United States Environmental Protection Agency

Optimization Review Report
Remedial Process Optimization Study

Olin Corporation (McIntosh Plant)
Operable Unit 1
McIntosh, Washington County, Alabama
EPA Region 4

OPTIMIZATION REVIEW

OLIN CORPORATION (MCINTOSH PLANT) SUPERFUND SITE,

OPERABLE UNIT 1
MCINTOSH, WASHINGTON COUNTY, ALABAMA
EPA REGION 4

FINAL REPORT
January 2020

EXECUTIVE SUMMARY

NATIONAL OPTIMIZATION STRATEGY BACKGROUND

The U.S. Environmental Protection Agency's (EPA's) definition of optimization is as follows:

> "*Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation, which may facilitate progress towards site completion. To identify these opportunities, Regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply some other approaches to identify opportunities for greater efficiency and effectiveness*."[1]

An optimization review considers the goals of the remedy, available site data, conceptual site model (CSM), remedy performance, protectiveness, cost-effectiveness, and closure strategy. A strong interest in sustainability has also developed in the private sector and within federal, state, and municipal governments. Consistent with this interest, principles of green remediation and environmental footprint reduction are now routinely considered during optimization reviews, when applicable.

This optimization review includes reviewing site documents, interviewing site stakeholders, visiting the site for one day and compiling a report that includes recommendations intended to improve the following:

- Remedy effectiveness
- Technical improvement
- Cost reduction
- Progress to site closure
- Reuse/revitalization
- Energy and material efficiency

The recommendations are intended to help the site team identify opportunities for improvements in these areas. Analysis of recommendations, beyond that provided in this report, may be needed prior to implementation. All recommendations are based on an independent review and represent the opinions of the optimization review team. The recommendations are not requirements; they are provided for consideration by the EPA Region and other site stakeholders. Also, note that while the recommendations provide some details, they do not replace other, more comprehensive, planning documents such as work plans, sampling plans, and quality assurance project plans (QAPPs).

The national optimization strategy includes a system for tracking the outcome of the recommendations and includes a provision for follow-up technical assistance from the optimization review team as mutually agreed upon by the site management team and EPA Office of Land and Emergency Management (OLEM; and the Office of Superfund Remediation and Technology Innovation [OSRTI]).

[1] EPA, 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

SITE-SPECIFIC BACKGROUND

The Olin Corporation (McIntosh Plant) Superfund Site (CERCLIS ID# ALD008188708) Operable Unit 1 (OU1) was nominated for an optimization review by the Region 4 Site Remedial Project Managers (RPMs) and Optimization Coordinators in January 2018. The focus of this optimization review is to evaluate historical groundwater data and provide recommendations to optimize the current remedial response and associated Site characterization and monitoring.

The Olin Corporation Site (Site) is located near the city of McIntosh, Washington County, Alabama in EPA Region 4 (R4). The Site is an active chemical production facility, producing sodium hydroxide and related products. The Olin property encompasses 2,200 acres, with historical and current industrial operations conducted on about 1,500 acres. The facility is bounded to the east by the Tombigbee River and to the north by the Ciba-Geigy/BASF chemical manufacturing facility and to the south and west by property owned by other parties. The western part of the Olin property is underlain by an extensive salt dome formation.

Olin constructed a mercury cell chlor-alkali plant (Mercury Cell Plant) at the Site in 1952 to produce hydrochloric acid, sodium hypochlorite, and other products by electrolysis of brine extracted from the salt dome formation. The Alabama (Calabama) Chemical Company began operation of a chlorinated organics plant on property immediately south of the Olin plant in 1954. Olin purchased the Alabama Chemical Company in 1954 and later constructed facilities producing fungicides and fungicide precursors. The pesticide manufacturing areas were collectively referred to as the Crop Protection Chemicals (CPC) plant. The original mercury cell production unit was terminated in 1978. Operations at the CPC were terminated in 1982.

Historical waste management practices on Site resulted in contamination of groundwater, soil, and sediment. The Olin facility initiated a groundwater investigation and remedial actions in 1980 as part of the Resource Conservation and Recovery Act (RCRA) permitting process. Several solid waste management units (SWMUs) were identified at that time. The subsequent RCRA Corrective Action Program (CAP) included installation of a groundwater extraction and treatment system (pump and treat [P&T]) and removal actions at SWMUs. The RCRA CAP is overseen by the Alabama Department of Environmental Management (ADEM).

The Site was placed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1984. A Record of Decision (ROD) selecting remedies for the Site was issued in 1994.The Olin Corporation is the only potentially responsible party (PRP) for Site.

The Olin Site is managed as two operable units (OUs). OU1 consists of the active chemical production facility and groundwater contamination. OU2 consists of a natural freshwater lake (basin) that received wastewater discharge from the plant through 1974, the wastewater drainage ditch, and floodplain adjacent to the river. The following report focuses on OU1.

SUMMARY OF CONCEPTUAL SITE MODEL

Several historical industrial operations were likely sources of contamination to groundwater.

- The Weak Brine Pond was an earthen structure constructed in 1952 that functioned as a process brine unit and received multiple waste streams including those from operation of the Mercury Cell Plant. The Weak Brine Pond was considered a likely source of mercury leaching to the subsurface during the Remedial Investigation (RI).
- The CPC Plant was dismantled and removed in 1984. The area was capped with a 2-ft thick compacted clay cover and revegetated. The CPC Landfill was located in an area that was used to

neutralize acidic wastewater between 1954 and 1972, about 400 ft southeast of the Weak Brine Pond. The landfill is unlined and in contact with the surficial clay. Contaminants of concern (COCs) associated with the CPC Plant and Landfill include chlorobenzene, chloroform, and polychlorinated benzenes in addition to mercury.

- Two adjacent historical sanitary landfills (SLF) located in the northeastern part of the Site were constructed for the disposal of sanitary waste, trash, and debris. However, the waste cells potentially received hexachlorobenzene and mercury sludges. The historical SLF area appears to be the source of carbon tetrachloride and chlorobenzene plumes as well as a small 1,4-dichlorobenzene plume migrating south/southeast.
- The former Mercury Cell Plant was demolished and capped in 1986, and sumps and trenches were filled with clay and the area covered with asphalt. The mercury drum storage pad was also closed during the SWMU remediation under RCRA. The former Mercury Cell Plant was a potential source of mercury to groundwater.
- Two lime ponds were used until 1976 to manage spent lime slurry used to absorb chlorine gas from vent streams. The ponds were closed in 1979 by applying ash for stabilization, a clay cap, topsoil, and vegetation. Mercury was detected in soil borings in the vicinity of the ponds.
- The stormwater, brine filter backwash, and pollution abatement (pH) ponds handled waste from 1972 to 1976. Both high and low-pH wastewater was generated by plant industrial processes. These features were clean-closed under RCRA between 1985 and 1986. During closure, accumulated solids and portions of clay liners from these ponds were placed in the Weak Brine Pond and subsequently capped.

COCs identified in the ROD include chlorinated benzenes, chloroform, and metals such as arsenic, beryllium, cadmium, lead, and mercury. The chemicals carbon tetrachloride and chloroform were not identified as COCs in the ROD, even though elevated concentrations were observed in groundwater. The primary COCs in groundwater in terms of exceedance of human health-based remedial goals and spatial distribution are mercury, carbon tetrachloride, 1,4-dichlorobenzene, and chloroform. Chlorobenzene concentrations define the extent of affected groundwater in some areas.

Site remedial goals are Groundwater Protection Standards (GWPS) approved by ADEM under the RCRA CAP. GWPS are based on federal EPA Maximum Contaminant Levels (MCLs) or risk-based calculations based on human exposure from ingestion of affected groundwater.

Groundwater under the Site is present in two major saturated formations: the alluvial and Miocene aquifers. The alluvial aquifer underlies the surficial clay/silt unit and is about 55 to 80 feet (ft) in thickness extending from about 30 ft above mean sea level (amsl) to 60 ft below mean sea level (bmsl). The alluvial unit consists of fine to medium sand trending to coarser sand and gravel at depth, in most areas.

The Miocene series underlies the alluvial sand unit, ranging in thickness from 275 ft to 600 ft. The uppermost layer of the Miocene is a confining clay unit ranging from 80 to 110 ft in thickness encountered between 75 to 150 ft bgs. The upper Miocene aquifer, encountered at about 220 ft below ground surface, is a highly permeable sand and gravel unit. The Miocene aquifer consists of two saturated zones separated by another confining unit, thought to be laterally continuous and impermeable to upward vertical movement of groundwater. A lower Miocene aquifer overlies the caprock of the salt dome.

Groundwater from the alluvial aquifer is not a drinking water source and land use restrictions prevent use of Site groundwater from the alluvial aquifer as a source of drinking water. The Miocene aquifer is the primary source of drinking water for the McIntosh area. Miocene groundwater is also extracted for industrial use at both the Olin and upgradient Ciba/BASF plant.

The alluvial aquifer is unconfined with relatively flat gradients across the plant in the absence of pumping. Potentiometric surfaces measurements indicate a groundwater divide running north to south in the central part of the Site. Groundwater west of the Mercury Cell Plant area flows west. Groundwater east of the main industrial plant flows east/southeast and discharges to the Tombigbee River during low river stage (gaining) and reverses (losing) during periods of high river water. A potentiometric low in the alluvial aquifer is observed west of the plant near wells WP6A, WE3, and WP10. A higher water table is observed farther west of the groundwater low in the area of the brine wells. There is a steep hydraulic gradient with a high near well MGW1 and the low near WE3.

The salt dome formation west of the main industrial process area is about 4,500 ft in diameter and greater than 2 miles deep. Nine brine wells are known to have been completed in the salt dome over the history of the Olin plant to provide brine for chlor-alkali production. Six brine wells were abandoned by 1994.

Primary releases from sources identified above migrated under the influence of gravity through the surficial clay to the alluvial aquifer. After entry into the alluvial groundwater, plumes migrated with groundwater flow to the east/southeast and west of the groundwater divide in the alluvial aquifer. Releases from brine ponds resulted in the formation of a dense brine layer containing mercury at the base of the alluvial aquifer on the surface of the Miocene clay. Multiple historical sources of contamination were present at different locations and during different time frames, resulting in several detached and comingled plumes in the alluvial aquifer.

Low level concentrations of VOCs (below GWPS) have been observed in the Miocene aquifer, but elevated concentrations of mercury have not been observed to date. Concentrations of COCs exceeding GWPS have been detected in Miocene-level monitoring wells on the Ciba/BASF property upgradient of the Olin facility. Regulators have expressed concern that continued pumping in the Miocene aquifer may draw down or spread contamination in a formation used as a regional drinking water supply.

A P&T system consisting of five recovery wells (Corrective Action [CA]1 through CA5) was installed in the alluvial aquifer in 1987. The ROD selected continued operation of the RCRA CAP P&T system as part of the remedy with the addition of two extraction wells. The goal of extraction wells CA1 through CA5 was to maintain hydraulic capture of groundwater plumes. The remedial objective of extraction at additional wells CA6 and CA7 was to remove contaminant mass in the interior of the plume. The groundwater treatment system was designed to receive a combined flow of 550 gallons per minute (gpm) from extraction wells CA2 through CA7 (groundwater from CA1 was discharged directly to surface water). The treatment process for extracted water included pH neutralization, clarification to remove iron and aluminum hydroxides, air stripping to remove VOCs and carbon absorption processes to remove mercury.

A phased shutdown of the P&T system was approved by ADEM in 2015 under the RCRA CAP. Wells CA6 and CA7 were shut down in 2015, pumping ceased at CA4 and CA5 in July 2015. Pumping from wells CA1 and CA2 was terminated in 2016, and pumping ceased at CA3 in July 2017. The groundwater P&T system had been completely shut down for one year at the time of the optimization review.

KEY FINDINGS

- Groundwater under the Olin Site has not attained GWPS. There are currently no remedial actions addressing groundwater contamination. No active remedial strategy has been proposed to address residual groundwater contamination.
- No active primary sources are ongoing at the Site. However, residual contamination remains in the unsaturated soils above the alluvial aquifer. Contamination entrained or adsorbed in the vadose zone may function as an ongoing, low-level, secondary source of contamination to groundwater. Several lines of evidence support the conclusion that there is continued, low-level,

discharge of contaminant mass to groundwater from secondary sources. Apparent low-level secondary source areas include the former Weak Brine Pond, the former CPC Landfill, and the SLF.

- Stability of plumes in the absence of the extraction remedy will depend on the strength of continuing sources (i.e. contaminant mass discharge from residual secondary sources) offset by physical attenuation processes (dilution, dispersion) for inorganic contaminants and physical attenuation processes and biodegradation for organic COCs.
- PRP consultants performed a Bioscreen analysis that supported the conclusion that groundwater plumes would be stable after the termination of the P&T remedy. The optimization team does not believe that Bioscreen analysis used to support discontinuation of CA well operation accurately represents COC plume migration in the absence of extraction from the CA wells.
- Potentiometric surface maps indicate a groundwater low or trough in the alluvial aquifer west of the industrial area. Groundwater elevations as of January 2018, after termination of the P&T, were in the range of 3.5 to 5 ft amsl, surrounded by higher elevations in the range of 8 to 10 ft amsl within about 600 to 1,000 ft distance. The fate of groundwater in the vicinity of WE3 is a significant source of uncertainty in the Site CSM. Since groundwater at WE3 is not migrating laterally north, south, east, or west, a reasonable conclusion is that groundwater from the alluvial aquifer may be migrating vertically to the Miocene. However, the pathway or conduit to the Miocene aquifer is unknown. The vertical migration from the alluvial aquifer into the Miocene aquifer appears to create a hydraulic boundary that prevents further westward migration of plumes in the alluvial aquifer.
- There are currently no potentially open exposure pathways at the Site. Institutional controls (ICs) prevent use of affected alluvial groundwater, work controls and work plans prevent unintentional contact with affected soils, and the potential for vapor intrusion (VI) has been evaluated and determined to be insignificant for commercial property use. Contamination in the Miocene aquifer is currently below GWPS.
- Periodic groundwater reporting would be enhanced by improving statistical trend analysis on data from individual groundwater wells. The method of demonstrating that a well had attained remedial goals specified in the RCRA permit was three consecutive sampling results below the GWPS. However, this method is not consistent with current guidance under CERCLA.

RECOMMENDATIONS

The optimization team provides the following recommendations to improve remedy effectiveness and advance the Site toward attaining GWPS:

Groundwater at the Olin Site is likely to remain above GWPS without further active remediation. However, risks to human health and the environment are low, and continued operation of the CA wells in their current configuration is unlikely to provide measurable improvements in protecting human health and the environment or achieving Site closure. The optimization team presents three remedial strategies that are all protective of human health and the environment but differ in terms of cost and remedy duration. The strategies are summarized as follows:

- *Aggressive Source Remediation*: This strategy prioritizes Site closure by conducting aggressive remediation of residual secondary sources. The cost of implementing this strategy and the potential disruption to facility operations are high. Details are provided on a strategy to investigate potential secondary sources (e.g. Weak Brine Pond, clay under process areas). Aggressive source remediation measures would depend on the COC and the nature of the source. Given the potential for the contamination to be present within the surficial clay, intrusive methods such as excavation or in situ mixing are likely remedial approaches.

- *Source Control*: This strategy focuses on controlling discharges from secondary sources to allow restoration areas of the alluvial aquifer outside of the immediate source areas and to protect the Miocene aquifer. The recommendation includes re-establishing a groundwater extraction system, with optimized extraction locations to control contaminant mass migration from secondary sources. Restoration of the aquifer outside of the source areas might occur in a timely manner, but the source areas themselves would remain until directly addressed. The same characterization steps as outlined in the previous approach are suggested to better inform the design of the hydraulic control system and limit the number of extraction wells and the extraction rates to control costs.
- *Long-Term Evaluation*: This strategy relies on the potential for the plumes to be stable and the absence of current exposures to human health and ecological receptors. Actions over the foreseeable future involve monitoring the stability of the contaminant plumes. The strategy eventually transitions to aggressive remediation when land use changes.

The optimization team recommends updates to the current PRP reporting documents. Demonstrations of plume stability should include statistical evaluation trends at individual monitoring wells for priority COCs. As groundwater data can be variable, a non-parametric trend evaluation such as the Mann-Kendall test for trend is recommended.

Monitoring and decision documents discuss a dense brine plume at the interface of the lower alluvial aquifer and the Miocene clay in the area of CA7. A figure identifying the extent of the residual brine plume, based on conductivity or total dissolved solids measurements, would be helpful in visualizing the brine plume that may be a long-term, low-level source of contamination.

To further support the CSM development, the optimization team recommends installation of an additional Miocene monitoring well and an investigation of historical information related to potential construction of brine wells or oil and gas exploration in the area of the potentiometric low in the alluvial aquifer west of the industrial process area. Historical exploration wells drilled in the area just east of the salt dome could be potential conduits for discharge of contamination in the alluvial aquifer to the Miocene.

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NOTICE AND DISCLAIMER

Work described herein, including preparation of this report, was performed by HydroGeoLogic, Inc. (HGL) for the U.S. Environmental Protection Agency (EPA) under Task Order 0066 of EPA contract EP-S7-05-05 with HGL. The report was approved for release as an EPA document, following the Agency's administrative and expert review process.

This optimization review is an independent study funded by EPA that evaluates existing data, discusses the conceptual site model (CSM), analyzes remedy performance, and provides suggestions for improving remedy efficacy, reducing cost, and making progress toward Site reuse and closure at the Olin Corporation (McIntosh Plant) (Site). Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by EPA.

Recommendations are based on an independent evaluation of existing Site information, represent the technical views of the optimization review team, and are intended to help the Site team identify opportunities for improvements in the current remediation strategy and operation and maintenance plan. These recommendations do not constitute requirements for future action; rather, they are provided for consideration by the EPA Region and other Site stakeholders.

While certain recommendations may provide specific details to consider during implementation, these are not meant to supersede other, more comprehensive planning documents such as work plans, sampling plans and Quality Assurance Project Plans (QAPPs), nor are they intended to override Applicable or Relevant and Appropriate Requirements (ARARs) established in the Record of Decision. Further analysis of recommendations, including review of EPA policy, may be needed before implementation.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization practices from site assessment to site completion implemented by the U.S. Environmental Protection Agency Office of Land and Emergency Management (OLEM) and the Office of Superfund Remediation and Technology Innovation (OSRTI)[1]. The project contacts are as follows:

ORGANIZATION	CONTACT	CONTACT INFORMATION
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[1] EPA, 2012. Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28.

LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	micrograms per liter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
cm/sec	centimeters per second
ADEM	Alabama Department of Environmental Management
amsl	above mean sea level
AOC	Administrative Order on Consent
ARAR	Applicable or Relevant and Appropriate Requirement
BDY	boundary monitoring well
bgs	below ground surface
bmsl	below mean sea level
CA	corrective action
CAE	corrective action effectiveness monitoring well
CAP	RCRA Corrective Action Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
CPC	Crop Protection Chemicals
CSM	conceptual site model
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
ft	feet/foot
ft/day	feet per day
ft/yr	feet per year
FYR	Five-Year Review
GWPS	groundwater protection standard
HGL	HydroGeoLogic, Inc.
HQ	EPA Headquarters
IC	institutional control
MCL	Maximum Contaminant Level
NPL	National Priorities List
OLEM	Office of Land and Emergency Management
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
P&T	pump and treat
PCNB	pentachloronitrobenzene
PGM	program monitoring well
POC	point of compliance monitoring well
PRP	potentially responsible party
QAPP	Quality Assurance Project Plan
R	retardation factor
R4	EPA Region 4
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment

RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
SLF	sanitary landfill
SWMU	solid waste management unit
TCAN	tetrachloroacetonitrile
VOC	volatile organic compound

1.0 OBJECTIVES OF THE OPTIMIZATION REVIEW

For more than a decade, the Office of Land and Emergency Management (OLEM) has provided technical support to the U.S. Environmental Protection Agency (EPA) regional offices by using independent (third party) optimization reviews at Superfund sites. The Olin Corporation (McIntosh Plant) (CERCLIS ID# ALD008188708) Operable Unit 1 (OU1) was nominated for an optimization review by the Region 4 (R4) Site Remedial Project Managers (RPMs) and Optimization Coordinators in January 2018. The focus of this optimization review is to evaluate historical data and provide recommendations to optimize the current remedial response and associated Site characterization and monitoring.

This optimization review used existing environmental data to interpret the conceptual site model (CSM), identify potential data gaps, and recommend improvements to the remedy. The optimization review team evaluated the quality of the existing data before using the data for these purposes. The evaluation for data quality included a brief review of data collection and management methods (where practical, the Site Quality Assurance Project Plan [QAPP] is considered), the consistency of the data with other Site data, and the potential use of the data in the optimization review. Data that were of suspect quality were either not used as part of the optimization review or were used with the quality concerns noted. Where appropriate, this report provides recommendations made to improve data quality.

2.0 OPTIMIZATION REVIEW TEAM

The optimization review team, which collaborated with representatives of EPA Headquarters (HQ) and EPA R4, consists of the independent, third-party participants listed in Table 1.

TABLE 1. Site Optimization Review Team

NAME	ORGANIZATION	TELEPHONE	EMAIL
Doug Sutton	HydroGeoLogic, Inc.	732-784-2812	dsutton@hgl.com
Mindy Vanderford	HydroGeoLogic, Inc.	713-865-2223	mvanderford@hgl.com

[1] Attended the Site meeting on July 31, 2018.
[2] Participated in scoping and review calls.

The following individuals contributed to the optimization review process, including attendance at the R4 review meeting or Site visit:

TABLE 2. Other Optimization Review Contributors

NAME	ORGANIZATION	TITLE/ROLE
Kirby Biggs	EPA HQ	Optimization Program Manager
Elizabeth Walden	EPA R4	Remedial Project Manager
Gregory McDermott	Neptune	Contractor for R4
Austin Pierce	ADEM	Remedial Project Manager
Keith Roberts	Olin Corporation	Director Environmental Remediation
Chinnathambi Esakki Perumal	Olin Corporation	Hydrogeologist
Anthony W. Englund	Wood	Engineer/Olin Contractor
Lisa O'Brien	Olin Corporation	Environmental, Health and Safety
Andy Kennedy	Olin Corporation	Environmental, Health and Safety

Notes:

[1] Attended the Site meeting on July 31, 2018.
[2] Participated in scoping and review calls.
R4 = EPA Region 4
HQ = Headquarters
ADEM = Alabama Department of Environmental Management

Documents reviewed for the optimization effort are listed in Appendix A.

3.0 SITE BACKGROUND

3.1 SITE DESCRIPTION

The Olin Corporation Superfund Site (Site) is located near the city of McIntosh in Washington County, Alabama, EPA R4 The Site is an active chemical production facility, producing sodium hydroxide and related products. The Olin property encompasses 2,200 acres, with historical and current industrial operations conducted on about 1,500 acres. The facility is bounded to the east by the Tombigbee River and to the north by the Ciba-Geigy/BASF chemical manufacturing facility, and to the south and west by property owned by other parties. The western part of the Olin property is underlain by an extensive salt dome formation. Several rail lines run to and through the property. Surrounding land use includes chemical industrial facilities, rural residential and agricultural property, and undeveloped forest and riparian habitat.

Olin constructed a mercury cell chlor-alkali plant (Mercury Cell Plant) at the Site in 1952. The chlor-alkali process produced chlorine, hydrochloric acid, sodium hypochlorite, sodium hydroxide, and hydrogen gas (chlor-alkali chemicals) by electrolysis of brine extracted from the salt dome formation. The original mercury cell production unit was terminated in 1978 and replaced by a diaphragm process. Most recently, a membrane cell production unit was added. Currently, the plant operates the diaphragm and membrane cell production processes. Plant inputs and products are shipped by rail, river barge, and truck. An energy cogeneration plant operated by Alabama Power is located at the Site.

The Alabama (Calabama) Chemical Company began operation of a chlorinated organics plant on property immediately south of the Olin plant in 1954. Olin purchased the Alabama Chemical Company in 1954 and later constructed facilities producing fungicides and fungicide precursors pentachloronitrobenzene (PCNB), trichloroacetonitrile (TCAN), and 5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole (Terrazole) on the property. The PCNB, TCAN and Terrazole manufacturing areas were collectively referred to as the Crop Protection Chemicals (CPC) plant. Operations at the CPC were terminated in 1982.

Historical waste management practices on Site resulted in contamination of groundwater, soil and sediment. Groundwater quality investigations began in the late 1970's. The facility came under Resource Conservation and Recovery Act (RCRA) regulation in 1980. Olin initiated a groundwater extraction and treatment (pump and treat [P&T]) remedy in 1987 under the RCRA Corrective Action Program (CAP) permit ALD 008 188 708. EPA conducted a RCRA Facility Assessment (RFA) that listed 52 solid waste management units (SWMUs) and six areas of concern at the Olin Site. Several SWMUs have been the subject of removal actions and closure under RCRA (Woodward-Clyde, 1993).

The Site was placed on the National Priorities List (NPL) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1984. The Ciba-Geigy/BASF plant to the north of Olin is also listed on the NPL.

The Olin Site is managed as two operable units (OUs). OU1 consists of the active production facility and groundwater contamination. OU2 consists of a natural freshwater lake (basin) that received wastewater discharge from the plant through 1974, the wastewater drainage ditch, and floodplain adjacent to the river (**Figure 1**). The following report focuses on OU1. Mercury and chloroform are the primary contaminants of concern (COCs) in OU1 groundwater.

Olin signed an Administrative Order on Consent (AOC) with EPA R4 in 1990. Following completion of a Remedial Investigation/Feasibility Study (RI/FS) in 1991, a Record of Decision (ROD) selecting remedies for the Site was issued in 1994. A chronology of Site events is presented in Table 3.

The Olin Corporation facility is currently regulated under a RCRA post-closure permit with the Alabama Department of Environmental Management (ADEM) as the lead agency for remediation of OU1. The Olin Site is also regulated under CERCLA with EPA R4 as the lead agency. The Olin Corporation is the only potentially responsible party (PRP) for Site.

TABLE 3. Site Chronology

Date	Action
1952 – 1982	Olin Mercury Cell Plant constructed and began operation.
1954	Olin acquired the Alabama Chemical Company chlorinated organics plant.
1955 – 1956	Olin constructed a PCNB plant on the former Alabama Chemical Company property.
1973 – 1982	Olin TCAN plant constructed and operated.
1973	CPC Plant expanded to produce TCAN and Terrazole.
1974	Discharge of untreated wastewater to the basin was terminated.
1978	Olin began operation of the diaphragm cell caustic soda/chlorine plant.
1979	Groundwater contamination was discovered.
1980	The Olin plant was regulated under a RCRA permit, and Olin installed 43 groundwater monitoring wells.
1982	The CPC Plant and Mercury Cell Plant were shut down.
1984 - 1986	RCRA post-closure permit activities conducted, including demolition and removal of surface impoundments and waste pile material; Olin clean-closed ten SWMUs.
1984	The Olin McIntosh Site was placed on the NPL.
1986	The CPC Plant was decommissioned, dismantled, and the area capped.
1987	RCRA CAP groundwater P&T began under RCRA.
1988	Olin closed four of six former mercury cell brine wells.
1989	Initial RI/FS was completed. The AOC between Olin and EPA R4 was signed.
1994	The RI/FS was completed, and the ROD for Olin OU1 was signed.
1995	A Consent Decree finalizing settlement for responsible party performance was enacted.
1998	The PRP completed the Remedial Design and began implementation of the Remedial Action.
2004	The Final Remedial Action Report was approved.
2006	The First Five-Year Review (FYR) was completed.
2011	The Second FYR was completed.
2014	The RI/FS for OU2 was completed, and the OU2 ROD was signed. Olin requested a permit modification to shut down remedy extraction wells.
2015	ADEM approved the permit modification, and a phased shut down of corrective action (extraction) wells began.
2016	The Third FYR was completed.
2017	The groundwater P&T system was completely terminated

3.2 Remedial Action Objectives

The goal of remediation at the Site, consistent with the requirements of Section 121 of CERCLA and the National Contingency Plan, is to reduce the mobility, toxicity, and volume of contaminated groundwater. EPA set Remedial Action Objectives (RAOs) for the Site in a technical memorandum amending the work plan for the 1991 RI/FS based on preliminary characterization results. The RAOs are as follows:

- Prevent ingestion and direct contact with groundwater having contaminant concentrations with a cumulative cancer risk in excess of 1 x 10^{-4} to 1 x 10^{-6} or a Hazard Index greater than 1.
- Prevent ingestion and direct contact with soils having contaminant concentrations with a cumulative cancer risk in excess of 1 x 10^{-4} to 1 x 10^{-6} or a cumulative Hazard Index greater than 1.
- Prevent ingestion and direct contact with surface water having contaminant concentrations with a cumulative cancer risk in excess of 1 x 10^{-4} to 1 x 10^{-6} or a cumulative Hazard Index greater than 1.
- Prevent direct contact and ingestion of contaminated dust from the Site having contaminant concentrations with a cumulative cancer risk in excess of 1 x 10^{-4} to 1 x 10^{-6} or a cumulative Hazard Index greater than 1.

The RAO of the RCRA CAP was to hydraulically contain contaminated groundwater beneath the facility, to withdraw and treat affected groundwater, and reduce concentrations of COCs in groundwater until they attain remedial goals. The cleanup levels presented in Section 6.5 of the ROD are listed in Table 4.

TABLE 4. 1994 ROD Cleanup Levels

Constituent	Cleanup Goal
Groundwater	**Micrograms per liter [µg/L]**
Alpha-BHC	0.013
Benzene	5
Chlorobenzene	100
1,2,4-Trichlorobenzene	70
1,2-Dichlorobenzene	600
1,3-Dichlorobenzene	75
1,4-Dichlorobenzene	75
Mercury	2
Pentachlorobenzene	29
Pentachloronitrobenzene	0.29
Soil	**Milligrams per kilogram [mg/Kg]**
Benzene	5
Chlorobenzene	79
1,2-Dichlorobenzene	1,645
1,3-Dichlorobenzene	140
1,4-Dichlorobenzene	140
1,2,4-Trichlorobenzene	1,000
Mercury	55

Notes:
1. Alpha-BHC = alpha hexachlorobenzene, a constituent associated with discharge from the Ciba/BASF facility upgradient of Olin.
2. It is unclear why groundwater cleanup levels were not provided for carbon tetrachloride and chloroform in the ROD.

3.3 SELECTED REMEDY

Remedial actions for groundwater selected in the ROD are as follows:

- Extraction of groundwater from horizontal and vertical wells (additions to the RCRA CAP) with on-Site treatment (P&T). Extraction wells would be designed to capture, for treatment, the area of contamination including the area of dense brine accumulation.
- Upgrade and extend the cap over the old CPC landfill to encompass the drainage ditch area and contaminated soils with a multimedia cap with additional groundwater monitoring.
- Quarterly monitoring and maintenance of clay caps over sanitary landfills, the lime ponds, and the strong brine pond, the asphalt cover over the Mercury Cell Plant, and the fencing around the well sand residue.
- Monitoring to determine the effectiveness of the groundwater treatment in reducing contaminant migration, and
- Institutional controls (ICs) for land use and groundwater use restrictions.

The ROD stipulated that the P&T system could be terminated when maximum groundwater concentrations were below the EPA Primary Maximum Contaminant Levels (MCL) for 10 COCs or if remedy performance evaluations indicated that concentrations at extraction wells have become asymptotic above MCLs.

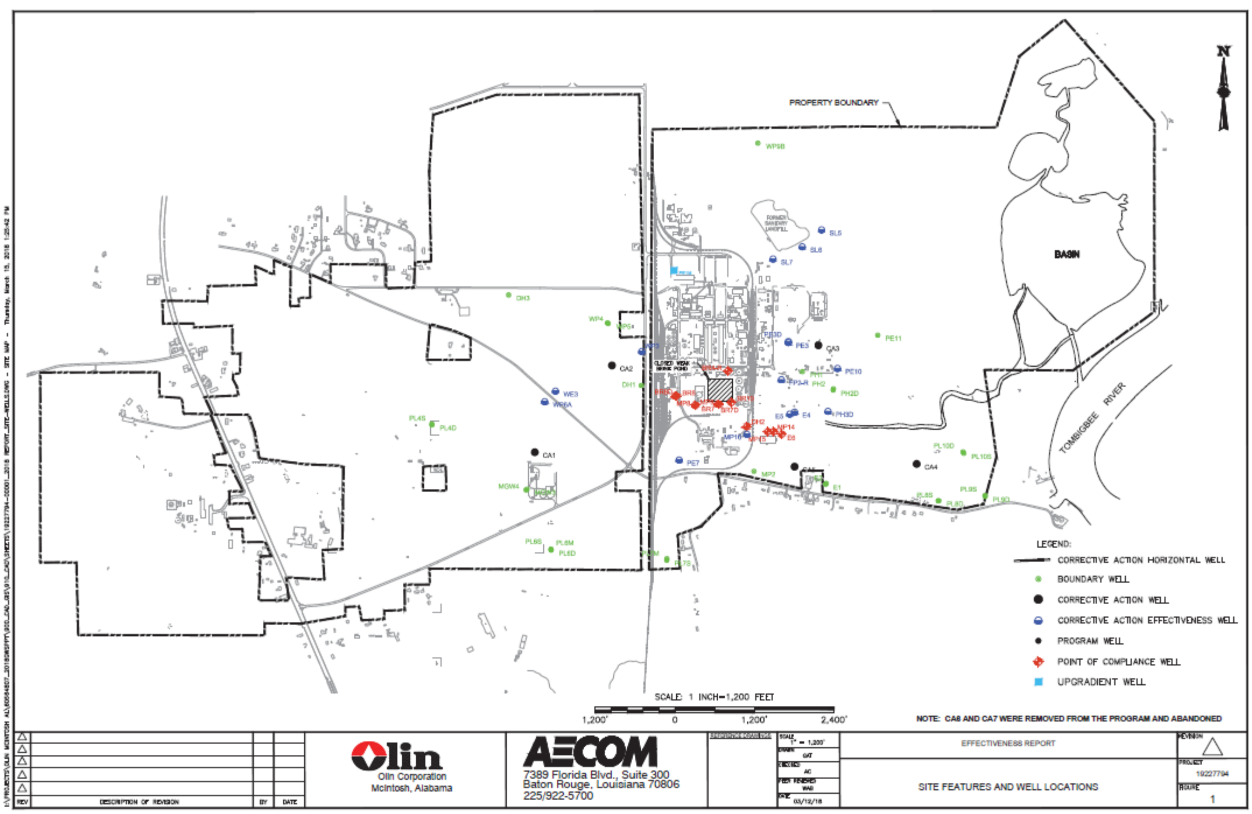

Figure 1: Olin Corporation McIntosh Plant Site Map [Excerpted from the Annual Effectiveness Report (AECOM, 2018), all figures are reproduced at full size in Appendix B].

4.0 FINDINGS

4.1 WORKING CONCEPTUAL SITE MODEL

The optimization team's working CSM based on investigation efforts to date is presented below.

4.1.1 Primary and Secondary Sources of Contamination

The primary sources (Figure 2) that may have contributed contaminant mass to groundwater include the following former industrial process areas:

Weak Brine Pond

The Weak Brine Pond was an earthen structure constructed in 1952 that functioned as a process brine unit and received multiple waste streams including those from operation of the Mercury Cell Plant. The dimensions of the pond were about 340 by 340 feet (ft).

The pond received waste derived from the stormwater pond, brine filter backwash pond, and pollution abatement (pH) pond during SWMU closure activities under RCRA (early to mid-1980s). Material removed from these impoundments was placed in the Weak Brine Pond, stabilized and solidified with cement dust. The total volume of consolidated waste in the Weak Brine Pond is about 33,000 cubic yards. The former pond was capped with compacted clay and a synthetic membrane and is vegetated. Pond closure did not include installation of a liner on the bottom of the pond.

The Weak Brine Pond was considered a likely source of mercury leaching to the subsurface in the RI. The former Weak Brine Ponds is in the vicinity of the groundwater divide, and, as a result, groundwater plumes emanating from the pond area migrate both east and the west. Brine from the pond appears to have migrated vertically to the base of the alluvial aquifer and along the top of the Miocene clay at the time of the RI. Alluvial groundwater monitoring wells in the vicinity of the former Weak Brine Pond include BR7, BR10, and MP8. Monitoring well DH2, southeast of the Weak Brine Pond, is screened at the alluvial/Miocene boundary.

Former CPC Plant and CPC Landfill

The CPC Plant was constructed in 1952, initially manufacturing monochlorobenzene and adding PCNB in 1956 and TCAN and Terrazole in 1973. The plant was decommissioned in 1982 and dismantled and removed in 1984. The area was capped with a 2-ft thick compacted clay cover and revegetated. The former CPC Plant is located just south of the Weak Brine Pond.

The former CPC Landfill is in an area that was used to neutralize acidic wastewater between 1954 and 1972, about 400 ft southeast of the Weak Brine Pond. The landfill is unlined and in contact with the surficial clay. COCs potentially originating from the CPC Plant and Landfill include chlorobenzene, chloroform, and polychlorinated benzenes as well as mercury. Groundwater monitoring wells in the vicinity of the CPC Landfill include E6 and MP16.

Sanitary Landfills

Two adjacent sanitary landfills (SLF) intended for the disposal of sanitary waste, trash and debris at the Site encompass about 12 acres in the northeastern area of the Site. However, the waste cells potentially received hexachlorobenzene and mercury sludges. Borings indicated the presence of chlorinated benzenes and mercury in soil during the RI.

The historical SLF area appears to be the source of carbon tetrachloride and chlorobenzene groundwater plumes as well as a small 1,4-dichlorobenzene plume migrating south/southeast. The landfill area is overgrown with dense vegetation. Monitoring wells SL5, SL6 and SL7 monitor the downgradient boundaries of the landfill area.

Former Mercury Cell Plant

The former Mercury Cell Plant occupies an area about 180 by 250 ft. The plant was shut down by 1982 and demolished and capped in 1986. All aboveground structures were demolished, sumps and trenches were filled with clay and the area covered with asphalt. The mercury drum storage pad was also closed during the SWMU remediation under RCRA. There are no alluvial monitoring wells in the immediate vicinity of the former Mercury Cell Plant, due to the density of industrial structures. The nearest well west of the area is deep alluvial monitoring well WP3, which has had some of the highest observed concentrations of mercury in groundwater at the Site. It is unclear whether the contamination at WP3 is from a source underneath the Mercury Cell Plant or if it is from a source beneath the Weak Brine Pond. Extraction well CA3 is east of the Mercury Cell Plant area and has shown historically low concentrations of mercury (with higher concentrations of carbon tetrachloride, apparently migrating from the SLF).

Lime Ponds

Two lime ponds were used until 1976 to manage spent lime slurry used to absorb chlorine gas from vent streams. The ponds were constructed about 10 to 15 ft above the natural grade. The ponds were closed in 1979 by applying ash for stabilization, a clay cap, topsoil, and vegetation. Mercury was detected in soil borings in the vicinity of the ponds.

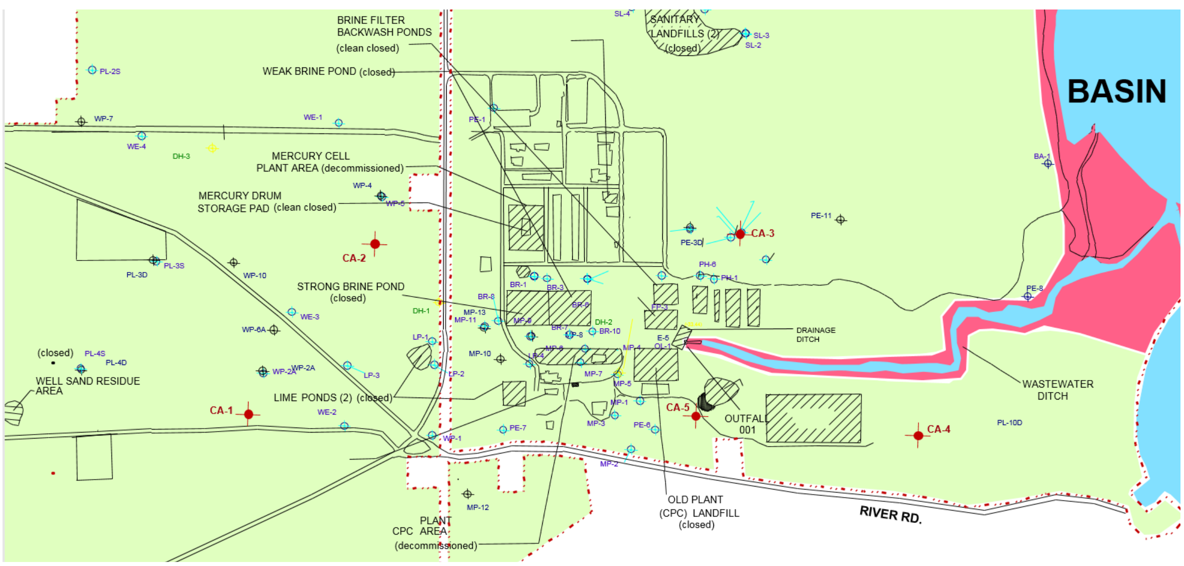

Figure 2: Olin Site Potential Source Areas [Excerpted from Olin Corporation slide presentation during July 2018 Site Visit; all figures are reproduced at full size in Appendix B]

Strong Brine Pond, Stormwater, Brine Filter, Pollution Abatement, and Backwash Ponds

The Strong Brine Pond was a holding pond for concentrated brine process fluid pumped from brine wells for use in the Mercury Cell Plant. The pond was part of a process unit rather than a waste handling unit. The pond was constructed partially above-grade in the native clay with dimensions of about 340 ft by 340 ft. The pond was decommissioned in 1985.

The stormwater, brine filter backwash, and pollution abatement (pH) ponds handled waste between 1972 and 1976. The pollution abatement pond was used to adjust the pH of wastewater prior to polishing treatment in a neutralization tank. Both high and low-pH wastewater was generated by plant industrial processes. These features were clean-closed under RCRA between 1985 and 1986. Pond closure identified an acceptable limit for residual pH between 2 and 12.5 standard units. During closure, accumulated solids and portions of clay liners from these ponds were placed in the Weak Brine Pond and subsequently capped.

The former Weak Brine Pond, the former CPC Plant and Landfill, and the SLF north of the main plant are likely the most significant contributors of contamination to groundwater. The Mercury Cell Plant is another potential contributor of mercury, and unlined ditches conveying wastewater were also likely sources.

The majority of SWMUs identified during the RFA and closed under RCRA are unlikely to discharge to groundwater under current conditions.

4.1.2 Contaminants of Concern

COCs identified in the ROD include chlorinated benzenes, chloroform, and metals such as arsenic, beryllium, cadmium, lead, and mercury. The chemicals carbon tetrachloride and chloroform were not identified as COCs in the ROD, even though elevated concentrations were observed in groundwater (EPA 2016). The primary COCs in groundwater in terms of exceedance of health-based or remedial goals and spatial distribution are mercury, carbon tetrachloride, 1,4-dichlorobenzene, and chloroform. Chlorobenzene concentrations define the extent of affected groundwater in some areas

Releases of waste included brine and wastewater at various pH levels. Monitoring data indicate groundwater pH currently varies between about 3.5 and 12 standard units and conductivity can be as high as 200 Siemens per meter, depending on the sampling location. Salinity and extreme pH in groundwater can affect COC fate and transport. Extreme geochemical conditions can also mobilize metals naturally present in soils such as arsenic, manganese, and iron.

Site remedial goals are Groundwater Protection Standards (GWPS) approved by ADEM under the RCRA CAP. GWPS are based on federal MCLs or risk-based calculations based on human exposure from ingestion of affected groundwater. GWPS for priority COCs are listed in Table 4 and priority COCs, GWPS, and recent high concentrations are listed in Table 5.

TABLE 5. Remedial Goals and Recent High Concentrations for Groundwater

Contaminant	Groundwater Protection Standard [µg/L]	Basis for Standard	Recent High Concentration [µg/L] (Well Location)
Mercury (inorganic)	2	MCL	72.9 (BR7)
Chloroform	80	Unknown (GWPS not specified in ROD)	1,500 (E6)
Chlorobenzene	100	MCL	270 (SL7)
Carbon tetrachloride	5	MCL	29 (SL6)
1,4-Dichlorobenzene	75	MCL	320 (MP9)

Note: Recent high concentrations reported in *Annual Effectiveness Report Eighth Permit Reporting Period* (AECOM, 2018) and *Vapor Intrusion Risk Evaluation* (Amec 2018).

Soil remedial goals were developed to be protective for the soil leaching to groundwater migration pathway. Remedial goals for mercury in the ROD are 2 μg/L in groundwater and 55 milligrams per kilogram (mg/kg) in soil. The ROD does not provide different remedial goals for various geochemical forms or oxidation states of mercury. Remedial goals for chlorobenzene are 100 μg/L in groundwater and 79 mg/kg in soil.

The RCRA CAP identified mercury, chloroform, and 1,4-dichlorobenzene as 'tracking' analytes for the purpose of evaluating the efficacy of the P&T remedy.

4.1.3 Geology and Hydrogeology

The main industrial area of the plant consists of about 60 acres of relatively flat topography with surface elevations of about 40 to 50 ft above mean sea level (amsl). A topographic high of greater than 50 ft amsl extends north to south, west of the production facility and east of the brine well field. This topographic high creates a surface water drainage divide, with the eastern part of the property draining to low-lying areas near the Olin Basin, Tombigbee River, and the floodplain. A steep bluff located approximately 4,000 ft east of the main plant area defines the edge of the low-lying floodplain area, which is about 25 ft lower in elevation than the upland areas immediately to the west.

A 65-acre natural fresh water oxbow basin (Olin Basin) is located north and east of the main industrial plant. The basin received industrial and stormwater discharge through a drainage ditch from 1952 to 1974. Historically, the basin was in contact with the Tombigbee River during seasons with high water. Contamination in the basin and floodplain is managed under OU2. The drainage ditch previously extended from Outfall 001 east of the CPC Landfill to the Olin Basin. The drainage ditch was re-routed in 1974 to bypass the Basin and discharge into the inlet channel to the Tombigbee River.

The upper geologic strata at the Site are composed of recent alluvium of about 80 to 100 ft thickness. The alluvium consists of beds of clay, silt, sand, and gravel. Surficial soils are composed primarily of clays, sandy clay, and clayey silt, with shallow fill, ash, and debris in some areas of the plant. The surficial clay extends from ground surface to about 10 to 35 ft below ground surface (bgs).

Groundwater under the Site is present in two major saturated formations: the alluvial and Miocene aquifers. The alluvial aquifer underlies the surficial clay/silt unit and is about 55 to 80 ft in thickness extending from about 30 ft amsl to 60 ft below mean sea level (bmsl). The alluvial unit consists of fine to medium sand trending to coarser sand and gravel at depth, in most areas. The boring logs note that extraction well CA4 sits in a depression in the Miocene clay with alluvial sediments trending from coarse to fine with depth.

The alluvial aquifer is unconfined with relatively flat gradients across the plant in the absence of pumping. Potentiometric surfaces measured in the alluvial aquifer (Figure 3) indicate a groundwater divide running north to south in roughly the same area as the surface water divide. Groundwater in the western part of the plant area flows west. Groundwater east of the main industrial plant flows east/southeast and discharges to the Tombigbee River during low river stage (gaining) and reverses (losing stream) during periods of high river water. A potentiometric low in the alluvial aquifer is observed west of the plant in the area of WP6A, WE3, and WP10. Farther west of the groundwater low, a higher water table is observed in the alluvial aquifer in the area of the brine wells. There is a steep hydraulic gradient with a high near well MGW1 and the low near WE3.

Alluvial aquifer parameters used in the Bioscreen analysis (presented in the *Corrective Action Review and Recommendations* report) are a porosity of 20 percent; hydraulic gradient between 0.0073 feet per foot (ft/ft) to 0.0012 ft/ft, and hydraulic conductivity between 0.0087 centimeters per second (cm/sec) (24.6 ft/day) in the east and 0.0028 cm/sec (7.9 ft/day) in the west (Amec, 2014). Groundwater velocities were said to be between 0.2 and 16 ft/day during the Site visit. Hydraulic conductivities cited in the ROD are between 4 and 40 ft/day.

The Miocene series underlies the alluvial sand unit, ranging in thickness from 275 ft to 600 ft. The uppermost layer of the Miocene is a confining clay unit ranging from 80 to 110 ft in thickness encountered between 75 to 150 ft bgs. The boring log from monitoring well DH3, west of the plant, indicates that the clay unit extends from about 75 ft bgs to 177 ft bgs with fine to coarse sand and silt while the log from DH1 indicates the clay is present between 163 and 222 ft bgs. A cross section constructed of data from east to west through the plant area showing the alluvial and Miocene units is shown in Figure 4 (cross sections are included in Appendix B).

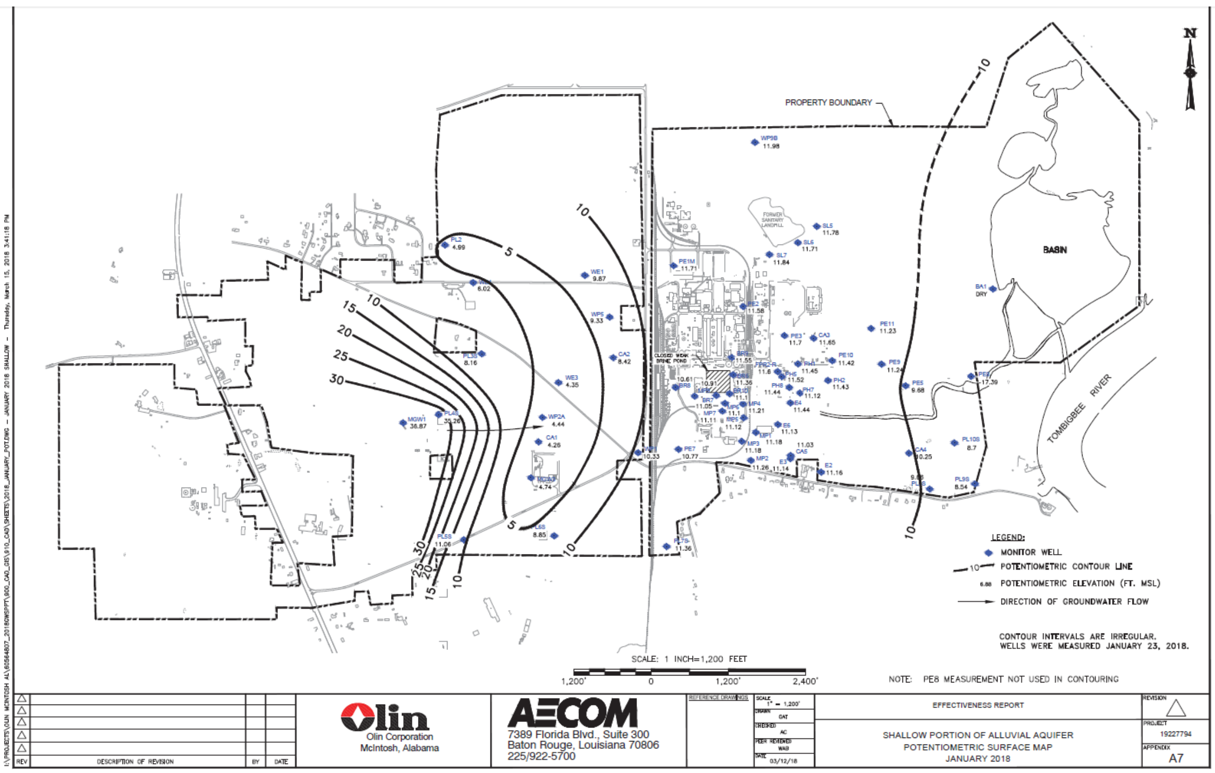

Figure 3: Olin Site Groundwater Elevation Map [Excerpted from the Annual Effectiveness Report (AECOM, 2018); all figures are reproduced at full size in Appendix B]

The upper Miocene aquifer is a highly permeable sand and gravel unit. The Miocene aquifer consists of two saturated zones separated by a confining unit, thought to be laterally continuous and impermeable to upward vertical movement of groundwater. A lower Miocene aquifer overlies the caprock of the salt dome. (Woodward-Clyde, 1993). The natural gradient of the Miocene aquifer is to the east/southeast.

Several industrial water supply wells at the Olin and adjacent Ciba-Geigy/BASF facility are screened in the Miocene aquifer. Five production wells in the Miocene are in active use at the Olin facility. Historically, Olin extracted water from additional wells screened in the Miocene aquifer.

The monitoring network in the Miocene is limited to a few wells, located primarily in the western part of the Site. Monitoring wells in the Miocene include the production wells and MP8, DH1, DH2, DH3, and MGW 4.

The Olin plant was located to exploit the salt dome formation as a source of brine for chlor-alkali production. The salt dome formation west of the main industrial process area is about 4,500 ft in diameter and greater than 2 miles deep. The cap rock is at a depth of about 500 ft bgs. Nine brine wells are known to have been completed in the salt dome over the history of the plant to provide brine for chlor-alkali production. Six brine wells were abandoned by 1994. The salt dome has also been used to store high-pressure air (1,200 pounds per square inch [psi]) for off-peak power production by Alabama Electric Cooperative and to store natural gas.

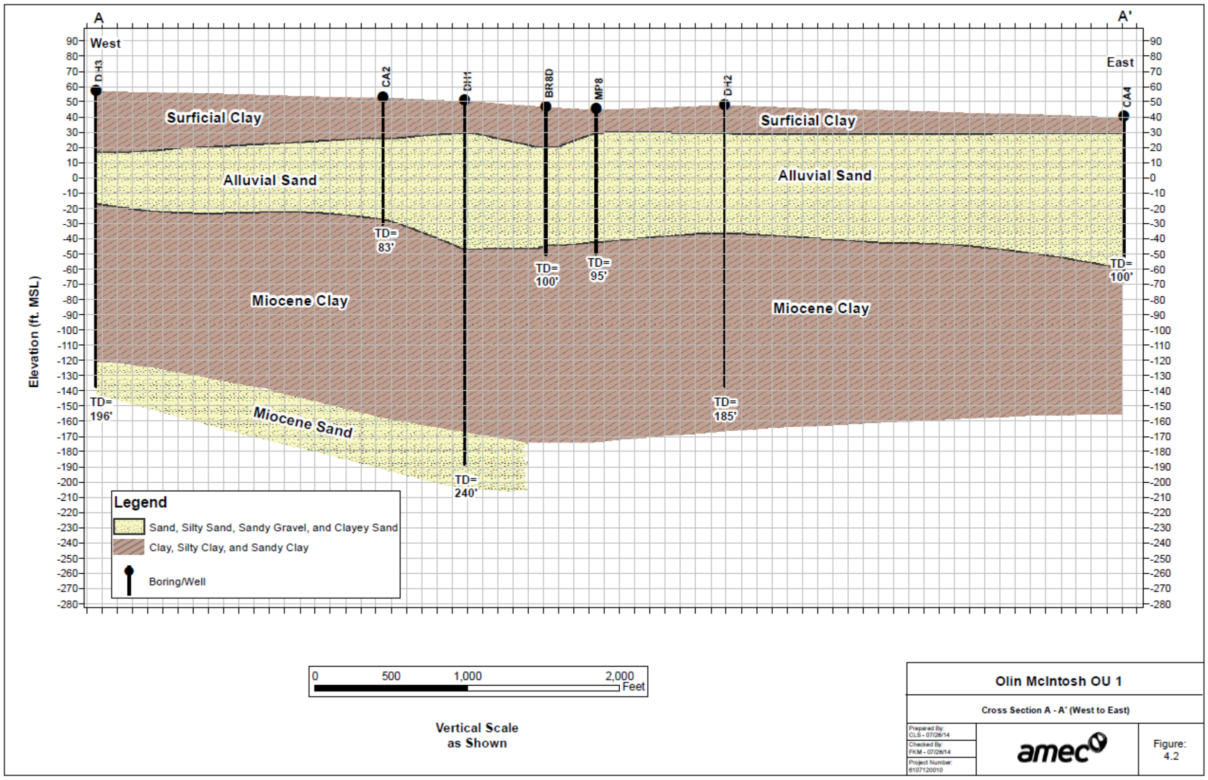

Figure 4: Olin Site Cross Section [Excerpted from the *Corrective Action Review and Recommendations for Operable Unit 1* (Amec, 2014); all figures are reproduced at full size in Appendix B]

4.1.4 Contaminant Fate and Transport

Primary releases from sources identified in Section 4.1.1 migrated under the influence of gravity through the surficial clay to the alluvial aquifer. After entry into the alluvial groundwater, plumes migrated with groundwater flow to the east/southeast and west of the groundwater divide. Releases from the Strong and Weak Brine Pond area resulted in the formation of a dense brine layer containing mercury at the base of the alluvial aquifer on the surface of the Miocene clay. Volatile organic compounds (VOCs) migrated to the alluvial aquifer from the CPC Plant and SLF areas.

Contamination originating near the Strong and Weak Brine Ponds and the former Mercury Cell Plant tended to migrate to the west, in the direction of the potentiometric low in the alluvial aquifer between PL3S/D and WE3 as well as to the east. Releases from the former CPC Plant and CPC Landfill migrated southeast as did releases from the SLF and drainage ditches east of the main industrial area. Multiple historical sources of contamination were present at different locations and during different time frames, resulting in several detached and comingled plumes across the Site.

Low level concentrations of VOCs have been observed in the Miocene aquifer, but elevated concentrations of mercury have not been observed to date. Contamination has been observed in the Miocene unit under the Ciba-Geigy/BASF plant. Regulators have expressed concern that continued pumping in the Miocene aquifer may draw down or spread contamination in a formation used as a regional drinking water supply.

Concentration trends at various wells have been developed using linear regression techniques on untransformed data. The majority of monitoring locations in the network show generally decreasing trends since 1987, and plume footprints have either decreased or remained stable under the various pumping regimes. However, many locations show highly variable results that do not appear to be seasonal (e.g. resulting from variations in the Tombigbee River level or seasonal rainfall) and some monitoring locations show increasing trends for specific COCs.

4.1.5 Remedial System Performance

A P&T system consisting of five recovery wells (CA1 through CA5) was installed in the alluvial aquifer in 1987. The initial remedial design was approved by ADEM under the RCRA CAP. The ROD selected continued operation of the RCRA CAP P&T system as part of the remedy along with two additional extraction wells.

The two new extraction wells were installed during the Remedial Action implementation. Well CA7 is a horizontal extraction well installed in 2001 south of the Weak Brine Pond and north the former CPC Plant. The goal of pumping at CA7 was to recover mercury, 1,4-dichlorobenzene, and chloroform within a dense brine layer at the interface between the alluvial aquifer and the Miocene clay (Amec, 2014) (about 40 ft bgs). CA7 is about 1,400 ft long with a 500-ft screen length. A vertical groundwater extraction well (CA6) was installed just west of the CPC Landfill to reduce contaminant mass in the CPC area.

The goal of extraction wells CA1 through CA5 was to maintain hydraulic capture of groundwater plumes, and the remedial objective of extraction at CA6 and CA7 was to remove contaminant mass in the interior of the plume. CA1, located west and south of the lime ponds, intercepted plumes of 1,4-dichlorobenzene and chloroform. Groundwater extracted from CA1 did not require treatment prior to discharge to Outfall 001 with subsequent discharge to the drainage ditch and the Olin Basin.

CA2 is located directly west of the former Mercury Cell Plant and recovered mercury plumes migrating west from the Strong and Weak Brine Ponds and the Mercury Cell Plant. Concentrations of mercury at CA2 before P&T shutdown were in the range of 10 to 20 μg/L, and VOC concentrations were below GWPS. Historical high concentrations of mercury in groundwater have been observed at source area wells BR8/8D, BR10, MP9, and BR7 and downgradient well WP3.

CA3 is located east of the former Mercury Cell Plant and primarily recovered the carbon tetrachloride plume emanating from the SLF area, intercepting low concentrations of mercury and chloroform. CA4 and CA5 are located southeast of the CPC Landfill (2,100 ft and 550 ft, respectively) and intercepted plumes with low levels of mercury and VOCs. CA6 is located immediately adjacent to the CPC Landfill, and intercepted historically high concentrations of chloroform and mercury.

Annual reports issued between 2011 and 2017 indicated ongoing operation and maintenance issues with extraction wells related to iron fouling. Fouling resulted in lower flow rates and significant costs to clean the wells.

The groundwater treatment system was designed to receive a combined flowrate of 550 gallons per minute (gpm) from extraction wells CA2 through CA7. The treatment process for extracted water included pH neutralization, clarification to remove iron and aluminum hydroxides, air stripping to remove VOCs and carbon absorption processes to remove mercury (URS, 2011).

Performance evaluation criteria outlined in the CAP permit for the P&T remedy included (URS, 2011):

- Evaluation of the capture zone to confirm plumes are intercepted by extraction wells,
- Demonstration of decreasing concentration trends for COCs,
- Evaluation to determine if hazardous waste or hazardous constituents are being released into the environment; and
- Confirmation that COCs are not detected in monitoring wells designated as boundary wells.

Data on pumping rates and contaminant mass extraction were not found in the literature reviewed. The performance evaluation for the P&T remedy did not include tracking the amount of contaminant mass removed versus the amount remaining in the subsurface. Estimates of cost or energy used per unit of mass removal were also not reported during the period of remedy operation.

A formal model-based review of capture zones of CA wells was not found in the literature reviewed, although a review was cited in an annual report (URS, 2013). Remedy performance was primarily evaluated by plotting potentiometric surface measurements. From the data reviewed, it is uncertain if the CA wells were creating optimal gradients for plume capture or were interfering with each other creating stagnant zones of residual contamination.

The RCRA permit specified annual reporting of semiannual groundwater monitoring results. The monitoring network consists of Point of Compliance (POC) wells to document quality of groundwater passing the POC, upgradient wells to represent background conditions, Corrective Action Effectiveness (CAE) wells to evaluate the efficacy of the CAP, and boundary (BDY) wells to delineate the extent of contamination. Additional wells not addressing specific monitoring objectives are designed Program (PGM) wells. Monitoring wells have been sampled semi-annually for about 30 years for water levels, a suite of analytes including COCs, and physical parameters under the RCRA CAP.

A letter dated May 29, 2014 was submitted to ADEM by the PRPs requesting that pumping in two CA wells (CA6 and CA7) be suspended. The 2014 *Corrective Action Review and Recommendations* report (Amec, 2014) provided justification for the termination of the P&T remedy using concentration trend analysis and modeling of groundwater data (discussed in Section 4.2). The PRPs submitted a letter dated December 1, 2014, requesting a phased shutdown of all P&T components. The letter included groundwater concentrations that would trigger contingent remedial responses, including potential re-activation of extraction wells.

A phased shutdown of the P&T system was approved by ADEM in 2015 under the RCRA CAP. Wells CA6 and CA7 were shut down in 2015, pumping ceased at CA4 and CA5 in July 2015 followed by quarterly groundwater monitoring (Wood, 2018). Pumping from wells CA1 and CA2 was terminated in 2016, and pumping ceased at CA3 in July 2017. The groundwater P&T system had been completely shut down for one year at the time of the optimization review.

The effect of the shutdown of the P&T system has been to flatten the groundwater gradient in the developed area of the plant, but there is still a flow divide with groundwater east of the railroad tracks flowing toward the Tombigbee River and groundwater west of the railroad tracks flowing toward a local potentiometric low near wells WP10 and WE3. Drawdown resulting from operation of the CA wells also masked the groundwater low west of the plant, which did not become readily apparent until water levels were measured in the absence of CA well operation.

A Declaration of Restrictive Covenants was recorded on October 9, 2001, which prohibits the use of the remediated surface area for any purpose other than industrial use and prohibits the use of water from the remediated portion of the alluvial aquifer as a source of potable water. (Olin, 2018).

4.1.6 Potential Human and Ecological Exposure Pathways

Potentially complete human exposure pathways of concern for Olin OU1 are ingestion of affected groundwater, vapor intrusion (VI), and direct contact with contaminated soils. Ecological exposure pathways are addressed in OU2.

Groundwater from the alluvial aquifer is not a drinking water source and ICs prevent use of Site groundwater from the alluvial aquifer as a source of drinking water. The Miocene aquifer is the primary source of drinking water for the McIntosh area. The McIntosh Water Department provides municipal water to the community of McIntosh from a public well located within three miles of the Site, and members of the adjacent community do not use private wells as a potable water source. Municipal water is regularly tested and treated before distribution to ensure that the community is not exposed to any groundwater contamination in the Miocene aquifer. Concentrations of COCs in the Miocene are currently below GWPS.

The Third FYR (EPA, 2016) included a recommendation to investigate the potential for VI at the Site. The PRP developed a VI risk evaluation in accordance with EPA guidance using the EPA's Vapor Intrusion Screening Levels (VISLs) calculator (Amec 2018). Maximum concentrations observed in alluvial groundwater in January 2017 were compared against VISL values based on conservative exposure scenarios for commercial/industrial workers. The evaluation used a very conservative assumption for depth to groundwater of 5 ft bgs. The actual depth to the alluvial aquifer at the Site is between 10 to 50 ft bgs, with surficial soils composed of dense clay.

COCs exceeding the calculated VISLs consisted of carbon tetrachloride, chloroform, 1,4-dichlorobenzene, and hexachlorobenzene. Each of these COCs exceeded screening levels at from 1 (hexachlorobenzene) to 19 (chloroform) groundwater monitoring locations. Monitoring wells BR8, BR8D, and SL7 showed exceedances of VISL and are within 100 ft of Site building. Potential VI risk was estimated for existing and potential future buildings using an EPA VI model based on the Johnson and Ettinger analytical solution and Site-specific input parameters (rather than the default parameters used to calculate the VISLs).

The results of the VI model indicate that hazard indices for all COCs and locations are less than 1. All calculated risks for carcinogenic effects were below 1×10^{-6} with the exception of a potential future building at well location E6 where risk was calculated to be 1×10^{-5}. This value is still within the range of CERCLA target cancer risk of 1×10^{-6} to 1×10^{-4}. There are no current plans to construct a building at this location, and if future plans include a building at this location, there are several engineering mechanisms to mitigate potential VI risk.

Selected soil remedies such as capping and industrial work control plans and training prevent direct human exposure to affected soils. There are currently no potentially complete exposure pathways involving soil and groundwater for OU1.

4.2 Summary of Findings and Critical Data Gaps

4.2.1 Remedial Action

Groundwater concentrations at the Olin Site have not attained GWPSs. There are currently no remedial actions addressing groundwater contamination. The 2014 Olin *Corrective Action Review and Recommendations* (Amec, 2014) report presented arguments for terminating the P&T remedy but did not address the RAO for attainment of remedial goals.

The PRP appears to propose a monitored natural attenuation (MNA) remedy; however, no formal report addressing EPA requirements for selecting MNA as a remedy has been submitted. Selecting an MNA remedy under CERCLA would require determining that the mechanisms and rate of attenuation are sufficient to achieve remedial goals in the same timeframe as active remediation. In addition, a demonstration of a “clear and meaningful” decreasing trend in the absence of active remediation and demonstration that the plume is not expanding are required (USEPA 2015). The PRP has not demonstrated a biogeochemical pathway for contaminant destruction or detoxification, and the dominant attenuation pathway appears to be dilution. An additional remedial strategy will be required to treat or remove residual contamination consistent with RAOs under both CERCLA and RCRA.

4.2.2 Residual Source Material

Primary source area remediation was conducted in the 1980s under RCRA. No active primary sources (i.e. leaking tanks or pipelines or process discharge above permitted levels) are ongoing at the Site. However, residual contamination remains in the unsaturated soils above the alluvial aquifer. Contamination entrained or adsorbed in the vadose zone may function as an ongoing, low-level, secondary source of contamination to groundwater. Several SWMUs were capped and stabilized, but were not lined on the bottom, so waste is in contact with subsurface soil.

Several lines of evidence support the conclusion that there is continued, low-level, discharge of contaminant mass to groundwater from secondary sources. Apparent low-level secondary source areas include the former Weak Brine Pond, the former CPC Landfill, and the SLF.

Monitoring wells BR7 and BR10 are located adjacent to the Weak Brine Pond and continue to exhibit elevated mercury concentrations (72.5 µg/L and 46.7 µg/L, respectively in the first semiannual event of 2018). Furthermore, these elevated concentrations are part of overall increasing mercury concentration trends at these two wells. There is also a strong statistically increasing trend for chloroform at BR7 from 2012 to 2018 (calculated using the EPA Statistical Tool 2014). The trend for chloroform at BR10 may also be increasing. The proximity of these concentrations to the Weak Brine Pond and trends exhibited after years of groundwater extraction, suggest an ongoing source of mercury and chloroform.

The CPC Landfill continues to be a source of chloroform and mercury and potentially 1,4-dichlorobenzene to groundwater as indicated by stable and high concentrations at adjacent monitoring wells. POC well E6 is located just east of the former CPC Landfill and has historically shown high concentrations of chloroform and mercury. Chloroform concentrations at E6 have shown a decreasing trend between 2012 and 2018, likely due to the influence of pumping at CA5, but recent concentrations remain elevated (1,200 µg/L in January 2018). Elevated concentrations of 1,4-dichlorobenzene remain at well MP16 west of the CPC Landfill with a recent concentration of 300 µg/L in January 2017 (MP16 is currently not sampled due to mechanical problems with the well).

The SLF also appears to have ongoing, low-level discharge of COCs. Concentrations of chlorobenzene and carbon tetrachloride both remain above GWPS at SL7, and exceedances of the GWPS also occur at SL5 and SL6 for carbon tetrachloride and tetrachloroethene (PCE). Concentrations of these COCs were historically higher at these monitoring wells, and some of the decreasing trends might be attributed to changes in groundwater flow directions resulting from changes in remedy pumping. Monitoring wells SL5, SL6, and SL7 are all located to the southeast of the SLF, and this was the likely direction of groundwater flow during full operation of CA1 through CA7. However, reductions in the flow rates from these wells and eventual shutdown of these wells appears to result in groundwater flow to the northeast from the SLF. An additional investigation in the area of the SLF was conducted in May 2018 by installing temporary wells east of the SLF plume. Groundwater sampling results were non-detect for chlorobenzene and carbon tetrachloride, indicating that the current monitoring network delineates the extent of the plume to the east.

Overall, asymptotic concentrations at source-area monitoring wells under pumping conditions indicate that there is likely a continued low-level source of contaminant mass to groundwater. Evidence of a depleted source would include strongly decreasing to non-detect conditions at source wells with the center of plume mass moving downgradient. The data indicate a steady, low-level source feeding groundwater in several areas. The Bioscreen evaluation was run with the assumption that there was no residual mass in the source zone. Data reviewed do not support this conclusion.

No estimate of original mass in the source versus mass removed has been made. There is no estimate of the current mass in the source zones (although Bioscreen was used to estimate total dissolved/dissolvable mass throughout the plume). Contaminant mass may be held in low permeability strata such as clays or silts and be subject to slow release or back diffusion over time. Caps installed over waste areas would slow, but not entirely eliminate leaching through contaminated material. The extent of the residual brine plume in the lower alluvial aquifer near the Miocene clay and its function as a low-level source of mercury to groundwater is not known.

4.2.3 Bioscreen Model and Hydraulic Containment

One RAO of the RCRA CAP was to hydraulically contain contaminated groundwater beneath the facility. The hydraulic containment RAO was intended to ensure maintenance of a stable or decreasing plume footprint in the alluvial aquifer and prevent migration of contaminated groundwater to the Miocene Formation, surface water, and off-Site properties. Stability of plumes in the absence of the extraction remedy will depend on the strength of continuing sources (i.e. contaminant mass discharge from residual secondary sources) offset by physical attenuation processes (dilution, dispersion) for inorganic contaminants and physical attenuation processes and biodegradation for organic COCs.

The 2014 remedy review report documented a Bioscreen (Newell et al., 1996) analysis indicating that groundwater plumes would not migrate beyond Olin property boundaries. Bioscreen is a screening-level spreadsheet tool developed in 1996 to simulate hydrocarbon transport. The primary uses of the tool were intended to be for estimating plume migration in the absence of remedial actions, decision support for implementation of MNA remedies at hydrocarbon sites, and for estimating persistence of hydrocarbon plumes.

Bioscreen is based on a simple analytical model and is not designed to model complex flow regimes with variable seepage velocities, geochemical transformations (outside of aerobic hydrocarbon degradation), preferential flow paths, back-diffusion from low-permeability strata or complex source zones.

The accuracy and relevance of the Bioscreen output is dependent on the simplifying assumptions used in adopting the model and on the quality of the input parameters. One critical input parameter that controls the output is the retardation coefficient (R), which is based on the tendency for a contaminant to adsorb to soil during transport. The higher the retardation coefficient, the slower the transport and plume expansion. Therefore, the use of a higher R results in a more stable simulated plume.

The Bioscreen analysis concluded that the mercury plume would be very stable, migrating less than 100 ft over the course of 100 years. R values used for mercury ranged from 866.3 to 4,733. Combining these values with the assumed hydraulic conductivity, hydraulic gradient, and porosity for Mercury Plume 2B, the transport velocity for mercury in Mercury Plume 2B in the Bioscreen analysis was 0.000055 ft/day. However, based on the plume extent in 1987 (at least 1,300 ft from the Weak Brine Pond to WP3) or the plume extent in 2006 (at least 2,100 ft from the Weak Brine Pond to WE3), the transport velocity for mercury in this plume had to be higher than 0.1 ft/day. Similar analyses can be done for the other plumes and the other COCs analyzed in the Bioscreen analysis, with the overall conclusion that the Bioscreen analysis severely underestimates the potential for plume migration.

One noticeable contributor to overestimating the R and therefore underestimating contaminant transport velocity is the assumption that the fraction of organic content is 0.02. This value is the upper range of the values provided in the Bioscreen manual and likely overestimates the fraction of organic carbon by approximately an order of magnitude.

Although the use of a high R also leads to higher initial COC mass adsorbed to the soil within the plume, it does not lead to a more conservative analysis because the Bioscreen input assumes that there is no ongoing source. As discussed in Section 4.2.3, the optimization team believes that there are ongoing secondary sources that can continue to sustain the various COC plumes.

In summary, the optimization team does not believe that Bioscreen analysis used to support discontinuation of CA well operation accurately represents COC plume migration in the absence of extraction from the CA wells. Furthermore, the optimization team believes that the plumes are significantly more mobile in the absence of pumping than suggested by the Bioscreen analysis. This mobility is apparent in the increasing and decreasing trends that have occurred as a result of various groundwater extraction scenarios. Many of the observed trends, particularly for mercury, would not have been possible based on the model input used for the Bioscreen analysis. Elevated concentrations near source area wells such as BR7 and BR10 are likely to eventually migrate farther than forecasted in the absence of active remediation.

4.2.4 Low Potentiometric Surface West of Plant

Potentiometric surface maps indicate a groundwater low or trough in the alluvial aquifer west of the industrial area near monitoring wells WE3, WP6A, and WP10. Groundwater elevations as of January 2018, after termination of the P&T, were in the range of 3.5 to 5 ft amsl, surrounded by higher elevations in the range of 8 to 10 ft amsl within about 600 to 1,000 ft distance. Extraction wells CA1 and CA2 are located south and east of the potentiometric low and may have contributed to lower elevations while they were in operation. Groundwater extraction at CA1 and CA2 ended in 2016; however, the depression in the alluvial aquifer is still observed in 2018.

The fate of groundwater in the vicinity of WE3 is a significant source of uncertainty in the Site CSM. Since groundwater at WE3 is not migrating laterally north, south, east, or west, a reasonable conclusion is that groundwater from the alluvial aquifer may be migrating vertically to the Miocene. However, the pathway or conduit to the Miocene aquifer is unknown. The vertical migration from the alluvial aquifer into the Miocene aquifer appears to create a hydraulic boundary that prevents further westward migration in the alluvial aquifer. Once in the Miocene aquifer, contaminant migration would follow groundwater flow to the east toward the facility production wells. This CSM is supported by the water levels measured in the Miocene monitoring wells (DH1, DH2, and DH3). DH1, which is the Miocene monitoring well closest to the facility production wells, has the lowest water level of the three wells. In addition, DH1, which is located between the western potentiometric low in the alluvial aquifer and the production wells in the Miocene aquifer, has had detections in the past several years of chlorobenzenes, chloroform, and mercury. Chlorobenzenes in DH1 should not result from Miocene migration from the north because the facility production wells are located between DH1 and potential sources to the north.

Most boring logs from the Site indicate that the Miocene clay is a substantial barrier to downward flow. However, a cross section in the area the former evaporator (near borings DB-13 and P-34 [see Appendix B]) show a sandy channel in the Miocene clay. There are insufficient data from the western part of the Site to determine if the Miocene clay is thin or if there are sand channels present in the area of the potentiometric low.

The Olin plant was located to take advantage of a salt dome formation just west of the industrial process area. The potentiometric low in the alluvial aquifer is just east of the location of the current brine extraction wells. The area around salt domes along the Gulf Coast has historically been subject to oil and gas exploration. Extensive oil and gas exploration projects were conducted between the 1930s and the 1940s. McIntosh is 20 miles from Alabama's largest inland oil field at Citronelle, Alabama. It is unknown when the brine formation was discovered or if the area around the Olin brine wells was subject to oil and gas exploration before construction of the plants in the 1950s. The potentiometric low in the alluvial aquifer could be caused by a preferential flow path such as sand channels in the Miocene clay or by historical exploration borings in the salt dome area.

4.2.5 Statistical Data Analysis

The 2014 *Corrective Action Review and Recommendations* report (Amec, 2014) provided justification for the termination of the P&T remedy using concentration trend analysis of groundwater data to demonstrate plume stability. Several issues with the analyses were identified during the optimization review.

The use of linear regression for data trending involves a number of underlying assumptions that are not necessarily met in the individual monitoring well datasets. Several of the datasets show significant variability and unacceptably low coefficients of determination (r^2 values or “goodness of fit”) with linear trending indicating that a non-parametric trend method such as the Mann-Kendall test may be more appropriate to statistically evaluate trends.

The concentration trend graphs were shown, but the level of confidence in the strength of increasing or decreasing trends was not provided. In order to test the confidence on the regression trend, a t-test may be used to test that the true slope is different from zero. In addition, exploratory statistics such as median and coefficient of variation, distribution, and outlier analysis for the well datasets are not shown. A measure of variability in the data can provide important information in evaluating the CSM and potential physical or chemical influences on contaminant mobility and persistence.

The method of demonstrating that a well had attained remedial goals specified in the RCRA permit was three consecutive sampling results below the GWPS. This method is not consistent with current guidance under CERCLA.

5 RECOMMENDATIONS

Site-specific recommendations are provided for the five of the six major areas associated with optimization: remedy effectiveness, cost reduction, technical improvement, progress toward Site closure, and energy and materials efficiency (property reuse or revitalization is not relevant to the Site as the property is currently in use). Table 6 provides a summary of the recommendations and estimated costs (or savings) for implementing each recommendation. The levels of certainty for the cost estimates provided are comparable to those typically prepared for CERCLA FS reports (-30 to +50 percent) and are considered rough estimates for planning purposes.

5.1 REMEDIAL STRATEGY

Groundwater at the Olin Site is likely to remain above GWPS without further active remediation due to low-level, ongoing, secondary sources. However, risks to human health and the environment are low, and continued operation of the CA wells is unlikely to provide measurable improvements in protecting human health and the environment or achieving Site closure. The appropriate remedial strategy for the Site will depend on the specific objectives of the overseeing regulatory authorities. The optimization team presents three remedial strategies that are all protective of human health and the environment but differ greatly in terms of cost and remedy duration. The strategies are presented in the three subsections below and are summarized as follows:

- *Aggressive Remediation:* This strategy prioritizes Site closure by conducting aggressive remediation of secondary source areas. The cost of implementing this strategy and the potential disruption to facility operations are high.
- *Source Control:* This strategy focuses on control of discharges from secondary sources to allow restoration areas of the alluvial aquifer outside of the source areas and to protect the Miocene aquifer. The cost of implementing this strategy is likely similar to the cost of operating the CA wells. Restoration of the aquifer outside of the source areas might occur in a timely manner, but the source areas themselves would remain until directly addressed.
- *Long-Term Evaluation:* This strategy relies on the potential for the plumes to be stable and the absence of current exposures to human health and ecological receptors. Actions over the foreseeable future involve monitoring the stability of the contaminant plumes. The strategy eventually transitions to aggressive remediation when land use changes.

5.1.1 Aggressive Source Remediation

This remedial approach focuses on source remediation, recognizing that the existing low-level plumes will attenuate over time once the sources are addressed. The initial step will be to identify and characterize the remaining sources. Direct-push should be used to collect ground water grab samples in the vicinity of the Weak Brine Pond, CPC Plant and Landfill, and SLF. If direct-push is not capable of advancing through the surficial clay, then an alternate technique will be needed. Mini-sonic with push-ahead sampling can potentially be used. Alternatively, a drilling technique (hollow stem auger, mud rotary, or sonic) could be used to penetrate and case off the shallow clay; direct-push could be used for sampling within the alluvial aquifer.

The grab samples would be collected in transects and at multiple depth intervals to try to target the location and depth of remaining sources. Once the areas of the locally elevated concentrations are identified, vadose zone soil sampling can be conducted if appropriate. Figure 5 outlines the optimization team's suggestions for the transect locations near the Weak Brine Pond and CPC area, with 50-ft horizontal spacing between sampling locations within a transect. A transect to the east of the SLF is also recommended. Note that the figure does not include any characterization around the former Mercury Cell Plant because the optimization team understands that this area is not accessible for intrusive work due to ongoing facility operations. If a source is present, it will become apparent with concentration trends at WP3 or other monitoring locations once the other sources have been addressed. The optimization team cannot offer source remediation options for this location given that it is inaccessible for intrusive work.

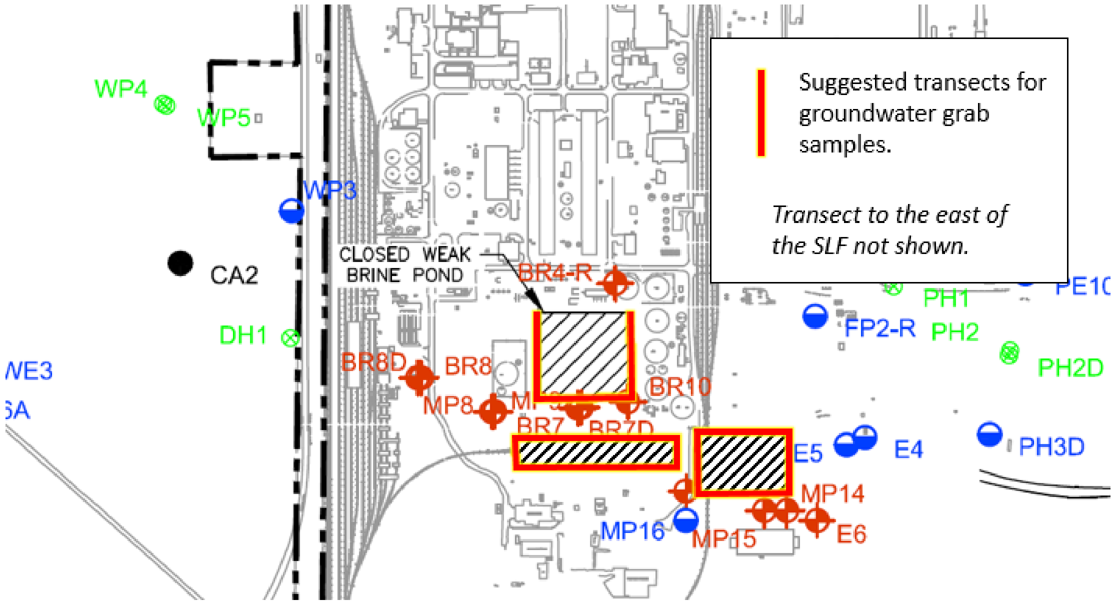

Figure 5: Suggested Sampling Transects. [Base map from the Annual Effectiveness Report (AECOM, 2018)]

Specific aggressive source remediation measures would depend on the COC and the nature of the source. Given the potential for the contamination to be present within the surficial clay, intrusive methods such as excavation or in situ mixing are likely remedial approaches. The costs will be highly dependent on the horizontal and vertical extent of the source and the method for treating it. Aggressive source remediation could be implemented incrementally as former waste or process areas are redeveloped to expand or enhance industrial operations.

5.1.2 Source Control

Like the aggressive source remediation approach, this approach focuses on the secondary source areas, recognizing that the existing low-level plumes will attenuate over time once the sources are addressed. The same characterization steps as outlined in the previous approach are suggested to better inform the design of the hydraulic control system and limit the number of extraction wells and the extraction rates. One potential outcome might be that extraction from CA7 and potentially a new extraction well near SL6 and SL7 are sufficient. The treatment system and operation and maintenance of the remedy would likely be very similar to that of the CA well remedy with the exception that fewer wells are used.

Restarting groundwater extraction should be preceded by theoretical capture zone analysis to optimize the location and extraction rate for wells in the system. The goal of groundwater extraction optimization would be to minimize plume migration, volume of groundwater removed and cost of operation while maximizing contaminant removal.

5.1.3 Long-Term Evaluation

This approach recognizes that current extents of the COC plumes are significantly smaller relative to historical conditions and that there are no current human or ecological exposures. As such, this approach consists of monitoring the plumes over time to evaluate plume stability and defer source remediation until access to potential residual sources is readily available. To the west, contamination is expected to migrate toward WE3 and the discharge vertically into the Miocene aquifer where, based on the current interpretation of the CSM, it is presumably extracted by an industrial production well on the property. Therefore, in the absence of any additional remedial activities, the plume would not expand farther to the west in the alluvial aquifer and would remain on-property with no expected human or ecological exposures under current land use (assuming concentrations in the Miocene remain below GWPS).

To the east, the degree of future plume migration is uncertain. The current residual sources are different in strength and location than the original sources, and it is unclear where these sources are located with respect to the groundwater divide. Additional groundwater monitoring data over time will provide a better indication of the potential for plume migration to the east toward the Tombigbee River.

Under this approach, the current monitoring program, with minor modifications, would continue and the data would be evaluated for plume stability or the potential for plume migration (see Section 5.2.1). Assuming the current optimization team CSM for the western potentiometric low is correct, the focus on the western portion of the plume would be to confirm the plume is captured by the potentiometric low and the facility production wells, and that concentrations in the Miocene do not exceed remedial goals.

A Miocene aquifer monitoring well could be installed in the general vicinity of WE3 to confirm groundwater levels and concentrations. The well should be installed with sonic drilling with continuous coring and should be double cased to reduce drawdown or leakage from the alluvial to the Miocene. The boring log can be evaluated to determine if natural lithology is responsible for the potentiometric low. If the clay is continuous, then it is likely that historical boreholes from exploratory drilling are the cause of the connection between the alluvial aquifer and the Miocene aquifer. If there are sand lenses, then perhaps there are natural connections between the alluvial aquifer and Miocene aquifer. More importantly, water levels and water quality sampling from this new monitoring well can be used to confirm the conceptual model.

The Miocene water level will need to be lower than that at DH3 and higher than that at DH1 for flow toward the production wells. Water quality sampling should confirm the presence and magnitude of Site COCs. Water levels should continue to be measured from the existing well network. Water quality sampling for the western plume can be limited to annual sampling from BR7, BR7D, BR8, BR8D, BR10, CA2, MP9, WP3, WE3, WP4, WP6A, and DH1. Given the long screen interval of the CA wells, multiple intervals of CA2 may need to be sampled during the first few events to determine the appropriate intervals to sample over the long term.

For the eastern portion of the plume, statistical concentrations trends would need to be evaluated for plume stability (see Section 5.2). If the plume has the potential to migrate and will eventually migrate to the river at unacceptable concentrations, then active remediation as discussed in Sections 5.1.1. or 5.1.2 will be needed in a timely manner. If data suggest that the plume will not reach the river at unacceptable concentrations, then monitoring for tracking purposes can continue. Eventually, when access allows, the optimization team assumes that the source of any ongoing groundwater contamination will be addressed to prevent further groundwater contamination and allow eventual aquifer restoration.

Water levels should continue to be measured from the existing well network. Water quality sampling for the eastern plume can be limited to semiannual sampling from CA4, CA5, E4, E5, E6, MP14, MP15, MP16, PH3D, PL8S/D, PL9S/D, and PL10S/D. Given the long screen interval of the CA wells, multiple intervals of CA4 and CA5 may need to be sampled during the first few events to determine the appropriate intervals to sample over the long term.

This approach could also be implemented for the carbon tetrachloride and chlorobenzene associated with the SLF. Three additional temporary groundwater wells were installed in the SLF area in May 2018. The sampling locations were selected to delineate the chlorobenzene and carbon tetrachloride plumes to the east of the SLF. Sampling data showed non-detect values for the COCs. These data demonstrate that the plumes do not appear to be migrating to the east. Water levels should continue to be measured from the existing well network near the SLF, and water quality sampling for the SLF can be limited to semiannual sampling from SL5, SL6, SL7, PE11.

The monitoring program listed above represents a significant reduction in monitoring relative to the current program and could result in significant savings. However, the optimization team recognizes that the Site stakeholders may want to sample more wells than those listed above to provide additional information at the boundaries or upgradient. The cost of the monitoring program described above might be half of the cost of the current monitoring program. These cost savings would be offset by the cost of installing a new Miocene well near WE3, which is estimated to be $50,000.

5.2 Monitoring and Reporting

5.2.1 Statistical Trend Analysis

Demonstrations of plume stability should include evaluation of statistical trends at individual monitoring wells for priority COCs.

Annual reports currently present concentration trend graphs for priority COCs in monitoring wells. Trend analysis is performed by linear regression of untransformed data; however, many of the data sets may not meet the statistical criteria for using linear regression as a trending method. If linear regression is going to be used for determining trends and plume stability, then exploratory data analysis (e.g. data distribution, outlier analysis) should be used to demonstrate that the data sets meet appropriate criteria such as following a normal data distribution. Methods such as log-transformation of the raw data may be required for the distribution to be compatible with analysis by linear regression (e.g. log-normal distribution). Datasets that have no distinct distribution should be evaluated for trend by using non-parametric methods such as the Mann-Kendall test for trend with the level of confidence in the trend indicated. Statistical trend results should be listed in a table by well, for ease of interpretation.

The optimization team recommends reviewing the EPA *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance* (USEPA, 2009), the ProUCL Technical Manual (Singh and Singh 2013) or the MAROS Software Manual (AFCEC, 2012) for improved statistical analysis of trends. EPA has also published a software tool and guidance for statistical interpretation of data (see Section 5.2.2) to demonstrate attainment of remedial goals that can also be used for exploratory data analysis and evaluation of statistical trends.

In addition to evaluation of statistical trends at individual well locations, plume stability can be demonstrated by estimating and evaluating a trend on total dissolved mass in the plume over time, mass discharge or flux from the source, or the area exceeding MCLs. Several methods of plume stability analysis are provided in the MAROS software (AFCEC, 2012) and the Mass Flux Toolkit (Farhat et al., 2006).

The RCRA CAP permit identified a metric of attainment of remedial goals as three consecutive semi-annual monitoring results below remedial goals. This metric does not meet the standard under CERCLA, which is identified in the 2014 EPA Attainment Guidance (USEPA, 2014). EPA has published an updated spreadsheet-based groundwater statistical analysis tool including methods recommended above and in the attainment guidance to evaluate statistical concentrations trends. The attainment evaluation may be used for individual COCs as a basis to negotiate their deletion from routine analysis.

The cost of modifying the statistical approach to non-parametric methods such as Mann-Kendall, will likely be negligible compared to ongoing data analysis and reporting costs.

5.2.2 Identify Location of Dense Brine Plume in Alluvial Aquifer

Monitoring and decision documents discuss a dense brine plume at the interface of the lower alluvial aquifer and the Miocene clay in the area of CA7. The brine plume contains high residual levels of mercury. The brine plume is not identified on any figures found during the optimization review, either in cross sections or on areal extent maps. A figure identifying the extent of the residual brine plume, based on conductivity or total dissolved solids measurements, would be helpful in visualizing the brine plume that may be a long-term, low-level source of contamination. The cost of evaluating historical data and depicting the dense brine plume on a map is likely negligible compared to ongoing reporting costs.

5.2.3 Annotated Cross-Section

Understanding of Site remedial progress will be improved if annual reports include annotated cross sections showing the depth and location of well screens along a transect with concentrations of key COCs indicated. The addition of annotated cross sections will support determinations of plume stability or shrinkage. The cost of including annotated cross sections in annual reports is estimated to be about $2,000 annually.

5.3 INVESTIGATION OF WESTERN POTENTIOMETRIC LOW

Regardless of the remedial strategy adopted (see Section 5.1), the optimization team believes that the CSM associated with the western potentiometric low and contaminant fate and transport in this area should be better understood. Recommendation 5.1.3 includes the installation of a Miocene aquifer monitoring well, and due to the existing western plumes, this well should likely be installed regardless of the remedial strategy selected. To further support the CSM development, the optimization team recommends an investigation of historical information related to potential construction of brine wells or oil and gas exploration in the area of the potentiometric low in the alluvial aquifer west of the industrial process area. Historical exploration wells drilled in the area just east of the salt dome could be potential conduits for discharge of contamination in the alluvial aquifer to the Miocene. The Alabama Oil and Gas Board or the Alabama Geological Survey records should be reviewed to identify drilling activity that took place before the 1950s. The cost for the new well and the savings associated with a potentially revised monitoring program are provided in Section 5.1.3. The additional historical investigation might cost $15,000.

TABLE 6. Recommendations and Cost Summary

RECOMMENDATION	EFFECTIVENESS	COST REDUCTION	TECHNICAL IMPROVEMENT	SITE CLOSURE	REUSE REVITALIZATION	ENERGY AND MATERIAL EFFICIENCY	ESTIMATED CAPITAL COST	CHANGE IN ANNUAL COST
5.1 Remedial Strategy								
5.1.1 Source Remediation	X			X			Not Estimable	
5.1.2 Source Control	X		X	X			Comparable to historical CA operation	
5.1.3 Long-Term Evaluation	X	X	X	X			$50,000	potential 50 percent reduction in monitoring costs
5.2 Monitoring and Reporting								
5.2.1 Statistical Trend Analysis	X		X	X			N/A	N/A
5.2.2 Identify Location of Dense Brine Plume in Alluvial Aquifer	X		X	X			N/A	N/A
5.2.3 Prepare annotated cross sections								$2,000
5.3 Investigation of Western Potentiometric Low	X	X	X	X			$15,000	

"X" Indicates that the recommendation pertains to the indicated optimization category
Values in parentheses "()" indicate estimated annual cost savings
M = Million $

APPENDIX A:

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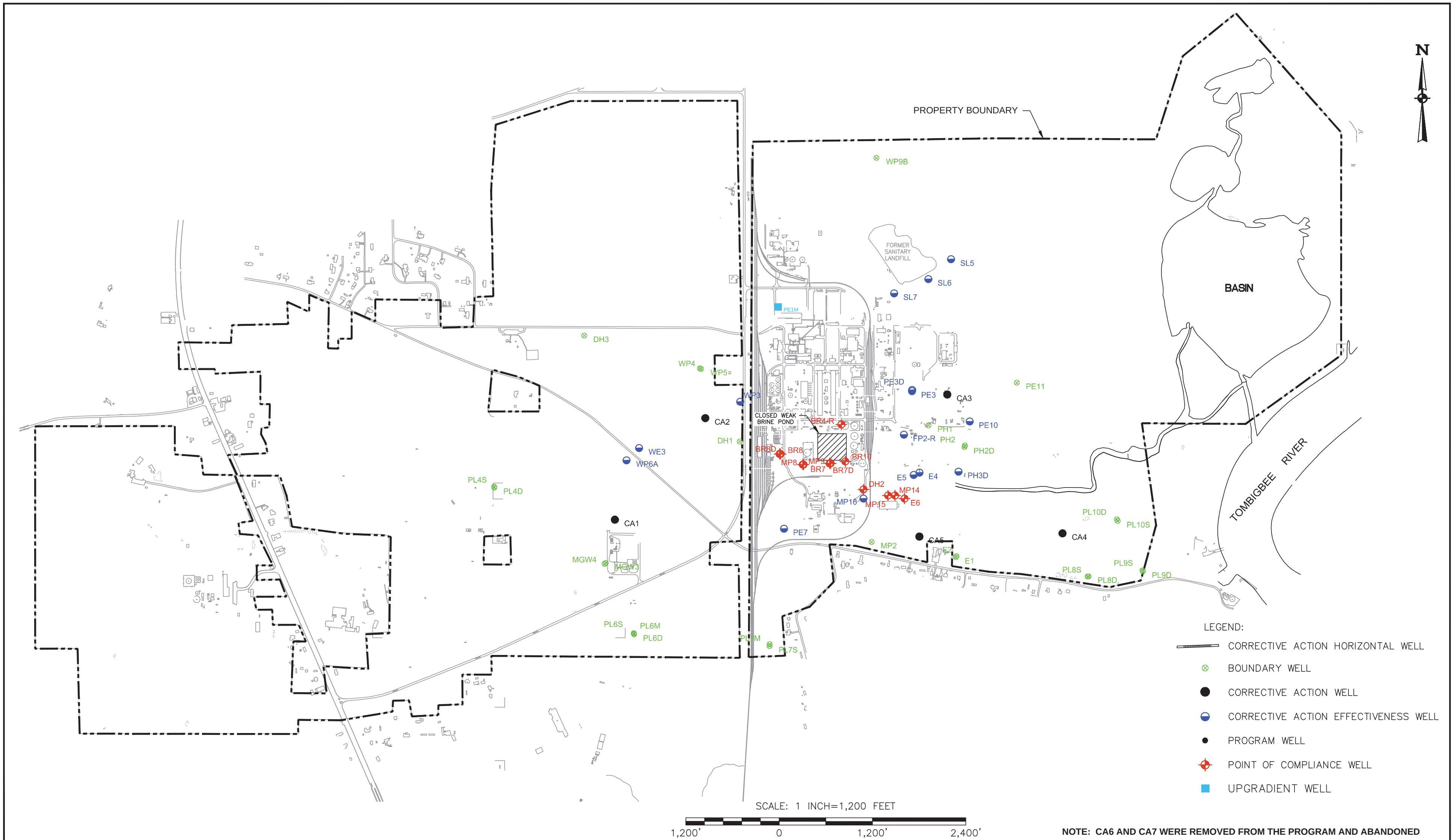
APPENDIX B:

SUPPORTING FIGURES



NOTE: CA6 AND CA7 WERE REMOVED FROM THE PROGRAM AND ABANDONED

REV	DESCRIPTION OF REVISION	BY	DATE
△			
△			
△			
△			
△			

Olin Corporation
McIntosh, Alabama

AECOM
7389 Florida Blvd., Suite 300
Baton Rouge, Louisiana 70806
225/922-5700

REFERENCE DRAWINGS

SCALE	1" = 1,200'
DRAWN	GAT
CHECKED	AC
PEER REVIEWED	WAB
DATE	03/12/18

EFFECTIVENESS REPORT

SITE FEATURES AND WELL LOCATIONS

REVISION △

PROJECT 19227794

FIGURE 1

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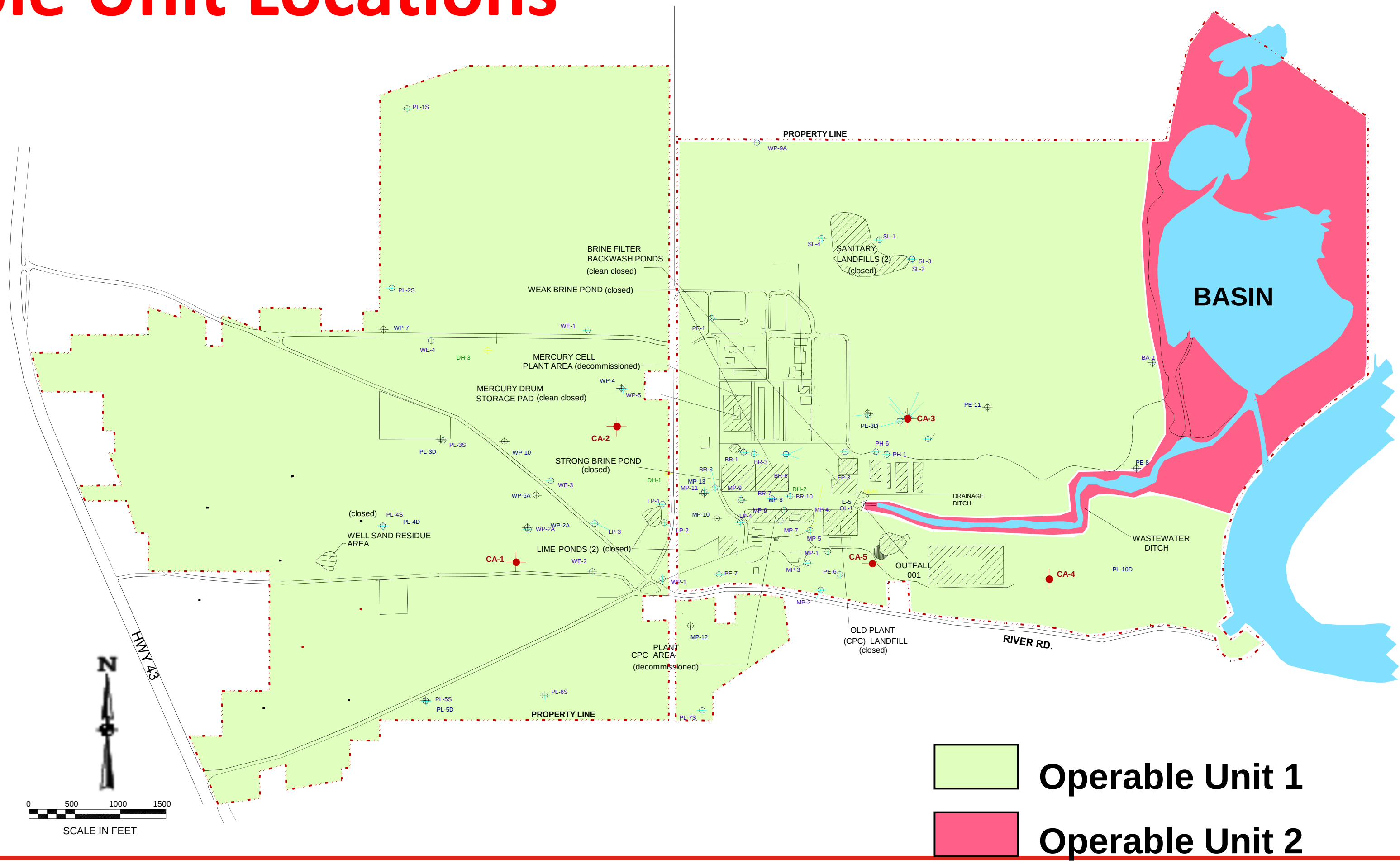
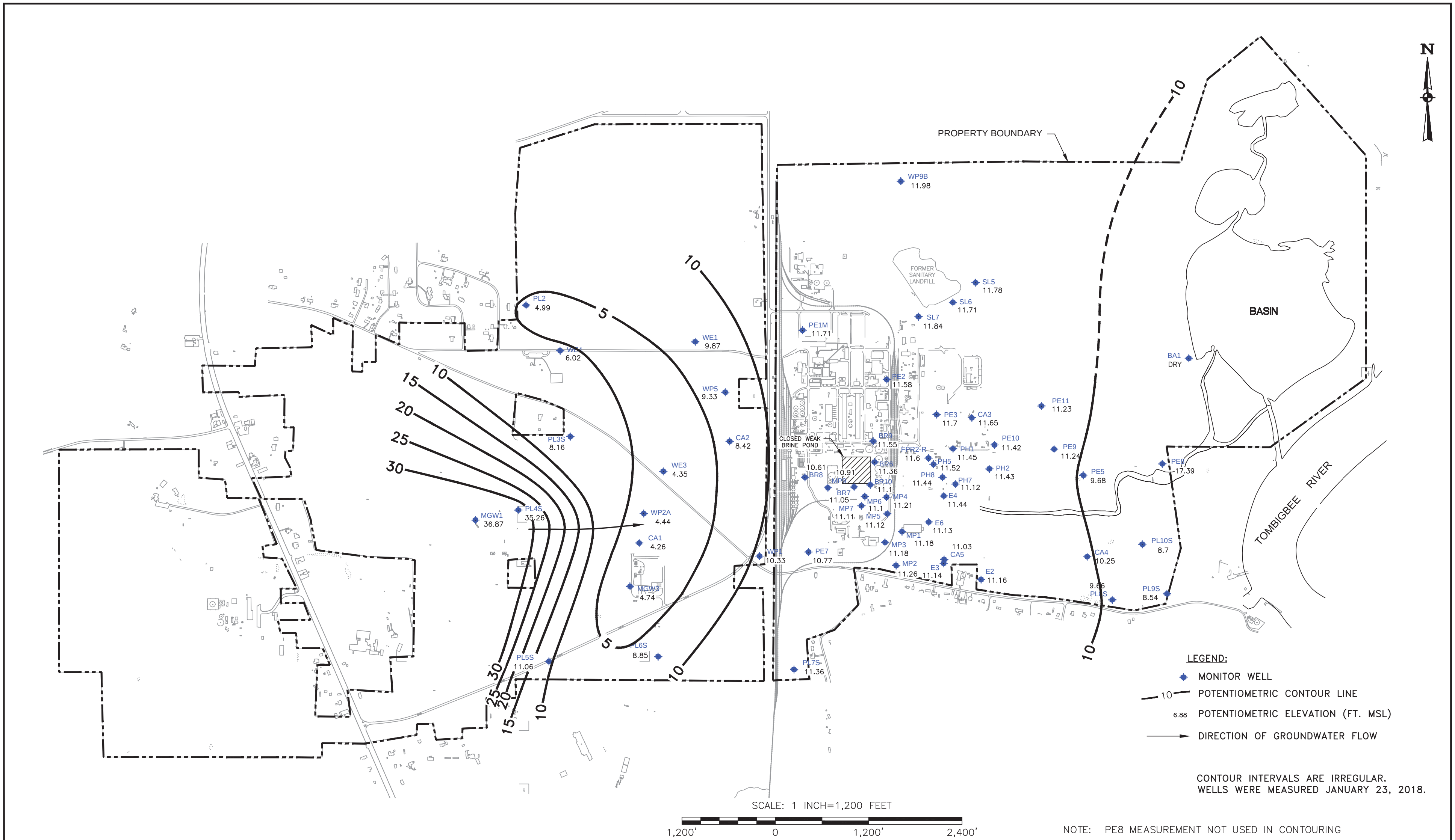
Operable Unit Locations





I:\PROJECTS\OLIN MCINTOSH AL\60564807_2018GWSPPT\900_CAD_GIS\910_CAD\SHEETS\2018_JANUARY_POT.DWG -- JANUARY 2018 SHALLOW -- Thursday, March 15, 2018 3:41:18 PM

REV	DESCRIPTION OF REVISION	BY	DATE

Olin
Olin Corporation
McIntosh, Alabama

AECOM
7389 Florida Blvd., Suite 300
Baton Rouge, Louisiana 70806
225/922-5700

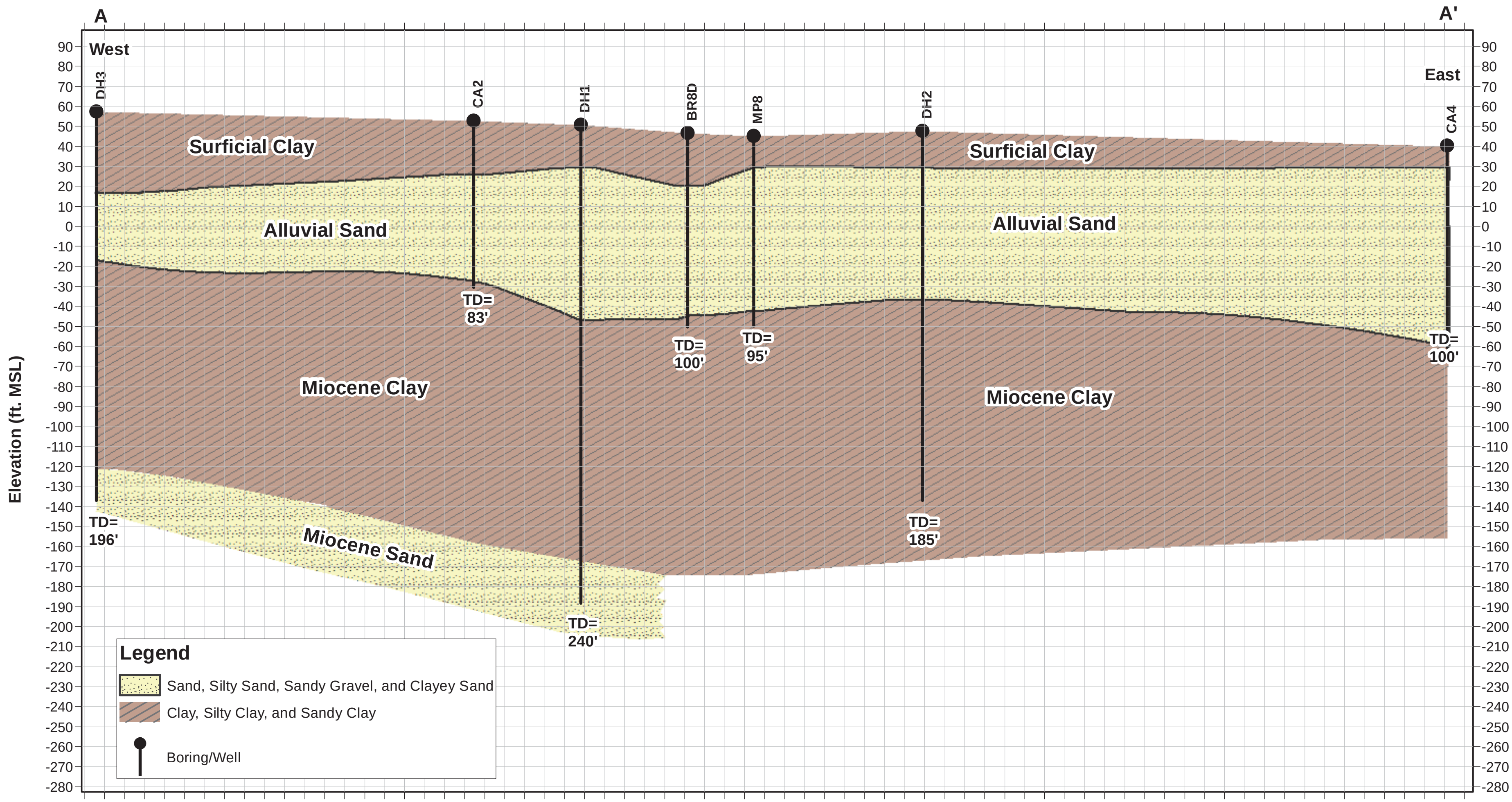
REFERENCE DRAWINGS

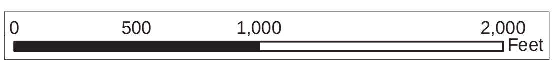
SCALE	1" = 1,200'
DRAWN	GAT
CHECKED	AC
PEER REVIEWED	WAB
DATE	03/12/18

EFFECTIVENESS REPORT

SHALLOW PORTION OF ALLUVIAL AQUIFER
POTENTIOMETRIC SURFACE MAP
JANUARY 2018

REVISION	
PROJECT	19227794
APPENDIX	A7





Vertical Scale
as Shown

Olin McIntosh OU 1

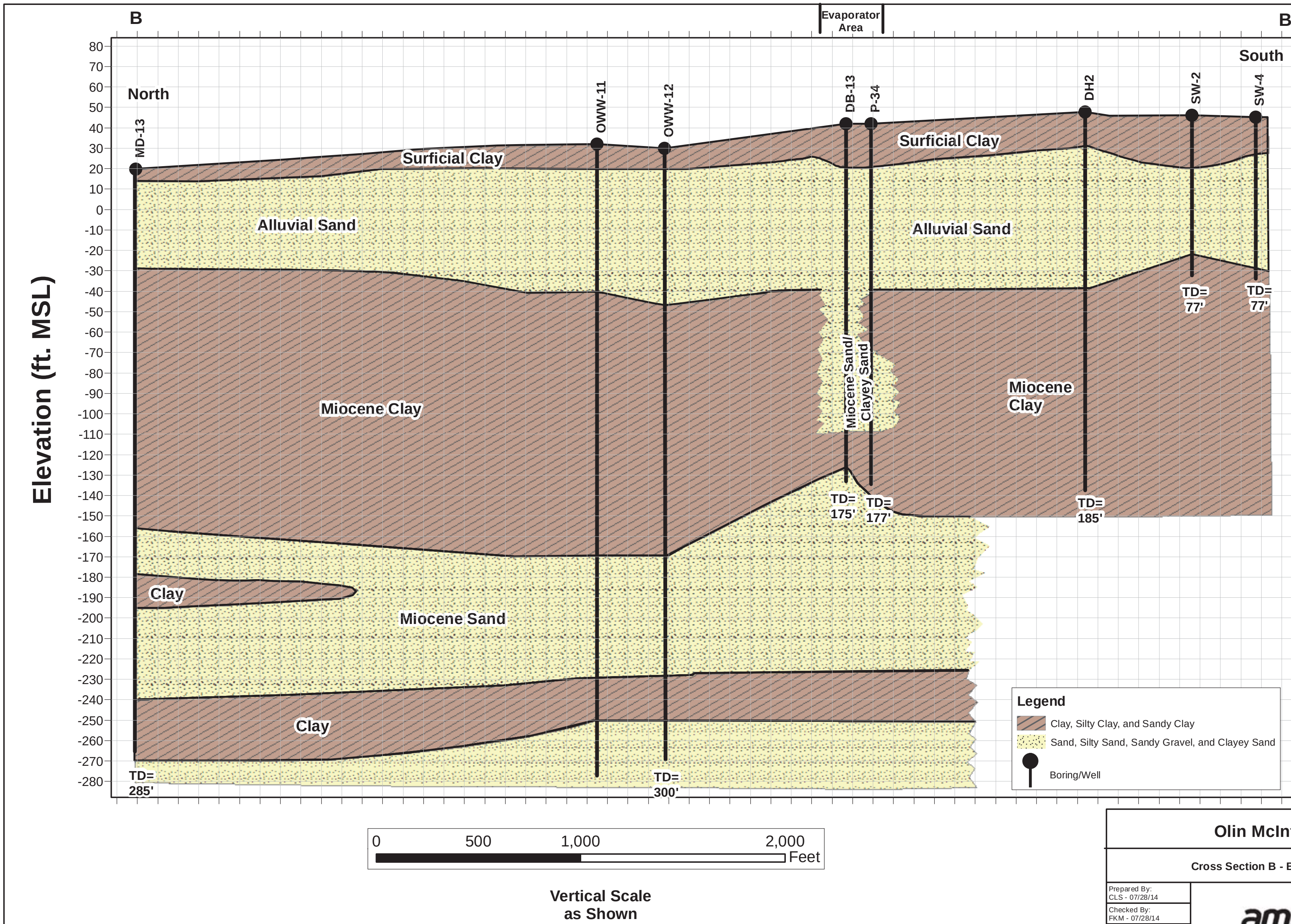
Cross Section A - A' (West to East)

Prepared By: CLS - 07/28/14
Checked By: FKM - 07/28/14
Project Number: 6107120010

amec

Figure: 4.2

Path: G:\Projects_GIS\Projects2007\olin_mcintosh\OU1\mxds\plumes_aug_2013\mxds\sectionA.mxd



Olin McIntosh OU 1

Cross Section B - B' (North to South)

Prepared By: CLS - 07/28/14

Checked By: FKM - 07/28/14

Project Number: 6107140010

amec

Figure: 4.3

Path: G:\Projects_GIS\Projects2007\olin_mcintosh\OU1\mxds\plumes_aug_2013\mxds\sectionB.mxd

APPENDIX C:

Olin Comments on the Draft

Optimization Review Report

Environmental Remediation Group

Olin Corporation

3855 North Ocoee Street, Suite 200
Cleveland, TN. 37312
(423) 336-4388
FAX (423) 336-4166
kdroberts@olin.com

January 8, 2020

SENT VIA E-MAIL

Ms. Beth Walden
Remedial Project Manager
United States Environmental Protection Agency – Region 4
61 Forsyth Street NW
Atlanta, GA 30303

RE: Comments on the Draft Optimization Review Report
Remedial Process Optimization Study
Operable Unit 1
Olin Corporation – McIntosh Facility
McIntosh, Washington County, AL

Dear Ms. Walden:

Olin Corporation (Olin) appreciates the opportunity to review the United States Environmental Protection Agency's (USEPA's) *Draft Optimization Review Report – Remedial Process Optimization Study* (Optimization Report) for Olin's McIntosh Operable Unit 1 (OU1) Site (Site), dated November 2019.

Olin agrees with the Optimization Report's conclusions that there are currently no potentially open exposure pathways at the Site, risks to human health and the environment are low, and continued operation of the Corrective Action (CA) wells is unlikely to provide measurable improvements in protecting human health and the environment or achieving Site closure.

Olin does not concur with the Optimization Report's conclusion that no remedial strategy has been proposed to address residual groundwater contamination. The phased CA well shutdown and demonstration monitoring period are not intended to lead to the termination of corrective/remedial action at the Site. Instead, it is a transition to a passive, long term monitoring and evaluation approach. The active pump and treat approach implemented for 30 years greatly improved Site groundwater conditions, but, as noted in the Optimization Report, improvements diminished over time, as expected. The large data set generated over more than 30 years also improved Site knowledge and supports a passive approach to continue to protect human health and the environment.

Olin has demonstrated the effectiveness of a passive approach in compliance with our Alabama Hazardous Waste Facility Permit ALD 008 188 708 (Permit). Alabama Department of Environmental Management (ADEM) has regulated and managed this process in accordance with Alabama Hazardous Waste Program regulations (ADEM Admin Code r. 335-14).

Olin will continue groundwater monitoring at the Site until constituent concentrations have decreased below groundwater protection standards for three consecutive years, as required by ADEM Administrative Code r. 335-14, or until the groundwater monitoring data indicate that an alternative strategy is required. Monitoring, evaluation, and reporting will continue to be performed as required by ADEM Administrative Code r.335-14 and our Permit.

The Optimization Report listed concerns regarding the BIOSCREEN model evaluation. The report stated that the model inputs did not assume a continuing source; this statement is not accurate. The model included a persistent but slowly decaying source. A source half-life was calculated by the model based on the estimated dissolved mass in the plume consistent with the August 1996 *BIOSCREEN Natural Attenuation Decision Support System User Manual Version 1.3.* Source decay is discussed in Section 3.1.3 of the August 14, 2014 *OU-1 Corrective Action Review and Recommendations – Revision 01.*

USEPA further expressed concern regarding plume migration rates estimated by BIOSCREEN. The BIOSCREEN model was used to support initiation of a demonstration period for a phased shut-down of the CA wells as approved by ADEM and described in a Permit modification. Continuation of the shut-down is based on empirical data and distribution trends over more than 30 years, in addition to the model. The overall analysis supports continuation of the corrective action demonstration as reported in the eight semi-annual progress reports for the Phased Corrective Action Well Removal. Ongoing effectiveness and protectiveness will be demonstrated by the monitoring program until constituent concentrations have decreased below groundwater protection standards.

USEPA also identified potential monitoring/data gaps such as wells to monitor northeast migration from the former Sanitary Landfill (SLF). ADEM requested and Olin installed and sampled temporary groundwater wells in the vicinity of the SLFs in Spring of 2018. The results were provided to USEPA in the June 20, 2018 *Former Sanitary Landfill Groundwater Investigation Report* (SLF Report). The evaluation in the Optimization Report did not include information from the SLF report. The SLF Report details the investigation which included temporary wells installed northeast and east of the SLFs and concluded that carbon tetrachloride and chlorobenzene plume boundaries do not extend beyond the currently-existing monitoring points, SL5 and PE11. Groundwater near the SLFs predominately flows east so that monitoring well SL5 would suitably identify potential eastward migration. Additional monitoring wells are not necessary. ADEM approved the report in a letter dated July 24, 2018.

The Optimization Report recommended the installation of a Miocene monitoring well near the area of low groundwater elevations west of the industrial area. Boring logs for DH1 and DH3 show that the Miocene confining unit is intact and approximately 100 feet thick west of the plant. DH1 and DH3 are approximately 1,500 feet from the groundwater low west of the industrial area and located east and north of the area, respectively. The layout of these two data points makes it improbable that the confining unit is not present in this area of low groundwater elevations. As noted in Section 4.2.4 (page 18) of the Optimization Report, impacts to groundwater in the Miocene would likely be low and captured by Olin's production wells located northeast of the manufacturing area. Constituent migration would also be observed by ongoing monitoring at DH1 which is downgradient from the groundwater low area in the Miocene aquifer. Results from DH1 and DH3 show that constituent concentrations are below groundwater protection standards. The installation of an additional Miocene well is not expected to provide additional information beyond what is already known for the Miocene. A new well would provide redundant information and is not necessary.

Olin also requests one change to the report text. Section 4.1.3 (Page 10) states that "The drainage ditch extends from Outfall 001 east of the CPC Landfill to the Olin Basin." Please revise this to state "The drainage ditch previously extended from Outfall 001 east of the CPC Landfill to the Olin Basin. The drainage ditch was re-routed in 1974 to bypass the Basin and discharge into the inlet channel to the Tombigbee River."

Olin appreciates the opportunity to participate in the optimization review process. We are confident that our current strategy is now and will be protective of human health and the environment for the foreseeable future. Continued monitoring consistent with the approved corrective action program and groundwater monitoring plan associated with our Permit will provide data to confirm its effectiveness. We further believe that the Remedial Action Objectives set by USEPA and listed in the Optimization Report will be met.

Please contact me at 423-336-4388 or via email at kdroberts@olin.com with any questions.

Sincerely,

Keith Roberts
Director, Environmental Remediation

cc: Ben King (ADEM)*
Austin Pierce (ADEM)*
Chinny Esakkiperumal (Olin)*
Lisa O'Brien (Olin)*
Cynthia Draper (Wood)*
Tony Englund (Wood)*

* Sent via email