements have been obtained in the Seep 1 CKD Area. In 2008, 51 pH exceedances were observed. Most of the exceedances were located on the east end of Seep 1 CKD Area. To control these exceedances, the Seep 1 CKD Area was augmented with a vertical barrier wall (see Section 2.2.4.3 of the RI Report). During the most recent effectiveness monitoring in May 2009, no exceedances were recorded at the Seep 1 CKD Area.

1.3.2.2 Mercury Flux Analysis

The second line of evidence of the effectiveness of the IR actions is from an analysis of the flux of mercury from the Site. Although reduction of mercury is not a removal action objective of the approved and constructed IR activities, significant mercury flux reduction is being realized by the IR actions based on analytical sampling of leachate collected in the ILRS and the Edge Drain and modeling results using a discrete flux analysis developed with the U.S. EPA and the MDEQ. An analysis of mercury flux in groundwater was performed to estimate the amount of mercury flux towards Lake Michigan before the implementation of the IR actions (pre-IR) as compared to conditions after the implementation of the IR actions (post-IR or existing).

Pre-IR mercury flux is estimated as the sum of the existing flux to the lake and the flux removed by the ILRS drains, Edge Drain, and the TLC system. The concentration distribution of mercury in the ILRS drains and the Edge Drain is based on analytical samples of leachate collected March 23, June 14, and August 9, 2007. The mass flux of mercury removed by each ILRS drain and the Edge Drain is estimated as the product of the average drain flow and mercury concentration. Mercury flux reduction realized by the TLC System is estimated from mercury concentration data in beach monitoring wells during operation of TLC System. Mercury concentration distribution data near the lakeshore prior to implementation of the ILRS collections drains is not available. Flux reduction resulting from contouring the CKD piles and cover soils to reduce surface ponding and infiltration in 1995 was not included in this evaluation.

Existing mercury flux estimates were calculated using updated 2009 groundwater quality data where available, supplemented by 2006-2008 data where 2009 data was not available. The estimate of mercury flux from the Site for the first quarter of 2009 is 48.2 mg/day with the majority contributed by the Pine Court Seep area. This flux does not account for attenuation if any, between the location of the calculation cross section and the lake. The estimated mercury flux removed by IR actions (excluding any contribution from temporary beach collection at Pine Court Seep area) is 40.7 mg/day and is described in more detail below. Mercury flux analysis calculations are detailed in Appendix A.

1.3.2.2.1 West CKD Area Mercury Flux Analysis

The estimated mercury flux to the lake from the West CKD Area in the first quarter of 2009 is 0.2 mg/day. The estimated mercury flux removed by the West CKD IR beach collection drains is 1.4 mg/day. The pre-IR flux is estimated to have been 1.6 mg/day.

1.3.2.2.2 Pine Court Seep Area Mercury Flux Analysis

The estimated mercury flux to the lake from the Pine Court Seep area in the first quarter of 2009 is 45.3 mg/day. Since the Pine Court Seep area collection drains were not operating during sampling, the estimated pre-IR flux is 45.3 mg/day.

1.3.2.2.3 Seep 2 CKD/Guard Rail Seep Area Mercury Flux Analysis

The estimated mercury flux to the lake from the Seep 2 CKD/Guard Rail Seep Area in the first quarter of 2009 is 0.9 mg/day. The estimated mercury flux removed by the Seep 2 CKD Area IR beach collection drains is 2.3 mg/day. The estimated mercury flux removed by the Guard Rail Seep area IR beach drains is 0.4 mg/day. The estimated mercury flux removed by the Edge Drain is 24.3 mg/day. The pre-IR flux is estimated to have been 27.9 mg/day.

1.3.2.2.4 Seep 1 CKD Area Mercury Flux Analysis

The estimated mercury flux to the lake from the Seep 1 CKD Area in the first quarter of 2009 is 1.9 mg/day. The estimated mercury flux removed by the Seep 1 CKD Area IR beach collection drains is 12.4 mg/day. This estimate under-predicts the mercury removed because mercury concentration and flow data are representative of Seep 1 CKD Area IR beach collection drain conditions prior to installation of the slurry wall vertical barrier at the east end of Seep 1 CKD Area. The pre-IR flux is estimated to have been 14.3 mg/day.

1.3.2.3 GSI Criteria Exceedance

The RI Report contains a discussion of generic Part 201 Groundwater Surface Water Interface (GSI) criteria exceedances. As noted in the tables, the data were compared to all criteria, but only those criteria that were exceeded are listed on the Tables 5a, 5b, and 5c. Only groundwater sample results from beach wells are compared to GSI criteria. Figures 4-1, 4-2, and 4-3 show the relationship of the onsite wells to the IR collection drains at the Site. For purposes of this discussion, the following well nests will be considered to be beach wells:

West CKD Area: B3018, B3016, B3019, and B3074

Seep 2 CKD Area (including Pine Court Seep area & Guard Rail Seep area): B2095, B2096, B2053, B2097, B2041, B2038, B2035, B2054, B2055, and B2098

Seep 1 CKD Area: B1013, B1032, B1014, B1043, B1045, B1036, and B1044

Data from all sampling events were used in the evaluation. IR actions have improved the baseline conditions at the Site. Therefore, the most recent data are the most relevant to the current baseline conditions. Current baseline conditions will be used to assess the need for additional response actions to supplement the IR that are in place.

Tables 5a, 5b, and 5c summarizes all analytical data collected at each of the wells noted above for the West, Seep 2, and Seep 1 CKD Areas, respectively. Some of these wells have been subsequently sampled for mercury as part of the mercury flux evaluation. Wells are either downgradient of the collection trenches, or are located near the beach but do not have collection trenches upgradient. These two types of well locations will be discussed separately.

For the wells that are downgradient of the trenches, it is important to recall that according to the conceptual model these wells may be located in one of two general zones: (1) the capture zone of the trench for water that has traveled under the trench and then is captured by the collection trenches; or (2) the stagnation zone behind the collection trenches where although the water is not being captured by the collection trenches, its travel velocity is slowed down by the flattening of the hydraulic gradients induced by the operation of the collection trenches.

The concentrations observed in the wells that exceed generic GSI criteria were compared with preliminary mixing zone-based criteria, as explained in Appendix C. The mixing zone that was assumed for the data was a factor of ten mixing (referred to below as “mixing zone” for simplicity), consistent with Michigan Part 31 rules, for all parameters except pH and mercury. The details of the preliminary mixing zone evaluation, regulatory basis, and conclusions are in Appendix C. The mitigation of the pH and mercury flux is discussed in Sections 1.3.2.1 and 1.3.2.2, respectively.

As discussed above, data from the sampling of the wells located downgradient of the collection trenches was compared with an assumed mixing zone for GSI criteria. This evaluation is provided in Appendix C. Accordingly, submission of an application for the MDEQ to develop final mixing zone-based GSI cleanup criteria should be based on the monitoring data from the appropriate wells, the status of remedy approval, and the pertinent Michigan rules and guidance.

The groundwater qualities of the wells that are near the beach and not downgradient of the collection trenches were also compared with the preliminary mixing zone-based criteria. As with the wells that are downgradient of the trenches, mercury and pH were not included in this evaluation. Mercury and pH are addressed in Sections 1.3.2.1 and 1.3.2.2, respectively.

1.4 Site Conceptual Model

1.4.1 West CKD Area

The West CKD pile is generally prism-shaped with a near-horizontal upper surface, and a lower surface that deepens northward, toward an escarpment at the beach as shown on the RI Report Figure 4-2b (Barr, 2009a). The extent of CKD shown on Figure 3-1b of the RI Report was determined using data from boreholes (B3001, B3002, B3003, B3004, B3005, B3006, B3007, B3009 B3011, B3012, B3013, B3014, B3017, B3021, B3022, B3023, B3024, B3025, B3026, and B3027), EM surveys, and topographic changes at the West CKD Area. Boring logs for the referenced boreholes are included in Appendix 3-4 of the RI Report (Barr, 2009a). The EM surveys conducted at the Site are included as Appendix 3-6 of the RI Report (Barr, 2009a). The EM conductivity contours for the West CKD Area are shown on Figure B-13 of that appendix. The topographic contours from the April 2005 topographic Site survey are shown on Figure 3-1a of the RI Report. The surface area of the West CKD pile is approximately 5.4-acres. Approximately 1.7-acres of tee boxes and fairways are located above the CKD extent. CKD mixed with soil was present on the West CKD Area beach, possibly as a result of West CKD pile sloughing. The interpretation of the soil/CKD extent was based on field screening and analytical soil sample results from soil boreholes along the beach as discussed in the West CKD Area Augmentation Preliminary Design Report (Barr, 2008a). The mixed soil/CKD on the beach was removed in 2008/2009, and a modified fill zone was constructed downgradient of the IR drain.

The West CKD Area can be divided into four subparts, namely, the western, central, eastern, and beach. The majority of the West CKD pile is located above the regional groundwater table as shown in the RI Report Figures 4-16a and 4-16b (Barr, 2009a). The exception is the northern toe of the central portion of the CKD pile which is seasonally saturated by the regional groundwater table. Shown in RI Report Figure 4-16a, the perched groundwater is in close proximity to the toe of the CKD slope indicating that the perched groundwater likely contacts the CKD where it migrates north and downward to the regional groundwater. The groundwater in temporary wells installed in boreholes B3008 and B3010 was measured above the bottom of CKD at approximately 602 and 609 feet MSL, respectively, providing evidence that perched groundwater contacts CKD. The groundwater elevation data is included in Table 4-5a of the RI Report (Barr, 2009a).

The western portion (west of borehole B3003) of the West CKD pile rests on limestone bedrock, and the central and eastern portions are on native soil above limestone bedrock as shown in RI Report Figure 4-2e (Barr, 2009a). The western portion of the West CKD pile does not produce much leachate likely because less of the CKD is saturated (RI Report Figure 4-11g). In addition, this area includes minimal irrigated areas and steep slopes with primarily tall grass vegetation which suggests insignificant infiltration. The lack of pH exceedances measured in the downgradient monitoring well nest at borehole B3018 is evidence that less leachate is generated on the west portion of the West CKD pile than in other areas. Groundwater quality data is included in Table 5-6a of the RI Report (Barr, 2009a).

The leachate observed at the beach from the West CKD pile is generated in the center and eastern portions of the pile as supported by leachate impacts observed in downgradient monitoring well nests at boreholes B3016 and B3019 shown on Figure 6-5b and 6-6c of the RI Report (Barr, 2009a). A clay layer beneath the central portion of the CKD pile is evident in boreholes B3013 and B3015. Based on water levels observed in W3113, the clay layer appears to act as a low permeability barrier perching groundwater. Groundwater elevation data for West CKD monitoring wells is included in Table 4-5a of the RI Report (Barr, 2009a). The perched groundwater potentially contacts CKD generating leachate. CKD saturated is shown on RI Report Figure 4-11g (Barr, 2009a). This clay layer also retards downward movement of leachate deeper into the buried bedrock valley shown on RI Report Figure 4-5 (Barr, 2009a). In borehole B3015, the pH of the soil located above the clay layer and below CKD was measured at 10.5-11 s.u. indicating that this soil was likely impacted by leachate generated from the overlying CKD. The pH of the clay layer in borehole B3015 was measured at 7 providing support that the clay layer acts a barrier for downward leachate migration. Interflow may also be occurring along the top of the West CKD pile, producing leachate that emerges near the bottom of the escarpment where it is collected in the drain. Typically, CKD is less permeable than unconsolidated soils making it more likely for surface water infiltration to flow across the top of the CKD pile rather than travel through the CKD pile. The median permeability of shallow (<15 feet bgs) non-CKD soils at the Site was 9.7×10^{-4} cm/sec, and the median permeability of Site CKD was 6.9×10^{-6} (RI Report Appendix 4-3). Therefore, surface water infiltration is expected flow along the

CKD surface through the overlying unconsolidated soils generating leachate. Interflow along the CKD surface is also supported by the findings from the geotechnical investigation of the Seep 2 CKD Area slope failure conducted by Hanson Engineering P.C discussed in RI Report Section 1.3.4.5. It was determined that the slope failure was due to increased moisture and pore pressure at the interface between the cover material and the CKD surface.

In addition to interflow generating leachate in the central and eastern portions of the pile, leachate migrates downward in the southeastern portion of the West CKD Area pile as supported by groundwater impacts observed in the deeper monitoring wells on the east portion of the site (RI Report Figure 6-5c). Downward migration of leachate is also supported by the downward vertical gradients observed in monitoring well nest installed at B3014 (RI Report Table 4-6a). The clayey soil is notably absent in the vicinity of borehole B3014 which is in this area. The monitoring well nest installed at B3014 typically contains the highest concentrations of potential COCs. This well nest is also located upgradient of the highest potential COC concentrations on the West CKD Area beach.

The marker shale is only present near the southern edge of the West CKD pile (RI Report Figure 4-8a) and is generally not considered to be a major factor in influencing the generation or flow of leachate in the West CKD Area. The marker shale was only present in boreholes B3012, B3017, and B3020.

Groundwater elevations in the bedrock at the West CKD Area are influenced by the pumping of the City of Petoskey (City) wells, specifically City Wells 4 and 5 as discussed in RI Report Section 4.6.4.2 (Barr, 2009a). Regional groundwater at the West CKD Area generally flows northward towards Lake Michigan; however, seasonal fluctuations within monitoring wells suggest that regional groundwater is influenced by pumping of City Well 5 in particular. Evidence of this is visible in groundwater elevation trends in the monitoring well nests installed at boreholes B3013, B3014, and B3020. These well nests, specifically in the deeper wells, show groundwater elevations that fall to near or below average lake level during the summer months corresponding to peak municipal water usage. It is important to note that seasonal groundwater fluctuations are not evident in monitoring wells W3113 and W3120; demonstrating that the low permeability barrier (i.e., the clay discussed previously or marker shale) restricts groundwater flow between the shallow wells and the deeper wells in these well nests. The groundwater elevation data for the monitoring wells are in Table 4-5a of the RI Report (Barr, 2009a).

The hydraulic gradient of the regional groundwater seasonally reverses during times of high pumping of City Well 5 (RI Report Figure 4-12a). Perched groundwater is not affected by gradient reversals as indicated by the groundwater elevation data observed in monitoring wells W3113 and W3120. As stated above, W3113 shows no evidence of being influenced by pumping of City Well 5 based on the groundwater elevation data. Upgradient of the CKD pile in borehole B3020, an unsaturated zone of limestone is present below the shale during times of high pumping of City Well 5 which indicates the perched groundwater is not affected by the gradient reversals. Perched water will eventually flow to the north and merge with the regional groundwater table near the base of the West CKD Area pile northern escarpment. Even though the gradient temporarily reverses during times of high groundwater usage, leachate does not impact the municipal wells. This statement is supported by the upgradient well nests installed at boreholes B3013 and B3020 for which no exceedances of pH have been observed, see RI Report Figure 6-5b (Barr, 2009a). The water quality data from the well nest installed at borehole B3014 also supports the statement that leachate does not impact the municipal wells. In response to the gradient reversal during peak pumping of City Well 5, it is expected that leachate will migrate downward. On Figure 6-5c of the RI Report, the pH is lower in the deeper wells than the shallower wells indicating that the leachate likely does not migrate deep enough to impact City Well 5. The decrease in pH also provides evidence that the leachate mixes with upgradient groundwater as it migrates downward during the gradient reversals.

The soil/CKD removed from the beach was typically saturated as observed during excavation and was not likely affected by changes in hydraulic gradient. Leachate generation on the beach was primarily associated with surface disturbances. As discussed in RI Report Section 2.2.7.1, Effectiveness Monitoring, the observed pH in Lake Michigan prior to the West CKD Area augmentation was less than 9.0 at the West CKD Area except immediately after times of surface disturbances (e.g., cleaning/jetting vehicles on the beach).

The majority of high pH measurements from the Spring 2005 and Fall 2005 targeted shoreline survey are downgradient of the central and eastern portions of the West CKD pile (RI Report Appendix 2-1). The highest concentrations of potential Site COCs on the beach are located in the monitoring well nest installed at borehole B3019, further evidence that the leachate penetrates the limestone on the eastern portion for the pile (RI Report Table 5-6a). Monitoring well data from W3116 supports the conclusion that shallow interflow is generated in the central West CKD Area (RI Report Figure 6-5b).

Surface runoff from the West CKD Area is collected by the under drain system and routed east, outfalling to West Unnamed Creek (RI Report Appendix 1-2d). Neither analyte exceedances nor occurrences of elevated pH have been observed in the creek, demonstrating that the creek is not impacted by CKD (RI Report Appendix 5-2 and Tables 5-2 and 5-3). However, at the mouth of the stream elevated pH data points were measured on occasion, which have been attributed to algae blooms from golf course fertilizer runoff. On November 8, 2005, pH readings were observed to rise throughout the day and fall again in the evening while conductivity was observed to remain relatively constant throughout the day. The pH readings in the morning were between 7.40-7.97 s.u., the mid-day readings were between 8.61-9.13 s.u., and the evening readings were between 8.48-8.87 s.u. The specific conductance was measured between 271 and 550 μmhos. This trend in pH and conductivity is indicative of photosynthesizing organisms' impact on an aquatic system. Additionally, this area was observed to have more vegetation indicating an influence of algae and fertilizer. Thus, the pH impacts were likely a result of algae blooms rather than leachate.

The identified COCs for the West CKD Area are summarized in Table 4a (for soil) and Table 5a (for groundwater).

Chloride, ammonia, sulfate, pH, and TDS are general parameters that are associated with CKD, exceed generic Part 201 criteria, and have the demonstrated ability to migrate from the West CKD Area pile to a potential point of exposure (RI Report Tables 5-4a and 5-6a). Aluminum, arsenic, copper, lead, iron, mercury, nickel, selenium, silver, and vanadium are metals that are associated with CKD, exceed generic Part 201 criteria, and have the demonstrated ability to migrate from the West CKD Area to a potential point of exposure (RI Report Table 5-4a and 5-6a).

Based on the conceptual model for the West CKD Area, the dominant mechanism of leachate generation is saturated CKD which discharges near shore at the location of the IR drain. This is based on the fact the IR drain pH included in RI Report Figure 2-4a remains high throughout the year coupled with perched groundwater flow through CKD migrating toward the drain. While, the municipal pumping mixes leachate and regional groundwater during the year, impacted groundwater is discharged near shore in the location of the existing drains. Based on the operation of the existing IR drains, the IR drains and the modified fill zone are effective at controlling the identified COCs in this location. A representation of the West CKD Area site conceptual model for winter and summer conditions is provided on Figures 2-1a and 2-1b, respectively.

1.4.2 Seep 2 CKD Area

The Seep 2 CKD Area pile is situated parallel to Lake Michigan, with its long axis having an east-west orientation (RI Report Figure 3-1b). The surface area of the Seep 2 CKD Area pile is approximately 34.8 acres. Approximately 8.9-acres of tee boxes, fairways, and greens are located within the CKD extent. The extent of CKD shown on RI Report Figure 3-1b was determined using data from boreholes (B2027, B2070, B2071, B2073, B2088, B2089, B2057, B2052, B2009, B2026, B2090, B2031, B2001, B2028, and B2032), EM surveys, and topographic changes at the Seep 2 CKD Area. Boring logs for the referenced boreholes are included in Appendix 3-4 of the RI Report (Barr, 2009a). The EM surveys conducted at the Site are included as Appendix 3-6 of the RI Report (Barr, 2009a). The EM conductivity contours for the Seep 2 CKD Area are shown on Figure B-7 of that appendix. The topographic contours from the April 2005 topographic Site survey are shown on Figure 3-1b of the RI Report.

The Seep 2 CKD Area consists of three seep areas, namely, Seep 2, Guard Rail, and Pine Court. The Seep 2 seep area is the eastern portion of the Seep 2 CKD Area consisting of the CKD pile south of the Edge Drain. The Guard Rail Seep area is located north of the central portion of the Seep 2 CKD pile. The Pine Court Seep area portion of the Seep 2 CKD Area is generally west of the line between boreholes B2031 and B2038. A representation of the Pine Court Seep area site conceptual model is provided on Figures 2-2a and 2-2b for the winter and summer conditions, respectively. A representation of the Seep 2 and Guard Rail Seep area site conceptual model is provided on Figure 2-3.

The lateral extent of leachate impacts at the Seep 2 CKD Area were defined during the Targeted Shoreline Survey conducted in Spring 2005. Data from this survey are included in Appendix 2-1a of the RI Report (Barr, 2009a). The locations of impact at the Pine Court Seep area were within two defined areas separated by approximately 160 feet. The first area was located north of Lots 3 and 4 (approximately 240 feet wide and 30 feet northward into Lake Michigan) with pH readings ranging from 9.0 to 10.42 and elevated specific conductivity readings. The second area was generally located north of Lot 6 (approximately 40 feet wide and extended up to 10 feet northward into Lake Michigan with pH readings ranging from 9.01 to 9.65). The locations of impact at the Guard Rail Seep area were within two defined areas separated by approximately 90 feet. The first area was approximately 35 feet wide and extended up to 10 feet northward into Lake Michigan with pH readings ranging from 9.02 to 9.39 and elevated specific conductivity readings. The second area was approximately 35 feet wide and extended up to 5 feet northward into Lake Michigan with pH reading ranging from

9.09 to 9.71. The locations of impact at the Seep 2 seep area was approximately 500 feet wide with pH readings ranging from 9.00 to 12.09 and elevated specific conductivity readings. Elevated pH readings (>9.0) were measured up to 30 feet northward into Lake Michigan.

The entire Seep 2 CKD Area is underlain by limestone, with a "marker" shale layer present within the limestone unit. Figure 4-3b of the RI Report depicts the typical stratigraphic sequence for the Seep 2 CKD Area: 1) soil cover overlying CKD which may rest on either soil or bedrock, and 2) highly fractured and fairly uniform limestone bedrock containing an approximately 15 to 20-foot thick marker shale unit. The bedrock topography of the Seep 2 CKD Area is shown on Figure 4-6 of the RI Report (Barr, 2009a). As shown on the rotasonic borehole logs included in Appendix 3-6 of the RI Report, the uppermost bedrock unit encountered in most of the boreholes was limestone. The topography and extent of the marker shale and the boreholes on which the interpretations are based are shown on Figure 4-8b of the RI Report (Barr, 2009a). The marker shale has an asymmetric anticline shape with an east-west trending fold axis. The shale generally dips to the south under the western side of the pile and to the north under the eastern side of the pile. The bedrock surface drains to the north toward the Edge Drain on the eastern side of the pile. At the western portion of the pile, the northern edge marker shale layer rises in elevation and perches groundwater until it flows off the northern edge.

All of the CKD at the Seep 2 CKD Area lies above the regional groundwater table. The bottom contours of the CKD pile of the Seep 2 CKD Area and the boreholes on which the contours are based are shown on Figure 4-11b of the RI Report (Barr, 2009a). Figures 4-12b, 4-13b, 4-14b, and 4-15b show the groundwater contours for the Seep 2 CKD Area for July 2006, September 2006, January 2007, and March 2007, respectively. Inspection of these figures shows that the bottom elevation of the CKD and the regional groundwater table do not intersect.

In general, the regional groundwater flow is seasonally variable due to the City Well 5 groundwater pumping across the Seep 2 CKD Area. Groundwater generally flows north in this area during times of lower groundwater usage (e.g., RI Report Figure 4-14b for January 2007); however, for a portion of the Seep 2 seep and all of the Guard Rail Seep areas, the horizontal hydraulic gradient seasonally reverses during times of high usage (e.g., RI Report Figure 4-12b for July 2006). In the Pine Court Seep area, the seasonal regional groundwater pumping does induce a significant southwest and downward migration of leachate during times of peak pumping of City Well 5. The affects of this are observed (e.g., elevated pH and COCs) in monitoring wells W2318, W2319, W2420, W2322, W2422, W2522, W2325, W2425, and W2356. Even though the gradient temporarily reverses during times of high usage, leachate does not impact the City wells. This statement is supported by the upgradient well nest water quality data observed in the RI Report Figures 6-6a, 6-6b, and 6-6i. In these RI Report figures, the pH and mercury concentrations measured in the wells closer to City Well 5 (monitoring well nests at B2042, B2056, B2093, B2044, and B2022) are lower than those measured in wells near the saturated CKD source (monitoring well nests B2025 and the TLC wells) demonstrating attenuation.

The regional groundwater within the Seep 2 seep area releases within close proximity of the shoreline as evidenced by the upward hydraulic gradients observed in the Seep 2 CKD Area beach wells (RI Report Table 4-6b). Groundwater and leachate flow at the Seep 2 CKD Area is illustrated on RI Report Figure 1-4e. Groundwater contours on RI Report Figures 4-17a to 4-17c and Figures 4-20a to 4-20c show that deep regional groundwater migrating towards Lake Michigan has an upward trend and releases within close proximity of the beach. The lack of pH exceedances in deep monitoring wells located adjacent to the Lake Michigan shoreline (e.g., W2335 and W2354) show additional evidence of an upward vertical gradient.

The main receptor of leachate generated in the Seep 2 CKD Area would be the regional groundwater discharge point, Lake Michigan; however, the Edge Drain and the IR drains installed in the Seep 2 CKD Area and Guard Rail Seep area have been proven to be effective at controlling pH in Lake Michigan. Effectiveness monitoring data collected since the installation of the IR drains are included in Appendix 2-8 of the RI Report (Barr, 2009a). These data show that the installed IR drains have been effective (i.e., pH <9.0 in the lake) since 2007.

Perched groundwater is not affected by gradient reversals as indicated by the groundwater elevation data observed in monitoring wells W2122, W2125, W2133, W2142, W2144/W2242, W2156/W2256, W2158, W2163, and W2193. These wells show no evidence of being influenced by pumping of City Well 5 based on the groundwater elevation data. In addition, an unsaturated zone of limestone is present under the shale and perched groundwater during times of high pumping at boreholes B2025, B2022, and B2044 as shown in RI Report Figure 4-17b (Barr, 2009a). Perched water will eventually flow to the north and merge with the regional groundwater table near the base of the Seep 2 CKD Area pile northern escarpment.

The primary mechanism for leachate production at the Seep 2 CKD Area is perched groundwater interacting with the northern portion of the CKD pile. Saturated CKD was encountered in the borehole at S2RW-2. The boring log for this borehole is included in the RI Report Appendix 3-4b. It is clearly evident that groundwater is perched above the marker shale based on groundwater elevation data from monitoring wells W2120, W2122, W2125, W2133, W2144, W2244, W2146, W2163, and W2164. Inspection of the perched groundwater elevation data and the bottom of CKD contours shown on Figure 4-11b of the RI Report reveals that additional saturated CKD is likely present in other locations along the northern edge of the CKD pile. This is also supported by the fact that the Edge Drain collects leachate year round (RI Report Figures 2-2c and 2-3a).

Perched groundwater in the Seep 2 CKD Area and Guard Rail Seep area flows north along the marker shale as supported by the perched groundwater elevation data from monitoring wells W2120, W2122, W2125, W2133, W2144, W2244, W2146, W2163, and W2164. The shale retains leachate in a bowled structure in the vicinity of borehole B2063. The marker shale likely acts as a leaky aquitard allowing migration of leachate and impacted groundwater downward through some areas of the marker shale. This is evident in pH levels observed in monitoring wells W2225, W2325, W2233, W2246, and W2263 that are screened below the marker shale. At the northern extent of the marker shale, perched groundwater flows downward to the regional groundwater table allowing leachate to migrate into the regional groundwater table. This is supported by pH impacts measured in monitoring wells W2130 and W2138 and from leachate collected in the Edge Drain located at the northern edge of the marker shale.

Leachate generated from saturated CKD in the vicinity of S2RW-2 migrates over and through the marker shale to the regional groundwater. In S2RW-2, S2RW-4, and S2RW-5, pH was observed around 12-13. The influence of pumping at City Well 5 draws leachate from this area downward and to the southwest as high pH impacts were observed in deep monitoring wells W2322, W2422, and W2326 (RI Report Figures 6-6a, 6-6b, and 6-6g). The fact that pH in regional groundwater below the shale (W2356 and W2456) is higher pH than the perched groundwater above the shale (W2226 and W2156) supports a migration pathway of leachate from the TLC location to the Pine Court Seep area. This impact is significant to the Pine Court Seep area because the shallow regional groundwater does not exhibit high pH indicative of a local source. For example pH in W2127, W2150, W2152, and W2162 are only lightly impacted even though they are in close proximity to the edge of the shale on the western portion of the Pine Court Seep area. In fact, the impacts at W2158 do not appear to influence regional groundwater at W2152 which are in close proximity.

Leachate generation from surface water infiltrating through the CKD pile is not expected to be significant at the Seep 2 CKD Area. This is because CKD is generally less permeable than the unconsolidated cover soils and the CKD is sloped to drain; therefore, infiltrated water will more likely flow through the unconsolidated cover soils over the surface of the CKD (CKD surface interflow) than infiltrate into the CKD. As discussed above, CKD is less permeable than unconsolidated soils. The permeability of shallow (<10 feet bgs) unconsolidated non-CKD soils in the Seep 2 CKD Area ranged between 3.3 x10^{-4} to 7.8 x 10^{-3} cm/sec with average of 3.2 x 10^{-3} cm/sec, and the permeability of CKD in the Seep 2 CKD Area ranged between 6.3 x 10^{-6} to 5.8 x 10^{-3} cm/sec with average of 5.1 x 10^{-4} cm/sec (see RI Report Table 4-4). Therefore, surface water infiltration is expected to flow along the CKD surface potentially generating leachate. The exception is a localized area near B2025 extending down slope to B2006. This is the only location at the Site where flow on top of CKD would migrate to ground within the CKD limits based on ground surface and CKD surface topography.

Water can infiltrate into the CKD from the surface. Moist and wet CKD was observed in several of the Seep 2 CKD Area boreholes located above the perched and regional groundwater tables (See RI Report Appendix 3-4b). Water contents were measured between 39.6% to 102.4% for CKD in the Seep 2 CKD Area (RI Report Appendix 4-3). As discussed above, it is less likely for water to penetrate CKD than to move along the CKD surface; therefore, infiltration is expected to generate less leachate than other sources. However, it is probable that water will infiltrate the CKD pile in low flat areas that are not well drained (see RI Report Appendix 1-2d). In the center of stormwater drainage area S2-90 is a low area that does not appear to be well drained likely indicating an area of potential higher infiltration. This area is located just east of B2058 which may explain why the pH measured in this well is higher than the pH measured in surrounding wells. Stormwater drainage area S2-58 located near the TLC wells is another relatively flat area that is poorly drained. S2-58 receives overland flow from the east stormwater drainage area S2-56 as shown in RI Report Appendix 1-2d (Barr, 2009a). In addition, elevation monitoring data from S2OW-1 conducted in conjunction with the TLC operation shows more responsiveness to precipitation than other wells (upgradient and side gradient) in the area. This well is located within the CKD limits and is at the toe of a slope of CKD.

Bedrock surface interflow is a result of surface water infiltration flowing along the top of the bedrock surface. In areas where CKD is near or directly on top of bedrock, leachate is expected to be generated when surface water infiltration flows along the bedrock surface and contacts the overlying CKD. CKD was observed to be within one foot of the bedrock in boreholes B2003, B2006, B2009, B2094, S2OW-1, S2RW-1, S2RW-2, S2RW-3, S2RW-4, and S2RW-5 making it possible to generate leachate from bedrock surface interflow. Boring logs for the Seep 2 CKD Area are included in

Appendix 3-4 of the RI Report (Barr, 2009a). Evidence of bedrock surface interflow was observed in boreholes B2042, B2049, and S2OW-1 where wet soils were located above unsaturated limestone.

Leachate generation from interflow and infiltration is expected to vary based on precipitation (rainfall/snowmelt) and the locations of generation are expected to be difficult to isolate. The affect of precipitation on leachate generation is correlated to fluctuation in elevations and flows observed in the IR drains (Section 2.0 of the RI Report (Barr, 2009a)). When B2006 was drilled in December of 2005, moist soil was observed above the bedrock, and when S2OW-1 was drilled April of 2008 (after 1.2 inch rain event on 4/25/08 and 4/26/08), wet soil was observed. These two borings were drilled at the same location. This provides additional support that the bedrock surface interflow is dependent on rainfall/snowmelt events. This is also evidence that bedrock surface interflow is intermittent and is not easily located.

Surface runoff collected from the Seep 2 CKD Area is routed south then northwest around the Seep 2 CKD pile, directly north of the pile, or east into the Seep 1 CKD Area. (RI Report Appendix 1-2d). Surface runoff routed around the west side of the pile outfalls into a drainage swale on the south side of Coastal Drive upgradient from the Pine Court Seep area lift station. Surface runoff routed north of the pile discharges into a drainage swale on the south side of Coastal Drive west of the Guard Rail Seep area or sheet flows off the northern slope of the pile and into roadside drainage swales. A small portion of the eastern Seep 2 CKD Area is routed east across Coastal Drive into the Seep 1 CKD Area collection drain network.

The identified COCs for the Seep 2 CKD Area are summarized in Table 4b (for soil) and Table 5b (for groundwater).

Chloride, ammonia, sulfate, pH, and TDS are general parameters that are associated with CKD, exceed generic Part 201 criteria, and have the demonstrated ability to migrate from the Seep 2 CKD Area pile to a potential point of exposure. Aluminum, copper, iron, mercury, nickel, selenium, silver, and vanadium are metals that are associated with CKD, exceed generic Part 201 criteria, and have the demonstrated ability to migrate from the Seep 2 CKD Area to a potential point of exposure.

In summary, the CKD at the Seep 2 CKD Area is located above the regional groundwater; however, CKD is saturated by groundwater perched above the marker shale. The Seep 2 CKD Area is comprised of three areas: the Seep 2 seep, Guard Rail seep, and Pine Court seep areas. Leachate is effectively controlled in the Seep 2 and Guard Rail seep areas by the existing IR drains including the

Edge Drain. The Pine Court Seep area leachate is primarily generated in the vicinity of S2RW-1and then it migrates to the Pine Court beach area following a tortuous pathway due to City Well 5 pumping (i.e., seasonally drawn downward and to the southwest). This mixed and attenuated leachate migrates to the location of the Pine Court IR drains. The existing TLC extraction system and operation of the IR drains in the Pine Court Seep area are positively affecting discharge in the Pine Court Seep area.

1.4.3 Seep 1 CKD Area

The Seep 1 CKD Area consists of one CKD pile situated parallel to Little Traverse Bay, with its long axis having an east-west orientation as shown on RI Report Figure 3-1c (Barr, 2009a). The surface area of the Seep 1 CKD pile is approximately 15.5-acres. Approximately 2.68-acres of tee boxes, fairways, and greens are located within the CKD extent (RI Report Appendix 1-2d).

The western and central portion of the Seep 1 CKD pile lies on limestone bedrock at its southern half, and soil at its northern half (Figures 4-4a and 4-4c of the RI Report). The eastern side of the pile lies on soil above limestone bedrock (Figure 4-4d of the RI Report). The western side of the Seep 1 CKD pile is thicker than the eastern side as shown in RI Report Figures 4-4a and 4-4d (Barr, 2009a). Two bedrock depressions at the center of the pile near boreholes B1022 and B1023 contain CKD saturated by the regional groundwater table (see RI Report Figures 4-4c, 4-4f, 4-7, 4-11c, and 4-11h). As shown on RI Report Figure 4-8c, except at the western end of the pile, the marker shale is largely absent in the Seep 1 CKD Area (see RI Report Figure 4-8c). Hence, the shale is not a significant factor in leachate flow. Although the shale at the western end of the pile may potentially perch groundwater up into the overlying CKD, it likely acts as a leaky aquitard, as evidenced by leachate concentrations measured in groundwater samples collected beneath the shale (RI Report Figure 6-7a). The interpretation of the CKD location and the geology in this area is based on geophysical surveys and borings including downhole geophysics, core observations, and pH field screening of soil/CKD.

The Seep 1 CKD Area groundwater table shows only minor seasonal variation; however, a groundwater divide is evident on the south side of the Seep 1 CKD Area outside of the CKD limits (RI Report Figures 4-12c through 4-15c). The groundwater divide is due to pumping of City Wells 3 and 5 located to the south and southwest of the Seep 1 CKD Area, respectively. The effect of pumping from the City wells is described in Section 4.6.4.2 of the RI Report and shown on Figure 4-33a (Barr, 2009a). Leachate generated within the Seep 1 CKD pile does not migrate towards the municipal wells. This statement is supported by the upgradient well nests installed at boreholes B1025, B1027, B1030, and B1033 for which no exceedances of pH have been observed.

The primary mechanisms for leachate production at the Seep 1 CKD Area are: CKD saturated by the regional groundwater table and interflow.

Site data show that the regional groundwater table contacts the CKD pile in an isolated area near boreholes B1022 and B1023. Boreholes B1022 and B1023 both show evidence of moist to wet CKD. In addition, the boring log for B1022 shows the bottom of CKD at an elevation of 599.5 ft MSL while RI Report Table 4-5c shows groundwater elevations in W1122 (screened in the CKD) ranging from 606.18 to 619.04 ft MSL. The isolated area of CKD saturated by regional groundwater represents less than an estimated 1% of the Seep 1 CKD (RI Report Figure 4-11h). This small area of saturated CKD is located upgradient of a channelized section of the beach with approximately six feet of silt, sand, and gravel filling the bedrock channel as observed in boreholes B1031, B1034, B1035 (RI Report Figure 4-7). Additionally, Seep 1 CKD Area augmentation design boreholes B1037, B1038, B1040, and B1041 show evidence of the channel. This bedrock channel is located between boreholes B1034 and B1031 (see RI Report Figure 4-4e). A preferential flow path for leachate generated from the saturated CKD exists within this portion of the Seep 1 CKD Area is clearly demonstrated by pH levels observed in this area (RI Report Table 5-6c). Subsequent to Seep 1 CKD Area ILRS collection drain installation, pH exceedances were observed during effectiveness monitoring along this portion of the shoreline (RI Report Appendices 2-8b, 2-8c, and 2-8d). The Seep 1 CKD Area augmentation barrier wall was installed to address these exceedances by cutting off the flow path in the unconsolidated material along the beach.

In addition to the contribution from saturated CKD, leachate is also generated by interflow along the top of the CKD pile or by interflow on top of the limestone bedrock where CKD is in contact with the bedrock. Typically, CKD is less permeable than unconsolidated soils making it more likely for surface water infiltration to flow across the top of the CKD pile rather than travel through the CKD pile. The median permeability of shallow (<15 feet bgs) non-CKD soils at the Site was 9.7×10^{-4} cm/sec, and the median permeability of Site CKD was 6.9×10^{-6} (RI Report Appendix 4-3). Therefore, surface water infiltration is expected to flow along the CKD surface through the overlying unconsolidated soils generating leachate. The significance of interflow at the Seep 1 CKD Area is evidenced by the "road seep" discussed in Section 2.1.5 of the RI Report (Barr, 2009a) and the shallow nature of the initial Seep 1 CKD Area shoreline impacts.

Bedrock surface interflow is a result of surface water infiltration flowing along the top of the bedrock surface. In areas where CKD is near or directly on top of bedrock, leachate is expected to be generated when surface water infiltration flows along the bedrock surface and contacts the overlying CKD. CKD was observed to be within two feet of the bedrock in the boreholes B1003, B1021, B1022, and B1023 making it possible to generate leachate from bedrock surface interflow.

Leachate generation from interflow and infiltration is expected to vary based on precipitation as supported by fluctuation in elevations and flows observed in the IR collection drains corresponding to rainfall/snowmelt events as discussed in Section 2.0 of the RI Report.

Shallow leachate migrates towards Lake Michigan through the CKD pile and underlying soil as evident in pH exceedances in shallow monitoring wells (e.g., W1117 and W1118) (see RI Report Table 5-6c). Shallow leachate also migrates downward through the CKD and underlying soil to the regional groundwater table as evident in pH exceedances in deep monitoring wells (e.g., W1417 and W1418) (see RI Report Table 5-6c). Monitoring well data show that regional groundwater within the Seep 1 CKD Area is under the influence of an upward hydraulic gradient. Groundwater contours on RI Report Figures 4-21a and 4-21b show that deep regional groundwater migrating towards Lake Michigan has an upward trend and releases within close proximity of the shoreline. Additionally, groundwater pH exceedances are not evident in deep monitoring wells located adjacent to the Lake Michigan shoreline (e.g., W1332 and W1414) (see RI Report Table 5-6c). These trends indicate that leachate produced in the Seep 1 CKD Area does infiltrate deep regional groundwater, but is contained and diluted by the regional groundwater via the upward vertical hydraulic gradient.

Surface runoff collected from this area is generally routed east and outfalls into the East-Unnamed Creek #1. As discussed in Section 3.1.4.5 of the RI Report (Barr, 2009a), based on the results of the Bay Harbor Lake assessment, there are no signs that CKD or CKD leachate is present in or is currently impacting Bay Harbor Lake. The Bay Harbor Lake assessment is discussed in Section 3.1.4.5 of the RI Report (Barr, 2009a).

The identified COCs for the Seep 1 CKD Area are summarized in Table 4c (for soil) and Table 5c (for groundwater).

Chloride, ammonia, sulfate, pH, and TDS are general parameters that are associated with CKD, exceed generic Part 201 criteria (see RI Report Table 5-6c), and have the demonstrated ability to migrate from the Seep 1 CKD Area pile to a potential point of exposure (see RI Report Tables 5-4c and 5-6c). Aluminum, arsenic, copper, iron, mercury, nickel, selenium, silver, and vanadium are metals that are associated with CKD, exceed generic Part 201 criteria (see RI Report Table 5-6c), and have the demonstrated ability to migrate from the Seep 1 CKD Area to a potential point of exposure (see RI Report Tables 5-4c and 5-6c).

The dominant leachate generation mechanisms at the Seep 1 CKD Area are shallow interflow which contacts CKD near the bedrock surface in the western portions of the pile and regional groundwater saturating CKD in the central portion of the pile. The municipal well pumping influences the gradient but does not significantly affect the migration of the leachate in the Seep 1 CKD Area. Based on the high pH observed in the IR drains throughout the year, saturated CKD exists in the western and central portions of the Site. The leachate generated in these areas discharges to and is effectively controlled by the existing IR drains and the vertical barrier wall. A representation of the Seep 1 CKD Area site conceptual model is provided on Figure 2-4.

2.0 Identification and Screening of Technologies

2.1 Introduction

This section presents the remedial action objectives (RAOs) for the West CKD, Pine Court Seep, Seep 2 CKD, and Seep 1 CKD Areas. RAOs have been developed for the source material (typically referred to herein as CKD) and for groundwater and surface water. RAOs provide a basis for evaluating potential remedial technologies and remedial action alternatives. Development of site-specific RAOs has included consideration of the Applicable or Relevant and Appropriate Requirements (ARARs) and the results of the conceptual model for the Site presented in the RI Report and Section 1.4.

This section also presents the development and screening of potential remediation technologies for the Site. The evaluation of these technologies is consistent with the information presented in Section 1, along with U.S. EPA guidance. A broad range of potential remediation technologies was considered in the screening, assembled into alternatives, and evaluated.

2.2 Remedial Action Objectives and ARARs

The RAOs for the Site are:

- Protection of human health by reducing exposure (direct contact, ingestion, inhalation) to soil (including CKD and CKD-impacted soil), groundwater (including leachate and leachate-impacted groundwater), or surface water that exceeds applicable water quality standards, and

- Protection of human health and the environment by minimizing the off-site migration of leachate that causes surface water to exceed applicable water quality standards.

Development of RAOs for CKD and leachate at the Site includes consideration of current as well as potential future risks which may be associated with the use of the Site. The land use for the Site is expected to continue as a multi-use area with mixed residential, commercial, open space and recreational land uses. As discussed in the RI Report, the CKD impacted groundwater at the Site needs to be managed in order to protect human health and the environment.

CERCLA requires that remedies comply with ARARs under federal environmental laws and state environmental laws or facility siting laws, or provide grounds for seeking a waiver of the requirement. In addition to ARARs, other advisories, criteria, or guidelines may be considered in developing RAOs, as appropriate.

ARARs are classified as location-specific, chemical-specific, and action-specific. Potential location-specific and chemical-specific ARARs for both CKD and leachate are listed in Tables 2 and 3, respectively.

Most of the location-specific ARARs are not applicable to the Site. Those that may potentially apply to remedial actions at the Site include the existing Administrative Order on Consent (AOC), and those that address work in or near waters of the State including wetlands, rivers, streams, coastal zones, or floodplains, as shown in Table 2. ARARs that apply to these locations will be addressed in the discussion of specific actions that would be anticipated in or near these zones as applicable to specific alternatives.

Additional details on chemical-specific ARARs for leachate are described below (Section 2.2.1), and in Table 3.

Action-specific ARARs (e.g., Resource Conservation and Recovery Act [RCRA], NPDES Discharge) are linked to specific remedial actions, and will be addressed in the context of detailed remedy evaluations in Section 4.

In accordance with the goals of the long-term remedy identified in Section VIII of the AOC, further response activities will accomplish all of the following:

- Integrate the IR actions as appropriate;
- Prevent unacceptable exposures to surface waters and sediment impacted by CKD waste material;
- Design, construct, and operate long-term response activity to prevent discharge of groundwater containing hazardous substances above state criteria from the Site to surface waters of the state;
- Prevent unacceptable risk from human direct contact with CKD waste materials;
- Prohibit exacerbation, prevent new releases and unacceptable exposure, and place land use and resource use restrictions related to CKD waste material;

- Construct and maintain erosion control measures for underlying CKD waste material;
- Ensure adequate financial resources are available in an acceptable form and amount to assure the performance of the response activities necessary to protect human health or the environment in perpetuity;
- Ensure that any other unacceptable exposures are adequately addressed and assure the effectiveness and integrity of the long-term response activities.

2.2.1 Chemical-Specific RAOs for Soil/CKD

Michigan Environmental Remediation Standards Natural Resources and Environmental Protection Act (NREPA), §20104 of 1994 PA 451 Part 201 establishes cleanup standards for achieving soil quality at remediation sites. Direct contact soil criteria are developed in R299.5720. Criteria based on soil leaching hazardous substances to groundwater are included in R299.5722. Criteria for soil based on indoor inhalation of hazardous substance vapors volatized from soil are included in R299.5724. Criteria for soil based on inhalation of hazardous substances in ambient air are included in R299.5726. Criteria for contaminated environmental media based on other injury are included in R299.5728.

The Michigan chemical-specific remediation standards for soil for each of these pathways were compared directly to the site-specific analytical results for unconsolidated materials in Table 5-2 of the RI Report. Chemicals in the CKD or other soil samples (non-CKD) that exceed these criteria were noted in the RI Report. The chemicals of concern in the CKD that exceed the direct contact exposure criteria (R299.5720) are summarized in Tables 4a, 4b, and 4c.

2.2.2 Chemical Specific RAOs for Groundwater and Surface Water

Numerous potential chemical-specific ARARs have been promulgated by both the federal and state governments for groundwater and surface water. The potential chemical-specific ARARs are summarized in Table 3. The following sections address the potential application of these ARARs in accordance with regulations promulgated by the State of Michigan for addressing groundwater at contaminated sites.

2.2.2.1 Federal Standards for Groundwater

The Safe Drinking Water Act (SDWA) established maximum contaminant levels (MCLs) and maximum contaminant level goals (MCLGs) for public drinking water systems. The MCLGs set at levels above zero are potential ARARs for current or potential sources of drinking water. The State of Michigan has adopted MCLs for inclusion in the Part 201 rules for groundwater that may be used as drinking water. The State rules are equal to or more stringent than the Federal rules, and therefore, State standards have primacy. The State rules are discussed below.

2.2.2.2 State Standards for Groundwater

Michigan Environmental Remediation Standards NREPA, §20104 of 1994 PA 451 Part 201 establishes groundwater quality standards that are developed for relevant exposure pathways. Criteria for adverse aesthetic impacts to aquifers are developed in R299.5709. Criteria based on ingestion of groundwater as drinking water are included in R299.5710. Criteria based on human dermal contact with groundwater are included in R299.5712. Criteria for groundwater based on hazardous substance vapors emanating from groundwater to indoor air are included in R299.5714. Criteria for groundwater based on protection of surface water resources (waters of the State) from hazardous substances in venting groundwater are included in R299.5715.

The Michigan chemical-specific remediation standards for groundwater for each of these pathways were compared directly to the site-specific analytical results for groundwater from the Site in Table 5-4 of the RI Report. Concentrations of chemicals in the groundwater analytical results that exceed these criteria were noted. The chemicals of concern in the groundwater that exceed any of the above-listed criteria are summarized in Tables 5a, 5b, and 5c.

2.2.2.3 Federal Ambient Water Quality Criteria for Surface Water

The Federal Ambient Water Quality Criteria (FAWQC) established under Section 303 or 304 of the Clean Water Act (CWA) for priority pollutants may be relevant and appropriate, depending on the circumstances of the site (40 CFR 310.430(e)(2)(i)(E)). The FAWQC for human health are promulgated for exposures that include (1) drinking water and consuming fish and (2) consuming fish only. The FAWQC are also promulgated for aquatic life protection. The FAWQC are not considered ARARs for protection of human health at the Site because the State of Michigan has water quality standards that are more stringent and, thus, take primacy. FAWQC may be relevant and appropriate for the protection of aquatic life. However, at the time of the development of the FAWQC for aquatic life protection, sufficient data were not available to derive aquatic life criteria for all priority pollutants. Therefore, the lowest report effects levels (LRELs) available in the scientific literature for these chemicals were published in lieu of criteria. The LREL are To Be Considered (TBC) values.

2.2.2.4 State Standards for Surface Water

Michigan Environmental Remediation Standards NREPA 1994 PA 451 Part 31 establishes water quality standards for waters of the State for which there is no specific designation. These standards include: acute standards applicable to the mixing zone, chronic standards applicable after the mixing zone, and wildlife standards. These values are incorporated into the standards established for groundwater venting to surface water, which were described above and provide the basis for identifying COCs for the Site. Compliance with these standards is to be determined for the Site in accordance with R 299.5716.

2.2.3 Site-Specific Chemicals of Concern (COCs)

The identification of site-specific COCs was based on the comparison of known source material (CKD) and groundwater quality at the Site to the soil and water quality ARARs. As noted in the previous sections, the State of Michigan Part 201 Rules have been identified as the most stringent ARARs for both CKD leachate and surface water impacted by groundwater venting.

2.2.3.1 West CKD Area

Analytical data was obtained from samples of unconsolidated material collected from 22 borings installed at the West CKD Area during the RI. Analytical results are compared to Michigan Part 201 Direct Contact Criteria in Table 4a. As shown in Table 4a, the following COCs have been identified for source materials at the site: chloride.

Groundwater quality data obtained from samples collected from each of eight monitoring well nests installed at the West CKD Area during the RI were compared with the applicable groundwater quality standards in Table 5a. As shown in the table, the following COCs have been identified for groundwater at the West CKD Area : inorganics – chloride, % Ammonia that will become NH_3 in surface water, pH, total dissolved solids (TDS), sulfate; and metals – aluminum, arsenic, copper, iron, lead, mercury, nickel, selenium, silver, and vanadium.

2.2.3.2 Seep 2 CKD Area (including Pine Court and Guard Rail Seep areas)

Analytical data was obtained from samples of unconsolidated material collected from 27 borings installed at the Seep 2 CKD Area during the RI. Analytical results are compared to Michigan Part 201 Direct Contact Criteria in Table 4b. As shown in the table, the following COCs have been identified for source materials at the site: chloride and arsenic.

Groundwater quality data obtained from samples collected from each of 34 monitoring well nests installed at the Seep 2 CKD Area during the RI were compared with the applicable groundwater quality standards in Table 5b. As shown in the table, the following COCs have been identified for groundwater at the Seep 2 CKD Area: inorganics – chloride, nitrogen-ammonia, % Ammonia that will become NH_3 in surface water, pH, TDS, sulfate; and metals – aluminum, copper, iron, mercury, nickel, selenium, silver, and vanadium.

2.2.3.3 Seep 1 CKD Area

Analytical data was obtained from samples of unconsolidated material collected from 18 borings installed at the Seep 1 CKD Area during the RI. Analytical results are compared to Michigan Part 201 Direct Contact Criteria in Table 4c. As shown in Table 4c, the following COCs have been identified for source materials at the site: chloride.

Groundwater quality data obtained from samples collected from 18 monitoring well nests installed at the Seep 1 CKD Area during the RI were compared with the applicable groundwater quality standards in Table 5c. As shown in the table, the following COCs have been identified for groundwater at the Seep 1 CKD Area: chloride, nitrogen-ammonia, % Ammonia that will become NH_3 in surface water, pH, TDS, sulfate; and metals – aluminum, arsenic, copper, iron, manganese, mercury, nickel, selenium, silver, and vanadium.

2.2.4 Summary of Site-Specific COCs and RAOs

CKD from the Site contains chloride and arsenic above Michigan Part 201 Direct Contact Criteria. No other exceedances were identified for any other parameters for the other potential pathways of concern. Cover soils from the Site did not contain any parameters with concentrations above applicable criteria. Screening of soil/CKD samples for protection of drinking water and GSI criteria was not performed due the abundance of Site groundwater data.

CKD impacted groundwater from the Site contains chloride, nitrogen ammonia, pH, TDS, sulfate, aluminum, arsenic, iron, lead, mercury, nickel, selenium, and vanadium above Part 201 R299.5710; ingestion of groundwater as drinking water. CKD impacted groundwater from the Site contains chloride, pH, TDS, arsenic, copper, lead, mercury, nickel, selenium, silver, and vanadium above Part 201 R299.5715; protection of surface water resources (waters of the State) from hazardous substances in venting groundwater. No other exceedances were identified for any other parameters for the other potential pathways of concern.

The RAOs for the Site are therefore as follows:

1. Protection of human health from direct contact exposure to CKD containing elevated levels of chloride and arsenic.

2. Protection of human health from direct contact and ingestion exposure to CKD impacted groundwater containing elevated levels of chloride, pH, TDS, sulfate, aluminum, arsenic, iron, lead, manganese, sodium, and vanadium.

3. Protection of human health and the environment from venting of CKD impacted groundwater containing chloride, pH, TDS, arsenic, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc to surface water.

2.2.5 Mixing Zone – Rules and Applicability

As discussed previously, the AOC required COCs above state criteria to be addressed. For certain COCs that exceed GSI criteria, a mixing zone under state law may apply.

This section is a discussion of the applicability of The Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), associated rules, and MDEQ guidance and operational memorandum to the authorization of a GSI mixing zone for the venting of groundwater from the Site into Lake Michigan.

The Site which includes the West CKD, Seep 2 CKD (including Pine Court Seep area and Guard Rail Seep area) is a “facility” as defined in Section 20101(o) of NREPA, and is undergoing an IR action under Part 201 of the Act. The Work Plan (Barr, July 2005), previous hydrogeological investigations and observations as well as the testing of the beach wells and along the lake shoreline confirm that groundwater is venting into the lake. The beach well and shoreline data indicate that the venting groundwater exceeds a number of standards and criteria established by the MDEQ (the GSI pathway is relevant). Given these circumstances, a review of the MDEQ rules and regulations (below) indicate that CMS may as part of a response plan request the Department to authorize a mixing zone for the discharge of the venting groundwater at the Development.

Section 20120(a) (Cleanup criteria) of NREPA allows the MDEQ to establish cleanup criteria and approve of remedial actions in the categories listed in the subsection. Subsection 15 is applicable to the Site and requires that the venting of groundwater into surface water from a facility comply with the requirements of Part 31 of NREPA and associated rules. The subsection further establishes that a permit from the MDEQ for the venting is not required if the discharge is provided for in an approved remedial action plan.

Part 31 {3109(a)} confirms that the MDEQ allows for mixing zones for discharges of venting groundwater and provides that the mixing zones for venting groundwater will be developed in similar manner as those for point source discharges and will be equally as protective of surface waters. The rule confirms that a discharge permit for the venting is not required if the discharge is provided for in an approved remedial action plan.

The development of the water quality standards and criteria for venting groundwater by the Department is discussed in Rule 299.5716. Subpart 6 of the rule requires the Department to develop standards under Part 31 to serve as generic GSI criteria and it defines compliance with Act and the rules as non-exceedance of the GSI criteria. It further indicates that if compliance with the criteria cannot be achieved (then under subpart 7), the discharger may request that the Department authorize a response that includes a mixing zone.

Subpart 1 of the Rule 299.5716 states that GSI can be considered a relevant pathway when a remedial investigation or best professional judgment indicates that a hazardous substance in groundwater is reasonably expected to vent to surface water in concentrations that exceed the generic GSI criteria. This has been documented at the Site. The subpart lists a number of factors to be used in making the relevant pathway discussion which include the presence of a hydraulic connection between groundwater and the surface water, the proximity of surface water to the source areas and the groundwater plume that currently, or may in the future be expected to, exceed the generic GSI criteria, and facility-specific evidence of natural attenuation.

The generic GSI criteria developed under Parts 31 (R 323.1057) and 201 are contained in Rule 299.5744 (table 1) and the footnotes that constitute Rule 299. 5750. A discussion of the GSI criteria, their applicability and use are provided in the Remediation and Redevelopment Division's (RRD) Operational Memo 5.

The location of the GSI monitoring points at the Development meet the requirements of R 299.5716(10) as the locations are vertical wells in the saturated zone, close to the lake, and the groundwater in the wells is representative of groundwater entering surface water.

Mixing zones are discussed in Rule 323.1082 developed under Part 31 of the Act. Subsection 1 of the Rule indicates that the final acute value (FAV) for aquatic life is not to be exceeded unless the

Department determines or the discharger can demonstrate (subsection 7 of the Rule) that an acute mixing zone is acceptable. In subsection 5 of the Rule it states that mixing zones in the Great Lakes can allow no greater than a 10 to 1 dilution of lake water to venting groundwater unless a demonstration under subsection 7 shows that a greater dilution is appropriate. Subsection 7 contains a list of information that must be obtained during a mixing zone demonstration including the location, size and shape of the mixing zone and the amount of dilution at the boundaries of the mixing zone. For discharges to the Great Lakes the location at which discharge-induced mixing ceases must be defined.

Rule 323.1082 in subsection (6) presents additional restrictions and stipulations applicable to mixing zones for bioaccumulative chemicals of concern (BCCs). Mercury is a listed BCC and these restrictions apply to the venting of mercury from the Site to the lake. The Rule prohibits the authorization of mixing zones for new discharges of BCCs, however, subsection (6)(b) allows the authorization of mixing zones for BCCs through November 14, 2010. Since the discharge of mercury at the Site is historical subsection (6)(b) would apply to the Site. In addition, there are allowances for some discharges beyond the cutoff date in subsections (6)(c) and (d). Subsection (6)(d) allows the Department at the request of an existing discharger of a BCC to grant mixing zones beyond the November 14, 2010, date based upon a number of listed technical and economic considerations.

The applicability of water quality standards is discussed in R 323.1090, and subsection (1) states that the standards do not apply within mixing zones, except for the physical standards listed in R 323.1050.

Rule 323.1098 discusses Antidegradation and the special conditions that apply to new or increased loading of pollutants by any source to surface waters of the state where water quality standards are applicable. Subsection (8)(c) excludes (with the exception of discharges to Outstanding State Resource Waters, or Department case-by-case determinations) response actions taken to alleviate a release that may pose an imminent and substantial danger under CERCLA and/or Part 201 of NREPA. In addition, the loadings to the lake from the site are not new (ongoing prior to 1997) and the response actions taken to date including the interception and disposal of the more significant seeps have reduced the loadings.

Summaries of GSI well data from the Site have been provided to confirm that some GSI criteria have been exceeded at the GSI wells at the Site. These data are included in Appendix C, Tables 1 through 3 for the Seep 1 CKD, Seep 2 CKD, and West CKD Areas, respectively. The summaries compare maximum values [Rule 299.5716(7)] for each parameter from each monitoring location to the GSI criterion. The overall maximum value for each parameter at each area is also provided. All the maximum concentrations that exceed the criteria are highlighted in yellow and those overall maximum concentrations that are over 10 times greater than the criterion are highlighted in green. The mercury GSI criterion was exceeded by over 10 fold and the criteria for TDS, pH, selenium, and vanadium were exceeded at all three areas. Appendix C, Table 4 provides the calculation of the Generic Facility-Specific GSI criteria for those substances whose value is dependent on the pH and/or hardness of the receiving water. Appendix C, Tables 5 through 7 are the raw data tables used in the development of the summary comparison tables.

2.2.5.1 Conclusion

The Site meets the conditions contained in the laws and rules that govern mixing zones at the GSI and is entitled to request for the authorization of a mixing zone for the venting of groundwater. The site is a facility engaged in an IR action under Part 201. Previous investigations and observations establish that there is a hydraulic connection from the groundwater at the Site to surface waters of the state and that the venting is an existing and historical discharge. Beach well data and previous observations and analysis of the seep areas demonstrate that concentrations of hazardous substances in the groundwater venting to the surface water at the site have the potential to exceed the generic GSI criteria. In this case, since the IR is one designed to alleviate a release that may pose an imminent and substantial danger, and the discharges are existing (prior to 1997 – RRD Operational Memorandum No. 5) the venting of the groundwater is excluded from the Antidegradation requirements.

The request for mixing zone-based GSI criteria for TDS, pH, selenium, vanadium, and other parameters likely to exceed GSI criteria (except mercury – restrictions discussed below) should receive consideration by the Department. The potential exceedances for these parameters are not excessive and the IR actions taken to date have made a significant reduction in the flow of leachate into the lake, the concentrations of the COCs in the GSI wells and thus the potential loadings to the lake. Previous investigations/reports indicate that the venting levels of concern are limited.

CMS will provide a demonstration under the Rule as appropriate for water bureau review prior to the authorization of a GSI mixing zone. It is anticipated that declining concentrations due to IR actions and a demonstration of their impacts to the receiving water will resolve all issues regarding TDS, pH, selenium and vanadium.

In summary, the IR actions appear to have reduced venting concentrations of the parameters considered in this evaluation. An application for the MDEQ to develop final mixing zone-based GSI cleanup criteria will be pursued as appropriate for the Site remedy.

2.2.6 Technical Impracticability – Rules and Applicability

As discussed previously, the AOC requires COCs above State criteria to be addressed. Mercury concentrations in beach wells exceed GSI criteria (1.3 ng/L) and are not subject to a mixing zone determination as discussed in Section 2.2.5. This State criteria can be waived under CERCLA §121(d)(4) based on several factors including Technical Impracticability, or by the State through appeal to the Director and demonstration that a GSI standard is "Unachievable" pursuant to NREPA.

CMS will submit a Technical Impracticability Demonstration to explain the basis for concluding that the mercury GSI standard is unachievable. The Demonstration will be completed consistent with the Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration, OSWER Directive No. 9234.2-25, dated September 1993. It includes evaluation of six components:

- **TI Levels**: specific ARARs or media cleanup standards for which TI determinations are sought
- **TI Zone**: spatial area over which the TI decision will apply
- **Conceptual Model**: model that describes site geology, hydrology, groundwater contamination sources, transport, and fate
- **Restoration Potential**: an evaluation of the restoration potential of the site, including data and analyses that support any assertion that attainment of ARARs or media cleanup standards is technically impracticable from an engineering perspective. At a minimum, this generally should include:
    - a demonstration that contamination sources have been, or will be, removed and contained to the extent practicable;
    - an analysis of the performance of any ongoing or completed remedial actions;
    - predictive analyses of the timeframes to attain required cleanup levels using available technologies; and

  - o a demonstration that no other remedial technologies (conventional or innovative) could reliably, logically, or feasibly attain the cleanup levels at the Site within a reasonable timeframe.

- **Cost**: estimates of the cost of the existing or proposed remedy options, including construction, operation, and maintenance costs

- **Additional Information**: any additional information or analyses that EPA deems necessary for the TI evaluation.

For Sites where complete restoration of the contaminated groundwater is deemed technically impracticable, an Alternative Remedial Strategy (ARS) is to be developed that is protective of human health and the environment and satisfies the statutory and regulatory requirements of CERCLA. The ARS typically addresses three items; (1) prevention of exposure to contaminated groundwater, (2) remediation of contamination sources, and (3) remediation of aqueous contaminant plumes. The alternatives evaluated in this AE are intended to substantially comport with the ARS, but will be expanded upon, as appropriate, in the subsequent completion of the Technical Impracticability Demonstration.

2.3 General Response Actions

Identification of general response actions capable of meeting the site-specific RAOs is the first step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988).

General response actions are broadly defined as actions that can be used to address the impacted media at a given site. General response actions are evaluated to determine whether they can meet the site-specific RAOs, as discussed in Section 2.2. The following general response actions are evaluated for the impacted media at the West CKD Area, Pine Court Seep area, Seep 2 CKD Area, and Seep 1 CKD Area.

Source Materials/Cement Kiln Dust (CKD)

- No action
- Institutional controls
- Removal
- Containment and Isolation

Groundwater

- No action
- Institutional controls
- Collection of CKD-Impacted Water (Removal)
- Containment and Isolation

Source Materials/Cement Kiln Dust (CKD)

- Other Engineering Controls
- Disposal

Groundwater

- Other Engineering Controls
- Disposal

These actions are also intended to address surface water by limiting leachate migration to surface water. Each of these general response actions includes one or more remedial technologies or process options that are assembled and screened (see Section 2.5) in order to develop alternatives for the Site.

2.3.1 Identification of Areas and Volume of Impacted Media

Identification of the volumes and areas of the affected media is the second step in the process of developing and screening potential remedial alternatives for the site (U.S. EPA, 1988).

The approximate extent of CKD was determined by geophysical surveys using Electromagnetic Induction (EM); Direct Current Resistivity Imaging (DCR); and Seismic Refraction (Refraction) methods, and confirmed at various locations with the installation of soil borings, as described in the RI Report. Estimated surfaces for the top of CKD, top of weathered bedrock, and top of competent bedrock were created in Land Development Desktop (LDD) software using the results of the geophysical surveys.

Volume of CKD at each of the seep areas was calculated using information from borings installed during the RI and from results of the geophysical surveys. These volumes were then combined with groundwater data obtained from monitoring wells to calculate the volume of saturated CKD. The highest observed groundwater levels in the monitoring wells, generally in the winter/spring, were used to represent a "high" water table. Saturated CKD volumes were calculated based on these "high" groundwater conditions and therefore are indicative of the maximum observed amount of saturated CKD.

2.3.1.1 West CKD Area

The approximate extent of CKD in the West CKD Area is shown on Figure 1-2 and occupies a footprint area of approximately 5.4 acres. The estimated volume of CKD in the West CKD Area is approximately 100,000 cubic yards (CY) as shown in Table 1. The estimated extent of CKD located below the water table is shown on RI Figure 4-39a.

Data from the targeted shoreline surveys conducted in the May/June 2005, prior to construction of the West CKD ILRS, are shown on Figure 3-1. High pH (pH >9) discharge was initially noted along approximately 500 feet of shoreline. As discussed in the West CKD Area conceptual model, groundwater and infiltrating surface water contacts buried CKD and results in the shallow downgradient CKD-impacted groundwater (leachate) exhibiting an elevated pH. The shallow leachate migrates through the upper portion of the saturated zone towards Lake Michigan. Shallow leachate also migrates downward to the regional groundwater table where it is subject to seasonal reversals of flow direction induced by pumping of City Well 5. The leachate in the shallow and regional groundwater can discharge to Lake Michigan and result in areas where lake water pH is above 9 in the near-shore area.

2.3.1.2 Pine Court Seep Area

The approximate extent of CKD in the Pine Court Seep area is shown on Figure 1-2 and occupies a footprint area of approximately 11.1 acres. The estimated volume of CKD in the Pine Court Seep area is approximately 286,000 CY as shown in Table 1. The volume of CKD located below the water table is estimated to be less than 1 percent of the total CKD volume.

Data from the targeted shoreline surveys conducted in May/June 2005, prior to any IR construction, is shown on Figure 3-2. High pH (pH >9) discharge was initially noted along approximately 450 feet of the shoreline. As discussed in the Pine Court Seep area conceptual model, groundwater and infiltrating surface water contacts buried CKD and results in the shallow downgradient CKD-impacted groundwater (leachate) exhibiting an elevated pH. The shallow leachate migrates through the upper portion of the saturated zone towards Lake Michigan. Shallow leachate also migrates downward to the regional groundwater table where it is subject to seasonal reversals of flow direction induced by pumping of City Well 5. The leachate in the shallow and regional groundwater can discharge to Lake Michigan and result in areas where lake water pH is above 9 in the near-shore area.

2.3.1.3 Seep 2 CKD/Guard Rail Seep Area

The approximate extent of CKD in the Seep 2 CKD/Guard Rail Seep Area is shown on Figure 1-2 and occupies a footprint area of approximately 23.7 acres. The estimated volume of CKD in the Seep 2 CKD/Guard Rail Seep Area is approximately 870,000 CY as shown in Table 1.

Data from the targeted shoreline survey conducted in May/June 2005, prior to IR construction, is shown on Figure 3-2. High pH discharge was initially noted along approximately 500 feet of the Seep 2 CKD Area and 150 feet of the Guard Rail Seep area shorelines. As discussed in the Seep 2

CKD/Guard Rail Seep Area conceptual model, groundwater and infiltrating surface water contacts buried CKD and results in the shallow downgradient CKD-impacted groundwater (leachate) exhibiting an elevated pH. The shallow leachate migrates through the upper portion of the saturated zone towards Lake Michigan. Shallow leachate also migrates downward to the regional groundwater table where it is subject to seasonal reversals of flow direction induced by pumping of City Well 5. The leachate in the shallow and regional groundwater can discharge to Lake Michigan and result in areas where lake water pH is above 9 in the near-shore area.

2.3.1.4 Seep 1 CKD Area

The approximate extent of CKD in the Seep 1 CKD Area is shown on Figure 1-2 and occupies a footprint area of approximately 15.5 acres. The estimated volume of CKD in the Seep 1 CKD Area is approximately 550,000 CY as shown in Table 1. The volume of CKD located below the water table is estimated to be less than 1 percent of the total CKD volume.

Data from the targeted shoreline survey conducted in May/June 2005, prior to IR construction, is shown on Figure 3-3. High pH discharge was initially noted along approximately 1050 feet of the Seep 1 CKD Area shoreline. As discussed in the Seep 1 CKD Area conceptual model, groundwater and infiltrating surface water contacts buried CKD and results in the shallow downgradient CKD-impacted groundwater (leachate) exhibiting an elevated pH. Leachate migrates through the upper portion of the saturated zone, and in select portions of the Seep 1 CKD Area and discharges to Lake Michigan near the shoreline. This discharge can result in areas where lake water pH is above 9 in the near-shore area.

2.4 Identification and Screening of Technology Types and Process Options

Identification and screening of technologies and process options is the third step in the process of developing and screening potential remedial alternatives for the site (U.S. EPA, 1988).

2.4.1 Identification and Screening of Technologies

In accordance with U.S. EPA guidance, three criteria are used to screen technologies and process options: effectiveness, implementability, and cost (U.S. EPA, 1988). These three criteria are described below. Using these three criteria, Tables 6a, 6b, 7a, and 7b present the initial screening results for the possible technologies and process options identified for CKD and leachate, respectively.

2.4.1.1 Effectiveness

The evaluation of effectiveness is based on the following factors: (1) the ability of a process option to address the COCs at the site; (2) the ability of the process option to function under the conditions specific to the site; and (3) the potential for adverse impacts to occur during implementation of the process option. This evaluation incorporates the consideration of both short-term and long-term impacts to the site. The proposed rule entitled *Standards for the Management of Cement Kiln Dust* (U.S. EPA, 1999) and the *Draft Technical Background Document on Ground Water Controls at CKD Landfills* (U.S. EPA, 1998) were also used in assessing the degree of effectiveness of several treatment technologies and process options for COCs. Other references as footnoted on the tables and previous experience were also used to evaluate the effectiveness of specific technologies and process options.

2.4.1.2 Implementability

The implementability evaluation is based on technical and logistical feasibility. Technical implementability includes the status and performance of a technology for the given site conditions. Logistical feasibility is based on infrastructure and non-technical aspects of implementability including: the availability of treatment, storage, and disposal services (including capacity); the availability of necessary equipment and skilled workers to implement the technology; potential obstacles in securing acceptance for remedial technologies; the ability to secure approvals for onsite, as well as offsite actions; and the potential resistance of residents, governmental entities, or organizations to the collateral impacts or perceived deleterious effects of proposed actions.

2.4.1.3 Cost

The cost evaluation in Tables 6a and 7a shows approximate unit costs or relative cost characterizations for application of each technology. The costs do not include associated functions such as site preparation, material preparation, or site restoration. Where technologies are not well-represented by a unit cost, the overall cost of implementation is characterized as low, medium, or high relative to other general response actions. At this stage in the screening process, the cost analysis is made on the basis of engineering judgment, and each process option is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type. Cost estimates do not include negative economic impact to the golf course, the Bay Harbor Development, or the community.

2.4.1.4 Results

Evaluation results are shown in Tables 6a, 6b, 7a, and 7b. Those options that display certain characteristics including: (1) ineffectiveness; (2) non-implementability; (3) poor suitability to the site conditions, or (4) considerable expense relative to other alternatives within the same technology group are eliminated from further consideration at the completion of this screening step, as noted in the far right column of each table.

2.4.1.4.1 Process Options Retained For Soil (CKD)

The general response actions retained for CKD include: no action, institutional controls, removal, containment and isolation, other engineering controls, and disposal. Site-specific response actions are formulated based on these retained general response actions and applicable remedial technology. The site-specific response actions for CKD include: no action; institutional controls; removal by excavation with offsite disposal, excavation and reuse, and excavation and treatment with offsite disposal or reuse; containment and isolation by containment cell construction, horizontal barriers, vertical barriers, and consolidation; and In-situ treatment. The No Action response was retained as a basis for comparison with the other response actions (in accordance with the requirements of the NCP). Land development and use restrictions were retained as institutional controls. Land development and use restrictions could include continued land use as a golf course with adjacent mixed residential uses to protect human health from exposure to CKD that is left in place.

Excavation with offsite disposal was retained because it is a commonly used response action and meets the RAOs. Excavation with offsite disposal is the most viable disposal option when compared with construction of a lined, onsite disposal facility because of the limited site size and the implementability challenges of temporarily storing CKD during construction of a RCRA containment cell onsite. For offsite disposal, consistent with requirements in Michigan law, CKD would be disposed in a local RCRA subtitle D landfill.

Excavation and reuse was not retained because of the anticipated implementability and effectiveness challenges associated with this technology. Potential reuse options considered in the evaluation included recycling at another cement kiln and land application as a nutrient or soil amendment. Some of the challenges associated with reusing CKD material in one or more of these scenarios included: the potential need for extensive chemical and physical testing requirements to determine an appropriate loading rate for land application as a soil amendment, identification of a market large enough to handle the calculated volume of CKD, and potential to create a more widespread exposure scenario at land application fields.

Excavation and reuse as feedstock for cement kiln was also not retained because of the uncertainties associated with the ability of cement kiln facilities to accept large volumes of CKD. In addition, excavated CKD would have to be stored and transported in batches, depending on the requirements of the cement kiln facilities, leading to additional storage fees and possible exposure scenarios. The potential distance from the site to any facility large enough to use the available volume also limits the potential for beneficial reuse of the CKD.

Excavation and treatment (ex situ) of the CKD was not retained because of the anticipated implementability and effectiveness challenges associated with available treatment technologies. The challenges would include: extensive testing to determine effective reagent additions and processing requirements, identification of a market large enough to handle a calculated volume of treated materials.

On-site containment cell was retained because it could be used as a response action and meets the RAOs. Consisting of an impermeable geomembrane liner constructed below and above the existing CKD is limited by the site size and the implementability challenges of temporarily storing CKD during construction of a RCRA containment cell onsite. Site limitations include sloping for safety, long-term integrity, and constructability of the geomembrane. In addition, the site is assumed to require a minimal increase in final grade to be consistent with the current site use. For these reasons an on-site containment cell at this Site would require a significant amount of CKD be removed and disposed of off-site to implement this process option.

Onsite contouring and installation of an improved soil cover was retained as a viable containment and isolation technology. The soil cover option was retained because it is commonly used in containment applications and meets the RAOs. During Site redevelopment beginning in 1994, onsite contouring and installation of a cover soil was completed. The CKD piles were contoured and covered with a soil layer with drainage to support golf course operation. The cover and vegetation were designed to eliminate direct contact exposure to the CKD and to date have been observed to accomplish this function with routine maintenance practices. Improvement of this cover system through the combination of contouring and installation of an improved soil cover in targeted locations will reduce the potential for direct contact with CKD, reduce the potential for water or wind erosion of CKD, reduce infiltration, and provide a base for establishing vegetation which will enhance erosion resistance.

The option of incorporating a flexible membrane liner in the cover system was retained and is the most viable containment and isolation technology when compared with other capping process options in the horizontal barrier technology type. Incorporation of a flexible membrane liner further reduces the potential for direct contact with CKD and nearly eliminates the potential for contact of surface water infiltration with CKD which as described in the Site conceptual models is a source of leachate generation.

Other covering and capping options were evaluated and not retained for further consideration. These included an asphalt cap, a clay cap, and an evapotranspiration cap. The option of an asphalt cap was not retained for use as an onsite containment and isolation technology because it would conflict with the intended reuse of area as a golf course. The option of a low permeability, clay cap was not retained for use as an onsite containment and isolation technology because it was no more effective than a soil cover at restricting exposure to the covered material, but was more expensive than a soil cover system. In addition, an acceptable, local clay source of sufficient volume would be difficult to find. Clay would have also been susceptible to freeze-thaw and wet-dry cycling. Considerable maintenance would be required to keep deep rooted plants from becoming established in the cover soil above the clay cover. An evapotranspiration cap was not retained because seasonal variations in evapotranspiration potential limit the effectiveness of this type of cap in this climate. It is also more expensive than a soil cover system.

Onsite consolidation was retained as a viable containment and isolation technology for areas of a relatively small footprint of CKD which can be relocated with a larger pile, such as the ‘bottleneck’ relocation at the East CKD Area. Onsite consolidation of CKD aids in reducing exposure to CKD by minimizing the area that CKD will occupy on the site and the area of CKD may contact infiltration water.

In situ chemical encapsulation was not retained because it is an unproven technology and has not been previously implemented or demonstrated to be effective in this application. Also, laboratory and pilot scale tests would be required to determine the encapsulation media, feasibility and effectiveness. Uniformity of application and long-term chemical stability/compatibility of the encapsulation media would need to be evaluated. If proven to be effective, and concerns such as coverage area and stability could be addressed, implementation of a full scale system would take additional years.

Bottom liner such as injection of grout/cement below the CKD was not retained because it would not be effective at eliminating exposure to CKD and eliminating infiltration. It would also be difficult to implement based on the geology. The number of injection points to ensure adequate coverage would likely result in exorbitant cost and would take a long time to implement.

Vertical barriers were not retained because they would not be any more effective at eliminating exposure to CKD than existing site conditions. In addition, implementation can be an issue since the depth of the material exceeds the practical limit of most equipment. Bedrock also limits options for barrier construction.

Dynamic compaction was not retained because the acceptance of this technology by neighboring property owners is questionable due to ground vibrations and noise pollution created during the process of dynamic compaction. Other engineering controls such as in-situ treatment using Accelerated Carbonation Technology (ACT) was not retained because of the uncertainty associated with the ability of this process to fully remediate all CKD in-situ. Bench scale and pilot scale testing would be required to evaluate the effectiveness and implementability of this process option. There is insufficient demonstration of this unproven technology and it would be expected to take a long time to implement after a lengthy technology development and testing process.

2.4.1.4.2 Process Options Retained For Groundwater

The general response actions retained for leachate include: no action, institutional controls, removal, containment and isolation, in-situ treatment, and disposal. Site-specific response actions, including combinations of one or more of these general response actions, were formulated based on the retained general response actions and applicable remedial technologies. The site-specific general response actions that will be considered for groundwater include: no action; institutional controls; removal by extraction wells or collection trenches; containment and isolation by upgradient extraction wells, upgradient collection trenches, vertical barriers, horizontal barriers; and monitored natural attenuation. Those response actions that will generate leachate or a wastewater stream will also require leachate management.

The general response actions retained for site-specific consideration of leachate management include: on-site treatment at a wastewater treatment facility with discharge to surface water via a new NPDES permit; on site pretreatment and disposal to an offsite POTW for treatment and discharge to surface water via an existing NPDES permit; offsite disposal using deep injection well; on-site disposal using deep injection well; offsite land application of collected leachate; and evaporation of leachate using an offsite evaporation pond. Leachate management response actions are described in Section 2.4.1.2.3.

The No Action response was retained as a basis for comparison with the other response actions (in accordance with the requirements of the NCP). Groundwater use restrictions were retained as an institutional control. Groundwater use restrictions would prohibit the use of groundwater from beneath the Site as a drinking water source. Managed irrigation practices were also retained as an institutional control. Managing the amount of water applied to the golf course would balance the needs of Bay Harbor to maintain the course (vegetation, playability, etc.) with the mitigation of infiltration to the underlying CKD pile.

Each of the retained removal and containment and isolation technologies is suited for certain portions of the Site and can be effective and implementable in aggregate, as discussed in Section 3.0. These technologies were retained because they are commonly used as groundwater migration control/containment applications and meet the RAOs.

Collection of the CKD impacted water using extraction wells and collection trenches was retained because these are demonstrated technologies that can be effective at controlling groundwater migration and are capable of collecting large volumes of water. These are also readily implementable options as they are currently in use at the Site.

Containment and isolation using upgradient extraction wells was retained because it is potentially effective in minimizing groundwater flow through the contaminated media, can be used to collect large volumes of water in order to minimize migration of impacted groundwater at the Site, and is readily implementable. Upgradient isolation and extraction wells may be used in conjunction with down-gradient leachate collection, treatment, and discharge technologies or horizontal barrier to enhance effectiveness. An upgradient collection trench was not retained because it is not as effective as the other containment technologies and it would be more difficult to implement than a series of extraction wells.

Containment using slurry wall/grout injection was retained because it can be effective at limiting migration of groundwater containing chemical compounds. Installation in bedrock, however, would require special grout injection procedures and consequently is considered for cost-effective reduction of leachate volume collected. This option would be effective if used in conjunction with leachate collection processes. A vertical barrier using sheet pile was not retained because bedrock will impede installation (piling cannot be driven into bedrock) in certain portions of site. Therefore, sheet pile would not be technically implementable except possibly in limited portions of the West CKD Area and Seep 1 CKD Area shorelines where unconsolidated soils are present.

Downgradient hydraulic containment using an infiltration gallery was retained because it reduces groundwater gradient through contaminated media and provides localized barrier to transmission of upgradient groundwater. It also aids in attenuation of CKD impacted groundwater. It is a readily implementable option and relies on a source of clean water and therefore is well suited to use in combination with upgradient groundwater diversion which supplies ample water.

The horizontal barriers retained for screening of remedial technologies for CKD-impacted groundwater are the same as the ones retained for CKD and are discussed in Section 2.4.1.4.1.

In situ treatment of groundwater by the physical/chemical treatment process of neutralization was not retained because of the potential long-term loss of effectiveness due to precipitation reactions and the Pine Court Seep area CO_2 Pilot Injection System, a site-specific test of this technology, has only been moderately effective at controlling lake pH.

2.4.1.4.3 Leachate Management Response Actions

Several methods of water management were evaluated to determine the most feasible response actions for treatment and disposal of the collected leachate. Any final remedial alternatives that will include leachate collection will also require collection and disposal of water as a long term remedy component. Technologies and process options evaluated for treatment and disposal of collected leachate include:

- Onsite treatment at a wastewater treatment facility with discharge to surface water via a new NPDES permit.
- Onsite pretreatment and disposal to an offsite POTW for treatment and discharge to surface water via an existing NPDES permit.
- Offsite disposal using deep well injection. Onsite disposal at a deep well was included in the screening of process options as per the MDEQ's request.

- Offsite land application of collected leachate.

- Evaporation of leachate using an offsite evaporation pond.

Potential remediation actions involving water collection at the Site are likely to produce an average flow of approximately 62,000 to 84,000 gallons per day, based on a projected average flow of 43 to 58 gallons per minute (gpm) from the ILRS after remedial action implementation. Preliminary data on the quality of the leachate generated at the Site during the IR actions suggest that pH, organic carbon, total dissolved solids, and mercury are likely to be the primary criteria that will affect consideration of leachate management options. The following paragraphs provide a detailed evaluation of the above listed leachate management options using the flows and water quality from the Site.

Onsite Treatment at a Wastewater Treatment Facility with Discharge to Surface Water via a New NPDES Permit

Onsite leachate treatment would likely consist of a multi-step effort. The first step would likely be neutralization to reduce the pH. It is anticipated that reducing the pH will result in the precipitation of solids that would be expected to remove some portion of the metals of concern. This precipitate would be removed by clarification or filtration and then rendered suitable for offsite disposal as a solid waste. After neutralization and filtration, some chemicals of concern may remain in the leachate at concentrations above the chemical-specific ARARs for NPDES discharge. It is unlikely that a chemical additive could materially improve mercury removal as the mercury in the leachate solution is already at a very low concentration. Mercury concentrations measured in the IR collection drains ranged from approximately 5 to 486 ng/L and are summarized in Table 2, Appendix A. At the low levels, only marginal improvement via treatment effectiveness is achievable. Regardless of influent mercury concentration, the treated effluent would be above the proposed effluent limit of 1.3 ng/L for any new direct discharge sources to the Great Lakes, including Lake Michigan.

Treatment alone is unable to reduce mercury concentrations to the Great Lakes effluent limit. CMS submitted an application for an NPDES permit for treatment and discharge of the leachate from the East CKD Area. A copy of the permit application was included as Appendix D to the *Feasibility Study, East CKD Area, Revision 2.0 – June 4, 2008*. The work done in support of the permit application showed, through pilot testing with water from the Site, that treatment can be of significant benefit when much higher initial mercury concentrations are present. The mercury concentrations are on average much higher at the Site than the highest concentration of mercury observed in the East CKD Area. The initial total mercury concentration in the groundwater used in the pilot-tests was as high as 600 to 700 ng/L. The treatment process studied in the pilot-testing included neutralization to a pH between 7 and 7.5, enhanced chemical precipitation using a metal precipitating reagent (MCX), and filtration. Results from the pilot testing showed that this combination of physical/chemical treatment processes had the potential to lower the mercury concentration in the treated leachate from approximately 500 to about 20-30 ng/L. The preliminary results from this pilot testing were presented to the U.S. EPA and the Michigan MDEQ at a meeting with CMS on January 18, 2006.

Even though treatment alone may not achieve the required concentration levels, it may be possible to obtain an NPDES permit for a discharge, provided the concentration could be reduced by blending the treated water stream with upgradient diversion water. The upgradient diversion water may carry some natural background mercury concentration. After mixing with as little as 300 gpm of upgradient diversion water, a treated effluent with a mercury concentration of 30 ng/L could meet a Great Lakes Initiative (GLI) standard of 1.3 ng/L.

Onsite Pretreatment and Disposal to an Offsite POTW for Treatment and Discharge to Surface Water via an Existing NPDES Permit

In the event that an NPDES permit for direct discharge cannot be obtained, leachate pretreated at the Site using the neutralization and clarification/filtration processes described previously could be discharged to a sewer for additional treatment at a municipal wastewater treatment facility or publicly owned treatment works (POTW). Some water from the Site is currently trucked to Traverse City for disposal into a POTW, and leachate collected from an initial recovery system installed at the Site in the mid-1990’s discharged leachate to the City of Petoskey POTW.

In general, the U.S. EPA is in favor of using POTWs for final treatment and removal of mercury from wastewater, so this approach may meet with acceptance by state and federal agencies.

The ability of a POTW to accept pretreated leachate from the Site is dependent on several factors including: total volume of flow; temperature of the water; organic loading; total dissolved solids loading; and total mercury loading. Of these factors, the primary consideration for acceptance of treated leachate by a POTW is likely the total mercury and TDS load to the facility. The potential impact of site mercury and TDS on the receiving POTW will need to be addressed on a case by case basis with the receiving POTW.

It should be noted that, if this water disposal approach is adopted, permission to send the remainder of the LTB water (from the East CKD Area) to the POTW may also be sought.

A potentially serious limitation for this disposal approach is the logistics of getting the pretreated leachate to the POTW and the possibility that the POTW may need upgrades to successfully accept the pretreated leachate. Treatment plant upgrades and transport considerations may adversely affect both the implementability (timing and logistics) and cost-effectiveness of this option.

Offsite Disposal Using Deep Well injection

Leachate currently being collected as a component of the IR at the Site is being disposed of offsite into a deep injection well. This well is a commercial waste receiving well located in Johannesburg, Michigan. The well is drilled into the Dundee formation at a depth in excess of 2,000 feet below the ground surface. This area of the subsurface is known to contain fluids that are not suitable for withdrawal and use as potable water, irrigation supply, or industrial make-up. Deep well injection has developed as an effective disposal method for waste streams as it delivers the material through a double lined well into a deep geologic formation. The well is sealed against surrounding strata. The existence of multiple layers of nearly impermeable geologic zones between the disposal zone and the usable aquifer above, as well as the density of the leachate (equal to or greater than water) provides certainty that the material does not migrate upward and impact the shallow aquifer that may be used as drinking water. Deep well injection is engineered to prevent impacts to surface water or groundwater from the waste stream. Due to uncertainties with respect to committed capacity for the commercial well that is currently in use and lack of control over operating and maintenance outages, a CMS owned and controlled injection well has been permitted. This technology is currently being used and has been a successful technology in managing this waste stream.

Onsite Disposal Using Deep Well injection

Leachate currently being collected as a component of the IR at the Site is being disposed offsite into a deep injection well. The onsite disposal using deep well injection process option assumes a suitable geologic formation exists at the Site and has been retained at MDEQ’s request. Limited data exists as to the viability of an injection well drilled within piping distance of the treatment facilities in Emmet County. In addition an implementable forcemain alignment from the Treatment Plant to the injection well would be needed.

Offsite Land Application of Collected Leachate

Land application of solids and aqueous residuals is a technology used by some industries as well as waste water treatment plants. The technology involves the spray application of the residual waste stream onto the surface of land where the water as well as the contaminants from the waste stream would be absorbed into surface plant material or adhered to and attenuated by soils. Maximum attenuation typically occurs with substantive plant growth and non-sandy soils. Most waste streams managed through this technology have a nutrient base that supports plant growth. MDEQ guidance for load application limits the volume of water to 40 inches per year over the application area.

The nature of the leachate waste stream is predominantly mineral with cation and anion COCs including: arsenic, mercury, sulfate, and chloride. The high salt nature of the waste stream would likely have a negative impact on surface plant growth and may significantly reduce plant uptake as a method of COC reduction. The high salt content would also limit the duration for which a plot could be used for land application. Significant pretreatment would be required to reduce the salt in the waste stream. Inadequate removal would force relocation of the land application site to avoid excessive salinity build-up in the soil. Also some metals such as arsenic and mercury are not beneficial to plant growth and have minimal uptake rates even when plant growth is sustained. Additionally, soils in the area generally have a significant sand component.

It is anticipated that land application of this waste stream would result in minimal removal of COCs prior to the dilution of the waste stream in the groundwater below the application area. If this technology were selected for the Site discharge, it would also need to handle the water from the rest of the LTB site. In order to manage the total LTB waste stream through land application, the following would be needed:

- Approximately 100 acres of land to handle the volume to assure minimum potential for runoff
- A 100-acre spray application system
- Storage for up to 27,000,000 gallons of waste water due to seasonal and precipitation limits on application
- Nutrient additions to attempt to maintain some surface growth to attempt uptake and minimize erosion

Since this technology relies on specific attenuation methods of plant uptake and soil attenuation to reduce COCs and those methods appear likely to be ineffective with this waste stream, dilution of the waste water by groundwater below the Site appears to be the predominant attenuation mechanism. Since most areas in the proximity of the Site use the groundwater as drinking water, this technology is likely to be met with significant public opposition. Thus, offsite land application is not likely to be a viable technology for addressing this waste stream and has not been retained.

Evaporation of Leachate Using an Offsite Evaporation Pond

Evaporation/Settling ponds have been used for the management of aqueous waste streams where separation of solids can be facilitated. This option envisions the potential use of lined ponds that would not allow for percolation of constituents through the soil and into the aquifer. Over time, the water in the pond would be evaporated and remaining solid residuals would be removed and disposed of in a permitted landfill.

In order to manage an aqueous waste stream flow rate of 70,000 to 100,000 gallons per day, multiple settling units would need to be constructed. The number of units would be based on the stages of separation necessary to promote maximum solids removal. Laboratory testing of the waste stream indicated a natural settling of only a negligible portion of the mineral content of the water in 24 to 48 hours. Even with bench-scale controlled pH adjustments, less than one percent of the volume of the waste steam was separable as a solid phase. This left the remainder of constituents dissolved in the aqueous phase for natural or energy-assisted evaporation. This is generally considered an insufficient result for use of this technology.

Some additional constraints on this technology include:

- Availability of over 300 acres of land within underground pipe access from all leachate collection areas
- Construction, operation, and maintenance of bermed, lined, and aerated settling ponds with controls for chemical addition
- Drying/rendering transportation and disposal of solids

Additionally, natural evaporation processes are not favored due to moisture saturation of air close to Lake Michigan, annual precipitation that exceeds annual evaporation, and relatively low average temperatures. Therefore, energy-assisted evaporation would likely be the principal method employed to address water volumes. This would be prohibitive due to the cost of energy and would produce much greater greenhouse gas emissions relative to other options. This alternative is therefore not retained for further consideration.

2.5 Alternative Assembly and Screening Evaluation

The next step in the process of developing and screening potential remedial alternatives for the Site is the assembling of a range of site-wide alternatives from retained technology types and process options and screening against short and long-term aspects of effectiveness, implementability, and cost (Section 4.2.6 and 4.3; U.S. EPA, 1988).

2.5.1 Assembling a Range of Alternatives

As discussed previously, Tables 6b and 7b provide a summary of the retained general response actions, technology types and process options for CKD and CKD impacted groundwater, respectively. These retained technology types and process options are assembled into site wide alternatives by combining different technology types to address the media (CKD and CKD impacted groundwater) of concern. Table 8a provides a summary of the assembled site-wide alternatives array. These site-wide alternatives include a combination of implementable general response actions and medium-specific actions that provide a range of improvement toward meeting RAOs and include the following:

1. No Action

   The no-action alternative constitutes the absence of any remedial actions.

2. Existing IR Actions (Collection)

   A combination of institutional controls, targeted removal, groundwater migration controls including extraction wells and collection trenches, isolation and containment including vertical barriers, and monitored natural attenuation.

3. Existing IR Actions and Upgradient Groundwater Diversion

   Alternative 2 with the addition of upgradient groundwater diversion; an isolation and containment feature to reduce both saturated CKD thickness and hydraulic gradients across the Site.

4. Existing IR Actions and Enhanced Groundwater Containment

   Alternative 3 with the addition of an infiltration gallery; an isolation and containment feature downgradient of the existing collection trench alignment.

5. Existing IR Actions and Soil Cover Improvements

   Alternative 2 with the addition of improved soil cover features, primarily improving higher infiltration zones; a horizontal barrier component of isolation and containment.

6. Existing IR Actions and Impermeable Cap

   Alternative 2 with the addition of an impermeable cap; an isolation and containment feature.

7. Removal

   Removal of all CKD from the Site and off-site disposal.

8. On-site Containment Cell

   Excavation of all CKD, construction of bottom liner system with a collection piping system, replacement of CKD that fits into the existing CKD footprint, construction of an impermeable cap, temporary facilities for hauling, temporary stockpiling CKD onsite, stormwater management, and erosion control, and off-site disposal of CKD that does not fit on the Site. An upgradient groundwater diversion system may be required for this alternative to mitigate high water table infringement upon the CKD pile. This alternative incorporates elements of alternatives 2, 3, 6, and 7.

2.5.2 Screening Evaluation of Assembled Alternatives

The screening of the alternative assemblies is summarized in Table 8b. The objective of the screening is to evaluate the assembled alternatives ability to achieve protection of human health and the environment from each potential pathway of concern at the Site. The Site-specific COCs and RAOs (as discussed previously in Section 2.2.4) are listed below with applicable general response actions.

1. Protection of human health from direct contact exposure to CKD containing elevated levels of chloride and arsenic.

   This is achievable through institutional controls, removal, and containment and isolation, or a combination thereof.

2. Protection of human health from direct contact and ingestion exposure to CKD impacted groundwater containing elevated levels of chloride, pH, TDS, sulfate, aluminum, arsenic, iron, lead, manganese, sodium, and vanadium.

   This is achievable through institutional controls, removal (collection), containment and isolation, and other engineered controls, or a combination thereof.

3. Protection of human health and the environment from venting of CKD impacted groundwater containing chloride, pH, TDS, arsenic, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc to surface water.

   This is achievable through institutional controls, removal (collection), containment and isolation, and other engineered controls, or a combination thereof.

Some of the Site-specific COCs are more amenable to general response actions that are more readily implementable, effective, and cost sensitive. For example, for CKD, the direct contact exposure pathway can be effectively mitigated through a combination of institutional controls (land use restrictions) and containment and isolation (existing soil cover and maintenance thereof). The exposure pathway for ingestion of CKD-impacted water can be effectively mitigated by institutional controls restricting use of the groundwater as a drinking water source. The venting of CKD impacted groundwater to surface water (Lake Michigan) is a more challenging pathway to address due the proximity of the receptor to the waste piles, the limestone bedrock geology, and sensitivity of the receptor to specific COCs, namely mercury. The other COCs are not bioaccumulative and are addressed in Section 2.2.5. Thus, the primary objective of the alternatives assembly and screening is to evaluate the ability of process options or combinations of process options to address pH and mercury in CKD impacted groundwater venting to surface water. The screening has been performed to evaluate the effectiveness, implementability, and cost of the alternatives to address these primary COCs and pathway.

The purpose of this screening evaluation is to reduce the number of alternatives that will undergo a more thorough and extensive analysis, and therefore, are more generally evaluated in this phase than during the detailed analysis. The alternatives are compared on an equivalent basis to allow for differentiation between alternatives.

2.5.2.1 pH Control

The existing IR actions are highly effective at meeting the AOC compliance standard of pH less than or equal to 9.0 s.u. as discussed previously in Section 1.3.2 and in Table 8a. All of the other alternatives (with the exception of no action) are expected to minimize the sporadic and short lasted pH excursions above 9.0. Performance of improvements to the existing soil cover or installation of a cap would provide protection against short-term increases in interflow and groundwater flow to the beach collection drains, which would reduce the potential for the beach collection drains to be temporarily overwhelmed. Complete removal or on-site containment cell would effectively mitigate long-term pH exceedances resulting from CKD impacts to groundwater.

2.5.2.2 Mercury Control

The existing IR actions are highly effective at minimizing mercury flux to the lake at the West, Seep 2 (excluding Pine Court Seep area), and Seep 1 CKD Area. The estimated flux reduction from existing interim actions at these areas is approximately 40.3 mg/day of the estimated total flux 43.1 mg/day (93.5% reduction). The addition of diversion or capping is not anticipated to significantly reduce the mercury mass loading from these areas due to the relatively low amount of mercury which is not controlled by the existing IR actions.

The Pine Court Seep area is the largest contributor to total flux at the Site based on the first round of discrete flux analysis (see Appendix A). The existing IR action (beach collection trench) at Pine Court Seep area is estimated to account for approximately 2.7 mg/day or about 6% of the estimated flux (45 mg/day), not accounting for TLC. Diversion is anticipated to provide substantial improvement to mercury mass loading from the Site by reducing the flow of CKD impacted groundwater to the lake through gradient control. Improvements to the existing soil cover or capping is also anticipated to improve the mercury mass loading by reducing the interflow resulting from infiltration in infiltration susceptible zones (these zones are shown in Appendix Figure 1-2d of the RI Report; one of the high infiltration zones is suspected to be in the vicinity of B2025). Complete removal or on-site containment cell would effectively mitigate long-term mercury loading resulting from CKD impacts to groundwater.

2.5.2.3 Alternatives Retention

The alternatives considered for retention are shown in Table 8b and include all of the alternatives from the array with the exception of Alternatives 4 (enhanced groundwater containment via infiltration galleries) and 8 (on-site containment cell).

Alternative 4 provides minimal improvement to pH and mercury control for cost relative to other alternatives; specifically diversion which is another process option under isolation and containment that addresses the source of contamination rather than controlling the resulting impacted groundwater.

The on-site containment cell alternative 8 contains some significant implementability challenges and has a cost similar to complete removal, which provides a commensurate level of effectiveness toward pH and mercury control. Managing the CKD on-site in a containment cell would likely require many of the same remedial features associated with the other alternatives, specifically including significant off-site disposal. The CKD could not be safely consolidated on-site within the current CKD footprint with significantly raising grade (on the order of more than 10 feet). Thus, a significant portion of the excavated CKD would require off-site disposal. This alternative would require the significant temporary facilities, site preparation requirements, restoration needs, and short-term exposures to the residential areas and workers associated with complete removal. Additionally, other associated remedial features including institutional controls and cap system would be included, and potentially diversion to address high water table infringement on the cell. Despite all of these challenges, the absence of impacts to groundwater from contained CKD could not be guaranteed as engineered controls are not 100% effective and small leaks from the cell may occur. CKD entrainment in bedrock fractures and along the bedrock escarpment would exist after conventional excavation technologies. Thus, on-site containment cell was not retained for further analysis.

2.6 Alternative Screening

The next step following the evaluation of a wide-range of alternatives (as was conducted in Section 2.5) is to perform an alternative screening (Section 4.3.3, EPA, 1988). This screening further evaluates the more favorable, and viable, (retained) alternatives that have preserved the range of treatment and containment technologies initially developed. This screening results in retention of a set of remedial alternatives for detailed analysis which provide a site-wide approach to mercury flux reduction. This approach is consistent with developing an alternative remedial strategy necessary to reduce mercury flux to acceptable levels. The target number of alternatives to retain for detailed analysis following this step, including containment and no action, should not typically exceed ten.

For this screening, alternatives retained from Section 2.5 are applied to West CKD, Seep 2 CKD, and Seep 1 CKD Areas individually to optimize achievement of the removal of mercury across the Site. The estimated cost for each of these alternatives is plotted against estimated mercury removal on

Figures 6-1 through 6-4 for the West CKD, Pine Court, Seep 2 CKD, and Seep 1 CKD Areas, respectively. The assembly and screening of the alternatives array in Section 2.5 daylighted the need to more fully evaluate alternatives for addressing mercury at a portion of the Seep 2 CKD Area, specifically for the Pine Court Seep area. Thus, six alternatives relating only to Pine Court Seep area were included in this screening as shown in Table 8c. These alternatives included the core alternatives associated with the CKD piles (collection [existing IR actions], diversion, capping, and removal) but also included soil cover/surface water improvements.

Results of this alternative screening are shown in Table 8c. In general, mercury flux reduction is most effectively achieved by controlling the most significant mercury sources (e.g., areas of high continuous groundwater flow through CKD). This appears to be specifically relevant to the Pine Court Seep area, where remedies such as diversion would significantly reduce the amount of perched groundwater that contacts the CKD pile in this area. Consistent with the findings in Section 2.5, additional mercury reduction does not appear to be necessary or viable in the West CKD, Seep 2 CKD/Guard Rail Seep, or Seep 1 CKD Areas based on the mercury flux evaluation work to-date.

The results of this alternative screening indicate that the existing IR actions should be considered further for all areas due to the high effectiveness in pH control and mercury reduction. All of the alternatives are expected to aid in minimizing pH excursions in surface water during the range of environmental conditions observed at the Site. However, alternatives focused on minimizing infiltration, such as soil cover/surface water improvements or capping, related to precipitation and melt events would be expected to result in fewer excursions by minimizing interflow and volumetric loading to the beach collection trenches. Consistent with the findings in Section 2.5 and the effectiveness monitoring results discussed previously in Section 1.3.2, additional pH controls do not appear to be necessary or viable in the West CKD, Seep 2 CKD/Guard Rail Seep, or Seep 1 CKD Areas.

Thus, process options which focus on mercury removal from the Pine Court Seep area, which will provide the greatest mercury reduction effectiveness site-wide, were primarily retained. Alternatives retained for detailed analysis are developed in Section 3.0.

3.0 Development of Remedial Alternatives

3.1 Development of Remedial Alternatives

Assembling site-wide alternatives using combinations of remedial technologies or process options to address all affected media is the final step in the process of developing and screening potential remedial alternatives for the Site (U.S. EPA, 1988). This section describes the retained technologies and process options, assembled and screened alternatives from Section 2 in the form of eight (8) detailed remedial alternatives for the Site. These detailed remedial alternatives, which focus on Pine Court Seep area mercury flux reduction, are summarized in Table 9 and potential remedy-specific ARARs are included in Table 10. Detailed and comparative analyses of the remedial alternatives developed in this Section are presented in Section 4.

3.1.1 Remedial Alternative 1 – No Action

The no-action alternative constitutes the absence of any remedial actions. No action is considered in this evaluation as a basis for comparison to all other potential remedial actions as required by the National Contingency Plan (NCP) and U.S. EPA Guidance for Conducting Remedial Investigations and Feasibility Studies (U.S. EPA, 1988).

The estimated Site loading of mercury to the lake for this alternative is 89.0 mg/day as detailed in Appendix A. For a 30-year implementation period, this amounts to nearly 970 grams of mercury. For each CKD seep area, the estimated mercury flux to the lake for this alternative is:

- West CKD Seep Area: 1.6 mg/day
- Pine Court Seep area: 45.3. mg/day
- Seep 2 CKD/Guard Rail Seep Area: 27.8 mg/day
- Seep 1 CKD Area: 14.3 mg/day

Prior to implementation of existing IR actions, lakeshore pH regularly exceeded pH 9.0 at all seep areas. Figures 3-1, 3-2, and 3-3 show pH observations for the targeted shoreline survey in Spring 2005 prior to implementation of IR actions. Effectiveness monitoring data summaries and figures for both lakeshore and pools pH are presented in Appendix 2-8 of the RI Report (Barr, 2009a).

3.1.2 Remedial Alternative 2 – Existing IR Actions

This alternative consists of groundwater migration control, targeted CKD removal, containment and isolation, natural attenuation, institutional controls, and treatment and disposal of groundwater paired to form a remedial alternative representative of the existing Site conditions. The primary basis for this alternative is the existing IR actions for the Site. This alternative integrates existing IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives identified in the AOC, Section VIII, paragraph 14, item x. This alternative is the baseline remedial alternative for the Site as of May 31, 2009. The conceptual layout for Alternative 2 is shown on Figure 7-1.

Active groundwater migration control is provided in the existing IR actions by means of collecting impacted groundwater with the ILRS at the West CKD Area, Pine Court Seep area, Seep 2 CKD Area/Guard Rail Seep area, and Seep 1 CKD Area. The Site ILRS consists of over 3,000 feet of perforated collection drains installed in beach trenches downgradient of the CKD piles that intercept high pH leachate discharging to the lake and the Edge Drain. The Edge Drain consists of approximately 1200 feet of perforated collection drain near the toe of the CKD slope in the northeast portion of the Seep 2 CKD Area pile and intercepts impacted perched groundwater. Impacted perched groundwater flow not captured by the Edge Drain in this area (flow under the drain or leakage through shale) migrates downward to the regional aquifer and is the primary source of the high pH discharge observed in the Seep 2 CKD/Guard Rail Seep Areas prior to installation of the IR beach collection drains. Active groundwater migration control provided by the West CKD ILRS is enhanced by the low permeability modified fill zone (MFZ) and a geosythentic clay liner (GCL) cover system installed in the Spring of 2009. Active groundwater migration control provided by the Seep 1 CKD Area ILRS east collection drain is enhanced by the low permeability slurry barrier wall and a CGL cover system installed in October 2008. The barriers installed at the West and Seep 1 CKD Areas improve the effectiveness and efficiency of the ILRS by slowing migration of impacted groundwater to the lake and mitigating unnecessary capture of un-impacted flow from lakeside of the collection drains. The ILRS and augmentation to the ILRS through May 31, 2009 is described in detail in Section 2.0 of the RI Report and construction record drawings of the ILRS are included in Appendix 2-3 of the RI Report (Barr, 2009a).

Active groundwater migration control is also presently provided by means of collecting impacted groundwater from the TLC System near B2025 in the Seep 2 CKD Area; however, this system is not included in this alternative because its influence has yet to manifest itself at the lakeshore and downgradient beach wells used to evaluate the effectiveness of this remedial alternative at controlling lakeshore pH and minimizing mercury flux, respectively.

The Site ILRS collection drains drain by gravity to lift stations and collected leachate is pumped to an on-site treatment plant. The average Site-wide collection rate from the existing ILRS including the Edge Drain is estimated to be 65 gpm. For each CKD seep area, the estimated average collection rates for this remedial alternative are:

- West CKD Area: 11 gpm (prior to modified fill backfill installation)
- Pine Court Seep area: 10 gpm
- Edge Drain: 13 gpm
- Seep 2 CKD and Guard Rail Seep Areas: 14 gpm
- Seep 1 CKD Area: 17 gpm (prior to slurry barrier wall installation)

ILRS collection rates show seasonal trends with the highest flows in the spring, lowest flows throughout the summer, and flows recovering in fall. ILRS collection rates correlate directly with rainfall/snowmelt and seasonal fluctuations in the regional groundwater table. Of all the ILRS drains, the Pine Court Seep area drains are most affected and the Edge Drain is the least affected in terms of rate of flow increases due to rainfall/snowmelt.

The 2009 first quarter Site mercury flux to the lake was calculated at 48.2 mg/day as detailed in Appendix A. This value is representative of operating conditions with no collection from the Pine Court Seep area IR drains. Existing mercury flux reduction with collection from the Pine Court Seep area IR drains is estimated to be 2.7 mg/day. As a result, the Site-wide mercury flux to the lake for this remedial alternative is 45.5 mg/day. For a 30-year implementation period, this amounts to nearly 500 grams of mercury. This mercury flux constitutes a Site-wide reduction of approximately 43.5 mg/day (49% compared to pre-IR conditions). For each CKD seep area, the estimated mercury flux to the lake is:

- West CKD Seep Area: 0.2 mg/day (89% reduction from pre-IR conditions)
- Pine Court Seep area: 42.6 mg/day (6% reduction from pre-IR conditions)
- Seep 2 CKD/Guard Rail Seep Areas: 0.9 mg/day (97% reduction from pre-IR conditions)
- Seep 1 CKD Area: 1.9 mg/day (87% reduction from pre-IR conditions)

The existing IR actions are effective at minimizing mercury flux to Lake Michigan at the West CKD Area, Seep 2 CKD Area/Guard Rail Seep area, and Seep 1 CKD Area. The majority of the remaining mercury flux to the lake (94%) for this remedial alternative is at the Pine Court Seep area.

Most of the effectiveness monitoring data points collected show continued high effectiveness of the ILRS at controlling lakeshore pH below 9.0. Figures 5-1 through 5-7 show lakeshore pH observations for effectiveness monitoring performed in April and May 2009. No lakeshore pH exceedances were observed during these monitoring events at the Seep 2 CKD Area/Guard Rail Seep area or West CKD Area. At the Pine Court Seep area the lakeshore pH exceeded 9.0 thirty (30) times during the April 2009 event (pH range of 9.0 to 9.5) and once during the May 2009 event (pH equal to 9.1). Collection from the Pine Court Seep area ILRS did not resume until May 1, 2009. At the Seep 1 CKD Area the lakeshore pH exceeded 9.0 five (5) times at the east end of the Seep 1 CKD Area trench during the April 2009 event (pH range 10.2 – 11.6) and zero times during the May 2009 event. Effectiveness monitoring data summaries and figures for both lakeshore and pools pH are presented in Appendix 2-8 of the RI Report (Barr, 2009a). As the recently augmented areas of the ILRS continue to operate, including collection drain reconstruction and the low permeability MFZ at the West CKD Area, resumed collection from the Pine Court Seep area IR collection drains, and the Seep 1 CKD Area slurry barrier wall, continued performance improvement is expected over time.

As a part of this alternative soil/CKD located downgradient of the West CKD ILRS was removed in the winter of 2008/2009, to fulfill the U.S. EPA order requirement to augment the existing West CKD ILRS. A total of 12,435 tons of soil/CKD was removed from the beach. The soil/CKD was transported to Waters Landfill for disposal. Section 2 of the RI Report describes the removal in detail. Since removal generally occurred downgradient of the beach monitoring wells used to evaluate mercury flux to the lake, any mercury flux reduction from this removal action is unlikely to be realized in mercury flux computations. This removal action is expected to provide enhanced control of lakeshore pH. The April and May 2009 lakeshore effectiveness monitoring data supports the position that beach CKD removal has already improved control of lakeshore pH.

The role of natural mechanisms at the Site in attenuation of pH and mercury are discussed in detail in the RI Report (Barr 2009a and are reviewed briefly here). Stiff diagrams for groundwater samples at the Site are in RI Appendix 6-1. As leachate mixes with groundwater, its chemical properties change. These changes are illustrated using Stiff diagrams and are included in the RI Report. The ratio of divalent cations to monovalent cations (Ca+Mg : Na+K) can be used as an indicator of the degree to which leachate has blended with groundwater. It can be seen from Figure 6-2 of the RI Report that the ratio of divalent:monovalent cations can be used as an indicator of leachate attenuation. As leachate mixes with groundwater, its constituents of concern are also attenuated. In general, samples with a ratio of divalent:monovalent cations below 0.07 (eq:eq) were considered unattenuated leachate, as this is the approximate point of divergence between trends in pH and chloride. Samples with a ratio of divalent:monovalent cations between 0.07 and 2.0 were considered a mixture of leachate and groundwater. Samples with a ratio of >2.0 were considered unimpacted groundwater, as this is the point where the pH trend flattens. As shown on Figure 6-3 of the RI Report, Site samples fall into a wide-ranging continuum with respect to the ratio of divalent:monovalent cations (Ca+Mg : Na+K). As expected, pH is attenuated as the ratio of divalent:monovalent cations increases, due to dilution, precipitation of carbonate alkalinity, and neutralization with groundwater acidity. As shown on Figure 6-4 of the RI Report, mercury is also attenuated as the ratio of divalent:monovalent cations increases, due to dilution as well as precipitation of the mercury-bearing fatty acid surfactants (Barr, 2009a). Also included on Figures 6-3 and 6-4 is chloride concentration. The change in chloride concentration as leachate mixes with groundwater is a reasonable measure of the degree of dilution that occurs. It can be seen that, as the leachate is mixed with sufficient groundwater to affect its chemical properties, trends in pH and mercury concentration begin to diverge from the trend in chloride concentration. This suggests mercury attenuation by the reaction mechanisms previously discussed, in addition to dilution.

Institutional controls will consist of groundwater use limitations. The site is expected to continue to be used as golf course with adjacent mixed residential and recreational land uses. Maintenance of the existing vegetated cover would be part of the long-term operation and maintenance (O & M) for the Site. Groundwater use restrictions would prohibit the use of groundwater as a drinking water source. A mixing zone determination for those parameters discussed in Section 2.2.5 and a technical impractability demonstration in support of an alternative remedial strategy for mercury are required for this alternative.

The CKD-impacted groundwater collected from the IR collection drains is treated at the on-site treatment plant and will likely be disposed in one of three ways: (1) the collected groundwater would be piped to the treatment plant to be treated and discharged to surface water using an NPDES permit; (2) the collected groundwater would be conveyed to an offsite POTW, treated at the POTW and discharged to surface water; or (3) the collected groundwater would be injected in a deep well offsite. These disposal options are discussed in detail in Section 2.4.2.3. There are variables with each of these options that strongly affect the cost of implementation variables, including the treatment requirements, transportation, and various improvements to facilities and infrastructure. This AE assumes for purposes of cost estimates that treated leachate will be disposed of by means of injection into a deep well offsite.

Detailed cost estimates for this remedial alternative are included in Appendix E.

3.1.3 Remedial Alternative 3 – Existing IR Actions and Targeted Surface Water Improvements

This alternative consists of all paired technology types and process options detailed in Remedial Alternative 2 (Existing IR Actions) and enhanced isolation of the CKD by means of surface water improvements in the Pine Court Seep area to form Remedial Alternative 3. This alternative integrates existing IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives identified in the AOC, Section VIII, paragraph 14, item x. The conceptual layout for Alternative 3 is shown on Figure 7-2.

As part of this alternative the existing CKD cover system will be modified to provide surface water drainage at locations identified as potential recharge areas (e.g. surface depressions where ponding occurs) in and around the Pine Court Seep area CKD extent. Conceptually, these modifications will include grading to provide positive drainage and installation of catch basins and storm sewer piping to collect and route surface water away from the Pine Court Seep area. Surface water improvements within the existing CKD extent are expected to reduce infiltration water that migrates downward into and across the top of the CKD. Surface water improvements upgradient of the CKD extent are expected to reduce infiltration water that infiltrates and migrates northward as interflow across the top of rock and seasonally saturates CKD near the bottom of the pile.

This alternative also includes storm sewer system improvements along Pine Ridge Court and Coastal Drive to collect surface runoff. Surface runoff in these areas, particularly during spring and early fall wet weather conditions, appears to infiltrate rapidly and flow downgradient toward the lake where it has been observed to overwhelm the capacity of the Pine Court Seep area ILRS.

These conceptual surface water improvements are expected to result in a net mercury flux reduction of 4.7 mg/day at the Pine Court Seep area. This estimate is based on an estimated 1.7 gpm reduction in average leachate flow at mercury concentration of 500 ng/L.

The projected Site-wide mercury flux to the lake for implementation of this remedial alternative is estimated to be 40.8 mg/day, approximately 3 to 5 years after implementation of surface water improvements. The estimated mercury loading to the lake for a 30-year implementation of this remedial alternative is nearly 450 grams. Enhanced control of lakeshore pH is also expected for this remedial alternative since the Pine Court Seep area ILRS is less likely to be overwhelmed during spring and early fall rainfall events when lakeshore pH exceedances have historically been observed to occur more frequently.

Detailed cost estimates for this remedial alternative are included in Appendix E.

3.1.4 Remedial Alternative 4 – Existing IR Actions, Targeted Surface Water Improvements, and Targeted Upgradient Diversion

This alternative consists of all paired technology types and process options detailed in Remedial Alternative 3 (Existing IR Actions and Targeted Surface Water Improvements) with migration and source generation control of impacted groundwater by means of targeted upgradient groundwater to form Remedial Alternative 4. Diversion has been found to be beneficial at other CKD sites. This alternative integrates existing IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives identified in the AOC, Section VIII, paragraph 14, item x. The conceptual layout for Alternative 4 is shown on Figure 7-3.

As part of this alternative, upgradient perched groundwater will be provided using groundwater extraction wells installed above the marker shale south of Pine Court Seep area along Coastal Woods Court. Perched groundwater diversion will reduce perched groundwater flow and elevations on top of the marker shale; this has multiple benefits. Reducing perched groundwater elevations will decrease the saturated thickness of CKD in the Pine Court Seep area thereby minimizing generation of impacted groundwater. Migration of impacted perched groundwater is also reduced both vertically through (leakage) and northward over the lip of the marker shale. Recharge to the regional groundwater table by impacted perched groundwater is the primary source of mercury flux to the lake at the Pine Court Seep area. As a result, reducing impacted perched groundwater flow and the mass of mercury in that flow with perched groundwater diversion is expected to significantly aid the existing ILRS at minimizing mercury flux to the lake.

The estimated perched groundwater flow could be reduced to approximately 25 gpm in the Pine Court Seep area. This assumes that a control elevation of 630 feet, MSL upgradient of the CKD area along Coastal Woods Court is achievable. This computation also assumes that a control elevation of 630 feet, MSL results in a 50 percent or more reduction of the flow at the northern extent of the shale limits. For cost estimation, a conceptual perched groundwater diversion system consisting of 15 extraction wells screened from elevations 610 to 630 feet, MSL was considered as shown on Figure

7-4. The number of extraction wells, the extraction well production rates, and resulting perched groundwater flow reductions would be determined during remedial design. As a result, a remedial design investigation would be necessary prior to full-scale implementation.

Perched groundwater diversion extraction rates will be selected to provide a margin of safety against drawing leachate from the CKD back toward the diversion wells. In addition, sentinel wells will be located between the diversion wells and the northern shale extent to allow measurement of groundwater elevations and other indicators as a means to confirm that groundwater gradients and flow directions are as planned. Discharge piping will be installed to route non-impacted groundwater extracted with the perched diversion system north of the CKD limits and to the lake.

Also as a part of this alternative, the upgradient regional groundwater will be controlled to optimize regional groundwater diversion in the Pine Court Seep area. It appears that existing operation of City Well 5 influences much of the regional groundwater flow at the West and Seep 2 CKD Areas as described in Section 4.6 of the RI Report (Barr, 2009a). Regional groundwater flows toward the lake in these areas significantly decrease or reverse during summer months when water withdrawal is sustained at its highest levels. Regional groundwater diversion in the Pine Court Seep area aids the ILRS by reducing seasonal peaks of upgradient groundwater flow. The results from the groundwater modeling (see Appendix D1) showed that groundwater flow to the lake could be reduced by approximately 30 percent for a diversion system controlling upgradient regional groundwater elevations to 580, feet along Coastal Woods Court upgradient of the Pine Court Seep area during high groundwater conditions (approximately July through October).

Optimized operation of an upgradient regional groundwater diversion well(s) conceptually includes modifying groundwater extraction rates to reduce or reverse regional groundwater gradients toward the lake during high regional groundwater conditions, particularly during the spring when lakeshore exceedances have most frequently been observed. Similar to perched diversion, extraction rates will be selected to provide a margin of safety against drawing leachate from the CKD back toward a regional diversion well(s). In addition, sentinel wells will be located between the diversion well and the CKD extent to allow measurement of groundwater elevations and other indicators as a means to confirm that groundwater gradients and flow directions are as planned. Discharge piping will be installed to route non-impacted groundwater extracted from a diversion well(s) west to the adjacent creek. The creek side slopes may need to be stabilized and existing culverts downstream of the discharge point may need to be replaced prior to discharge. Alternatively, discharge to the existing wetland may be necessary to maintain the wetland.

These groundwater diversion systems would provide some lowering of the head differential across the regional groundwater table, reducing groundwater flow (and thus, contaminant flux) toward the Lake. Perched groundwater diversion is also expected to reduce contaminant flux by means of reducing groundwater contact with CKD (reduction in both groundwater flow and groundwater elevation).

These conceptual groundwater diversion systems are expected to result in a net mercury flux reduction of 13.3 mg/day at the Pine Court Seep area when paired with the other technology types and process options in this alternative.

The projected Site-wide mercury flux for implementation of this remedial alternative is estimated to be 27.6 mg/day once it has been operating for several years and its full effect to be realized. The estimated mercury loading to the lake for a 30-year implementation of this remedial alternative is nearly 300 grams. Some improved control of lakeshore pH in the Pine Court Seep area compared to Alternative 2 is also expected since seasonal regional groundwater flow peaks will be reduced. Minimizing these large short term changes to the groundwater flow rates provides ILRS operating staff with greater flexibility to respond to changes in observed conditions.

Detailed cost estimates for this remedial alternative are included in Appendix E.

3.1.5 Remedial Alternative 5 – Existing IR Actions, Targeted Surface Water Improvements, Targeted Leachate Collection, and Targeted Upgradient Diversion

This alternative consists of all paired technology types and process options detailed in Remedial Alternative 4 (Existing IR Actions, Targeted Surface Water Improvements, and Targeted Upgradient Diversion) with migration and source generation control of impacted groundwater by means of targeted leachate collection (TLC) to form Remedial Alternative 5. This alternative maximizes integration of existing IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives identified in the AOC, Section VIII, paragraph 14, item x. The conceptual layout for Alternative 5 is shown on Figure 7-4.

As part of this alternative the existing TLC System will be expanded and integrated into the existing Site-ILRS. Similar to perched groundwater diversion, TLC will reduce perched groundwater flow and elevations on top of the marker shale; this has multiple benefits. Reducing perched groundwater elevations will decrease the saturated thickness of CKD in the Pine Court Seep area thereby minimizing generation of impacted groundwater. Migration of impacted perched groundwater is also reduced both vertically through (leakage) and northward toward the lake on top of the marker shale in the vicinity of the extraction wells. Recharge to the regional groundwater table by impacted perched groundwater is the primary source of mercury flux to the lake at the Pine Court Seep area. As a result, reducing impacted perched groundwater flow and the mass of mercury in that flow with TLC is expected to significantly aid the existing ILRS at minimizing mercury flux to the lake.

Conceptually the expanded TLC System would consist of the three existing recovery wells (S2RW-1, S2RW-4, and S2RW-5) optimized to collect leachate and minimize discharge to the regional aquifer, as shown on Figure 7-4. The estimated total collection rate for the expanded TLC System, assuming excess water is diverted by a perched groundwater diversion system and surface water improvements, is 12 gpm. The CKD-impacted groundwater collected from the TLC would be disposed of in one of three ways: (1) the collected groundwater would be piped to the treatment plant to be treated and discharged to surface water using an NPDES permit; (2) the collected groundwater would be conveyed to an offsite POTW, treated at the POTW and discharged to surface water; or (3) the collected groundwater would be injected in a deep well offsite. These disposal options are discussed in detail in Section 2.4.2.3. There are variables with each of these options that strongly affect the cost of implementation variables, including the treatment requirements, transportation, and various improvements to facilities and infrastructure. This AE assumes for purposes of cost estimates that treated leachate will be disposed of by means of injection into a deep well offsite.

Expanded TLC is expected to result in a net mercury flux reduction at the lake of 10.5 mg/day. This estimate is based on a collection rate of 12 gpm at average mercury concentration of 400 ng/L. When paired with TLC, perched groundwater diversion is expected to result in a net mercury flux at the lake reduction of 9.6 mg/day.

The projected Site-wide mercury flux to the lake for implementation of this remedial alternative is estimated to be 20.8 mg/day, once all paired components have been operating together for 3 to 5 years. The estimated mercury loading to the lake for a 30-year implementation of this remedial alternative is nearly 230 grams. Improved control of lakeshore pH may to be minimal for this remedial alternative compared to Alternative 4 although it does add layers of redundancy related to overall lakeshore pH control, and may have long-term benefits that are difficult to quantify.

Detailed cost estimates for this remedial alternative are included in Appendix E.

3.1.6 Remedial Alternative 6 – IR Actions, Targeted Impermeable Cover System, and Targeted Upgradient Diversion

This alternative consists of all paired technology types and process options detailed in Remedial Alternative 5 (Existing IR Actions, Targeted Impermeable Cover System, and Targeted Upgradient Diversion) with containment and isolation provided by consolidation of CKD and a targeted impermeable cover system to form Remedial Alternative 6. Targeted surface water improvements were not paired with these technology types and process options because the impermeable cover system renders the surface water improvements unnecessary. This alternative also maximizes integration of existing IR actions with the final remedial alternative for the Site as appropriate, which is one of the objectives identified in the AOC, Section VIII, paragraph 14, item x. The conceptual layout for Alternative 6 is shown on Figure 7-5.

As part of this alternative the smaller disconnected CKD area west of Coastal Woods Court, ‘dogbone area’, may be removed and consolidated with the main Pine Court Seep area as shown on Figure 7-5. CKD removal procedures would be based upon visual verification of bedrock at the base of excavation or pH profiling if native soils are present (e.g. sidewalls). However, removal verification is likely to be impeded by the presence of perched groundwater and interflow (with or without dewatering) which imposes significant challenges for verification and for handling excavated materials. This saturated material can be very difficult to handle, as disturbing such CKD can produce a low-strength, somewhat flowable gel-like mixture (Todres, et al., 1992a and 1992b). The difficult material-handling properties may dictate the excavation program, and will make complete removal of the CKD below groundwater improbable.

CKD removal from the dogbone area is expected to, in time, progressively aid the Pine Court Seep area west collection drain at controlling lakeshore pH and minimizing mercury flux to the lake.

Also as part of this alternative, infiltration of precipitation and irrigation water contacting CKD in the approximate Pine Court Seep area would be substantially eliminated by: contouring the pile to promote positive drainage and prevent ponding; constructing a 4-foot soil cover system over an approximate 16-acrea area that incorporates a flexible membrane liner; constructing a surface water drainage system; and establishing vegetation to minimize erosion and promote evapotranspiration. Following installation of the impermeable cover system the golf course will be fully restored.

Consolidation, compaction, contouring, and covering the CKD would provide a significant barrier to direct exposure to the CKD and minimize the migration of contaminants to groundwater, thereby reducing the mass flux of COCs from source material to groundwater and subsequently to surface water. Groundwater modeling results (see Appendix D2) showed that a conceptual impermeable cover system may reduce Pine Court Seep area regional groundwater flows by approximately 25% in summer months and by less than 5% in winter months. The conceptual consolidation of the dogbone area and installation of the impermeable cover system is expected to result in a mercury flux reduction to the lake of 9.3 mg/day. This estimate is based on an estimated 3.4 gpm reduction in average leachate flow at mercury concentration of 500 ng/L (twice that of surface water improvements alone, see Remedial Alternative 3). When paired with consolidation and an impermeable cap, perched groundwater diversion is expected to result in a net mercury flux at the lake reduction of 11.6 mg/day.

The projected Site-wide mercury flux to the lake for implementation of this remedial alternative is estimated to be 24.6 mg/day once all paired components have been operating together for 3 to 5 years. The estimated mercury loading to the lake for a 30-year implementation of this remedial alternative is nearly 270 grams. Improved control of lakeshore pH is expected to be minimal for this remedial alternative compared to Alternatives 4 and 5 although it does add layers of redundancy related to overall lakeshore pH control.

Detailed cost estimates for this remedial alternative are included in Appendix E. Cost estimates do not include negative economic golf course, the Bay Harbor Development, or the community.

3.1.7 Remedial Alternative 7 – Modified IR Actions, Targeted Removal

This alternative consists of CKD Removal from the entirety Pine Court Seep area and as described in Remedial Alternative 2: active groundwater migration control with existing IR actions except collection from the Pine Court Seep area ILRS, natural attenuation, institutional controls, and treatment and disposal of groundwater. The institutional controls for this alternative are the same as those described for Alternative 2. These institutional controls would remain for an indefinite period of years, as the rate at which site groundwater will recover to conditions similar to those upgradient of the East CKD Area will depend on many factors, including the presence of residual CKD even after excavation. This alternative integrates some of the existing IR actions with the final remedial alternative for the Site as appropriate, which largely meets the objective identified in the AOC, Section VIII, paragraph 14, item x. The conceptual layout for Alternative 7 is shown on Figure 7-6.

As a part of this alternative, approximately 350,000 cubic yards (CY) of CKD and impacted overburden will be removed from the entirety of the Pine Court Seep area. Impacted CKD and mixed soil/CKD would be excavated, loaded into haul trucks, and transported to a RCRA Subtitle D landfill for disposal as nonhazardous waste. CKD removal procedures would be based upon visual verification of bedrock at the base of excavation or pH profiling if native soils are present (e.g. sidewalls). However, removal verification is likely to be impeded by the presence of perched groundwater and interflow (with or without dewatering) which imposes significant challenges for verification and for handling excavated materials. This saturated material can be very difficult to handle, as disturbing such CKD can produce a low-strength, somewhat flowable gel-like mixture (Todres, et al., 1992a and 1992b).

The difficult material-handling properties may dictate the excavation program, and will make complete removal of the CKD below groundwater improbable. The geology in the Pine Court Seep area is somewhat unfavorable to complete removal of CKD. It is difficult to remove CKD retained in weathered bedrock and bedrock fractures and a relatively sizeable fraction of CKD in the Pine Court Seep area appears to be offset by less than 2 feet from bedrock features.

Transportation of nearly 350,000 CY of material for disposal, and an approximate equal about of backfill material to the Site will have a substantial impact on the public during the construction. In addition, portions of U.S. Highway 31 will likely need to be modified or improved to accommodate increased traffic and the size of vehicles regularly entering and exiting the Site for approximately 2 construction seasons.

Excavation, dewatering, and dust control best management practices (BMPs) are expected to increase the quantity and worsen the quality of leachate during removal activities. Excavation in the saturated zone breaks up wet CKD and mixes it; effectively accelerating mineral hydration reactions in the CKD. Excavation also exposes previously covered non-weathered and unsaturated CKD to precipitation which will add to the leachate that must be managed. Increased gradients resulting from dewatering will produce increased flow rates toward the excavation area and through surrounding unexcavated CKD.

Dewatering can be expected to produce flows as high as 150 gpm. It is anticipated that dewatering of impacted groundwater will be required during removal at an average rate of 75 gpm (includes perched groundwater, interflow, precipitation, and dust control BMPs). High pH water removed from the excavation would be filtered to remove solids, pretreated onsite to neutralize pH, and disposed of using one of the options described in Section 3.1.2. Temporary treatment facilities would need to be constructed on-site as part of the dewatering system. Following removal, the site would be backfilled with clean soil and fully restored to its present use as a golf course.

Complete CKD removal from the Pine Court Seep area would, in time, result in substantial elimination of high pH discharge and mercury flux to the lake from the existing Pine Court Seep area CKD source. However, since the difficult nature of handling saturated CKD is likely to make complete CKD removal improbable, some small amount of CKD is likely to remain in place. Also, removal of the CKD source material will not immediately eliminate the existing plume of CKD-impacted groundwater. Consequently, pH discharge zones and mercury flux from the former CKD footprint can be expected to diminish over time, but at an unknown rate. Operation of the Pine Court Seep area IR collection drains is not included in this remedial alternative.

Removal of CKD from the Pine Court Seep area is expected to, in time; result in a net mercury flux reduction of 42.2 mg/day at the Pine Court Seep area compared to existing conditions. The projected long-term Site-wide mercury flux for implementation of this remedial alternative is estimated to be 3.4 mg/day. However, the construction activities for CKD removal will increase the mass loading of mercury and other metals and inorganics to the lake for the entire period of CKD excavation and saturated zone backfill. The long-term mercury mass loading from this alternative is approximately 120 grams for a 30-year period with no change in the first two years and steady decline for the next eight years until the steady-state discharge of 3.4 mg/day is achieved. Large surface areas of presently covered CKD will be exposed to workers and the potential for environmental impacts due to windborne mobility of CKD is increased.

Detailed cost estimates for this remedial alternative are included in Appendix E. Cost estimates do not include negative economic golf course, the Bay Harbor Development, or the community.

3.1.8 Remedial Alternative 8 – Removal

This alternative consists of removal of CKD from the entirety of the Site and is expected to take five (5) construction seasons to complete. It is anticipated that dewatering of groundwater will be required during the removal and the dewatering flow will be treated to neutralize high pH CKD-impacted groundwater and discharged to the Lake. The institutional controls for this alternative are the same as those described for Alternative 2. These institutional controls would remain for an indefinite period of years, as the rate at which Site groundwater will recover to conditions similar to those upgradient of the East CKD Area will depend on many factors, including the presence of residual CKD even after excavation.

This alternative uses none of the IR actions installed at the Site, and in fact removes all of them. Consequently, this alternative is inconsistent with the AOC, Section VIII, Paragraph 15, item x, which calls for integration of the response activities, as appropriate.

CKD would be removed from the entirety of the Site, loaded into trucks, and transported to a RCRA Subtitle D landfill for disposal as nonhazardous waste. Over 2 million CY of soil/CKD would need to be removed from the Site, of which a considerable amount would be saturated. All of the difficulties related to handling, removal verification, transportation, dewatering, and increased mass loading in Remedial Alternative 7 applies to this alternative but on a much larger scale (over 5 times the CKD volume described in Remedial Alternative 7).

Removal of CKD from the entirely of the Site will, in time, result in net mercury flux reduction of 44.6 mg/day at the Site compared to existing conditions. The projected long-term Site-wide mercury flux for implementation of this remedial alternative is estimated to be 0.9 mg/day. However, the construction activities for CKD removal will increase the mass loading of mercury and other metals and inorganics to the lake for the entire period of CKD excavation and saturated zone backfill. The long-term mercury mass loading from this alternative is 187 grams for a 30-year period with no change in the first two years and steady decline for the next eight years until the steady-state discharge of 0.9 mg/day is achieved. Finally, this alternative will require a technical impractability demonstration in support of an alternative remedial strategy for mercury.

Detailed cost estimates for this remedial alternative are included in Appendix E. Cost estimates do not include negative economic golf course, the Bay Harbor Development, or the community.

4.0 Detailed Analysis of Alternatives

4.1 Introduction

This section presents the detailed and comparative analyses of the alternatives developed for the Site in Section 3. The components of these alternatives are summarized in Table 20. The alternatives include:

- Alternative 1 – No Action
- Alternative 2 – Existing Interim Response (IR) Actions
- Alternative 3 – Existing IR and Targeted Surface Water (SW) Improvements
- Alternative 4 – Existing IR, Targeted SW Improvements, and Targeted Upgradient Diversion
- Alternative 5 – Existing IR, Targeted SW Improvements, Targeted Upgradient Diversion, and Targeted Leachate Collection
- Alternative 6 – IR, Targeted Upgradient Diversion, and Targeted Impermeable Cover System
- Alternative 7 – Modified IR and Targeted Removal
- Alternative 8 – Removal

The NCP criteria are used as a basis to compare the relative advantages and disadvantages of each alternative. The criteria include (U.S. EPA, 2003, NCP):

1. Overall Protection of Human Health and the Environment
2. Compliance with ARARs
3. Long-Term Effectiveness and Permanence
4. Reduction of Mobility, Toxicity, or Volume through Treatment
5. Short-Term Effectiveness
6. Implementability
7. Cost
8. State Acceptance
9. Community Acceptance

Criteria included under numbers 1 through 7 were used in this detailed analysis of alternatives. Important characteristics of the evaluation criteria are summarized in Table 11.

While the criteria for state acceptance will be evaluated in the remedy selection process, the effort on the part of CMS to accelerate the investigation and remedy for the Site is intended to be responsive to strongly expressed community and state interests. Several of the factors that are responsive to public concerns in the remedy development and selection process include: addressing public health and direct environmental impacts; continued augmentation of IR actions; and development of alternatives that are consistent with both regulator expectations and the existing land use.

4.2 Individual Analysis of Alternatives

Detailed analysis summaries of the alternatives based on the seven of the nine NCP criteria are included in Tables 12 through 19 and detailed cost estimates for the alternatives are included in Appendix E. The following subsections of text provide specific details on the evaluation of each alternative in comparison to the criteria and a determination of the overall score for each alternative. The overall score is used to rank the alternatives and is developed from individual scores that are based on the ability of the alternative to meet each of the seven criteria. Each of the seven criteria is weighted evenly and a score between 1 and 5 is assigned. A score of 1 is assigned when low achievement of the criterion is expected, 3 when moderate achievement is expected, and 5 when high achievement is expected. Intermediate scores of 2 and 4 are assigned when low to moderate and moderate to high achievement is expected. The highest achievable overall score is 35.

4.2.1 Remedial Alternative 1 – No Action

Alternative 1 is the no action alternative, which is the absence of any further remedial actions including the operation and maintenance of the existing IR actions. No action is considered in this evaluation as a baseline for comparison to all other potential remedial actions. Under this alternative, no deliberate action is taken to address CKD or impacted groundwater at the Site. However, contaminants will be naturally removed and/or attenuated over time. This alternative is not expected to alter the pH impacts and mercury discharge to the lake in the foreseeable future. The estimated mercury loading to the lake for this combination of technologies is 89.0 mg/day.

Table 12 provides a detailed analysis of this alternative and develops scores based on each of the criteria. As shown in Table 12, this alternative is not expected to meet the objectives for any of the following criteria: protection of human health and the environment; compliance with ARARs; short or long-term effectiveness; or reduction in toxicity, mobility, or volume (TMV) through treatment. Therefore, a score of 1 was assigned to each of these criteria categories. Implementation for this alternative consists of ending leachate collection from the ILRS drains. The cost for this alternative is assumed to equal to the IR activity and investigation costs to date. The overall score for this alternative is 15.

4.2.2 Remedial Alternative 2 – Existing IR Actions

Alternative 2 includes operation of the existing IR including:

- Existing ILRSs at West CKD Area, Pine Court Seep area, Seep 2 CKD Area (including Guard Rail Seep area and Edge Drain), and Seep 1 CKD Area,
- Downgradient barriers at the West CKD Area and Seep 1 CKD Area, and
- Maintenance of the existing CKD covers.

The existing CKD cover system provides a direct exposure barrier to the CKD and reduces the migration of contaminants to groundwater, thereby reducing the mass flux of COCs from source material to groundwater and subsequently to surface water. Downgradient hydraulic containment intercepts the discharge of leachate to Lake Michigan reducing the mass flux of COCs from impacted groundwater to Lake Michigan. This remedy nearly eliminates the potential for direct exposure to leachate along the shoreline and minimizes impacts to surface water. The collected leachate would be treated with physical/chemical processes to reduce toxicity, mobility, and volume (TMV). The disposal of the treated water will be to a permitted disposal location. Institutional controls provide community protection in the form of groundwater use restrictions and cover maintenance. The estimated mercury loading to the lake for this combination of technologies is 45.5 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 13. As shown in Table 13, four of the seven category scores were assessed as moderate to high (4) and three of the seven category scores were assessed as moderate (3) achievement of criterion. This alternative is expected to meet the RAOs for soil and groundwater. A variance from the State Water Quality Standards for some COCs (sulfate, chloride, TDS, and some metals) in a discharge to Lake Michigan may be required, including a mixing zone determination as discussed in Section 2.2.5. Modification to existing Petoskey Well(s) seasonal operating patterns near the Site could significantly alter regional groundwater flows and discharge of impacted groundwater to Lake Michigan.

The combination of remedial technologies in this alternative has already been implemented. The cost for this alternative is assumed to equal to the IR activities and investigation costs to date and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in

Appendix E. The total cost for this alternative is approximately $105 million and the overall score is 25.

4.2.3 Remedial Alternative 3 – Existing IR Actions and Targeted Surface Water Improvements

Alternative 3 is similar to Alternative 2 and includes operation of the existing IR (Site ILRS, West and Seep 1 CKD Areas downgradient barriers, and existing CKD cover). Unlike Alternative 2, this alternative also includes targeted surface water improvements at the Pine Court Seep area. Reduction of infiltration from surface water improvements limits the volume of leachate generated and is also expected to reduce the magnitude of peak flows historically observed at the Pine Court Seep area ILRS improving downgradient hydraulic containment during wet weather conditions. The estimated mercury loading to the lake for this combination of technologies is 40.8 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 14. As shown in Table 14, four of the seven category scores were assessed as moderate to high (4) and three of the seven category scores were assessed as moderate (3) achievement of criterion. In general this alternative is more favorable than Alternative 2 because of increased long-term effectiveness expected from surface water improvements at a small cost relative to other alternatives; however the magnitude of improved effectiveness was not sizeable enough to warrant higher scoring for long term effectiveness.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, targeted surface water improvement, and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $106 million and the overall score is 25.

4.2.4 Remedial Alternative 4 – Existing IR Actions, Targeted Surface Water Improvements, and Targeted Upgradient Diversion

Alternative 4 is similar to Alternative 3 and includes operation of the existing IR (Site ILRS, West and Seep 1 CKD Area downgradient barriers, and existing CKD cover) and targeted surface water improvements. Unlike Alternative 3, this alternative also includes targeted upgradient groundwater diversion. Perched groundwater diversion in the Pine Court Seep area will aid downgradient hydraulic containment by reducing groundwater flow from upgradient and reducing groundwater contact with CKD by reducing both groundwater flow and groundwater elevation above the marker shale. The quantity of water collected by the diversion system may be considered a large quantity withdrawal, and appropriate procedures for permits for CERCLA actions would be followed. Also, upland wetlands may require consideration for protection from dewatering as an ARAR. Regional groundwater diversion in this alternative includes the control and operational optimization of a diversion system to seasonally reduce or reverse regional groundwater gradients toward the lake. The estimated mercury loading to the lake for this combination of technologies is 27.6 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 15. As shown in Table 15, five of the seven category scores were assessed as moderate to high (4) and two of the seven category scores were assessed as moderate (3) achievement of criterion. This alternative was assessed to achieve higher scores than Alternative 3 for both long and short-term effectiveness because both impacts to groundwater and the flow of impacted groundwater will be reduced thereby reducing the overall mercury flux to the lake relatively soon after implementation. However, perched groundwater diversion may require an extensive design investigation and increased levels of long-term O&M add to the costs resulting in this alternative achieving a lower score for cost criterion when compared to Alternative 3.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, targeted surface water improvements, installation of a perched groundwater diversion system, upgradient regional groundwater diversion well(s), and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $115 million and the overall score is 26.

4.2.5 Remedial Alternative 5 – Existing IR Actions, Targeted Surface Water Improvements, Targeted Upgradient Diversion, and Targeted Leachate Collection

Alternative 5 is similar to Alternative 4 and includes operation of the existing IR (Site ILRS, West and Seep 1 CKD Area downgradient barriers, and existing CKD cover), targeted surface water improvements, and targeted upgradient diversion. Unlike Alternative 4, this alternative also includes targeted leachate collection (TLC). TLC in the Pine Court Seep area will aid downgradient hydraulic containment by reducing impacted groundwater flow from upgradient and reducing groundwater contact with CKD by reducing both groundwater flow and groundwater elevation above the marker shale in the vicinity of the recovery wells. The estimated mercury loading to the lake for this combination of technologies is 20.8 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 16. As shown in Table 16, six of the seven category scores were assessed as moderate to high (4) and one of the seven category scores was assessed as moderate (3) achievement of criterion. This alternative was assessed to achieve higher achievement of TMV criterion when compared to Alternative 4 because TLC increases the volume of impacted groundwater collected and treated to reduce pH. In general, this alternative also has higher long-term effectiveness because TLC and targeted diversion together result in a greater overall mercury flux reduction than targeted diversion alone; however the magnitude of improved effectiveness was not sizeable enough to warrant higher scoring of criterion.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, targeted surface water improvements, installation of a perched and regional groundwater diversion system, targeted leachate collection, and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $122 million and the overall score is 27.

4.2.6 Remedial Alternative 6 – Existing IR Actions, Targeted Upgradient Diversion, and Targeted Impermeable Cover System

Alternative 6 includes operation of the existing the existing IR collection drains, West and Seep 1 CKD Area downgradient barriers, targeted diversion, and an impermeable cover system. Targeted diversion of upgradient groundwater coupled with reduction of infiltration through consolidation and an impermeable cover system limits the volume of leachate generated. Consolidation, compaction, contouring, and covering the Pine Court Seep area would provide a significant barrier to direct exposure to the CKD and minimize the migration of contaminants to groundwater, thereby reducing the mass flux of COCs from source material to groundwater and subsequently to surface water. Downgradient hydraulic containment intercepts the discharge of leachate to Lake Michigan reducing the mass flux of COCs from impacted groundwater to Lake Michigan. This remedy nearly eliminates the potential for direct exposure to leachate along the shoreline and minimizes impacts to surface water. The collected leachate would be treated with physical/chemical processes to reduce TMV. The disposal of the treated water will be to a permitted disposal location. Institutional controls provide community protection in the form of groundwater use restrictions and engineered cover maintenance. The estimated mercury loading to the lake for this combination of technologies is 24.6 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 17. As shown in Table 17, four of the seven category scores were assessed as moderate to high (4), two of the seven category scores was assessed as moderate (3), and one of the seven category scores was assessed as low to moderate achievement of criterion. This alternative was assessed to have lower achievement of TMV, implementability, and cost criterion when compared to Alternative 5. TMV and cost had lower achievement of criterion because this alternative does not include long-term TLC and has a higher overall cost than Alternative 5. Implementability was scored two points lower because installation of an impermeable cover system would result in closure of portions of the golf course for approximately two construction seasons and this may not be acceptable to Bay Harbor Golf Club Inc. or neighboring property owners.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, installation of a perched and regional groundwater diversion systems, short-term targeted leachate collection, consolidation of CKD, installation of an impermeable barrier, and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $130 million and the overall score is 23.

4.2.7 Remedial Alternative 7 – Modified IR Actions and Targeted Removal

Alternative 7 includes targeted removal of CKD from the entirety of the Pine Court Seep area, offsite CKD disposal of CKD at a RCRA Subtitle D landfill, and operation of the existing IR excluding the existing Pine Court Seep area beach collection drains. Removal nearly eliminates the long-term potential for direct exposure to CKD at the Pine Court seep area and greatly reduces the CKD source of contaminants to groundwater at the Site, thereby mitigating the mass flux of COCs from source material to groundwater and subsequently to surface water. After removal, the residual impacted groundwater will naturally attenuate, eventually reducing the long-term potential for direct exposure to leachate along the Pine Court Seep area shoreline. At other CKD areas, downgradient hydraulic containment intercepts the discharge of leachate to Lake Michigan reducing the mass flux of COCs from impacted groundwater to Lake Michigan at remaining CKD Areas. The collected leachate from excavation dewatering and the IR collection drains would be treated with physical/chemical processes to reduce toxicity, mobility, and volume (TMV). The disposal of the treated water will be to a permitted disposal location. Institutional controls provide community protection in the form of groundwater use restrictions and cover maintenance. The estimated mercury loading to the lake for this combination of technologies is 3.4 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 18. As shown in Table 18, one of the seven category scores is 5, with high achievement of criterion realized. The other five categories received scores ranging from 2 to 4. Both implementability and cost achieved low to moderate achievement of criterion (2) in this alternative. Implementability achieved this score because removal of CKD from the Pine Court Seep area would result in closure of portions of the golf course for approximately two construction seasons and this may not be acceptable to Bay Harbor Golf Club Inc. or neighboring property owners. Cost achieved this score because relative to other alternatives, except complete removal, costs for this alternative are significantly greater. This remedy is expected to meet the soil and water RAOs in the long term, but direct discharge of excavation water to the Lake may not meet water ARARs in the short term.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, removal and disposal of CKD from the Pine Court Seep area, golf course restoration, and the net present value of future O&M costs (30 years, 3%). O&M costs assume long-term leachate disposal rates at $0.04 per gallon of leachate. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $167 million and the overall score is 21.

4.2.8 Remedial Alternative 8 – Removal

Alternative 8 includes full removal of CKD from the Site and offsite disposal at a RCRA Subtitle D landfill. Removal nearly eliminates the long-term potential for direct exposure to CKD at the Site and greatly reduces the CKD source of contaminants to groundwater at the Site, thereby mitigating the mass flux of COCs from source material to groundwater and subsequently to surface water. After removal, the residual impacted groundwater will naturally attenuate, eventually reducing the long-term potential for direct exposure to leachate along the shoreline and future high pH impacts to surface water. The high pH leachate collected during dewatering will be neutralized and disposed of off-site. Although the reduction in pH is a favorable factor in TMV reduction through treatment, there is the potential for significant increases in mercury and other COC loading to the Lake during removal. Also, even with complete removal, institutional controls would need to remain for an indefinite period of years, as the rate at which Site groundwater will recover to conditions similar to those upgradient of the CKD areas will depend on many factors, including the presence of residual CKD even after excavation. The estimated mercury loading to the lake for this combination of technologies is 0.9 mg/day.

A detailed analysis of this alternative and development of scores based on each of the criteria is included in Table 19. As shown in Table 19, one of the seven category scores is 5, with high achievement of criterion realized. The other five categories received scores ranging from 1 to 4. Short-term effectiveness, implementability, and cost achieved low achievement of criterion in this alternative. There will be significant short-term adverse impacts to the community and an increase in metals mass loading to the lake. Full removal of the CKD is also the most difficult alternative to implement and the most expensive. Implementability will be highly difficult because complete removal would result in closure of much of the golf course for approximately five years and this may not be acceptable to Bay Harbor Golf Club Inc. or neighboring property owners. This remedy is expected to meet the soil and water RAOs in the long term, but direct discharge of excavation water to the Lake may not meet water ARARs in the short term.

The cost for this alternative is assumed to equal to the IR activities and investigation costs to date, removal and disposal of CKD from the entirety of the Site, golf course restoration, and the net present value of future O&M costs (30 years, 3%). This remedy assumes no leachate collection or disposal. The detailed costs for this alternative are presented in Appendix E. The total cost for this alternative is approximately $408 million and the overall score is 17.

4.3 Comparative Analysis

The following text provides a detailed comparative analysis of the alternatives based on the seven NCP criteria. A brief summary of the comparative analysis is included in Table 20. Based on the individual analysis performed on the alternatives in Section 4.2, Alternative 5 is the highest ranking alternative with an overall score of 27, followed by Alternative 4 with an overall score of 26, Alternatives 2 and 3 with an overall score of 25, Alternative 6 with an overall score of 23, Alternative 7 with an overall score of 21, and Alternative 8 with an overall score of 17. The baseline alternative (Alternative 1) was the lowest ranking alternative with an overall score of 15.

4.3.1 Protection of Human Health and the Environment

Alternatives 2 through 6 scored highest because they incorporate a combination of engineered and institutional controls to meet the cleanup standards and provide protection from existing contamination. The existing soil cover system or an improved soil cover will reduce exposure to CKD (direct contact, ingestion, and inhalation) and minimize the migration of contaminants in the CKD to groundwater and surface water by limiting infiltration. Groundwater migration controls (collection system, flow barrier, diversion, TLC) eliminate direct exposure to leachate along the shoreline and discharge of leachate to Lake Michigan.

Alternatives 7 and 8 scored moderate (3) on protection of human health and the environment because of the significant potential and expected impacts to the environment and community during CKD removal. The source of contamination would be removed from the site, which is favorable, but not materially more protective than covering in place. Residual impacts to groundwater would attenuate following source removal.

4.3.2 Compliance with ARARs

All of the alternatives are anticipated to result in substantial compliance with the ARARs, except for Alternative 1. However, a variance will be needed to meet the state-determined COC discharge limits. In addition, target criteria for natural attenuation of COCs in the mixing zone will need to be agreed upon. The work will be done in a manner consistent with state and federal laws, rules and regulations, as indicated in the ARARs tables (Tables 2, 3 and 11). Therefore, Alternatives 2 through 8 received a score of 4.

4.3.3 Long-Term Effectiveness

Alternatives 7 and 8 scored the highest on long-term effectiveness because of relatively low long-term mercury flux values compared to other alternatives. Both of these alternatives have in common CKD removal from the Pine Court Seep area where more than 94% of the existing mercury flux to the lake exists. CKD excavation, transportation, and placement in a landfill mitigates risk of direct exposure to CKD on the site and provides that discharge of high pH leachate at the lakeshore will be alleviated over the long term. Some risks associated with the CKD would be transferred to a disposal location that is sited, designed, and operated in a manner that effectively manage long-term risk, and there would be a significant component of risk (e.g., mercury emissions, potential for accidents) due to the construction activities themselves. Alternatives 4 through 6 received a score of 4 because source material will remain onsite and engineered and institutional controls will be implemented and maintained to provide long-term effectiveness. Alternatives 2 and 3 received a slightly lower score of 3 because relative to Alternatives 4 through 6, long-term mercury flux reduction to the lake is smaller and operation changes to Petoskey Municipal Well(s) have the potential to significantly alter regional groundwater flows and discharge of impacted groundwater to Lake Michigan.

4.3.4 Reduction of Toxicity, Mobility, and Volume (through Treatment)

Alternative 5 scored the highest on reduction of TMV because it constitutes the largest amount of leachate collected and treated for pH. Alternatives 2 through 4, 6, and 7 scored just below Alternative 5 because somewhat less leachate would be collected and treated. Alternative 8 was also rated low on reduction in TMV through treatment because, in contrast to Alternative 5, which reduces pH and removes mercury and other metals through treatment, Alternative 8 may increase mercury and metals loading for the duration of CKD excavation activities. None of the alternatives was considered to reduce the TMV of the CKD itself as the CKD is not treated. This applies to Alternative 7 and 8 as well because source removal does not treat to address the TMV of the CKD.

4.3.5 Short-Term Effectiveness

Alternative 4 and 5 received the highest score for short-term effectiveness because there would be limited exposure to workers during construction of the remaining remediation systems. The RAOs for the Site would be realized in a relatively short time period following construction for Alternatives 4 and 5. Alternatives 2, 3, and 6 scored below Alternatives 4 and 5 because the overall effectiveness related to mercury flux reduction is less. Alternative 7 scored below Alternatives 2 through 6 because there would be extended exposure to workers and the public during CKD removal, the overall time duration from initiation to completion of remedial actions and achievement of RAOs would be longer than the other alternatives, there would be significant community impact from truck traffic, and there would be an increase in mercury and other metals mass loading to the Lake as a result of exposing CKD and dewatering activities. Alternative 8 scored below Alternative 7 because all the short-term impacts described above for Alternative 7 would be magnified for CKD removal from the entire site.

4.3.6 Implementability

With the exception of Alternative 1, Alternatives 2 through 5 scored the highest on implementability because it uses reliable technologies, readily available equipment and area for treatment facilities, and its effectiveness is relatively easy to monitor. Alternative 6 and 7 scored below Alternatives 2 through 5 because they would result in closure of portions of the golf course for approximately two construction seasons and this may not be acceptable to Bay Harbor Golf Club Inc. or neighboring property owners. Also, existing steep slopes on the lakeside of the CKD piles complicate both impermeable cap installation and CKD removal. Alternative 8 scored below Alternatives 6 and 7 because the engineered facilities, controls, and construction activities necessary to perform a full removal, and the availability of a disposal facility to accept a large volume of CKD make Alternative 8 very difficult to implement.

4.3.7 Cost

With the exception of Alternative 1, Alternatives 2 and 3 scored highest on cost. Alternatives 2 and 3 would cost approximately $105 and $106 million for capital and 30 years of O&M, respectively. Alternatives 4 through 6 scored slightly lower on costs to reflect higher costs estimated to be $114, $122, and $130 million for capital and 30 years of O&M, respectively. Alternative 7 scored lower than Alternatives 1 through 6 to reflect higher costs estimated to be $167 million. Alternative 8 scored the lowest of all alternatives to reflect the highest cost of all alternatives estimated to be nearly $400 million. Long-term disposal costs were estimated to be $0.04 per gallon of leachate disposed in these costs estimates. Deviations from this estimated disposal cost, either higher or lower, could have a significant impact cost estimates for Alternatives 2 though 7.

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