

EXPANDED SITE INSPECTION AND REMOVAL ASSESSMENT REPORT

ST. CROIX ALUMINA (RENAISSANCE PARK) SITE

ST. CROIX, U.S. VIRGIN ISLANDS

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Table of Contents

1	Introduction	1
1.1	Site Location	1
1.2	Site Description	2
1.3	Site History.....	2
1.4	Description of Operations and Waste Generation.....	3
1.5	Documented Spills and Releases.....	5
1.6	Previous Investigations	6
2	Scope/Field Activities.....	10
2.1	Radiological Screening	10
2.2	pH Measurements.....	11
2.3	Sampling.....	11
2.3.1	Background Soil Sampling	12
2.3.2	Waste Sampling	12
2.3.3	Surface Water/Sediment Sampling.....	13
2.3.4	Ground Water Sampling	14
2.3.5	Blanks	14
2.3.6	Decontamination.....	14
2.4	Sample Handling and Shipping.....	15
2.5	Analytical Procedures	16
3	Physical Characteristics and Observations	18
3.1	Source Areas	18
3.1.1	Red Mud Disposal Area A.....	18
3.1.2	Red Mud Disposal Area B	19
3.1.3	Ash Disposal Pond.....	19
3.1.4	Former Bauxite Storage Shed	20
3.2	Surface Water Migration Pathway	20
3.2.1	Red Mud Settling Pond.....	20
3.2.2	Upper Cooling Pond	20
3.2.3	Lower Cooling Pond.....	21
3.2.4	Overland Flow Pathways	21
3.2.5	Surface Water Pathway Receptors.....	22
3.3	Ground Water Pathway	23
3.3.1	Regional Geology	23
3.3.2	Site Geology.....	24
3.3.3	Hydrogeology	25
3.3.4	Aquifer Use and Usability	26
4	Analytical Results.....	28
4.1	Background Soil.....	28
4.2	Waste Materials.....	30
4.2.1	Red Mud Disposal Area A.....	30
4.2.2	Red Mud Disposal Area B	33
4.2.3	Ash Disposal Pond.....	35
4.2.4	Former Bauxite Storage Shed	36
4.3	Surface Water/Sediment.....	38

Table of Contents - Continued

4.3.1 Background Surface Water/Sediment Sample Locations 38

4.3.2 Red Mud Disposal Area A 39

4.3.3 Red Mud Settling Pond 40

4.3.4 Upper Cooling Pond 42

4.3.5 Lower Cooling Pond 44

4.3.6 West Ditch 45

4.3.7 Coastal Mangrove Areas 46

4.3.8 Alucroix Channel 47

4.4 Ground Water 48

5 Conclusion 51

5.1 Source Areas 51

5.2 Surface Water Migration Pathway 51

5.3 Ground Water Migration Pathway 52

6 References 53

List of Tables

1. Sample Locations
2. Sample Descriptions and Analyses
3. pH measurements (Highest to Lowest) – Solid Matrix Samples
4. pH measurements (Highest to Lowest) – Aqueous Samples
5. Sample Dispatch and COC Information – CHEMTECH
6. Sample Dispatch and COC Information – DESA
7. Sample Dispatch and COC Information – NAREL
8. Stratigraphy and Aquifer Determinations from Monitoring Well Logs
9. Historical Ground Water Results for Metals and Water Quality Parameters
10. Background Soil Sampling Results – SVOCs and Aroclors
11. Waste Sampling Results – SVOCs and Aroclors
12. Surface Water Sampling Results – SVOCs and Aroclors
13. Sediment Sampling Results – SVOCs and Aroclors
14. Ground Water Sampling Results – SVOCs and Aroclors
15. Ground Water and Blank Sampling Results – VOCs
16. Rinsate Blank Sampling Results – SVOCs and Aroclors
17. Minimum and Maximum Values for pH and Contaminants of Concern per Investigated Area
18. Background Soil Sampling Results – pH and Inorganics
19. RMA Waste Sampling Results – pH and Inorganics
20. RMA Depositional Area Waste Sampling Results – pH and Inorganics
21. RMB Waste Sampling Results – pH and Inorganics
22. ADP Waste Sampling Results – pH and Inorganics
23. FBS Waste Sampling Results – pH and Inorganics
24. Surface Water Sampling Results – pH, Inorganics, and Chloride
25. Sediment Sampling Results – pH and Inorganics
26. Sediment Sampling Results – TOC and Grain Size
27. Ground Water Sampling Results – pH, Inorganics, and Chloride
28. Rinsate Blank Sampling Results – Inorganics and Chloride
29. Background Gamma Count Rate Measurements Collected Northeast of the Site
30. Background Exposure Rate Measurements Collected Northeast of the Site
31. Gamma Count Rate Measurements Collected Along the Northern Fence Line of the Site
32. Gamma Count Rate Measurements Collected in Harvey (Bethlehem Village and Profit Hills)
33. Gamma Count Rate Measurements Collected Inside the Pedro Cruz Ballfield Located in Matthews Charles
34. Gamma Count Rate Measurements Collected Inside the Pedro Cruz Recreational Area Located in Matthews Charles
35. Exposure Rate Measurements Collected in Red Mud Disposal Area A Located Near the Northern Boundary of the Site
36. SAM-940 Gamma Dose Rate Results

List of Tables - Continued

37. Gamma Spectroscopy Analyses Results of Background Soil Samples Collected Primarily from the Northeast Portion of the Site
38. Alpha Spectroscopy Analyses of Background Soil Samples Collected Primarily from the Northeast Portion of the Site
39. Radiological Results of Background Soil Samples Collected Primarily from the Northeast Portion of the Site
40. Gamma Spectroscopy Analyses Results of Surface and Subsurface Waste and Sediment Samples
41. Alpha Spectroscopy Analyses Results of Surface and Subsurface Waste and Sediment Samples
42. Net Radiological Analyses Results of Surface and Subsurface Waste and Sediment Samples with Background Subtracted
43. Radiological Results of Surface Water and Ground Water Samples

List of Figures

1. Site Location Map
2. Site Features Map
3. Site Layout Map
4. Sample Location Map
5. pH Field Measurements
6. Red Mud Disposal Area A – Metals Results Map
7. Red Mud Disposal Area B, Ash Disposal Pond, and Former Bauxite Storage Shed – Metals Results Map
8. Surface Water – Metals Results Map
9. Sediment – Metals Results Map
10. Ground Water – Metals Results Map
11. Chloride Results Map
12. Gamma Count Rate Measurements Collected Along the Northern Fence Line of the Site (Table 31)
13. Gamma Count Rate Measurements Collected In Harvey (Table 32)
14. Gamma Count Rate Measurements Collected Inside the Pedro Cruz Ballfield Located in Matthews Charles (Table 33)
15. Gamma Count Rate Measurements Collected Inside the Pedro Cruz Recreational Area Located in Matthews Charles (Table 34)
16. Surface Exposure Rates on the Red Mud Disposal Area “A” (Table 35)
17. SAM-940 Gamma Spec Data (Table 36)

List of Figures - Continued

- 18. Radiological Results of Background Soil Samples Collected Primarily from the Northeast Portion of the Site (Table 39)
- 19. Net Radiological Analyses Results of Surface and Subsurface Waste and Sediment Samples with Background Subtracted (Table 42)

List of Appendices

- A. Logbooks and Field Data Sheets
- B. Photo Documentation
- C. Traffic Reports/Chain-of-Custody
- D. Existing Well Logs
- E. Radiological Assessment Report
- F. Laboratory Analytical Results

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1 Introduction

Under the Authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Superfund Amendments and Reauthorization Act of 1986 (SARA), the U.S. Environmental Protection Agency (EPA) Region 2 Emergency and Remedial Response Division (ERRD) and Weston Solutions, Inc. (WESTON[®]) have completed an investigation of the St. Croix Alumina (Renaissance Park) site (“the Site”) in St. Croix, U.S. Virgin Islands (USVI). The Site is listed in the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) under EPA ID No. VIN000206465. It is a former alumina refinery where bauxite ore processing residues, including red mud and caustic wastewaters, were deposited in on-site disposal areas. The investigation was a combined effort to complete an Expanded Site Inspection (ESI) under the Region V Superfund Technical Assessment and Response Team III (START III) contract and a Removal Assessment (RA) with radiological measurements under the Removal Support Team 2 (RST 2) contract.

The EPA team completed a sampling and screening effort at the Site from September 12-21, 2011. Sample collection efforts and procedures were combined to accommodate the data requirements of both the EPA Remedial and Removal programs. EPA investigated source areas and migration pathways, including ground water contamination, overland flow of red mud from source areas into downslope surface impoundments and other water bodies, and radioactivity levels in source and receptor areas. Waste samples were collected to characterize sources, and background soil samples were collected as reference for comparison. Surface water and sediment samples were collected to evaluate the impact of waste sources to the on-site and off-site overland flow pathway. Ground water samples were collected from existing on-site monitoring wells to characterize ground water quality in specific areas of the Site and evaluate the impact to ground water. Source areas, sampling locations, and residential areas to the north (Bethlehem Village/Profit Hills [a.k.a. Harvey] and Estate Profit [a.k.a. Matthews Charles]) were screened with radiation detection monitors to evaluate radioactivity and potential exposures.

1.1 Site Location

The Site is located within the South Shore Industrial Complex along the south-central coast of St. Croix. The subject property, which consists of several parcels and has a total surface area of approximately 1,250 acres [SCSE, 2002], is currently owned by St. Croix Renaissance Group, LLLP (SCRG). The property is zoned for industrial use and is bordered by the HOVENSA oil refinery on the east; USVI government property (Container Port and Molasses Pier) on the southeast; the Caribbean Sea on the south; a municipal landfill, wastewater treatment plant, racetrack, and Henry E. Rohlsen Airport on the west; and the Bethlehem Village/Profit Hills (a.k.a. Harvey) and Estate Profit (a.k.a. Matthews Charles) residential neighborhoods across a four-lane highway on the north. A Site Location Map and Site Vicinity Map are presented in Figures 1 and 2, respectively.

1.2 Site Description

The Site is a former refinery where bauxite ore was processed for alumina extraction, and residues from the process were deposited on site. The alumina refinery was constructed in the mid-1960s, at which time the on-site ship channel (Alucroix Channel, a.k.a. Krause Lagoon Channel) was dredged and Krause Lagoon was filled. Alumina refining operations began in 1968. The former refinery consisted of administrative offices and other buildings; material storage structures (silos, tanks, and shed); grinding operations; digestion, thickening, filtration, precipitation, and calcination operations; coal- and oil-fired boilers; water desalination units; warehouses; laboratories; maintenance facilities; storm water collection and cooling ponds; bauxite residue (i.e., red mud) disposal areas; recreational areas; and a dock that provides access to the ship channel.

The refinery operated from 1968 through December 2000, with some intervening idle years. SCRG has since begun redevelopment of the Site, including the removal of former refinery tanks and equipment. Currently the Site consists of the dock and ship channel, coal-fired power plant, coal storage area, conveyors, steam-turbine building, desalination units, ethanol dehydration plant (presently inactive), machine shop, maintenance and administration buildings, settling and cooling ponds, and former disposal areas. The former bauxite storage shed also remains for possible future use. In addition, the Diageo rum distillery in the northern portion of the property was constructed in 2009-2010 and began operating in November 2010. Molasses tanks for the distillery are installed in the former location of refinery tanks. Figure 3 shows the Site Layout including major features.

1.3 Site History

Historically, portions of the Site were used for sugar cane production, as evidenced by pre-1900 ruins in the western and northeastern portions of the property, and the subject property had various owners prior to construction of the alumina refinery. In 1937, the property was transferred from West Indian Sugar Factory, Inc. to private ownership. The U.S government took over the property in 1942, and subsequently transferred it to Municipality of St. Croix in 1949. Harvey Aluminum, Inc. (HAI) purchased the property from Government of the Virgin Islands in 1962 and constructed the refinery in the mid-1960s.

Martin Marietta Alumina (MMA) purchased HAI in 1968, the year alumina refining operations began, and continued alumina production at the Site until 1985. Refining operations were discontinued from 1985 to 1989. Virgin Islands Aluminum Company (VIALCO) purchased the property from MMA in 1989, and resumed refining operations from 1989 until 1995. St. Croix Alumina, LLC (SCA), a subsidiary of Aluminum Company of America (ALCOA), purchased the property from VIALCO in 1995, and refining operations were suspended from 1995 to 1998. ALCOA resumed refining operations in 1998, which continued through December 2000. Administrative and maintenance staff for ALCOA remained at the facility until 2002. SCRG

purchased the property from ALCOA in 2002 and initiated efforts to convert it to a mixed use industrial/commercial site.

1.4 Description of Operations and Waste Generation

The former refinery at the Site extracted alumina (Al_2O_3) from bauxite via the Bayer process, which involved crushing and grinding of the ore; dissolution of alumina with caustic soda at high temperatures and pressures; separation and on-site disposal of undigested solid residues (i.e., red mud) from the supernatant; precipitation as alumina hydrate; and washing and calcination of the hydrate to form crystalline alumina. Raw materials used at the facility included bauxite ore, caustic soda, phosphoric acid, sulfuric acid, lime, flocculants, biocides, calcium fluoride, and coal. Bauxite is a naturally occurring, heterogeneous material composed primarily of one or more aluminum hydroxide minerals (principally gibbsite, boehmite, and diaspore) plus various mixtures of silica (SiO_2), iron oxide (Fe_2O_3), titania (TiO_2), aluminosilicates (clay, etc.), and other impurities in trace amounts [USGS, 2001].

The principal waste material generated by bauxite processing at the Site was red mud, which consists primarily of undigested metal oxides that precipitate and settle out of the process solution. The lower-volume, coarser fraction of the residue is referred to as red sand. After separation and removal of excess water, the red mud was mixed with seawater in an attempt to neutralize remaining caustic solution and form less viscous slurry for conveyance to on-site disposal areas [G&M, 1995]. Red mud can contain elevated levels of metals, and the pH of red mud characteristically ranges from 10 to 12 due to the use of caustic soda during the extraction process. Red mud is also known to contain technologically enhanced naturally occurring radioactive material (TENORM), including thorium and uranium. TENORM is naturally occurring radioactive material (NORM) that has been processed in such a manner that its concentration has increased. In the case of the Site, the use of sodium hydroxide to dissolve aluminum oxide from the ore caused lower solubility compounds, including thorium and uranium, to concentrate in the red mud.

From the onset of operations at the Site in 1968 until the early 1970s, the red mud was deposited in the “old red mud ponds”, designated herein as Red Mud Disposal Area B (RMB). This area is located in the center portion of the Site, south of the former refinery (see Figure 3). RMB, which was built on top of a mangrove swamp, covers approximately 81 acres and consisted of seven disposal cells surrounded by perimeter dikes built of carbonate material. The red mud deposited in RMB was approximately 30 percent solids and 70 percent liquids, with the liquids being a mixture of caustic soda and seawater. Excess caustic liquid drained to a dewatering pond in the southeastern part of the source area for recycling and evaporation (this pond was subsequently used for ash disposal, as described below). Based on a review of plant records, an estimated total of 1,229,149 metric tons of red mud were produced at the facility from 1968 to 1972; that waste quantity is attributed to RMB since it was the active waste disposal unit during that timeframe [IST, 2010b]. RMB has since been partially covered with top soil and a limestone capping layer

(i.e., caliche), and some of it has revegetated, but red mud deposits remain exposed throughout the area.

Beginning in the early 1970s, red mud was placed into the “new red mud ponds”, designated herein as Red Mud Disposal Area A (RMA), which covers about 78 acres near the northwest corner of the Site (see Figure 3). A graded toe road that defines the southern limits of RMA forms the crest of the original containment dike constructed prior to disposal of red mud within the area. Waste deposition in RMA began in approximately 1972 after a modification in the separation process enabled the red mud to be pumped out at a greater percent solids concentration (approximately 50 percent). RMA was subdivided into seven cells of diked red mud, some of which reached elevations in excess of 100 feet above mean sea level (MSL) [BCI, 1993]. Red mud was deposited in RMA using a process called “dry stacking”, whereby red mud slurry was pumped into the northern end of each cell and allowed to flow southward by gravity and form a natural slope of 2 to 5 percent. After a drying period of about six months, the residue was bulldozed and compacted. In 1977, the composition of the red mud slurry being deposited in RMA was reported to be approximately 55 percent solids [D&M, 1977]. After 1983, the slurry also included fly ash from the coal-fired boiler. Based on a review of plant records, an estimated total of 4,613,449 metric tons of red mud were produced at the facility from 1973 to 2000; that waste quantity is attributed to RMA since it was the active waste disposal unit at the beginning of 1973 [IST, 2010b]. In addition, approximately 110,000 metric tons of fly ash were placed into RMA. Boreholes completed in 2006 indicated red mud thicknesses of 28 to 60 feet throughout RMA.

Red mud in both on-site disposal areas has been shown to maintain high pH levels and contain elevated levels of arsenic, chromium, mercury, selenium, and vanadium. A 1993 analysis of red mud from both on-site disposal areas indicated the presence of thorium and uranium, however, radioisotope analysis was not conducted [Wagh, 1993].

Other wastes were generated and deposited at the Site as a result of power production. Beginning in 1983, fly ash from the coal-fired boiler was mixed with red mud prior to disposal in RMA, as described above. The bottom ash from the coal-fired boiler was deposited in the former RMB dewatering pond, designated herein as the Ash Disposal Pond (ADP). ADP is located in the approximate center of the subject property and is surrounded on three sides by RMB, as shown in Figure 3. Laboratory analysis of waste samples from ADP has indicated the presence of arsenic, mercury, and selenium.

While the alumina refinery was operational, bauxite ore was stored on site in the large, open air and roofed shed designated herein as the Former Bauxite Storage Area (FBS). FBS is located within the former refinery operational area in the north-central portion of the subject property and west of Alucroix Channel (see Figure 3). When the refinery ceased operation, some unprocessed bauxite was left in the FBS. Alumina and red mud from decommissioning of tanks and other equipment were added to the bauxite pile upon shutdown, and the FBS has also been

used to stage some debris. The FBS shed currently contains a pile that covers approximately 1 acre; the pile consists of a mixture of red mud, alumina, bauxite, and debris, with approximately 8 to 14 inches of residual red mud from decommissioning of equipment covering the surface.

The alumina refinery used approximately 50 million gallons per day of cooling water pumped from Alucroix Channel and subsequently discharged to two ponds constructed in the early 1970s: the 30-acre Upper Cooling Pond (UCP) and the 150-acre Lower Cooling Pond (LCP). These caliche-lined holding basins (i.e., surface impoundments) in the western and southern portions of the property were constructed for cooling and treatment of process water and retention and treatment of storm water [G&M, 1995]. The LCP was initially constructed with twenty outfalls, but silting problems occurred and one primary discharge point to the ship channel has been used since 1981. This outfall is regulated through a Territory Pollution Discharge Elimination System (TPDES) permit issued by Virgin Islands Department of Planning and Natural Resources (VIDPNR) and is designated as Outfall 001A [SSPAI, 2010]. At the time of the EPA investigation in 2011, approximately 2.5 million gallons per day of process water from desalination and storm water flowed through the cooling ponds. The recent cessation of desalination in 2012 has reduced this flow to include only storm water.

1.5 Documented Spills and Releases

There have been various documented petroleum releases at the Site throughout the years and a resultant plume of separate-phase petroleum hydrocarbons exists on the water table in the eastern portion of the Site, north of Alucroix Channel [G&M, 1995; SSPAI, 2010]. About 40 wells have been installed over the years to monitor the plume and remove light non-aqueous phase liquid (LNAPL) and contaminated ground water from the subsurface. Leaks from tanks and associated piping at the Site and the adjacent HOVENSA facility created the plume, which is being remediated under an Administrative Consent Order with EPA. These remedial activities are overseen by the Resource Conservation and Recovery Act (RCRA) Branch of EPA and are not discussed further in this report, except in the context of Site-wide ground water. In addition to the various petroleum spills, there have been other releases at the Site as described below.

During the plant shutdown in 1985, approximately 19 million gallons of spent caustic liquor containing arsenic and chromium and diluted with seawater were pumped into the cooling ponds. The release resulted in a layer of solids (i.e., milky white precipitate) that was subsequently dredged for disposal in RMB. Additional releases of more than 80,000 gallons of plant liquor to the cooling ponds are documented for the period from 1992 to 1994. During the same timeframe, there were releases of fly ash and filtrate to the cooling ponds, sulfuric acid to the ground and to the ship channel, and coal particulate to the ship channel [G&M, 1995].

In September 1998, wind-blown fugitive dust, identified as bauxite by VIDPNR, was deposited onto residential properties located 750 feet north of the Site as a result of Hurricane Georges. Observations by VIDPNR indicated that reddish material had been deposited onto the residential structures and their drinking water cisterns. EPA sampling confirmed that bauxite was in the

cisterns.. VIDPNR issued a Notice of Violation (NOV) to St. Croix Alumina (SCA) for the fugitive dust release, determining that there were no precautionary measures in place to secure the stockpiled bauxite from hurricane winds.

Residents located north of the Site have reported red dust deposition on rooftops, inside cisterns, in outdoor gardens, and on indoor furniture associated with hurricanes and other high wind events.

In November 2001, approximately 25,000 gallons of sulfuric acid spilled from a leaking aboveground tank (T-26-1) to Alucroix Channel. VIDPNR issued an order to SCA requiring it to address this spill. Three monitoring wells (MW-1, MW-2, and MW-3) were installed and sampled by SCA to evaluate the impact of the spill on ground water. Removal of contaminated soil and residual acid was completed in 2002.

In March 2002, a release of red mud from RMA into the sea and shoreline mangrove wetland areas occurred during heavy rainfall. The release occurred after SCA had performed unpermitted grading and recontouring work in RMA. Storm water carrying red mud discharged from RMA, flowed down an unpaved roadway, and entered the drainage ditch that runs along the western boundary of the Site (i.e., the West Ditch). The red mud laden runoff continued along the western boundary of the Site, passed through an 18-inch culvert, and entered a mangrove-lined drainage area. The red mud release then breached beach berms, entered shoreline wetland areas and the sea, and was transported west by shoreline currents. Red mud was observed to be deposited as far as a beach road that runs along the landfill located west of the Site. The release deposited 6 to 10 centimeters (cm) of red mud along the bottom of the drainage path, including 7.5-cm thickness in the deeper part of the mangrove wetland areas. SCA performed berm reinforcement in April 2002, and red mud was removed from the west ditch in June 2002, but subsequent releases in January and April 2003 led to re-accumulation of red mud in the west ditch, including mangrove wetland areas. In September 2003, the west ditch was rerouted from the coastal mangrove area to the LCP.

The persistent erosion problem from RMA continues. The 2006 aerial photograph of the Site and observations made by EPA in June and September 2011 show the migration of red mud across the Site from RMA downslope to the interconnected on-site surface impoundments: the Red Mud Settling Pond (RMS), UCP, and LCP. The aerial photograph and EPA observations also document the erosion and migration of red mud from exposed areas within RMB.

1.6 Previous Investigations

There have been several investigations at the Site throughout the years, including installation of ground water monitoring wells in 1982 and 1995 to evaluate red mud disposal areas. Several efforts in recent years have been conducted to evaluate the waste material that remains on Site, including those events described here.

In 1977, Dames & Moore (D&M) on behalf of MMA completed soil borings to evaluate geotechnical aspects of three areas (RMA, RMB, and Area C [southeast portion of Site]) for feasibility of red mud storage. Geotechnical analyses of red mud samples classified it as inorganic silt of low plasticity with permeability of 5×10^{-6} centimeters per second (cm/s), while semi-quantitative analyses indicated that chromium and vanadium were present in the red mud. A 20-foot-high containment dike of marl was observed at the south end of RMA, while the east and west ends of the dike joined natural high ground at the 40-foot contour. While portions of RMA were found to be directly underlain by the natural marl formation (i.e., Kingshill aquifer), which consists of silty and clayey sand and gravel, RMB and Area C were found to be underlain by highly plastic, silty clay (i.e., Lagoonal Clay) with permeabilities of 10^{-9} to 10^{-6} cm/s [D&M, 1977].

In April 1982, EPA performed a RCRA inspection at the Site. EPA observed two types of process waste being deposited in RMA: red mud (the majority of waste) and wash water used to remove organic matter from the aluminum hydrate crystals in tanks (a washing process that occurred over a 3- to 5-day period every two months). EPA collected samples of both waste materials for EP toxicity metals analysis. The results showed that the red mud exceeded the allowable concentration for mercury, and the wash water exceeded the arsenic and selenium limits [EPA, 1983].

From December 1981 to February 1982, Geraghty and Miller, Inc. (G&M) on behalf of MMA installed twelve monitoring wells (G-1 through G-12) at the Site and collected preliminary ground water samples. The investigation found that the refinery was underlain by strata of moderate to high permeability, ground water flows south toward the channel and sea, and fresh ground water exists under the northern portion of the Site. Elevated levels of pH, fluoride, arsenic, cadmium, and chromium were detected in on-site ground water in the vicinity of the red mud disposal areas [G&M, 1982]. Additional ground water sampling events in July 1983, December 1983, March 1984, June 1984, January 1989, and March 1989 confirmed the elevated levels of pH, fluoride, arsenic, cadmium, and chromium in on-site ground water. G&M reported in 1989 that well G-12 had been destroyed and well G-2 had been damaged [G&M, 1989].

In 1993, a characterization of the Site red mud was conducted on behalf of VIALCO. Elemental analysis of red mud samples from both disposal areas indicated elevated concentrations of silver, arsenic, chromium, selenium, and vanadium. Elemental analysis also indicated elevated concentrations of thorium and uranium in red mud samples from both disposal areas, however, radioisotope analysis was not conducted [Wagh, 1993]. Also in 1993, a geotechnical evaluation of RMA indicated that the red mud water content was 30 to 55%, the dikes consisted of red mud and compacted marl, and the disposal cell elevations ranged from 40 to 110 feet at that time [BCI, 1993]. VIALCO applied for and was granted a Coastal Zone Management (CZM) permit for expansion of RMA in September 1994.

In 1995, G&M on behalf of VIALCO completed an environmental assessment at the Site. G&M installed six additional monitoring wells (GM-13, GM-13D, GM-14, GM-18, GM-19, and GM-22) and collected ground water samples from the new wells and five existing on-site monitoring wells (G-3, G-4, G-7, G-9, and G-11). The results indicated the presence of arsenic and selenium above primary drinking water standards (i.e., Maximum Contaminant Levels [MCL]) in the immediate vicinity of the red mud disposal areas. Secondary drinking water standards for aluminum, pH, chloride, fluoride, total dissolved solids (TDS), and sulfate were also exceeded in on-site ground water. Monitoring well GM-13D, located along the south perimeter of RMA and completed within the underlying limestone aquifer, showed an arsenic concentration of 836 micrograms per liter ($\mu\text{g/L}$). The 1995 investigation also included collection of solid samples from the cooling ponds; chromium was detected in both cooling ponds and arsenic was detected in the LCP [G&M, 1995].

Beginning in approximately 1994, about 40 wells have been installed in the northern and northeastern sections of the Site to evaluate and remediate the existing petroleum hydrocarbon plume. These wells include VW-1 through VW-38, as well as wells MMX and MM9. There are also several wells on the western edge of the HOVENSA property that are used to monitor and contain the plume. The wells currently included in the semiannual perimeter ground water monitoring program for this plume are G-11, GM-14, VW16, VW22 (dry), VW25, VW27, VW37, and MMX. The sampling program includes petroleum-related contaminants and indicates that these perimeter wells remain outside the influence of the plume [EPA, 1982-2011].

In 2001, Arthur D. Little Inc. (ADLI) completed an environmental due diligence assessment of the Site on behalf of ALCOA. ADLI observed that RMA was uncovered and contained several steep, unvegetated slopes, and reported that it was undergoing restoration. ADLI also reported that bottom ash from the coal-fired boiler was still being disposed of in the unlined settling pond (i.e., ADP) at that time [ADLI, 2001].

In March 2009, EPA collected four surface waste samples (including one environmental duplicate sample) from three locations within RMA. The samples were analyzed for Target Analyte List (TAL) and Toxicity Characteristic Leaching Procedure (TCLP) metals. TAL analyses indicated maximum arsenic, mercury, and vanadium concentrations of 20.2 milligrams per kilogram (mg/kg), 0.32 mg/kg, and 695 mg/kg, respectively. TCLP analyses indicated maximum arsenic, chromium, and selenium concentrations of 24.8 $\mu\text{g/L}$, 1,010 $\mu\text{g/L}$, and 96.7 $\mu\text{g/L}$, respectively, which are below the threshold criteria for characteristic hazardous waste. The TAL analyses indicated the presence of chromium, but the results were considered to be unusable [WESTON, 2009].

In April-May 2010, Integrated Science & Technology, Inc. (IST) on behalf of SCRG completed a subsurface soil and ground water sampling investigation of the RMB and ADP areas. Direct-push borings encountered red mud to depths greater than 24 feet in RMB and black ash to a depth of 15.5 feet in ADP. Other debris, including fabric and black ash, were also encountered

within red mud deposits in the southwest corner of RMB. The Lagoonal Clay was encountered beneath the waste materials throughout the area. Analytical results for the investigation indicated elevated concentrations of arsenic, chromium, mercury, selenium, and vanadium in the waste materials deposited at the Site and in monitoring well GM-22. Elevated levels of arsenic and vanadium were also detected in monitoring well GM-18. The investigation also showed that the deposited red mud waste and associated shallow ground water maintain high pH levels. Inorganic analysis of aqueous samples collected from monitoring well GM-22, believed to represent red mud leachate in RMB above the clay confining layer, indicated arsenic at 5,100 µg/L and a pH of 12.81 [IST, 2010a].

In December 2010, VIDPNR completed a field sampling event at the Site. Soil, sediment, and surface water samples were collected from on- and off-site locations, including the red mud disposal areas, Alucroix Channel, and the cooling ponds. The analytical results indicated elevated concentrations of arsenic, chromium (including hexavalent chromium), mercury, selenium, vanadium, and uranium at on-site locations, including the UCP and red mud disposal areas.

In July 2011, the EPA National Decontamination Team conducted an aerial radiological survey of the Site, HOVENSA, and residential areas to the north through the Airborne Spectrophotometric Environmental Collection Technology (ASPECT) program. The ASPECT program uses radiation detectors calibrated according to International Atomic Energy Agency (IAEA) specifications and specifically designed for airborne detection and measurement of low-level gamma radiation from naturally occurring and man-made sources. The ASPECT survey results indicated that areas associated with red mud deposition show concentrations of thorium and uranium at approximately 7 picocuries per gram (pCi/g) and 1 pCi/g, respectively, compared to respective background concentrations of approximately 0.09 pCi/g and 0.18 pCi/g (measured in the residential areas to the north). Conversion to exposure units (excluding contributions from cosmic radiation) yielded an exposure rate of 17 microroentgens per hour (µR/hr) from red mud deposition areas, compared to an exposure rate of 2 µR/hr in residential areas to the north [EPA, 2011].

2 Scope/Field Activities

This section describes the screening, sampling, sample management, and analytical procedures implemented during the September 2011 field activities. All activities were completed and all samples were collected as part of the combined ESI-RA with radiological measurements. The logbooks and field data sheets from the field activities are included in Appendix A, and photo documentation is included in Appendix B.

The EPA team completed the sampling and screening effort at the Site from September 12-21, 2011. EPA investigated source areas and migration pathways, including the overland flow of red mud from source areas into water bodies at the Site. Waste samples were collected to characterize sources, and background soil samples were collected as reference for comparison. Surface water and sediment samples were collected to evaluate the impact of waste sources to the on-site and off-site overland flow pathway. Ground water samples were collected from existing on-site monitoring wells to characterize ground water quality in specific areas of the Site and evaluate the impact to ground water. Source areas, sampling locations, and residential areas to the north (Bethlehem Village/Profit Hills and Estate Profit) were screened with radiation detection monitors to evaluate radioactivity and potential exposures.

During the ESI-RA sampling event, WESTON personnel collected totals of 74 waste samples, 7 waste/sediment samples, 17 soil samples, 11 unfiltered ground water samples, 11 filtered ground water samples, 52 surface water samples, and 52 sediment samples (the totals include environmental duplicate samples) from locations on and in the vicinity of the Site. WESTON logged sample locations electronically using Global Positioning System (GPS) equipment and performed post-processing differential correction of the GPS data in accordance with EPA Region 2 GPS Standard Operating Procedures. The processed GPS data for the sample locations has been transferred to the Sample Location Map (Figure 4) using Geographic Information Systems (GIS).

Table 1 presents the latitude and longitude coordinates of sample locations, expressed in decimal degrees. Table 2 presents the sample descriptions and analyses performed for all samples collected during the September 2011 sampling event.

2.1 Radiological Screening

Prior to collecting samples from the waste source areas (RMA, RMB, ADP, and FBS), as well as many of the surface water/sediment sample locations, EPA performed radiological screening of proposed sample locations using a Ludlum Model 19 MicroR meter. Areas of approximately 100 square feet around each proposed location were screened and red mud waste samples were collected from the location within the area with the highest reading. Upon sample collection, EPA measured gamma exposure rates (expressed in $\mu\text{R/hr}$) at ground surface and at 1 meter height for each location. Additionally, EPA performed dose rate screening of RMA and RMB

using a SAM-940 nuclide detector equipped with a 2-inch by 2-inch sodium iodide (NaI) probe. At each screening location, the SAM-940 acquired measurements over a 3-minute time interval.

EPA also performed gamma count rate surveys measuring gamma activity as counts per minute (cpm) along the northern fence-line north of RMA, and in adjacent off-site locations to the north of RMA including the Bethlehem Village/Profit Hills (Harvey) residential area, Estate Profit (Matthews Charles) residential area, the Pedro Cruz Ballfield, and the Pedro Cruz Recreation Area. These surveys were performed with the Rapid Assessment Tool (RAT), which included a Ludlum Model 2241 meter equipped with a 2-inch by 2-inch NaI probe mounted in a stroller. All radiological screening activity locations were recorded using GPS equipment. Radiological screening results are discussed in the May 2012 EPA report titled *Radiological Assessment Report, St. Croix Alumina (Renaissance Park) Site, St. Croix, U.S. Virgin Islands (RAR)*, dated May 2012.

2.2 pH Measurements

Based on the expected high pH (corrosive) nature of red mud, the sampling team measured the pH of all samples collected during the ESI-RA sampling event for site characterization and to identify samples that might be corrosive enough to require compliance with applicable regulations regarding air transport to the laboratories. WESTON calibrated the pH meters used for these measurements with pH 7 and pH 10 buffer solutions using a two-point calibration at least on a daily basis. Aqueous samples were field-tested for pH according to EPA Method 9040C directly at the sampling location or from an extra aliquot brought back to the command post. Solid samples were field-tested for pH according to EPA Method 9045D, using the following procedures:

- A 20-gram aliquot of sample was weighed and mixed with 20 milliliters of deionized water in an unused 2-ounce (125-mL) glass jar.
- The mixture was shaken for 5 minutes and then allowed to settle for at least one hour.
- The sampling team measured the pH of the mixture, and recorded the pH measurement on a field log sheet.

Tables 3 and 4 present the pH measurements for solid and aqueous matrix samples, respectively. Both data sets are sorted from highest (i.e., most alkaline) to lowest. The pH measurements for all samples are presented in Figure 5.

2.3 Sampling

During the ESI-RA sampling event, WESTON personnel collected a total of 74 waste samples from the four source areas (RMA, RMB, ADP, and FBS), 7 waste/sediment samples from the RMA Depositional Area, 17 background soil samples, 11 unfiltered ground water samples, 11 filtered ground water samples, 52 surface water samples, and 52 sediment samples (the totals

include environmental duplicate samples) from locations on and in the vicinity of the Site. Table 1 lists the sample location coordinates and Figure 4 depicts the sample locations. Table 2 lists the sample descriptions and associated analyses.

2.3.1 Background Soil Sampling

The EPA team collected a total of 17 background soil samples (the total includes environmental duplicate samples) from areas on and near the Site believed to be unaffected by the alumina refinery operations, specifically the northeast portion of the subject property and an area near the WWTP west of the Site. Surface soil samples were obtained by collecting material directly from the 0- to 6-inch depth interval below ground surface (bgs) with a dedicated, disposable plastic scoop. Subsurface soil samples were retrieved from depths ranging from 16 to 42 inches bgs with decontaminated bucket augers. Subsurface soil samples were obtained by boring to refusal with a bucket auger. Once refusal was encountered by the auger, a second hole was bored adjacent to the first hole to a depth approximately one foot shallower than the refusal depth. At that point, a decontaminated bucket auger head was exchanged for the one used to bore to depth, and the subsurface sample was collected with the clean auger at a depth just above refusal. For each sample, the retrieved soil was collected into and homogenized in a dedicated aluminum tray before filling respective sample containers. Remaining soil not used for field pH measurements or laboratory analyses was discarded at the sampling location.

2.3.2 Waste Sampling

The EPA team collected a total of 74 waste samples from the four identified waste sources (RMA, RMB, ADP, and FBS) at the Site, as well as 7 waste/sediment samples from the RMA Depositional Area (the totals include environmental duplicate samples). A total of 51 environmental samples were collected from RMA, including surface waste samples, subsurface waste samples, surface water samples, and sediment samples. A total of 22 environmental samples were collected from RMB, including surface and subsurface waste samples. A total of 13 environmental samples were collected from ADP, including surface waste samples, subsurface waste samples, surface water samples, and sediment samples. A total of four environmental surface waste samples were collected from FBS.

Waste sampling in all areas was conducted preferentially where waste (e.g., red mud or ash) had come to be located through disposal or migration and where it was currently exposed at the surface. Waste samples were collected using dedicated, disposable plastic scoops and aluminum trays. Surface waste samples were collected from the 0- to 3-inch depth interval. Subsurface waste samples were retrieved from the depths noted in Table 2 with decontaminated, stainless-steel bucket augers. Remaining waste material not used for field pH measurements or laboratory analysis was discarded at the sampling location.

Surface waste samples in all areas were obtained by collecting material directly from the surface using a dedicated, disposable plastic scoop. Surface waste material was scooped into dedicated, disposable aluminum trays and homogenized prior to filling respective sample containers.

Due to the dense, fine-grained, and dry composition of the waste material in the top portion of RMA, the proposed sample collection technique of coring or augering straight down from the surface proved prohibitive. The direct-push slam-bar coring device got stuck in the first hole, and the fine, dry material released from auger heads before it could be extracted to the surface. As a field modification, the subsurface waste samples in RMA were collected by augering into the sidewalls of exposed erosion channels at depths greater than 24 inches below the top of the channel. By augering into the side of erosion channels, subsurface waste samples could be collected diagonally or horizontally and required less material to auger through. Subsurface sample depths in this area are measured from the ground surface at the top of the pile directly above the sample. Subsurface waste material was collected into and homogenized in a dedicated, disposable aluminum tray before filling respective sample containers.

Subsurface waste samples in RMB and ADP were obtained by boring to a depth greater than 24 inches bgs with a bucket auger. The depth at which subsurface samples were collected was contingent upon the depth at which the auger encountered refusal. Once refusal was encountered by the auger, a second hole was bored adjacent to the first hole to a depth approximately one foot shallower than the refusal depth. At that point, a decontaminated bucket auger head was exchanged for the one used to bore to depth, and the subsurface sample was collected with the clean bucket auger at a depth just above refusal. Subsurface waste material was collected into and homogenized in a dedicated aluminum tray before filling respective sample containers.

Subsurface waste samples were not collected from the FBS area due to the absence of red mud waste material below 24 inches in the waste pile.

2.3.3 Surface Water/Sediment Sampling

EPA collected a total of 52 surface water samples and 52 sediment samples (the totals include environmental duplicate samples). Two of the surface water samples were collected from RMA. Sample SW-RMA-WST12 was collected from the ponded water at the top of the pile near waste sample location RMA-WST12. Sample RMA-SW57 was collected from the runoff flowing off the pile during a rainstorm on September 20, 2011.

Surface water samples were collected directly into the required containers, without the use of sampling devices, by submerging the bottles. Surface water samples were obtained from perimeter areas where water depths were shallow (i.e., less than 6 inches). The surface water samples from RMA were collected directly into sample containers from surface water sources (i.e., ponded water and runoff). At each specific location where both surface water and sediment samples were collected, surface water samples were collected prior to sediment samples.

Sediment samples were generally collected in correlation to surface water sample locations. Sediment samples were collected with dedicated, disposable plastic scoops from the 0- to 6-inch depth interval and were homogenized in dedicated, disposable aluminum trays prior to filling respective containers. Sediment samples from the RMA Depositional Area were retrieved with a stainless-steel bucket auger prior to homogenization and containerization. All remaining sediment not used for field pH measurements or laboratory analysis was discarded at the sampling location.

2.3.4 Ground Water Sampling

The EPA team collected a total of 11 unfiltered ground water samples and 11 filtered ground water samples (each total includes one environmental duplicate sample). Ground water samples were collected from existing on-site monitoring wells using low-flow sampling procedures. Wells were purged and sampled at a flow rate below 500 milliliters per minute (mL/min) with a bladder pump. Dedicated, disposable bladders and sample tubing were used for each well. During well purging, the following field indicator parameters were measured and recorded at 3- to 5-minute intervals: pH, temperature, dissolved oxygen (DO), and conductivity. Wells were purged until these indicator parameters stabilized for three consecutive readings. In-line analyzers and continuous readout displays were used. The bladder pump was decontaminated prior to sampling and between well sampling locations. Filtered ground water samples were collected through in-line, dedicated, disposable, 0.45-micron filter cartridges.

2.3.5 Blanks

Five rinsate blanks were collected to demonstrate adequate decontamination of non-dedicated sampling equipment. Deionized water was poured over the equipment (hand augers, bladder pumps) and into the sample containers. Four trip blank samples (in conjunction with the ground water samples for volatile organic compounds (VOC) analysis) were collected to demonstrate that atmospheric VOCs were not seeping into sample vials and that there was no cross-contamination between samples.

2.3.6 Decontamination

All non-dedicated sampling equipment involved in soil, waste, and ground water sampling activities (i.e., stainless-steel auger buckets and bladder pumps) was decontaminated prior to and between each sample location. Decontamination was conducted on location and all wastewater was collected into a 5-gallon bucket. The decontaminating procedure consisted of scrubbing the equipment with an Alconox and tap water solution to remove all visual contamination. The equipment was then generously washed with a deionized water pressure spray and allowed to air dry. Rinsate blanks were collected to demonstrate the adequacy of the decontamination procedures.

2.4 Sample Handling and Shipping

Based on a review of available literature on alumina extraction by the Bayer process, as well as existing site-specific information and analytical results, a WESTON dangerous goods (DG) shipping advisor determined that the radioactive and corrosive (high pH) natures of the red mud waste required the field team to ensure that samples offered for shipment by air transport were identified, labeled and packaged in accordance with current International Air Transport Association (IATA) regulations. The WESTON DG shipping advisor determined that the red mud samples from the Site would not be regulated for radiation per IATA regulations and that the radiation component would not have to be considered for shipping purposes. Therefore, pH was the determining factor for safe sample handling and shipping.

As described above in Section 2.3, the sampling team measured the pH of all samples collected during the ESI-RA sampling event. Samples that indicated a pH less than 11.0 were packaged and shipped to the laboratories as environmental samples, while samples with pH of 11.0 or greater were packaged and shipped as dangerous goods (corrosive solids, N.O.S.). Traffic reports (TR)/chain-of-custody (COC) forms, sample labels, custody seals, and other sample documents were completed as specified in the *EPA Contract Laboratory Program (CLP) Guidance for Field Samplers* (May 2010) and *OSWER Directive 9200.1-103, Inclusion of Scribe into the Role of Tracking Superfund Sampling Data* (November 2010).

Each sample container was labeled with sample ID, collection date and time, and required analyses. Aqueous samples for metals and radioactive element analyses were preserved with nitric acid (HNO₃) to pH less than 2. Aqueous samples for VOC analysis were preserved with hydrochloric acid (HCl) to pH less than 2. One custody seal signed by the sampling team was affixed across the closure of each sample container. Each container was sealed in a locking polyethylene bag and placed in a plastic cooler lined with a large plastic bag (i.e., garbage bag). Samples for organic, inorganic, chloride, and TOC analyses were packed with sufficient ice (sealed in polyethylene bags) to cool the samples to 4°C (ice preservation was not required for radiological or grain-size analyses). Non-combustible, adsorbent cushioning material was placed in the cooler to minimize the possibility of container breakage. The large plastic bag was then sealed, the cooler was closed, and custody seals and strapping tape were affixed to the outer packaging.

For shipping and safety purposes, each solid sample that indicated a pH greater than 11.0 was handled as corrosive solids. These samples were classified as follows: UN 3262, Class 8, Corrosive solid, basic, inorganic, n.o.s. (bauxite processing mixture), PG II, Packing instruction Y844, Limited Quantity. The maximum quantity per package (cooler) was 5 kilograms (kg) and the maximum quantity per inner container was 0.5 kg. All coolers were lined with a trash bag, padding, and ice (if required) per normal shipping procedures as described above. WESTON ensured that the outsides of sample containers, plastic bags, and shipping containers were free of red mud or other waste material. Labels on the coolers included a Class 8 sticker, a Limited

Quantity label, a WESTON address label with the laboratory name on it, and a label with the following: UN 3262 / Corrosive solid, basic, inorganic, n.o.s., (bauxite processing mixture) / Net Qty = X Kg, where X is the net weight of samples in the cooler.

With the exception of ground water samples SCA-GW06 and SCA-GW06F collected from monitoring well GM-22, aqueous samples (surface water, ground water, and blanks) were packaged and shipped as environmental samples due to pH levels below 11.0. Due to a pH reading of 12.78 for well GM-22, the unpreserved portions of the sample (TCL SVOCs and Aroclors) were classified as Corrosive liquid, basic, inorganic, n.o.s. (bauxite processing mixture) and were shipped accordingly inside U.N. Specification Packaging. The sample containers were taped shut, sealed within locking polyethylene bags, and packaged with ice and padding inside sealed metal cans. A maximum of four metal cans were packaged inside each appropriate cardboard box. Labels on these outer boxes included a Class 8 sticker, a WESTON address label with the laboratory name on it, and a label with the following: UN 1760 / Corrosive liquid, basic, inorganic, n.o.s., (bauxite processing mixture).

WESTON conducted screening with a Ludlum MicroR meter to confirm that radiation levels did not exceed 250 $\mu\text{R/hr}$ on the outside of any sample container or cooler. Sample coolers and boxes were shipped via common carrier (i.e., Federal Express) to the laboratories. Information relating to the shipment of samples, including the airbill number, sample quantity, and sample types, was reported to the EPA Sample Management Office on the day of or morning after each shipment.

WESTON maintained each sample on ice and under custody until the sample pH was recorded and the determination for shipping procedures completed. The chain-of-custody and sample dispatch information are presented in Tables 5, 6, and 7. Copies of the chain-of-custody records and associated shipping airbills are included in Appendix C.

2.5 Analytical Procedures

The following laboratory analytical procedures were used on this project:

- With a few exceptions, the samples collected in September 2011 were analyzed by the EPA Region 2 Laboratory (EPA-DESA) in Edison, New Jersey for TAL metals according to method EPA 200.7 / SOP C-109 and for mercury according to method EPA 245.1 / SOP C-110.
- All waste samples and selected background soil, surface water, sediment, and ground water samples were analyzed by the EPA National Air and Radiation Environmental Laboratory (EPA-NAREL) in Montgomery, Alabama for radiological characteristics. Solid samples were analyzed for radioisotopes of radium, thorium, and uranium by gamma spectroscopy (including Ra-226, Ra-228, Th-232, and U-238) and alpha spectroscopy (including Th-230, Th-232, U-234, U-235, and U-238). Aqueous samples

were analyzed for radioisotopes (including Ra-226, Ra-228, Th-230, Th-232, U-234, U-235, and U-238) and total uranium by alpha spectroscopy. The isotopic analyses by alpha spectroscopy are generally more accurate than the gamma spectroscopy analyses.

- Surface water and unfiltered ground water samples were analyzed by EPA-DESA for chloride according to Method EPA 300.0 / SOP C-94.
- Sediment samples were analyzed by EPA-DESA for total organic carbon (TOC) according to method EPA 415.1 mod / SOP C-88 and for grain-size distribution according to method ASTM D422-63 / BIO 8.3.
- Approximately 20 percent of the samples were analyzed by Chemtech Consulting Group (CHEMTECH) in Mountainside, New Jersey for Target Compound List (TCL) semivolatile organic compounds (SVOC) and Aroclors through the EPA Contract Laboratory Program (CLP) under Case No. 41746.
- Unfiltered ground water samples and trip blanks were analyzed by CHEMTECH for TCL VOCs under CLP Case No. 41746.

Table 2 shows the applicable laboratory analyses for all samples collected during the ESI-RA sampling event. The samples were received by the laboratories intact and under custody.

3 Physical Characteristics and Observations

This section describes the environmental setting for the Site, including hydrology and geology, and the observations recorded by EPA regarding Site and source conditions and overland drainage pathways. EPA identified and investigated several areas of environmental concern at the Site. Source areas used for disposal or abandonment of waste materials include the RMA, RMB, ADP, and FBS. Surface impoundments and other water bodies along the surface water migration pathway affected or threatened by contaminant migration include the RMS, UCP, LCP, west ditch (WES), coastal mangrove wetland areas, Alucroix Channel (ACC), and the Caribbean Sea. At the time of the EPA investigation in 2011, approximately 2.5 million gallons per day of process water from desalination and storm water flowed through the cooling ponds. The recent cessation of desalination in 2012 has reduced this flow to include only storm water. Photo Logs for the areas of concern at the Site are included in Appendix B. In addition to the areas of concern, impacts to ground water were investigated.

3.1 Source Areas

3.1.1 Red Mud Disposal Area A

RMA covers about 78 acres near the northwest corner of the Site (see Figure 3).. A graded toe road that defines the southern limits of RMA forms the crest of the original containment dike constructed prior to disposal of red mud within the area. RMA received estimated totals of 4,613,449 metric tons of red mud and 110,000 metric tons of ash. The RMA red mud pile exceeds elevations of 100 feet above MSL, and boreholes completed in 2006 indicated red mud thicknesses of 28 to 60 feet throughout RMA.

A release of red mud from RMA to the ocean and shoreline mangrove wetland areas via the west ditch was documented in 2002, and additional releases of red mud to mangrove wetland areas occurred in 2003. The releases occurred after SCA had performed unpermitted grading and recontouring work of the red mud storage area. Measurable quantities of red mud were observed to be deposited within mangrove wetland areas. Although runoff has since been rerouted, the persistent erosion problems from RMA continue. Storm water has created large erosion channels throughout most of RMA, and runoff water carries red mud off the pile in large quantities. The 2006 aerial photograph of the Site and observations made by EPA in June and September 2011 show the migration of red mud across the Site from RMA downslope to the interconnected on-site surface impoundments: the RMS, UCP, and LCP.

3.1.1.1 RMA Depositional Area

EPA observed a large area south of the RMA waste pile covered with up to 2.5 feet of red mud (designated herein as the RMA Depositional Area). During a rainstorm on September 20, 2011, EPA observed red mud-laden runoff flowing off the RMA pile, through the RMA Depositional Area, and into downstream water bodies. This runoff water flowing into and across the RMA Depositional Area exhibited a pH of 10.55. EPA collected eight waste/sediment samples (RMA-

SD57 to RMA-SD63 and RMS-SD47) for TAL metals analysis from seven locations within the RMA Depositional Area. The samples consisted of red mud and showed field pH levels as high as 10.48. Drainage through the RMA Depositional Area leads directly to the RMS and UCP.

3.1.2 Red Mud Disposal Area B

The RMB former disposal area covers approximately 81 acres in the center portion of the Site, south of the former refinery, and it surrounds ADP on three sides (see Figure 3). RMB, which was built on top of a mangrove swamp, consisted of seven disposal cells surrounded by perimeter dikes built of carbonate material. Excess caustic liquid from RMB drained to a dewatering pond in the southeastern part of the source area (i.e., the ADP). RMB received an estimated total of 1,229,149 metric tons of red mud during its years of operation. The April-May 2010 subsurface investigation by IST indicated red mud to depths greater than 24 feet in RMB. Elevated concentrations of arsenic, chromium, mercury, selenium, and vanadium were detected in the RMB waste and in monitoring wells GM-22. Elevated levels of arsenic and vanadium were also detected in monitoring well GM-18. The investigation also showed that the deposited red mud waste and associated shallow ground water maintain high pH levels. The Lagoonal Clay was encountered beneath the waste materials throughout the area. The aqueous samples collected from monitoring well GM-22, believed to represent red mud leachate in RMB above the clay confining layer, showed arsenic at 5,100 µg/L and a pH of 12.81.

The RMB disposal area is partially covered with top soil and a caliche capping layer, and some of it has revegetated, but there are several exposed areas of red mud and associated runoff routes. Drainage pathways from RMB include discharge pipes to the UCP on the north and west sides and discharge to the LCP along the southern edge. The southern drainage pathway is partially fed by a man-made drainage ditch that originates at ADP and flows south through areas of exposed red mud within RMB. Water levels in the available monitoring wells also suggest the possibility of an eastern component to shallow ground water flow from this portion of the Site toward Alucroix Channel.

3.1.3 Ash Disposal Pond

The ADP surface impoundment is located in the approximate center of the subject property and is surrounded on three sides by RMB (Figure 3). ADP was used for the disposal of ash from on-Site boilers. The total area of ADP is approximately 15 acres, the southeast corner of which consists of exposed ash with some vegetated areas; the remainder consists of an unlined disposal pond. The amount of ash deposited in ADP is unknown. During the April-May 2010 subsurface investigation by IST, black ash deposits were encountered as deep as 16 feet bgs. The volume of waste in the accessible portion of ADP (i.e., southeast corner) is conservatively estimated at 5,957 cubic yards (yd³). A drainage ditch leads south from ADP through RMB and ultimately to the LCP. Water levels in the available monitoring wells also suggest the possibility of an eastern component to shallow ground water flow from this portion of the Site toward Alucroix Channel.

3.1.4 Former Bauxite Storage Shed

FBS is a roofed storage shed with open sides that measures approximately 3.8 acres. FBS was formerly used for the storage of bauxite ore and currently contains a 1-acre pile of red mud, alumina, bauxite, and debris; the pile reaches a maximum height of about 15 feet. Red mud and alumina were transferred to FBS from piping and machinery at the time the facility was shut down. Although FBS is covered by a roof, observations made by EPA in September 2011 indicate that the roof leaks, that rainwater has caused erosion and migration of the stockpiled red mud, that red mud has breached a silt fence along the south side of the pile, and that erosion channels have cut through a containment berm. The primary drainage pathway from FBS flows south-southwest to a storm water basin. In addition to the overland drainage pathways, ground water flows south and east and discharges to Alucroix Channel just east of FBS.

3.2 Surface Water Migration Pathway

The primary overland drainage pathways to surface water at the Site flow south from RMA, through the RMA Depositional Area and Red Mud Settling Pond to the UCP, and subsequently to the LCP. The LCP discharges to Alucroix Channel via permitted outfall and possibly to the coastal mangrove wetland areas via culverts observed during the 2011 investigation. The discharge from the RMS to the northern end of the UCP is via outfall. Drainage from RMB also discharges west to the UCP and south to the LCP, and drainage from ADP flows south through RMB to the LCP. The drainage pathway from FBS is primarily south-southwest to a storm water basin.

3.2.1 Red Mud Settling Pond

The RMS receives red mud runoff from RMA and transports it to the cooling ponds. Observations made by EPA in June and September 2011 and aerial photos show the migration of red mud across the site from RMA downslope to the RMS. As described above, the RMS receives red-mud-laden runoff from the RMA waste pile. In turn, drainage through the RMS discharges via outfall to the UCP. During the September 2011 investigation, EPA observed large quantities of red mud throughout the RMS. Field pH levels in RMS ranged from 9.53 to 10.10 for aqueous samples and 9.68 to 10.48 for solid samples.

3.2.2 Upper Cooling Pond

The 30-acre UCP is a caliche-lined holding basin in the western portion of the property along the west edge of RMB. It was constructed along with the LCP in the 1970s for cooling of process water and retention of storm water. The alumina refinery pumped approximately 50 million gallons per day of seawater from Alucroix Channel, used it as cooling water, and subsequently discharged it to the cooling ponds. At the time of the EPA investigation in 2011, flow through the UCP and into the LCP (via spillway) was approximately 2.5 million gallons per day. The recent cessation of desalination in 2012 has reduced this flow to include only storm water. Red mud is present in significant quantities throughout the UCP.

3.2.3 Lower Cooling Pond

The 150-acre LCP is a caliche-lined holding basin in the low-elevation southern portion of the property along the southern edge of RMB. It was constructed along with the UCP in the 1970s for cooling of process water and retention of storm water. Red mud is present in significant quantities throughout the LCP. The LCP was initially constructed with 20 outfalls to Alucroix Channel and the Caribbean Sea, but silting problems occurred and one primary discharge point (TPDES Outfall 001A) to the ship channel has been used since 1981.

3.2.4 Overland Flow Pathways

Topography at the SCA site generally slopes south toward the Caribbean Sea (Figure 1). There are multiple drainage pathways to surface water from Site sources (Figure 3). Appendix B includes photo documentation depicting many of the overland drainage pathway features at the Site, in downstream order beginning at RMA.

The primary overland drainage pathways at the Site originate from RMA, flow south through the RMA Depositional Area and RMS to the UCP, and subsequently flow to the LCP. The discharge from the RMS to the northern end of the UCP is via outfall. The LCP discharges to Alucroix Channel via permitted outfall and possibly to the coastal mangrove wetland areas via culverts observed during the 2011 investigation. The historical drainage pathway to the West Ditch, which is classified as a perennial surface water body by VIDPNR, is also evaluated. The 2002-2003 red mud releases entered the northern end of the West Ditch, which historically flowed directly south through the coastal mangrove wetland areas to the Caribbean Sea, but was rerouted to the northwest corner of the LCP after the 2002-2003 releases.

The RMB disposal area was partially covered with limestone fill and some of it has revegetated, but there are several exposed areas and associated runoff routes. The aerial photograph and EPA observations document the erosion and migration of red mud from exposed areas within RMB. Drainage pathways from RMB include discharge pipes to the UCP on the north and west sides of RMB and discharge to the LCP along the southern edge. The southern drainage pathway is partially fed by a man-made drainage ditch that originates at ADP and flows south through areas of exposed red mud within RMB.

Although FBS is covered by a roof, observations made by EPA in September 2011 indicate that red mud has breached a silt fence along the south side of the pile and that erosion channels have cut through a containment berm. The primary drainage pathway from FBS flows south-southwest to a storm water basin. Water levels in the available monitoring wells also suggest the possibility of an eastern component to shallow ground water flow from RMB, ADP, and FBS toward Alucroix Channel.

3.2.5 Surface Water Pathway Receptors

The industrial development of the Site and neighboring industrial facilities in the 1960s resulted in the destruction of 260 hectares (642 acres) of mangrove wetland within the Krause Lagoon (i.e., Alucroix Channel). This former wetland complex was once the largest and most important on the south side of St. Croix in terms of high species diversity. Mangroves are legally-protected wildlife habitat in the USVI. A study of waterbird breeding populations conducted by VIDPNR determined that Krause Lagoon is one of the most highly ranked saline wetlands on St. Croix. According to the study, about 50 percent of mangrove and associated saline wetlands have either been degraded or destroyed as a result of coastal development, with the greatest loss occurring in Krause Lagoon. The data gathered by VIDPNR researchers suggested that Krause Lagoon was formerly the best lagoon habitat for waterbirds and several other species. Industrial development of Krause Lagoon resulted in the loss of habitat for up to four species of waterbirds, including the Least Bittern (*Ixobrychus exilis*), which is protected under the Migratory Bird Treaty Act (16 U.S. C. §§ 703-711). The LCP is surrounded by mangroves and remains an important habitat for waterbirds. EPA observed brown pelicans and snowy egrets in the LCP, including pelicans foraging for fish such as tilapia.

From September 9-16, 2011, WESTON personnel including a Certified Wetland Scientist performed reconnaissance to observe wetlands located at and in the vicinity of the Site. The observed wetlands were compared to wetlands mapping included in the U.S. Fish and Wildlife Service National Wetland Inventory (NWI) database. WESTON evaluated the type of vegetated wetlands along the surface drainage pathway for the Site per 40 CFR 230.3, and also evaluated the continuity of vegetated wetland frontage along water bodies including the UCP, LCP, Alucroix Channel, west ditch, and coastal areas. The WESTON wetland scientist observed hydric soils, wetland hydrology, and wetland vegetation (primarily mangroves) at all locations designated as wetlands in the NWI, including the UCP and LCP, the barrier island marsh/swamp complexes south and west of the LCP, and the red mangrove swamps located along both sides of Alucroix Channel. In addition, the west ditch was found to contain wetland areas, although it is not included as a wetland in the NWI. Wetland frontage was documented along the on-site water bodies, including the UCP, LCP, and west ditch (upper and lower sections).

The coastal area at the Site is a fishery. During the 2011 investigation, EPA observed a person fishing for consumption in the ocean near the location of the historical red mud release. Molasses Pier at the end of Alucroix Channel is also regularly used for fishing by the local population. These locations are part of fishing areas that extend along the entire south shore of St. Croix. Leatherback, green, and hawksbill sea turtle habitats are also located along the south shore of St. Croix. The green sea turtle is a federally-designated threatened species; the hawksbill and leatherback sea turtles are federally-designated endangered species.

3.3 Ground Water Pathway

The Site is underlain directly by the Kingshill aquifer, the principal source of ground water in St. Croix. The southern portion of the Site, including the red mud deposits in RMB, is underlain by an average of 12 feet of Lagoonal Clay that might impede downward migration of contaminants into the aquifer. Previous investigations have shown the presence of fresh water in the aquifer beneath the northern portion of the Site, with a transition zone leading to a sharp increase in salinity just north of the channel and RMB. The 1982 investigation by G&M indicated that baseline water quality at the Site is better than the Fairplain and Barren Spot well fields. A 1990 study indicated that there is a limited amount of usable ground water in the aquifer at the Site (up to about 100,000 gallons per day [gpd]) [TAHAL, 1990]. A follow-up study indicated that ten wells drilled in 1990 could produce up to 432,000 gpd of good-quality fresh water [Bioimpact, 1991]. These wells are not known to have been used except as irrigation for the north slope of RMA in the late 1990s [SSPAI, 2010].

3.3.1 Regional Geology

The island of St. Croix consists of two physiographic areas: (1) rugged hills and low mountains that make up the Northside Range and East End Range, and (2) low-lying to gently rolling hills of the Central Limestone Plain, in which the Site is located. The Northside and East End ranges are horst blocks consisting primarily of the Cretaceous-age Mount Eagle Group, a diverse assemblage of well-lithified, volcanogenic, sedimentary strata, as well as some early-Tertiary igneous intrusive rocks. The Central Limestone Plain is underlain by rocks of the Kingshill Basin, a graben structure filled with a series of poorly-lithified limestone formations of early Miocene to Pliocene age. In ascending order, the rock units of the Kingshill Basin include the Jealousy Formation, Kingshill Limestone (La Reine Member and Mannings Bay Member), and Blessing Formation. Although the deepest drilling of the Kingshill Basin is approximately 1,500 feet below land surface, the total thickness of sediments in the basin might approach 6,000 feet.

The relatively flat-lying rocks of the Kingshill Basin represent a shallowing sequence of marine deposition, from deep-water sediments to shelf and slope facies to reef and lagoon deposits. The early Miocene-age Jealousy Formation consists mainly of planktonic, foraminifera-rich muds, with some basal layers of calcareous conglomerate. A distinctive but unexplained color change marks the boundary between the dark, blue-gray to gray Jealousy Formation and the overlying light buff Kingshill Limestone of Miocene age.

The Kingshill Limestone consists of the basal La Reine Member, a lithologically diverse unit dominated by planktonic foraminiferal carbonate mud and marl, and the upper Mannings Bay Member, which consists of thinly-bedded limestone strata characterized by benthic foraminifera and shelf-derived carbonate clasts. The Blessing Formation of Pliocene age, which unconformably overlies the Mannings Bay Member along St. Croix's southern coast, consists of reef and shelf limestone with patchy zones of dolomitization. The Blessing Formation is thickest (up to 100 feet) at and in the immediate vicinity of the Site, in an area formed by a subsidiary

Pliocene-age graben structure. The Mannings Bay Member and Blessing Formation are coarser-grained than the underlying rocks (they contain poorly-lithified carbonate sand and gravel) and are more affected by diagenetic alteration. Clay-rich alluvium fills some karst cavities in the Blessing Formation and Mannings Bay Member at the Barren Spot well field located northeast of the Site.

Unconsolidated Quaternary-age deposits consisting of alluvial fan, debris flow, beach deposits, and lagoon sediments cover some areas of the central plain, primarily along the northern and southern margins. The alluvial-fan deposits along the Northside Range consist mainly of silt- or clay-rich material less than 30 feet in thickness. In addition, clayey to gravelly alluvium ranging in thickness from 30 to 80 feet fills Pleistocene-age stream valleys incised through the limestone. In some areas, the alluvium contains dark, terrigenous material derived from weathering of the Cretaceous rocks. In areas immediately overlying the Kingshill Limestone, the alluvium consists of light-colored, carbonate material derived from the limestone, and it is difficult to distinguish alluvium from the underlying formations. The Quaternary deposits are thickest (up to 130 feet) along the south coast and near the Site, where alluvium and lagoon deposits underlie the former Krause Lagoon [USGS, 2002].

3.3.2 Site Geology

The stratigraphic units encountered at the Site during previous subsurface investigations include Lagoonal Clay underlain by the Blessing Formation and Kingshill Limestone (i.e., the upper Kingshill aquifer). The northern portion of the Site, including most of RMA, is an outcrop area of the geologic units that make up the upper Kingshill aquifer, the Mannings Bay Member and Blessing Formation. Exposures of the upper Kingshill aquifer stratigraphic units can be observed in cuts and excavations at the Site and surrounding area. In the area south of RMA, Lagoonal Clay overlies the Blessing Formation in a wedge that thickens south toward the Caribbean Sea. The Lagoonal Clay, which has an average thickness of 12 feet beneath RMB, also contains lenses and layers of sand-rich material.

Table 8 provides the stratigraphic descriptions of the screened interval for numerous on-site monitoring wells. Existing monitoring well logs for the Site are included in Appendix D. Monitoring well and boring logs for the Site show that the wells are completed in a wide variety of carbonate deposits indicative of the poorly-lithified Kingshill aquifer. The descriptions include: limestone ranging from highly weathered to very hard; marl; carbonate sand, gravel, silt, and clay deposits, often with limestone fragments, cobbles, and lenses; caliche; and calcarenite. Color descriptions range from white to orange, and in some cases light grays. There is also a wide range of permeabilities reported, from very low permeability to very permeable. The deposits range from soft to very hard, and voids have been encountered in some boreholes. The Lagoonal Clay is present throughout the southern portion of the Site, but it has not been encountered throughout most of the northern portion of the Site. Weathered limestone of the

Blessing Formation was encountered beneath the Lagoonal Clay in at least one well (G-6) in the southeastern portion of the Site and in direct-push borings in RMB.

3.3.3 Hydrogeology

The principal aquifer on St. Croix is the Kingshill aquifer, which consists of the Kingshill Limestone and Blessing Formation. The Site is located in the outcrop area for the most permeable and porous section of the Kingshill aquifer. The upper Kingshill aquifer consists of the Blessing Formation and Mannings Bay Member, which are more permeable and porous than the underlying units. In formations below the upper aquifer, primary porosity is microscopic with coarser sediments having undergone cementation and recrystallization that destroyed the original permeability. Diagenetic factors such as dissolution of unstable minerals and karstification have affected the permeability of the upper Kingshill aquifer. The Kingshill can be difficult to distinguish from the overlying alluvium that's derived from the aquifer rocks.

Although the Kingshill aquifer is widespread in the Central Plain region, water production is patchy and is poor in large areas. Production in the aquifer is limited to areas where terrigenous components have allowed porosity to be preserved, or production stems from incursion of alluvial aquifers. Fractures within the Kingshill Limestone are also a potential source of water and have been developed in water supply drilling. Most large-yield wells completed in the Kingshill aquifer are also screened in alluvium that overlies or infills incised channels. The alluvial deposits serve as a temporary storage zone for rainfall, runoff, and ground water slowly entering the Kingshill aquifer. The transmissivity of the River Gut alluvial deposits ranges from 20-450 square meters per day (m^2/d). The Fairplain well field is located in this alluvial valley.

Ground water in the Kingshill aquifer beneath the Site is under water-table or semi-confined conditions and generally flows southward to the Alucroix Channel and Caribbean Sea. Water is generally within a few feet of mean sea level (MSL). Ground water in the Lagoonal Clay and fill materials above the Kingshill aquifer is at higher elevation, possibly indicating that there is infiltration to the Kingshill aquifer via a downward flow gradient or discharge to the ship channel and the Caribbean Sea. In 2010, seepage of ground water into the north end of Alucroix Channel and stalagmite-like encrustations at the discharge point were observed. The ship channel is considered to be a major ground water discharge location, with an estimated flow of 25 gallons per minute (gpm) into the northwestern portion of the channel.

In the area south of RMA, Lagoonal Clay overlies the Blessing Formation in a wedge that thickens to the south toward the Caribbean Sea. Previous subsurface investigations indicate that the Lagoonal Clay beneath RMB averages 12 feet in thickness and can be very dense, with hydraulic conductivities from 10^{-9} to 10^{-6} centimeters per second (cm/s). However, layers and lenses of sand and gravel have also been encountered within the Lagoonal Clay. Although the Lagoonal Clay underlies a significant portion of the Site, the majority of RMA is located north of the Lagoonal Clay and sits directly atop the Kingshill aquifer.

In addition to the on-site stratigraphy, the River Gut just west of the Site is an alluvial-filled stream valley. The Fairplain wells are primarily completed within the alluvium to depths of 57 to 105 feet.

Table 9 presents a summary of historical on-site ground water results for contaminants of concern (arsenic, chromium, mercury, selenium, and vanadium) and water quality parameters.

3.3.4 Aquifer Use and Usability

The Site is located in the outcrop area of the most permeable and porous section of St. Croix's principal aquifer. The large number of wells completed in the Kingshill aquifer attests mostly to its areal extent (approximately 30 square miles) and to the limited supply available from other sources rather than its production capabilities. The underlying Jealousy Formation is not a significant water producer and is considered the hydrologic basement, mainly due to declining water quality with increasing depth. The discontinuous alluvial aquifer is not a reliable source of ground water due to limited areal extent. Production of fractured bedrock wells in USVI has met limited success, with very low sustainable yields of less than 1.0 liter per second (L/s). Although the Kingshill aquifer does not have great water quality or production, it is the best of scarce ground water resources on the island.

In 1990, Tahal Consulting Engineers Ltd on behalf of VIALCO completed an assessment of potable ground water at the Site. This evaluation of two test wells (V-1 and V-2), drilled to 100 and 120 feet in the northeastern portion of the Site, indicated that there is a sufficient fresh water supply for approximately 110,000 gallons per day (gpd) at the Site and that the ground water quality in the aquifer at the Site was better than expected [TAHAL, 1990]. Further evaluation of aquifer characteristics, which included installation of ten additional wells (V-3 through V-12) and a pumping test in the northeastern portion of the Site, estimated a production level of 432,000 gpd of good-quality fresh water from the wells. The wells ranged in depth from 130 to 175 feet and were completed in limestone and marl. Well yields for nine of the ten wells ranged from 40 to 50 gallons per minute (gpm). Specific conductance upon drilling ranged from 1,200 to 2,400 micromhos per centimeter ($\mu\text{mhos/cm}$) and dropped significantly upon development and pumping [Bioimpact, 1991]. These wells are not known to have been used except as irrigation for the north slope of RMA in the late 1990s [SSPAI, 2010].

There are numerous inactive well fields located within the Site vicinity, the closest being the Fairplain well field to the west and the Barren Spot well field to the northeast. The chloride concentrations in the northern portion of the Site (generally 100 mg/L to 1,000 mg/L) are similar to those found in public supply wells that have been used for potable water withdrawal. For instance, Fairplain Well 6 showed chloride concentrations ranging from 258 mg/L to 540 mg/L during periodic monitoring by USGS from 1987 to 2001, and Barren Spot Well 7 showed chloride at 288 to 722 mg/L during the 1960s. USGS has reported that the Kingshill aquifer in St. Croix's south-central coast area is subject to industrial contamination or to saltwater intrusion if pumped heavily, and the island has transitioned largely to seawater desalination in recent

years. Although the public-supply wells are currently inactive, they are available for future use or emergency purposes. In addition, the aquifer is still used as a source of private potable water within 4 miles of the Site. Community supply wells serving the Pepper Tree Terrace and Mutual Homes housing complexes are located between 2 to 3 miles northeast and 3 to 4 miles northwest of the Site sources, respectively.

4 Analytical Results

The analytical results for the September 2011 EPA sampling event are presented in this section. The TCL organics results (VOCs, SVOCs, and Aroclors) did not show elevated concentrations in the on-site sources or pathways and are not included further in the discussion. Tables 10 through 16 present a complete set of the organic analytical results, separated according to sample type.

The inorganics results and radiological results, as well as chloride where applicable, are discussed below according to area of concern. Table 17 presents the minimum and maximum results for pH, arsenic, chromium, mercury, selenium, and vanadium within each area of concern and according to matrix (solid and aqueous). Tables 18 through 28 present pH values and the complete EPA-DESA data set, including inorganics, chloride, TOC, and grain size. Figures 6 through 10 present the arsenic, chromium, mercury, selenium, and vanadium results according to sample location type. Figure 11 presents the chloride results.

Tables 29 through 36 present the radiological screening results from the field investigation, while Figures 12 through 17 present the spatial distribution of the radiological screening results. Tables 37 through 43 present the radiological laboratory results, while Figures 18 and 19 show the spatial distribution of radiological laboratory results for background and on-site areas, respectively. The radiological screening and laboratory analytical results are discussed in further detail in the EPA report titled *Radiological Assessment Report, St. Croix Alumina (Renaissance Park) Site, St. Croix, U.S. Virgin Islands*, dated May 2012, which is included as Appendix E.

The gamma spectroscopy results for Th-232, Ra-226, and U-238 presented in this report were estimated using other radioisotopes with the assumption of secular equilibrium. The gamma spectroscopy results for Ra-228 presented in this report were estimated using the actinium-228 energy peak. Since the isotopic analyses by alpha spectroscopy are generally more accurate than the gamma spectroscopy analyses, only Ra-226 and Ra-228 results were evaluated from the gamma spectroscopy analyses along with the thorium and uranium alpha spectroscopy analyses.

The electronic files for the laboratory analytical results, including electronic data deliverables, are included on the data disc in Appendix F.

4.1 Background Soil

Inorganics:

EPA analyzed eight background soil samples (including one environmental duplicate) for TAL Metals. Surface soil samples BG-S01 through BG-S06 were collected from the 0- to 6-inch depth interval in the northeastern portion of the Site. Soil sample BG-SS02 was collected at the same location as BG-S02 from a depth of 16 inches bgs, which was the maximum auger refusal depth in the northeastern portion of the Site. Subsurface soil sample BG-S16A for TAL Metals analysis

was collected at a depth of 3.5 ft bgs from an area near the WWTP west of the Site. As shown below, the concentrations of Site-related contaminants were low relative to red mud and ash waste samples. Table 18 presents the metals results for background soil samples.

- Aluminum, iron, and sodium concentrations in background soil samples ranged from 3,100 to 30,000 mg/kg; 3,400 to 30,000 mg/kg; and 130 to 890 mg/kg, respectively.
- Arsenic was detected at concentrations ranging from 2.6 to 5.0 mg/kg in the northeastern background soil samples, and at 2.9 mg/kg in sample BG-S16A.
- Chromium was detected at concentrations ranging from 8.2 to 48 mg/kg in the northeastern background soil samples, and at 28 mg/kg in sample BG-S16A.
- Mercury concentrations in the northeastern background soil samples ranged from non-detect (three samples) to 0.128 mg/kg (this value was qualified for potential high bias). Mercury was not detected in sample BG-S16A.
- Vanadium was detected at concentrations ranging from 10 to 64 mg/kg in the northeastern background soil samples, and at 110 mg/kg in the background subsurface soil sample.
- Selenium, antimony, cadmium, and silver were not detected in any of the background soil samples.

Radiological Isotopes:

EPA analyzed 12 background soil samples (including one laboratory duplicate) for radium, thorium, and uranium isotopes. Surface soil samples BG-S01 and BG-S07 through BG-S15 were collected from the 0- to 6-inch depth interval in the northeastern portion of the Site. Sample BG-S16A for radiological analyses was collected from the 0- to 6-inch depth interval from the area near the WWTP west of the Site.

- Ra-226 results ranged from 0.03 to 0.57 pCi/g in the background soil samples, with an average result of 0.28 pCi/g.
- Ra-228 results ranged from 0.03 to 0.74 pCi/g in the background soil samples, with an average result of 0.34 pCi/g.
- Th-230 results ranged from 0.15 to 0.86 pCi/g in the background soil samples, with an average result of 0.46 pCi/g.
- Th-232 results ranged from 0.04 to 0.73 pCi/g in the background soil samples, with an average result of 0.36 pCi/g.

- U-234 results ranged from 0.04 to 0.33 pCi/g in the background soil samples, with an average result of 0.23 pCi/g.
- U-235 results ranged from 0.00 to 0.06 pCi/g in the background soil samples, with an average result of 0.02 pCi/g.
- U-238 results ranged from 0.12 to 0.34 pCi/g in the background soil samples, with an average result of 0.23 pCi/g.

4.2 Waste Materials

The contaminants of concern in the red mud waste deposited in both waste disposal areas (RMA and RMB), as well as the FBS, include arsenic, chromium, mercury, selenium, and vanadium, as well as antimony, cadmium, and silver. The red mud waste also contains elevated concentrations of aluminum, iron, and sodium. Radiological contaminants of potential concern include the isotopes of radium, thorium and uranium including Ra-226, Ra-228, Th-230, Th-232, U-234, U-235, and U-238. The primary radiological contaminant at the Site is associated with the Th-232 decay chain.

The contaminants of concern in the waste ash deposited in ADP are arsenic, mercury, and selenium, as well as antimony and cadmium. The ash contains elevated concentrations of sodium, but does not contain elevated levels of aluminum or iron. The chromium and vanadium concentrations in the ash samples were comparable to background soil concentrations. The radiological contaminants of potential concern in waste ash deposited in the ADP include the isotopes of radium, thorium, and uranium and were found to occur at levels that are one to two orders of magnitude lower than those observed in source areas RMA, RMB, and FBS.

4.2.1 Red Mud Disposal Area A

The EPA sampling team collected surface and subsurface waste samples consisting of red mud from the RMA pile. Field pH readings for the RMA red mud samples indicated pH values ranging from 9.45 to 12.52. The results confirm that the red mud waste material in RMA contains arsenic, chromium, mercury, selenium and vanadium, as well as antimony, cadmium, and silver. The analytical results confirm that radioisotopes are present above background in the red mud samples and that Th-232 and Ra-228 are the most prolific isotopes in the waste material.

Inorganics:

EPA analyzed 21 surface waste samples (including one environmental duplicate) and 20 subsurface waste samples (including one environmental duplicate) from RMA for TAL Metals. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depths of subsurface samples ranged from > 2 ft bgs to 8 ft bgs. All waste samples collected from RMA consisted of red mud. Table 19 presents the pH and metals results for RMA waste samples.

- Aluminum, iron, and sodium concentrations in the red mud samples collected from RMA ranged from 36,000 to 140,000 mg/kg; 170,000 to 380,000 mg/kg; and 4,400 to 95,000 mg/kg, respectively.
- Arsenic was detected in all waste samples collected from RMA, at concentrations ranging from 3.6 to 16 mg/kg in surface samples and 3.3 to 15 mg/kg in subsurface samples.
- Chromium was detected in all waste samples collected from RMA, at concentrations ranging from 280 to 870 mg/kg in surface samples and 250 to 1,500 mg/kg in subsurface samples.
- Mercury was detected in all waste samples collected from RMA, at concentrations ranging from 0.138 to 0.422 mg/kg in surface samples and 0.076 to 0.513 mg/kg in subsurface samples.
- Selenium was detected in nine surface waste samples collected from RMA, at concentrations ranging from 2.6 to 16 mg/kg. Selenium was not detected in subsurface samples from RMA.
- Vanadium was detected in all waste samples collected from RMA, at concentrations ranging from 490 to 1,300 mg/kg in surface samples and 470 to 790 mg/kg in subsurface samples.
- Antimony was detected at concentrations of 3.1 mg/kg in one surface sample and 3.1 to 7.4 mg/kg in four subsurface samples collected from RMA. Cadmium was detected at concentrations ranging from 0.35 to 1.6 mg/kg in seventeen surface samples and 0.9 to 1.7 mg/kg in five subsurface samples collected from RMA. Silver was detected at concentrations ranging from 0.58 to 1.6 mg/kg in seventeen surface samples and 0.9 to 1.3 mg/kg in five subsurface samples collected from RMA.

Radiological Isotopes:

EPA analyzed 23 surface waste samples (including one environmental duplicate) and 20 subsurface waste samples (including one environmental duplicate) from RMA for radium, thorium, and uranium isotopes. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depths of subsurface samples ranged from > 2 ft bgs to 8 ft bgs. All waste samples collected from RMA consisted of red mud.

- Ra-226 and Ra-228 results for the RMA waste samples ranged from 1.6 to 6.7 pCi/g and 10 to 24 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the samples ranged from approximately 11 to 27 pCi/g.
- Th-230 and Th-232 results for the RMA waste samples ranged from approximately 1 to 6 pCi/g and 5 to 22 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-

232 with background subtracted) in the samples ranged from approximately 6 to 25 pCi/g.

- U-234 results for the RMA waste samples ranged from 1.2 to 6.5 pCi/g, U-235 results ranged from non-detect to 0.30 pCi/g, and U-238 results ranged from 1.3 to 5.9 pCi/g.

4.2.1.1 RMA Depositional Area

The EPA sampling team collected surface sediment/waste samples consisting of red mud from RMA Depositional Area. Field pH readings for the RMAD samples ranged from 9.84 to 10.48, with the exception of a pH reading of 7.52 in sample RMA-SD61. The results confirm that the waste material in RMAD contains arsenic, chromium, mercury, selenium and vanadium, as well as antimony, cadmium, and silver. The analytical results confirm that radioisotopes are present above background and that Th-232 and Ra-228 are the most prolific isotopes.

Inorganics:

EPA analyzed seven surface sediment/waste samples (including one environmental duplicate) from RMAD for TAL Metals. The samples collected in this area consisted of red mud from the 0- to 6-inch depth interval. Table 20 presents the metals results for the RMAD samples.

- Aluminum, iron, and sodium concentrations in samples collected from RMAD ranged from 22,000 to 47,000 mg/kg, 130,000 to 380,000 mg/kg, and 1,100 to 21,000 mg/kg, respectively.
- Arsenic was detected at elevated concentrations in all waste samples collected from RMAD, at concentrations ranging from 7.8 to 18 mg/kg.
- Chromium was detected at elevated concentrations in all waste samples collected from RMAD, at concentrations ranging from 180 to 410 mg/kg.
- Mercury was detected at elevated concentrations in all waste samples collected from RMAD, at concentrations ranging from 0.137 to 0.469 mg/kg.
- Selenium was detected at elevated concentrations in six of seven waste samples collected from RMAD, at concentrations ranging from 2.3 to 3.7 mg/kg.
- Vanadium was detected at elevated concentrations in all waste samples collected from RMAD, at concentrations ranging from 400 to 980 mg/kg.
- Antimony was detected in all waste samples collected from RMAD, at concentrations ranging from 3.6 to 10 mg/kg. Cadmium was detected in four of seven waste samples collected from RMAD, at concentrations ranging from 0.34 to 0.61 mg/kg. Silver was detected in all waste samples collected from RMAD, at concentrations ranging from 0.61 to 1.3 mg/kg.

Radiological Isotopes:

EPA analyzed seven surface sediment/waste samples (including one environmental duplicate) from RMAD for radium, thorium, and uranium isotopes. The waste samples collected in this area consisted of red mud from the 0- to 6-inch depth interval.

- Ra-226 and Ra-228 results for the RMAD sediment/waste samples ranged from 0.8 to 3.1 pCi/g and 5 to 11 pCi/g. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the samples ranged from approximately 5 to 14 pCi/g.
- Th-230 and Th-232 results for the RMAD sediment/waste samples ranged from 0.6 to 1.8 pCi/g and 4 to 10 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the samples ranged from approximately 4 to 11 pCi/g.
- U-234 results for the RMAD sediment/waste samples ranged from 0.5 to 1.5 pCi/g, U-235 results ranged from non-detect to 0.2 pCi/g, and U-238 results ranged from 0.5 to 1.5 pCi/g.

4.2.2 Red Mud Disposal Area B

During the September 2011 sampling event, EPA collected surface and subsurface waste samples consisting of red mud from RMB. Field pH readings for the RMB waste samples ranged from 8.06 to 12.59. The results confirm that the red mud waste material in RMB contains arsenic, chromium, mercury, selenium and vanadium, as well as antimony, cadmium, and silver. The radiological results indicate that the red mud waste material in RMB contains isotopes of radium (Ra-228), thorium (Th-230, Th-232), and uranium (U-234, U-235, U-238).

Inorganics:

EPA analyzed 13 surface waste samples and 9 subsurface waste samples (including one environmental duplicate) from RMB for TAL Metals. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depths of subsurface samples ranged from 3 ft bgs to 10 ft bgs. All waste samples collected from RMB consisted of red mud. Table 21 presents the metals results for RMB waste samples. Table 21 presents the metals results for RMA waste samples.

- Aluminum, iron, and sodium concentrations in waste samples collected from RMB ranged from 18,000 to 150,000 mg/kg; 67,000 to 490,000 mg/kg; and 630 to 70,000 mg/kg, respectively.
- One sample, RMB-WST24A, indicated non-detect results for arsenic, mercury, and selenium, and low concentrations for chromium (16 mg/kg) and vanadium (37 mg/kg).

- Arsenic was detected in all other waste samples collected from RMB, at concentrations ranging from 6 to 21 mg/kg in surface samples and 7.4 to 17 mg/kg in subsurface samples.
- Chromium was detected in all other waste samples collected from RMB at elevated concentrations ranging from 250 to 1,800 mg/kg in surface samples and 180 to 970 mg/kg in subsurface samples.
- Vanadium was detected in all other waste samples collected from RMB, at elevated concentrations ranging from 490 to 1,300 mg/kg in surface samples and 470 to 790 mg/kg in subsurface samples.
- Mercury was detected at concentrations ranging from 0.045 to 0.348 mg/kg in nine surface samples and 0.055 to 0.075 mg/kg in three subsurface samples collected from RMB.
- Selenium was detected at a concentration of 3.1 mg/kg in one surface waste sample collected from RMB. Selenium was not detected in subsurface samples from RMB.
- Antimony was detected in four surface waste samples collected from RMB, at concentrations of 3.3 to 7.6 mg/kg. Cadmium was detected in four surface waste samples collected from RMB, at concentrations of 0.5 to 3.8 mg/kg. Antimony and cadmium were not detected in subsurface samples from RMB. Silver was detected at concentrations ranging from 0.73 to 3.1 mg/kg in six surface samples and 1.6 mg/kg in one subsurface sample collected from RMB.

Radiological Isotopes:

EPA analyzed 13 surface waste samples and 9 subsurface waste samples (including one environmental duplicate) from RMB for gamma spectroscopy and radiological isotope analyses for radium, thorium and uranium. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depths of subsurface samples ranged from 3 ft bgs to 10 ft bgs. All waste samples collected from RMB consisted of red mud.

- Ra-226 and Ra-228 results for the RMB waste samples ranged from 0.9 to 9 pCi/g and 7 to 25 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the samples ranged from approximately 8 to 29 pCi/g.
- Th-230 and Th-232 results for the RMB waste samples ranged from 1.1 to 9 pCi/g and 6 to 21 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the samples ranged from approximately 7 to 25 pCi/g.
- U-234 results for the RMB waste samples ranged from 1.1 to 6.3 pCi/g, U-235 results ranged from non-detect to 0.5 pCi/g, and U-238 results ranged from 0.8 to 7 pCi/g.

4.2.3 Ash Disposal Pond

The EPA team collected surface and subsurface waste samples consisting of ash from ADP. Field pH readings for the ADP waste samples ranged from 6.83 to 10.17. The results confirm that the ash waste material in ADP contains arsenic, mercury, and selenium, as well as antimony and cadmium. EPA also collected solid (sediment) and aqueous (surface water) samples for TAL metals and mercury analysis at the water's edge in ADP. The results confirm the presence of arsenic and mercury in solid samples and arsenic in the aqueous samples.

Inorganics:

EPA analyzed two surface waste samples and two subsurface waste samples (including one environmental duplicate) from ADP for TAL Metals. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depth of the duplicate subsurface samples was 4 ft bgs. All waste samples collected from ADP consisted of ash. Table 22 presents the metals results for ADP waste samples.

- Aluminum, iron, and sodium concentrations in waste samples collected from ADP ranged from 3,900 to 16,000 mg/kg; 5,900 to 27,000 mg/kg; and 7,000 to 27,000 mg/kg, respectively.
- Arsenic was detected in all waste samples collected from ADP, at concentrations of 30 and 35 mg/kg in the surface samples and 5.6 and 13 mg/kg in the duplicate subsurface samples.
- Mercury was detected in the surface waste samples collected from ADP, at concentrations of 0.094 and 0.218 mg/kg, but was not detected in the duplicate subsurface samples.
- Selenium was detected in all waste samples collected from ADP, at concentrations of 8.9 and 10 mg/kg in the surface samples and 10 and 11 mg/kg in the duplicate subsurface samples.
- Chromium and vanadium were detected in the waste samples collected from ADP, but at relatively low concentrations ranging from 7.3 to 23 mg/kg and 22 to 99 mg/kg, respectively. These concentrations are comparable to the background soil concentrations presented in Section 4.2.
- Antimony (4.0 and 4.5 mg/kg) and cadmium (0.41 and 0.57 mg/kg) were detected in the surface waste samples collected from ADP, but were not detected in the subsurface samples. Silver was not detected in the waste samples collected from ADP.

Radiological Isotopes:

EPA analyzed two surface waste samples, three subsurface waste samples (including one environmental duplicate), and one sediment sample from ADP for gamma spectroscopy and radiological isotope analyses for radium, thorium and uranium. The surface waste samples were collected from the 0- to 3-inch depth interval, and the depth of the duplicate subsurface samples was 4 ft bgs. All waste samples collected from ADP consisted of ash.

- Ra-226 and Ra-228 results for the ADP waste and sediment samples ranged from 0.6 to 1.6 pCi/g and 0.7 to 1.3 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the samples ranged from approximately 0.6 to 1.6 pCi/g.
- Th-230 and Th-232 results for the ADP waste and sediment samples ranged from 0.6 to 1.9 pCi/g and approximately 1 to 1 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the samples ranged from approximately 1 to 2.5 pCi/g.
- U-234 results for the ADP waste and sediment samples ranged from 0.6 to 1.5 pCi/g, U-235 results ranged from non-detect to 0.1 pCi/g, and U-238 results ranged from 0.6 to 1.4 pCi/g.

4.2.4 Former Bauxite Storage Shed

EPA collected surface waste samples consisting of red mud from FBS and from an overland migration pathway behind the shed. Field pH readings for the FBS waste samples ranged from 9.02 to 10.93. The inorganic results show that the red mud waste material at the surface of the FBS pile and running off the pile contains arsenic, chromium, mercury, selenium, and vanadium, as well as antimony, cadmium, and silver. The radiological results of surface waste samples collected from the FBS pile indicate that isotopes of radium (Ra-228), thorium (Th-230, Th-232), and uranium (U-234, U-235, U-238) are present in the waste material.

Inorganics:

EPA analyzed four surface waste samples from FBS for TAL Metals. Three samples were collected from the 0- to 3-inch depth interval of the waste pile in the shed, and one sample was collected from the 0- to 3-inch depth interval of the drainage pathway south of the shed. All waste samples collected from FBS consisted of red mud. Table 23 presents the metals results for FBS waste samples.

- Aluminum, iron, and sodium concentrations in the red mud samples collected from FBS ranged from 68,000 to 100,000 mg/kg; 62,000 to 220,000 mg/kg; and 5,100 to 110,000 mg/kg, respectively.

- Arsenic was detected in the FBS waste pile samples at concentrations ranging from 12 to 47 mg/kg and in the drainage pathway sample at 6.3 mg/kg.
- Chromium was detected in the FBS waste pile samples at concentrations ranging from 140 to 240 mg/kg and in the drainage pathway sample at 99 mg/kg.
- Mercury was detected in the FBS waste pile samples at concentrations ranging from 0.136 to 0.236 mg/kg and in the drainage pathway sample at 0.098 mg/kg.
- Selenium was detected in the FBS waste pile samples at concentrations ranging from 2.4 to 3.2 mg/kg, but was not detected in the drainage pathway sample.
- Vanadium was detected in the FBS waste pile samples at concentrations ranging from 460 to 660 mg/kg and in the drainage pathway sample at 180 mg/kg.
- Antimony was detected in two FBS waste pile samples at concentrations of 4.1 and 6.0 mg/kg. Cadmium was detected in the FBS waste pile samples at concentrations ranging from 0.56 to 0.87 mg/kg and in the drainage pathway sample at 0.72 mg/kg. Silver was detected in the FBS waste pile samples at concentrations ranging from 0.81 to 1.2 mg/kg. Antimony and silver were not detected in the drainage pathway sample.

Radiological Isotopes:

EPA collected four surface waste samples from FBS for gamma spectroscopy and radiological isotope analyses for radium, thorium and uranium. Three samples were collected from the 0- to 3-inch depth interval of the waste pile in the shed, and one sample was collected from the 0- to 3-inch depth interval of the drainage pathway south of the shed. All waste samples collected from FBS consisted of red mud.

- Ra-226 and Ra-228 results for the FBS waste samples ranged from 1.0 to 2.1 pCi/g and 5 to 10 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the FBS waste pile samples ranged from approximately 7 to 12 pCi/g, and the sum of radium in the drainage pathway sample was 5.1 pCi/g.
- Th-230 and Th-232 results for the FBS waste samples ranged from 0.9 to 2.3 pCi/g and 4 to 10 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the FBS waste pile samples and drainage pathway sample ranged from approximately 5 to 12 pCi/g.
- U-234 results for the FBS waste samples ranged from 0.9 to 2.6 pCi/g, U-235 results ranged from non-detect to 0.1 pCi/g, and U-238 results ranged from 0.7 to 2.4 pCi/g.

4.3 *Surface Water/Sediment*

EPA collected a total of 52 surface water samples and 52 sediment samples (the totals include environmental duplicate samples). Two of the surface water samples were collected from RMA. Sample SW-RMA-WST12 was collected from the ponded water at the top of the pile near waste sample location RMA-WST12. Sample RMA-SW57 was collected from the runoff flowing off the pile during a rainstorm on September 20, 2011. Table 24 presents the metals and chloride results for surface water samples, including a comparison to Ambient Water Quality Criteria (AWQC), as expressed by the national recommended Criterion Continuous Concentration (CCC) for protection of aquatic life in saltwater promulgated under Section 304(a)(1) of the Clean Water Act. Table 25 presents the metals results for sediment samples.

4.3.1 **Background Surface Water/Sediment Sample Locations**

Inorganics:

EPA analyzed four surface water samples designated as background for TAL Metals. Another sample collected from the intake channel on the east side of Alucroix Channel is also considered to represent background conditions. Surface water sample location BG-SW53, which showed elevated concentrations of arsenic, chromium, and vanadium compared to other background locations, was collected along the coast west of the site and near the municipal landfill. Therefore, it is unknown if the elevated concentrations at this location are Site-related.

- Aluminum, iron, and sodium concentrations in the background surface water samples ranged from 460 to 28,000 µg/L; 640 to 51,000 µg/L; and 98,000 to 8,400,000 µg/L, respectively.
- Arsenic was detected at a concentration of 85 µg/L in surface water sample BG-SW53, but was not detected in the other background surface water samples.
- Chromium was detected at concentrations of 7.7 and 75 µg/L in surface water samples BG-SW55 and BG-SW53, respectively, but was not detected in the other background surface water samples.
- Vanadium was detected in three of four background surface water samples, at concentrations ranging from 22 to 270 µg/L.
- Mercury, selenium, antimony, cadmium, and silver were not detected in the background surface water samples.

EPA analyzed five background sediment samples for TAL Metals, including sample ACC-SD52.

- Aluminum, iron, and sodium concentrations in the background sediment samples ranged from 3,500 to 17,000 mg/kg; 4,500 to 24,000 mg/kg; and 1,400 to 4,300 mg/kg, respectively.

- Arsenic was detected in the background sediment samples at concentrations ranging from 1.2 to 5.5 mg/kg.
- Chromium was detected in the background sediment samples at concentrations ranging from 9.6 to 27 mg/kg.
- Vanadium was detected in the background sediment samples at concentrations ranging from 18 to 110 mg/kg.
- Mercury, selenium antimony, cadmium, and silver were not detected in the background sediment samples.

Radiological Isotopes:

EPA did not analyze the background surface water or sediment samples for gamma spectroscopy or radiological isotope analyses, nor did EPA perform radiological screening in this area.

4.3.2 Red Mud Disposal Area A

Inorganics:

EPA analyzed one surface water runoff sample (RMA-SW57) from RMA for TAL Metals. The sample was visibly laden with red mud and its pH was measured at 10.55.

- Aluminum, iron, and sodium concentrations in the surface water runoff sample were 280,000 µg/L; 500,000 µg/L; and 1,200,000 µg/L, respectively.
- Arsenic was detected at a concentration of 150 µg/L in the surface water runoff sample.
- Chromium was detected at a concentration of 2,900 µg/L in the runoff sample.
- Selenium was detected at a concentration of 54 µg/L in the runoff sample.
- Vanadium was detected at a concentration of 5,200 µg/L in the runoff sample.
- Mercury was detected at a concentration of 0.710 µg/L in the runoff sample.
- Antimony, cadmium, and silver were not detected in the surface water runoff sample.

Radiological Isotopes:

EPA analyzed surface water runoff sample RMA-SW57 and ponded water sample SW-RMA-WST12 from RMA for gamma spectroscopy and radiological isotope analyses for radium, thorium, and uranium. The pH of sample RMA-SW57 was measured at 10.55 and the pH of sample SW-RMA-WST12 was measured at 10.43.

- Ra-226 and Ra-228 results for runoff sample RMA-SW57 were 6 and 21 pCi/L, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228) in the sample was approximately 27 pCi/L.
- Ra-226 and Ra-228 results for ponded water sample SW-RMA-WST12 were 0.5 and 5 pCi/L, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228) in the sample was approximately 6 pCi/L.
- Th-230 and Th-232 results for runoff sample RMA-SW57 were 0.54 and 3.4 pCi/L, respectively.
- Th-230 and Th-232 results for ponded water sample SW-RMA-WST12 were non-detect and 0.31 pCi/L, respectively.
- U-234, U-235, and U-238 results for runoff sample RMA-SW57 were 5.1 pCi/L, non-detect, and 3.5 pCi/L, respectively.
- U-234, U-235, and U-238 results for ponded water sample SW-RMA-WST12 were 5 pCi/L, non-detect, and 2.5 pCi/L, respectively.

4.3.3 Red Mud Settling Pond

Inorganics:

EPA analyzed four surface water samples (including one environmental duplicate) from RMS for TAL Metals. Red mud was visually observed at all sample locations. Water was not present at location RMS-SW47 during sample collection.

- Aluminum, iron, and sodium concentrations in surface water samples collected from RMS ranged from 10,000 to 94,000 µg/L; 1,200 to 52,000 µg/L; and 460,000 to 2,800,000 µg/L, respectively.
- Arsenic was detected at concentrations ranging from 29 to 160 µg/L in the surface water samples collected from RMS.
- Chromium was detected at concentrations ranging from 430 to 16,000 µg/L in the surface water samples collected from RMS.
- Selenium was detected at concentrations ranging from 55 to 650 µg/L in three surface water samples collected from RMS; sample RMS-SW46 was non-detect.
- Vanadium was detected at concentrations ranging from 1,300 to 4,500 µg/L in the surface water samples collected from RMS.

- Mercury, antimony, cadmium, and silver were not detected in the surface water samples collected from RMS.

EPA analyzed five sediment samples (including one environmental duplicate) from RMS for TAL Metals. Red mud was visually observed in all RMS sediment samples.

- Aluminum, iron, and sodium concentrations in the RMS sediment samples ranged from 38,000 to 74,000 mg/kg; 120,000 to 340,000 mg/kg; and 16,000 to 33,000 mg/kg, respectively.
- Arsenic was detected in the RMS sediment samples at concentrations ranging from 7 to 15 mg/kg.
- Chromium was detected in the RMS sediment samples at concentrations ranging from 360 to 480 mg/kg.
- Mercury was detected in the RMS sediment samples at concentrations ranging from 0.14 to 0.338 mg/kg.
- Selenium was detected at a concentration of 2.7 mg/kg in sediment sample RMS-SD47, but was not detected in the other RMS sediment samples.
- Vanadium was detected in the RMS sediment samples at concentrations ranging from 370 to 1,100 mg/kg.
- Cadmium was detected in the RMS sediment samples at concentrations ranging from 0.68 to 4.4 mg/kg. Antimony and silver were not detected in the RMS sediment samples.

Radiological Isotopes:

EPA analyzed one surface water sample (RMS-SW45) and one sediment sample (RMS-SD45) from RMS for gamma spectroscopy and radiological isotope analyses for radium, thorium, and uranium.

- Ra-226 and Ra-228 results for surface water sample RMS-SW45 were 1.4 and 16 pCi/L, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228) in the sample was approximately 18 pCi/L.
- Ra-226 and Ra-228 results for sediment sample RMS-SD45 were 3.3 and 12 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the sample was approximately 15 pCi/g.
- Th-230 and Th-232 results for surface water sample RMS-SW45 were 0.54 and 1.66 pCi/L, respectively.

- Th-230 and Th-232 results for sediment sample RMS-SD45 were 2.0 and 10 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the sample was approximately 11 pCi/g.
- U-234, U-235, and U-238 results for surface water sample RMS-SW45 were 9 pCi/L, 0.5 pCi/L, and 5 pCi/L, respectively.
- U-234, U-235, and U-238 results for sediment sample RMS-SD45 were 2.0 pCi/g, non-detect, and 1.8 pCi/g, respectively.

4.3.4 Upper Cooling Pond

Inorganics:

EPA analyzed eight surface water samples from UCP for TAL Metals. Red mud was visually observed at all sample locations.

- Aluminum, iron, and sodium concentrations in surface water samples collected from UCP ranged from 230 to 74,000 µg/L; 110 to 29,000 µg/L; and 9,100,000 to 13,000,000 µg/L, respectively.
- Arsenic was detected in seven of eight surface water samples collected from UCP, at concentrations ranging from 9.8 to 27 µg/L.
- Chromium was detected at concentrations ranging from 150 to 780 µg/L in the surface water samples collected from UCP.
- Selenium was detected at a concentration of 37 µg/L in surface water sample UCP-SW37, but was not detected in the other UCP surface water samples.
- Vanadium was detected at concentrations ranging from 45 to 1,500 µg/L in the surface water samples collected from UCP.
- Mercury, antimony, cadmium, and silver were not detected in the surface water samples collected from UCP.

EPA analyzed eight sediment samples from UCP for TAL Metals. Red mud was visually observed in all UCP sediment samples.

- Aluminum, iron, and sodium concentrations in the UCP sediment samples ranged from 49,000 to 86,000 mg/kg; 44,000 to 180,000 mg/kg; and 13,000 to 60,000 mg/kg, respectively.
- Arsenic was detected in the UCP sediment samples at concentrations ranging from 8.1 to 26 mg/kg.

- Chromium was detected in the UCP sediment samples at concentrations ranging from 220 to 550 mg/kg.
- Mercury was detected in the UCP sediment samples at concentrations ranging from 0.076 to 0.314 mg/kg.
- Vanadium was detected in the UCP sediment samples at concentrations ranging from 330 to 640 mg/kg.
- Cadmium was detected in three of eight UCP sediment samples, at concentrations ranging from 0.97 to 1.3 mg/kg. Silver was detected at a concentration of 1.1 mg/kg in sample UCP-SD38, but was not detected in the other UCP sediment samples.
- Selenium and antimony were not detected in the UCP sediment samples.

Radiological Isotopes:

EPA analyzed two surface water samples and three sediment samples from UCP for gamma spectroscopy and radiological isotope analyses for radium, thorium, and uranium.

- Ra-226 and Ra-228 results for UCP surface water samples ranged from 0.2 to 0.7 pCi/L and 1.0 to 10 pCi/L, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228) in the samples ranged from approximately 1.2 to 11 pCi/g.
- Ra-226 and Ra-228 results for UCP sediment samples ranged from 0.5 to 3.2 pCi/g and 2.4 to 13 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the samples ranged from approximately 2 to 15 pCi/g.
- Th-230 and Th-232 results for UCP surface water samples ranged from non-detect to 0.4 pCi/L and non-detect to 1.8 pCi/L, respectively.
- Th-230 and Th-232 results for UCP sediment samples ranged from 0.9 to 2.7 pCi/g and 3 to 10 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the samples ranged from approximately 3 to 12 pCi/g.
- U-234 results for UCP surface water samples ranged from 1.2 to 1.9 pCi/L, U-235 results ranged from non-detect to 0.3 pCi/L, and U-238 results ranged from 1.0 to 1.4 pCi/L.
- U-234 results for UCP sediment samples ranged from 2.8 to 3.3 pCi/g, U-235 results ranged from approximately 0.2 to 0.2 pCi/g, and U-238 results ranged from 2.5 to 2.8 pCi/g.

4.3.5 Lower Cooling Pond

Inorganics:

EPA analyzed eight surface water samples from LCP for TAL Metals. Red mud was visually observed at sample locations LCP-SW31, LCP-SW32, and LCP-SW33.

- Aluminum, iron, and sodium concentrations in surface water samples collected from LCP ranged from non-detect to 15,000 µg/L; non-detect to 8,700 µg/L; and 3,800,000 to 9,300,000 µg/L, respectively.
- Arsenic was detected at concentrations ranging from 19 to 220 µg/L in the surface water samples collected from LCP.
- Chromium was detected in five of eight surface water samples collected from LCP, at concentrations ranging from 17 to 240 µg/L.
- Selenium was detected at a concentration of 25 µg/L in surface water sample LCP-SW30, but was not detected in the other LCP surface water samples.
- Vanadium was detected at concentrations ranging from 130 to 2,200 µg/L in the surface water samples collected from LCP.
- Mercury, antimony, cadmium, and silver were not detected in the surface water samples collected from LCP.

EPA analyzed eight sediment samples from LCP for TAL Metals. Red mud was visually observed in samples LCP-SD31, LCP-SD32, and LCP-SD33.

- Aluminum, iron, and sodium concentrations in the LCP sediment samples ranged from 9,800 to 95,000 (J) mg/kg; 5,200 to 41,000 (J) mg/kg; and 5,100 to 56,000 (J) mg/kg, respectively.
- Arsenic was detected in the LCP sediment samples at concentrations ranging from 5.2 to 34 (J) mg/kg.
- Chromium was detected in the LCP sediment samples at concentrations ranging from 35 to 570 (J) mg/kg.
- Selenium was detected in two of eight sediment samples collected from LCP, at concentrations of 1.7 mg/kg (LCP-SD28) and 2.9 mg/kg (LCP-SD30).
- Vanadium was detected in the LCP sediment samples at concentrations ranging from 110 to 590 (J) mg/kg.

- Mercury, antimony, cadmium, and silver were not detected in the LCP sediment samples.

Radiological Isotopes:

EPA analyzed one sediment sample (LCP-SD33) from the LCP for gamma spectroscopy and radiological isotope analyses for radium, thorium and uranium. The sample was collected from the 0- to 3-inch depth interval. Red mud was present in the sample. Surface water samples were not collected from the LCP for gamma spectroscopy or radiological isotope analyses.

- Ra-226 and Ra-228 results for sediment sample LCP-SD33 were 0.1 and 0.3 pCi/g, respectively. The sum of radium (i.e., sum of Ra-226 and Ra-228 with background subtracted) in the sample was approximately 0 pCi/g.
- Th-230 and Th-232 results for sediment sample LCP-SD33 were 0.3 and 0.4 pCi/g, respectively. The sum of thorium (i.e., sum of Th-230 and Th-232 with background subtracted) in the sample was approximately 0.4 pCi/g.
- U-234, U-235, and U-238 results for sediment sample LCP-SD33 were 3.7 pCi/g, 0.2 pCi/g, and 3.4 pCi/g, respectively.

4.3.6 West Ditch

Inorganics:

EPA analyzed three surface water samples (including one environmental duplicate) from WES for TAL Metals. Red mud was visually observed at sample location WES-SW22/WES-SW23. Water was not present at location WES-SW25, where red mud was also visually observed.

- Aluminum, iron, and sodium concentrations in surface water samples collected from WES ranged from 310 to 1,200 µg/L; 470 to 1,800 µg/L; and 5,800,000 to 6,900,000 µg/L, respectively.
- Arsenic, chromium, mercury, selenium, vanadium, antimony, cadmium, and silver were not detected in the surface water samples collected from WES.

EPA analyzed four sediment samples (including one environmental duplicate) from WES for TAL Metals. Red mud was visually observed in samples WES-SD22/WES-SD23 and WES-SD25.

- Aluminum, iron, and sodium concentrations in the WES sediment samples ranged from 24,000 to 41,000 mg/kg; 26,000 to 55,000 mg/kg; and 1,100 to 26,000 mg/kg, respectively.

- Arsenic was detected in the WES sediment samples at concentrations ranging from 4.0 to 8.1 mg/kg.
- Chromium was detected in the WES sediment samples at concentrations ranging from 33 to 160 mg/kg.
- Mercury was detected at a concentration of 0.049 mg/kg in sediment sample WES-SD23, but was not detected in duplicate sample WES-SD22 or the other WES sediment samples.
- Vanadium was detected in the WES sediment samples at concentrations ranging from 110 to 210 mg/kg.
- Silver was detected at a concentration of 0.73 mg/kg in sediment sample WES-SD25.
- Selenium, antimony, and cadmium were not detected in the WES sediment samples.

Radiological Isotopes:

EPA did not analyze any surface water or sediment samples from the West Ditch for gamma spectroscopy or radiological isotope analyses. Radiological screening results in the West Ditch were similar to screening results recorded in background areas.

4.3.7 Coastal Mangrove Areas

Inorganics:

EPA analyzed thirteen surface water samples from MAN for TAL Metals. Red mud was visually observed at sample locations MAN-SW17 and MAN-SW20.

- Aluminum, iron, and sodium concentrations in surface water samples collected from MAN ranged from 120 to 24,000 µg/L; non-detect to 28,000 µg/L; and 540,000 to 11,000,000 µg/L, respectively.
- Arsenic was detected in eleven of thirteen MAN surface water samples, at concentrations ranging from 8.0 (J) to 41 µg/L.
- Chromium was detected in five of thirteen MAN surface water samples, at concentrations ranging from 5.6 to 71 µg/L.
- Vanadium was detected in eight of thirteen MAN surface water samples, at concentrations ranging from 20 to 110 µg/L.
- Mercury, selenium antimony, cadmium, and silver were not detected in the surface water samples collected from MAN.

EPA analyzed thirteen sediment samples from MAN for TAL Metals. Red mud was visually observed in samples MAN-SD17 and MAN-SD20.

- Aluminum, iron, and sodium concentrations in the MAN sediment samples ranged from 790 to 34,000 (J) mg/kg; 1,000 to 50,000 mg/kg; and 5,400 to 48,000 (J) mg/kg, respectively.
- Arsenic was detected in the MAN sediment samples at concentrations ranging from 2.8 (J) to 18 mg/kg. Sample MAN-SD19 showed the highest arsenic concentration.
- Chromium was detected in the MAN sediment samples at concentrations ranging from 3.9 to 140 (J) mg/kg. Sample MAN-SD20 near the former west ditch showed the highest chromium concentration.
- Cadmium was detected at a concentration of 0.7 mg/kg in sediment sample MAN-SD19, but was not detected in the other MAN sediment samples.
- Vanadium was detected in the MAN sediment samples at concentrations ranging from 10 to 210 (J) mg/kg. Sample MAN-SD20 near the former west ditch showed the highest vanadium concentration.
- Mercury, selenium, antimony, and silver were not detected in the MAN sediment samples.

Radiological Isotopes:

EPA did not analyze any surface water or sediment samples from the Coastal Mangrove Area for gamma spectroscopy or radiological isotope analyses. Radiological screening results in the West Ditch were similar to screening results recorded in background areas.

4.3.8 Alucroix Channel

Inorganics:

EPA analyzed five surface water samples from the western edge of ACC for TAL Metals. Red mud was not visibly apparent at the ACC sample locations.

- Aluminum was not detected in the surface water samples collected from ACC. Iron and sodium concentrations in ACC surface water samples ranged from non-detect to 140 µg/L and 8,700,000 to 10,000,000 µg/L, respectively.
- Arsenic was detected at concentrations of 8.5 and 11 µg/L in surface water samples ACC-SW01 and ACC-SW07, respectively. Arsenic was not detected in samples ACC-SW04, ACC-SW05, and ACC-SW06.

- Chromium, mercury, selenium, vanadium, antimony, cadmium, and silver were not detected in the surface water samples collected from ACC.

EPA analyzed five sediment samples from the western edge of ACC for TAL Metals. Red mud was not visibly apparent in the ACC sediment samples. The furthest downstream sample at the mouth of the channel (ACC-SD01) showed lower concentrations than the samples collected closer to Site sources.

- Aluminum, iron, and sodium concentrations in the ACC sediment samples ranged from 1,100 to 25,000 mg/kg; 1,100 to 69,000 mg/kg; and 4,100 to 35,000 mg/kg, respectively.
- Arsenic was detected in the ACC sediment samples at concentrations ranging from 2.2 to 12 mg/kg.
- Chromium was detected in the ACC sediment samples at concentrations ranging from 7.0 to 51 mg/kg.
- Mercury was detected at a concentration of 0.062 mg/kg in sediment sample ACC-SD07, but was not detected in the other ACC sediment samples.
- Selenium was detected at a concentration of 3.4 mg/kg in sediment sample ACC-SD05, but was not detected in the other ACC sediment samples.
- Vanadium was detected in the ACC sediment samples at concentrations ranging from 8.2 to 130 mg/kg.
- Antimony (2.4 mg/kg), cadmium (0.48 mg/kg), and silver (1.8 mg/kg) were detected in sediment sample ACC-SD06, but were not detected in the other ACC sediment samples.

Radiological Isotopes:

EPA did not analyze any surface water or sediment samples from Alucroix Channel for gamma spectroscopy or radiological isotope analyses, nor did EPA perform radiological screening in this area.

4.4 Ground Water

The EPA team collected a total of 11 unfiltered ground water samples and 11 filtered ground water samples (each total includes one environmental duplicate sample) from ten existing on-site monitoring wells.

Inorganics:

EPA analyzed unfiltered and filtered ground water samples (including one environmental duplicate for each) from ten on-site monitoring wells for TAL Metals.

- The reported concentrations of calcium, magnesium, manganese, potassium, and chloride confirm the location of the freshwater/saltwater interface in the Kingshill aquifer approximately at the north end of Alucroix Channel and RMB. The wells are categorized as saltwater (GM-19), freshwater/saltwater mixture (G-11, GM-14), or freshwater (G-9, GM-13D, GM-18, GM-22, VW16, VW25, and VW37). The freshwater chemistry in wells GM-18 and GM-22, both of which are screened at least partially in fill above the Lagoonal Clay, is believed to result from a perched water or mounding situation. High sodium concentrations in well GM-22 are indicative of process seawater leaching from the RMB waste material rather than saltwater interface impacts.
- Samples from monitoring well GM-22, which is screened in the Lagoonal Clay and overlying red mud/sand fill material, represent the caustic leachate within and emanating from the red mud. Samples from this well repeatedly show highly elevated pH levels above 12.3 (the most recent reading by EPA was 12.78). Historically, the well has shown elevated concentrations of arsenic, chromium, mercury, selenium, vanadium, aluminum, and fluorides in both unfiltered and filtered samples, with a maximum arsenic concentration of 5,100 µg/L. The samples collected by EPA from well GM-22 had a noticeable yellowish-green color. The results showed arsenic, chromium, mercury, selenium, vanadium, and aluminum at elevated concentrations, with the arsenic concentrations at 2,700 µg/L and 2,800 µg/L in the unfiltered and filtered samples, respectively.
- The sample from well GM-13D indicated the presence of arsenic at 180 µg/L in both the unfiltered and filtered samples. The samples also showed the presence of vanadium at 28 and 27 µg/L, respectively, and a pH of 9.28. This well has been compromised by siltation or some other blockage to the point where only the top few feet of the screened interval is unblocked.
- Two wells that hadn't been previously sampled for metals showed potential indications of current red mud impacts to the fresh ground water in the upper Kingshill aquifer:
 - Well VW25, located downgradient (south) of RMA and east of the RMS and completed in the upper Kingshill aquifer, showed estimated arsenic concentrations of 17 µg/L and 8.3 µg/L in the unfiltered and filtered samples, respectively. The unfiltered result exceeds the MCL (10 µg/L) and the filtered result is close. Chromium was detected in the unfiltered sample at a concentration of 41 µg/L (below the MCL of 100 µg/L), and vanadium was detected in both samples at concentrations of 77 µg/L and 42 µg/L, respectively (there is no MCL for vanadium). The unfiltered sample also exceeded the secondary MCL for iron (300 µg/L) with a concentration of 940 µg/L.

- The unfiltered sample from well VW37, located along the western edge of RMA and completed in the upper Kingshill aquifer, showed the presence of chromium at 5.1 µg/L and also showed exceedances of the secondary MCLs for aluminum and iron.
- Mercury and selenium were detected only in the ground water samples from monitoring well GM-22.
- Antimony, cadmium, and silver were not detected in any of the ground water samples.
- Some forms of arsenic are more subject to leaching and have greater solubility with increasing pH. The high arsenic concentrations detected in filtered ground water and leachate samples collected at the Site seems to be indicative of these phenomena.

Radiological Isotopes:

EPA analyzed seven unfiltered groundwater samples from on-site monitoring wells for radiological analyses for radium, thorium, and uranium. The analytical results of these analyses indicate the following:

- Ra-226 results ranged from non-detect to 0.3 pCi/L. Ra-228 was not detected.
- Th-230 results ranged from non-detect to 0.2 pCi/L. Th-232 was not detected.
- U-234 results ranged from non-detect to 1.6 pCi/L, U-235 results ranged from non-detect to 0.3 pCi/L, and U-238 results ranged from 0.1 to 1.4 pCi/L.

5 Conclusion

The results of the September 2011 EPA sampling investigation at the Site show that migration of red mud and related contaminants from source areas continues to have an impact on downstream water bodies and ground water in the Kingshill aquifer and overlying units. The contamination poses a potential threat to receptor areas, including mangrove wetland areas, waterbird and endangered/threatened species habitats, fisheries, and fresh ground water in the Kingshill aquifer. The Site conditions and analytical results, as presented in Sections 3 and 4, provide evidence of hazardous substance migration in both the surface water and ground water pathways from on-site disposal areas.

5.1 Source Areas

The uncontained waste material in the four identified sources at the Site showed elevated levels of pH, inorganic contaminants, and radioisotopes. The red mud and runoff water in all three red mud disposal areas generally showed pH ranging from approximately 9.5 to 12.5, compared to background pH levels of approximately 7 to 8.5. The highest observed pH readings (above 12.5) were found in Red Mud Disposal Area A and Red Mud Disposal Area B. The waste material also showed the highest concentrations of inorganic and radiological contaminants of concern. The highest concentrations of vanadium and chromium were observed in the red mud waste from Red Mud Disposal Area A and Red Mud Disposal Area B, and the highest arsenic levels were detected in red mud leachate (well GM-22) and ash from the Ash Disposal Pond. The highest activity levels for radioisotopes were found in the red mud waste from Red Mud Disposal Area A and Red Mud Disposal Area B.

5.2 Surface Water Migration Pathway

At the time of the EPA investigation in 2011, approximately 2.5 million gallons per day of process water from desalination and storm water flowed through the cooling ponds. The recent cessation of desalination in 2012 has reduced this flow to include only storm water. The primary overland drainage pathways to surface water at the Site originate from Red Mud Disposal Area A and flow south through the RMA Depositional Area and Red Mud Settling Pond to the Upper Cooling Pond, and subsequently to the Lower Cooling Pond. Overland drainage from Red Mud Disposal Area B discharges north and west to the Upper Cooling Pond and south to the Lower Cooling Pond. The southern drainage pathway is partially fed by a man-made drainage ditch that originates at the Ash Disposal Pond and flows south through areas of exposed red mud within Red Mud Disposal Area B. The Lower Cooling Pond discharges to Alucroix Channel via a permitted discharge outfall and possibly to the coastal mangrove wetland area via culverts observed by EPA.

Historically, the West Ditch also acted as a drainage pathway from Red Mud Disposal Area A directly to the coastal mangrove area; the West Ditch has since been diverted through the Lower Cooling Pond. The drainage pathway from the Former Bauxite Storage Shed is south-southwest to a storm water basin. Water levels in the available monitoring wells also suggest the possibility

of an eastern component to shallow ground water flow from Red Mud Disposal Area B, the Ash Disposal Pond, and the Former Bauxite Storage Shed toward Alucroix Channel.

Aerial photographs and on-site observations show the migration of red mud from the disposal areas throughout past and current on-site drainage pathways. Red mud is clearly present throughout the Red Mud Settling Pond and Upper Cooling Pond, within a large portion of the Lower Cooling Pond, and intermittently within the West Ditch and coastal mangrove wetland areas. The red mud in the West Ditch and coastal mangrove wetland areas is believed to be residual contamination from prior releases. Analytical results for contaminants of concern (pH, arsenic, chromium, mercury, selenium, vanadium, and radioisotopes of radium and thorium) verify the downstream transport of red mud and relative dilution with distance from the sources. Site-related contaminants were detected at concentrations above background throughout the Red Mud Settling Pond and Upper Cooling Pond, and in some areas of the Lower Cooling Pond, West Ditch, Alucroix Channel, and coastal mangrove wetland areas.

The downstream surface impoundments and other water bodies include sensitive environmental receptors that are affected or potentially threatened by contaminant migration from the original source areas. In addition to the coastal mangrove wetland areas, the West Ditch, Lower Cooling Pond, and Alucroix Channel are bordered by mangrove wetlands. The Upper Cooling Pond is also bordered by mangrove wetlands, however, the vegetation along this surface impoundment is sparser than the rest. The coastal area, including the Lower Cooling Pond, provides habitat for fish and waterbirds such as brown pelicans and egrets. The south shore of St. Croix, including the Site and vicinity, is a regularly-used fishery and it provides habitat for federally-designated threatened and endangered species (green, hawksbill, and leatherback sea turtles).

5.3 Ground Water Migration Pathway

The historical and recent ground water data for the Site indicate that site contaminants from on-site disposal areas have had an impact on ground water and pose a threat to the underlying Kingshill aquifer, but the nature and extent of the impacts are not fully understood. The analytical results show approximate order of magnitude changes progressing through red mud leachate in overlying fill, Lagoonal Clay underlying the southern portion of the Site, and the Kingshill aquifer beneath the northern portion of the Site. As shown in previous studies, this aquifer is a viable source of fresh water at the Site despite the presence of the saltwater interface near the head of Alucroix Channel. Additional ground water investigation (i.e., a Remedial Investigation) at the Site is warranted to delineate the extent of the impact of red mud and the location of the saltwater interface, as described in the WESTON/EPA document titled *Ground Water Assessment Summary, St. Croix Alumina (Renaissance Park) Site, St. Croix, U.S. Virgin Islands (RAR)*, dated May 2012.

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Tables

Figures

Appendices
