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Nov 05 2020

CORRECTIVE ACTION PLAN UPDATE

Site Name and Location:	**Marshall Steam Station** **8320 East Carolina Highway 150** **Terrell, NC 28682**
Groundwater Incident No.:	Not Assigned
NPDES Permit No.:	NC0004987
NCDEQ CCR Impoundment Ranking:	Low-Risk
Date of Report:	December 31, 2019
Permittee and Current Property Owner:	Duke Energy Carolinas, LLC 526 South Church Street Charlotte, NC 28202-1803 (855)355-7042
Consultant Information:	SynTerra Corporation 148 River Street, Suite 220 Greenville, SC 29601-2567 (864) 421-9999
Latitude and Longitude of Facility:	N 35.59778/W -80.965

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Note to the Reader from Duke Energy

Duke Energy Carolinas, LLC (Duke Energy) is pleased to submit this groundwater Corrective Action Plan (CAP) for the Marshall Steam Station (MSS) located in Catawba County, North Carolina. Since 2010, Duke Energy has been engaged in extensive site investigation activities to comprehensively characterize environmental conditions in soil, groundwater, surface water, and sediments associated with the presence of coal combustion residuals (CCR) in and around the MSS coal ash basin. Activities have been performed in compliance with the North Carolina Coal Ash Management Act of 2014, as amended (CAMA), as well as the United States Environmental Protection Agency's (USEPA) CCR Rule. In 2018, the North Carolina Department of Environmental Quality (NCDEQ) ranked the ash basin at the MSS as low-risk pursuant to CAMA.

Thousands of multi-media samples have been collected at the MSS yielding over 190,000 individual analyte results. All of this work has been coordinated with the NCDEQ, which has provided review, comments, and approvals of plans and reports related to these activities. This CAP provides the results of these extensive assessment activities, and presents a robust corrective action program to address groundwater conditions where concentrations of constituents of interest (COI) are above applicable regulatory criteria. Closure plan(s) to address the ash basin source area are submitted separately.

As detailed in this CAP, Duke Energy has begun to implement, and will continue implementing, source control measures at the site, including (i) complete ash basin decanting to lower the hydraulic head within the ash basin and decrease hydraulic gradients, reducing groundwater seepage velocities and COI transport potential; and (ii) complete ash basin closure, as well as closure of adjacent ash management areas. In addition, we intend to implement a robust groundwater remediation program that includes actively addressing COI in groundwater above applicable standards at or beyond the compliance boundary using a combination of groundwater extraction and clean water infiltration. These corrective action measures will most effectively achieve remediation of the groundwater through the use of groundwater extraction wells along the ash basin dam and to the east and north of the dam; and (ii) clean water infiltration wells to the north of the ash basin dam and east of the ash basin. Significantly, groundwater modeling simulations indicate (i) these measures will address COI at or beyond the compliance boundary; and (ii) at such time the site-specific considerations detailed within this CAP have been satisfied, including, but not limited to, securing all required state approvals, installing the necessary equipment, and commencing full-

scale system operation, COI at or beyond the compliance boundary will meet the remedial objectives in nine years.

This CAP contains over 2,500 pages of technical information that we believe represents one of the most detailed and well supported corrective action plans ever submitted to the NCDEQ and forms the basis of the robust groundwater remediation approach described above. Thousands of labor hours by PhD-level scientists, engineers, and geologists have been performed to obtain and evaluate the large amount of data generated at the MSS and inform this CAP. This combined effort has enabled a comprehensive understanding of site conditions, creation of a highly detailed three-dimensional groundwater flow and solute transport model used to simulate remediation scenarios, and evaluation and selection of a site-specific corrective action program for the MSS. Duke Energy believes it is also important to provide a science-based perspective on these extensive studies, which include the following key findings:

- **The human health and ecological risk assessments performed for the MSS using USEPA guidance demonstrate that risks to potential human health and ecological receptors associated with the coal ash basin are not measurably greater than risks posed by naturally occurring background conditions.**

- **Ash basin-related constituents have not affected, nor are they predicted to affect, off-site water supply wells. This has been confirmed by analytical results from groundwater samples and water level measurements collected from over 180 monitoring wells over 30 separate monitoring events, and performing over 200 groundwater and geochemical modeling simulations**.

In addition, even though no off-site wells were affected, Duke Energy has already provided owners of surrounding properties within 0.5-mile radius of the ash compliance boundary with permanent water solutions through either connection to public water supply or installation of water filtration systems under a program approved by the NCDEQ. These alternate water supplies provide additional peace of mind for our neighbors. Importantly, ongoing multi-media sampling of the nearby surface water aquatic systems, including Lake Norman, confirm that these surface water systems are healthy with robust fish populations.

Duke Energy looks forward to proactively implementing this CAP.

EXECUTIVE SUMMARY

(CAP Content Section Executive Summary)

ES.1 Introduction

SynTerra prepared this groundwater corrective action plan (CAP) on behalf of Duke Energy Carolinas, LLC (Duke Energy). The plan pertains to the Marshall Steam Station (MSS, Plant, or Site) coal combustion residuals (CCR) ash basin in Catawba County, North Carolina (**Figure ES-1**). For MSS, the following additional sources are considered adjacent to the ash basin and are components of the CAP: Dry Ash Landfills (Phase I and Phase II), photovoltaic (PV) structural fill, access road structural fill, the Industrial Landfill (ILF) No. 1 subgrade structural fill, coal pile, and gypsum pad.

This CAP Update addresses the requirements of Section 130A-309.211(b) of the North Carolina General Statutes (G.S.), as amended by Coal Ash Management Act (CAMA) of 2014. The CAP Update is consistent with North Carolina Administrative Code (NCAC), Title 15A, Subchapter 02L .0106 corrective action requirements, and with the CAP guidance provided by the North Carolina Department of Environmental Quality (NCDEQ) in a letter to Duke Energy, dated April 27, 2018 and adjusted on September 10, 2019 (**Appendix A**).

This CAP Update evaluates remedies for constituents of interest (COIs) in groundwater associated with the MSS ash basin and adjacent additional sources listed above, which are considered sources of COIs, that are at or beyond the compliance boundary to the east of the ash basin. Specifically, this CAP Update focuses on constituent concentrations detected greater than applicable North Carolina groundwater standards [NCAC Title 15A, Subchapter 02L, Groundwater Classification and Standards (02L); Interim Maximum Allowable Concentrations (IMAC); or background values, whichever is greater] at or beyond the compliance boundary.

In accordance with G.S. requirements, a CAP pertaining to MSS was previously submitted to the NCDEQ in two parts, as follows:

- *Corrective Action Plan Part 1 – Marshall Steam Station Ash Basin* (HDR, 2015b)
- *Corrective Action Plan Part 2 (included CSA Supplement 1 as Appendix A) – Marshall Steam Station Ash Basin* (HDR, 2016b)

This CAP Update considers data collected through May 2019.

Ash basin closure is detailed in a separate document prepared by AECOM. Closure scenarios include a closure-in-place and closure-by-excavation scenario. Therefore, the groundwater remediation alternatives evaluated and recommended in this CAP Update consider both the closure-in-place scenario and closure-by-excavation scenario. Groundwater modeling simulations indicate the closure-by-excavation and closure-in-place scenarios would have a similar effect on COI concentrations in groundwater.

Summary of CAP Approach

As stated above, this CAP Update meets the corrective action requirements under G.S. Section 130A-309.211(b) and Subchapter 02L .0106. The preferred groundwater remediation approach assumes source control through either basin closure-in-place or closure-by-excavation. The groundwater remediation approach presented in this CAP Update can be implemented under either scenario. The focus of groundwater corrective action at the MSS is reducing COIs to concentrations less than applicable criteria at or beyond the compliance boundary consistent with Subchapter 02L .0106(e)(4) and to address Subchapter 02L .0106(j). Applicable criteria in this case are defined as the 02L groundwater standard, interim maximum allowable concentration (IMAC), or background, whichever is greatest, defined as the COI criterion. If a COI does not have an 02L standard or IMAC, then the background value defines the COI criteria.

Duke Energy has implemented, or plans to implement the following multi-component Corrective Action Plan at the MSS:

Source Control Measures

- Ash basin decanting is currently underway and will reduce the hydraulic head and gradients in the area of the dam, thereby significantly reducing the hydraulic driving force for potential COI migration in groundwater. As of December 1, 2019, approximately 128,400,000 gallons water have been removed from the ash basin and the water elevation has decreased by 7.3 feet. Groundwater modeling indicates that the average linear velocity of groundwater will decrease from a range of 0.01 to 5 feet per day (ft/day) under pre-decanting conditions to 0.01 to 1 ft/day post-decanting.
- Completion of ash basin closure activities.

Groundwater Remediation Measures

- A robust groundwater remediation approach is planned for the MSS that includes actively addressing COIs in groundwater with concentrations greater than applicable standards at or beyond the compliance boundary using a

combination of groundwater extraction and treatment along with clean water infiltration. Site data and groundwater models were used to evaluate and optimize an effective remedial approach to reduce COI concentrations east of the ash basin. The following is a summary of components of the preferred remediation system that would be installed east of the ash basin:

- 66 new groundwater extraction wells along the buttress of the ash basin dam and to the east of the basin towards the unnamed tributary of Lake Norman
- 24 vertical clean water infiltration wells between the ash basin and unnamed tributary located east of the ash basin
- Groundwater treatment, as needed, to meet discharge criteria

Effectiveness Monitoring Plan (EMP)

- Duke Energy has prepared an effectiveness groundwater monitoring plan, which is discussed in **Section 6.8** and provided in **Appendix O** of this CAP Update. This EMP includes an optimized groundwater monitoring network for the ash basin based on site-specific COI mobility and distribution. The EMP is designed to be adaptable and would target key areas where changes to groundwater conditions are most likely to occur due to corrective action implementation or basin closure activities. The plan includes provisions for a post-closure monitoring program in accordance with G.S. Section 130A-309.214(a)(4)k upon completion of basin closure activities.

Details and supporting rationale for these CAP activities are provided in the following sections.

ES.2 Background

Plant Operations

MSS began electrical power generation operations in 1965. The station currently operates four coal-fired steam units. CCR materials, composed primarily of fly ash and bottom ash, were initially deposited in the ash basin by hydraulic sluicing operations. In 1984, fly ash sluicing was replaced with a dry fly ash handling system. In early 2019, a dry bottom ash collection system became active. All bottom ash and fly ash is currently handled dry. The MSS ash basin has operated under a National Pollutant Discharge Elimination System (NPDES) Permit issued by the NCDEQ Division of Water Resources (DWR) since initial operations began.

Pursuant to G.S. Section 130A-309.213(d)(1), a November 13, 2018 letter from NCDEQ to Duke Energy, documented the classification of the CCR surface impoundment at MSS as low-risk (**Appendix A**). The letter cited that Duke Energy has "established permanent water supplies as required by G.S. Section 130A-309.211(cl)" and has "rectified any deficiencies identified by, and otherwise complied with the requirements of, any dam safety order issued by the Environmental Management Commission…pursuant to G.S. Section 143-215.32."

The relevant closure requirements for low-risk impoundments are in G.S. Section 130A-309.214(a)(3), which states low-risk impoundments shall be closed as soon as practicable, but no later than December 31, 2029.

Additional Adjacent Source Areas

The closed Dry Ash Landfills are located adjacent to the east (Phase I) and northeast (Phase II) portions of the ash basin. In December 1983, the North Carolina Department of Environment and Natural Resources (NCDENR) Division of Waste Management (DWM) issued an initial permit (Permit No. 1804-INDUS) to operate the Dry Ash Landfills. Phase I consists of approximately 14.5 acres and approximately 522,000 cubic yards (cy) of fly ash, which was placed from September 1984 through March 1986. Phase II consists of approximately 46 acres and approximately 4,064,000 cy of fly ash, which was placed from March 1986 through 1999. The landfill units are unlined and were closed with a soil cover system.

The photovoltaic farm structural fill (PV Structural Fill), located adjacent to and partially on top of the northwest portion of the ash basin, was constructed of fly ash under the structural fill rules found in 15A NCAC 13B .1700 *et seq.*, and bottom ash, under Duke Energy's Distribution of Residuals Solids (503 Exempt) Permit Number WQ0000452, which was issued by NCDENR Division of Water Quality (DWQ). Placement of dry ash in the PV Structural Fill began in October 2000. The PV Structural Fill covers approximately 83 acres and contains approximately 5,410,000 cy of ash. The PV Structural Fill is unlined and was closed with a soil cover system in February 2013.

The access road structural fill, adjacent to the ash basin waste boundary south of the PV Structural Fill, was constructed of fly ash under the structural fill rules found in 15A NCAC 13B .1700 *et seq*. The access road structural fill covers approximately 2.5 acres and contains approximately 128,000 cy of ash outside of the ash basin waste boundary. Construction of the unlined structural fill began in 1997 and was completed in 1998.

The subgrade for portions of the Industrial Landfill No. 1 (ILF, Permit No. INDUS-1812) was constructed of fly ash under the structural fill rules found in 15A NCAC 13B .1700

et seq. The subgrade structural fill, which contains approximately 726,000 cubic yards of ash, was closed with a soil cover in 2013. The ILF was constructed over portions of this unlined structural fill and the northern reach of the ash basin.

Coal is stored south of the ash basin, immediately north of the steam station, on approximately 35 acres. The coal pile is unlined. However, in 2018, lined holding basins were built west and east of the coal pile as part of a water redirect project. These Retention Basins receive coal pile storm water runoff collected from the coal pile through a concrete-lined perimeter ditch and associated collection trench.

Gypsum, a byproduct of the coal combustion process, is stored on an approximately 3.5-acre lined concrete pad located west of the coal pile and retention basin.

These additional source areas are located within the same groundwater drainage system as the ash basin. Therefore, COIs that have the potential to migrate in groundwater from these additional source areas at or beyond the ash basin compliance boundary and above regulatory criteria are addressed as part of the CAP for the ash basin.

Pre-Basin Closure Activities

To accommodate closure of the ash basin, decanting (removal) of free water from the basin began with the removal of stop logs (gravity-feed) on July 16, 2019, as required by a Special Order by Consent (SOC) issued through North Carolina Environmental Management Commission (EMC) on April 25, 2018 (EMC SOC WQ S17-009, Appendix B of **Appendix J**). Mechanical decanting (pumping) of free water from the basin commenced on September 13, 2019. The SOC requires completion of decanting by March 31, 2021. Decanting of free, ponded water from the ash basin before closure is expected to reduce or eliminate seepage from constructed or non-constructed seeps. Constructed seeps are seeps on or within the dam structure that convey wastewater via a pipe or constructed channel to an NPDES-regulated receiving water. Seeps that do not meet the constructed seep definition are considered non-constructed seeps. Decanting is considered an important component of the corrective action strategy because it will significantly reduce the hydraulic head and gradients, thereby reducing the groundwater flow velocity and COI migration potential associated with the ash basin. As of December 1, 2019, 128.4 million gallons of water have been removed from the ash basin and the elevation of the ponded water within the basin has decreased by 7.3 feet.

Basis for CAP Development

A substantial amount of data related to the MSS ash basin and adjacent source areas has been collected to date. A summary of the MSS assessment documentation used to prepare this CAP Update is presented in **Table ES-1.**

TABLE ES-1
SUMMARY OF MSS ASSESSMENT DOCUMENTATION

Comprehensive Site Assessment Report - Marshall Steam Station Ash Basin [HDR Engineering, Inc. of the Carolinas (HDR, 2015a)]
Corrective Action Plan Part 1 - Marshall Steam Station Ash Basin (HDR, 2015b)
Corrective Action Plan Part 2 (included CSA Supplement 1 as Appendix A) - Marshall Steam Station Ash Basin (HDR, 2016b)
Comprehensive Site Assessment Supplement 2 - Marshall Steam Station Ash Basin (HDR, 2016a)
Comprehensive Site Assessment Update - Marshall Steam Station (SynTerra, 2018a)
Preliminary Updated Groundwater Flow and Transport Modeling Report - Marshall Steam Station (Falta Environmental, SynTerra, and FRx, Inc., 2018)
Human Health and Ecological Risk Assessment Summary Update – Marshall Steam Station (SynTerra, 2018b)
Community Impact Analysis of Ash Basin Closure Options at the Marshall Steam Station (Exponent, 2018)
Marshall Steam Station HB 630 Provision of Permanent Water Supply Completion Documentation (Duke Energy, 2018)
Closure Options Analysis (AECOM, 2018)
Ash Basin Pumping Test Report - Marshall Steam Station (SynTerra, 2019a)
Estimating Partition coefficient (K_d) for Modeling Boron Transport Using EPQ Method 1316 – Marshall Steam Station (SynTerra, 2019b)
Surface Water Evaluation to Assess 15A NCAC 02B - Marshall Steam Station (SynTerra, 2019c)
2018 CAMA Annual Interim Monitoring Report (SynTerra, 2019d)
Updated Background Threshold Values for Constituent Concentrations in Groundwater (SynTerra, 2019e)

NCDEQ reviewed the 2018 Comprehensive Site Assessment (CSA) Update, and in an August 17, 2018 letter to Duke Energy, NCDEQ stated that sufficient information was provided to allow preparation of this CAP Update (**Appendix A**).

The assessment work referenced in the documents listed in **Table ES-1** has resulted in a large dataset that has informed the development of this CAP Update. As of September 2019, the following data collection and analyses activities have been completed and are summarized in **Table ES-2** below:

TABLE ES-2
SUMMARY OF MSS ASSESSMENT ACTIVITIES

Tasks	Total
Total Monitoring Wells Installed (CAMA, CCR wells around ash basin)	186
Groundwater Monitoring Events	32
Groundwater Samples Collected	2,858
Individual Analyte Results	190,632
Off-Site Water Supply Well Sampling (Total inorganic analysis) - Number of Analyses	2,616
Ash Pore Water - Number of Analyses (Total and dissolved)	19,154
Ash Pore Water Sampling Events	17
Surface Water Monitoring Events	16
Surface Water Sample Locations	29
Area of Wetness Sample Events	11
Ash Samples (Within ash basin analyzed for SPLP)	14
Soil Samples Collected	437
Soil Sample Locations	97
Sediment Sample Locations	12
Geotechnical Soil Sample Locations	44
Geochemical Ash, Soil, Partially Weathered Rock, Whole Rock Samples	103
Hydraulic Conductivity Tests (Slug Tests, Pumping Tests, Packer Tests, FLASH Analysis of Bedrock HPF Data)	119
Groundwater Flow & Transport Simulations	124
PHREEQC Geochemical Simulations	84

Prepared by: BER Checked by: WCG

Notes:
Data available to SynTerra as of September 2019
FLASH – Flow-Log Analysis of Single Holes
HPF – Heat Pulse Flow
SPLP – Synthetic Precipitation Leaching Procedure
PHREEQC – pH Redox Equilibrium in computer code C

A constituent management process was developed by Duke Energy at the request of NCDEQ to gain understanding of the COI behavior and distribution in groundwater and to aid in selection of the appropriate remedial approach. The COI management process consists of three steps:

1. Performing a detailed review of the applicable regulatory requirements under NCAC, Title 15A, Subchapter 02L.
2. Understand the potential mobility of site-related COIs in groundwater based on site hydrogeology and geochemical conditions.
3. Determine the COI distribution at the MSS ash basin and adjacent source areas under current and predicted future conditions.

This COI management process is supported by multiple lines of evidence including empirical data collected at the site, geochemical modeling, and groundwater flow and transport modeling. This approach has been used to understand and predict COI behavior in the subsurface related to the ash basin and adjacent source areas or COIs that are naturally occurring. COIs that have migrated at or beyond the compliance boundary at concentrations greater than 02L, IMAC and background values that are related to an ash basin or an adjacent source would be subject to corrective action. COIs that are naturally occurring at concentrations greater than the 02L standard do not require corrective action. Details on the COI management approach are presented in **Section 6.1.**

Groundwater

In conformance with requirements of G.S. Section 130A-309.211, groundwater corrective action is the main focus of this CAP Update. Groundwater COIs to be addressed with corrective action are those that exhibit concentrations in groundwater at or beyond the compliance boundary greater than the 02L standard, IMAC, or background concentrations, whichever is greatest.

Soil

Unsaturated soil COI concentrations are generally consistent with background concentrations or are less than regulatory screening values. In the few instances where unsaturated soil COI concentrations in downgradient locations are greater than Preliminary Soil Remediation Goal (PSRG) Protection of Groundwater (POG) standards or background values, concentrations are within range of Piedmont background values or there are no mechanisms by which the COIs could have migrated from the ash basin or adjacent sources to the unsaturated soils. Furthermore, these COI occurrences are not

present in groundwater at the same location greater than applicable regulatory criteria. For these reasons, the soil concentrations do not warrant consideration as potential secondary source of constituents to the groundwater. Therefore, the CAP Update focuses on remediation of groundwater associated with the ash basin and adjacent source areas.

Risk Assessment

The human health and ecological risk assessments were prepared using standard USEPA methods and demonstrate no measurable difference in modeled risks to potential human or ecological receptors compared with background concentrations. The updated risk assessments for the MSS are presented in **Section 5.4** and **Appendix E** of this CAP Update. Data from water supply wells and Lake Norman indicate no evidence of increased risk posed by groundwater migration associated with the ash basin and adjacent source areas based on evaluation of concentrations of CCR constituents in environmental media and potential receptors.

Risk Ranking

In accordance with G.S. Section 130A-309.211(c1) of House Bill 630 (2016), Duke Energy connected 62 households to public water supply and installed three water filtration systems at occupied residences within a 0.5-mile radius of the ash basin compliance boundary. Additionally, Duke Energy voluntarily provided permanent water solutions to six properties, including businesses and churches, within a 0.5-mile radius of the MSS compliance boundary that were otherwise not eligible per G.S. Section 130A-309.211(c1). Provision of permanent water supply and installation of filtration systems, along with certain improvements to the ash basin dam, resulted in the MSS ash basin being classified as low-risk.

ES.3 CSM Overview

The Conceptual Site Model (CSM) is a written and graphical representation of the hydrogeologic conditions and COI interactions specific to the Site and is critical to understanding the subsurface conditions related to the ash basin and adjacent source areas. The updated CSM developed for the MSS included in this CAP Update is based on a U.S. Environmental Protection Agency (USEPA) document titled "Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model" (EPA, 2011). This document describes six CSM stages for a project life cycle. The CSM is an iterative tool designed to assist in the decision-making process for site characterization and remediation as the site progresses through the project life cycle and new data become available. The current MSS CSM is consistent with Stage 4

"Design CSM", which allows for iterative improvement of the site CSM during design of the remedy while supporting development of remedy design basis (USEPA, 2011).

Multiple lines of evidence have been used to develop the CSM based on the large data set generated for the MSS. The remedial action evaluation to meet the effectiveness criteria in the CAP guidance provided by NCDEQ is also based on the updated CSM (NCDEQ, 2019).

The following provides an overview of the updated CSM for the MSS ash basin and adjacent source areas, which forms the basis of this CAP Update. Supporting details for the CSM are presented in **Section 5**.

Key conclusions of the CSM include the following:

- **No material increases in risks to human health have been identified related to the ash basin and adjacent source areas. The Site-specific risk assessment indicates no measurable difference between evaluated Site-related risks and risks imposed by background concentrations.** Site-specific risk assessments indicate incomplete exposure pathways and no risk to residential receptors near the ash basin and adjacent source areas (no complete exposure pathways).
- **The ash basin and adjacent source areas do not cause an increase in risks to ecological receptors**. The assessment did not indicate an increase of risks to aquatic wildlife receptors (mallard duck, great blue heron, bald eagle, and river otter) evaluated for the Lake Norman exposure area. Two receptors had limited modeled risk with hazard quotients (HQ) greater than 1.0: the muskrat (7.2) and killdeer (4.6). However, the modeled risks are considered negligible based on natural and background conditions.
- **Groundwater from the ash basin area has not and does not flow toward any water supply wells based on groundwater flow patterns and the location of water supply wells in the area around the Site, and evaluation of groundwater analytical data.** Groundwater data collected from water supply wells and on-Site monitoring wells, groundwater elevation measurements from 32 monitoring events, and groundwater flow and transport modeling results all indicate that Site COIs are not affecting, and have not affected, water supply wells.
- **The permanent water solution implemented by Duke Energy provides qualified owners of surrounding properties with water supply wells within a 0.5-mile of the ash basin compliance boundary with access to the public water supply or water filtration systems.** The hydrogeologic data collected at MSS

confirms that Site-related COIs have not affected off-Site water supply users. Groundwater modeling predicts that Site related COIs will not affect off-Site water supply users. Nevertheless, Duke Energy connected 62 households to public water supply and installed three water filtration systems at surrounding occupied residences in accordance with G.S. Section 130A-309.211(c1). Six additional properties, including businesses and churches, within a 0.5-mile radius of the MSS compliance boundary were also provided permanent water solutions by Duke Energy, although they did not meet the eligibility requirements outlined in G.S. Section 130A-309.211(c1).

- **The hydrogeologic setting at the MSS ash basin and adjacent source areas limits COI transport.** The Site, located in the Piedmont Physiographic Province, conforms to the general hydrogeologic framework for sites in the Blue Ridge/Piedmont area, which are characterized by groundwater flow in a slope-aquifer system within a local drainage basin with a perennial stream (LeGrand, 2004). Predictive groundwater flow and transport model simulations indicate that ash basin decanting will affect groundwater flow patterns within the basin by lowering hydraulic heads in and around the ash basin dam, which will reduce the hydraulic gradients, thereby reducing the rate of COI transport prior to completion of basin closure. As of December 1, 2019, 128.4 million gallons of water have been removed from the ash basin and the elevation of the ponded water within the basin has decreased by 7.3 feet.
- **The physical setting and hydraulic processes control the COI flow pattern within the ash basin, underlying groundwater system, and downgradient areas**. The ash basin is predominantly a horizontal water flow-through system. Groundwater enters the upgradient side of the ash basin; it is supplemented by rainfall infiltration and flows laterally through the middle of the ash basin under a low horizontal gradient, and then flows downward near the dam. This flow system results in limited downward migration of COIs into the underlying saprolite upgradient from the dam. Near the dam, COIs in water either discharge through the NPDES permitted outfall or flow downward out of the basin and under the dam. Beyond the dam, groundwater flows upward toward Lake Norman (*e.g.,* discharge zone), limiting downward migration of COIs to the area near the dam. Exceptions occur at 3 of the 16 well clusters installed within the basin, where COIs are detected in groundwater underlying the ash basin. Outside of the ash basin, near the southern portion of the closed Dry Ash Landfill (Phase II), landfilled dry ash has resulted in the leaching of COIs to the underlying bedrock.

- **Horizontal distribution of COIs in groundwater east of the MSS ash basin is limited spatially.** The physical extent of constituent migration to the east of the basin is controlled by hydrologic divides, dilution from unaffected groundwater, and the groundwater to surface water discharge zones.
- **Geochemical processes stabilize and limit certain constituent migration along the flow path.** Each COI exhibits a unique geochemical behavior related to the partition coefficient (K_d), response to geochemical parameters (*i.e.,* pH and reduction-oxidation potential [Eh]), and sorption capacity of the soil and/or rock matrix. Based on geochemical modeling, the following observations can be made:
    - Non-conservative, reactive COIs (*e.g.*, beryllium, chromium, and vanadium) will remain in mineral phase assemblages that are stable under variable Site conditions, demonstrating sorption as an effective attenuation mechanism.
    - Variably reactive COIs *(e.g.,* cobalt, iron, and manganese) can exhibit mobility depending on geochemical conditions and availability of sorption sites.
    - Conservative, non-reactive COIs (*e.g.,* boron, lithium, and sulfate) migrate in groundwater as soluble species and are not strongly attenuated by reactions with solids but are reduced in concentration with distance primarily by physical processes such as mechanical mixing (dispersion), dilution, and diffusion into less permeable zones. Sorption of boron to clay particles might occur, especially for groundwater with slightly alkaline to alkaline pH values. Maximum boron sorption occurs at pH values between 7.5 standard units (S.U.) and 10 S.U., then decreases at pH values greater than 10 S.U. (EPRI, 2005; ATSDR, 2010).

  The groundwater corrective action strategies evaluated herein consider the potential for dynamic geochemical conditions under closure-by-excavation and closure-in-place scenarios and account for potential mobilization of COIs.
- **COIs in groundwater are contained within Duke Energy's property.** COI distribution extends from the ash basin toward Lake Norman and the unnamed tributary east of the ash basin. Flow and transport model simulations predict COI migration in groundwater below adjacent portions of Lake Norman are limited; however, bedrock fracture orientation data suggest that the simulated eastward extent of COI migration may be over-predicted. The groundwater concentrations predicted below Lake Norman are a result of the hydraulic heads created by the impounded ash basin free water. This groundwater eventually

discharges to the overlying surface water, where COIs are reduced in concentration by physical processes such as mechanical mixing (dispersion) and dilution. Flow and transport groundwater model predictions indicate basin decanting will lower the hydraulic head within the ash basin and reduce COI transport.

- **Groundwater/surface water interaction has not resulted in exceedances of North Carolina Administrative Code, Title 15A, Subchapter 02B, Surface Water and Wetland Standards (02B) in Lake Norman.** The downgradient stream (unnamed tributary east of the basin) and Lake Norman are groundwater discharge zones that limit the horizontal transport of constituents downgradient of the basin. Due to the limited presence and mobility of most constituents in the groundwater system, the groundwater associated with the ash basin generally has not caused, and will not cause, current surface water quality standards in Lake Norman to be exceeded. However, under seasonal low-flow conditions, elevated hardness has been reported at SOC seep S-1 in the tributary east of the ash basin and Phase I landfill. Duke Energy is actively addressing this occurrence in compliance with the SOC.
- **The aquatic systems (unnamed tributary and Lake Norman) surrounding the MSS ash basin are healthy based on multiple lines of evidence including robust fish populations, species variety and other indicators based on years of sampling data.** Lake Norman has been monitored by Duke Energy since 1959. Over the years, specific assessments have been conducted for water quality and chemistry as well as abundance and species composition of phytoplankton, zooplankton, macroinvertebrates, aquatic macrophytes, fish, and aquatic wildlife. These assessments have all demonstrated that Lake Norman has been an environmentally healthy and functioning ecosystem, and ongoing sampling programs have been established to ensure the health of the system will continue. Furthermore, these data indicate that there have been no significant effects to the local aquatic systems related to coal ash constituents over the last 60 years.
- **Most of the COIs identified in the CSA Update occur naturally in groundwater at concentrations greater than the 02L standard or IMAC.** Groundwater at MSS naturally contains barium, chromium, cobalt, iron, manganese, total radium, and vanadium at concentrations greater than their respective 02L standard or IMAC. The occurrence of inorganic constituents in groundwater of the Piedmont Physiographic Province is well documented in the literature. For example, vanadium has natural background concentrations in all flow zones at the Site greater than its IMAC. Therefore, vanadium is evaluated based on its Site-

specific, statistically derived background value, and additional lines of evidence to determine whether constituent concentrations represent migration from the ash basin and/or an additional source area, or are naturally occurring. The same consideration is given for other COIs with naturally occurring concentrations greater than applicable regulatory criteria.

These CSM aspects, combined with the updated human health and ecological risk assessments, provide the basis for the corrective action plan developed for the ash basin and adjacent source areas.

ES.4 Corrective Action Approach

Corrective Action Objectives and Zones Requiring Corrective Action

Migration of COIs related to the ash basin in groundwater at or beyond the compliance boundary occurs in localized areas to the east of the ash basin. Groundwater corrective action was also evaluated for the adjacent source areas. However, because they lie within the drainage network of the ash basin, and groundwater flow from these areas and the ash basin is southeastward, groundwater from the adjacent source areas would be captured through the groundwater remediation system east of the ash basin. To satisfy G.S. and maintain compliance with 02L, the corrective action approach planned for the Site will focus on restoring ash basin- and adjacent source area-affected groundwater at or beyond the compliance boundary. The following remedial objectives address the regulatory requirements of NCAC Title 15A Subchapter 02L for the MSS CAP Update:

- Restore groundwater quality at or beyond the compliance boundary by returning COIs to the 02L/IMAC groundwater quality standards, or applicable background concentrations (whichever are greater), or as closely thereto as is economically and technologically feasible consistent with Subchapter 02L .0106(a).
- Use a phased CAP approach that includes initial active remediation with effectiveness monitoring of remedy implementation followed by monitored natural attenuation (MNA) as provided in Subchapters 02L .0106(j) and (l).
- If appropriate given future site conditions, Duke Energy may seek approval of an alternate plan that does not require meeting groundwater 02L/IMAC/applicable background concentration values after satisfying the requirements set out in Subchapter 02L .0106(k).

The ash basin compliance boundary is displayed on **Figure ES-1**. Groundwater concentrations greater than 02L/IMAC/applicable background concentration values occur locally at or beyond the compliance boundary in two areas:

1. In the limited area east of the compliance boundary, between the ash basin and unnamed tributary
2. Along limited areas downgradient of the ash basin dam, within the compliance boundary (coincides with the Lake Norman shoreline)

The areas of proposed groundwater corrective action under either closure scenario are shown on **Figure ES-2.**

Summary of Source Control and Corrective Measures

It is critical to take into account all various activities Duke Energy has/will perform to improve subsurface conditions at MSS related to the ash basin and adjacent source areas. The remedial program incorporates source control by basin decanting and closure, active groundwater remediation and effectiveness monitoring. **Table ES-3** summarizes the discrete components of the planned corrective action for COI-affected groundwater.

TABLE ES-3
COMPONENTS OF SOURCE CONTROL, ACTIVE REMEDIATION, AND MONITORING

Groundwater Remedy Component	Rationale
Source Control Activities	
Ash Basin Decanting	Active source remediation by removing ponded water in the ash basin. Decanting will lower the hydraulic head within the basin and reduce hydraulic gradients, reducing groundwater seepage velocities and COI transport potential. Decanting will return the groundwater flow system to its approximate natural condition, flowing toward the axis of the perennial stream valley, then east. Decanting was first initiated on July 16, 2019 with the removal of stop logs from the outfall. Mechanical decanting commenced on September 13, 2019. As of December 1, 2019, 128.4 million gallons of water have been removed from the ash basin and the elevation of the ponded water within the basin has been reduced by 7.3 feet. Decanting is required to be complete on or before March 31, 2021. In addition, ash basin decanting is expected to be effective in reducing or eliminating seeps identified in the SOC.
Ash Basin Closure	The ash basin closure-in-place scenario or closure-by-excavation scenario are considered source control/removal activities. Extensive groundwater modeling indicates that either method results in similar effects with respect to groundwater remediation.

TABLE ES-3
COMPONENTS OF SOURCE CONTROL, ACTIVE REMEDIATION, AND MONITORING

Groundwater Remedy Component	Rationale
Source Control Activities	
Closure of Adjacent Additional Sources	Closure-in-place of the PV Structural Fill and Dry Ash Landfill Phase II will reduce the potential of COI migration from these sources. Installation of an impermeable cover system will prevent infiltration of precipitation through these sources and reduce COI leaching potential to underlying groundwater. Additionally, due to the unique hydrogeologic setting and close proximity to Waters of the US, the Dry Ash Landfill Phase I is proposed to be excavated. The Structural Fill Access Road will also be removed as part of Ash Basin Closure (under closure-by-excavation), or capped with an impermeable cover system under the closure-in-place scenario. The Industrial Landfill No.1 Structural Fill Subgrade will be capped with a geosynthetic liner when the landfill is expanded.
Active Groundwater Remediation Activities	
Active Groundwater Remediation	Groundwater remediation focuses on meeting the remedial objectives at the compliance boundary. These efforts will focus near the basin dam area and areas north of the dam toward the unnamed tributary east of the basin where COIs are present at concentrations greater than applicable criteria. To meet the above-referenced CAP objectives, 66 extraction wells and 24 clean water infiltration wells are planned to be placed in areas to reduce COI concentrations based on actual site data and groundwater modeling simulations.

TABLE ES-3
COMPONENTS OF SOURCE CONTROL, ACTIVE REMEDIATION, AND MONITORING

Groundwater Remedy Component	Rationale
Institutional Controls and Monitoring	
Permanent Water Solution for Water Supply Well Users within a 0.5-mile radius of the Ash Basin Compliance Boundary and Associated Water Filtration System Maintenance	Groundwater data at the Site indicates that surrounding water supply wells have not been and are not affected by Site-related COIs. However, Duke Energy installed 62 connections to public water supply and 3 water filtration systems for qualifying occupied households. Six additional properties, including businesses and churches, within a 0.5-mile radius of the MSS compliance boundary were also provided permanent water solutions by Duke Energy, although they did not meet the eligibility requirements outlined in G.S. Section 130A-309.211(c1). Duke Energy's actions were approved by NCDEQ, which addresses stakeholder concerns. Duke Energy maintains the water filtration systems on behalf of the residents.
Maintain Ownership and Institutional Controls (ICs) Consisting of a Land Use Restriction	ICs in the form of a Declaration of Perpetual Land Use Restrictions may be requested in the future based on the results of the groundwater remediation activities.
Effectiveness Groundwater Monitoring	Duke Energy plans to monitor the groundwater to confirm the corrective action objectives are met and maintained over time. This monitoring program includes provisions for monitoring COIs within the compliance boundary as required under NCAC Title 15A. 0107(k)(2). Flow and transport plus geochemical modeling have been conducted to predict future groundwater conditions after closure. Effectiveness monitoring will provide data to validate modeling or provide input for future model refinement. The CAP Update includes a comprehensive review of groundwater data collected through June 2019 and a plan to optimize the monitoring program. Within 30 days of CAP approval, Duke Energy would implement the effectiveness monitoring program.

TABLE ES-3
COMPONENTS OF SOURCE CONTROL, ACTIVE REMEDIATION, AND MONITORING

Groundwater Remedy Component	Rationale
Institutional Controls and Monitoring	
Provision for Adaptive Management of Groundwater Remedies	The MSS ash basin and surrounding area is a complex site; therefore, Duke Energy believes it is important to allow for an adaptive approach during implementation of this CAP. This approach is consistent with the Interstate Technology and Regulatory Council (ITRC) document titled *Remediation Management of Complex Sites* (ITRC, 2017). This approach may include adjustments to the groundwater remedy, if necessary, based on new data, or if conditions change.

Prepared by: BDW Checked by: WCG

Corrective Action at Remediation Zones

The areas proposed for groundwater remediation in accordance with 02L requirements are east of the ash basin beyond the compliance boundary and downgradient of the dam (**Figure ES-2**). A wide variety of potential groundwater remedial technologies were initially screened as part of this CAP Update to identify the most applicable remedial methods based upon site specific hydrogeologic conditions and COI distribution in groundwater. After initial screening, the following remedial alternatives were further evaluated in detail:

- Remedial Alternative 1: Monitored Natural Attenuation
- Remedial Alternative 2: Groundwater extraction, clean water infiltration, and in-situ treatment with chemical amendments
- Remedial Alternative 3: Groundwater extraction and clean water infiltration

These remedial alternatives were further screened against the following criteria outlined in Section 6.D.iv. (1-10) of the CAP guidance (NCDEQ, 2019):

- Protection of human health and the environment
- Compliance with applicable federal, state, and local regulations
- Long-term effectiveness and permanence

- Reduction of COI toxicity and mobility, and volume of COI-affected groundwater
- Short-term effectiveness at minimizing effects on the environment and local community
- Technical and logistical feasibility
- Time required to initiate
- Predicted time required to meet remediation goals
- Cost
- Sustainability
- Community acceptance

Groundwater modeling simulations were performed to evaluate the effectiveness of the alternatives and to develop the most effective approach. The results of the analysis indicate that Alternative 3: Groundwater extraction combined with clean water infiltration will most effectively achieve the remedial objectives presented above. The well layout is illustrated on **Figure ES-3** and consists of:

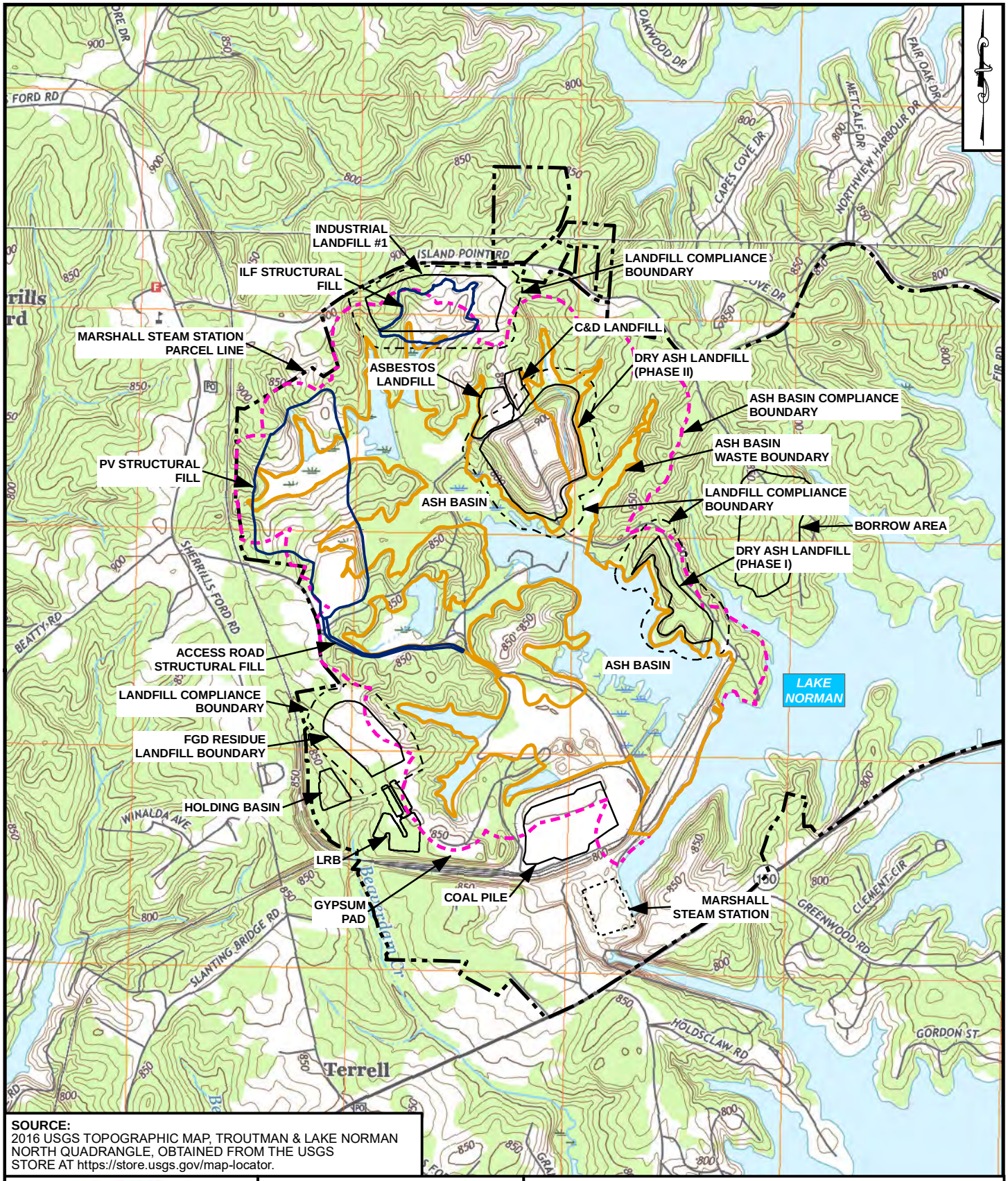
- Sixty-six (66) groundwater extraction wells along the buttress of the dam and to the east and north of the dam
- Twenty-four (24) clean water infiltration wells to the north of the dam and east of the ash basin

It is recommended that prior to implementation, pilot testing of the proposed alternatives will be conducted. Pilot testing and treatment tests to be conducted include: 1) groundwater extraction, 2) clean water infiltration, and 3) treatment testing of water for clean water infiltration. Pilot study results will inform the design of the full-scale system. Planned activities prior to full-scale implementation, where either submittal of the remedial performance monitoring plan (*i.e.,* effectiveness monitoring plan), or the pilot test work plan and permit applications (as applicable) will be submitted to NCDEQ within 30 days of CAP approval to fulfill G.S. Section 130A-309.211(b)(3).

Duke Energy will also be addressing additional primary sources, including the Dry Ash Landfill Phase I and Phase II (INDUS-1804) and the PV Structural Fill, with NCDEQ Division of Waste Management (DWM) in separate submittals. The Dry Ash Landfill Phase I (INDUS-1804) is proposed to be excavated and the PV Structural Fill and Dry Ash Landfill Phase II are proposed for additional closure measures including

installation of a geosynthetic liner and cover system. Installation of an impermeable cover system on the PV Structural Fill and Dry Ash Landfill Phase II will prevent infiltration of precipitation through these sources and reduce COI leaching potential to underlying groundwater. These are source control measures that will assist groundwater corrective action downgradient of these facilities.

As a further source control measure, Duke Energy proposes to excavate the Dry Ash Landfill Phase I due to the unique hydrogeologic setting and close proximity to surface water receptors. The land space could provide additional room for groundwater remediation infrastructure or corrective action plan modification, if deemed necessary, without interfering with ash basin closure or site operations. Vertical migration of COIs beneath and downgradient of the Dry Ash Landfill Phase I is not limited or intercepted by the flow-through ash basin system, as described in the updated CSM herein. Excavation of the Dry Ash Landfill Phase I will remove the source and reduce additional migration of COIs.



SOURCE:
2016 USGS TOPOGRAPHIC MAP, TROUTMAN & LAKE NORMAN NORTH QUADRANGLE, OBTAINED FROM THE USGS STORE AT https://store.usgs.gov/map-locator.

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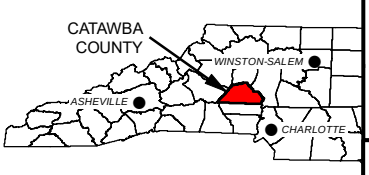

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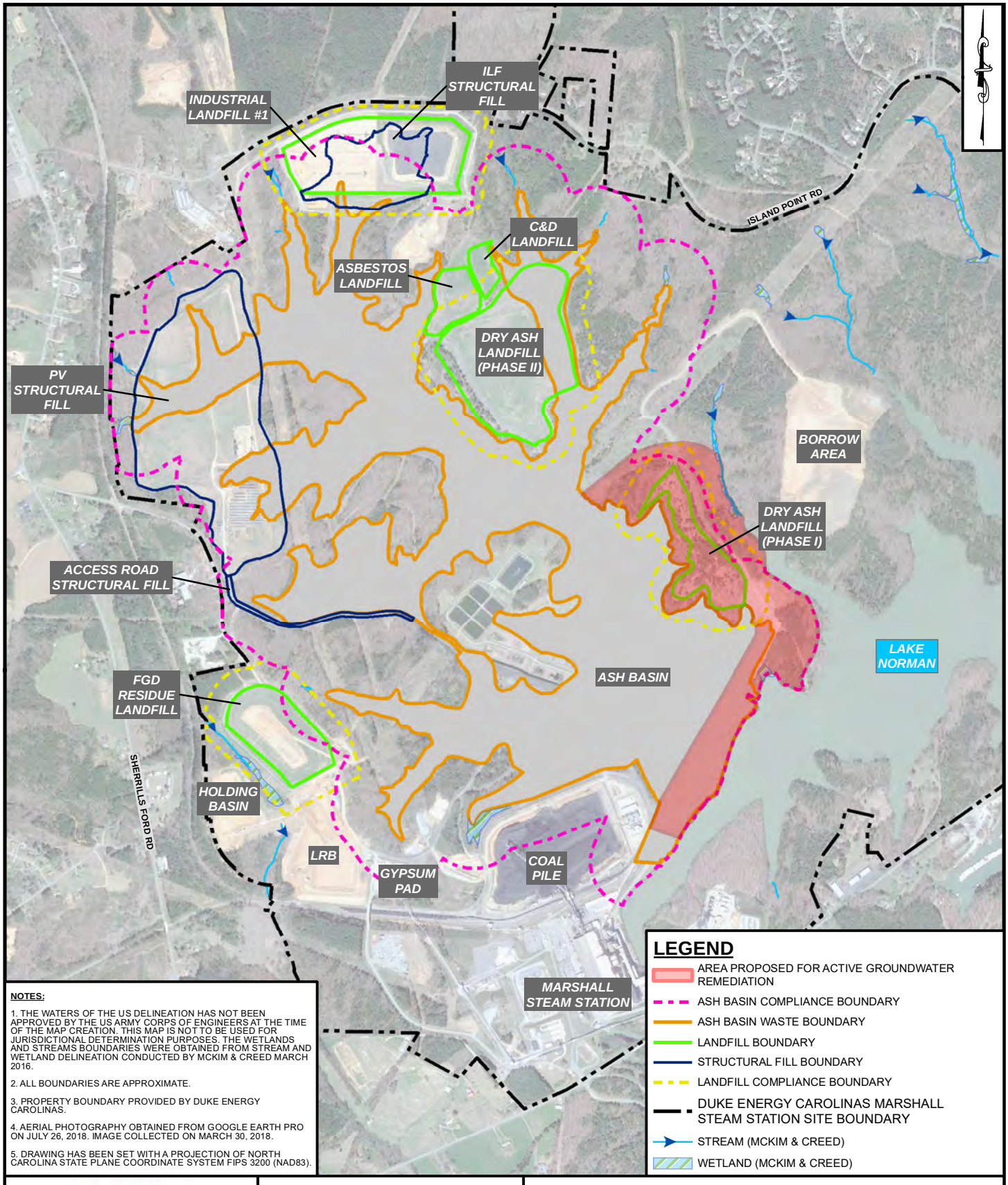
FIGURE ES-1
USGS LOCATION MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

DRAWN BY: B. YOUNG	DATE: 05/15/2019
REVISED BY: B. YOUNG	DATE: 12/10/2019
CHECKED BY: E. WEBSTER	DATE: 12/10/2019
APPROVED BY: B. WILKER	DATE: 12/10/2019
PROJECT MANAGER: B. WILKER	

GRAPHIC SCALE
1,000 0 1,000 2,000
(IN FEET)



NOTES:

1. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
2. ALL BOUNDARIES ARE APPROXIMATE.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

LEGEND

- AREA PROPOSED FOR ACTIVE GROUNDWATER REMEDIATION
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS MARSHALL STEAM STATION SITE BOUNDARY
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
750 0 750 1,500
(IN FEET)

DRAWN BY: B. YOUNG	DATE: 08/27/2019
REVISED BY: C. WYATT	DATE: 12/18/2019
CHECKED BY: E. WEBSTER	DATE: 12/18/2019
APPROVED BY: B. WILKER	DATE: 12/18/2019
PROJECT MANAGER: B. WILKER	

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FIGURE ES-2
AREAS PROPOSED FOR CORRECTIVE ACTION
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure ES-3

Proposed Corrective Action Approach

Provided in separate electronic figure file as a large sheet size

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Appendix I **Monitored Natural Attenuation Report**

Appendix J **Surface Water Evaluation to Assess 15A NCAC 02B .0200 Compliance for Implementation of Corrective Action under 15A NCAC 02L .0106 (k) and (l)**

Surface Water Future Conditions Evaluation to Assess 15A NCAC 02B .0200 Compliance for Implementation and Termination of Corrective Action under 15A NCAC 02L .0106 (k), (l), and (m)

Appendix K **Remedial Alternative Cost Estimate Details**

Appendix L **Sustainability Calculations**

Appendix M **Remediation Alternative Summary**

Appendix N **Proposed Remedial Alternative Design Calculations**

Appendix O **Effectiveness Monitoring Plan**

Appendix P **2019 Additional Assessments**

LIST OF ACRONYMS

02B	NCAC Title 15A, Subchapter 02B. Surface Water and Wetland Standards
02L	NCAC Title 15A, Subchapter 02L. Groundwater Classification and Standards
AOW	area of wetness
aq	aqueous
ASTM	ASTM International
AWWA	American Water Works Association
BTV	Background Threshold Value
bgs	below ground surface
BMP	Best Management Practices
BR	bedrock flow zone
CAMA	Coal Ash Management Act of 2014
CAP	Corrective Action Plan
CBD	citrate-bicarbonate-dithionite
CCR	Coal Combustion Residuals
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COI	Constituent of Interest
CSA	Comprehensive Site Assessment
CSM	Conceptual Site Model
cy	cubic yards
D	deep flow zone
Duke Energy	Duke Energy Carolinas, LLC
DWM	Division of Waste Management
DWQ	Division of Water Quality
DWR	Division of Water Resources
E&SC	Erosion and Sediment Control
Eh	reduction-oxidation potential (volts)
EMC	Environmental Management Commission
EMP	Effectiveness Monitoring Program
EPRI	Electric Power Research Institute
ELCR	excess lifetime cancer risk
°F	degrees Fahrenheit

LIST OF ACRONYMS (CONTINUED)

FGD	flue gas desulfurization
FLASH	Flow-Log Analysis of Single Holes
ft	feet
GCL	geosynthetic clay liner
gpm	gallons per minute
G.S.	General Statutes
GWPS	groundwater protection standard
HAO	hydrous aluminum oxide
HDPE	high density polyethylene
HFO	hydrous ferric oxide
HPF	heat pulse flowmeter
HQ	hazard quotient
IAP	Interim Action Plan
IC	institutional control
IDW	investigation derived waste
ILF	Industrial Landfill
IMAC	Interim Maximum Allowable Concentration
IMP	Interim Monitoring Plan
ITRC	Interstate Technology and Regulatory Council
ISV	in-situ vitrification
k	hydraulic conductivity
K_d	partition coefficient
kg/yr	kilograms per year
lbs	pounds
L/kg	liter per kilogram
LEAF	leaching environmental assessment framework
LLDPE	linear low-density polyethylene
LOAEL	least observed adverse effects level
LPB	low permeability barrier
LRB	lined retention basin
LTM	long term monitoring
MAROS	Monitoring and Remediation Optimization System
mg/kg	milligrams per kilogram
MGD	million gallons per day
mm	millimeter
MNA	monitored natural attenuation

LIST OF ACRONYMS (CONTINUED)

MSS	Marshall Steam Station
MW	megawatt
NCAC	North Carolina Administrative Code
NCDHHS	North Carolina Department of Health and Human Services
NCDENR	North Carolina Department of Environment and Natural Resources
NCDEQ	North Carolina Department of Environmental Quality
n_e	effective porosity
NOAEL	no observed adverse effects level
NORR	Notice of Regulatory Requirements
NPDES	National Pollutant Discharge Elimination System
NPV	net present value
NRTR	Natural Resources Technical Report
NTU	Nephelometric Turbidity Units
O&M	operation and maintenance
OEES	Occupational and Environmental Epidemiology Section
OFA	other federal agency
ORP	oxidation-reduction potential
PE	polyethylene
Plant/Site	Marshall Steam Station
PBTV	Provisional Background Threshold Value
PPE	personal protection equipment
PPI	Plastic Pipe Institute
PRP	potential responsible party
POG	protection of groundwater
POTW	publically owned treatment works
psi	pounds per square inch
PRB	permeable reactive barrier
PSRG	preliminary soil remediation goal
PV	Photovoltaic
PVC	poly-vinyl chloride
RCRA	Resource Conservation and Recovery Act
RQD	rock quality designation
RS	restricted designation
S	shallow flow layer
SAC	strong acid cation

LIST OF ACRONYMS (CONTINUED)

SAP	sampling and analysis plan
SBA	strong base anion
SOC	Special Order of Consent
SPLP	synthetic precipitation leaching procedure
SPP	Storm Water Permitting Program
SSL	statistically significant level
S.U.	standard units
TDS	total dissolved solids
TOC	total organic carbon
TSS	total suspended solids
TZ	transition zone
µg/L	micrograms per liter
UIC	underground injection control
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WAC	weak acid cation
WBA	weak base anion
ZVI	zero-valent iron

1.0 INTRODUCTION

(CAP Content Section 1)

SynTerra prepared this groundwater corrective action plan (CAP) Update on behalf of Duke Energy Carolinas, LLC (Duke Energy). The plan pertains to the Marshall Steam Station (MSS, Plant, or Site) coal combustion residual (CCR) ash basin and adjacent source areas. Duke Energy owns and operates MSS, located in Terrell, Catawba County, North Carolina (**Figure 1-1**).

In accordance with Section 130A-309.211(b) of the North Carolina General Statutes (G.S.), as amended by Coal Ash Management Act of 2014 (CAMA), Duke Energy is submitting this groundwater CAP Update to prescribe methods and materials to restore groundwater quality associated with CAMA-regulated units. This CAP Update evaluation considers constituent concentrations detected greater than applicable North Carolina groundwater standards [NC Administrative Code (NCAC), Title 15A, Subchapter 02L, Groundwater Classification and Standards (02L); Interim Maximum Allowable Concentrations (IMAC); or background values], whichever is greater, at or beyond the compliance boundary.

In accordance with G.S. requirements, a CAP for MSS was previously submitted to the North Carolina Department of Environmental Quality (NCDEQ) in two parts:

- *Corrective Action Plan Part 1 – Marshall Steam Station Ash Basin* (HDR, 2015b)
- *Corrective Action Plan Part 2 (included Comprehensive Site Assessment Supplement 1 as Appendix A) – Marshall Steam Station Ash Basin* (HDR, 2016b)

This CAP Update is being submitted to NCDEQ as originally requested in a June 2, 2017, letter from NCDEQ to Duke Energy. In an April 5, 2019, letter to Duke Energy, NCDEQ issued revised CAP deliverable schedules and also requested assessment of additional potential sources of constituents to groundwater at MSS, stating that sources hydrologically connected to the ash basin are to be assessed and included in an updated CAP. The coal pile and gypsum storage pad areas were identified as additional sources hydrologically connected to the ash basin.

In addition to the CAP Update, Duke Energy is required to submit a CCR Surface Impoundment Closure Plan (Closure Plan) to NCDEQ on/before December 31, 2019 under separate cover. This CAP Update has been developed to be effective with the various closure scenarios developed for the Site.

CAP content and submittal schedule are in accordance with subsequent correspondence between NCDEQ and Duke Energy, including CAP content guidance issued by NCDEQ on April 27, 2018 and adjusted on September 10, 2019. This CAP Update includes section references to the document titled, *Corrective Action Plan Content for Duke Energy Coal Ash Facilities* (provided in **Appendix A**), beneath report section headings and within text in to facilitate the review process.

1.1 Background

(CAP Content Section 1.A)

A substantial amount of assessment data has been collected for the MSS ash basin and contiguous additional source areas to support this CAP Update. The Comprehensive Site Assessment (CSA) Update Report, dated January 31, 2018 (SynTerra, 2018a), was performed in accordance with requirements in 15A NCAC 02L .0106 (g). The CSA:

- Identified the source(s) and causes of constituents of interest (COIs) in groundwater.
- Found no imminent hazards to public health and safety.
- Identified receptors and potential exposure pathways.
- Sufficiently determined the horizontal and vertical extent of COIs in soil and groundwater.
- Determined the geological and hydrogeological features influencing the movement, chemical makeup, and physical characteristics of COIs.

NCDEQ provided review of the CSA Update to Duke Energy in a letter dated April 26, 2018, and stated the information provided sufficiently warranted preparation of this CAP Update. This CAP Update builds on previous documents to provide a CAP for addressing the requirements in 15A NCAC 02L .0106 for corrective action and the restoration of groundwater quality.

Detailed descriptions of Site operational history, the conceptual site model (CSM), physical setting and features, geology/hydrogeology, and findings of the CSA and other CAMA-related work are documented in the following reports:

- *Comprehensive Site Assessment Report — Marshall Steam Station Ash Basin* (HDR 2015a)
- *Corrective Action Plan Part 1 — Marshall Steam Station Ash Basin* (HDR, 2015b)
- *Corrective Action Plan Part 2* (included CSA Supplement 1 as Appendix A) — *Marshall Steam Station Ash Basin* (HDR, 2016a)

- *Comprehensive Site Assessment Supplement 2 — Marshall Steam Station Ash Basin* (HDR, 2016b).
- *Comprehensive Site Assessment Update – Marshall Steam Station Ash Basin* (SynTerra, 2018a).
- *Ash Basin Pumping Test Report – Marshall Steam Station* (SynTerra, 2019a)
- *Estimating Partition Coefficient (K_d) for Modeling Boron Transport Using EPA Method 1316 – Marshall Steam Station* (SynTerra, 2019b)
- *Surface Water Evaluation to Assess 15A NCAC 02B.0200 Compliance for Implementation of Corrective Action Under 15A NCAC 02L .0106 (k) and (l) – Marshall Steam Station* (SynTerra, 2019c)
- *2018 CAMA Annual Interim Monitoring Report* (SynTerra, 2019d)

1.2 Purpose and Scope

(CAP Content Section 1.B)

The purposes of this corrective action plan approach are the following:

- Restore groundwater affected by the ash basin and adjacent source areas at or beyond the ash basin compliance boundary to the applicable groundwater standards, or as close to the standards as is economically and technically feasible, in accordance with Subchapter 02L .0106(a). In the future, alternative standards may be proposed as allowed under 02L .0106(k). This approach is considered reasonable given the documented lack of human health or ecological risk at the MSS.
- Address response requirements contained within 15A NCAC 02L .0107(k) for exceedances of standards (1) in adjoining classified groundwater, (2) presenting an imminent hazard to public health and safety, and/or (3) in bedrock groundwater that might potentially affect a water supply well.
- Meet the requirements for corrective action plans found in G.S. Section 130A-309.211(b).

The scope of the CAP and this CAP Update is defined by G.S. Section 130A-309.211, amended by CAMA. The legislation required, among other items, assessment of groundwater at coal combustion residual impoundments and corrective action in conformance with the requirements of Subchapter 02L. These corrective actions for restoration of groundwater quality requirements were codified into G.S. Section 130A-309.211, which was further amended by House Bill 630 to require a provision for

alternate water supply for receptors within 0.5 mile downgradient from the established compliance boundary.

Based on conditions and results from the Site investigations, this CAP Update develops and compares alternative methods for corrective action and presents the recommended plan. This CAP Update presents a holistic, multi-component corrective action approach for groundwater COIs associated with the ash basin and adjacent sources at or beyond the compliance boundary, to the east of the ash basin. Initial design information and steps necessary for implementation are included in the CAP Update. Once the CAP is approved by NCDEQ, implementation is planned to begin within 30 days, as required by the G.S.

1.3 Regulatory Basis for Corrective Action
(CAP Content Section 1.C)

Comprehensive groundwater assessment activities, conducted in accordance with a Notice of Regulatory Requirements (NORR) issued to Duke Energy on August 13, 2014 by the North Carolina Department of Environment and Natural Resources (NCDENR) (**Appendix A**) and multiple subsequent regulatory requests, indicate the ash basin and the related adjacent units have contributed to constituent concentrations in groundwater greater than applicable regulatory standards beyond the ash basin compliance boundary.

The regulatory requirements for corrective action at coal combustion residuals surface impoundments under CAMA are in G.S. Section 130A-309.211(b), (c), and (c1). G.S. Section 130A-309.211(b) requires that the CAP shall provide for groundwater restoration in conformance with the requirements of Subchapter L of Chapter 2 of Title 15A of the North Carolina Administrative Code (15A NCAC Subchapter 02L). In accordance with G.S. Section 130A-309.211(b)(1), the groundwater CAP shall include, at a minimum, the following (*CAP Content Section 1.C.a*):

- A description of all exceedances of the groundwater quality standards, including any exceedances that the owner asserts are the result of natural background conditions
- A description of the methods for restoring groundwater in conformance with the requirements of Subchapter L of Chapter 2 of Title 15A of the NCAC and a detailed explanation of the reasons for selecting these methods
- Specific plans, including engineering details, for restoring groundwater quality
- A schedule for implementation of the groundwater corrective action plan

- A monitoring plan for evaluating the effectiveness of the proposed corrective action and detecting movement of any constituent plumes
- Any other information related to groundwater assessment required by NCDEQ

In addition to CAMA, requirements for CAPs are also contained in Subchapter 02L .010(e), (h) and (i).

Section 02L .0106(e)(4) requires implementation of an approved CAP for restoration of groundwater quality at or beyond the compliance boundary in accordance with a schedule established by the Secretary.

To comply with 02L .0106(h), CAPs must include (*CAP Content Section 1.C.b)**:***

- A description of the proposed corrective action and reasons for its selection
- Specific plans, including engineering details where applicable, for restoring groundwater quality
- A schedule for the implementation and operation of the proposed plan
- A monitoring plan for evaluating the effectiveness of the proposed corrective action and the movement of the constituent plume

This CAP Update presents an evaluation of the options for corrective action under Subchapter 02L .0106(j), (k), and (l).

- Under paragraph (j), corrective action would be implemented using remedial technology for restoration of groundwater quality to the standards (02L).
- Under paragraph (k), a request for approval of a corrective action plan may be submitted without requiring groundwater remediation to the standards (02L) if the requirements in (k) are met.
- Under paragraph (l), a request for approval of a corrective action plan may be submitted based on natural processes of degradation and attenuation if the requirements in (l) are met.

This CAP Update has been prepared in general accordance with the NCDEQ guidance document titled *Corrective Action Plan Content for Duke Energy Coal Ash Facilities,* which provides an outline of the technical content and format presented in the NCDEQ's letter dated September 10, 2019, provided in **Appendix A** (*CAP Content Section 1.C.c*).

The MSS ash basin meets the low-risk classification criteria set forth in CAMA for CCR surface impoundments. On October 12, 2018, the NCDEQ confirmed that Duke Energy satisfactorily completed the alternate water provisions under G.S. Section 130A-309.211(c1). On November 13, 2018, the NCDEQ confirmed that Duke Energy rectified prior dam safety deficiencies, reclassifying the ash basin from its prior draft ranking of "intermediate" to "low-risk." A low-risk coal combustion residuals surface impoundment may be closed by excavation, closure-in-place, or a hybrid approach.

Ash basin closure is detailed in a separate document prepared by AECOM. Closure scenarios include a closure-in-place and closure-by-excavation scenario. The CAP approach described herein can be implemented under either scenario.

1.4 List of Considerations by the Secretary for Evaluation of Corrective Action Plans

(CAP Content Section 1.D.a through g)

Potential targeted active remedial alternatives were developed using the criteria included in the NCDEQ's CAP Guidance (NCDEQ 2018). An evaluation of remedial alternatives was performed based on the following criteria:

- Protection of human health and the environment
- Compliance with applicable federal, state, and local regulations
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Short-term effectiveness at minimizing impact on the environment and local community
- Technical and logistical feasibility
- Time required to initiate
- Predicted time required to meet remediation goals
- Cost
- Community acceptance

In the evaluation of CAPs as specified in 02L .0106(i), the criteria include the following:

- A consideration of the extent of any violations
- The extent of any threat to human health or safety
- The extent of damage or potential adverse impact to the environment

- Technology available to accomplish restoration
- The potential for degradation of the constituents in the environment
- The time and costs estimated to achieve groundwater quality restoration
- The public and economic benefits to be derived from groundwater quality restoration

These 02L .0106(i) criteria form the basis for defining the screening criteria outlined in **Section 6.6** for use in evaluating remedial alternatives in **Section 6.7**.

In addition, institutional controls (provided by the restricted designation [RS]) may be proposed by Duke Energy to limit access to groundwater use (Subchapter 02L .0104). The RS designation may be requested for areas outside of an established compliance boundary when groundwater might not be suitable for use as drinking water supply without treatment. RS designation is a temporary designation and is removed by the NCDEQ Director upon a determination that the quality of the groundwater has been restored to the applicable standards or when the groundwater has been reclassified by the NCDEQ. NCDEQ is authorized to designate existing or potential drinking water (Class GA groundwater) as RS where the Director has approved a CAP, or the termination of corrective action, that will not result in the immediate restoration of such groundwater to the standards established in 02L.

1.5 Facility Description
(CAP Content Section 1.E)

1.5.1 Location and History of Land Use
(CAP Content Section 1.E.a)

MSS is located on the west bank of Lake Norman on NC Highway 150 E near the town of Terrell, Catawba County, North Carolina (**Figure 1-1**). MSS is a four-unit coal-fired electricity generating plant with a combined capacity of approximately 2,090 megawatts (MW). Operation of Unit 1 (350 MW) began in 1965, and operation of Unit 2 (350 MW) began in 1966. Operation of Unit 3 (648 MW) began in 1969, and operation of Unit 4 (648 MW) began in 1970. Cooling water for MSS is provided by Lake Norman, which was created to serve this purpose.

The area surrounding MSS generally consists of residential properties, undeveloped land, and Lake Norman (**Figure 1-2**). Natural topography at the Site generally slopes downward from an approximate high elevation of 885 feet North American Vertical Datum of 1988 (NAVD88) along ridges west and north of the basin to an approximate low elevation of 775 feet at the base of the ash

basin dam. Downstream of the dam, Lake Norman encompasses approximately 32,000 acres at a full pond elevation of 760 feet, with an average elevation of 756 feet.

The station and supporting facilities lie within a 1,446-acre parcel owned by Duke Energy. Based on a review of available historical aerial photography, the Site consisted of a combination of agricultural land and woodlands prior to the impoundment of the Catawba River for the formation of Lake Norman. **Figure 1-3** presents a 1962 topographic survey map depicting the area of the MSS Site prior to its development and construction of Lake Norman. **Figure 1-4** presents an aerial photograph taken in 1950 prior to development of the Site and construction of Lake Norman (*CAP Content Section 1.E.a*).

The MSS ash basin, approximately 394 acres in size, is located north of the station, and is generally bounded by an earthen dam and natural ridges to the west (Sherrills Ford Road) and north (Island Point Road). Sherrills Ford Road and Island Point Road, located along topographic ridges, represent hydrologic divides that affect groundwater flow within an area approximately one mile west, north and northeast of the ash basin (*CAP Content Section 5.b*) (**Figure 1-2**). Topography to the east of Sherrills Ford Road generally slopes downward toward Lake Norman to the southeast. Topography along Island Point Road, to the north and northeast of the ash basin generally slopes downward toward Lake Norman to the southeast.

Land use within the 0.5-mile radius of the ash basin compliance boundary generally consists of undeveloped land and Lake Norman to the east, undeveloped land and residential properties located to the north and west, portions of MSS (outside the compliance boundary), undeveloped land, and residences to the south, and commercial properties to the southeast along North Carolina Highway 150.

The Catawba County zoning map indicates that the majority of the properties fronting Sherrills Ford and Island Point Roads are zoned Residential (R20 or R30). The Duke Energy property is zoned General Industrial (GI). No significant change in land use surrounding MSS is anticipated.

1.5.2 Operations and Waste Streams Coincident with the Ash Basin

(CAP Content Section 1.E.b)

Coal-Related Operational Storage and Waste Streams Coincident with the Ash Basin

Coal is a highly combustible sedimentary or metamorphic rock typically dark in coloration and present in rock strata known as coal beds or seams. Coal is predominantly made up of carbon and other elements such as hydrogen, oxygen, nitrogen, and sulfur as well as trace metals. The composition of coal makes it useful as a fossil fuel for combustion processes. Coal results from the conversion of dead vegetative matter into peat and lignite. The exact composition of coal varies depending on the environmental and temporal factors associated with its formation.

Coal has arrived at MSS through rail transportation since operations began. Coal storage has historically occurred at the Site's coal pile located immediately north of the powerhouse and south/adjacent to the ash basin (**Figure 1-2**). Coal is conveyed via transfer belts to the station where it is pulverized before being used in the boilers.

NCDEQ identified the coal pile as a potential additional source area adjacent to the ash basin. The coal pile is not regulated under CAMA; however, assessment and characterization was conducted, and the findings are incorporated into this CAP.

Coal ash and other CCRs are produced from coal combustion. The smaller ash particles (fly ash) are carried upward in the flue gas and are captured by an air pollution control device, such as an electrostatic precipitator. The larger ash particles (bottom ash) fall to the bottom of the boiler.

Approximately 70 percent to 80 percent of ash produced during coal combustion is fly ash (Electric Power Research Institute [EPRI] 1995). Typically, 65 percent to 90 percent of fly ash has particle sizes that are less than 0.010 millimeter (mm). In general, fly ash has a grain size distribution similar to that of silt. The remaining 20 percent to 30 percent of ash produced is considered bottom ash. Bottom ash consists of angular particles with a porous surface and is normally gray to black in color. Bottom ash particle diameters can vary from approximately 38 mm to 0.05 mm. In general, bottom ash has a grain size distribution similar to that of fine gravel to medium sand (EPRI 1995).

Non-Coal-Related Operational Storage and Waste Streams Coincident with the Ash Basin

The gypsum storage pad, which is lined and located southeast of the ash basin, has also been identified by NCDEQ as a potential additional source area adjacent to the ash basin. The gypsum pad is not regulated under CAMA; however, potential effects are considered adjacent to the ash basin. Therefore, assessment and characterization were completed and the findings incorporated into this CAP. Results of the assessment conducted at the lined gypsum storage pad indicate no impacts to underlying soil or groundwater as a result of gypsum storage and operation. Therefore, the gypsum storage pad is not being carried forward for corrective action in this CAP Update.

Environmental incidents (*i.e.*, releases) have occurred at MSS that initiated notifications to NCDEQ. The historical incidents most often consisted of minor releases of petroleum constituents near the intake canal or around the steam station. A summary of historical on-site environmental incidents at MSS is provided in **Table 1-1**. None of these incidents were near the ash basin nor had an effect on the ash basin COI distribution in groundwater. No non-coal related operations or environmental incidents (*i.e.,* releases that initiated notification to NCDEQ) are known to have occurred within the vicinity of the ash basin; therefore, no environmental incidents at MSS are relevant to this CAP and are not included as components of this CAP Update.

1.5.3 Overview of Existing Permits and Special Orders by Consent

(CAP Content Section 1.E.c)

NPDES Permit / Special Order by Consent

Duke Energy is authorized to discharge wastewater from the MSS ash basin to Lake Norman (Outfall 002) in accordance with National Pollutant Discharge Elimination System (NPDES) Permit NC0004987, which was renewed by NCDEQ on May 1, 2018. The sources of wastewater include non-contact cooling water, ash basin discharge, sanitary waste, cleansing and polishing water, low volume wastes, and storm water from process areas.

The facility operates the following outfalls:

- **Outfall 001**: Once-through cooling water and intake screen backwash.
- **Outfall 002**: Treated wastewater from the ash settling basin (consisting of metal cleaning wastes, coal pile runoff, ash transport water, storm water,

low volume wastes, landfill leachate, and flue gas desulfurization (FGD) wet scrubber wastewater).

- **Outfall 005**: Discharge from the new lined retention basin. Basin will accept wastes from holding basin (coal pile runoff), ash transport water, various sumps, storm water runoff, FGD wastewater, and various low volume wastes such as boiler blowdown, oily waste treatment, wastes/ backwash from the water treatment processes, plant area wash down water, equipment heat exchanger water, landfill leachate, and ash transport water.
- **Outfalls 002A and 002B**: Yard sump overflows.
- **Outfall 007**: The emergency spillway of the ash basin. The spillway is designed for a flood greater than a 100-year event. Sampling of this spillway is waived due to unsafe conditions associated with sampling during an overflow event.
- **Internal Outfall 001 / 001A:** Yard sump (wastewater from the yard sump 2, the yard sump 3, the fly ash silo yard sump, and storm water) discharging to the retention basin.
- **Internal Outfall 003**: Non-contact cooling water from the induced draft fan control house to the intake for cooling water pumps.
- ***Internal Outfall 004****: Treated FGD wet scrubber wastewater, and storm water to the ash settling basin.* (Note: this outfall has been abandoned and is no longer active)
- **Internal Outfall 006**: Treated FGD wet scrubber wastewater to the retention basin. During the transition period, both outfalls (004 and 006) can be discharging.
- **Internal Outfall 010 from Holding Basin**: Coal pile runoff, and storm water to the retention basin.

A Special Order by Consent (SOC) was issued to Duke Energy on April 18, 2018, to address the elimination of seeps from Duke Energy's ash basins during the separate and independent process of ash basin closure. The SOC provided definition for constructed seeps [seeps that (1) are on or within the dam structures and (2) convey wastewater via a pipe or constructed channel directly to a receiving water] or non-constructed seeps (seeps that do not meet the "constructed seep" definition). Ash basin decanting is now underway and is expected to substantially reduce or eliminate discharge from the seeps.

The SOC requires Duke Energy to accelerate ash basin decanting. After completion of decanting, remaining seeps, if not dispositioned in accordance with the SOC, are to be characterized. After post-decanting seep characterization, an amendment to the CAP and/or Closure Plan, may be required to address remaining seeps. The SOC terminates 180 days after decanting or 30 days after approval of the amended CAP. Basin decanting at MSS via gravity flow began on July 16, 2019 with the removal of stop logs from the outlet structure. Mechanical decanting (pumping) began on September 13, 2019. Since the commencement of decanting, as of December 1, 2019, 128.4 million gallons of water have been removed from the ash basin and the elevation of the ponded water within the basin has decreased by 7.3 feet. The SOC requires completion of decanting by March 31, 2021.

Permitted Solid Waste Facilities

There are three solid waste permits associated with MSS:

1. Permit 1804-INDUS-1983, which includes:
    - Dry Ash Landfill (Phase I)
    - Dry Ash Landfill (Phase II)
    - Construction & Demolition (C&D) Landfill
    - Asbestos Landfill
2. Permit 1812-INDUS-2008 (Industrial Landfill No. 1)
3. Permit 1809-INDUS- [Flue Gas Desulfurization (FGD) Residue Landfill]

The double-lined Industrial Landfill No. 1 (ILF) is located north and upgradient of the ash basin. The C&D, Asbestos, and unlined Dry Ash Landfill Phase II are proximal to each other, adjacent to the northern portion of the ash basin. The unlined Dry Ash Landfill Phase I is located immediately east and downgradient of the ash basin. The closed FGD Residue Landfill is located upgradient and west of the southern portion of the ash basin (**Figure 1-1**). The FGD Landfill was constructed with an engineered, single-liner system and was capped with a 40-mil linear low-density polyethylene (LLDPE) geomembrane, geocomposite drainage layer, and two feet of final cover soil. The closed Dry Ash Landfills (Phase I and Phase II), constructed of fly ash generated from MSS, are located within the ash basin groundwater drainage system and are addressed as part of this CAP Update.

Additional Permits

In addition to NPDES wastewater discharge permit NC0004987 and solid waste permits (as mentioned above), the facility also holds air permit #03676T57, and a hazardous waste permit NCD043678879 as a Resource Conservation and Recovery Act (RCRA) small quantity generator.

The facility is subject to federal NPDES storm water discharge permit requirements per 40 Code of Federal Regulations (CFR) §122.26 (b)(14)(vii). MSS received a separate NPDES industrial storm water discharge permit (NCS000548), effective May 15, 2015, from the North Carolina Division of Energy, Mineral, and Land Resources Storm Water Permitting Program (SPP). The facility discharges to Lake Norman, a class WS-IV, B, CA water in the Catawba River Basin. Storm water discharges are subject to the monitoring requirements specified in Permit No. NCS000548.

Erosion and sediment control (E&SC) permits are required for construction and excavation related activities including general construction projects and environmental assessment and remediation projects if the area of disturbance is greater than one acre. Multiple E&SC permits have been obtained for various projects implemented at the Station, including environmental related projects, such as well installation and access road construction. Most of the E&SC permits are closed as the related projects are completed. E&SC permits will continue to be obtained prior to implementation of additional construction projects, as appropriate.

2.0 RESPONSE TO CSA UPDATE COMMENTS IN SUPPORT OF CAP DEVELOPMENT

(CAP Content Section 2)

2.1 Facility-Specific Comprehensive Site Assessment (CSA) Comment Letter

(CAP Content Section 2.A)

On January 31, 2018, Duke Energy submitted a CSA Update to NCDEQ. In a letter from NCDEQ to Duke Energy dated August 17, 2018, NCDEQ stated that sufficient information had been provided in the 2018 CSA Update to allow preparation for the CAP Update. The letter also provided a number of CSA-related comments and items required to be addressed prior to or as part of the CAP submittal (**Appendix A**).

2.2 Duke Energy's Response to NCDEQ Letter

(CAP Content Section 2.B and 2.B.a)

Responses to all NCDEQ comments within the August 17, 2018 letter are summarized in **Appendix B**. Duke Energy received additional, informal comments to the CSA Update Report from the NCDEQ Mooresville Regional Office (MRO) which are also addressed in **Appendix B**. Additional content related to NCDEQ's comments is either included within section of the CAP Update or as standalone appendices to this CAP Update, such as the groundwater modeling report and surface water evaluation report.

Activities that directly addressed NCDEQ comments include:

- Groundwater samples continued to be collected on a quarterly basis as part of the MSS Interim Monitoring Plan (IMP). Additional sampling results augmented the groundwater quality database. Comprehensive groundwater analytical data are included in **Appendix C**, Table 1.
- Since the CSA Update submittal, additional assessments have been completed including additional well installations, pumping tests, bedrock evaluation (including geophysical borehole surveys), groundwater to surface water interaction, soil sampling, slug testing, geochemical modeling and associated sampling, and groundwater flow and transport modeling. The results of these assessments have been used to provide additional supporting information for this CAP Update. The assessment reports have either been previously submitted to NCDEQ or are attached as appendices to this report.
- Characterization of fractured bedrock based on additional evaluation of lineaments, the bedrock fracture system, and the bedrock matrix was conducted.

A report summarizing the evaluation and implications for bedrock groundwater flow and transport is included in **Appendix F**.

- Additional assessment of Lake Norman surface water and sediment was performed in August 2018. There were no constituent concentrations greater than 02B surface water standards attributable to the groundwater plume(s). A report summarizing the sampling, results, evaluation, and conclusions of the surface water evaluation was submitted to NCDEQ in March 2019 and is included in **Appendix J**.
- An evaluation of potential groundwater migration and associated impacts to surface water under future conditions was conducted. Based on the evaluation, future groundwater discharge to Lake Norman from areas potentially affected by the ash basin and adjacent source areas are not predicted to cause COI concentrations in surface water greater than 02B surface water standards. The evaluation is presented in **Appendix J**.
- Background values for soil and groundwater were updated. Information about background determinations is presented in **Section 4.0**.
- The MSS flow and transport model and geochemical model were updated to incorporate additional assessment data and information. The models were used to evaluate current and predicted future Site conditions. The flow and transport model report is provided as **Appendix G**. The geochemical model report is provided as **Appendix H**.
- The MSS CSM was updated to improve understanding of Site conditions and to support remedy design based upon updated Site data, assessment results, and model predictions. The updated CSM is presented in **Section 5.0.**

3.0 OVERVIEW OF SOURCE AREAS BEING PROPOSED FOR CORRECTIVE ACTION

(CAP Content Section 3)

The MSS ash basin is the only CAMA-regulated unit at the Site. Additional primary sources located within or adjacent to the ash basin and considered in this CAP include:

- Closed Dry Ash Landfills (Phase I and Phase II)
- Photovoltaic (PV) structural fill
- Structural fill beneath Industrial Landfill No. 1
- Access road structural fill
- Coal pile
- Gypsum pad

CAMA defines CCR surface impoundments as topographic depressions, excavations, or diked areas formed primarily of earthen materials, without a base liner, and that meet other criteria related to design, usage, and ownership (G.S. Section 130A-309.201).

The CCR surface impoundment (ash basin) at MSS and the adjacent sources are the focus of this CAP Update. A certification that consensus was reached with the NCDEQ DWR regarding sources not considered for corrective action as part of this CAP Update was provided in a letter from NCDEQ to Duke Energy dated April 5, 2019 (**Appendix A**). A summary of these facilities, their status of inclusion or exclusion as part of the source area, and the rationale for inclusion or exclusion is provided in **Table 3-1** (*CAP Content Section 3.B*).

Results of the assessment conducted at the lined gypsum storage pad indicate no impacts to underlying soil or groundwater as a result of gypsum storage and operation. Therefore, the gypsum storage pad is not being carried forward for corrective action in this CAP Update.

The closed Dry Ash Landfills (Phase I and Phase II) are under NCDEQ DWM regulatory oversight and are monitored on a semiannual basis. The PV Structural Fill is inspected on a yearly basis by NCDEQ DWM. Groundwater sampling data indicate constituents similar to COIs identified from CAMA groundwater monitoring of the ash basin (*e.g.,* boron) are present in groundwater beneath and within a limited horizontal extent of the landfill and structural fill footprints. Duke Energy is proposing to excavate the Dry Ash Landfill Phase I (INDUS-1804). Excavation of the Dry Ash Landfill Phase I

will remove the source and reduce additional migration of COIs east of the ash basin toward the unnamed tributary. The Dry Ash Landfill Phase II (INDUS-1804) and the PV Structural Fill are proposed for additional closure measures including installation of a geosynthetic liner and cover system. Installation of an impermeable cover system on the Dry Ash Landfill Phase II and PV Structural Fill will prevent infiltration of precipitation through these sources and reduce COI leaching potential to underlying groundwater. These are source control measures that will assist groundwater corrective action downgradient of these facilities.

The additional primary sources listed above generally lie within the ash basin compliance boundary. A very limited portion of the southwest corner of the PV Structural Fill lies beyond the ash basin compliance boundary. A combination of historical groundwater data (MW-12S/D) and additional wells installed in 2019 (PVSF-4 cluster) confirm there are no COI concentrations greater than 02L, IMAC, or background, whichever is greatest (**Appendix C**, Table 1); therefore, MNA is proposed as a viable remedial alternative between the compliance boundary and Duke Energy property boundary (see **Appendix I**). Similarly, coal pile and gypsum pad assessment results indicate no impacts from these identified sources to underlying soil or groundwater at or beyond the ash basin compliance boundary. Groundwater flow from beneath any of these features is predicted to flow within the flow fields of the ash basin. Therefore, any corrective actions identified for the ash basin compliance boundary would also address COIs potentially related to the facilities identified above. Groundwater flow is not predicted to migrate to the north and west beyond the compliance boundary in the future. The corrective action approach for the ash basin and adjacent source areas is discussed in detail in **Section 6.5**.

4.0 SUMMARY OF BACKGROUND DETERMINATIONS

(CAP Content Section 4)

Metals and inorganic constituents, typically associated with CCR material, are naturally occurring and present in the Piedmont physiographic province of central North Carolina. The metals and inorganic constituents occur in soil, groundwater, surface water, and sediment. Background analytical results are used to compare detected constituent concentration ranges from the source area relative to native conditions.

The statistically derived background values for the site are used for screening of assessment data collected in areas of potential migration of COIs from a source area. If the assessment data concentrations are less than background, it is likely COI migration has not occurred in the area. If the assessment data concentrations are greater than background, additional lines of evidence are used to determine whether the concentrations represent migration from a source area. Additional lines of evidence include, but may not be limited to:

- Evaluation of whether the concentration is within the range concentrations detected at the Site, or within the range for the region
- Evaluation of whether there is a migration mechanism through the use and interpretation of hydraulic mapping (across multiple flow zones), flow and transport modeling, and understanding of the CSM
- Evaluation of concentration patterns (*i.e.,* do the patterns represent a discernable plume or migration pattern?)
- Consideration of natural variations in site geology or geochemical conditions between upgradient (background locations) and downgradient areas
- Consideration of other constituents present at concentrations greater than background.

The MSS and nine other Duke Energy facilities (Allen Steam Station, Belews Creek Stream Station, Buck Steam Station, Cape Fear Steam Electric Plant, Cliffside Steam Station, Dan River Steam Station, Mayo Steam Electric Plant, Riverbend Steam Station, and Roxboro Steam Electric Plant) are situated in the Piedmont physiographic province of north-central North Carolina. The nine Duke Energy facilities are located within an approximate 150-mile radius from MSS. Statistically derived background values from these facilities provide a geographic regional background range for comparison. Generally, background values derived from the Piedmont facilities are similar, with some exceptions.

As more background data become available, the background values may be updated to continue to refine the understanding of background conditions. However, these multiple lines of evidence, and additional steps in the evaluation process, will continue to be important tools to distinguish between background conditions and areas affected by constituent migration.

Background sample locations were selected to be in areas that represent native conditions, not affected by the Site coal ash basin or adjacent source areas. Background locations for all media, including groundwater, surface water, soil, and sediments are illustrated in **Figure 4-1** (*CAP Content Section 4.A*). Tables referenced in this section present background datasets for each media, statistically calculated background threshold values (BTVs) for soil and groundwater, and background dataset ranges for surface water and sediment.

Background soil and groundwater locations approved by NCDEQ, as well as statistically derived BTVs, are detailed in **Sections 4.1** and **4.2**. BTVs were not calculated for surface water and sediment; however, background locations for surface water and sediment were approved by NCDEQ as part of the evaluation of potential groundwater to surface water impacts (**Appendix J**) and are detailed in **Section 4.3** and **4.4**.

4.1 Background Concentrations for Soil

The locations of the background soil borings are shown on **Figure 4-1**. The soil background dataset with the appropriate protection of groundwater (POG) preliminary soil remediation goals (PSRGs) and background values is included in **Appendix C,** Table 4 (*CAP Content Section 4.B*). Background soils samples were collected from multiple unsaturated depth intervals that were greater than one foot above the seasonal high water table elevation. The MSS background soil boring locations, unsaturated soil depth interval and number of discrete samples collected from the unsaturated soil depth interval are provided in **Table 4-1**.

The suitability of each of these locations for evaluating background conditions was addressed in a technical memorandum (May 26, 2017). Soil data appropriate for inclusion in the statistical analysis to determine background values was approved by NCDEQ in a response letter dated July 7, 2017. Additional soil samples were collected from background soil borings in August 2017 to satisfy the minimum number of soil samples for statistical calculation of BTVs as required by NCDEQ in a letter dated April 28, 2017.

Soil background values related to COIs at MSS were calculated using unsaturated background soil data collected from May 2015 to March 2017 and submitted to NCDEQ

in the *Comprehensive Site Assessment Update – Marshall Steam Station*, dated January 31, 2018. NCDEQ DWR provided comments and approval of BTVs in a response letter dated June 15, 2018 (**Appendix A**). BTVs were calculated in accordance with the *Revised Statistical Methods for Developing Reference Background Concentrations for Groundwater and Soil at Coal Ash Facilities* (HDR and SynTerra, 2017).

Soil BTVs were updated in 2019 and are provided, along with the previously approved soil BTVs and North Carolina Piedmont soil background ranges for comparison, in **Table 4-2** (*CAP Content Section 4.B*). The updated 2019 BTVs were calculated using data from approved background unsaturated soil samples collected June 2015 to April 2017, however the 2019 dataset retained extreme outlier concentrations when data validation and geochemical analysis of background groundwater concentrations indicated that those previously identified outlying concentrations did not result from sampling error or laboratory analytical error. The approach used to evaluate whether extreme outlier concentrations should be retained in background soil datasets is presented the technical memorandum prepared by Arcadis titled, "*Background Threshold Value Statistical Outlier Evaluation – Allen, Belews Creek, Cliffside, Marshall, Mayo, and Roxboro Sites,"*, which was provided as an attachment to the *Updated Background Threshold Values for Constituent Concentrations in Groundwater* (SynTerra, 2019e). The updated BTVs were calculated in accordance with the *Revised Statistical Methods for Developing Reference Background Concentrations for Groundwater and Soil at Coal Ash Facilities* (HDR and SynTerra, 2017).

4.2 Background Concentrations for Groundwater

The groundwater system beneath the Site is divided into the following three layers to distinguish the interconnected aquifer system: the shallow flow layer, deep (transition zone) flow layer, and the bedrock flow layer. Background groundwater monitoring wells installed within each flow zone include:

- Shallow flow zone: BG-1S, BG-2S, BG-3S, GWA-4S, GWA-5S, GWA-6S, GWA-8S, GWA-12S, MS-10, MW-4
- Deep flow zone: BG-1D, GWA-4D, GWA-5D
- Bedrock flow zone: BG-1BRA, BG-2BR, BG-3D, BG-3BR, GWA-6D, GWA-8D, GWA-12BR, MW-4D

The locations of the background monitoring wells are shown on **Figure 4-1**. The suitability of each of these locations for background purposes was evaluated in the *Updated Background Threshold Values for Groundwater* technical memorandum (May 26, 2017). Groundwater data appropriate for inclusion in the statistical analysis to determine BTVs was approved by NCDEQ in a response letter dated July 7, 2017.

NCDEQ DWR provided further comments and approval of BTVs in a response letter dated October 11, 2017, provided in **Appendix A**.

Groundwater BTVs in each flow zone at MSS were updated in 2019 and are provided, along with the original groundwater BTVs for comparison, in **Table 4-3**. The updated BTVs were calculated using concentration data from background groundwater samples collected from 2010 (beginning of compliance monitoring) to December 2018 (SynTerra, 2019e). BTVs were calculated in accordance with the *Revised Statistical Methods for Developing Reference Background Concentrations for Groundwater and Soil at Coal Ash Facilities* (HDR and SynTerra, 2017). No additional background groundwater monitoring wells have been added to the monitoring well network. Three wells (BG-3D, GWA-6D, GWA-8D) were historically included in the background dataset for the deep flow layer. However, after a thorough review of monitoring well construction logs, it was determined that these three wells are screened within the bedrock flow zone. Therefore, these wells were included in the bedrock flow zone background dataset. The updated background datasets for each flow zone used to statistically assess naturally occurring concentrations of inorganic constituents in groundwater are presented in the report *Updated Background Threshold Values for Constituent Concentrations in Groundwater* (SynTerra, 2019e) provided to NCDEQ on June 13, 2019. The updated background dataset for each hydrogeologic flow zone consists of an aggregate of total (non-filtered) concentration data pooled across background monitoring wells installed within that flow layer. The background datasets contained more than the required minimum of 10 valid sample data (**Appendix C**, Table 1) (*CAP Content Section 4.C*).

Both sets of BTVs from 2018 and 2019, in addition to ranges of background concentrations collected at similar sites in the Piedmont hydrogeological province, are used for understanding natural background conditions at the Site and are provided for comparative purposes in **Table 4-3** (*CAP Content Section 4.C and 5.A.a.vii*).

4.3 Background Concentrations for Surface Water

The Site is located in the Catawba River watershed along the western shoreline of Lake Norman in Catawba County. The ash basin designated effluent outfall is approximately 100 feet downgradient from the base of the ash basin dam where it discharges to Lake Norman (NPDES Outfall 002).

Background surface water sample locations for MSS are located upstream, or outside potential groundwater impact from the source area to surface water. Surface water background sample locations are outside of future groundwater to surface water migration pathways from the source area as determined by groundwater predictive modeling results.

Background surface water sample locations include two streams upgradient of the ash basin on Duke Energy property, and two locations in Lake Norman east and upstream of MSS. Background surface water sample locations are shown on **Figure 4-1**. Locations are summarized as follows based on surface water body and spatial distribution relative to the source area:

- Lake Norman sample locations upstream of potential groundwater migration to surface water from the ash basin area: SW-105, SW-106
- Minor streams upgradient of the ash basin, northwest of potential groundwater migration to surface water from the ash basin: SW-7, SW-8

Background surface water data are used for general comparative purposes. The analytical results provide a comparative range of naturally occurring constituent concentrations present at background locations. Background data sets from each location include data from five or more samples. Surface water samples from background locations have been collected in accordance with NCDEQ guidance as part of periodic sampling events, which include the comprehensive sampling event in August 2018 used to assess surface water compliance for implementation of corrective action under 15A NCAC 02L .0106 (k) and (l). Analytical results from background surface water sample locations indicate all constituent concentrations are less than 02B standards, with the exception of dissolved oxygen at SW-105 and temperature at SW-106. Background surface water analytical results compared with 02B and USEPA criteria are included in **Table 4-4** (*CAP Content Section 4.D*).

4.4 Background Concentrations for Sediment

All background sediment sample locations are co-located with background surface water sample locations in the minor streams upgradient of the ash basin and Lake Norman. Background sediment sample locations are located upstream, or outside potential groundwater migration from the source areas to sediment. Sediment background sample locations remain outside of future migration areas as determined by groundwater predictive modeling.

Background sediment sample locations are shown on **Figure 4-1** and include:

- Lake Norman: SW-105, SW-106
- Minor streams: SW-7, SW-8

Background sediment data are used for general comparative purposes. The analytical results provide a comparative range of naturally occurring constituent concentrations

present at background locations. Background data sets include one sample collected from each location. Sediment samples were collected concurrently with a background surface water sample. Background sediment analytical results are presented in **Table 4-5** (*CAP Content Section 4.E*). Analytical results for sediment samples are included in **Appendix C**, Table 5 *(CAP Content Section 4.E).*

5.0 CONCEPTUAL SITE MODEL

(CAP Content Section 5)

The Conceptual Site Model (CSM) is a descriptive and illustrative representation of the hydrogeologic conditions and COI interactions specific to the Site. The purpose of the CSM pertaining to the MSS ash basin and adjacent source areas is to provide a current understanding of the distribution of constituents with regard to the Site-specific geology/hydrogeology and geochemical processes that control the transport and potential presence of COIs in various media. This information is also considered with respect to exposure pathways to potential human and ecological receptors.

The CSM presented in this section is based on an U.S. Environmental Protection Agency (USEPA) document titled *Environmental Cleanup Best Management Practices: Effective Use of the Project Life Cycle Conceptual Site Model* (USEPA, 2011). That document describes six CSM stages for an environmental project life cycle and is an iterative tool to assist in the decision-making process for characterization and remediation during the life cycle of a project as new data becomes available. The six CSM stages for an environmental project life cycle are described below:

1. **Preliminary CSM Stage** – Site representation based on existing data; conducted prior to systematic planning efforts.
2. **Baseline CSM Stage** – Site representation used to gain stakeholder consensus or disagreement, identifies data gaps and uncertainties; conducted as part of the systematic planning process.
3. **Characterization CSM Stage** – Continual updating of the CSM as new data or information is received during investigations; supports remedy decision making.
4. **Design CSM Stage** – Targeted updating of the CSM to support remedy design.
5. **Remediation/Mitigation CSM Stage** – Continual updating of the CSM during remedy implementation; and providing the basis for demonstrating the attainment of cleanup objectives.
6. **Post Remedy CSM Stage** – The CSM at this stage is used to support reuse planning and placement of institutional controls if warranted.

The current MSS CSM is consistent with Stage 4, "Design CSM", which allows for iterative improvement of the Site CSM during design of the remedy while supporting development of remedy design basis (USEPA, 2011). A three-dimensional depiction of

the CSM under conditions prior to decanting and basin closure is presented as **Figure 5-1**.

Anticipated changes to Site conditions, such as with decanting and basin closure, have been incorporated into the CSM based on groundwater modeling simulations. Predicted and observed effects will be compared on an ongoing basis to further refine the CSM.

5.1 Site Geologic and Hydrogeologic Setting
(CAP Content Section 5.A.a)

5.1.1 Site Geologic Setting
(CAP Content Section 5.A.a)

The groundwater system at the ash basin and adjacent source areas is divided into the following three layers to distinguish the interconnected groundwater system: the shallow flow zone, deep (transition zone) flow zone, and the bedrock flow zone. The following is a summary of the natural hydrostratigraphic unit assessment observations:

- **Shallow flow zone –** Shallow soil includes fill, regolith, and saprolite. Fill material, used in the construction of the ash basin dam, generally consisted of reworked silts, clays, and sands. The range of fill thickness observed in the ash basin main dam was 18 feet to 65 feet. Regolith or residuum is in-place weathered soil that consists primarily of silt with sand, clayey sand, sandy clay, clay with gravel, and clayey silts. Saprolite is soil developed by in-place weathering of rock that retains remnant bedrock structure (such as a planar fabric associated with relict foliation). Saprolite consists primarily of medium dense to very dense silty sand, sandy silt, sand, sand with gravel, sand with clay, clay with sand, and clay. Sand particle size ranges from fine- to coarse-grained. The thickness of saprolite/weathered rock observed was in the range of less than 10 feet to more than 80 feet. Shallow flow layer wells are typically labeled with an "S" or "DU" designation, although there are some exceptions where "S" wells are screened in ash.
- **Deep flow zone –** The deep flow zone (transition zone) consists of a relatively transmissive zone of significantly weathered, fractured bedrock encountered below the shallow zone. The deep flow layer at the Site is varied in thickness and depth. Observations of core recovered from this zone included rock fragments, unconsolidated material, and highly oxidized bedrock material. Some "D" wells were completed in fractured

bedrock, and were re-classified as bedrock wells for data evaluation, as documented in the *2018 CAMA Annual Interim Monitoring Report* (SynTerra, 2019d). Deep flow layer wells are typically labeled with a "D" designation.

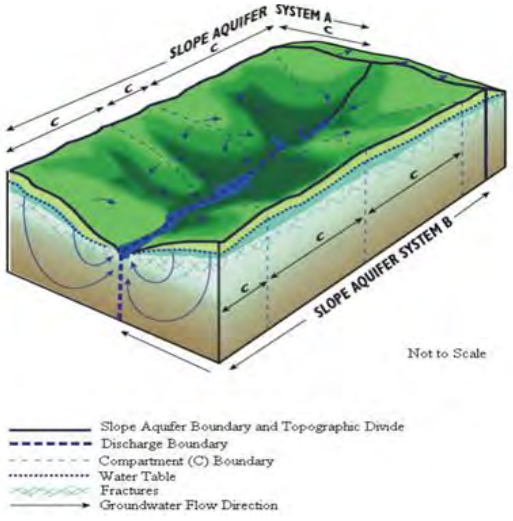
- **Bedrock flow zone –** Based on sample recovery, bedrock is defined as sound rock that is generally slightly weathered to unweathered and fractured to varying degrees. The primary rock types in the immediate vicinity of the ash basin are several varieties of gneiss, granite, and schist. Groundwater movement in the bedrock flow zone occurs in secondary porosity represented by fractures. The majority of water-producing fracture zones are found within the top 50 feet of competent rock. Water-bearing fractures in bedrock are often only mildly productive. The bedrock hydraulic conductivity and overall volumetric rate of groundwater flow at the Site also decreases with increasing depth below the top of rock (**Appendix F**). The observed decline in bedrock hydraulic conductivity and hydraulic aperture with increasing depth is consistent with expectations based on the literature. In areas where a preferential fracture set exists, groundwater flow is anisotropic and occurs preferentially parallel to the predominant strike of bedrock fractures. Bedrock wells are typically labeled with a "BR", "BRL", "BRLL", or "BRLLL" designation. A detailed evaluation of bedrock conditions is presented in **Appendix F** (*CAP Content Section 5.A.a.iv*).

5.1.2 Site Hydrogeologic Setting
(CAP Content Section 5.A.a)

The groundwater system in the natural materials (shallow/deep /bedrock) at MSS is consistent with the regolith-fractured rock system and is characterized as an unconfined, interconnected aquifer system indicative of the Piedmont Physiographic Province.

A conceptual model of groundwater flow in the Piedmont, which is applicable to the MSS Site, was developed by LeGrand (1988, 1989) and Harned and Daniel (1992) (**Figure 5-2**). The model assumes a regolith and

FIGURE 5-2
LEGRAND SLOPE AQUIFER SYSTEM



bedrock drainage basin with a perennial stream. The model describes conditions before ash-basin construction, but the general groundwater flow directions are still relevant under pre-decanting conditions. Groundwater is recharged by rainfall infiltration in the upland areas followed by discharge to the perennial stream. Flow in the regolith follows porous media principals, while flow in bedrock occurs in fractures. Rarely does groundwater move beneath a perennial stream to another more distant stream or across drainage divides (LeGrand, 1989).

Topographic drainage divides approximately coincide with natural groundwater divides within the slope-aquifer system. The areas between the topographic divides are flow compartments that are open-ended down slope. Compartmented groundwater flow, applicable to the ash basin, is described in detail in *A Master Conceptual Model for Hydrogeological Site Characterization in the Piedmont and Mountain Region of North Carolina* (LeGrand, 2004).

5.1.2.1 Groundwater Flow Direction
(CAP Guidance Section 5.A.a.i)

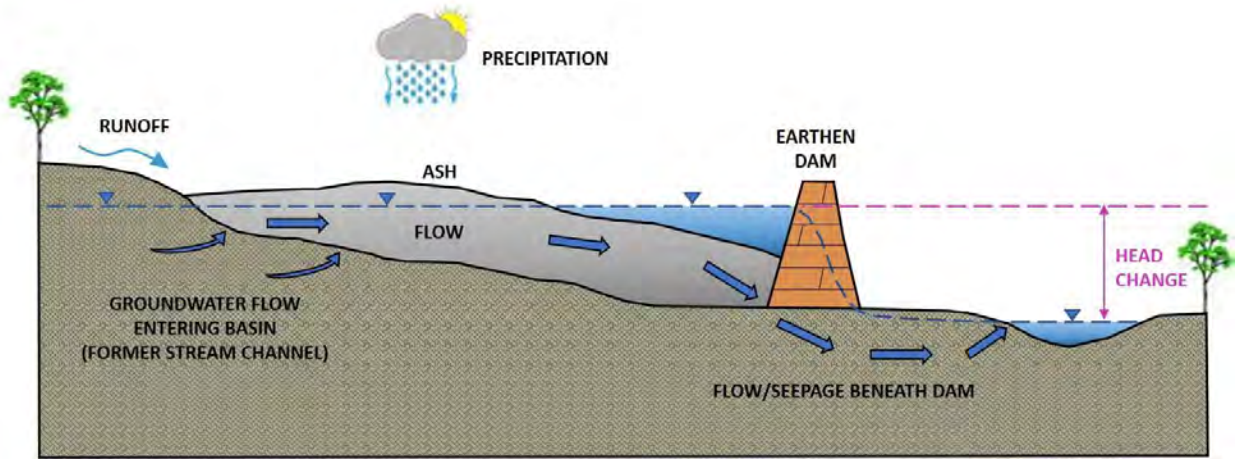
Groundwater divides are located west and north of the Site, concurrent with topographic ridges along Sherrills Ford Road to the west and Island Point Road to the north. Groundwater within this flow compartment flows toward the southeast (Lake Norman). This flow compartment contains the MSS ash basin and the additional adjacent sources. The topographically controlled flow direction provides natural hydraulic control of constituent migration from the ash basin and adjacent sources within the stream valley system, with the predominant direction of groundwater flow being from the northwest to the southeast from the ash basin toward Lake Norman.

The ash basin was constructed within a former perennial stream valley. The ash basin's physical setting is a flow-through system with groundwater movement into the upgradient end, flowing laterally through the middle regions and downward near the dam (**Figure 5-3**). Near the dam, vertical hydraulic gradients, imposed by hydraulic pressure of basin surface water, promote downward vertical gradients into the groundwater system. Beyond the dam, groundwater flows upward. Generally, the physical setting of the ash basin and adjacent sources within a perennial stream valley limits the horizontal and vertical migration of constituents to areas near and directly downgradient of the dam. The primary flow path of the groundwater remains in the stream valley system that encompasses the ash

basin. Therefore, adjacent source areas upgradient and side-gradient of the basin have groundwater divides that limit groundwater flow in these directions. Groundwater in the vicinity of the adjacent source areas beyond the ash basin waste boundary, such as the coal pile and gypsum pad, flows toward the former perennial stream valley that encompasses the ash basin.

Exceptions to the typical groundwater flow pathway occur at MSS in the vicinity of the Phase I Landfill where the hydraulic head of the operational basin induced groundwater flow to the north across a small topographic ridge, toward an unnamed tributary. The reduction of the head in the basin will result in the groundwater flow direction returning to the natural flow direction toward the southeast.

FIGURE 5-3
GENERALIZED PROFILE OF ASH BASIN PRE-DECANTING FLOW CONDITIONS IN THE PIEDMONT



Note: Drawing is not to scale

Water level surface maps for each groundwater flow zone were constructed from pre-decanting groundwater elevations obtained in May 2019 (**Figures 5-4a, 5-4b and 5-4c**). May 2019 water level measurements and elevations are presented in **Table 5-1**. General groundwater flow directions can be determined from the water level contours. Groundwater flow directions developed from water-level elevations measured in the shallow, deep and bedrock wells indicated groundwater flow at the Site is generally from upland areas to the north and west into the ash basin flow compartment and then outward to the east/southeast toward Lake Norman.

Predictive flow and transport model simulations indicate that the cessation of sluicing and subsequent decanting in the ash basin will reduce the potential for COI transport prior to complete closure of the basin. Model simulations predict downward migration of groundwater below the dam east of the ash basin will be limited without the presence of ponded water in the basin.

The following are conclusions pertaining to groundwater flow beneath the Site:

- Horizontal groundwater flow velocities in areas with free ponded water within the ash basin are less than those seen upgradient of the ash basin and below the ash basin dam.
- Downward vertical gradients occur just upstream of the ash basin dam.
- Upward vertical gradients occur beyond or downstream of the dam, which is the main groundwater discharge zone.

Empirical Site data from over 30 monitoring events over multiple seasonal variations and groundwater flow and transport modeling simulations support groundwater flow is away from water supply wells and that there are no groundwater exposure pathways between the source area and the pumping wells used for water supply in the vicinity of the Site. Domestic water supply wells now connected to public water supply or connected to a filtration system are outside, or upgradient of the groundwater flow system containing the ash basin and adjacent source areas. Domestic and public water supply wells are not affected by constituents released from the source area or by the different closure scenarios, according to groundwater flow and transport model simulations.

5.1.2.2 Groundwater Seepage Velocities

(CAP Content Section 5.A.a.i)

Groundwater seepage velocities were calculated for pre-decanting conditions using horizontal hydraulic gradients determined from pre-decanting water level measurements collected in May 2019 (**Table 5-2**). Hydraulic conductivity (K) and effective porosity (n_e) values were taken from the updated flow and transport model (**Appendix G**). Calibrated conductivity and porosity values for each flow zone were used to align velocity calculations with model predictions.

The flow and transport model provided subdivided hydraulic conductivity zones and a calibrated hydraulic conductivity for each flow zone and model flow layer. Simulated hydraulic conductivity values were 1.0 feet per day (ft/day) for the shallow flow zone, 1.5 ft/day for the deep flow zone, and 0.7 ft/day for the bedrock flow zone. Hydraulic conductivity values used in calculating seepage velocity were selected based on area's location within or proximity to subdivided hydraulic conductivity zones by model flow layer. The flow and transport model uses estimated effective porosity values of thirty percent for the shallow and deep flow zone, and one percent for the bedrock flow zone (**Appendix G**).

The horizontal groundwater seepage flow velocity (v_s) can be estimated using a modified form of the Darcy Equation:

$$v_s = \frac{K}{n_e}\left(\frac{dh}{dl}\right)$$

Using the May 2019 groundwater elevation data, the average horizontal groundwater flow velocity in the vicinity of the ash basin is:

- 0.06 ft/day (approximately 21 ft/yr) in the shallow flow zone
- 0.09 ft/day (approximately 34 ft/yr) in the deep flow zone
- 0.86 ft/day (approximately 315 ft/yr) in the bedrock flow zone

The bedrock seepage velocities presented in **Table 5-2** are approximately one order of magnitude greater than the shallow and deep flow zone seepage velocities, because the bedrock effective porosity value derived from the flow and transport model (0.01) is one order of magnitude less than the corresponding value for the shallow and deep flow zones (0.3). More detail on fractured bedrock at MSS is provided in **Appendix F**.

Groundwater modeling predicts groundwater elevation changes associated with closure activities will change localized flow velocities and result in a more pronounced groundwater divide upgradient, north and west of the ash basin. As of December 1, 2019, the elevation of free water in the ash basin has decreased by 7.3 feet in response to gravity and mechanical decanting efforts, indicating significant water level changes in the basin have already occurred.

For visualization, velocity vector maps of groundwater under pre-decanting and future conditions were developed. The pre-decanting conditions map was created from comprehensive Site data incorporated into the calibrated flow and transport model. The future condition maps were created using predicted flow fields for the closure-by-excavation and closure-in-place scenarios. Saturated conditions in the deep zone are relatively constant across the Site; therefore, the deep flow zone was selected for the velocity vector maps.

- Velocity vector map for groundwater in the deep flow zone under pre-decanting conditions - **Figure 5-5a**
- Velocity vector map for groundwater in the deep flow zone under closure-by-excavation scenario - **Figure 5-5b**
- Velocity vector map for groundwater in the deep flow zone under closure-in-place scenario - **Figure 5-5c**

These depictions illustrate potential future changes in groundwater flow compared to pre-decanting groundwater flow throughout the Site. Key conclusions from the predictive model simulation of future ash basin closure conditions include the following:

- North of the ash basin, velocity vectors under pre-decanting conditions (**Figure 5-5a**), closure-by-excavation (**Figure 5-5b**) and closure-in-place conditions (**Figure 5-5c**) indicate groundwater velocity is greatest upgradient (north) of the basin near the ILF (0.2 to 0.5 ft/day) and east of the Dry Ash Landfill Phase I (0.1 to 1.0 ft/day). Groundwater flows predominately southward in the direction of the ash basin.
- Northwest of the basin, the velocity vectors under pre-decanting conditions (**Figure 5-5a**), closure-by-excavation (**Figure 5-5b**) and closure-in-place conditions (**Figure 5-5c**) indicate a groundwater flow direction from PV Structural Fill area toward the ash basin with a flow velocity that generally ranges from 0.01 ft/day to 0.1 ft/day, with smaller areas of increased velocities up to 0.2 ft/day. Groundwater flows east in the general direction of the ash basin.
- East of the basin, downgradient of the ash basin and adjacent sources, model simulations indicate a general decrease in groundwater velocity toward surface water receptors after decanting

compared to pre-decanting conditions. General velocities under pre-decanting conditions east of the basin range from 0.01 ft/day to 1.0 ft/day (**Figure 5-5a**); predicted velocities closure-by-excavation east of the basin generally range from 0.01 ft/day to 0.5 ft/day (**Figure 5-5b**) and closure-in-place east of the basin generally range from 0.001 ft/day to 1.0 ft/day. Groundwater east of the basin flows in the general direction of the unnamed tributary.

- Within the basin, the velocity vectors under pre-decanting conditions (**Figure 5-5a**), closure-by-excavation (**Figure 5-5b**) and closure-in-place conditions (**Figure 5-5c**) indicate that groundwater generally flows southward and southeasterly with a flow velocities generally ranging from 0.001 ft/day to 0.5 ft/day (pre-decanting conditions), from 0 ft/day to 1.0 ft/day (closure-by-excavation), and 0 ft/day to 0.2 ft/day (closure-in-place).
- Velocity vectors depictions for pre-decanting and future post-closure scenarios support that groundwater flow from the ash basin is consistent with historic hydrology of the slope-aquifer system of LeGrand (1988, 1989) and does not, and will not, flow in the direction of residential areas and water supply wells to the west and north.

5.1.2.3 Hydraulic Gradients

(CAP Content Section 5.A.a.i)

Horizontal hydraulic gradients at the Site were calculated from water levels collected from various wells located in the vicinities of the ash basin, PV Structural Fill, and Dry Ash Landfills (Phase I and Phase II), coal pile and gypsum storage pad. The water level elevations collected in May 2019 are summarized in **Table 5-1**. Based on hydraulic gradient calculations using May 2019 groundwater elevation data, the average horizontal hydraulic gradients (measured in feet/foot) for each flow zone is: 0.02 ft/ft (shallow flow zone), 0.02 ft/ft (deep flow zone), and 0.01 ft/ft (bedrock flow zone) (**Table 5-2**). Hydraulic gradients are circum-neutral across large areas of the ash basin due to the influence of standing water.

Vertical hydraulic gradients were calculated at clustered wells from the water level data and the midpoint elevations of the well screens (**Table 5-3**). Within the ash basin, a small upward vertical gradient occurred between the ash pore water and the deep flow zone at well pair AB-12SL/-12D (-0.06 ft/ft). To the southeast, downstream (east) of the ash basin dam, an upward

gradient between the deep and bedrock flow zones was observed at well cluster AB-1D/-1BR (-0.12 ft/ft). This well cluster also indicated a smaller upward gradient between AB-1D and AB-1S (-0.03 ft/ft). Additionally, the lower bedrock wells at this well cluster (AB-1BRL/-1BRLL/-1BRLLL) are free-flowing artesian wells. Artesian conditions, indicating upward hydraulic gradients, were also encountered at AB-2 during the deep bedrock evaluation (see **Appendix F** for more detail). These findings support the conceptual site model, as described above, where there is upward flow immediately downgradient of the ash basin dam. A downward vertical gradient is expected, with support from flow and transport modeling, to be present in the shallow, deep, and bedrock flow zones on the upstream side of the ash basin dam.

The Dry Ash Landfill Phase I is located on a narrow topographic ridge east of the ash basin. Under pre-decanting conditions in May 2019 the vertical gradient in the area was generally downward. A downward vertical gradient of 0.12 ft/ft occurred between the shallow and deep flow zones at well pair AL-1S/-01D. In comparison, the deep and bedrock pairing at this well cluster (AL-1D/-1BR) indicated a small upward gradient of -0.05 ft/ft. Well cluster GWA-11S/-11D/-11BR lies to the southeast of the AL-1 cluster, between the landfill boundary and Lake Norman. The vertical hydraulic gradient between the shallow and deep flow zone (GWA-11S/-11D) was downward (0.03 ft/ft). Additionally, a very slight downward hydraulic gradient (0.01 ft/ft) was observed between the deep and bedrock flow zones (GWA-11D/-11BR). The trends of downward groundwater flow in this area are due to the small topographical ridge that lies between the landfill and Lake Norman.

To the north of the ash basin is the Dry Ash Landfill Phase II. Upward groundwater flow gradients exist at the southern side of the landfill between the shallow and deep flow zones as well as between deep and bedrock flow zones. The well pair AL-2S/-2D indicated a gradient of -0.03 ft/ft between the shallow and deep flow zones. AL-2D/-2BR indicated a downward vertical gradient of -0.03 ft/ft between the deep and bedrock flow zones. The water level elevations from this well cluster also indicated downward groundwater flow in the lower bedrock at this location with the gradient at AL-2BR/-2BRL being 0.07 ft/ft and 0.01 ft/ft at AL-2BRL/-2BRLL.

At the north side of the Dry Ash Landfill Phase II, groundwater flow was almost exclusively downward. At the northeastern corner of the landfill at the well pair AL-3S/-3D, the vertical hydraulic gradient was found to be 0.02 ft/ft between the ash pore water and deep flow zones. Likewise, the gradient between the deep and bedrock flow zones (AL-3D/-3BR) was 0.04 ft/ft. On the northwestern side of the landfill is the well cluster AL-4D/-4BR/-4BRL. The gradient between the deep flow zone and bedrock (AL-4D/-4BR) was 0.03 ft/ft downward, or neutral compared to the upward flow observed in the bedrock between AL-04BR/-04BRL (-0.16 ft/ft). The overwhelmingly downward flow gradient in this portion of the landfill creates the potential for migration of constituents from the landfill into the groundwater system with migration toward the ash basin.

The PV Structural Fill is located to the northwest corner of the MSS Site. The groundwater gradient in this area is downward, as predicted by the CSM due to the majority of the footprint located outside of the former stream valleys encompassed by the ash basin. Four well clusters (PVSF-1 through PVSF-4), installed in 2019 to evaluate this area, indicate neutral to downward hydraulic gradients ranging from 0.00 ft/ft (PVSF-2S/-2D) to 1.19 ft/ft (PVSF-4D/-BR). Slightly upward gradients were observed at PVSF-3 between PVSF-3S/-3D (-0.02 ft/ft) and PVSF-3S/-3BR (-0.01 ft/ft), which may limit COI migration with depth. At the request of NCDEQ, one lower bedrock (greater than 130 feet bgs) well is being installed at the PVSF-2 cluster in December 2019. Additional information on vertical hydraulic gradients in this area will be available at a later date.

Downgradient of the PV Structural Fill, in the vicinity of the structural fill access road, the hydraulic gradient between ash pore water and bedrock (AB-6S/-6D) was 0.03 ft/ft downward; the bedrock hydraulic gradient (AB-6D/-6BRA) was also slightly downward, 0.01 ft/ft. The constituent migration in groundwater from this area is also toward the ash basin flow compartment (*CAP Content Section 5.A.a.iii*).

The coal pile is located south of the ash basin. Similar to other adjacent source areas that lie outside of the ash basin waste boundary, downward hydraulic gradients are predominant. Three well clusters were installed along the perimeter of the coal pile in March 2019. Vertical hydraulic gradients in these wells range from 0.00 ft/ft (CP-2S/-2D) to 0.01 ft/ft (CP-1S/-1D and CP-3S/-3D). At the request of NCDEQ, one bedrock well (CP-

1BR) was installed at the CP-1 cluster on the northeast corner of the coal pile in November 2019. This location lies within the ash basin compliance boundary. Additional results of this evaluation will be available in 2020; however, the corrective actions presented herein account for potential impacts from the coal pile.

The gypsum storage pad lies immediately west of the coal pile, also south of the ash basin. Three well clusters were installed along the perimeter of the gypsum pad in March 2019. Downward vertical hydraulic gradients were calculated north of the gypsum pad (0.01 ft/ft at GP-2S/-2D). Vertical gradients at GP-1S/-1D and GP-3S/-3D, south and southeast of the gypsum pad, are considered neutral.

5.1.2.4 Particle Tracking Results

(CAP Content Section 5.A.a.ii)

Particle tracking is not available for Marshall.

5.1.2.5 Subsurface Heterogeneities

(CAP Content Section 5.A.a.iii)

The nature of groundwater flow across the Site is based on the character and configuration of the ash basin relative to specific Site features such as manmade and natural drainage features, engineered drains, streams, and lakes; hydraulic boundary conditions; and subsurface media properties.

Natural subsurface heterogeneities at the Site are represented by three flow zones that distinguish the interconnected groundwater system: the shallow flow zone, deep flow zone, and the bedrock flow zone. The shallow flow zone is composed of residual soil/saprolite. Typically, the residual soil/saprolite is partially saturated and the water table fluctuates within it. Water movement is generally preferential through the weathered/fractured and fractured bedrock of the transition zone where permeability and seepage velocity is enhanced. Groundwater within the Site area exists under unconfined, or water table, conditions within the saprolite, transition zone and in fractures and joints of the underlying bedrock. The shallow water table and bedrock water-bearing zones are interconnected. The saprolite, where saturated thickness is sufficient, acts as a reservoir for supplying groundwater to the fractures and joints in the bedrock.

Based on the orientations of lineaments and open bedrock fractures at MSS, horizontal groundwater flow within the bedrock should occur

approximately parallel to the hydraulic gradient, with no preferential flow direction (**Appendix F**). Consistent with this interpretation, the current groundwater flow model for MSS does not simulate plan-view anisotropy.

NORR CSA guidance requires a "site map showing location of subsurface structures (*e.g.,* sewers, utility lines, conduits, basements, septic tanks, drain fields, etc.) within a minimum of 1,500 feet of the known extent of contamination" in order to evaluate the potential for preferential pathways. Identification of piping near and around the ash basins was conducted by Stantec in 2014 and 2015, and utilities at the Site were included on a 2015 topographic map by WSP USA, Inc. and presented on Figure 4-1 of the CSA Update (CSA Update, 2018).

Based on groundwater flow direction at MSS, subsurface utilities are not viewed as potential preferential pathways for COI migration, as Lake Norman serves as the lower hydraulic boundary for groundwater flow from ash basin and other potential source areas at the Site.

5.1.2.6 Bedrock Matrix Diffusion and Flow
(CAP Content Section 5.A.a.iv)

Matrix Diffusion Principles
When solute plumes migrate through fractures, a solute concentration gradient occurs between the plume within the fracture versus the initially clean groundwater in the unfractured bedrock matrix next to the fracture. If the matrix has pore spaces connected to the fracture, a portion of the solute mass will move by molecular diffusion from the fracture into the matrix. This mass is therefore removed, at least temporarily, from the flow regime in the open fracture. This effect is known as matrix diffusion (Freeze and Cherry 1979). When the plume concentrations later decline in the fractures (*e.g.,* during plume attenuation and/or remediation), the concentration gradient reverses and solute mass that has diffused into the matrix begins to diffuse back out into the fractures. This effect is sometimes referred to as reverse diffusion.

Matrix diffusion causes the bulk mass of the advancing solute plume in the fracture to advance slower than would occur in the absence of mass transfer into the matrix. This effect retards the advance of any solute, including relatively non-reactive solutes like chloride and boron. The magnitude of plume retardation increases with increasing plume length, because longer

plumes have more contact for diffusion to transfer solute mass from the fracture to the matrix (Lipson et al 2006). The magnitude of plume retardation also increases with increasing matrix porosity.

If the solute sorbs to solids, the retarding effect increases. Sorption of solutes that have diffused into the matrix within the matrix occurs on a much larger surface area than would be the case if the solute mass remained entirely within the fracture. The combined effect of adsorption on the fracture surface and adsorption in the matrix further enhances plume retardation relative to the advance that would occur in the absence of adsorption. If sorption is reversible, when reverse diffusion occurs the sorbed mass can desorb and transfer back into the aqueous phase and diffuse back to the fractures. Solute mass that has been converted into stable mineral species would not undergo desorption.

Site-Specific Data Pertaining to Matrix Diffusion

The bedrock beneath the MSS site is crystalline, and consists of and granite, diorite, gneiss and schist. Solid samples of unfractured metamorphic rock and plutonic igneous rock have low porosities - rarely larger than 2%. In general, crystallite rock porosity is much lower than that of sedimentary rocks. Granite has primary (*i.e.*, matrix) porosity in the range of 0.05 to 1% Freeze and Cherry (1979). Pankow and Cherry (1996) cite a representative granite porosity of 0.6%. Ademeso et al (2012) reported matrix porosity values between 0.03 and 0.16% for a variety of crystalline rocks. Löfgren (2004) measured matrix porosity values between 0.16 and 0.48% for 75 unfractured granite, mafic volcanic, and metamorphosed granite samples. Zhou et al (2008) reported crystalline rock matrix porosity values between 0.3 and 4.1%.

The predominant bedrock fracture set near the ash basin at MSS strikes northeast-southwest, consistent with the results of the lineament evaluation; this fracture set dips to the southeast. The mean strike of open fractures at each location was approximately N37°E. The mean dip angle of open fractures at the logged locations was approximately 30 degrees toward the southeast. The inferred groundwater flow direction from water level elevations measured in wells across the site is consistent with the mean orientations of the fractures. The most abundant secondary fracture set is nearly horizontal. Fewer cross-cutting fractures were also observed, with various orientations. In general, groundwater flow at the Site is interpreted

to be anisotropic in plan view, with higher hydraulic conductivity toward the northeast-southwest (parallel to the Lake Norman shoreline), and lower hydraulic conductivity toward the northwest-southeast (perpendicular to the Lake Norman shoreline) (**Appendix F**).

Overall, the bedrock hydraulic conductivity at the Site and calculated fracture apertures decrease with increasing depth below the top of rock (**Appendix F**). The observed decline in bedrock hydraulic conductivity and hydraulic aperture with increasing depth is consistent with expectations based on the literature (Gale, 1982 and Neretnieks, 1985), and indicates that the overall volumetric rate of groundwater flow in the bedrock decreases with depth (**Appendix F**).

Rock core samples from bedrock locations which represent areas of affected groundwater migration, south and southeast of the ash basin and are interpreted to coincide with zones of preferential groundwater flow were analyzed for porosity, bulk density and thin section petrography.

The reported matrix porosity values ranged from 0.83 percent to 5.82 percent with an average of 2.66 percent. Bulk density ranged from 2.607 grams per cubic centimeter (g/cm^3) to 2.752 g/cm^3 with an average of 2.696 g/cm^3 (**Appendix F**). Petrographic evaluation classified all samples as igneous rocks. Based on the relative abundances of minerals (quartz, alkali feldspar, and plagioclase), the igneous rocks were classified as granodiorite, tonalite, monzonite, and quartz monzonite. Plagioclase crystals are extensively or locally altered into sericite/illitic clays in all of the thin section samples. The illitic clays are present in some moldic pores and fractures (**Appendix F**).

The reported matrix porosity values are within the range of those reported for crystalline rocks in the literature (Freeze and Cherry, 1979; Löfgren, 2004; Zhou and others, 2008; Ademeso and others, 2012). The presence of measurable matrix porosity suggests that matrix diffusion contributes to plume retardation at the site (Lipson and others, 2005). The influences of matrix diffusion and sorption are implicitly included in the groundwater fate and transport model as a component of the constituent partition coefficient (K_d) term used for the bedrock layers model.

5.1.2.7 Onsite and Offsite Pumping Influences
(CAP Content Section 5.A.a.v)

Current onsite pumping within the groundwater flow system containing the ash basin is ongoing with ash basin decanting. Mechanical decanting (pumping) was initiated on September 13, 2019. As of December 1, 2019, 128,400,000 gallons of water have been removed from the ash basin and the water elevation of free water within the basin has decreased by 7.3 feet. Effects of interim actions on the groundwater system are discussed more in **Section 6.1.1.8**.

Because much of the area surrounding the ash basin is comprised of residential properties, farm land, or undeveloped land, potential offsite pumping influences would be limited to domestic and public water supply wells. These water supply wells are outside, or upgradient of the groundwater flow system containing the ash basin. Flow and transport modeling indicated private water wells within the model area remove only a small amount of water from the overall hydrologic system (**Appendix G**).

5.1.2.8 Ash Basin Water Balance
(CAP Content Section 5.A.a.vi)

The ash basin and adjacent source areas are located within a single watershed and groundwater flow system. The location of the groundwater divides defining the edge of the watershed change due to decanting and closure activities because of changing hydraulic conditions. The flow and transport model was used to evaluate the ash basin hydraulic conditions prior to decanting, post-decanting and post-closure (both closure-in-place and closure-by-excavation). The estimated approximate groundwater flow budget in the ash basin watershed under each scenario is summarized in **Table 5-4**. Each scenario water balance was developed for using the results from flow and transport model current and predicted groundwater simulations (**Appendix G**). Under each simulation, an estimated 2 gpm of recharge was attributed to domestic septic return, and 2 gpm of discharge was attributed to domestic water usage (pumping).

Groundwater flow and transport modeling simulations indicate groundwater velocities in the vicinity of the ash basin will decline as the basin is decanted and closed. The model estimates discharge to Lake Norman downgradient of the ash basin footprint is reduced from approximately 217 gpm during pre-decanting conditions to approximately

117 gpm after closure. Discussion of the water balance to support these estimates is provided below.

Pre-Decanting Conditions Water Balance

(CAP Content Section 5.A.a.vi)

Under pre-decanting conditions, the watershed area that contributes groundwater flow toward the basin is estimated to be approximately 1,327 acres. Removing the areas that do not contribute recharge to the groundwater system (capped or lined) and the free water surface of the ash basin pond, the remaining area is approximately 1,161 acres.

- Groundwater recharge from the watershed area of 1,161 acres is estimated to be 482 gallons per minute (gpm). This includes 346 gpm of direct recharge to the watershed and 136 gpm of direct recharge to the basin. The ash basin pond accounts for 80 gpm of recharge.
- Approximately 270 gpm are removed by the modeled drains within the ash basin (*e.g.,* finger lakes and canals) and 75 gpm are removed by modeled drains outside of the ash basin (*e.g.,* streams and ditches).
- Groundwater that flows through and immediately under the dam, and then discharges to surface water downstream of the dam, is estimated to be 217 gpm.

Post-Decanting Conditions Water Balance

(CAP Content Section 5.A.a.vi)

A water balance was developed for the simulated groundwater system under post-decanting conditions (**Table 5-4**). Groundwater recharge to the watershed totals approximately 518 gpm. Approximately 346 gpm of recharge occurs to the watershed outside of the ash basin and 170 gpm of recharge occurs directly to the basin. Discharge from the watershed can be categorized as follows: ash basin water (16 gpm); drainage inside the ash basin (284 pgm); drainage outside the ash basin (66 gpm); flow through and under the dam (150 gpm). The estimated groundwater discharge flow rate to Lake Norman is reduced by 67 gpm from the pre-decanting simulations.

Post-Closure Conditions Water Balances

(CAP Content Section 5.A.a.vi)

Changes to hydraulic conditions at the Site are predicted due to decanting and closure activities. The flow and transport model was used to evaluate

the ash basin hydraulic conditions that would occur after decanting and closure of the ash basin under both closure-in-place and closure-by-excavation scenarios (**Table 5-4**). The estimates presented below are subject to uncertainty related to the subsurface hydraulic conductivity distribution, but are useful in understanding potential general hydrogeological conditions at the Site.

Under a closure-in-place scenario, capping of the ash would prevent direct recharge to the ash basin. Recharge would occur only to the watershed outside of the ash basin (336 gpm).

- Capping of the basin would also preclude flow removed from the ash basin pond.
- Ditches and streams that form within the ash basin footprint are simulated as drains. Drains also include flow removed within the footprint of the former ponded water (pore water) behind the dam. These features discharge a combined 158 gpm to the natural surface water drainage network within the ash basin flow-through system.
- Drainage outside the basin accounts for 43 gpm.
- Groundwater that flows through and immediately under the dam, and then discharges to the surface water downstream of the dam, is estimated to be 135 gpm.

Under a closure-by-excavation scenario, ash is removed and portions of the basin would revert to an open water pond. Recharge would occur by direct recharge to the basin (112 gpm) and direct recharge to the watershed outside of the ash basin (308 gpm).

- Ditches and streams that form within the former ash basin footprint are simulated as drains. Drains also include flow removed within the footprint of the former ponded water (pore water) behind the dam. These features discharge a combined 127 gpm to the natural surface water drainage network within the ash basin flow-through system.
- Drainage outside the basin accounts for 20 gpm.
- The open water pond would drain approximately 157 gpm.

- Groundwater that flows through and immediately under the dam, and then discharges to the surface water downstream of the dam, is estimated to be 117 gpm.

5.1.2.9 Effects of Naturally Occurring Constituents
(CAP Content Section 5.A.a.vii)

Metals and inorganic constituents, typically associated with CCR material, are naturally occurring and present in the Piedmont physiographic province of north-central North Carolina. The metals and inorganic constituents occur in soil, bedrock, groundwater, surface water, and sediment. During the CSA assessment, samples of soil and rock were collected during drilling activities and analyzed for metals and inorganic constituents. Results indicate that soil and rock at the MSS contain naturally occurring constituents that are also typically related to CCR material and likely affect the chemistry of groundwater at the Site.

Samples of background soil indicate that naturally occurring constituents, which are also typically related to CCR material, likely affect the chemistry of groundwater at the Site and are present at concentrations greater than the PSRGs POG values. Constituents with background values greater than PSRGs POG values include arsenic, barium, chromium (total), cobalt, iron, manganese, nickel, selenium and thallium (**Table 4-2**).

Samples of background groundwater indicate that naturally occurring constituents, which are also typically related to CCR material, are naturally present at concentrations greater than 02L standard or IMAC values. Constituents with background values greater than regulatory criteria include barium, chromium (total), cobalt, iron, manganese, radium (total), and vanadium (**Table 4-3**). Therefore, the downgradient concentrations of these constituents in groundwater are compared to background.

5.2 Source Area Location
(CAP Content Section 5.A.b)

The ash basin, located east of Sherrills Ford Road and to the north of the MSS, is generally bounded by an earthen dam and a natural ridge to the northeast, Island Point Road to the north and Highway 150 to the south, beyond the supporting station infrastructure (**Figure 1-2**). Sherrills Ford Road and Island Point Road, located along topographic ridges, represent hydrologic divides that affect groundwater flow within an area approximately one mile west, north and northeast of the ash basin. Topography to the east of Sherrills Ford Road generally slopes downward, across the area of the ash

basin and adjacent source areas, towards Lake Norman to the southeast. Topography along Island Point Road to the north and northeast of the ash basin of generally slopes downward toward Lake Norman to the southeast.

5.3 Summary of Potential Receptors

(CAP Content Section 5.A.c)

G.S. Section 130A-309.201(13) defines receptor as *"any human, plant, animal, or structure which is, or has the potential to be, affected by the release or migration of contaminants. Any well constructed for the purpose of monitoring groundwater and contaminant concentrations shall not be considered a receptor."* In accordance with the Notice of Regulatory Requirements (NORR) CSA guidance (**Appendix A**), receptors cited in this section refer to public and private water supply wells and surface water features.

The site-specific risk assessment conducted for the ash basin and adjacent source areas indicates no measurable difference between evaluated Site-related risks and risks imposed by background concentrations. It is determined that there is no identified material increases in risks to human health related to the ash basin and adjacent source areas. Additionally, multiple lines of evidence support that groundwater from the ash basin area has not and does not flow towards any water supply wells based on groundwater flow patterns and the location of water supply wells in the area. However, Duke Energy has implemented a permanent water solution that provides qualifying owners of surrounding properties with water supply wells within a 0.5-mile radius of the ash compliance boundary with a permanent water solution (either water filtration systems or connection to the municipal supply).

The site-specific risk assessment conducted for the ash basin also indicates that there is no increase in risks to ecological receptors. The Lake Norman aquatic systems surrounding the MSS are healthy based on multiple lines of evidence including robust fish populations, species variety and other indicators based on years of sampling data.

5.3.1 Surface Water

The Site is located in the Catawba River watershed. The ash basin is located along the west bank of Lake Norman (former Catawba River). North Carolina surface water classifications for Lake Norman are summarized on **Table 5-6**. The surface water intake for MSS plant use is located in Lake Norman at the southern end of the intake canal (**Figure 5-6**).

A depiction of surface water features – including wetlands, ponds, unnamed tributaries, seeps, streams, lakes, and rivers – within a 0.5-mile radius of the ash basin compliance boundary is provided in **Figure 5-6**. Surface water information

is provided from the Natural Resources Technical Report (NRTR) (AMEC, 2015). In addition, NPDES-permitted outfalls and locations covered by the SOC are shown on **Figure 5-6**. Non-constructed and dispositioned seep sample locations between the ash basin and Lake Norman are managed by the SOC and are subject to the monitoring and evaluation requirements contained in the SOC.

5.3.1.1 Environmental Assessment of Lake Norman

The National Pollutant Discharge Elimination System (NPDES) permit for the Marshall Steam Station (NPDES No. NC0004987) requires Duke Energy to conduct weekly to quarterly outfall and instream water quality monitoring at 13 locations, including two locations within Lake Norman. Trace elements (arsenic, selenium) monitoring in fish muscle tissue is also conducted annually in accordance with a study plan approved by the NCDEQ.

Lake Norman has been monitored by Duke Energy since 1959. Over the years, specific assessments have been conducted for water quality and chemistry as well as abundance and species composition of phytoplankton, zooplankton, macroinvertebrates, aquatic macrophytes, fish, and aquatic wildlife. These assessments have all demonstrated that Lake Norman has been an environmentally healthy and functioning ecosystem, and ongoing sampling programs have been established to ensure the health of the system will continue. Furthermore, these data indicate that there have been no significant effects to the local aquatic systems related to coal ash constituents over the last 60 years. More information related to environmental health assessments conducted for Lake Norman, including sampling programs, water quality and fish community assessments, and fish tissue analysis, can be found in **Appendix E**.

5.3.2 Availability of Public Water Supply

Catawba County owns the public water system serving the area around MSS but does not operate it. The City of Hickory, through contract with Catawba County, provides operations, maintenance, and management of the municipal water system, and anyone connected to the system becomes a customer of the City of Hickory. **Section 6.2.2** presents a more detailed discussion regarding water supply within a 0.5-mile radius of the ash basin compliance boundary.

5.3.3 Water Supply Wells

No public or private drinking water wells or wellhead protection areas were found to be located downgradient of the ash basin. This finding has been

supported by field observations, a review of public records, an evaluation of historical groundwater flow direction data and results of groundwater flow and transport modeling (**Appendix G**). A total of 127 private water supply wells and one public supply well were initially identified within the 0.5-mile radius of the ash basin compliance boundary (**Figure 5-7**). Most of these water supply wells are located north and west of the ash basin, along Sherrills Ford Road and Island Point Road. Additional discussion, with supporting material and data, of alternative water supply provisions (public supply or water filtration systems) provided by Duke Energy for surrounding occupied residences and findings of the drinking water supply well survey are included in **Section 6.2.2**. **Figure 5-8** illustrates properties within the 0.5 mile radius of the ash basin compliance boundary with reference to water treatment systems installed, along with vacant parcels and residential properties whose owners have decided to either opt out of the water treatment system program or did not respond to the offer.

5.3.4 Future Groundwater Use Area

Duke Energy owns the land and controls the use of groundwater on the land downgradient of the ash basin area within and beyond the predicted area of potential groundwater COI influence. Therefore, no future groundwater use areas are anticipated downgradient of the ash basin and adjacent source areas.

Under G.S. Section 130A-309.211(c1), Duke Energy provided permanent water solutions to all eligible households within a 0.5-mile radius of the ash basin compliance boundary. It is anticipated that these residences will continue to rely on municipal water or groundwater resources for water supply for the foreseeable future. Duke Energy has a performance monitoring plan in place, with details of the plan outlined in the *Permanent Water Supply – Water Treatment Systems, Performance Monitoring Plan* (Duke Energy, 2017). Duke Energy will provide quarterly maintenance of the water treatment systems to include replenishing expendables (salt for brine tank and neutralizer media) and providing system checks and needed adjustments. Laboratory samples of pre-treated and treated water will be collected annually to coincide with system installation, unless there is evidence the system is not performing properly, in which case samples will be collected more frequently.

5.4 Human Health and Ecological Risk Assessment Results

(CAP Content Section 5.A.d)

A human health and ecological risk assessment pertaining to MSS was prepared and is included in **Appendix E**. The risk assessment focuses on the potential impacts of CCR

constituents from the MSS ash basin and adjacent source areas on groundwater, surface water, and sediment. Groundwater flow information was used to focus the risk assessment on areas where exposure of humans and wildlife to CCR constituents could occur. Primary conclusions of the risk assessment include: 1) there is no evidence of risks to on-Site or off-Site human receptors potentially exposed to CCR constituents that may have migrated from the source area; and 2) there is no evidence of risks to ecological receptors potentially exposed to CCR constituents that may have migrated from the source area. This risk assessment uses analytical results from groundwater, surface water, and sediment samples collected March 2015 through June 2019.

Evaluation of risks associated with AOW locations and soil beneath the ash basin are not subject to this assessment and will be evaluated independent from the CAP. Consistent with the iterative risk assessment process and guidance, updates to the risk assessment have been made to the original 2016 risk assessment (HDR, 2016c) in order to incorporate new site data and refine conceptual site models. The original risk assessment was prepared in accordance with a work plan for risk assessment of CCR-affected media at Duke Energy sites (Haley & Aldrich, 2015).

The following risk assessment reports have been prepared:

1. *Baseline Human Health and Ecological Risk Assessment*, Appendix F of the *CAP Part 2* (HDR, 2016c)
2. *Comprehensive Site Assessment (CSA) Update* (SynTerra, 2018a)
3. *Human Health and Ecological Risk Assessment Summary Update for Marshall Steam Station*, Appendix B of *Community Impact Analysis of Ash Basin Closure Options at the Marshall Steam Station* (Exponent, 2018)

To help evaluate options for groundwater corrective action, this risk assessment characterized potential effects on human health and the environment related to naturally occurring elements, associated with coal ash, present in environmental media. This risk assessment follows the methods of the 2016 risk assessment (HDR, 2016c) and is based on NCDENR, 2003; NCDEQ, 2017; and USEPA risk assessment guidance (USEPA, 1989; 1991a; 1998).

Human health and ecological CSMs were developed and further refined to guide identification of exposure pathways, exposure routes, and potential receptors for evaluation. Additional information regarding groundwater flow and the treatment of source areas other than the ash basin was incorporated into the refinement of CSMs presented in **Appendix E**.

Environmental data evaluated in the risk assessment were compared to human health and ecological screening values. Risk assessment constituents of potential concern (COPCs) are different than COIs in that COPC are those elements in which the maximum detected concentration exceeded human health or ecological screening values. COPCs are carried forward for further evaluation in the deterministic risk assessment. Constituents remaining as a result of the screening were carried forward in the baseline assessment. **Appendix E** contains the results of the screening assessment. No unacceptable risks from exposure to environmental media were identified. Results of the human health risk assessment indicate the following:

- On-site groundwater poses no unacceptable risk for the construction worker under these exposure scenarios.
- Exposure to CCR constituents by current and future commercial/industrial worker, trespasser, and residences is incomplete.
- No evidence of carcinogenic or non-carcinogenic risks was identified in relation to the recreational swimmer, wader or boater exposure scenarios associated with Lake Norman.
- No evidence of carcinogenic or non-carcinogenic risks was identified in relation to the recreational fisher exposure scenario associated with Lake Norman.
- No evidence of material increase in carcinogenic risks related to the subsistence fisher exposure scenario is attributable to the ash basin. Hexavalent chromium concentrations in upstream surface water samples also resulted in modeled excess lifetime cancer risk (ELCR) within USEPA's target risk range. Modeled concentration of hexavalent chromium in fish tissue is likely overestimated.
- Potential non-carcinogenic risks from consumption of fish containing cobalt for the subsistence fisher were identified. Cobalt concentrations in upstream surface water samples resulted in similar modeled results. The subsistence fisher exposure scenarios overestimate risks based on exposure model assumptions.

Findings of the baseline ecological risk assessment include the following:

- No hazard quotients (HQs) based on no observed adverse effects levels (NOAELs) or least observed adverse effects levels (LOAELs) were greater than unity (1) for the aquatic wildlife receptors (mallard duck, great blue heron, bald eagle, and river otter) exposed to surface water or sediments from the Lake Norman area.

- Two endpoints, muskrat and killdeer had limited modeled risk results greater than unity for aluminum. The killdeer had limited NOAEL based modeled risk results greater than unity for barium, total chromium, copper, and selenium.
- The modeled risks are considered negligible based on natural and background conditions. The exposure models likely overstate risks to aluminum, barium, total chromium, copper, and selenium.

In summary, there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS. This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

5.5 CSM Summary

The MSS CSM presented herein describes and illustrates hydrogeologic conditions and constituent interactions specific to the Site. The CSM presents an understanding of the distribution of constituents with regard to the Site-specific geological/hydrogeological and geochemical processes that control the transport and potential impacts of constituents in various media and potential exposure pathways to human and ecological receptors.

In summary, the ash basin and adjacent source areas were constructed within a former perennial stream valley in the Piedmont of North Carolina, and exhibit limited horizontal and vertical constituent migration, with the predominant area of migration occurring near and downgradient of the ash basin dam. The upward flow of water into the basin minimizes downward vertical constituent migration to groundwater immediately underlying saturated ash in the upgradient ends of the basin. Due to the prevailing horizontal flow within the ash basin, there is limited vertical flow of ash basin pore water into the underlying groundwater. The elevated constituent concentrations found in groundwater near the dam are due to the operating hydraulic head in the basin. The ponded water in the basin is the most important factor contributing to constituent migration in groundwater.

Groundwater flow is away from water supply wells and there are no exposure pathways between the ash basin and the pumping wells used for water supply in the vicinity of the MSS Site based on empirical Site data from over 30 monitoring events over multiple seasonal variations and groundwater flow and transport modeling simulations. Risk assessment results conclude that there is no identified material increases in risks to human health related to the ash basin and adjacent source areas.

Through ash basin decanting and closure, the hydraulic head and the rate of constituent migration from the ash basin to the groundwater system will be reduced based on basin hydrogeology described above. Either closure scenario considered by Duke Energy will significantly reduce infiltration to the remaining ash, reducing the rate of constituent migration. Based on future predicted groundwater flow patterns, under post ash basin closure conditions, and the location of water supply wells in the area, groundwater flow direction from the ash basin is expected to be further contained within the stream valley and continue flowing south and southeast of the ash basin footprint, and therefore will not flow towards any water supply wells.

Multiple lines of evidence have been used to develop the CSM based on the large data set generated for MSS. The CSM provides the basis for this CAP Update developed for the MSS ash basin and adjacent source areas to comply with G.S. Section 130A-309.211, amended by CAMA.

6.0 CORRECTIVE ACTION APPROACH FOR SOURCE AREA 1 (ASH BASIN AND ADJACENT SOURCE AREAS)

(CAP Content Section 6)

Groundwater contains varying concentrations of naturally occurring inorganic constituents. Constituents in groundwater with sporadic and low concentrations greater than the corresponding standard (02L/IMAC/background value, as applicable) do not necessarily demonstrate horizontal or vertical distribution of COI-affected groundwater migration from the source area (ash basin and adjacent sources). Constituents with concentrations above corresponding standards were evaluated to determine if the level of concentration is present due to the source area. Constituents of interest (COI) are those constituents identified from the constituent management process described below. This evaluation assisted in identifying if a unit is subject to corrective action under G.S. Section 130A-309.211 and 15A NCAC 02L .0106.

A COI management process was developed by Duke Energy at the request of NCDEQ to gain understanding of the COI behavior and distribution in groundwater distribution and to select the appropriate remedial approach. Details of the COI management approach are provided in **Appendix H**. In general, the COI management process consists of three steps:

1. A detailed review of the applicable regulatory requirements under NCAC, Title 15A, Subchapter 02L and identification of areas where constituent concentrations were greater than the applicable criteria
2. An evaluation of the potential mobility of ash basin-related constituents in groundwater based on Site hydrogeology and geochemical conditions using results from the geochemical model (**Appendix H**)
3. An analysis of constituent distribution downgradient of the ash basin under pre-decanting and predicted future conditions

This COI management process is supported by multiple lines of evidence including empirical data collected at the Site, geochemical modeling, and groundwater flow and transport modeling. This approach has been used to understand and predict COI behavior in the subsurface related to the ash basin and adjacent source areas or COIs that are naturally occurring. COIs that have migrated beyond the compliance boundary at concentrations greater than 02L, IMAC and background that are related to an ash basin would be subject to corrective action. COIs that are naturally occurring at concentrations greater than 02L, IMAC and background do not require corrective

action. A detailed description of the COI management process and results are presented in **Section 6.1.3**.

6.1 Extent of Constituent Distribution

This section provides an in-depth review of constituent characteristics associated with source area 1 and the mobility, distribution and extent of constituent migration within, at, and beyond the point of compliance. As identified in **Section 3**, source area 1 includes the MSS ash basin and additional primary sources located within or adjacent to the ash basin, including:

- Closed Dry Ash Landfills (Phase I and Phase II)
- PV Structural Fill
- Structural fill beneath Industrial Landfill No. 1
- Access road structural fill
- Coal pile
- Gypsum pad

Due to the site hydrogeology as described in the CSM (**Section 5**), potential effects from the above listed units to groundwater would be addressed by the groundwater remedies proposed herein.

Results of the assessment conducted at the gypsum storage pad indicate no impacts to underlying soil or groundwater as a result of gypsum storage and operation (**Appendix C,** Table 1 and Table 4). Therefore, the gypsum storage pad is not being carried forward for corrective action in this CAP Update.

6.1.1 Source Material Within the Waste Boundary

(CAP Content Section 6.A.a)

An overview of the material within the MSS ash basin and adjacent source areas is presented in the following subsections. Waste boundaries are shown on **Figure 1-2**. Although there is no waste boundary associated with the coal pile, a description of material within the coal pile, along with other adjacent source areas, are included in **Section 6.1.1.7**.

6.1.1.1 Description of Waste Material and History of Placement

(CAP Content Section 6.A.a.i)

The MSS ash basin, approximately 394 acres in size, is located north of the station. The ash basin consists of a single cell impounded by the main

earthen dam located on the south end of the ash basin (**Figure 1-2**). The ash basin dam is an earthen embankment armored with rip rap on both the upstream and downstream faces of the dam. The perimeter of the basin is mostly unaltered and well-vegetated with the exception of the dam and a small shoreline section on the east (emergency spillway) that are armored with rip rap. The crest of the dam, which contains an access road, is raised about 10 feet higher than the ash basin water level. A 500-foot compliance boundary encircles the ash basin and is generally co-located with the property boundary on the western edge of the Site and Lake Norman shoreline on the east.

CCR materials, composed primarily of fly ash and bottom ash, were initially deposited in the unlined ash basin via sluice lines beginning in 1965. Fly ash precipitated from flue gas and bottom ash collected in the bottom of the boilers was sluiced to the ash basin using conveyance water drawn from Lake Norman. In 1984, MSS converted from a wet fly ash handling system to a dry fly ash handing system. Since 1984, fly ash has been disposed in the on-Site landfills. Bottom ash continued to be sluiced to the ash basin until early 2019 when the facility converted to a dry bottom ash collection system. All CCR material is currently handled dry.

6.1.1.2 Specific Waste Characteristics of Source Material
(CAP Content Section 6.A.a.ii)

Source characterization was performed through the completion of soil borings, installation of monitoring wells, and collection and analysis of associated solid matrix and aqueous samples. Source characterization was performed to identify the physical and chemical properties of the ash in the source areas. The source characterization involved determining physical properties of ash, identifying the constituents present in ash, measuring concentrations of constituents in the ash pore water, and performing laboratory analyses to estimate constituent concentrations from leaching of ash.

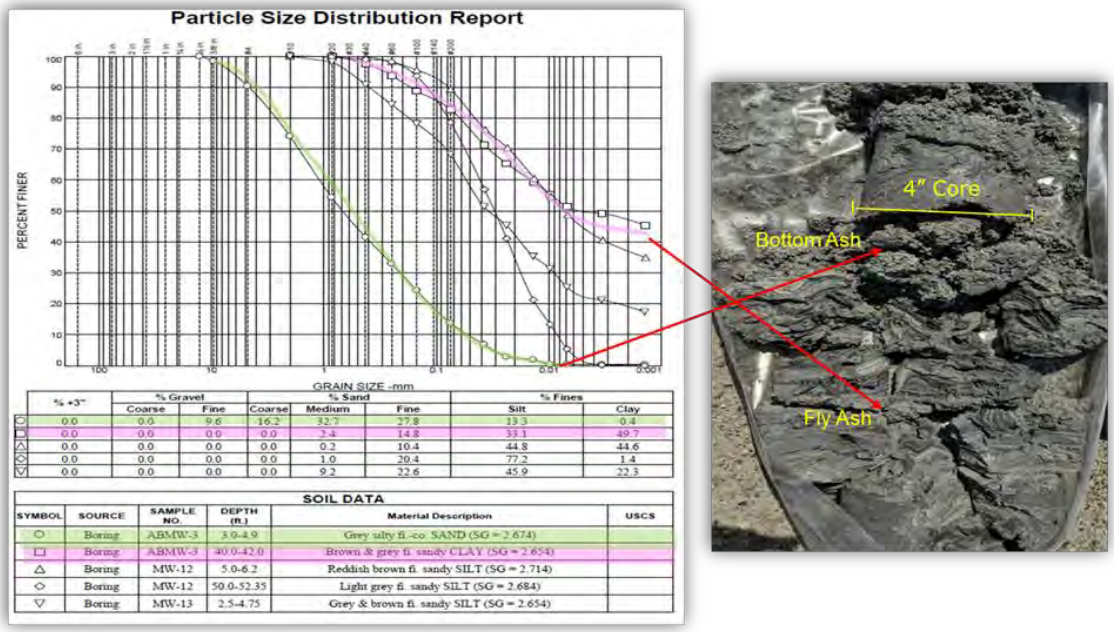
The physical and chemical properties of coal ash are determined by reactions that occur during the combustion of the coal and subsequent cooling of the flue gas. The hydraulically sluiced deposits of coal ash within the basin consist of interbedded fine- to coarse-grained fly ash and bottom ash materials. Fly ash is generally characterized as a moderately dense silty fine-grained sand or silt. Bottom ash is generally characterized as a loose,

poorly graded (fine- to course-grained) sand. Ash was generally described in field observations as gray to dark gray, non-plastic, loose to medium density, dry to wet, fine- to coarse-grained sandy silt texture.

Physical properties analyses (grain size, specific gravity, and moisture content) were performed on ten ash samples from the ash basin using ASTM International methods. Compared with soil, ash exhibits a lower specific gravity with a reported value of 2.164 (AB-7D). Moisture content of the ash samples ranges from 19.8 percent to 86.7 percent.

Within an ash basin, ash typically contains interbedded layers of fly ash and bottom ash as a result of the varying rates and pathways of bottom ash and fly ash settlement. **Figure 6-1** provides a depiction of the typical interbedded nature of fly ash and bottom ash within an ash basin, as seen from an ash boring photograph. Layers of bottom ash are typically more permeable than layers of fly ash due to the coarser grain size of bottom ash.

FIGURE 6-1
FLY ASH AND BOTTOM ASH INTERBEDDED DEPICTION



6.1.1.3 Volume and Physical Horizontal and Vertical Extent of Source Material
(CAP Content Section 6.A.a.iii)

Based on topographic and bathymetric surveys, the ash basin is estimated to contain approximately 14,033,000 cy of CCR (AECOM, 2019). Horizontal extent of CCR is represented by the ash basin waste boundary, landfill and structural fill waste boundaries as shown on **Figure 1-2**. Based on boring logs located within the ash basin, the maximum depth of CCR within the ash basin is estimated to be approximately 85 feet. The volume and physical horizontal and vertical extent of ash material within the basin under pre-decanting conditions are illustrated on a cross-section transect A-A' (**Figure 6-2**) along the centerline of the basin, from northwest to southeast. Volume and physical vertical and horizontal extent of ash material in the southern portion of the basin, and across the basin (west to east), are presented in **Figure 6-3** (B-B'), **Figure 6-4** (C-C') and **Figure 6-5** (D-D'). Additional details on waste materials contained within source areas adjacent to the ash basin are presented in **Section 6.1.1.7**.

6.1.1.4 Volume and Physical Horizontal and Vertical Extent of Anticipated Saturated Source Material
(CAP Content Section 6.A.a.iv)

Volume and physical horizontal and vertical extent of material under pre-decanting and post-closure (closure-in-place) conditions, within the basin is presented on **Figure 6-6**.

Closure-in-place simulated potential saturated ash thickness is based on closure model results with an underdrain system installed (**Appendix G**). Under ash basin closure by closure-in-place, the range of potential saturated ash thickness is between a few feet to 50 feet with greatest volume of saturated ash remaining in the south central portion of the ash basin near the dam (**Figure 6-6**). The horizontal extent of potential saturated ash under post-closure conditions generally mimics, to a lesser extent, pre-decanting conditions. The majority of potential saturated ash would remain along the former stream channels contained within the ash basin (**Figure 6-6**). However, the vertical extent of potential saturated ash would be significantly reduced from pre-decanting conditions under a closure-in-place scenario. Across the basin, saturated ash thicknesses would be reduced by approximately 10 to 20 feet (**Figure 6-6**). Under the closure-by-

excavation scenario, all of the ash in the ash basin would be excavated, and therefore, no saturated ash would remain in the ash basin footprint.

6.1.1.5 Saturated Ash and Groundwater
(CAP Content Section 6.A.a.v)

Based on the trend analysis results, the thickness of saturated ash remaining in place following closure (under a closure-in-place scenario) will have limited to no adverse effect on future groundwater quality. Layered ash within the basin has resulted in relatively low vertical hydraulic conductivity, further reducing the potential for downward flow of pore water into underlying residual material. The CSM indicates that the horizontal flow-through ash basin system results in low to non-detectable COI concentrations in groundwater underlying saturated ash within the basin except in the vicinity of the dam where downward vertical hydraulic gradients are observed. Boron is the CCR constituent most indicative of COI transport in groundwater from the source area as it has a minimal K_d value and has a discernable plume pattern. Using boron data to indicate COI distribution potentially related to the ash basin, the generalized horizontal flow-through system is consistent with Site-specific data as summarized in **Table 6-1**.

In summary, 24 of 27 monitoring wells screened beneath the ash basin demonstrate low (< 700 µg/L) to non-detectable boron concentrations consistent with the flow-through system, which suggests there is no correlation between the thickness of saturated ash and the underlying groundwater quality (**Table 6-1**).

A technical memorandum, titled *Saturated Ash Thickness and Underlying Groundwater Boron Concentrations – Allen, Belews Creek, Cliffside, Marshall, Mayo, and Roxboro Sites* (Arcadis, 2019), used two statistical methods (Mann-Kendall and linear regression trend analysis) to evaluate correlations between groundwater boron concentrations and saturated ash thickness, and between groundwater boron concentrations and ash pore water boron concentrations. The linear regression analysis was conducted using analytical data from Piedmont ash basins, including data from MSS.

The statistical evaluation was performed using a dataset which included 89 monitoring wells completed in shallow, transition, and bedrock groundwater zones directly beneath ash basins and 54 ash pore water monitoring wells completed in saturated ash at Piedmont sites. Linear

regression results indicated that 87% of the groundwater monitoring locations below saturated ash locations have less than 02L concentrations of boron in groundwater. Exceptions to this relationship occur for select groundwater wells located near ash basin dikes and dams. This is due to the downward vertical hydraulic gradient in these areas, which enhances migration of COIs.

At Marshall, shallow groundwater boron concentrations were positively correlated with saturated ash thickness (groundwater boron concentrations increased with increasing saturated ash thickness). For all groundwater zones, boron concentrations were negatively correlated with ash pore water concentrations (groundwater boron concentrations decreased with increasing ash pore water boron concentrations) (Arcadis, 2019). The positive correlation between groundwater boron concentrations and saturated ash thickness suggest that boron concentrations in groundwater will decrease as saturated ash thickness decreases due to decanting of the ash basin. Data demonstrate that concentrations for other, less mobile, constituents are also low below saturated ash.

Pre-decanting conditions represent the greatest opportunity for COI migration to occur, not because of the volume of saturated ash, but because of the existing ash basin hydraulic head and the downward vertical hydraulic gradient near the dam. Under post-decanting, the hydraulic head of the ash basin will be reduced, therefore, reducing the downward vertical gradient occurring near the dam and the rate of constituent migration from the ash basin to the groundwater system. Decanting the basin to reduce the vertical hydraulic gradient is the most important factor to limit further constituent migration in groundwater.

6.1.1.6 Chemistry within Waste Boundary
(CAP Content Section 6.A.a.vi)

Analytical sampling results associated with material from within the ash basin waste boundary are included in the following appendix tables or appendices:

- Ash solid phase: **Appendix C**, Table 4 *(CAP Content Section 6.A.a.vi.1.1)*
- Ash synthetic precipitation leaching procedures (SPLP): **Appendix C**, Table 6 *(CAP Content Section 6.A.a.vi.1.2)*

- Ash Leaching Environmental Assessment Framework: **Appendix H,** Attachment C *(CAP Content Section 6.A.a.vi.1.3)*
- Soil: **Appendix C**, Table 4 *(CAP Content Section 6.A.a.vi 1.4)*
- Ash pore water: **Appendix C**, Table 1 *(CAP Content Section 6.A.a.vi.1.6)*

Ash Solid Phase and Synthetic Precipitation Leaching Potential

(CAP Content Section 6.A.a.vi.1.1 and 6.A.a.vi.1.2)

Ash samples collected inside the ash basin waste boundary were analyzed for total extractable inorganics using USEPA Methods 6010/6020. For information purposes, ash samples were compared to soil background values and PSRG POGs. The ash analytical data do not represent soil conditions outside of or beneath the ash basins. Concentrations of arsenic, boron, chromium, molybdenum, and selenium in ash samples were greater than soil BTVs and the PSRG POGs (**Appendix C**, Table 4).

In addition, thirteen ash samples collected from borings completed within the ash basin and additional sources were analyzed for leachable inorganic constituents using synthetic precipitation leaching procedures (SPLP) USEPA Method 1312 (**Appendix C**, Table 6). The purpose of the SPLP testing is to evaluate the potential for leaching of constituents that might result in concentrations greater than the 02L standards or IMACs. SPLP analytical results are compared with the 02L or IMAC comparative values to evaluate potential source contribution; the data do not represent groundwater conditions. The results of the SPLP analyses indicated that concentrations of antimony, arsenic, barium, boron, chromium, cobalt, iron, lead, manganese, nickel, selenium, thallium, and vanadium were greater than the 02L or IMAC comparative value.

Ash Leaching Environmental Assessment Framework

(CAP Content Section 6.A.a.vi.1.3)

Ash samples were analyzed for extractable metals analysis, including hydrous ferric oxide (HFO)/ hydrous aluminum oxide (HAO), using the Citrate-Bicarbonate-Dithionite (CBD) method. Leaching environmental assessment framework (LEAF) is a leaching evaluation framework for estimating constituent release from solid materials. Leaching studies of consolidated ash samples from the MSS ash basin were conducted using two LEAF tests, USEPA methods 1313 and 1316 (USEPA, 2012a, b) and

(SynTerra, 2019b). The data are presented and discussed in the Geochemical Model Report presented in **Appendix H,** Attachment C.

Leaching test results, using USEPA LEAF method 1316, indicate that, even for conservative COIs such as boron, the leachable concentration of boron present in ash from MSS is considerably lower than the total boron concentration (**Appendix H,** Attachment C). The MSS data indicate that there is a process by which the COIs might become stable within the ash and would make the COI unavailable for leaching. The exact mechanisms of this process are unknown, however, literature suggests that incorporating COIs, such as boron, into the silicate mineral phases is a potential mechanism (Boyd, 2002). The leaching behavior of several COIs as a function of pH, examined using USEPA LEAF method 1313, demonstrated that for anionic COIs, the leaching increased with increasing pH and the cationic COIs showed the opposite trend (**Appendix H,** Attachment C).

Soil Beneath Ash

(CAP Content Section 6.A.a.vi.1.4 and 6.A.a.vi.1.5)

Soil samples within the ash basin waste boundary include samples collected from beneath the ash basin and samples collected from the fill material within the ash basin dam. Soil samples beneath the ash basin were saturated, including those obtained from borings associated with AB-3D, AB-4SL, AB-5D, AB-7D, AB-8D, AB-10D, AB-11D, AB-13D, AB-14D, AB-15D, AB-16D, AB-18D, AB-20D, GWA-1S/BR, SB-1, SB-2, SB-3, SB-7, SB-10, SB-11, SB-13, SB-14, SB-15. Temporary soil borings ("SB") were used for soil sample collection purposes (*i.e.,* no monitoring wells were installed at these locations).

Constituents considered for soil evaluation were limited to constituents identified as COIs for the MSS ash basin since soil impacts would be related to the source area interaction to the underlying soils and groundwater, which may migrate beyond the ash basin. The range of constituent concentrations in saturated soils within the waste boundary, along with a comparison with soil background values and North Carolina PSRG POG standards (NCDEQ February 2018), whichever is greater, is provided in **Appendix C**, Table 4. For constituents lacking an established target concentration for soil remediation (*e.g.,* chloride and sulfate), the equation presented in **Table 6-2** was used in general accordance with the references in the NCDEQ PSRG, May 2019 to calculate a POG value.

Where necessary, the PSRG POG values were calculated using laboratory testing and physical soil data for effective porosity (0.3) and dry bulk density (1.6 kg/L) prepared in part for flow and transport modeling for the Site. Soil water partition coefficients (K_d) were obtained from the *Groundwater Quality Signatures for Assessing Potential Impacts from Coal Combustion Product Leachate* (EPRI, 2012). The resulting PSRG POG values were calculated for chloride (938 milligrams per kilogram [mg/kg]) and for sulfate (1,438 mg/kg).

Saturated soil is considered a component of the groundwater flow system. The potential leaching and sorption of constituents in the saturated zone is included in the flow and transport and geochemical model evaluations (**Appendix G** and **H**) by continuously tracking the COI concentrations over time in the saprolite, transition zone, and bedrock materials throughout the models.

Unsaturated soil is considered a potential secondary source to groundwater. Constituents present in unsaturated soil or partially saturated soil (vadose zone) have the potential to leach into the groundwater system if exposed to favorable geochemical conditions for chemical dissolution to occur. Unsaturated soil samples within the ash basin waste boundary include samples collected from the fill material within and near the ash basin dam at the AB-2, CCR-5 and GWA-1 locations (**Figure 1-2**). Constituent concentrations from unsaturated soil samples within the waste boundary [AB-2S (6-7), CCR-5 (0.5-1), (2-3), GWA-1BR (8-10), (14-15.5), (18-20)] were compared with the North Carolina PSRG POGs or background values (**Table 6-3**). COI concentrations from the unsaturated soils within the waste boundary are not greater than the PSRG POGs or background values, whichever is greater.

The range of constituent concentrations in soils within and beyond the waste boundary, along with a comparison with background values and the PSRG POGs, is provided in **Appendix C**, Table 4. Soil SPLP constituent concentrations within the waste boundary, along with a comparison to 02L/IMAC, for comparative purposes only, is provided in **Appendix C**, Table 6.

Ash Pore Water

(CAP Content Section 6.A.a.vi.1.6 and 6.A.a.vi.3)

The ash basin is a permitted waste water treatment system. Water within the ash basin is not groundwater; therefore, isoconcentration maps were not prepared for ash pore water and comparison to 02L/IMAC/background values is not appropriate. Ash pore water data is presented in **Appendix C**, Table 1. **Figures 6-7a, 6-7b, and 6-7c** represent ash pore water distribution in cross section (A-A') from northwest to southeast across the ash basin. Means of ash pore water concentrations are provided for general purposes only. For further discussion of geochemical trends within the ash pore water, see **Appendix H**, Section 2. All ash pore water sample locations are shown on **Figure 1-2,** and analytical results are provided in **Appendix C**, Table 1.

Two groundwater monitoring wells located in areas that could be sensitive to changing Site conditions from ash basin closure activities, including decanting, were selected for monitoring water elevation and geochemical parameters. Water elevations are monitored with pressure transducers and geochemical parameters, including pH, oxidation reduction potential (ORP) and specific conductivity, are monitored using multi-parameter (or geochemical) sondes. Locations monitored with multi-parameter sondes are illustrated on **Figure 6-8**, and include:

- MW-7S: shallow flow zone monitoring well located east of the dam, between the ash basin and Lake Norman
- CCR-13S: shallow flow zone monitoring well located between the ash basin and Dry Ash Landfill Phase I

17 shallow groundwater monitoring wells and six isolated surface water bodies within the basin were fitted with pressure transducers to monitor water level changes before, during and after decanting of the ash basin.

AB-10S	AB-10SL	AB-12S	AB-12SL
AB-21S	AB-2S	AB-4S	AB-4SL
AL-1S	CCR-9S	CCR-11S	CCR-12S
CCR-14S	AB-3S	AB-3D	AB-5S
AB-8S	AB-9S	SG-1	SG-2
SG-3	SG-4	SG-5	SG-6

It should be noted that ash pore water monitoring well AB-3S has been observed to be dry as a result of basin decanting; therefore, the pressure transducer was decontaminated and relocated to the bedrock flow zone well at the same location, AB-3D. Two of the ponded water monitoring points installed in isolated bodies of free water within the southwestern portion of the ash basin (SG-2 and SG-3) have been removed due to ash basin operations (**Figure 6-8**). Geochemical water quality and hydrograph time series plots for each location are included on **Figures 6-9** and **6-10a** through **6-10d**. Observations of water elevation and multi-parameter records from monitored locations include:

- Ash pore water, shallow, and deep flow zone monitoring wells within the waste boundary show a response to ash basin decanting by reduced water elevation levels (**Figure 6-10a** through **6-10c**).
- Monitoring locations at areas of ponded water within the ash basin indicate a response to decanting by reduced water elevations (**Figure 6-10d**).
- Geochemical parameters located within the waste boundary (CCR-13S and MW-7S) show very slight variability in records since ash basin decanting commenced (**Figure 6-9**). This suggests geochemical conditions have remained stable under changing conditions at locations within the waste boundary.

In general, ash pore water and groundwater geochemical parameters appear stable under changing site conditions. Ash pore water pH and Eh do not appear to be significantly affected by lowering the ash basin pond's water level, and therefore, represent stable conditions in which an increase in constituent dissolution and mobility is unlikely to occur. Additionally, groundwater pH and Eh, monitored beneath and downgradient of the ash basin, are unaffected by even larger reductions in water levels, indicating stable geochemical conditions in which constituent dissolution and mobility are unlikely to occur.

Ash Pore Water Piper Diagrams

(CAP Content Section 6.A.a.vi.2)

Piper diagrams of ash pore water monitoring data and groundwater monitoring data from shallow, deep and bedrock background locations and locations downgradient and adjacent to the ash basin are presented on **Figure 6-11**. Data used for the Piper diagrams include ash pore water data

and groundwater data between January 2018 and May 2019 with charge balance errors less than 10 percent. Data were excluded from inclusion in the Piper diagrams if pH values were greater than 8.5 S.U. and turbidity values greater than 10 Nephelometric turbidity units (NTUs).

Ash pore water results tend to plot with higher proportions of sulfate, chloride, calcium, and magnesium, which is generally characteristic of ash pore water (EPRI, 2006). At MSS, ash pore water samples generally follow this generalization (**Figure 6-11**).

6.1.1.7 Other Potential Source Material

(CAP Content Section 6.A.a.vii)

Two unlined ash landfill units, referred to as the Dry Ash Landfills (NCDEQ Division of Solid Waste Permit No. 1804-INDUS), are located adjacent to the east (Phase I) and northeast (Phase II) portions of the ash basin (**Figure 1-2**). Phase I contains approximately 522,000 cy of fly ash, which was placed from September 1984 through March 1986. Placement of ash in the Phase II areas began around March 1986 and was completed in 1999. Phase II contains approximately 4,064,000 cy of fly ash. The landfill units are unlined and were closed with a soil cover system.

The PV Structural Fill was constructed of fly ash, under the structural fill rules found in 15A NCAC 13B .1700 *et seq.*, and bottom ash, under Duke Energy's Distribution of Residuals Solids (503 Exempt) Permit Number WQ0000452, which was issued by NCDENR Division of Water Quality (DWQ), and is located adjacent to and partially on top of the northwest portion of the ash basin (**Figure 1-2**). The PV Structural Fill, used for renewable energy research and production, contains a solar panel field on the southern portion of the structural fill unit. Placement of dry ash in the structural fill began in October 2000. The PV Structural Fill covers approximately 83 acres and contains approximately 5,410,000 cy of ash. The structural fill is unlined and was closed with a soil cover system in February 2013.

The access road structural fill, adjacent to the ash basin waste boundary, and south of the PV Structural Fill, was constructed of fly ash under the structural fill rules found in 15A NCAC 13B .1700 *et seq* (**Figure 1-2**). The access road structural fill covers approximately 2.5 acres and contains approximately 127,982 cubic yards of ash. Construction of the unlined structural fill road began in 1997 and was completed in 1998.

The subgrade for portions of the ILF No. 1 was constructed of fly ash under the structural fill rules found in 15A NCAC 13B .1700 *et seq*. The subgrade structural fill, which contains approximately 726,000 cy of ash, was closed with a soil cover in 2013. The ILF No. 1 was constructed over portions of this unlined structural fill and the northern reach of the ash basin (**Figure 1-2**).

Duke Energy will be addressing additional primary sources, including the Dry Ash Landfill Phase I and Phase II (INDUS-1804) and the PV Structural Fill, with NDCEQ DWM in separate submittals. The Dry Ash Landfill Phase I (INDUS-1804) is proposed to be excavated and the Dry Ash Landfill Phase II (INDUS-1804) and PV Structural Fill are proposed for additional closure measures including installation of a geosynthetic liner and cover system. Excavation of the Dry Ash Landfill Phase I will remove the source and reduce potential additional migration of COIs from the facility. Installation of an impermeable cover system at the PV Structural Fill and Dry Ash Landfill Phase II will prevent infiltration of precipitation through these sources and reduce COI leaching potential to underlying groundwater.

As a further source control measure, Duke Energy proposes to excavate the Dry Ash Landfill Phase I due to the unique hydrogeologic setting and close proximity to surface water receptors. The land space could provide additional room for groundwater remediation infrastructure or corrective action plan modification, if deemed necessary, without interfering with ash basin closure or site operations. Vertical migration of COIs beneath and downgradient of the Dry Ash Landfill Phase I is not limited or intercepted by the flow-through ash basin system, as described in the updated CSM. Excavation of the Dry Ash Landfill Phase I will remove the source and reduce additional migration of COIs. Decanting of the ash basin will also significantly reduce the hydraulic gradients within the basin and COI migration potential.

In an April 5, 2019, letter to Duke Energy, NCDEQ listed and requested assessment of additional potential sources of constituents to groundwater at Marshall stating that sources hydrologically connected to the ash basin are to be assessed and included in an updated CAP. The coal pile and gypsum storage pad areas were included as additional sources hydrologically connected to the ash basin.

The gypsum storage pad, which contains gypsum that is generated as a byproduct of generating coal, is approximately 4 acres and has a synthetic liner installed beneath the concrete pad. Gypsum is sold for beneficial reuse off-Site. Results of the assessment conducted at the lined gypsum storage pad indicate no impacts to underlying soil or groundwater as a result of gypsum storage and operation. Therefore, the gypsum storage pad is not being carried forward for corrective action in this CAP Update.

Coal stored on-Site is a not a waste product and therefore, is not regulated under North Carolina General Statutes (G.S.), as amended by CAMA. Therefore, no compliance or waste boundaries are associated with the coal pile. Coal has arrived at MSS through rail transportation since operations began. Coal is, and has historically been, stored at the Site's unlined coal pile located immediately north of the powerhouse and south/adjacent to the ash basin, on approximately 35 acres (**Figure 1-2**). Coal is conveyed via transfer belts to the station where it is pulverized before being used in the boilers.

To improve storm water management in the area of the coal pile, lined holding basins were built in 2018 west and east of the coal pile. These retention basins receive coal pile storm water runoff collected from the coal pile through a concrete-lined perimeter ditch and associated collection trench. Construction of the retention basins was associated with water redirect efforts to reroute storm water flows from the ash basin to the new Lined Retention Basins installed in 2018 (**Figure 1-2**). The reroute of storm water flows was completed to assist in ash basin closure.

The coal pile is exposed to erosion, oxidation, and precipitation. An estimated 50-95% of precipitation becomes runoff from coal piles (Davis and Boegly, 1981). Leachate from coal piles tend to be acidic, with pH values as low as 2 to 3 S.U. Chemical reactions occur at coal piles when water and oxygen is introduced to pyrite commonly found in coal. The chemical reaction typically results in iron and sulfate in solution, which is consistent with the values seen in the northern corner of the coal pile (CP-1S/D). Sulfate and low pH are potential indicator constituents of coal pile impact (EPRI, 2019). Low pH (average 4.0 S.U.) and elevated sulfate (350 mg/L) are present in shallow groundwater off the northern corner of the coal pile (CP-1S). These results also coincide with elevated concentrations of beryllium, cobalt, iron, manganese, sulfate, TDS, and thallium in CP-1S. In the deep

groundwater flow zone at CP-1D, concentrations of cadmium, cobalt, manganese, sulfate, and TDS are consistently greater than applicable comparative criteria. Although this location is within the ash basin compliance boundary, one additional bedrock well (CP-1BR) was installed in 2019 to delineate these COIs off the northern corner of the coal pile. These COIs are delineated horizontally downgradient by the CCR-4 and CCR-5 well clusters off the buttress of the ash basin dam. Furthermore, groundwater remedies presented herein account for any potential impacts as a result of coal handling and storage at the coal pile.

6.1.1.8 Interim Response Actions

(CAP Content Section 6.A.a.viii)

Interim response actions performed to date include active decanting of the ash basin, provision of permanent water supplies to qualifying households, and stabilization of the ash basin dam, as summarized on **Table 6-4**.

Ash Basin Decanting

(CAP Content Section 6.A.a.viii.1)

Ash basin decanting via gravity flow commenced on July 16, 2019, mechanical decanting commenced on September 13, 2019. Decanting is a form of active source remediation by removing ponded water in the ash basin, which is considered a critical component of reducing constituent migration from the ash basins. Reduction of constituent migration occurs through decanting by significantly reducing the hydraulic head and gradients, thereby reducing the groundwater seepage velocity and COI transport potential.

Prior to mechanical decanting, the elevation of ponded water in the ash basin was 789 feet. Flow and transport modeling simulations indicate decanting will lower hydraulic heads within and around the ash basins, flow directions within the basins will be more prominently eastward, and flow velocities will be reduced.

Water elevations were monitored using pressure transducers to record changing site conditions from ash basin decanting at the following locations (**Figure 6-8**):

- 18 groundwater monitoring wells located within and around the basins (17 currently active due to dry conditions at AB-3S).

- 6 locations within ponded water located in the ash basin (4 currently active due to site operations).

Ponded water and groundwater decanting network hydrographs, using water elevations recorded between May 2019 (sondes deployed in June, 2019) through October 2019 are depicted on **Figures 6-10a** through **6-10d**. Observations from hydrographs include:

- As of December 1, 2019, the water level in the free water in the ash basin has decreased by approximately 7.3 feet since the commencement of decanting (**Figure 6-10d**). Note the water elevations displayed on **Figure 6-10d** are not current to December 1, 2019.
- In September 2019, pressure transducer located in AB-3S was relocated to AB-3D due to dry conditions present in AB-3S.
- Isolated areas of ponded water within the ash basin have decreased on average by approximately one to three feet (**Figure 6-10d**). In SG-2 and SG-3, an increase in water level was observed due to site operations at associated ponded water. These monitoring points were subsequently removed due to site operations.
- All groundwater monitoring locations show a response to ash basin decanting through a reduction in shallow groundwater elevations (**Figures 6-10a** through **6-10c**).

Source Area Stabilization

(CAP Content Section 6.A.a.viii.2)

In December 2015, NCDEQ issued a draft risk classification for the MSS ash basin as "intermediate," requiring closure by December 31, 2024. Duke Energy subsequently made the required improvements to the dam pursuant to G.S. Section 130A-309.213(d)(1), including repairs/improvements to the overflow spillway. Improvements specifically consisted of hard armoring of the downstream slope of the dam and emergency spillway with concrete and/or riprap, and replacement of the principal spillway structure. NCDEQ provided correspondence, dated November 13, 2018, to confirm that Duke Energy rectified prior dam safety deficiencies, reclassifying the ash basin from its prior draft ranking of "intermediate" to "low-risk" (**Appendix A**).

6.1.2 Extent of Constituent Migration beyond the Compliance Boundary

(CAP Content Section 6.A.b)

This section is an overview of constituent occurrences beyond the ash basin compliance boundary. The compliance boundary for groundwater quality at the Site is defined in accordance with Title Subchapter 02L .0107(a) as being established at either 500 feet from the waste boundary or at the property boundary, whichever is closer to the waste. The Dry Ash Landfills Phase I and Phase II and ILF also have compliance boundaries approximately 250 feet from the landfill waste boundaries. The ash basin compliance boundary and landfill compliance boundary overlap in areas north (ILF) and east (Dry Ash Landfill Phase I) of the ash basin waste boundary (**Figure 1-2**). Groundwater constituent migration from the ash basin and landfills, along with the other adjacent source areas outlined in **Section 3**, is comingled and indiscernible.

Analytical sampling results associated with the ash basin and adjacent source areas for each media are included in the following tables and appendices:

- Soil: **Appendix C**, Table 4 and **Table 6-3** (*CAP Content Section 6.A.b.ii.1*)
- Groundwater: **Appendix C**, Table 1 and **Table 6-5** (*CAP Content Section 6.A.b.ii.2*)
- Seeps: **Appendix C**, Table 3 (*CAP Content Section 6.A.b.ii.3*)
- Surface water: **Appendix C**, Table 2 and **Appendix J** (*CAP Content Section 6.A.b.ii.4*)
- Sediment: **Appendix C**, Table 5 (*CAP Content Section 6.A.b.ii.5*)

Soil Constituent Extent

(CAP Content Section 6.A.b.ii.1)

Data indicate unsaturated soil concentrations are generally consistent with background concentrations or are less than PSRG POG or background, whichever is greater (**Table 6-3**). In the few exceptions, these soil concentrations are:

- generally within range of Piedmont background dataset concentrations (**Table 4-2**),
- delineated vertically by groundwater constituent concentrations less than applicable regulatory criteria in the corresponding monitoring well,

indicating the soil concentrations are not a secondary source of constituents to the groundwater, and/or

- lacking transport mechanisms by which the constituent could have migrated from the source area to the unsaturated soils.

Near the ash basin compliance boundary, east of the Dry Ash Landfill Phase I, concentrations of arsenic and selenium were detected slightly greater than the PSRG POG and background values (**Table 6-3**). However, these constituents are not present in groundwater at the same location greater than applicable regulatory criteria (**Appendix C**, Table 1); therefore, these soil concentrations do not warrant consideration as potential secondary source of constituents to the groundwater. For these reasons, no soil COIs were identified for the MSS and no soil concentrations are identified for corrective action at the Site.

Horizontal and vertical extent of constituent concentrations in soil is discussed further in **Section 6.1.4**.

Groundwater Constituent Extent

(CAP Content Section 6.A.b.ii.2)

The ash basin compliance boundary extends 500 feet beyond the ash basin waste boundary, or to the property boundary, whichever is closer. Groundwater concentrations greater than 02L/IMAC/applicable background concentration values occur locally at or beyond the compliance boundary east of the ash basin towards the unnamed tributary and the cove of Lake Norman.

The maximum extent of CCR-affected groundwater migration for all flow zones is generally represented by boron concentration greater than the 02L standard. Boron has migrated east of the ash basin towards the tributary and Lake Norman, at or beyond the compliance boundary. There is very limited land area between the ash basin compliance boundary and Lake Norman. These surface waters are groundwater discharge zones that limit the horizontal transport of constituents downgradient of the basin. However, constituent concentrations in groundwater have not caused, and will not cause, current surface water quality standards to be exceeded (**Appendix J**). Other areas of constituent migration, beyond the 02L boron plume, occur along the southern portion of the ash basin dam and consist of variably reactive constituents (*e.g.,* cobalt).

Section 6.1.3 includes a detailed matrix evaluation and rationale of groundwater constituents requiring corrective action, and **Section 6.1.4** provides

isoconcentration maps and cross sections depicting groundwater flow and constituent distribution in groundwater at or beyond the compliance boundary *(CAP Content Section 6.A.b.i)*.

Seep Constituent Extent

(CAP Content Section 6.A.b.ii.3)

Seeps at MSS are subject to the monitoring and evaluation requirements contained in the SOC. The SOC states that the effects from non-constructed seeps should be monitored. Attachment A to the SOC identifies the following seeps:

- Non-constructed seeps to be monitored — S-1, S-2, S-4
- Non-constructed seeps dispositioned — S-3

The SOC defines dispositioned:

1. The seep is dry for at least three consecutive quarters;
2. The seep does not flow to waters of the State;
3. The coal ash basin no longer impacts the seep for all COIs over four consecutive sampling events;
4. An engineering solution has eliminated the seep.

Non-dispositioned seeps, where monitoring conducted has indicated the presence of CCR effects, include: S-1 and S-2 (**Figure 5-6**). Seeps at MSS are contained within well-defined channels. Therefore, potential constituent migration related to seep flow are constrained in localized areas along the channel. Dry conditions have been consistently observed at seep S-2 and S-4 in 2019, likely a result of ash basin decanting. Surface water sampling conducted downstream of non-dispositioned seep S-1, in Lake Norman, demonstrates that flow from S-1 has not caused constituent concentrations greater than 02B standards in the reservoir. Analytical results for these samples are included in **Appendix C**, Table 2 and Table 3.

Surface Water Constituent Extent

(CAP Content Section 6.A.b.ii.4)

Surface water samples were collected from Lake Norman to confirm groundwater downgradient of the ash basin has not resulted in surface water concentrations greater than 02B water quality standards. A map of all surface water sample locations for groundwater discharge to surface water evaluation is included in **Appendix J**. Surface water samples were collected to evaluate acute

and chronic water quality values. Surface water samples were also collected at background locations (upstream of potential migration areas) within Lake Norman and minor streams upgradient of the source area. Analytical results were evaluated with respect to 02B water quality standards and background data. Surface water conditions is further discussed in **Section 6.2.1** and the full report for the MSS surface water current conditions can be found in **Appendix J**.

Additionally, environmental assessments of Lake Norman have all demonstrated that Lake Norman has been an environmentally healthy and functioning ecosystem, and ongoing sampling programs have been established to ensure the health of the system will continue. Furthermore, these data indicate that there have been no significant effects to the local aquatic systems related to coal ash constituents over the last 60 years. More information related to environmental health assessments conducted for Lake Norman, including sampling programs, water quality and fish community assessments, and fish tissue analysis, can be found in **Appendix E**.

Sediment Constituent Extent

(CAP Content Section 6.A.b.ii.5)

All sediment sample locations are co-located with surface water or tributary stream seep sample locations (**Figure 1-2**). Similar to saturated soils and groundwater, sediment is considered a component of the surface water system, and the potential leaching and sorption of constituents in the saturated zone is related to water quality. Because no regulatory standards are established for sediment inorganic constituents, both background sediment constituent concentration ranges and co-located surface water sample results are considered in this sediment evaluation. **Table 4-5** presents constituent ranges of background sediment datasets. Analytical results for all sediment samples are provided in **Appendix C**, Table 5**.**

Assessment of constituents in sediment from surface waters, including Lake Norman and seeps, was conducted through a comparison evaluation between sediment sample analytical results, from one-time grab samples, and constituent concentration ranges from background sediment datasets. Samples collected from Lake Norman and associated streams were compared with background dataset ranges from the respective surface water body.

As stated above, there are no regulatory standards established for inorganic constituents in sediment. The surface water evaluations conducted as part of the CAP Update (**Appendix J**) have concluded there are no concentrations greater

than the 02B surface water quality standards, nor are there predicted to be under future conditions. Additionally, the updated risk assessment, provided in **Appendix E**, concludes that there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS. This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

For these reasons, concentrations of constituents in sediment at the MSS do not warrant corrective action. Observations below are for comparative and informative purposes only.

Sediments Collected from Lake Norman

Six sediment samples have been collected from Lake Norman. Sediment sample locations (**Figure 1-2**) included:

- Upstream Areas of Lake Norman (background) — SW-105, SW-106
- Downgradient Areas of Lake Norman (four locations) — SW-101, SW-102, SW-103, SW-104 (immediate areas downgradient of affected groundwater plume)

Of the four downgradient sediment samples collected along the bank of Lake Norman, all four samples have constituent concentrations greater than the maximum detected concentration in background sediment including boron, chloride, cobalt, iron, manganese, strontium, and thallium. However, these detections do not warrant corrective action. The surface water evaluations conducted as part of the CAP Update (**Appendix J**) have concluded there are no concentrations greater than the 02B surface water quality standards, nor are there predicted to be under future conditions. Additionally, the updated risk assessment, provided in **Appendix E**, concludes that there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS. This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

Sediments Collected from Seeps

Sediment samples have been collected from the unnamed tributary of Lake Norman east of the ash basin and former active seep S-2. No flow has been consistently observed at seep S-2, downgradient of the ash basin dam, since

commencement of ash basin decanting. Sediment sample locations (**Figure 1-2**) included:

- Seep S-2 – S-02
- Unnamed tributary (seep S-1) – SW-06, SW-109, SW-110

Concentrations of chromium, cobalt, iron, manganese, and selenium in sediment at seep locations were greater than the maximum detected concentration in background sediment. However, these detections do not warrant corrective action. The surface water evaluations conducted as part of the CAP Update (**Appendix J**) have concluded there are no concentrations greater than the 02B surface water quality standards, nor are there predicted to be under future conditions. Additionally, the updated risk assessment, provided in **Appendix E**, concludes that there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS. This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

After completion of decanting, all seeps, constructed and non-constructed and if not dispositioned in accordance with the SOC, are to be characterized post-decanting for determination of seep disposition by the decanting process. The SOC defines dispositioned: 1) the seep is dry for at least three consecutive quarters; 2) the seep does not flow to waters of the State; 3) the coal ash basin no longer impacts the seep for all COIs over four consecutive sampling events; 4) an engineering solution has eliminated the seep. If a seep is dispositioned, no corrective action for the location would be evaluated. After seep characterization, an amendment to the CAP, may be required to address non-dispositioned seeps.

6.1.2.1 Piper Diagrams

(CAP Content Section 6.A.b.iii)

Piper diagrams can be used to graphically differentiate water sources in hydrogeology (Domenico and Schwartz 1998) by assessing the relative abundance of major cations (*i.e.*, calcium, magnesium, potassium, and sodium) and major anions (*i.e.*, chloride, sulfate, bicarbonate, and carbonate) in water.

Groundwater Piper Diagrams

Piper diagrams of groundwater monitoring data from shallow, deep and bedrock background locations and locations downgradient and adjacent to

the ash basin (in addition to ash pore water) are presented on **Figure 6-11**. Data used for the Piper diagrams include groundwater and ash pore water data between January 2018 and May 2019 with charge balance errors less than 10 percent. Data were excluded from inclusion in the Piper diagrams if pH values were greater than 8.5 S.U. and turbidity values greater than 10 Nephelometric turbidity units (NTUs).

The distribution of results on the Piper diagrams in **Figure 6-11** indicate groundwater in all three flow zones considered generally unaffected by the source area contains relatively lower proportions of sulfate, chloride, calcium, and magnesium. Unaffected groundwater trends toward containing greater sodium and potassium content than ash pore water data, which tend to plot with higher proportions of sulfate, chloride, calcium, and magnesium.

Seep and Surface Water Piper Diagrams

Piper diagrams of ponded source water, seeps, and Lake Norman surface water monitoring data (**Figure 6-12**) are used to assess the relative abundance of major cations (*i.e.*, calcium, magnesium, potassium, and sodium) and major anions (*i.e.*, chloride, sulfate, bicarbonate, and carbonate) in surface water. Data used for the piper diagrams include most recent available seep and surface water data (**Appendix C**, Table 2) with a charge balance between -10 and 10%. From ash pore water and groundwater piper diagrams (**Figure 6-11**), areas identified where ash pore water tends to plot is noted as "affected"; areas that show potential mixing with affected water is noted as "potential mixing", and areas that are similar to background (or native) water quality are noted as "generally unaffected".

- Areas displaying influence from COI-affected groundwater ("affected") include locations near the dam, south and southeast of the ash basin (SW-01, SW-10, SW-103, and SW-104). Seep location S-1 (former NPDES Seep Outfall 101) shows historical signs of mixing ash pore water.
- Areas displaying "potential mixing" with COI-affected groundwater include locations near the Outfall 007 and unnamed tributary, to the east of the ash basin (SW-101, SW-102, and SW-110).
- Surface water locations that are unaffected from ash pore water include SW-7, SW-8, SW-11, SW-105, and SW-106.

Although the groupings displayed on the Piper diagrams may indicate influence from COI-affected groundwater, COI concentrations in Lake Norman surface water remain, and are predicted to remain, less than 02B surface water quality standards.

6.1.3 Constituents of Interest (COIs)

(CAP Content Section 6.A.c)

This CAP Update evaluates the extent of, and remedies for, COIs associated with the ash basin and adjacent source areas that are at or beyond the ash basin compliance boundary detected at concentrations greater than regulatory criteria or background values, whichever is greater.

Site-specific COIs were developed by evaluating groundwater sampling results with respect at concentrations greater than regulatory criteria or background values, whichever is greater and additional regulatory input/requirements. The distribution of constituents in relation to the source area, co-occurrence with CCR indicator constituents such as boron and sulfate, and migration directions based on groundwater flow direction are considered in determination of groundwater COIs.

The following list of COIs has been developed for Marshall, which represents COIs presented in the CSA Update (SynTerra, 2018a), in addition to COIs added for federal regulatory consideration (lithium) and to accommodate NCDEQ requests (hexavalent chromium, total radium) (**Appendix B**):

- Antimony
- Arsenic
- Barium
- Beryllium
- Boron
- Cadmium
- Chloride
- Chromium (Hexavalent)
- Chromium (Total)
- Cobalt
- Iron
- Lithium
- Manganese
- Molybdenum
- Nickel
- Radium (Total)
- Selenium
- Strontium
- Sulfate
- Total Dissolved Solids (TDS)
- Thallium
- Vanadium

Soil

(CAP Content Section 6.A.c.i.1)

Unsaturated soil at or near the compliance boundary is considered a potential secondary source to groundwater. Constituents present in unsaturated soil or partially saturated soil (vadose zone) have the potential to leach into the groundwater system if exposed to favorable geochemical conditions for chemical dissolution to occur. Constituents considered for unsaturated soil evaluation were the same constituents identified as COIs for the ash basin, since soil impacts would be related to ash pore water interaction to the underlying soils within the basin and groundwater migration at or beyond the ash basin.

Samples of background soil indicate that naturally occurring constituents, which are also related to CCR material, likely affect the chemistry of groundwater at the Site and are present at concentrations greater than the PSRGs POG values. Constituents with background values greater than PSRGs POG values include arsenic, barium, chromium (total), cobalt, iron, manganese, nickel, selenium and thallium (**Table 4-2**).

Data indicate unsaturated soil COI concentrations are generally consistent with background concentrations or are less than regulatory screening values (**Table 6-3**). In the few instances where unsaturated soil COI concentrations are greater than PSRG POG standards or background values, COI concentrations are within range of background dataset concentrations or the constituent is not present in groundwater at the same location greater than applicable regulatory criteria (**Appendix C**, Table 1); therefore, these soil concentrations do not warrant consideration as potential secondary source of constituents to the groundwater. Furthermore, there is a lack of transport mechanisms by which the COI could have migrated from the source area to the unsaturated soils. Horizontal and vertical extent of COI concentrations in soil, and reasons why no necessary corrective action for soils is identified at the Site, is discussed further in **Section 6.1.4**.

Groundwater

(CAP Content Section 6.A.c.i.2)

A measure of central tendency analysis of groundwater COI data (February 2018 to May 2019) was conducted and means were calculated to support the analysis of groundwater conditions to provide a basis for defining the extent of the COI migration at or beyond the compliance boundary. A measure of central tendency analysis was completed to capture the appropriate measure of central tendency

(arithmetic mean, geometric mean, or median) for each dataset of constituent concentrations. Constituent concentrations in a single well might vary over orders of magnitude; therefore, a single sample result might not be an accurate representation of the concentrations observed over several months to years of groundwater monitoring. Evaluating COI plume geometries with central tendency data minimizes the potential for incorporating occasions where COIs are reported at concentrations outside of the typical concentration range, and potentially greater, or substantially less than enforceable groundwater standards. Previous Site assessment mapping based on single COI concentrations for each well might have overrepresented areas affected by the ash basin by posting a single data set on maps and cross-sections that might have included isolated data anomalies.

NCDEQ recommended use of a lower confidence limit (LCL95) rather than the central tendency value (**Appendix A**). LCL95 concentrations were calculated for each COI. The LCL95 concentration for the sample with the highest COI LCL95 concentration is provided for comparison to the COI mean concentration in Table 1 of the technical memorandum titled *COI Management Plan Approach – Marshall Steam Station* (**Appendix H**). The mean COI concentration is typically higher than the LCL95 concentration, and therefore, is more conservative for comparison to the COI criterion.

The mean of up to six quarters of valid data was calculated for each identified COI to analyze groundwater conditions and define the extent of COI migration beyond the compliance boundary. If less than four quarters of valid data were available, the most recent valid sample result was reported. For calculating geomeans, non-detect values were assigned the laboratory reporting limit and estimated (J-flag) values were treated as the reported value. Procedures for excluding data from calculating geomeans are based on USEPA's National Functional Guidelines (USEPA, 2017a, 2017b), published research about leaching of elements from coal combustion fly ash (Izquierdo, 2012), and professional judgement.

The following steps outline the approach followed in calculating central tendency values for constituent concentrations in groundwater:

1. If the maximum analytical value divided by the minimum value for each constituent was greater than or equal to 10 (*i.e.* the data set ranges over an

order of magnitude), the geometric mean of the analytical values was used.

2. If the maximum analytical value divided by the minimum value for each constituent was less than 10 (*i.e.* the data set range is within an order of magnitude), the arithmetic mean was used.
3. The median of the data was used for records that contain zeros or negative values (*e.g.*, total radium). Negative values were set to zero prior to calculating the median concentration.
4. If the dataset mode (most common) is equal to the RL, and the geometric mean or mean value is less than or equal to the dataset's mode, the value was reported as "<RL" (*e.g.* the reporting limit for boron is 50 µg/L; for wells with geometric mean or mean analysis concentrations less than 50 µg/L the mean analysis result would be shown as "<50").

Sample results were excluded from calculations for the following conditions:

- Duplicate sampling events for a given location and date. The parent (CAMA) sample was retained
- Turbidity was greater than 10 Nephelometric Turbidity Units (NTUs)
- pH was greater than 10 standard units (S.U.) (for antimony, arsenic, chromium, molybdenum, selenium, and vanadium only)
- Data flagged as unusable (R0 qualified)
- Data reported as non-detect with a reporting limit greater than the normal laboratory reporting limit

Table 6-5 presents the mean analysis of the COI data using groundwater monitoring sampling results from February 2018 to May 2019. Where means could not be calculated, the most recent valid sample was evaluated to determine whether the sample result is an appropriate representation of the historical dataset. Data from **Table 6-5** are used in evaluating COI plume geometry in the vicinity of the ash basin.

Constituent Management Approach

A COI Management Plan was developed at the request of NCDEQ to evaluate and summarize COI concentrations in groundwater at the Site (**Appendix H**). Results of this COI Management Plan are used to identify areas that may require corrective action and to determine appropriate Site-specific mapping of COI

concentrations on figures based on the actual distribution of each COI in Site groundwater. **Table 6-6** presents the COI management matrix for determining COIs subject to corrective action at Marshall.

- Groundwater COIs to be addressed with corrective action are those which exhibit concentrations in groundwater at or beyond the compliance boundary greater than the 02L standard, IMAC, or BTV, whichever is highest.
- The COI Management Plan is also used to discern constituents at naturally occurring concentrations greater than 02L that would not be subject to corrective action. Examples include naturally occurring COIs that do not exhibit a discernable plume or COI that have no correlation with other soluble constituents associated with coal ash or another primary source (e.g., boron or sulfate).

A three-step process was utilized in the COI Management Plan approach:

- An evaluation of the applicable regulatory context
- An evaluation of the mobility of target constituents
- A determination of the distribution of constituents within Site groundwater

The primary goal of the COI Management Plan is to utilize science-based evidence to determine the realistic distribution and behavior of coal ash-related constituents in groundwater. The COI Management Plan presents multiple lines of evidence used to understand the actual COI presence in the subsurface at the Site, uses results from the COI Management Plan approach to identify Site-specific COIs for inclusion for corrective action planning, and presents the COI mapping approach for the CAP. The COI Management Plan approach is described in detail in (**Appendix H**) and summarized below.

Numerous Site-assessment activities have been completed to date and support the CSM, as shown in **Table ES-2**. Data generated from these Site assessment activities have been considered within the COI Management Plan approach. Components of the Site assessment activities and data evaluations utilized within the COI Management Plan include the hydrogeologic setting, groundwater hydraulics, constituent concentrations, groundwater flow and transport modeling results, geochemical modeling results, and groundwater geochemical conditions.

Step 1: Regulatory Review

Step 1 of the COI Management Plan process considers the relevant regulatory references listed in **Appendix H**. The regulatory analysis starts with the current COI list identified in the CSA Update (SynTerra, 2018a) and 2019 Interim Monitoring Plans (IMP) submitted by Duke Energy, March 20, 2019, and approved by NCDEQ April 4, 2019 (**Appendix A**). COI concentrations were screened against their respective COI criterion defined as the maximum of the 02L groundwater quality standard, IMAC, and background. COI concentrations were screened against their respective COI criterion for groundwater monitoring locations at or beyond the compliance boundary. Groundwater COI concentrations used in the screening are based on a calculated central tendency value (mean) including data from 2018 through the 2nd quarter of 2019. Arithmetic mean COI concentrations were calculated when the range in COI concentrations was less than one order of magnitude. A geometric mean COI concentration was calculated when the range in COI concentrations was greater than one order of magnitude.

NCDEQ recommended use of a lower confidence limit (LCL95) concentration rather than the central tendency value (**Appendix A**). LCL95 concentrations were calculated for each COI and the LCL95 concentration for the sample with the highest COI LCL95 concentration is provided in Table 1 of the COI Management Approach (**Appendix H**) for comparison to the maximum COI mean concentration. Table 2 of the COI Management Approach (**Appendix H**) provides a comparison of the maximum COI central tendency concentrations compared with the maximum COI LCL95 concentration for wells located at or beyond the compliance boundary for the Allen Steam Station, Belews Creek Steam Station, Cliffside Steam Station, Marshall Steam Station, Mayo Steam Electric Plant, and Roxboro Steam Electric Plant Sites. The COI LCL95 concentrations were typically lower than the COI central tendency value with very few exceptions. The number of wells exceeding COI criteria using the COI LCL95 concentration was typically equal to or less than the number of wells exceeding COI criteria using the COI central tendency concentration.

There were two COI that had increases in the number of wells exceeding COI criteria; one well for boron and one well for chloride (**Appendix H**).

Chloride had an increase from two wells exceeding COI criterion based on the central tendency concentration to three wells exceeding COI criterion based on the LCL95 concentration. The additional well exceeding COI criterion based on the LCL95 concentration is AB-01BR. The LCL95 and the central tendency concentrations are 258 and 240 mg/L, respectively, compared to the COI criterion of 250 mg/L (**Appendix H**). Boron had an increase from seven wells exceeding COI criterion to eight wells exceeding COI criterion. The additional well exceeding COI criterion based on the LCL95 concentration is MW-06S. The LCL95 and the central tendency concentrations are 723 and 405 mg/L, respectively, compared to the COI criterion of 700 mg/L (**Appendix H**). The LCL95 concentration is based on the entire period of record while the COI central tendency concentration is based on data from 2018 through June 2019. Boron concentrations range from a maximum of 4,450 mg/L in September 2016 to 150 mg/L in May 2019 (most recent sample included in the evaluation). Boron concentrations have a statistically significant decreasing trend at MW-06S and the most recent sample (150 mg/L) was below the COI criterion (Attachment A of **Appendix I**). AB-01BR and MW-06S are located within the area of planned corrective action for the Site (**Figure ES-4**). Use of the COI central tendency concentrations in the COI Management Plan process provides conservative estimate of the extent of COI in Site groundwater.

Step 2: COI Mobility

Step 2 of the COI Management Plan process evaluates the COI mobility to identify hydrogeologic and geochemical conditions and relative COI mobility based on:

- Review of regulatory agency and peer-reviewed literature to identify general geochemical characteristics of COI,
- Analysis of empirical data and results from geochemical and flow and transport modeling conducted for the Site, and
- Identification of COI-specific mobility as conservative (non-reactive), non-conservative (reactive), or variably reactive COIs based on results from geochemical modeling (**Appendix H**).

Site-specific groundwater geochemical conditions that may affect COI transport and distribution are described in Table 1 of the COI Management Approach (**Appendix H**).

Step 3: COI Distribution

Step 3 of the COI Management Plan process evaluates the relative presence of COIs in Site groundwater. Descriptions of the horizontal and vertical distribution of COIs with mean concentrations above their respective COI criterion at and beyond the Compliance Boundary are summarized in Table 1 of the COI Management Approach (Appendix H) and provided in more detail in **Table 6-6**. The COI Management Plan approach considers the distribution of COIs on a Site-wide basis. These distributions are used for planning appropriate corrective action as well as determining which COIs to map on figures.

Primary descriptions of COI distributions include plume-like distributions for relatively mobile COI such as boron and sulfate and isolated location(s) for COIs that do not exhibit plume-like distributions. Boron is the COI with the most plume-like distributions. Some COIs with isolated exceedances of COI criteria are not associated with the boron plume and these exceedances are described in more detail in (**Table 6-6**) to place these exceedances within the context of the Site CSM.

Rationale for inclusion or exclusion of COI from mapping on figures in the 2019 CAP Update is based on the horizontal and vertical distribution of COIs with concentrations greater than their respective COI criterion. All wells that have COI mean concentration(s) greater than the COI criterion are listed in **Table 6-6**.

Outcome of COI Management Plan Process

Constituents with concentrations greater than the COI criterion beyond the compliance boundary were grouped by geochemical behavior and mobility. A comprehensive evaluation (*i.e.,* means and groupings) of available data was used to demonstrate constituent distribution and correlation with other soluble constituents associated with coal ash, and to evaluate the spatial occurrence with a discernable COI plume in the direction of groundwater flow downgradient of the source area. This evaluation emphasizes the depiction of those constituents that have migrated downgradient of the source area, in the direction of groundwater flow at concentrations greater than the COI criterion with a discernable plume that correlates with other soluble constituents.

COI were assigned to mobility categories based on geochemical modeling results and information derived from peer-reviewed literature. COI mobility categories

are based on the concept of conservative versus non-conservative COI introduced by NCDEQ in the January 23, 2019 CAP content guidance document. The use of three mobility categories for COI was first introduced during in-person COI Management meetings held with NCDEQ in September 2019 for the Allen, Marshall, Mayo, and Roxboro Sites. Based on geochemical modeling results, COI mobility categories were expanded from conservative versus non-conservative to include the following:

- Conservative, Non-Reactive COI: antimony, boron, chloride, lithium, sulfate and TDS. Geochemical model simulations support that these constituents would transport conservatively (Kd values <1 liter per kilogram [L/kg]) as soluble species under most conditions, and that the mobility of these COIs will not change significantly due to current geochemical conditions or potential geochemical changes related to remedial actions.
- Non-Conservative, Reactive COI: beryllium, chromium (total), strontium, and vanadium. Geochemical model simulations support that these constituents are subject to significant attenuation in most cases and have high Kd values indicating the mobility of these COIs is unlikely to be geochemically affected by current geochemical conditions or potential geochemical changes related to remedial actions.
- Variably Reactive COI: arsenic, barium, cadmium, chromium (VI), cobalt, iron, manganese, molybdenum, nickel, selenium, radium (total), and thallium. Geochemical model simulations, and resulting Kd values, support these constituents may be non-reactive or reactive in relation to geochemical changes and are dependent on the pH and Eh of the system. The sensitivity of these COIs to the groundwater pH and Eh indicates that these constituents could respond to natural changes, such as water level fluctuations imposed by seasonality, or decanting and source control activities that have the potential to change the groundwater pH or Eh.

As discussed in the CSA Update (SynTerra, 2018a) and the 2018 CAMA Annual Interim Monitoring Report (SynTerra, 2019d), not all constituents with results greater than background values can be attributed to the ash basin or another source area. Naturally occurring groundwater contains varying concentrations of inorganic constituents. Sporadic and low-concentration occurrences of these constituents in the groundwater data do not necessarily demonstrate horizontal

or vertical distribution of COI-affected groundwater migration from the ash basin and adjacent source areas.

COI Management Plan Summary

A three-step process was utilized for the COI Management Plan approach considering the regulatory context, the mobility of constituents, and the distribution of constituents within Site groundwater. A comprehensive, multiple lines of evidence approach was followed utilizing extensive Site data. The COI Management Plan approach incorporated numerous components of the Site CSM in a holistic manner. Clear rationale was provided for every step of the COI Management process.

For the regulatory review portion of the COI Management Plan, mean COI concentrations were compared with COI criteria to identify COI that exceeded their respective COI criterion. Use of the COI central tendency concentrations in the COI Management Plan process was shown to provide a conservative estimate of the extent of COI in Site groundwater. Exceedance ratio values indicate COI concentrations that exceed COI criteria are within one order of magnitude (ER <10) to two orders of magnitude (ER <100) above the COI criterion.

Using the COI management process (**Appendix H**), 5 of 22 inorganic groundwater COIs exhibit mean concentrations that are currently less than background values, 02L standard, or IMAC at or beyond the compliance boundary, and therefore do not warrant corrective action at the Site (**Table 6-6**). These five constituents include:

- Arsenic
- Cadmium
- Chromium (Total)
- Chromium (VI)
- Nickel

These constituents are not expected to migrate distances at or beyond the compliance boundary or migrate distances that would present risk to potential receptors, and are predicted, based on geochemical modeling, to remain at stable concentrations, typically less than background values, 02L standard, or IMAC. One exception to this conclusion might be enhanced mobility of pentavalent arsenic if Eh values are sufficiently high to allow such species to persist (**Appendix H**). However, the proposed remedial alternative would account for capture of dissolved constituents in groundwater.

The remaining 17 COIs exhibit mean concentrations greater than background values, 02L standard, or IMAC downgradient of the ash basin at or beyond the compliance boundary. These constituents warrant corrective action and include:

- Antimony
- Barium
- Beryllium
- Boron
- Chloride
- Cobalt
- Iron
- Lithium
- Manganese
- Molybdenum
- Selenium
- Strontium
- Sulfate
- Thallium
- Total Dissolved Solids (TDS)
- Total Radium
- Vanadium

As discussed in the CSA Update (SynTerra, 2018a) and the 2018 CAMA Annual Interim Monitoring Report (SynTerra, 2019d), not all constituents with results greater than background values can be attributed to the ash basin. Naturally occurring groundwater contains varying concentrations of inorganic constituents. Sporadic and low-concentration occurrences of these constituents in the groundwater data do not necessarily demonstrate horizontal or vertical distribution of COI-affected groundwater migration from the ash basin.

Results of the COI Management Plan evaluation were used to identify COI for mapping on figures in the CAP Update. COIs to be mapped include: boron, chloride, cobalt, iron, lithium, manganese, thallium, total dissolved solids, and total radium (**Appendix H**). The following COI have no exceedances of COI criteria or have isolated exceedances without a discernable plume, at or beyond the compliance boundary: antimony, arsenic, barium, beryllium, cadmium, total chromium, hexavalent chromium, molybdenum, nickel, selenium, sulfate, and vanadium. These constituents will not be mapped on figures in the 2019 CAP Update.

6.1.4 Horizontal and Vertical Extent of COIs

(CAP Content Section 6.A.d)

The COIs at the MSS have been delineated horizontally and vertically in groundwater based on sampling and analysis data collected from 186 monitoring wells present at the Site. At the request of NCDEQ, two additional bedrock wells

have been installed in December 2019 to vertically delineate COIs detected at the northern corner of the coal pile (CP-1BR) and east of the PV Structural Fill (PVSF-2BRL) (**Appendix P**). Both of these locations are within the ash basin compliance boundary. The results of these assessments will be available at a later date.

The majority of COIs are either present below their applicable standards, do not exhibit discernable plumes, or have migrated a limited distance from the ash basin in groundwater. Furthermore, an evaluation of Site data indicates that COI presence in groundwater decreases with depth (**Appendix F**). Supporting information for these findings are presented in the COI management evaluation presented in **Section 6.1.3** and detailed in **Appendix H**.

Boron, a conservative (nonreactive) constituent, is the main COI that is present in Site groundwater in a discernable plume. Boron typically has greater concentrations in CCR than in native soil and is relatively soluble and mobile in groundwater (Chu, et. al., 2017). Chloride, lithium, and TDS are also conservative constituents; however, these constituents display reduced discernable COI plume geometries compared to boron. Additional constituent concentrations identified as being greater than their respective groundwater regulatory standards or background values, and are associated with COI-affected groundwater migration from the ash basin, are generally coincident within the extent of the 02L boron plume at the Site. Non-conservative and variably reactive constituents have smaller plume geometries, generally consisting isolated and sporadic detections, relative to boron because of their high K_d values and reactivity, which reduce their mobility in groundwater.

Since naturally occurring COIs might be present at concentrations greater than Site-specific BTVs, isoconcentration maps of primary CCR indicator COIs (*i.e.*, boron, chloride, lithium, and TDS) are generally most representative of the groundwater COI plume extent in three-dimensional space.

Isoconcentration maps and cross-sections use groundwater analytical data to spatially and visually define areas where groundwater COI concentrations are greater than the respective constituent background values and/or 02L/IMAC. Mean data of groundwater COI monitoring sampling results from February 2018 to May 2019 provide an understanding of groundwater flow dynamics and direction to define the horizontal and vertical extent of the COI plume. Horizontal extent of the COI plume is depicted on isoconcentration maps for (**Figures 6-13a** through **6-22**). Vertical extent of the COI plume is represented

with mean concentrations displayed on cross-sectional depictions of the Site. Cross-section A-A′ (**Figures 6-7a** through **6-7c**) is oriented northwest to southeast and displays the general north-south basin footprint topography and depth of saturated ash in the former Holdsclaw Creek channel and free water near the dam.

Beyond the compliance boundary, the maximum extent of COI-groundwater affected by the ash basin occurs in the limited area east of the ash basin towards the unnamed tributary.

6.1.4.1 COIs in Unsaturated Soil

(CAP Content Section 6.A.d.i)

Based on the unsaturated soil evaulation, there are no constituents in soil associated with the source area that require corrective action at the MSS. Unsaturated soil at or beyond the compliance boundary is considered a potential secondary source to groundwater. Constituents present in unsaturated soil or partially saturated soil (vadose zone) have the potential to leach into the groundwater system if exposed to favorable geochemical conditions for chemical dissolution to occur. Therefore, constituents considered for unsaturated soil evaluation as related to the ash basin and adjacent source areas were the same constituents identified as COIs in groundwater related to the source areas.

An evaluation of the potential nature and extent of COIs in unsaturated soil beyond the waste boundary was conducted using data from well installation activities and an additional soil sampling event in April 2019. The sampling event in April 2019 was conducted to better delineate unsaturated soils based on CSA Update comments made by NCDEQ (**Appendix B**). Unsaturated soil samples near or beyond the compliance boundary include samples collected from AB-2S, AL-1, CCR-5, CCR-9, CP-3D, GP-1D, GP-3D, GWA-1BR, BGSB-GWA-2, GWA-2DA, GWA-7, ILF-2D, MW-10, MW-14BR, PVSF-3BR, and PVSF-4D. Unsaturated soil analytical results (**Appendix C**, Table 4) are compared to background values or PSRG POGs, whichever is greater (**Table 6-3**). COIs in saturated soil are considered and evaluated as part of the groundwater flow system, separate from this evaluation.

Constituents detected at concentrations greater than either background values or the PSRG POG standard in unsaturated soil samples (depth),

upgradient or downgradient of the ash basin, are presented on **Figure 6-23**, and include:

- Arsenic: AL-1D (32-34)
- Barium: B-11 (6.5-7.5), GP-3D (2-3)
- Cobalt: B-11 (6.5-7.5), GP-3D (5-10)
- Iron: D-11 (0-1), PVSF-3BR (2-4), (6-8)
- Manganese: B-11 (6.5-7.5), GP-3D (5-10)
- Selenium: AL-1D (32-34)
- Sulfate: GP-1D (0-5)
- Thallium: B-11 (6.5-7.5)

Although greater than a comparative criteria, these concentrations were generally within the range of concentrations detected in soil samples from upgradient and/or background locations (**Appendix C**, Table 4). Additionally, all unsaturated soil samples with values reported greater than the PSRG POG standard or background values are vertically delineated by groundwater constituent concentrations less than applicable regulatory criteria in the corresponding monitoring well (**Appendix C**, Table 1). Furthermore, there is a lack of transport mechanisms by which the COI could have migrated from the source area to the unsaturated soils. For these reasons, the soil concentrations do not warrant consideration as potential secondary source of constituents to the groundwater.

Because all unsaturated soil concentrations are generally within range of background soil concentrations, and all soil concentrations are delineated by groundwater concentrations, which indicates there is no potential secondary source to groundwater from leaching of soil, and the lack of transport mechanisms, additional soil sampling is not warranted and no soil exceedances are identified for corrective action at the Site.

6.1.4.2 Horizontal and Vertical Extent of Groundwater in Need of Restoration

(CAP Content Section 6.A.d.ii)

This section discusses the horizontal and vertical extent of groundwater in need of restoration in areas east of the ash basin. Groundwater is not in need of restoration adjacent to the ash basin to the south, west, and north

due to the lack of COIs above applicable standards in these areas. A limited number of COIs in groundwater are present at or beyond the compliance boundary to the east of the MSS ash basin. Additional detail for this area is provided below.

Eastern Extent of COI-Affected Groundwater

Boron, chloride, lithium, and TDS mean concentrations near the compliance boundary support the following observations regarding the eastern extent COI-affected by the ash basin groundwater:

- The extent of COIs within the shallow and deep flow zones east of the ash basin have relatively similar geometries and extend beyond the compliance boundary toward the tributary to the east. This supports the interpretation that these two zones are hydraulically connected. Chloride, lithium, and TDS plumes are contained within the extent of the 02L boron plume.
- COI-affected groundwater within bedrock is relatively limited compared to the shallow and deep plume geometry, and contained within the extent of the shallow and deep groundwater COI plumes. This supports the limited vertical migration of COIs described in the CSM. The eastern extent of COI-affected groundwater in bedrock is limited to immediately downstream of the dam (AB-1), beneath the Dry Ash Landfill Phase I towards the tributary (AL-1), and beneath the Dry Ash Landfill Phase II (AL-2).
- Shallow, deep and bedrock COI-affected groundwater at concentrations greater than 02L standards is horizontally limited to the area east of the ash basin towards the unnamed tributary and immediately downstream of the dam. The plume is delineated to the north by GWA-7S/D, in the upper portion of the draw towards the tributary. The 02L boron plume is delineated to the south by MW-8S/D and the additional wells further south along the dam.
- The vertical extent of COI-affected groundwater in bedrock has been adequately delineated (**Figures 6-7a** through **6-7c**). East of the ash basin towards the tributary, the vertical extent of COIs is delineated by AL-1BRL (205 feet into bedrock), GWA-11BR (10 feet into bedrock), MW-14BRL (230 feet into bedrock), and GWA-15D – the deep flow zone well furthest downgradient toward the shoreline.

- Immediately downstream of the dam, the vertical extent of the 02L boron plume is delineated by AB-1BRLLL (320 feet into bedrock). The vertical extent of COI-affected groundwater beneath the Dry Ash Landfill Phase II, the area of the deepest known CCR-affected groundwater, is delineated by AL-2BRLLL (345 feet into bedrock).

The groundwater COI plume shape relates to hydraulic conditions associated with the flow-through system described in the CSM (**Section 5**). Upward and neutral gradients limit COI migration from the ash pore water to groundwater below ash and below the basin, except near the dam where a downward vertical hydraulic gradient promotes downward COI migration in groundwater and beneath additional source areas beyond the footprint of the ash basin, where the hydraulics described in the CSM might not apply.

Downgradient of the dam, groundwater flows upward toward the discharge zone (Lake Norman), limiting downward migration of COIs to the area adjacent to the dam. The extent of COI-affected groundwater east of the dam is limited by hydraulic conditions in that area. Below the ash basin dam, a strong upward gradient is observed between the bedrock wells and the shallow flow zone at well cluster AB-1 (-0.01 to -0.06 ft/ft; **Table 5-3**). Three of the four bedrock wells at this location are artesian wells. The hydraulic head of AB-1BR is approximately 0.02 feet below top of the flush-mounted casing.

6.1.5 COI Distribution in Groundwater

(CAP Content Section 6.A.e)

As step two of the constituent management process and the geochemical modeling evaluation, COIs were grouped by geochemical behavior and mobility (**Section 6.1.3** and **Appendix H**). An evaluation (*i.e.,* mean analysis and mobility groupings) of available data was used to demonstrate constituent distribution in groundwater to evaluate the spatial occurrence with a discernable plume in the direction of groundwater flow direction downgradient of the ash basin and adjacent source areas (**Table 6-6**). The evaluation grouped constituents into three mobility groups: conservative (non-reactive), non-conservative (reactive), and variably reactive.

6.1.5.1 Conservative Constituents

(CAP Content Section 6.A.e.i)

Isoconcentration maps for conservative COIs boron and TDS display simulated plumes from the groundwater flow and transport model (**Appendix G**) to provide insight where empirical data is not available. The model outputs are modified where empirical data can refine model assumptions. The transport model calibration targets are boron and TDS concentrations measured in 181 monitoring wells in the first quarter of 2019. All sampled wells are included in the calibration. However, more recent wells and data that have been collected since that timeframe were not included in the updated model calibration process. Fall 2019 data from newly installed wells suggest the model predictions are conservative; the model over-predicts the actual groundwater concentrations in some isolated areas.

Isoconcentration maps for boron (**Figures 6-13a-c**), chloride (**Figures 6-14a-b**), lithium (**Figures 6-17a-c**), and TDS (**Figures 6-21a-c**) mean isoconcentration maps and cross section (**Figure 6-7a**) support the following observations regarding the extent of COI-affected groundwater represented by these conservative constituents:

- The conservative COI plumes for the shallow and deep flow zones have relatively similar plume geometries, with boron generally representing the greatest extent of COI migration.
- COI migration east of the ash basin and Dry Ash Landfill Phase I represents the leading edge of the COI-affected groundwater plume beyond the ash basin compliance boundary.
- The extent of COI-affect groundwater plumes within bedrock groundwater are generally reduced in comparison to shallow and deep groundwater isoconcentration maps. This indicates limited vertical migration of COIs, further supporting the CSM (**Section 5**).
- COI-affected groundwater in bedrock is horizontally limited to wells at four clusters beneath the basin (AB-6, AB-10, AB-12, PVSF-2), beneath the Dry Ash Landfill Phase I (AL-1) and Phase II (AL-2), east of the basin towards the tributary (MW-14), and east of the ash basin dam (AB-1). The areas above, beyond or near the ash basin waste boundary, were specifically targeted for an evaluation of groundwater flow within the deep bedrock (**Appendix F**). Vertical

delineation of COIs at these locations was achieved in 2019 through the installation of deep bedrock monitoring wells (**Appendix C**, Table 1).

- Based on the results of the coal pile and PV Structural Fill assessments (**Appendix P**), one additional bedrock well is being installed at two locations for vertical delineation: northern corner of the coal pile (CP-1BR) and eastern perimeter of the PV Structural Fill (PVSF-2BRL). Results of the additional assessments will be available at a later date. The deepest extent of the bedrock groundwater plume is beneath the Dry Ash Landfill (Phase II), where COIs are present approximately 200 feet into bedrock (AL-2BRLL). These concentrations were delineated vertically (boron <50 µg/L) with the installation of AL-2BRLLL, screened approximately 345 feet into bedrock (**Appendix F**).
- Boron concentrations, which best-represent CCR-affected groundwater migration, are vertically and horizontally bounded downgradient of the basin, beyond the compliance boundary, by either discharge zones or concentrations less than applicable regulatory criteria. COI-affected groundwater delineation is demonstrated by detected constituent concentrations that are less than regulatory standard or are not detected from groundwater monitoring wells GWA-7S/D, GWA-10S/D, AL-1BRL, GWA-11BR, GWA-15D, MW-6D, CCR-9DA, MW-10S/D, AB-1BRLLL, MW-7D, and MW-8S/D. The downgradient groundwater discharge zones (*i.e.*, surface water receptors) limit COI migration.

The maximum extent of COI-affected groundwater migration for all flow zones is represented by boron, with the exception of sporadic exceedances of variably reactive COIs (*e.g.,* cobalt, lithium, manganese) along the southern portion of the dam. Chloride and TDS concentrations identified as being greater than their respective groundwater regulatory standards are associated with COI-affected groundwater migration from the ash basin but are generally confined within the extent of the 02L boron plume.

Plume Behavior and Stability

(CAP Content Section 6.A.e.i.1)

Mann-Kendall trend analysis was performed using conservative constituent (boron, lithium and TDS) datasets for ash pore water and groundwater

wells within the waste boundary, between the waste boundary and compliance boundary, and at or beyond the compliance boundary (**Table 6-7**). Trend analysis and results were prepared by Arcadis U.S. Inc. and are included as Attachment A in **Appendix I**.

The analysis was performed using analytical results for samples collected from 2011 through 2019, for COIs requiring corrective action (**Table 6-7**). Trend analysis results are presented where at least four samples were available and frequency of detection was greater than 50%. Statistically significant trends are reported at the 95% confidence level. The analysis of constituent concentrations through time produced six possible results:

1. Statically significant, decreasing concentration trend (D)
2. Statically significant, increasing concentration trend (I)
3. Greater than 50% of concentrations were non-detect (ND).
4. Insufficient number of samples to evaluate trend (n <4) (NE)
5. No significant trend, and variability is high (NT)
6. Stable. No significant trend, and variability is low (S)

A total of 1,628 trends were evaluated. Excluding the NE and ND trends described above, 80% of the remaining trends were statistically decreasing, stable or had no trend. Only 13% of the trends were statistically increasing (**Appendix I**).

Groundwater wells within the waste boundary generally had no trends or stable trends, suggesting limited changing conditions and that the groundwater plume is stable. Mann-Kendall results for ash pore water and groundwater within the waste boundary indicate the following:

- Over 50% of ash pore water trend results indicate no trends for conservative constituents (*i.e*. boron, chloride, lithium and TDS) and approximately 30% of trend results indicate stable trends for these conservative constituents (**Table 6-7**).
- The data indicate overall improvements in groundwater COI concentrations.
- For shallow groundwater, increasing trends for TDS are grouped along the dam (wells CCR-05S, MW-08S, and MW-09S).

- In the deep and bedrock flow zones, boron and TDS are the most prevalent constituents with increasing concentration trends. These wells tend to be grouped along the dam and near the Dry Ash Landfill (Phase I).
- Wells with increasing COI concentration trends are generally located within the areas planned for groundwater remedial actions or are located in upgradient areas, which will also be addressed by the selected groundwater remedy (**Section 6.8**).

6.1.5.2 Non-Conservative Constituents
(CAP Content Section 6.A.e.ii)

Strontium mean isoconcentration maps (**Figures 6-20a-c**) and cross section (**Figure 6-7b**) support the following observations regarding the extent of COI-affected groundwater represented by this non-conservative constituent:

- The extent of strontium concentrations greater than background in all three groundwater flow zones are similar, with a reduced extent in bedrock, a trend similar to the distribution of conservative COIs (*i.e.*, concentration less than background at downgradient bedrock well GWA-11BR). The horizontal extent is generally contained within the ash basin waste boundary, beneath the Dry Ash Landfill Phase I and Phase II, and localized areas east of the basin toward the unnamed tributary.

6.1.5.3 Variably Conservative Constituents

Cobalt (**Figure 6-15**), iron (**Figures 6-16a-b**), manganese (**Figures 6-18a-c**), radium (total) (**Figures 6-19a-b**), and thallium (**Figure 6-22**) isoconcentration maps and cross section (**Figure 6-7c**) support the following observations regarding the extent of COI-affected groundwater represented by these variably reactive constituents:

- Contours of the variably reactive COIs within the shallow flow zone indicate concentrations greater than applicable regulatory criteria are sporadic, but are generally limited to the following areas: southern portion of ash basin (north of coal pile) and southern portion of dam, east of the ash basin and Dry Ash Landfill Phase I toward the unnamed tributary, east of PV Structural Fill, and beneath Dry Ash Landfill Phase II (AL-2). These localized plumes generally coincide

with the extent of conservative COIs, with the exception of the sourthern portion of the dam, where boron concentrations are less than the 02L standard.

- Deep flow zone groundwater COI plumes are limited to the following areas: primarily within the former perennial stream valley within the ash basin, PV Structural Fill, as well as isolated occurrences beyond Dry Ash Landfills (Phase I and Phase II).
- The greatest extent of variably reactive COIs in the deep flow zone is represented by manganese concentrations, which coincide with the areas mentioned above for the shallow zone (southern ash basin, ash basin dam, and east of the Dry Ash Landfill Phase I). Total radium is only detected above background in two deep flow zone wells – both east of the Dry Ash Landfill Phase I (AL-1D and GWA-15D).
- The extent of iron, manganese, and total radium concentrations in bedrock groundwater greater than applicable regulatory criteria generally overlap, with affected areas typically including: beneath the Dry Ash Landfill Phase II (AL-2) and central ash basin (AB-6, AB-10, AB-12), east of the Dry Ash Landfill Phase I (AL-1), and east of the basin dam (AB-1). Similar to conservative COIs, the COI-affected groundwater distribution is limited compared to the distribution within shallow and deep groundwater (*i.e.,* manganese).

6.2 Potential Receptors Associated with Source Area
(CAP Content Section 6.B)

CSA results indicate COI-affected groundwater has migrated to localized areas immediately downgradient of the MSS ash basin. COI-affected groundwater is limited to Duke Energy property. Flow and transport simulations predict limited migration in areas beneath Lake Norman immediate to the shoreline. In addition, these predictive model simulations may overestimate the extent of the COI migration beneath the lake because the predominant strike of bedrock fractures – and anticipated groundwater flow - is parallel to the shoreline rather than perpendicular to it. COI-affected groundwater from the ash basin does not reach any water supply wells, and modeling indicates this will remain the case in the future. Therefore, potential receptors are limited to Lake Norman and the unnamed tributary east of the ash basin. As the updated human health and risk assessment concluded, there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS (**Appendix E**). This conclusion is

further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

6.2.1 Surface Waters – Downgradient Within 0.5-Mile Radius of the Waste Boundary

(CAP Content Section 6.B.a)

A depiction of surface water features – including wetlands, ponds, unnamed tributaries, seeps, streams, lakes, and rivers – within a 0.5-mile radius of the ash basin compliance boundary is provided in **Figure 5-6** (*CAP Content Section 6.B.a.i and 6.B.a.ii*). The 0.5-mile radius from the ash basin compliance boundary, for which data is evaluated and depicted on figures, is greater than the required 0.5-mile radius of the waste boundary and is consistent with the water supply well survey. Surface water information is provided from the NRTR (AMEC, 2015). In addition, NPDES-permitted outfalls and locations covered by the SOC are shown on **Figure 5-6**. Non-constructed and dispositioned seep sample locations between the ash basin and Lake Norman are managed by the SOC and are subject to the monitoring and evaluation requirements contained in the SOC. Non-constructed seeps, currently covered under the SOC, that have the potential to not be fully dispositioned post-decanting are listed on **Table 6-8**. No constructed seeps are present at the MSS.

For groundwater corrective action to be implemented under 15A NCAC .02L .0106(k), groundwater discharge to surface water cannot result in exceedances of standards for surface waters contained in 15A NCAC 02B .0200 (02B). Surface water constituents with 02B standards include: arsenic, barium, beryllium, cadmium, chloride, chromium (hexavalent and trivalent), copper, fluoride, lead, mercury, nickel, nitrate and nitrite, selenium, silver, sulfate, total dissolved solids, thallium, total hardness, and zinc.

Surface water samples were collected from Lake Norman to confirm groundwater downgradient of the ash basin has not resulted in surface water concentrations greater than 02B water quality standards. A map of all surface water sample locations for groundwater discharge to surface water evaluation is included in **Appendix J** (*CAP Content Section 6.B.a.iv*). Surface water samples were collected to evaluate acute and chronic water quality values. Surface water samples were also collected at background locations (upstream of potential migration areas) within Lake Norman and minor streams upgradient of the source area. Analytical results were evaluated with respect to 02B water quality standards and background data.

Comparisons of surface water data with the applicable USEPA National Recommended Water Quality Criteria for Protection of Aquatic Life, Human Health and/or Water Supply (USEPA, 2015; 2018a; 2018b) was conducted on surface water samples from background locations, the unnamed tributary and Lake Norman. As stated by the USEPA, these criteria are not a regulation, nor do they impose a legally-binding requirement. Therefore, comparisons with these criteria are only for situational context. The constituents that have corresponding USEPA criteria but do not have 02B criteria are alkalinity, aluminum, antimony, iron and manganese (**Appendix J**).

Antimony was not detected in any of the surface water samples tested. Conversely, manganese was detected above the USEPA criterion at all locations, including background locations in Lake Norman, indicating that it is endemic to the area. Alkalinity and iron exceeded the USEPA criteria for the samples from the on-site background streams, but not in the surface water samples from the tributary, seep or lake. However, the few background exceedances for alkalinity were generally comparable to the screening criterion. Aluminum exceeded the USEPA criteria in the on-site background streams, the Lake Norman shoreline, and AOW seep location.

The surface water samples were collected in accordance with NCDEQ DWR Internal Technical Guidance: *Evaluating Impacts to Surface Water from Discharging Groundwater Plumes* - October 31, 2017. The full report for MSS groundwater discharge to surface water and the evaluation of surface waters to evaluate compliance with 15A NCAC 02B .0200 was submitted to NCDEQ on March 22, 2019. Surface water data has been reevaluated as a result of surface water quality standards updated by NCDEQ on June 6, 2019. The revised report is provided in **Appendix J**.

General findings of the evaluation of current surface water quality conditions at MSS include:

- Groundwater migration from the ash basin source area has not resulted in exceedances of the 15 NCAC 02B surface water quality standards in Lake Norman.
- Previously identified seeps are deemed covered by Special Order by Consent EMC SOC WQ S17-009 (SOC).

Surface Water – Future Conditions Evaluation

Based on current and future surface water evaluations, along with relevant media assessments, no COIs require remediation in surface water at MSS. An evaluation of potential future groundwater migration to surface water was conducted to identify areas where further evaluation might be warranted. For areas of potential future groundwater migration to surface water, a mixing model approach was used for the evaluation of future surface water quality conditions. Flow and transport modeling results were used to determine where groundwater migration from the ash basin might intersect surface water in the future. A groundwater to surface water mixing model approach was used to determine the potential surface water quality in the future groundwater discharge zones. The full report for MSS groundwater discharge to surface water under future conditions can be found in **Appendix J**.

General findings of the evaluation of future surface water conditions in potential groundwater discharge areas include:

- The evaluation demonstrates that under the closure-by-excavation scenario and the closure-in-place scenario, future groundwater migration from the ash basin would not result in constituent concentrations in Lake Norman or the unnamed tributary east of the ash basin greater than 02B surface water standards. The criteria for compliance with 02B is met, allowing further evaluation of potential corrective action under 15A NCAC 02L .0106 (k) or (l).
- Because this evaluation demonstrates that predicted resultant constituent concentrations in surface waters are less than 02B surface water standards, the results and conclusions of this evaluation support future corrective action termination under 15A NCAC 02L .0106 (m).

6.2.2 Water Supply Wells

(CAP Content Section 6.B.b)

A total of 127 private water supply wells and one public supply well were initially identified within the 0.5-mile radius of the ash basin compliance boundary (**Figure 5-7**). Most of these water supply wells are located north and west of the ash basin, along Sherrills Ford Road and Island Point Road.

No public or private drinking water wells or wellhead protection areas were found to be located downgradient of the ash basin, as discussed in **Section 5.4**. This finding has been supported by field observations, a review of public

records, an evaluation of historical groundwater flow direction data and results of groundwater flow and transport modeling (**Appendix G**). The location and information pertaining to water supply wells located upgradient or side-gradient of the facility, within 0.5 miles of the ash basin compliance boundary, were included in drinking water supply well survey reports.

6.2.2.1 Provision of Alternative Water Supply
(CAP Content Section 6.B.b.i)

Although results from local water supply well testing do not indicate effects from the source area at MSS, water supply wells identified within the 0.5-mile radius from the ash basin compliance boundary have been offered alternate water supply, per G.S. Section 130A-309.211(c1) requirements. No sampled water supply wells were deemed impacted by COI-affected groundwater. **Appendix C**, Table 1 summarizes analytical results for supply wells associated with the Site.

- Property eligibility was contingent that the property did not include:
- A business
- A church
- A school
- Connection to the public water supplier
- An empty lot

Of the 127 private water supply wells, Duke Energy identified a total of 79 eligible households near MSS qualifying for a permanent water solution. Of the 79 eligible households, 14 either opted out of the option to connect to a water treatment system or did not respond to the offer. Duke Energy installed water filtration systems on 3 households, and 62 households were connected to the public water supplier by Duke Energy in accordance with G.S. Section 130A-309.211(c1).

Additionally, Duke Energy voluntarily provided permanent water solutions to six properties, including businesses and churches, within a 0.5-mile of the MSS compliance boundary that were otherwise not eligible per G.S. Section 130A-309.211(c1).

On August 31, 2018, Duke Energy provided completion documentation to NCDEQ to fulfill the requirements of House Bill 630. NCDEQ provided

correspondence, dated October 12, 2018, to confirm that Duke Energy satisfactorily completed the alternate water provisions under G.S. Section 130A-3099.211(c1) at MSS. Both documents are provided in **Appendix D**.

Figure 5-8 illustrates properties within the 0.5 mile radius of the ash basin compliance boundary with reference to water treatment systems installed, along with vacant parcels and residential properties whose owners have decided to either opt out of the water treatment system program or did not respond to the offer. On-going periodic maintenance is provided by Duke Energy for the filtration system in accordance with the *Permanent Water Supply – Water Treatment Systems, Performance Monitoring Plan* (Duke Energy 2017). **Figure 5-7** shows the private and public water supply well locations and NCDEQ sample numbers.

6.2.2.2 Findings of Drinking Water Supply Well Surveys
(CAP Content Section 6.B.b.ii)

Results from surveys conducted to identify potential receptors for groundwater, including public and private water supply wells and surface water features within a 0.5-mile radius of the ash basin compliance boundary, have been reported to NCDEQ:

- *Drinking Water Supply Well and Receptor Survey, Marshall Steam Station Ash Basin* (HDR, 2014a)
- *Supplement to Drinking Water Supply Well and Receptor Survey, Marshall Steam Station Ash Basin* (HDR, 2014b)
- *Comprehensive Site Assessment Supplement 2, Marshall Steam Station* (HDR, 2016b),
- *2018 Comprehensive Site Assessment Update, Marshall Steam Station* (SynTerra, 2018a)

As documented in the 2018 CSA Update (SynTerra, 2018a), NCDEQ coordinated sampling of private water supply wells identified within a half-mile radius of the ash basin compliance boundary from February to October in 2015. NCDEQ performed sampling and analysis of the water supply wells identified within the 0.5 mile radius of the ash basin compliance boundary, if the owner agreed to have their well sampled. No sampled water supply wells were determined to be impacted by COI-affected groundwater. Analytical results for supply wells associated with the Site are

discussed in **Section 5.3.3** and included in **Table 6-9** (*CAP Content Section 6.B.b.ii* and *6.B.b.iii*) and **Appendix C,** Table 1 (*CAP Content Section 6.B.b.ii*).

No public or private drinking water wells or wellhead protection areas were found to be located downgradient of the ash basin. This finding has been supported by field observations, a review of public records, evaluation of historical groundwater flow direction data, and results of groundwater flow and transport modeling (**Appendix G**). The location and information pertaining to water wells located upgradient or side-gradient of the Site, within 0.5-miles of the compliance boundary, were included in the survey reports noted below.

The initial survey identified four public water supply wells within a 0.5-mile radius of the ash basin compliance boundary; however, one of those wells is not currently in use. Two water supply wells classified as transient, non-community are located at the Midway Restaurant and Marina and The Old Country Church. Both of these wells are located west and upgradient of the MSS ash basin. The Catawba County Environmental Health Department had records for one public water supply well owned by Duke Energy, which is not used for consumption.

A total of 127 private water supply wells were initially identified within the 0.5-mile radius of the ash basin compliance boundary. Most of these water supply wells are located north and west of the ash basin, along Sherrills Ford and Island Point Roads (**Figure 5-7**). All of the private water supply wells are located either upgradient or side-gradient of the ash basin.

6.2.3 Future Groundwater Use Areas
(CAP Content Section 6.B.c)

Duke Energy owns the land and controls the use of groundwater on the land downgradient of the ash basin area within and beyond the predicted area of potential groundwater COI influence. Therefore, no future groundwater use areas are anticipated downgradient of the ash basin and adjacent source areas.

It is anticipated that residences within a 0.5-mile radius of the ash basin compliance boundary will continue to rely on municipal water or groundwater resources for water supply for the foreseeable future; therefore, Duke Energy will provide periodic maintenance of the provided water treatment systems for each household that accepted the alternative water supply [(**Figure 5-8**) *(CAP Content Section 6.B.c.i)*].

Based on future predicted groundwater flow patterns, under post ash basin closure conditions, and the location of water supply wells in the area, groundwater flow direction from the ash basin is expected to be further contained within the stream valley and continue flowing south/southeast of the ash basin footprint, and therefore will not flow towards any water supply wells [(**Appendix G**) *(CAP Content Section 6.B.c.ii)*].

6.3 Human and Ecological Risks

(CAP Content Section 6.C)

Updated human health and ecological risk assessments were prepared for the MSS consistent with the CAP content guidance. The updated risk assessments incorporate results from surface water, sediments, and groundwater samples collected March 2015 through June 2019. Primary conclusions from the risk assessment updates include:

1. The ash basin does not cause an increase in risks to potential human receptors located on-Site or off-Site.
2. The ash basin does not cause an increase in risks to ecological receptors.

These conclusions are further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program. A more detailed discussion regarding human health and ecological risk associated with the ash basin can be found in **Section 5.4**. An update to the MSS human health and ecological risk assessment is included in **Appendix E.**

6.4 Description of Remediation Technologies

This section provides supplemental information beyond the CAP content guidance to introduce groundwater remediation technologies and considers a range of individual technologies that might be used to formulate comprehensive groundwater remediation alternatives for consideration at MSS. The most feasible remedial options identified will form the basis, in whole or in part, for the remedial alternatives evaluated in **Section 6.7**. Groundwater remediation technologies will be evaluated based upon two primary criterions:

- Can a technology be effective when addressing one or more site-specific COIs?
- Can a technology be feasibly implemented under site-specific conditions and be effective?

The remedial alternative screening includes the criteria in the NCDEQ CAP Guidance (April 27, 2018). Technologies that are clearly not workable under Site conditions will

not be carried forward. Technologies that have potential application will be retained for further consideration. Technologies retained for further consideration might be used to formulate comprehensive groundwater remedial alternatives in **Section 6.7**.

6.4.1 Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) is a groundwater remedy that relies on natural processes to reduce constituent concentrations in groundwater over time. The primary objective of an MNA strategy is to identify and quantify natural attenuation processes specific to a site and demonstrate that those processes will reduce constituent concentrations in groundwater to levels that below regulatory standards (USEPA, 1999).

MNA processes potentially applicable to inorganic constituents include:

- Dispersion
- Dilution
- Transformation
- Sorption
- Radioactive decay
- Phyto-attenuation
- Biological stabilization
- Chemical stabilization

Dilution from recharge to groundwater, mineral precipitation, and COI adsorption will occur over time and distance from the source area, thereby, reducing COI concentrations through attenuation. MNA can be used in combination with other remediation technologies such as source control. Routine monitoring of select locations for COI concentrations is used to confirm the effectiveness of the approach.

The USEPA does not consider MNA to be a "no action" option. Source control and long-term monitoring are fundamental components of any MNA remedy. Furthermore, MNA is an alternative means of achieving remediation objectives that might be appropriate for specific, well-documented site circumstances where its use will satisfy applicable statutory and regulatory requirements (USEPA, 1999).

The USEPA, as shown below, considers MNA to be in-situ (USEPA, 1999):

> *The term "monitored natural attenuation", as used in this Directive, refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a time frame that is reasonable compared to that offered by other more active methods. The "natural attenuation processes" that are at work in such a remediation approach include a variety of physical,*

> *chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization…"*

MNA is compared with other viable remediation methods during the remedy selection process. MNA should be selected only if it will meet site remediation objectives within a timeframe that is reasonable compared to that offered by other methods (USEPA 1999). A contingency remedy should be proposed at the time MNA is selected to be a site remedy (NCDWM, 2000).

The NCDEQ and USEPA have guidance documents that prescribe the investigative and analytical processes required for an MNA demonstration (NCDEQ, 2017). NCAC 02L provides additional requirements for MNA implementation. USEPA developed a tiered approach to support evaluation and, if appropriate, selection of MNA as a remedial technique (USEPA, 2007). Three decision tiers require progressively greater site information and data to assess the potential effectiveness of MNA as a remedy for inorganic constituents in groundwater.

MNA is retained for further consideration at MSS because groundwater COIs do not pose unacceptable risk to human health or the environment under conservative exposure scenarios and a source control measure will be implemented that eliminates or mitigates the source of CCR constituents in groundwater. The MNA evaluation for the technical applicability at MSS is provided in **Appendix I**.

6.4.2 In-Situ Technologies

Groundwater remediation technologies implemented in-situ, or in-place, are discussed below.

Low Permeability Barriers

When used for groundwater remediation, low permeability barriers (LPBs) are structures constructed in-situ to redirect or contain groundwater flow. Materials used to construct LPBs are either impermeable (*e.g.,* steel sheet pile) or have a permeability that is at least two orders of magnitude lower than the permeability of the saturated media that comprises a targeted groundwater flow path. For this reason, LPBs are typically keyed into a natural barrier to groundwater flow, such as a competent confining unit (*e.g*., aquitard) or bedrock to prevent groundwater from flowing under the LPB.

LPBs can be used to redirect groundwater away from a potential receptor, redirect groundwater away from a source area, or redirect COI laden groundwater towards a groundwater extraction system or in-situ groundwater treatment system (*e.g.*, permeable reactive barrier). The design and technique used to construct an LPB typically depends upon the length of the LPB, the depth to a competent confining layer or bedrock, and cost considerations. Sheet piling, trenching, and vertical drilling are the most common means to construct an LPB. Sheet piling and trenching are typically limited to depths of approximately 50 feet whereas installation of an LPB using drilling techniques can achieve depths greater than 50 feet. For this reason, construction of an LPB at MSS would involve installation by means of drilling because bedrock is approximately 80 feet below the ground surface at locations downgradient and east of the MSS ash basin.

Construction of an LPB at MSS would involve drilling to competent bedrock and injecting bentonite or cement grout into fractured bedrock, the transition zone, and possibly into saprolite flow zones. Keying the LPB into a natural barrier to groundwater flow such as a competent confining unit (*e.g.*, aquitard) or bedrock cannot be achieved with certainty due to the complex Piedmont geology present at the MSS. Installation of an effective low permeability barrier to depths approaching 80 feet would be technically challenging and costly. Another drawback to the implementation of an LPB over a large area is that it could cause groundwater to mound behind the barrier. This could increase the gradient and induce COIs to migrate downward, or result in groundwater flow around the barrier, possibly resulting in the migration of COIs into other areas of the Site. For these reasons, LPB technology will not be retained for further consideration.

Groundwater Infiltration and Flushing

In-situ groundwater flushing involves infiltration or injection of clean water into groundwater to accelerate flushing of target constituents. Constituents mobilized by flushing would be captured by an extraction well. Flushing can enhance natural constituent transport mechanisms such as advection, dispersion, and molecular diffusion. This technology is potentially applicable to a broad range of constituents. Furthermore, in-situ flushing has potential applicability at almost any depth. However, successful implementation is site-specific. Factors influencing the effectiveness include the degree of subsurface heterogeneity, the variability of hydraulic conductivity, and organic content of soil. Suitability testing of the clean water source and pre-design collection of data is important for most sites where this technology might be considered.

In-situ flushing can also be used to enhance conventional pump and treat technology at locations with limited natural recharge or low permeability. The introduction of clean water into groundwater enhances groundwater flow by increasing the hydraulic gradient between the point of infiltration and the point of extraction or discharge. Addition of clean water can mobilize COIs, such as boron, and enhance the hydraulic gradient to improve hydraulic capture of COIs.

Groundwater flushing by infiltration can be accomplished by many methods including vertical wells, horizontal wells, and infiltration galleries. Groundwater flushing is a technology that has possible application at MSS to enhance the capture of mobile constituents. Groundwater flushing is retained for further consideration.

Encapsulation

Encapsulation technologies act to prevent waste materials and constituents from coming into contact with potential leaching agents such as water. Materials used to encapsulate a waste must be both chemically compatible with the waste and inert to common environmental conditions such as rain infiltration, groundwater flow, and freeze/thaw cycles (USEPA 2002). Waste materials can generally be encapsulated in three ways: microencapsulation, macroencapsulation or in-situ vitrification (ISV).

Microencapsulation involves mixing the waste together with the encasing material before solidification occurs. Macroencapsulation involves pouring the encasing material over and around a larger mass of waste, thereby enclosing it in a solidified block. Grout, sulfur polymer stabilization/solidification, chemically bonded phosphate ceramic encapsulation, and polyethylene encapsulation are examples of the techniques that have been used to improve the long-term stability of waste materials (USEPA 2002). ISV involves the use of electrical power to heat and melt constituent laden soil and buried waste (*e.g.*, ash). ISV uses an array of electrodes that are inserted into the ground. Electrical power is applied to the electrodes, which establishes an electric current through the soil. The electric current generates sufficient heat (>2500˚F) to melt subsurface soil and waste materials. The molten material cools to form a hard monolithic, chemically inert crystalline glass-like product with low leaching characteristics (USEPA 1994). Two additional considerations associated with this technology are permanence of the reaction product insolubility and the ability to distribute reactants sufficiently to ensure adequate contact with the COIs.

Contact between the encasing material and affected media could pose a challenge in the transition zone and fractured rock formations. It is difficult to ensure that encasing material are uniformly distributed in transition zone and fractured bedrock to assure adequate encapsulation of affected media.

Microencapsulation and ISV would not be feasible for the areas south and southeast of the ash basin that would need to be encapsulated, due to the size and depths of the areas requiring groundwater remediation.

Encapsulation technologies are not carried forward for further evaluation for the following reasons:

- The area and depth requiring groundwater remediation is greater than feasible for this technology, which is best implemented in areas of limited size or extent.
- The varied geological conditions pose the unlikelihood that the performance of an implemented technology will be uniform.

Permeable Reactive Barrier

The USEPA defines a permeable reactive barrier (PRB) as being:

> *An emplacement of reactive media in the subsurface designed to intercept a contaminant plume, provide a flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals down-gradient of the barrier (USEPA 1997).*

Construction of PRBs involves emplacement of reactive media below the ground surface for the purpose of treating groundwater containing dissolved COIs. The PRB media is designed to be more hydraulically conductive than the saturated media surrounding the PRB so that groundwater will flow through the PRB media with little resistance. The depth and breadth of PRBs are oriented perpendicular to groundwater flow direction so that the PRB will intercept groundwater targeted for treatment. Design of the PRB thickness takes into account groundwater velocity and the need to provide sufficient groundwater residence and contact time for constituents to react with PRB media. PRBs can be installed as permanent or semi-permanent treatment units. The PRB reactive media in a permanent treatment unit is designed to remain emplaced over the needed timeframe whereas the reactive media in a semi-permanent treatment unit is designed to be replaced periodically once it is spent.

Two of the most common PRB designs are the continuous wall and the "funnel and gate." The continuous wall design involves the installation of a trench downgradient of a constituent plume and oriented perpendicular to groundwater flow. The funnel and gate configuration involves construction of two LPBs that redirect groundwater flow toward the PRB. This allows for a smaller PRB design and treatment of a greater volume of groundwater. A design factor for both designs is the ability for the PRB to be keyed into a low permeability confining layer or into bedrock to minimize the potential for groundwater underflow beneath the PRB.

Media commonly used in PRBs for the treatment of inorganic COIs includes zero-valence iron (ZVI), apatite, zeolites, and organic materials used to affect groundwater Eh and pH. The mechanisms that take inorganic constituents out of solution include adsorption, ion exchange, oxidation-reduction, or precipitation.

ZVI (Fe^0) is an effective reducing agent as it readily donates electrons to receptor molecules or constituents ($Fe^0 \rightarrow Fe^{+2} + 2e^-$). ZVI particles can remove divalent metallic cations through reductive precipitation, surface adsorption, complexation, or co-precipitation with iron oxyhydroxides. ZVI has been used to treat cationic metals such mercury (Hg^{+2}), nickel (Ni^{+2}), cadmium (Cd^{+2}), and lead (Pb^{+2}) (USEPA, 2009).

Apatite is a media used in PRBs to treat groundwater for the removal of certain metals in solution including lead, cadmium, and zinc. Apatite refers to a group of crystalline phosphate minerals; namely, hydroxylapatite, fluorapatite and chlorapatite. Apatite II™ is an amorphous form of a carbonated hydroxy-apatite that has random nanocrystals of apatite embedded in it. The apatite nanocrystals are capable of precipitating various phosphate phases of metals and radionuclides. Apatite II is also an efficient non-specific surface adsorber (Wright 2003).

Zeolite is any of a large group of minerals consisting of hydrated aluminosilicates of sodium, potassium, calcium, and barium. Zeolites have large internal surface areas capable of treating inorganics by both adsorption and cation exchange.

Limestone and materials containing limestone, such as recycled cement, can be used as a PRB media for raising the pH of acidic groundwater, like the pH found in mine runoff (Indraratna 2010).

Sulfate reduction facilitated by naturally occurring bacteria has been shown to effectively treat acidic to net alkaline groundwater containing dissolved heavy metals, including aluminum, in a variety of situations. The chemical reactions are facilitated by the bacteria *desulfovibrio*. This is a well-proven technology often used to treat acidic runoff from historic mining operations.

It would be technically challenging and cost prohibitive to construct an effective PRB in saprolitic/transition zone material up to 80 feet thick. PRB technology would be better suited to treat coal ash constituents that are less mobile and more reactive than boron.

The ability to maintain adequate reactive amendment concentrations at depth over an extended period of time is also a significant operational and performance consideration.

Elevated concentrations of non-target metals constituents dissolved in groundwater (*e.g.,* aluminum) can become problematic because they might precipitate within the treatment zone. The barrier could also become clogged and a large reduction in hydraulic conductivity could occur. Given the depth of these barriers, in-situ rehabilitation of the reactive media is considered infeasible; therefore, walls would have to be reconstructed on a periodic basis to address clogging or effectiveness of the chemical amendments. Given these limitations, constructed wall PRB technology will not be considered for application at the MSS Site.

A PRB, however, could also be implemented by the infiltration of chemical amendments into the subsurface through a grid of closely spaced vertical boreholes. This approach would emplace reactive chemicals in contact with affected groundwater so that treatment could occur in-situ as the groundwater migrates through the zone of infiltration. Should replenishment of the amendments be necessary in the future for continued groundwater treatment effectiveness, additional boreholes would be installed for the infiltration of the additional amendments. The placement of chemical amendments through drilled boreholes as a permeable reactive barrier is retained for further consideration to treat reactive COIs along the southern end of the dam at the MSS Site.

6.4.3 Groundwater Extraction

Groundwater extraction is often used when remediating mobile constituents in groundwater. Groundwater extraction can be used to withdraw affected groundwater from the subsurface for the purpose of reducing the mass of one or

more target constituent(s) in an aquifer. Groundwater extraction can be used to hydraulically contain affected groundwater and mitigate groundwater constituent migration. Groundwater extraction can be conducted using a variety of methods that are discussed in the following sub-sections.

Vertical Extraction Wells

A vertical well is the most common design for groundwater extraction. Drilling techniques used to install vertical groundwater extraction wells range from direct push technology, to hollow stem auger, mud rotary, air rotary, sonic drill rigs, and other methods. Groundwater extraction wells can be designed and screened in unconsolidated saturated media such as sand, saprolite, alluvium, transition zone, fractured bedrock, silts, and clays. Alternatively, groundwater extraction wells installed in bedrock can be completed as open-hole borings.

Low yielding aquifers can be problematic for vertical extraction wells. Relatively close spacing of vertical wells might be necessary to capture a constituent plume if the aquifer yield is low. Enhanced yield can be accomplished through infiltration of clean water upgradient of the wells to increase the availability of water and hydraulic head. Alternatively, low yielding wells can be effective through intermittent pumping to remove sorbed constituents with each pump cycle.

Pump options include submersible pumps and centrifugal pumps depending upon the anticipated yield, depth to water and well diameter. Shallow centrifugal pumps (shallow well jet pumps) can be used in small diameter wells where the groundwater level and desired pumping level is relatively shallow (less than 25 to 30 feet below the ground surface). Submersible pumps (deep-well jet pumps) can be used to extract groundwater from larger diameter wells with deeper groundwater levels. Deep-well jet pumps have the advantage of mechanical equipment above grade, and power needs to be provided to only a few pump stations rather than to every well, as with submersible pump systems. All require routine maintenance of the pumps, vaults, piping and well screens to sustain desired performance.

Groundwater modeling conducted for MSS indicates that vertical groundwater extraction wells can produce sufficient yield for effective constituent mass removal without supplemental measures. The use of vertical groundwater extraction wells is retained for further consideration.

Horizontal/Angular Extraction Wells

Horizontal groundwater extraction wells offer advantages over vertical groundwater extraction wells when access is difficult or to reduce the number of system elements requiring maintenance. For example, horizontal wells can be installed below buried utilities, buildings, and similar surface or near surface features. Also, horizontal wells are more efficient and effective when remediating constituent plumes distributed over a large area within a relatively thin flow zone. Fewer horizontal wells would be required under this scenario compared to the number of vertical wells that might be required to achieve similar remediation goals. Furthermore, recovery efficiency might be increased relative to vertical wells due to the ability of a single horizontal well to contact a larger horizontal area, particularly where the horizontal groundwater transmissivity is greater than the vertical transmissivity.

Installation of a directionally drilled horizontal well involves a drill bit that can be steered in three dimensions. The progress of directional boring installations is precisely monitored to avoid subsurface obstructions and to install the well as designed. Tracking accuracy generally decreases with increased depth of installation. Site hydrogeologic conditions can affect tracking accuracy during drilling.

Directionally drilled horizontal wells can be completed as blind holes (single-end completion) or surface-to-surface holes (double-end completion). Single-end holes involve one drill opening, with drilling and well installation taking place through this single opening. Borehole collapse might be more likely in single-ended drilling since the hole is left unprotected between drilling and reaming and between reaming and casing installation. An additional complication associated with single-ended completion involves the precise steering of reaming tools required to match the original borehole path. In contrast, double-end holes are typically easier to install since reaming tools and well casing can be pulled backward from the opposite opening, and the hole does not have to be left open.

Materials used for horizontal wells are typically the same or similar to those used for vertical wells. Factors to consider in the choice of the well screen and casing materials to be used with horizontal wells include axial strength, tensile strength, and flexibility (Miller, 1996).

Angle drilled wells are constructed in the same way as a vertical well with the exception that the drill rig mast is positioned at an angle that is purposely not plumb. The drilling mast angle and the targeted drilling depth will determine

horizontal offset of the well screen and submersible pump from the location where drilling was initiated. Otherwise, angled wells function in the same manner as vertical wells.

Installation through transition zones of saprolite and partially weathered rock can be challenging. Horizontal wells can be more costly to install as compared to vertical or angular wells, but can often replace more than one vertical well. Horizontal or angular wells could be used at MSS to effect remediation beneath areas not accessible from land surface (*e.g.,* beneath the ash basin spillway).

Groundwater modeling conducted for MSS indicates that vertical groundwater extraction wells can produce sufficient yield for the purposes of hydraulic containment and/or constituent mass removal. Vertical extraction wells are deemed more cost effective. The use of horizontal or angular groundwater extraction wells is not retained for further consideration.

Extraction Trenches

Shallow horizontal groundwater extraction (collection or intercept) trenches can be installed in areas near surface waters where groundwater might discharge. These trenches can be utilized to prevent groundwater from discharging into surface waters and can be effective in lowering or managing the water table.

Trenches might be used as temporary installations to intercept and monitor subsurface flow or can be retained as a permanent installation. Trenches must be deep enough to tap and provide an outlet for ground water that is in shallow, permeable strata or in water-bearing sand. The spacing of trenches varies with soil permeability and drainage requirements.

Extraction trenches function similar to horizontal wells but are installed with excavation techniques. They can be cost-effective to construct at shallow depths (less than or equal to 35 feet bgs) using conventional equipment. Trenches can be installed to depths of approximately 50 feet below ground surface using specialty equipment. Horizontal collection trenches are usually not cost-effective for deeper installations or bedrock applications. Horizontal collection trenches do have the advantage of generally having lower operations and maintenance costs compared with the costs of multiple vertical wells.

Shallow trenches are easy to install and can be an effective surface water protection supplement to a groundwater management system. If applied at MSS, trench technology effectiveness would be limited if used for the purpose of

groundwater extraction. The thickness of saprolite/transition zone downgradient of the ash basin is up to approximately 80 feet below ground surface. The use of horizontal extraction trenches will not be retained for further consideration.

Hydraulic Fracturing

The effectiveness of groundwater extraction systems can sometimes be improved in low permeability formations, including bedrock, with the use of hydraulic fracturing techniques.

Pneumatic fracturing involves injection of highly pressurized air into consolidated sediments to extend existing fractures and create a secondary network of fissures and channels. Similarly, hydraulic fracturing involves the use of high-pressure water or polymers to extend existing fractures and create a secondary network of fissures and channels.

Hydraulic fracturing generally involves the application of high pressures to propagate existing fractures or to create fractures following fracture nucleation. When hydraulic fracturing is applied to unconsolidated materials, a disk-shaped notch that serves as the starting point for the fracture is created with high-pressure water to cut into the formation. Pumping of a slurry of water and sand in a thick gel at high pressures, into the borehole propagates the fractures. Proppants are typically well-rounded, very coarse-grained quartz sand. The polymer is then broken or biodegrades and is pumped out of the formation. The proppants remain in place to keep the fractures open. The resultant fracture is a permeable sand-filled lens that might be as large as 60 feet in diameter (USEPA, 1995).

The presence of COIs in the bedrock groundwater at MSS is limited compared to the distribution and concentrations of COIs in the saprolite and transition zone groundwater, therefore the use of hydraulic fracturing to enhance remediation of bedrock groundwater is not retained for further consideration.

Phytoremediation

Phytoremediation involves the use of plants and trees as a means to extract groundwater. Water uptake by trees is used for plant growth and metabolism. Water uptake by plants and trees is ultimately released into the atmosphere via the pore-like structures on the leaves called stoma. Water on the leaves evaporates into the atmosphere. The loss of water by plants and trees is called transpiration. The amount of water transpired by plants, and therefore, water uptake by plants, is a function of the following:

- **Plant type** – Plants that are native to arid regions must conserve water and therefore transpire less than plants that are native to wet regions.
- **Temperature** – Transpiration rates increase with increasing temperature and decrease with decreasing temperatures.
- **Relative humidity** – Transpired water on plant leaves evaporate at a faster rate when the relative humidity is low and that results in a correspondingly higher transpiration rate. The opposite is true when the relative humidity is high.
- **Wind and air movement** – Increased movement of air around a plant will result in an increase in the rate of transpiration by the plant.
- **Availability of soil moisture** – Plants can sense when soil moisture is lacking and will reduce their transpiration rate.

The growth rate of selected plant species and the growing season can be limiting factors for the effectiveness of this technique. Maintenance can be long term and require, in most cases, fertilizing, regular monitoring, and harvesting.

Phytoremediation using tree well technology involves the installation of a 3- to 5-foot diameter boring to a target depth, typically a flow zone containing COIs. A Root Sleeve™ liner and aeration tubing are installed from ground surface to target depth. The boring is backfilled with soil that might include reactive media. If filled with reactive media, the tree well would serve as a PRB as well as a means to promote phytoremediation.

A tree is planted within the tree well (at land surface) followed by placement of a plastic cover over the soil surrounding the tree. The plastic cover minimizes infiltration of precipitation into the tree well. The tree well design forces the tree to draw water from the targeted depth via the Root Sleeve™ liner. Groundwater is also drawn through reactive media, if present. Consequently, the tree and the tree well are capable of uptake of some COIs and serve as a means of groundwater treatment and enhanced natural attenuation.

Ground cover plants stabilize soil/sediment and control hydraulics. In addition, densely rooted groundcover plants and grasses can also be used to remediate constituents. Phytoremediation groundcovers are one of the more widely used applications and have been applied at various bench- to full-scale remediation projects. Furthermore, in the context of this document, phytoremediation groundcovers are vegetated systems typically applied to surface soils as opposed

to Tree Wells which are targeted to deep soil and/or groundwater. The typical range of effectiveness for phytoremediation groundcovers is 1–2 feet below ground surface (bgs); however, depths down to 5 feet have been reported as within the range of influence under some situations (ITRC, 2009)

Constructed treatment wetlands are manmade wetlands built to remove various types of pollutants that may be present in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands, which is to act as filters. Wetlands are ideally suited to this role. They possess a rich microbial community in the sediment to effect the biochemical transformation of pollutants, they are biologically productive, and most importantly, they are self-sustaining.

Metals are removed in constructed wetlands by a variety of mechanisms including the following. Settling and sedimentation achieve efficient removal of particulate matter and suspended solids. The chemical process that results in short-term retention or long-term immobilization of contaminants is sorption. Sorption includes the combined processes of adsorption and absorption. Chemical precipitation involves the conversion of metals in the influent stream to an insoluble solid form that settles out (ITRC, 2003).

Phytoremediation technology can be also be used as a means to treat extracted groundwater. Aquaculture treatment technologies have been applied to the treatment of water. Those using aquatic plants, have been demonstrated capable treatment of metals and other non-metal elements including boron and arsenic (USEPA, 1982).

Phytoremediation technology can be used to extract groundwater; however, phytoremediation is not capable of achieving extraction rates necessary to achieve groundwater remediation within reasonable timeframes. The effectiveness of phytoremediation in terms of water removal and COI uptake will vary depending on the season of the year and the depth of affected groundwater. Therefore, phytoremediation is not retained for consideration for groundwater extraction at this time, but may be reconsidered in the future for areas accessible through the use of Tree Wells.

6.4.4 Groundwater Treatment

Several technologies exist for treatment of extracted groundwater to remove or immobilize constituents ex-situ, or above ground. The following technologies are

used for treatment of extracted groundwater. These groundwater treatment technologies are scalable for small to large flow rates.

pH Adjustment

Adjustment of the pH of extracted groundwater, if required prior to discharge, is a proven technology. Permitted discharges to Lake Norman will impose specific limits on the pH of discharged wastewater. The existing NPDES permitted outfalls at MSS maintain a pH from 6.0 to 9.0 standard units (S.U.). Facilities and equipment to adjust the pH of wastewater to satisfy NPDES discharge requirements are currently in-place at MSS.

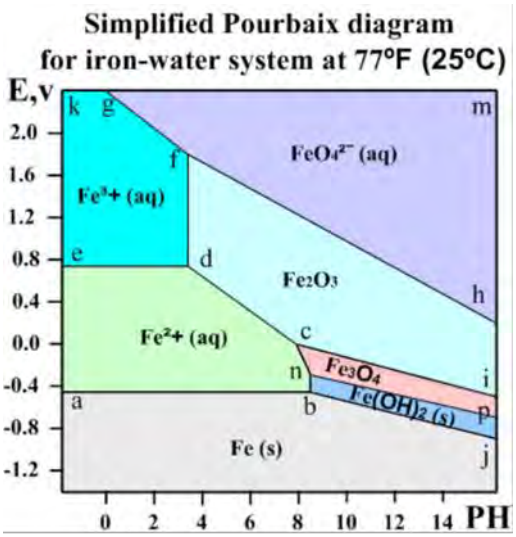
Groundwater monitoring has indicated that the pH from some monitoring wells is outside of these permit limits. With means to adjust pH already in place, it is assumed that the pH of extracted groundwater can be adjusted to meet the existing NPDES permit limits prior to discharge.

The means and technology needed to adjust the pH of extracted groundwater is well established and available at the Site. This treatment technology is retained for consideration in the future, if needed; however, has not been incorporated into a proposed remedial alternative at this time.

Precipitation

Precipitation of metals and other inorganic constituents has been used extensively in treating affected groundwater. The process involves the conversion of soluble (dissolved) constituents to insoluble particulates that will precipitate. The insoluble particles are subsequently removed by physical methods such as clarification or filtration. The process might involve adjustment of the wastewater pH and/or Eh (volts). The stability of soluble and insoluble metals and metal complexes is commonly illustrated in Pourbaix diagrams (pH vs E_h) (**Figure 6-24**).

FIGURE 6-24



https://rsteyn.wordpress.com/pourbaix-diagrams

As illustrated in the Pourbaix diagram, iron is soluble [aqueous (aq)] at a pH of approximately 3.5 S.U., or less, under aerobic conditions (Eh > 0 V). If the pH is increased, ferric (Fe^{+3}) iron will react to form insoluble [solid or (s)] complexes

and precipitate out of solution, provided that the redox potential (Eh) remains between 0.75 and 1.5 V. Adjustment of groundwater pH and Eh can be used to remove other metals including cadmium, chromium, copper, nickel, and zinc.

Flocculation is another method that can be used to remove inorganics from an aqueous waste stream. This technology involves adding a flocculent to extracted water and then removing (through sedimentation or filtration) formed particulates to reduce concentrations, such as total suspended solid (TSS).

Precipitation technology might be warranted as a means to treat, or pretreat, extracted groundwater to satisfy NPDES permitted discharge limits. Extracted groundwater is not expected to cause violations of the NPDES permit when discharged; therefore, precipitation technologies are not retained for further consideration.

Ion Exchange

Ion exchange processes are reversible chemical reactions that can be used for the removal of dissolved ions from solution and replacing them with other similarly charged ions. The ion exchange medium might consist of a naturally occurring material such as zeolites or a synthetic resin with a mobile ion attached to an immobile functional acid or base group. Mobile ions held by the ion exchange resin are exchanged with solute or target ions in the waste stream having a stronger affinity to the functional group.

Ion exchange resins can be cation resins or anion resins of varying strength. Ion exchange resins are generally classified as being:

- Strong acid cation (SAC) resins
- Weak acid cation (WAC) resins
- Strong base anion (SBA) resins
- Weak base anion (WBA) resins

Over time, a resin can become saturated with the targeted or competing ions. Breakthrough might occur when a resin becomes saturated. The possibility of breakthrough is evident when effluent concentrations of the targeted metal ion steadily increase over time and approach influent concentrations. Ion resins should be replaced or regenerated before breakthrough occurs. Ion selective boron resins are available and do not have the same competition considerations.

However, capacity and regeneration are still potential limitations and key design parameters.

Regeneration is laborious and requires safe handling of concentrated chemical reagents and waste. The first step in the co-flow regeneration process (regenerant is introduced via ion exchange bed influent) is to backwash the system with water. The regenerant solution is introduced to drive off ions and restores the resin capacity to about 60 to 80 percent of the total resin ion exchange capacity. Sodium hydroxide is a commonly used regenerant for WBA resins; weaker alkalis such as ammonia (NH_3) and sodium carbonate (Na_2CO_3) can also be used (SAMCO, 2019).

When sufficient contact time has passed, a slow water rinse is applied to the resin bed to push the regenerant solution throughout the resin and subsequently remove the regenerant from the system. The regenerant should be retained for proper disposal. The slow rinse is followed by a fast "raw" water rinse to verify water quality requirements are being met.

A limitation of this technology is that there must be a feasible and economical method to dispose of the regeneration effluent. An additional challenge could be groundwater influent streams that may have geochemical characteristics that result in interference in the ion exchange process. Because of these challenges ion exchange is not retained for further consideration.

Membrane Filtration

There are a number of permeable membrane filtration technologies that can be utilized to remove metals and other constituents from extracted groundwater. The most common is reverse osmosis. Microfiltration, ultrafiltration, and nanofiltration are also permeable membrane filtration technologies that are used less frequently.

All four technologies use pressure to force influent water through a permeable membrane. Permeable membrane filtration technologies are selected and designed so that influent water can pass through the membrane while target constituents are filtered (retained) by the membrane. The permeable membrane filtration technologies discussed differ in the size of the molecules filtered and the pressures needed to allow permeate to pass through the membranes.

Permeable membrane filtration technologies can filter one or more target constituents simultaneously and can achieve low effluent concentrations.

However, permeable membrane filtration technologies are also susceptible to fouling and often require a pretreatment step. They can also generate a high concentration reject effluent that might require additional treatment prior to disposal. These technologies typically have high capital and operational costs.

Membrane filtration at MSS is not carried forward for further evaluation for the following reasons:

- Extracted groundwater is not expected to be greater than permit discharge limits.
- The need for pretreatment and the high volume of reject effluent that requires additional treatment prior to disposal. These factors make the implementation of this technology costly and it requires high maintenance.

6.4.5 Groundwater Management

Extracted groundwater must be managed or used as supplemental process water prior to discharge. The disposition of extracted groundwater is discussed in the following sections.

National Pollutant Discharge Elimination System (NPDES) Permitted Discharge

The MSS has an NPDES permit (NC0004987) that authorizes the discharge of certain waste streams to Lake Norman. When MSS added the primary and secondary Lined Retention Basin (LRB), the Yard 1a Sump and other significant changes, NCDEQ issued a modified permit that became effective in May 2018. Outfall 005 is associated with the LRBs, which have capacity for the extracted groundwater. Outfall 002 is permitted to discharge water from the ash basin, during decanting and dewatering (removing the interstitial water from the ash). The NPDES permit states:

> *When the facility commences the ash pond/ ponds dewatering, the facility shall treat the wastewater discharged from the ash pond/ponds using physical-chemical treatment, if necessary, to assure state Water Quality Standards are not contravened in the receiving stream. Duke Energy shall notify DWR NPDES Permitting and DWR Mooresville Regional Office, in writing, within seven calendar days of installing additional physical-chemical treatment at this Outfall.*

A summary of the NPDES limitations for discharge through Outfall 002 during dewatering and for Outfall 005 is presented in **Table 6-10**. Anticipated

concentrations of COIs in extracted groundwater is not expected to exceed NPDES permit parameters.

Discharge of extracted groundwater utilizing NPDES Outfalls 002 or 005 is a viable option that is retained for further consideration.

Publicly Owned Treatment Works (POTW)

This groundwater management option involves the discharge of extracted groundwater to a sewer that discharges to the local POTW. The feasibility of this management option depends on a number of factors including:

- The proximity of the nearest sewer line relative to the groundwater extraction system
- The available capacity of a POTW to accept a new waste stream
- The suitability of a groundwater waste stream on POTW operations
- Capital costs, pretreatment requirements, and disposal fees

The City of Newton's Clark Creek Wastewater Treatment Plant (WWTP) is located at 1407 McKay Farm Rd, Newton, NC 28658, or about 19 miles west of the MSS Site. The plant is permitted for 5 MGD of wastewater. The average daily flow from the Marshall plant in 2018 was 2.38 MGD. Total flow rates required for treatment may be greater than 0.94 MGD as discussed in **Section 6.5**. It is unlikely that the City of Newton's WWTP will allocate a significant portion of its available capacity to a single industrial user.

Given the relatively high costs for construction of sewer piping and lift stations, and ongoing monthly sewer use charges, discharge of extracted groundwater to the City of Newton wastewater treatment plant is not retained for further consideration at this time.

Non-Discharge Permit / Infiltration Gallery

Management of treated groundwater by way of infiltration into underlying groundwater involves the construction of an infiltration gallery to receive and distribute the treatment effluent or wastewater. Discharge of extracted water by way of an infiltration gallery must not result in concentrations greater than 02L groundwater standards. Consequently, groundwater treatment must reliably produce an effluent waste stream that does not result in a groundwater violation set by the 02L standard.

The construction and use of infiltration galleries are permitted under 15A NCAC 02T .0700. The effectiveness of an infiltration system will depend in large part on the type of soils or classification of soils receiving the wastewater. Annual hydraulic loading rates shall be based on in-situ measurement of saturated hydraulic conductivity in the most restrictive horizon for each soil mapping unit. U.S. Department of Agriculture (USDA) soil map of MSS indicates that a majority of the native soils fall into the following classifications (USDA, 2019):

- Cecil sandy loam (CaB, CaC, and CaD)
- Pacolet gravelly fine sandy loam (PcC)
- Madison-Udorthents Complex (MkF4)
- Udorthents (Ud), loamy and clayey

The capacity of the most limiting layer of Cecil, Pacolet and Madison-Udorthent loams to transmit water is described as being moderately high to high (0.57 to 1.98 inches/hour). The capacity of the most limiting layer of this soil type (clayey Udorthents) is described as very low to high (0.00 to 0.98 inches/hour).

Before extracted water could be recycled for infiltration gallery use, inorganic constituents, including boron, chloride, cobalt, manganese among others, would have to be treated. Treatment would have to be sufficient so wastewater recycled to the groundwater system would not result in constituent concentrations greater than 02L groundwater standards. Treatment of conservative and variably conservative constituents could result in complicated systems with significant operation and maintenance efforts. Therefore, the use of infiltration galleries to dispose of treated groundwater is not retained for further consideration.

Non-Discharge Permit/Land Application

Land application of groundwater involves the application of extracted groundwater onto land to irrigate the vegetative cover and supplying the vegetative cover with nutrients beneficial for growth. The vegetative cover can include grasses, tree wells, wetland species, native species of trees and shrubs, and ornamental trees and shrubbery.

The primary focus of groundwater remediation efforts is to reduce boron concentrations at the anticipated compliance boundary to acceptable levels. Consequently, extracted groundwater would be expected to contain boron. Boron is essential for plant growth. More specifically, boron in soil must be continuously delivered to growing tissues through roots and vascular tissues to

maintain cell wall biosynthesis and optimal plant development (Takano 2006). Boron is also essential for plant nitrogen assimilation, for the development of root nodules in nitrogen-fixing plants, and for the formation of polysaccharide linkages in plant cell walls (Park 2002). If extracted groundwater is land applied, boron would be made available for plant uptake.

Extracted groundwater could be used to irrigate more than 300 acres of planted vegetative cover following the implementation of source control measures. Land application of extracted groundwater would occur within the existing and possibly future compliance boundary. A large-scale irrigation system could be used to apply thousands of gallons of water onto the vegetative cover daily. Of the water applied, much of it would be lost to evaporation, particularly during sunny dry periods. Likewise, water taken up by vegetation would be lost by way of plant transpiration. All remaining water would either infiltrate into the soil or migrate downslope to lowland areas via surface water runoff.

Land application of extracted groundwater must comply with 15A NCAC 02T – *Waste Not Discharged To Surface Waters*. Duke Energy would submit an application for a non-discharge permit in accordance with 15A NCAC 02T .0105 - .0109. General permits can be effective for up to eight years. General permits issued pursuant to 15A NCAC 02T shall be considered individual permits for purposes of compliance boundaries established under 15A NCAC 02L .0107. Permitted facilities shall designate an Operator in Responsible Charge and a back-up operator as required by the Water Pollution Control System Operators Certification Commission.

Application of wastewater to the ground surface or surface irrigation of wastewater is governed by 15A NCAC 02L .0500 - *Wastewater Irrigation Systems*. Requirements under this subsection include:

- A soil scientist must prepare a soil report that evaluates receiving soil conditions and who make recommendations for loading rates of liquids and wastewater constituents
- A hydrogeologic report must be prepared by a licensed geologist, soil scientist, or professional engineer for industrial waste treatment systems with a design flow of over 25,000 gallons per day
- The applicant must prepare a Residuals Management Plan

- Each facility shall provide flow equalization with a capacity of 25 percent of the daily system design flow unless the facility uses lagoon treatment
- Discharge areas shall be designed to maintain one-foot vertical separation between the seasonal high water table and the ground surface
- Automatically activated irrigation systems shall be connected to a rain or moisture sensor to prevent irrigation during precipitation events or wet conditions that would cause runoff

Setback requirements for irrigation sites (15A NCAC 02T .056) are summarized on **Table 6-11.**

The DWR might require monitoring and reporting to characterize the extracted groundwater and its effect on surface water, ground water, or wetlands.

Land application of extracted groundwater could be used as a means to maintain the vegetative cover that will be established following implementation of source control measures. However, the designated area would have to be able to take continuous flow during both dry and wet seasons, which would not be practical. Additionally, unless the vegetation is harvested, boron uptake will be returned to the soil and aquifer upon death and decomposition of the plant matter. Therefore, land application is not retained as an alternative means for management of extracted groundwater.

Beneficial Reuse

Beneficial reuse of extracted groundwater involves the evaluation of existing MSS water demand and the repurposing of extracted groundwater to satisfy a need for water. Beneficial reuse of extracted groundwater can do the following:

- Provide an alternative to groundwater treatment
- Reduce reliance on sources of non-potable water required for Station operations
- Reduce the need and capacity for wastewater treatment

A NCDEQ 2018 Annual Water Use Report for the MSS indicated that water was withdrawn from Lake Norman every day in 2018. The average daily withdrawal in a given month ranged from 724.2 million gallons per day (MGD) to 1312.4 MGD. The average daily discharge in a given month ranged from 723.6 MGD to 1310.8 MGD (NCDEQ, 2019).

Beneficial Reuse: Fire Protection

A limited amount of extracted groundwater might be used to supplement or supply water stored for fire suppression within MSS operations. However, the need for fire suppression water is limited, storage is problematic, and would not justify the effort and expense to substitute extracted groundwater for fire suppression water obtained from Lake Norman. Therefore, beneficial reuse of groundwater for fire protection is not retained for further consideration.

Beneficial Reuse: Non-Contact Cooling Water

Extracted groundwater was considered as a supplement or supply of makeup water to the non-contact cooling process for MSS operations. MSS has a once-through non-contact cooling system that pulls water from Lake Norman and discharges the water through Outfall 001. Challenges with this beneficial reuse include making a physical connection to the once-through cooling system to supply the extracted groundwater, and potential issues with extracted groundwater alkalinity. The alkalinity of extracted groundwater could pose potential scaling problems for some applications, although certain constituents that comprise alkalinity would be diluted by non-contact cooling water obtained from Lake Norman. The use of groundwater to supplement non-contact cooling water at MSS is not retained for further consideration.

Beneficial Reuse: Dust Suppression and Truck Wash

A limited amount of extracted groundwater can possibly be used for dust suppression during implementation of source control measures. Similarly, extracted groundwater can possibly be used for washing the tires of haul trucks leaving the ash basin during implementation of source control measures. The use of extracted groundwater for dust suppression and truck washing would be confined within the limits of the ash basin. However, the need for dust suppression and truck wash water is limited. The effort and expense to substitute extracted groundwater for other sources of clean water for dust suppression and truck washing is not justified. Therefore, beneficial use of the water is not retained for further consideration.

6.4.6 Technology Evaluation Summary

A summary of the remedial technologies presented above and the rationale for either retaining or rejecting a specific technology is presented on **Table 6-12**.

6.5 Evaluation of Remedial Alternatives
(CAP Content Section 6.D)

Technologies evaluated and retained for consideration as discussed in **Section 6.4** were used to formulate the following three groundwater remedial alternatives to remediate Site groundwater.

- Remedial Alternative 1: Groundwater Remediation by MNA
- Remedial Alternative 2: Groundwater Extraction, Infiltration and In-Situ Treatment
- Remedial Alternative 3: Groundwater Extraction and Clean Water Infiltration

These groundwater remedial alternatives are presented and described in the following subsections. Information to address *CAP Content Section 6.D.a.iv* is provided in **Section 6.6** and **Section 6.7**.

6.5.1 Remedial Alternative 1 – Monitored Natural Attenuation (MNA)
(CAP Content Section 6.D.a)

Alternative 1 is the use of MNA as a remedial alternative to address groundwater COI concentrations at or beyond the ash basin compliance boundary that are at actionable concentrations relative to regulatory standards.

The MSS site has undergone the extensive hydrogeologic characterization necessary to evaluate natural attenuation processes and rates. Site-specific groundwater data including saturated media within the saprolite, transition zone, and bedrock flow zones has been collected at MSS for MNA evaluation. A comprehensive analysis of MNA is provided in **Appendix I.**

MNA would involve the construction of 12 new monitoring wells to replace wells that would be abandoned during implementation of basin closure and source control measures. These replacement monitoring wells would be installed along geochemical transects to monitor groundwater concentration trends in the footprint of the ash basin. There is an extensive groundwater monitoring system that is associated with the ash basin and adjacent source areas (**Figure 1-2**). A majority of the wells have dedicated sampling equipment and an approved interim monitoring plan is in place**.** A subset of these monitoring wells could be immediately used for monitoring the effectiveness of Alternative 1.

6.5.1.1 Problem Statement and Remediation Goals
(CAP Content Section 6.D.a.i)

A limited number of CCR constituents in groundwater associated with the MSS ash basin and and adjacent source areas occur at or beyond the compliance boundary to the east of the ash basin at concentrations detected greater than applicable 02L standards, IMAC, or background values, whichever is greater. Remediation goals are to restore groundwater quality at or beyond the compliance boundary by returning COIs to acceptable concentrations (02L/IMAC or background, whichever is greater), or as closely thereto as is economically and technologically feasible consistent with 15A NCAC 02L .0106(a) (*CAP Content Section 6.D.a.i.2*). In the future, alternative standards may be proposed as allowed under 02L .0106(k). This approach is considered reasonable given the documented lack of human health or ecological risk at the MSS.

The following groundwater COIs to be addressed by corrective action are identified (**Table 6-6**) and discussed in **Section 6.1.3**: antimony, barium, beryllium, boron, chloride, cobalt, iron, lithium, manganese, molybdenum, selenium, strontium, sulfate, thallium, TDS, total radium, and vanadium. The majority of these COIs only occur at concentrations greater than applicable regulatory criteria in limited, and often isolated, locations and do not exhibit a discernable plume.

Detailed evaluations of constituent occurrence are presented in **Section 6.1**. More extensive discussion of the CSM can be found in **Section 5.0**, discussion of flow and transport modeling in **Appendix G**, and discussion of geochemical modeling in **Appendix H**.

6.5.1.2 Conceptual Model
(CAP Content Section 6.D.a.ii)

Aspects of the conceptual site model will change following source control, which is ongoing with decanting of the ash basin. The source of COIs in groundwater will be substantially reduced compared to existing conditions following decanting of the ash basin and closure. As of December 1, 2019, 128,400,000 gallons of water had been decanted at the MSS ash basin. Decanting will reduce the potentiometric head responsible for the downward vertical gradient behind the ash basin dam. A lower downward gradient would reduce downward COI migration. As a result, constituent

concentration reductions through natural attenuation processes are anticipated following decanting.

Currently, COIs in groundwater do not pose an unacceptable risk to human health or the environment under conservative exposure scenarios. Residential properties located north, west, and south of the ash basin are situated in topographically higher areas than the ash basin. The residential properties are located beyond the topographic divides that control flow from the basin. Therefore, the groundwater flow direction is locally toward the ash basin (to the east) and away from residential properties. If implemented alone, Groundwater Remedial Alternative 1: MNA would not pose an unacceptable risk to human health or the environment.

More information on one or more of the effective natural attenuation mechanisms for reducing the concentration of the COIs in groundwater can be found in **Appendix I**.

6.5.1.3 Predictive Modeling

(CAP Content Section 6.D.a.iii)

Predictive modeling has been conducted to estimate when boron concentrations would be reduced to 02L standards using MNA alone (primarily relying on natural attenuation by dilution). The simulations indicate boron concentrations would naturally attenuate to less than the 2L standard in approximately 700 years after basin closure (**Figure 6-25**). The extended timeframe to reach 2L is a result of relying on natural processes (*e.g.,* sorption, precipitation, ion exchange, advection, dispersion, and dilution) to act on the COIs. No active remedy is employed under MNA to enhance the groundwater remedy. The flow and transport modeling report that provides the predictions for boron is presented in **Appendix G.** Similarly, a geochemical modeling report is presented in **Appendix H.** It describes the natural attenuation of the constituents that have multiple natural attenuation mechanisms, in addition to dilution.

6.5.2 Remedial Alternative 2 – Groundwater Extraction, Infiltration and In-Situ Treatment

(CAP Content Section 6.D.a)

Groundwater Remedial Alternative 2 involves a multi-technology approach in two areas at MSS to address groundwater COI concentrations at or beyond the ash basin compliance boundary that are at actionable concentrations relative to regulatory standards. Area 1 is designated as the downgradient area east of the

ash basin along the dam and toward the unnamed tributary to Lake Norman. Area 2 is designated as the distal southern end of the ash basin dam and area immediately east of the coal pile. Concentrations of COIs, other than boron (*e.g.*, cobalt), are greater than applicable regulatory criteria in this area. Targeted COIs include: cobalt, lithium, manganese, strontium and thallium.

Predictive flow and transport modeling was conducted to conceptually design the groundwater remedial approach. The modeling was used to simulate the response of boron plume concentrations under a variety of groundwater extraction scenarios. Under this alternative, compliance is achieved in approximately 30 years from system start-up. The applicable technologies that comprise Alternative 2 are outlined below:

Area 1:

- 33 vertical groundwater extraction wells in the vicinity of the northern portion of the ash basin dam and the northeast tributary to Lake Norman where concentrations of boron in the saprolite, transition zone and bedrock exceed 02L standards
- 7.3 acres of shallow infiltration galleries installed along the northeast portion of the ash basin, between the basin and the tributary
- Pumps, associated piping, and control systems

Figure 6-26 illustrates the proposed locations of the extraction wells and infiltration gallery in Area 1.

The extraction wells would be completed in the transition (deep) zone and bedrock. Modeled screen intervals range from 125 to 165 feet bgs for 24 wells and from 230 to 245 ft bgs for 9 deeper wells. Estimated total flow from the extraction wells is 314 gpm (approximately 9.5 gpm per well). The groundwater extraction rate is based on predictive flow and transport modeling, which assumes a 50 percent extraction well efficiency. The extraction wells would be constructed as 6-inch inner-diameter wells with stainless steel wire-wrapped screens. Typical construction details for the vertical wells are presented in **Figure 6-27**.

Hydraulic conductivity and infiltration tests would be conducted to determine the yields of the extraction and infiltration wells in applicable flow zones for each technology. Hydraulic conductivity test results would be used to size pumps with the appropriate horsepower and capacity. Pumps, discharge piping,

pressure gauges, flow totalizers, check valves, flow control valves, and telemetry hardware would be included in a design package following hydraulic conductivity test evaluations.

Each extraction well would be piped to a manifold that will direct extracted groundwater to an equalization tank. Groundwater from the individual extraction wells is combined in the equalization tank. This results in a blending of the constituent concentrations and water parameters (*e.g.,* pH, dissolved oxygen, oxygen-reduction potential, and alkalinity). This provides more predictable and consistent water quality and flow to the treatment system or discharge point, as compared to the potential range of values from individual groundwater extraction wells.

A transfer pump would draw extracted groundwater from the equalization tank. Extracted groundwater would be discharged to Lake Norman through an NPDES outfall, likely Outfall 005 or 002.

The purpose of the infiltration of water into the shallow subsurface northeast of the dam is to flush and mobilize boron from upper flow zones for capture by the extraction well network and to help reduce the overall boron concentration in groundwater below the 02L standard. Predictive modeling estimates that the total area of the infiltration galleries is 7.3 acres. Total injected water is anticipated to be 46 gpm (0.067 MGD), which is approximately 6.3 gpm per acre. The predictive flow and transport model assumes a 10% loss to evapotranspiration for the infiltration gallery. Water suitable for infiltration could be withdrawn from Lake Norman and treated, as appropriate, prior to infiltration.

For each acre of the infiltration system, shallow (approximately 3-feet deep) trenches would be dug. Perforated piping would then be installed and bedded in clean gravel aggregate to enhance infiltration. The infiltration piping would be connected to distribution piping with associated valves, flow, and pressure meters. Each acre (cell) of the infiltration galleries would be independently monitored and flow adjusted accordingly. **Figure 6-28** presents a conceptual diagram of the water infiltration galleries.

Area 2:

COI concentrations other than boron are greater than comparative regulatory criteria in the southern portion of the ash basin dam. Targeted COIs include:

cobalt, lithium, manganese, strontium, and thallium. Remedial Alternative 2 would include the installation of a PRB to address the occurrence of these COIs above applicable standards.

Due to the relatively shallow depth of bedrock in this area of the Site and the heterogeneous nature of the fill material used to construct the on-lapping buttress of the ash basin dam, excavation/construction of a PRB as a backfilled trench is not recommended. A PRB, however, could be implemented through the installation of 143 infiltration borings for in-situ groundwater treatment along the ash basin dam using chemical amendments. Fill (comprised of boulders, blast remnants, etc.) occupies the area of the proposed infiltration wells. Direct push technology is likely not a viable option for placement of chemical amendments due to the heterogeneous fill encountered along the buttress of the dam. Drilled boreholes would be a preferable alternative. The projected completion zones, number and depth of infiltration borings are outlined below:

- Shallow/Saprolite (15 to 35 feet bgs):
    - 100 feet length / 10 feet spacing = 11 infiltration borings
    - 300 feet length / 10 foot spacing = 31 infiltration borings
- Transition Zone/Upper Bedrock (75 to 100 feet bgs):
    - 1,000 feet total length / 10 feet spacing = 101 infiltration borings

The type of chemical amendment and application has been estimated in consultation with Peroxychem, a specialty chemical manufacturer and maker of MetaFix™.

a) Initial vendor estimates of MetaFix™ to treat the shallow saprolite, upper bedrock over the estimated lengths outline above are greater than 60 tons
b) Vendor recommendation for emplacement chemical amendments is direct push borings (one-time use) in saprolite/fill east of the dam and open borehole in deep flow zone (upper bedrock)
c) Based on results of vendor experience and a desk-top study, boring spacing recommended to be 5-15 feet (staggered). Therefore a 10 foot spacing was used in the Alternative 2 design

The design for Alternative 2 is based on flow and transport modeling results (**Appendix G**), in addition to vendor consultation regarding chemical amendments for in-situ treatment.

6.5.2.1 Problem Statement and Remediation Goals *(CAP Content Section 6.D.a.i)*

A limited number of CCR constituents in groundwater associated with the MSS ash basin and adjacent source areas occur at or beyond the compliance boundary to the east of the ash basin at concentrations detected greater than applicable 02L standards, IMAC, or background values, whichever is greater. Remediation goals are to restore groundwater quality at or beyond the compliance boundary by returning COIs to acceptable concentrations (02L/IMAC or background, whichever is greater), or as closely thereto as is economically and technologically feasible consistent with 15A NCAC 02L .0106(a) (*CAP Content Section 6.D.a.i.2*). In the future, alternative standards may be proposed as allowed under 02L .0106(k). This approach is considered reasonable given the documented lack of human health or ecological risk at the MSS.

The following groundwater COIs to be addressed by corrective action are identified (**Table 6-6**) and discussed in **Section 6.1.3**: antimony, barium, beryllium, boron, chloride, cobalt, iron, lithium, manganese, molybdenum, selenium, strontium, sulfate, thallium, TDS, total radium, and vanadium. The majority of these COIs only occur at concentrations greater than applicable regulatory criteria in limited, and often isolated, locations and do not exhibit a discernable plume.

The conceptual model and predictive modeling discussions summarize the foundations for development of the groundwater extraction combined with clean water infiltration and treatment alternative. More extensive discussion of the CSM can be found in **Section 5.0**, discussion of flow and transport modeling in **Appendix G**, and discussion of geochemical modeling in **Appendix H**.

Periodic monitoring of Site groundwater is an important part of any remedial alternative. Twelve new/replacement monitoring wells would be installed during implementation of Alternative 2. These wells would be incorporated into the established Site-wide groundwater monitoring network to evaluate the performance and effectiveness of the groundwater remediation.

6.5.2.2 Conceptual Model

(CAP Content Section 6.D.a.ii)

The conceptual model and predictive modeling discussions summarize the foundations for development of the groundwater infiltration and extraction alternative. More extensive discussion of the CSM can be found in **Section 5**, discussion of flow and transport modeling in **Appendix G**, and discussion of geochemical modeling in **Appendix H**.

Affected groundwater associated with the ash basin and adjacent source areas, including the coal pile, ILF subgrade structural fill, Phase II Landfill and PV Structural Fill areas, flows down-gradient to the ash basin and any COIs are comingled with the ash basin plume. Thus, a remedy designed to address affected groundwater from the ash basin will also address groundwater from the adjacent source areas.

Groundwater Remedial Alternative 2, along with source control, will change certain aspects of the conceptual site model. Simulations of groundwater extraction along the Lake Norman shoreline predict that the current hydraulic gradient toward the lake would be reversed, inducing lake water infiltration into the groundwater system. Standing water in the ash basin would be decanted under any source control scenario being considered. When removed, the potentiometric head responsible for the downward vertical gradient behind the ash basin dam would be reduced. A lower downward gradient will reduce downward COI migration. As of December 1, 2019, 128,400,000 gallons of water had been decanted at the MSS ash basin.

This remedial alternative addresses conservative COIs (*e.g.*, boron, chloride, sulfate, TDS) through groundwater extraction along the ash basin dam and eastern roadway between the basin and tributary to Lake Norman. Alternative 2 would address additional variably reactive constituents through in-situ treatment along the southwestern portion of the ash basin dam.

Currently, COIs in groundwater do not pose unacceptable risk to human health or the environment under conservative exposure scenarios. If implemented, Groundwater Remedial Alternative 2 would not pose unacceptable risk to human health or the environment.

6.5.2.3 Predictive Modeling

(CAP Content Section 6.D.a.iii)

Site-specific data has been incorporated into Alternative 2 modeling and used to predict when boron concentrations outside the compliance boundary would satisfy 02L standards. Predictive modeling assumed that Alternative 2 was fully implemented concurrent with ash basin closure, beginning in year 2020. The simulated boron plume would recede within the 500-foot compliance boundary in approximately 30 years from system start-up (**Figure 6-29**). The time frame to achieve compliance for boron is significantly improved over Alternative 1, MNA where boron concentrations greater than the 02L standard are predicted to extend beyond the compliance boundary for up to 700 years (**Section 6.5.1**). However, no unacceptable risks to human health or the environment were identified under Alternative 1. The flow and transport modeling report (**Appendix G**) and geochemical modeling report (**Appendix H**) provide detailed predictions, descriptions, and explanations of the effects of groundwater extraction.

The combined groundwater flow rate for this extraction system is predicted to be 314 gpm or 0.45 MGD. This combined groundwater extraction rate is based on predictive flow and transport modeling, which assumes a 50 percent well efficiency. Hydraulic conductivity tests would be conducted during the design phase to determine actual groundwater extraction rates. The predictive flow and transport model assumes a 10% loss to evapotranspiration for the infiltration gallery. Infiltration tests would be conducted during the design phase to determine actual clean water infiltration rates.

6.5.3 Remedial Alternative 3 – Groundwater Extraction and Clean Water Infiltration

(CAP Content Section 6.D.a)

Groundwater Remedial Alternative 3 involves a multi-technology approach in two areas at MSS. This remedial alternative is designed to control migration of dissolved phase COIs at or beyond the ash basin compliance boundary that are at actionable concentrations relative to regulatory standards. Area 1 is designated as the northern portion of the ash basin dam and the northeast tributary to Lake Norman. Area 2 is designated as the southern end of the ash basin dam.

Predictive flow and transport modeling was conducted to conceptually design the groundwater remedial approach. The modeling was used to simulate the response of boron plume concentrations under a variety of groundwater extraction scenarios. Under this alternative, compliance is achieved in approximately 9 years from start-up. Concentrations of COIs, other than boron (*e.g.,* cobalt), are greater than applicable regulatory criteria in the southern portion of the ash basin dam. Targeted COIs include: cobalt, lithium, manganese, strontium and thallium. The network of groundwater extraction wells is designed to capture these COIs through active pumping. The spacing, depths, and extraction rates of extraction wells placed along the southern portion of the dam are comparable to other areas north and east of the dam, where the flow and transport model indicates effective remediation of mobile COIs.

The applicable technologies that comprise Alternative 3 are outlined below:

Areas 1 and 2 –

- A network of 66 vertical groundwater extraction wells would be installed along the lower buttress area of the ash basin dam, from the southern end toward the northern end, and to the northeast between the tributary to Lake Norman and the ash basin
- 24 vertical clean water infiltration wells would be installed along the northeast portion of the ash basin, between the basin and the tributary
- Pumps, associated piping, and control systems

Figure 6-30 illustrates the proposed locations of the extraction wells and infiltration wells in Areas 1 and 2. **Table 6-13** presents a summary of remediation components included in Alternative 3.

The groundwater extraction wells would be completed in the transition (deep) zone and bedrock; modeled screen intervals range from 145 to 245 feet bgs. Estimated total flow from the extraction wells is 652 gpm (approximately 9.9 gpm per well). The groundwater extraction rate is based on predictive flow and transport modeling, which assumes a 50 percent well efficiency. The extraction wells will be constructed as 6-inch inner-diameter wells. Typical construction details for the vertical extraction wells are presented in **Figure 6-27.**

Hydraulic conductivity and infiltration tests would be conducted to determine the yields of the extraction and infiltration wells in applicable flow zones for each

technology. Hydraulic conductivity test results would be used to size pumps with the appropriate horsepower and capacity. Pumps, discharge piping, pressure gauges, flow totalizers, check valves, flow control valves, and telemetry hardware would be included in a design package following hydraulic conductivity test evaluations.

Each extraction well would be piped to a manifold that will direct extracted groundwater to an equalization tank. Groundwater from the individual extraction wells is combined in the equalization tank. This results in a blending of the constituent concentrations and water parameters (*e.g.,* pH, dissolved oxygen, reduction-oxidation potential, and alkalinity). This provides more predictable and consistent water quality and flow to the treatment system or discharge point, as compared to the potential range of values from individual groundwater extraction wells.

A transfer pump would draw extracted groundwater from the equalization tank. Extracted groundwater would be discharged to Lake Norman through an NPDES outfall, likely Outfall 005 or 002.

The purpose of the clean water infiltration northeast of the dam is to flush and mobilize boron from upper flow zones for capture by the extraction well network and to help reduce the overall boron concentration in groundwater to below the 02L standard. Predictive modeling estimates that the total flow rate of infiltrated water is 285 gpm (0.41 MGD), which is an average of approximately 11.8 gpm per well. The groundwater infiltration rate is based on predictive flow and transport modeling, which assumes a 25 percent infiltration well efficiency. Water suitable for infiltration could be withdrawn from Lake Norman and treated, as appropriate, prior to infiltration.

Water distribution piping would be installed in trenches with electrical and effluent water piping. The infiltration well piping at each well head would be connected to distribution piping with associated valves, flow and pressure meters. Each well would be independently monitored and flow adjusted accordingly. Typical construction details for the vertical clean water infiltration wells are presented in **Figure 6-31.**

The design for Alternative 3 is based on flow and transport modeling results (**Appendix G**).

6.5.3.1 Problem Statement and Remediation Goals *(CAP Content Section 6.D.a.i)*

A limited number of CCR constituents in groundwater associated with the MSS ash basin and adjacent source areas occur at or beyond the compliance boundary to the east of the ash basin at concentrations detected greater than applicable 02L standards, IMAC, or background values, whichever is greater. Remediation goals are to restore groundwater quality at or beyond the compliance boundary by returning COIs to acceptable concentrations (02L/IMAC or background, whichever is greater), or as closely thereto as is economically and technologically feasible consistent with 15A NCAC 02L .0106(a) (*CAP Content Section 6.D.a.i.2*). In the future, alternative standards may be proposed as allowed under 02L .0106(k). This approach is considered reasonable given the documented lack of human health or ecological risk at the MSS.

The following groundwater COIs to be addressed by corrective action are identified (**Table 6-6**) and discussed in **Section 6.1.3**: antimony, barium, beryllium, boron, chloride, cobalt, iron, lithium, manganese, molybdenum, selenium, strontium, sulfate, thallium, TDS, total radium, and vanadium. The majority of these COIs only occur at concentrations greater than applicable regulatory criteria in limited, and often isolated, locations and do not exhibit a discernable plume.

The conceptual model and predictive modeling discussions summarize the foundations for development of the groundwater extraction combined with clean water infiltration and treatment alternative. More extensive discussion of the CSM can be found in **Section 5.0**, discussion of flow and transport modeling in **Appendix G**, and discussion of geochemical modeling in **Appendix H**.

Periodic monitoring of Site groundwater is an important part of any remedial alternative. Twelve new/replacement monitoring wells would be installed during implementation of Alternative 3. These wells would be incorporated into the established Site-wide groundwater monitoring network to evaluate the performance and effectiveness of the groundwater remedial alternative. In addition, a routine program of extraction and infiltration well performance monitoring and well rehabilitation/redevelopment would be implemented during system operation to maintain system effectiveness.

6.5.3.2 Conceptual Model

(CAP Content Section 6.D.a.ii)

The conceptual model and predictive modeling discussions summarize the foundations for development of the groundwater extraction and clean water infiltration alternative. More extensive discussion of the CSM can be found in **Section 5**, discussion of flow and transport modeling in **Appendix G**, and discussion of geochemical modeling in **Appendix H**.

Affected groundwater beneath the northern basin areas and adjacent source areas, including the coal pile, ILF subgrade structural fill, Phase II Landfill and PV Structural Fill areas flows downgradient to the ash basin and any COIs are comingled with the ash basin plume. Thus, a remedy designed to address affected groundwater from the ash basin will also address groundwater from the northern basin area.

Groundwater Remedial Alternative 3, along with source control, will change certain aspects of the conceptual site model. Simulations of groundwater extraction along the Lake Norman shoreline predict that the current hydraulic gradient toward the lake would be reversed, inducing lake water infiltration into the groundwater system. Standing water in the ash basin would be decanted under any source control scenario being considered. When removed, the potentiometric head that is producing the downward vertical gradient behind the ash basin dam will be reduced. A decreased downward gradient will reduce the rate of downward COI migration. As of December 1, 2019, 128,400,000 gallons of water had been decanted at the MSS ash basin.

Remedial Alternative 3 addresses conservative, non-conservative and variably reactive COIs through groundwater extraction along the ash basin dam and eastern roadway between the basin and tributary to Lake Norman. Clean water infiltration along the eastern roadway would flush boron from the unsaturated zone where it can be captured by the groundwater extraction wells.

Currently, COIs in groundwater do not pose an unacceptable risk to human health or the environment under conservative exposure scenarios. If implemented, Groundwater Remedial Alternative 3 would not pose an unacceptable risk to human health or the environment.

6.5.3.3 Predictive Modeling

(CAP Content Section 6.D.a.iii)

Site-specific data has been incorporated into Alternative 3 modeling and used to predict when boron concentrations outside the compliance boundary would satisfy 02L standards. Predictive modeling assumed that Alternative 3 was fully implemented concurrent with ash basin closure, beginning in year 2020. The simulated boron plume would recede within the 500-foot compliance boundary in approximately 9 years from start-up (**Figure 6-32**). The material differences between Alternatives 2 and 3 are (1) the number of groundwater extraction wells and associated total extraction rate, (2) infiltration of clean water via vertical wells as opposed to shallow infiltration galleries, and (3) active groundwater extraction along the southern portion of the dam buttress as opposed to in-situ treatment.

When compared to Alternative 2 (approximately 30 years), the estimated time frame for achieving compliance for boron under Remedial Alternative 3 (approximately 9 years) is an improvement. It is a significant improvement over Alternative 1 (MNA) where boron concentrations greater than the 02L standard are predicted to extend beyond the compliance boundary for up to 700 years. However, no unacceptable risks to human health or the environment were identified under Alternative 1. The flow and transport modeling report is presented in **Appendix G**, and geochemical modeling report is presented in **Appendix H.** Both of these reports provide detailed descriptions, predictions, and explanations of the effects of groundwater remediation under Alternative 3.

The combined groundwater flow rate for this extraction system is predicted to be 652 gpm or 0.94 MGD. This combined groundwater extraction rate is based on predictive flow and transport modeling, which assumes a 50 percent well efficiency. **Table 6-16** presents detailed extraction well design based on modeled parameters.

Predictive modeling estimates that the total flow rate of infiltrated clean water is 285 gpm (0.41 MGD), which is an average of approximately 11.8 gpm per well. The groundwater infiltration rate is based on predictive flow and transport modeling, which assumes a 25 percent infiltration efficiency to account for well skin effects. **Table 6-15** presents detailed infiltration well design based on model parameters. Hydraulic conductivity tests would be conducted during the design phase to determine actual groundwater

extraction rates. Infiltration tests would be conducted during the design phase to determine actual clean water infiltration rates.

6.6 Remedial Alternative Screening Criteria

(Supplemental Information for CAP Content Section 6.D.a.iv)

This section provides supplemental information beyond the CAP content guidance to describe the screening criteria used to evaluate groundwater remediation alternatives at the MSS. Each groundwater remedial alternative formulated and discussed in **Section 6.5** has undergone detailed comparative analysis using the screening criterion described below. These screening criteria are based upon the criteria outlined in 15A NCAC 02L .0106(i), 40 CFR 300.430, and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988). The screening criteria are as follows:

- Protection of human health and the environment
- Compliance with applicable regulations
- Short-term effectiveness
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume
- Technical and logistical feasibility
- Time required to initiate and implement corrective action
- Time required to achieve remediation goals
- Cost
- Community acceptance

Additional considerations for remedial alternative evaluations include:

- Adaptive site management and remediation considerations
- Sustainability

Protection of Human Health and the Environment

Protection of human health and the environment is paramount in the evaluation of any remedial alternative. Technologies and remedial alternatives are evaluated to determine whether they can achieve regulatory compliance within a reasonable time frame, without detriment to human health and the environment. Remedial alternatives that are not protective of human health and the environment should be rejected from consideration solely on this basis.

Compliance with Applicable Regulations

Technologies and alternatives are herein evaluated to assess compliance with applicable federal and state environmental laws and regulations. These include:

- CAMA (NC SB 729, Subpart 2)
- Groundwater Standards (NCAC, Title 15A, Subchapter 02L)
- CCR (40 CFR § 257.96)
- Well construction and maintenance standards (NCAC Title 15A Subchapter 02C)
- NPDES (40 CFR Part 122)
- Sediment erosion and control (NCAC Title 15A Chapter 04)

Technical and Logistical Feasibility

The ease or difficulty of implementing technologies and alternatives are assessed by considering the following types of factors as appropriate:

- Technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy
- Administrative feasibility, including activities needed to coordinate with agencies, and the ability and time required to obtain any necessary approvals and permits
- Availability of services and materials, including the availability of adequate off-Site treatment, storage capacity, and disposal capacity and services; as well as the availability of necessary equipment and specialists, and provisions to ensure any necessary additional resources

Time Required to Initiate and Implement Corrective Action Alternative

The time required to initiate and fully implement a groundwater remedial action takes into consideration the following activities, if applicable:

- Source control measures
- Bench-scale testing, if needed
- Treatability testing
- Pilot testing

- Hydraulic conductivity testing
- Groundwater remedial alternative system design
- Permitting
- System installation
- System startup

These activities might be requisite to finalize the system design, attain regulatory approval, or initiating construction. Therefore, these activities might dictate the time it takes to initiate and fully implement a remedial alternative.

Short-term Effectiveness

The short-term impacts of alternatives will be assessed considering the following:

- Protection of the community during implementation of the proposed remedial action
- Protection of workers during implementation of the proposed remedial action
- Potential environmental impacts during implementation of the proposed remedial action and the effectiveness of measures taken to mitigate potential environmental impacts
- Consideration of short-term responsiveness, increasing or decreasing concentrations during start-up and implementation
- Timeframe to achieve performance criteria

Long-term Effectiveness and Permanence

Technologies and alternatives are assessed for long-term effectiveness in reducing COI concentrations and permanence in maintaining those reduced concentrations in groundwater, along with the degree of certainty that technologies will be successful. Factors considered, as appropriate, include the following:

- Magnitude of residual risk remaining from untreated material remaining at the conclusion of remedial activities. The characteristics of the residuals should be considered to the degree that they could affect long-term achievement of remediation goals, considering their volume, toxicity, and mobility. Since there is no current risk, the potential for a remedial technology to increase potential risk to a receptor is considered in the evaluation process.
- Adequacy and reliability of controls as a means of evaluating alternatives in addition to managing residual risk.

Reduction of Toxicity, Mobility, and Volume

The degree to which technologies employ recycling or treatment that reduces toxicity, mobility, or volume will be assessed, including how treatment is used to address the principal risks posed at the Site. Factors considered, as appropriate, include the following:

- The treatment or recycling processes the technologies employ and constituents that will be treated
- The mass of COIs that will be destroyed, treated, or recycled
- The degree of expected reduction in toxicity, mobility, or volume
- The degree to which the treatment is irreversible
- What type and quantity of residuals will remain
- The type and quantity of residuals that will remain after treatment, considering the persistence, toxicity, and mobility of such substances and their constituents
- The degree to which treatment reduces the inherent hazards posed by risks at the Site

Time Required to Achieve Remediation Goals

This criterion includes the estimated time necessary to achieve remedial action objectives. This includes time required for permitting, pilot scale testing, design completion and approval, and implementation of approved remedies.

Cost

The costs of construction and long-term operation and maintenance of the technologies and alternatives are considered. Costs that are grossly excessive compared to overall effectiveness may be considered as one of several factors used to eliminate alternatives. Alternatives that provide effectiveness and implementability similar to that of another alternative by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated. Likewise, the fiscal benefit of a remedial alternative having relatively low capital costs might be offset by relatively high and long-term operation and maintenance (O&M) costs.

Community Acceptance

This assessment considers probable support, concerns, or opposition from community stakeholders about the alternatives. This assessment might not be fully informed until comments on the proposed plan are received. However, some general assumptions of how an alternative would be accepted by the community can be made.

Adaptive Management

Remediation alternatives are evaluated to determine whether an adaptive site management process would address challenges associated with meeting remedial objectives. Adaptive site management is the process of iteratively reviewing site information, remedial system performance, and current data to determine whether adjustments or changes in the remediation system are appropriate. The adaptive site management approach may be adjusted over the site's life cycle as new site information and technologies become available. This approach is particularly useful at complex sites where remediation is difficult and may require a long time, or where NCDEQ approves alternate groundwater standards for COIs, such as 4,000 µg/L for boron, pursuant to its authority under 15A NCAC 02L .0106(k). Duke Energy may request alternate standards for ash basin-related constituents, including boron, as allowed under 15A NCAC 02L .0106(k). Alternate standards are appropriate at the MSS given the lack of human health and ecological risks at the Site. Factors included in this evaluation include:

- Suitability to later modifications or synergistic with other technologies
- Information that could be gained from technology implementation to improve the Site Conceptual Model and better inform future remediation decision-making
- Ability to adjust and optimize the technology based on performance data
- Suitability for implementation in a sequential remedial action strategy
- Flexibility to implement optimization without significant system modifications

Sustainability

In accordance with sustainability corporate governance documents integral to Duke Energy and guidance provided by the USEPA, analysis of the sustainability of the remedial alternatives proposed in this CAP Update was identified as an important element to be completed as part of remedy selection process described herein.

Sustainable site remediation projects maximize the benefit of cleanup activities through reductions of the footprint of selected remedies, while preserving the effectiveness of the cleanup measures.

The USEPA, along with ASTM International, developed the Standard Guide to Greener Cleanups – ASTM E2893, which was utilized during the evaluation process as part of the remedial alternative selection effort. ASTM E2893 describes a process to evaluate and implement cleanup activities in order to reduce the footprint of remediation projects. Two primary approaches are described in the document: a qualitative Best

Management Practices (BMP) process and quantitative evaluation. Quantitative evaluation was utilized for remedy selection in this CAP Update.

As stated in the ASTM standard, during the remedial selection process, "… the user considers how various remedial options may contribute to the environmental footprint. Conducting a quantitative evaluation at this phase of the remedial alternative selection process provides stakeholders with information to help identify environmental footprint reduction opportunities for all alternatives that are protective of human health and the environment, comply with applicable environmental regulations and guidance, and meet project objectives" (ASTM, 2016).

Each remedial alternative has been assessed using SiteWise™, a public domain tool for evaluating remediation projects based on the overall footprint. SiteWise™ estimates collateral impacts through several quantitative sustainability metrics. The output data from SiteWise™ that can be utilized for remedial alternative comparison includes greenhouse gases, energy usage, and criteria air pollutants (including sulfur oxides, oxides of nitrogen, and particulate matter), water use, and resource consumption. The assessment quantified impacts associated with activities expected to occur during the remedial alternative construction phase, system operations where applicable and long-term monitoring.

Two core elements of the USEPA's Greener Cleanup principles were not quantified through the use of the SiteWise™ tool, as part of the alternatives evaluation: water consumption and waste generation. The analysis tool is set up to quantify the footprint of municipal water use and the accompanying discharge of wastewater for treatment to a publicly owned treatment works (POTW). The remediation activities proposed in the CAP Update do not use municipal water or discharge to a POTW, thereby making that input inapplicable for the calculation. Due to the difficulty of estimating reliable quantities of waste generated during construction, the input was considered too uncertain to use as a criterion. These two elements were set aside as less-relevant to remedy selection for the purposes of this CAP Update than the other quantifiable data points available. For the quantitative evaluation of alternatives discussed here, the primary assessments for consideration during sustainability screening are CO_2, NO_x, SO_x, PM_{10}, and energy usage related to materials procurement, installation and operation.

Results of these sustainability evaluations are presented and discussed in the detailed analysis sections of the specific alternatives (**Section 6.7**). Assumptions and parameters used in the sustainability calculations are presented in **Appendix L**.

6.7 Remedial Alternatives Criteria Evaluation

(CAP Content Section 6.D.a.iv)

Groundwater remediation alternatives 1, 2 and 3, as described in **Section 6.5**, were formulated based on the groundwater remediation technologies that were evaluated and retained for consideration per **Section 6.4**. The criteria for each groundwater remedial alternative were presented in **Section 6.6**. Detailed comparative analysis of the groundwater remediation alternatives are presented in the following subsections. A summary of the remediation alternative detailed analysis is also included in **Appendix M**.

6.7.1 Remedial Alternative 1 – Monitored Natural Attenuation

Protection of Human Health and the Environment

(CAP Content Section 6.D.a.iv.1)

There is no measurable difference between evaluated Site risks and risks indicated by background concentrations; therefore, no material increases in risks to human health related to the ash basin have been identified (**Appendix E**). The groundwater corrective action is being planned to address regulatory requirements. The risk assessment identified no current human health or ecological risk associated with groundwater downgradient of the ash basin. This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program. Water supply wells are located upgradient of the ash basin and permanent water solutions have been provided to those who selected this option.

Based on the absence of receptors, it is anticipated that MNA would continue to be protective of human health and the environment because modeling results indicate COI concentrations will diminish with time. Natural attenuation mechanisms will reduce COI concentrations, and model predictions indicate that no existing water supply wells would be impacted.

Compliance with Applicable Regulations

(CAP Content Section 6.D.a.iv.2)

Alternative 1 can be fully implemented in compliance with applicable laws and regulations. As it pertains to the selection of a groundwater remedy, the North Carolina Coal Ash Management Act of 2014 15A NCAC 13B .1636 states that the selected remedy will:

1) Be protective of human health and the environment
2) Attain approved groundwater protection standards

3) Control the source(s) of releases to reduce or eliminate, to the maximum extent practicable, further releases of constituents into the environment that may pose a threat to human health or the environment
4) Comply with standards for management of wastes as specified in Rule .1637(d)

As stated in **Section 6.8.1**, MNA would be protective of human health and the environment. MNA would eventually satisfy groundwater protection standards while being protective of human health and the environment going forward. The only waste generated by MNA would be investigation derived wastes (IDW) such as soil cuttings during the installation of monitoring wells and purge water generated during groundwater sampling. IDW can be managed in compliance with applicable management standards.

MNA would be conducted with the goal of achieving the 02L standards (15A NCAC 02L) at the compliance boundary. Groundwater remedial alternatives 2 or 3 would serve as a contingency groundwater remedy if MNA is later determined to be ineffective.

Samples of Lake Norman surface water immediately downgradient of the source area have been tested and comply with applicable 15A NCAC 02B standards (**Appendix J**). As demonstrated in the surface water future conditions evaluation, future groundwater migration from the source area under either closure-in-place or closure-by-excavation scenarios would not result in constituent concentrations at greater than 02B surface water standards in the unnamed tributary or Lake Norman (**Appendix J**).

New MNA monitoring well installations must satisfy applicable requirements of NCAC Title 15A Subchapter 02C, Well Construction Standards, including 15A NCAC 02C .0108 (*Standards of Construction*) and 15A NCAC 02C .0112 (*Well Maintenance*).

Compliance with applicable regulations should not materially affect the implementability, effectiveness, or cost of Groundwater Remedial Alternative 1. **Appendix I** includes a detailed evaluation of the applicability of Alternative 1: MNA as a remedial alternative for the Site.

Long-term Effectiveness and Permanence

(CAP Content Section 6.D.a.iv.3)

MNA would be an effective long-term technology, assuming source control and institutional controls (such as an RS designation) for the affected area. Natural attenuation mechanisms are understood and have been documented (**Appendix I**).

Implementation of MNA will not result in increased residual risk as current conditions and predicted conditions do not indicate unacceptable risk to human health or environment. Additionally, Duke Energy installed a permanent water solution (municipal water or filtration systems) at 65 households within a half-mile of the ash basin compliance boundary in accordance with G.S. Section 130A-309.211(c1). Furthermore, institutional controls (provided by the RS [restricted] designation) to limit access to groundwater use are proposed.

The adequacy and reliability of this approach would be documented with the implementation and maintenance of an effectiveness monitoring program to identify variations from the expected conditions. If factors that are not known at this time were to affect the attenuation process in the future, alternative measures could be taken. Monitoring will be in place to evaluate progress and allow sufficient time to implement changes.

Reduction of Toxicity, Mobility, and Volume

(CAP Content Section 6.D.a.iv.4)

COIs exist in the aquifer as molecules that interact with the natural components of the matrices to prevent mobility and toxicity to receptors. MNA can reduce aqueous concentrations while increasing solid phase concentrations and can therefore, under certain geochemical conditions, reduce COI plume concentrations, volume, and mass. There are no treatment or recycling processes involved with MNA as well as no residuals.

Short-term Effectiveness

(CAP Content Section 6.D.a.iv.5)

The stability and limited areal extent of the COI plume, along with the lack of unacceptable current risk to human and ecological receptors indicates current conditions are protective. Therefore, the technology is effective in the short-term.

There is an extensive network of monitoring wells associated with the ash basin. Groundwater monitoring parameters and the monitoring frequency would be used to evaluate changes in groundwater quality and effectiveness of the

remedial alternative through inter-well and intra-well comparisons. Although some wells within the immediate area of the basin will have to be abandoned and replaced as part of closure, monitoring wells along the waste boundary and at select downgradient areas would remain to monitor natural attenuation in the short-term.

Technical and Logistical Feasibility

(CAP Content Section 6.D.a.iv.6)

Groundwater Remedial Alternative 1 is technically feasible and readily implementable. Construction of Alternative 1 would involve the installation of approximately 12 MNA groundwater monitoring wells following completion of source control measures. The wells would be installed along geochemical transects to monitor constituent concentration trends within the footprint of ash basins because some existing wells would be removed during closure. Installation of groundwater monitoring wells is routine. It would involve a utility clearance of the area where monitoring wells will be installed. All groundwater monitoring wells would be installed by a licensed driller. Afterwards, each well installation would be surveyed for location and elevation. Material requirements, material availability, and the availability of specialized services (*e.g.*, licensed drillers, licensed surveyors) and labor are readily available. Implementation of MNA would not involve direct permitting. Once implemented, MNA would involve long-term groundwater monitoring and reporting. Otherwise, there are no "operations" associated with MNA.

MNA relies on natural attenuation processes, which would provide reliable results as long as the geochemistry (*e.g.*, pH and E_h) within the footprint of the ash basin achieves equilibrium while taking into account variability attributed to seasonality. However, natural attenuation processes could be affected by shifts in Site geochemistry beyond seasonal variability. An MNA effectiveness monitoring program (EMP) would be developed to assess the effectiveness of Alternative 1 and monitor key geochemical parameters within the ash basin footprint going forward.

Time Required to Initiate and Implement Corrective Action Technologies and Alternatives

(CAP Content Section 6.D.a.vi.7)

The time required for implementation of an MNA program could be as immediate as the approval of an approach since an extensive monitoring well

network already exists. Procedures for collection, analysis, and communication of results are also established and currently in place.

Predicted Time Required to Meet Remediation Goals

(CAP Content Section 6.D.a.iv.8)

The flow and transport model predicts that concentrations of COIs would meet 02L standards at the compliance boundary in approximately 700 years after ash basin closure (assumed as year 2032 in the model). This estimate is based on boron reaching a concentration of 700 µg/L at the existing compliance boundary (**Figure 6-25**).

Cost

(CAP Content Section 6.D.a.iv.9)

The cost estimate for this groundwater remediation alternative is based on capital costs for design and implementation including the installation of 12 new monitoring wells. The design costs include work plans, design documents and reports necessary for implementation of the alternative. Implementation costs include procurement and construction.

Costs to implement, operate, and manage the MSS MNA program would include annual costs and expenses associated with routine O&M, labor and materials to perform groundwater sampling. Costs also included routine labor for annual and 5-year reporting. A summary of the estimated costs for this alternative are provided in **Appendix K**.

Community Acceptance

(CAP Content Section 6.D.a.iv.10)

It is expected that there will be positive and negative sentiment about implementation of an MNA program. Community stakeholders might consider a 700-year time frame to achieve remediation goals for boron to be unacceptable. Community stakeholders with concerns regarding the capital and near-term O&M costs associated with the three alternatives may favor a less costly alternative. Until the final Site remedy is developed and comments are received and reviewed, assessment of community acceptance will not be fully known.

MNA as a remedial alternative would be protective of human health and the environment. Consistent with the USEPA Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P (April 21, 1999) the use of MNA "does not imply that EPA or the responsible parties are 'walking away' from cleanup or financial responsibility at a site."

Adaptive Site Management and Remediation Considerations

MNA is an adaptable process and can be an effective tool in identifying the need for alternative approaches if unexpected changes in Site conditions occur. An MNA program would not hinder or preempt the use of other remedial approaches in the future if conditions change. In fact, an effectiveness monitoring program is an essential part of any future remedial strategy. An MNA effectiveness monitoring program would provide information about changing Site conditions during and after source control measures.

Groundwater Remedial Alternative 1 is readily amenable to contingencies or modifications if it is later determined that MNA is an inadequate remedy, or that supplemental initiatives are necessary to enhance MNA performance.

Sustainability

Sustainability analysis was completed as described in **Section 6.6**. The footprint was quantified based on energy use and associated emissions, during the construction phase (*e.g.,* material quantities and transportation) and groundwater monitoring activities (*e.g.,* transportation). The results of the footprint calculations for MNA are summarized in **Table 6-14**. A summary of sustainability calculations for Alternative 1 can be found in **Appendix L**.

The footprint of Alternative 1 is the least energy-intensive of the remedial alternatives being considered, providing reduced, comparative footprint metrics in overall energy use and across all air emission parameters. Alternative 1 utilizes significantly fewer resources during construction and throughout the cleanup timeframe when compared to the other alternatives.

6.7.2 Remedial Alternative 2: Groundwater Extraction, Infiltration and In-Situ Treatment – Compliance in the Midterm

Protection of Human Health and the Environment

(CAP Content Section 6.D.a.iv.1)

Groundwater Remedial Alternative 2 is protective of human health and the environment. Groundwater COIs do not pose an unacceptable risk to potential receptors under conservative risk assessment exposure scenarios (**Appendix E**). Alternative exposure scenarios are not anticipated as long as Duke Energy owns and controls the property where groundwater COIs exist and institutional controls (*e.g.,* 15A NCAC 02L) remain in place. Furthermore, Lake Norman surface water immediately downgradient of the ash basin have been tested and comply with applicable 15A NCAC 02B standards (**Appendix J**). This conclusion

is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program.

The updated human health and ecological risk assessment concluded there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS (**Appendix E**). Potential risks to human health and the environment are within acceptable levels prescribed by the USEPA.

Compliance with Applicable Regulations

(CAP Content Section 6.D.a.iv.2)

Alternative 2 can be implemented in compliance with applicable laws and regulations. Those regulations would include: CAMA, groundwater standards, infiltration and extraction well installation and permitting**.** Waste generated by Alternative 2 would include IDW (*e.g.,* soil cuttings, purge water) and extracted groundwater. IDW can be managed in compliance with applicable management standards.

Alternative 2 would be conducted with the goal of achieving 02L groundwater standards (15A NCAC 02L) beyond the compliance boundary. Monitoring well and groundwater extraction well installations must satisfy applicable requirements of NCAC Title 15A Subchapter 2C, Well Construction Standards, including 15A NCAC 02C .0108 (*Standards of Construction*) and 15A NCAC 02C .0112 (*Well Maintenance*). Permits would be needed for groundwater withdrawal and surface water withdrawals from Lake Norman greater than 100,000 gallons per day.

Discharge of extracted water would be in compliance with appropriate discharge requirements, such as pH or other COI limitations in the NPDES permit, and proper operation and maintenance of an effectiveness monitoring system. Current requirements for a certified wastewater treatment plant operator for the influent to Outfall 002 would probably satisfy any future requirements for pretreatment/treatment of extracted groundwater prior to discharge via a permitted outfall.

Infiltration of chemical amendments along the southern portion of the ash basin dam would affect in-situ treatment of variably reactive COIs in groundwater. The infiltration of water into the shallow subsurface upgradient of the dam will aid in flushing COIs from unsaturated soils. Underground infiltration of water, or water with chemical amendments, must comply with 15A NCAC 02C .0225

(*Groundwater Remediation Wells*). Any amendments infiltrated into groundwater approved by the North Carolina Department of Health and Human Services (NCDHHS). A risk assessment evaluation must be completed and submitted to the Occupational and Environmental Epidemiology Section (OEES) of the Division of Public Health within NCDHHS for any amendment that is not already approved by NCDHHS.

Compliance with applicable regulations should not affect the implementability, effectiveness, or cost of Alternative 2.

Long-term Effectiveness and Permanence

(CAP Content Section 6.D.a.iv.3)

Groundwater extraction will contribute to effective and permanent achievement of groundwater standards by facilitating movement of impacted groundwater such that the COI plume is hydraulically controlled and COI mass is effectively removed as predicted by modeling results. Flow and transport modeling indicates that implementation of Groundwater Remedial Alternative 2, in conjunction with source control measures, would achieve 02L compliance for boron within approximately 30 years from system start-up. Furthermore, the mass of boron and related COI concentrations would be permanently reduced by groundwater extraction. In-Situ treatment would be used to address variably reactive COIs near the southern portion of the ash basin dam. Natural attenuation mechanisms would further reduce COI concentrations following the shutdown of the groundwater extraction system.

Coal ash constituents within the compliance boundary do not pose an unacceptable risk to human health since there are no complete routes for potential exposure. Construction of water supply wells is prohibited within the compliance boundary of an individually permitted disposal system (15A NCAC 02L .0107 (d)). Groundwater monitoring will continue at the compliance boundary in accordance with 02L.

The risk to human health and the environment is within acceptable levels prescribed by the USEPA. The risk to human health and the environment is also expected to decrease over time following implementation of Alternative 2. Performance monitoring would be conducted in accordance with the 02L standard, or applicable federal regulations. Institutional controls, including 15A NCAC 02L .0107(d), restrict activities that could result in exposure to groundwater COIs.

NPDES discharge requirements are protective of human health and the environment. Extracted groundwater discharged via NPDES Outfall 005 or 002 would comply with applicable discharge requirements and would not pose an unacceptable risk to human health and the environment.

Reduction of Toxicity, Mobility, and Volume

(CAP Content Section 6.D.a.iv.4)

Implementation of Alternative 2 would help reduce COI concentrations and, therefore, the toxicity, mobility, and volume of affected groundwater by groundwater extraction and altering groundwater chemistry in the south dam area with a PRB.

Constituents most amenable to groundwater extraction are the conservative/non-reactive COIs followed by variably reactive constituents. Groundwater extraction would have the least effect on non-conservative/reactive constituents. These constituents would be best addressed in-situ in the PRB.

Groundwater underlying the ash basin footprint also would be subject to the influences of natural attenuation. The mechanisms that naturally attenuate the concentrations of CCR inorganic constituents are dilution, dispersion, advection, sorption (including ion exchange and precipitation) and phyto-attenuation.

The volume of groundwater containing COIs at concentrations greater than groundwater standards would be reduced over a measurable time frame. For example, Groundwater Remedial Alternative 2 would permanently reduce the concentrations and areal extent of the boron plume in groundwater as defined by the 02L standard (700 μg/L).

The in-situ treatment of variably reactive COIs by chemical amendments will not reduce the volume of these constituents in the subsurface but will sequester them and make the COIs unavailable to advect with groundwater towards the natural discharge in Lake Norman.

Short-term Effectiveness

(CAP Content Section 6.D.a.iv.5)

The stability and limited areal extent of the COI plume, along with the absence of complete exposure pathways, indicates there are no short-term impacts to the environment, workers, or the local community. While there are areas with COI concentrations greater than 02L concentrations, the areas are not presenting unacceptable short-term risks.

Implementation of Groundwater Remedial Alternative 2 would be protective of communities adjacent to and near MSS. Installation of groundwater monitoring wells, groundwater extraction wells, discharge lines, collection tanks and related infrastructure are straight forward and routine tasks that can be conducted safely. Groundwater COIs do not pose an unacceptable risk to potential receptors under conservative risk assessment exposure scenarios (**Appendix E**).

Extracted groundwater would be managed via NPDES discharge. Compliance with NPDES Permit NC0004987 should make discharges of extracted groundwater protective of potential on-Site and off-Site receptors.

Hydraulic capture of groundwater near the groundwater extraction wells would be aided by the infiltration galleries and would occur soon after the groundwater extraction system is placed into service. Also, the advancement of the boron plume beyond the compliance boundary would be mitigated as long as hydraulic capture is sustained. The infiltration of chemical amendments along the southern portion of the ash basin dam would help to immobilize variably reactive COIs as they advect through the zone of treatment with groundwater.

Technical and Logistical Feasibility

(CAP Content Section 6.D.a.iv.6)

Groundwater Remedial Alternative 2 is technically feasible; however, implementation presents challenges. Direct push technology is likely not a viable option for placement of chemical amendments due to the heterogeneous fill encountered along the buttress of the dam. Drilled boreholes would be a preferable alternative. However, the estimated 143 drilled boreholes for emplacement of chemical amendments are not considered the most efficient technology to implement remediation in this area. Installation of the proposed groundwater extraction system, clean water infiltration, and in-situ treatment and would require significant efforts in planning, designing, and execution of site preparation. The extensive layout of groundwater remediation system wells, piping, and treatment system components, as well as site topography and access constraints pose significant challenges to constructability. However, with early awareness of the aforementioned complexities and effective communications between the design, implementation and project management teams, successful construction of the system would be anticipated. However, due to the implementability challenges with in-situ treatment mentioned above, this alternative is not considered the best alternative to achieve remediation goals.

Alternative 2 would be implemented concurrent with source control measures. Activities contemplated to implement Alternative 2 are routine with respect to the maturity of technologies used, material requirements and availability, and the availability of specialized services (*e.g.,* licensed drillers, electricians) and labor. Similarly, Remedial Alternative 2 is technically implementable with respect to the suitability and availability of extraction well installation locations and associated infrastructure. Most of the extraction well installations will be between the northern end of the ash basin dam and the access road, and between the ash basin and tributary to Lake Norman. Infiltration borings will be located along the southern portion of the dam.

Implementation of Remedial Alternative 2 can be achieved administratively. Obtaining an Underground Injection Control (UIC) permit to infiltrate water or water with chemical amendments pre-approved by NCDHHS should be a straightforward process. Likewise, obtaining groundwater and surface water withdrawal permits should be readily achievable. The NPDES permit may require modifications to allow for the discharge of groundwater.

Consideration for dam safety is paramount; however, it appears that there are ample locations on the lower buttress of the dam for the safe installation of extraction wells, infiltration borings and associated utilities. No well installations or construction will occur on the dam or lower buttress area without first obtaining the requisite permits from Duke Energy and North Carolina Environmental Quality Energy, Mineral and Land Resources.

In the area where in-situ remediation is proposed, fill (comprised of boulders, blast remnants, etc.) is beneath the surface. The extent of that fill is not known, but it is a major consideration in using direct push to insert the amendment into the area on a very close grid (*e.g.,* 10 foot spacing).

The area where infiltration is to be implemented slopes severely. This slope poses access challenges for construction. There is a challenge in construction of the shallow infiltration galleries proposed for this area in getting the water to infiltrate vertically rather than travel with the slope to Lake Norman. Also, significant excavation would be required for installation of the shallow infiltration galleries. Disturbing this steeply sloping area raises questions about the unacceptable transport of sediment into Lake Norman.

Time Required to Initiate and Implement Corrective Action Technologies and Alternatives

(CAP Content Section 6.D.a.iv.7)

Groundwater extraction and treatment proposed under Remedial Alternative 2 would be implemented concurrent with source control measures (basin closure). Hydraulic conductivity tests would be conducted to validate groundwater yields predicted by flow and transport modeling. Hydraulic conductivity test results would be used to refine predictive modeling and adjustments would be made to the groundwater remedial system design, if warranted.

Bench scale testing will be used to screen the effectiveness of MetaFix™ or other amendments to treat variably reactive COIs near the south end of the ash basin dam. A pilot test would be conducted following the selection of a chemical amendment based on bench scale testing results. Design of the groundwater extraction system proposed under Alternative 2 would be finalized afterwards.

Hydraulic conductivity tests, preparation of the final design, preparation of bid documents, and submission of bid documents to prospective bidders would be accomplished following NCDEQ approval of the CAP Update. No other prerequisites, such as permitting, bench scale testing, and pilot testing, are anticipated to delay initiation of Groundwater Remedial Alternative 2. Full-scale operation of the groundwater remediation system would be implemented following completion of construction, start-up, break-in, and NCDEQ approval.

Predicted Time Required to Meet Remediation Goals

(CAP Content Section 6.D.a.iv.8)

Groundwater extraction, infiltration, and in-situ treatment under Alternative 2 would be implemented concurrently with ash basin closure. Time to achieve the remediation goal of reducing the concentration of boron beyond the compliance boundary to levels less than the 02L standard was estimated by predictive flow and transport modeling to be approximately 30 years following full implementation of Remedial Alternative 2.

Cost

(CAP Content Section 6.D.a.iv.9)

Costs to implement, operate, and manage Groundwater Remedial Alternative 2 would include expenses associated with the design, permitting and construction management for the installation of 12 new monitoring wells, 33 groundwater extraction wells, 7.3 acres of clean water infiltration galleries, and 143 borings for the infiltration of chemical amendments.

Construction costs also include trenching for utilities and piping of infiltration water and extracted groundwater, equalization tanks, and piping infrastructure for the transfer of water to a permitted outfall. O&M expenses would include costs to operate the groundwater infiltration/extraction system, groundwater monitoring program, extraction system performance monitoring, and periodic reporting for a 30-year period.

Costs for implementation, O&M, monitoring, and reporting for Groundwater Remedial Alternative 2 are provided in **Appendix K**.

Community Acceptance

(CAP Content Section 6.D.a.iv.10)

It is expected that there will be positive and negative sentiment about implementation of a groundwater extraction system. No landowner is anticipated to be affected. It is anticipated that the extracted groundwater would be discharged through a NPDES permitted outfall that flows to Lake Norman and that the discharge would meet all permit limits. A groundwater extraction system that addresses potential COI plume expansion across the entire southern perimeter of the ash basin and east to the unnamed tributary may improve public perception of the groundwater remedy.

It is anticipated that groundwater extraction under Alternative 2 would generally receive more positive community acceptance than MNA under Alternative 1 since Alternative 2 involves more active measures to attempt in-situ treatment and physical extraction of COI mass from groundwater and would likely be perceived as more robust than MNA.

It is possible that some community stakeholders might have concerns with potential exposure to discharged groundwater via NPDES permit. Assurances that any means of groundwater management will be permitted and monitored by NCDEQ should alleviate stakeholder concerns. Stakeholder concerns should be further alleviated when they understand that extracted groundwater would undergo treatment, if necessary, and that constituent concentrations in the discharged groundwater would be within permitted limits. Until the final Site remedy is developed and comments are received and reviewed, assessment of community acceptance will not be fully known.

Adaptive Site Management and Remediation Considerations

Groundwater extraction using conventional well technology is an adaptable process. It can be easily modified to address changes to COI plume configuration

or COI concentrations. Individual well pumping rates can be adjusted or eliminated or additional wells can be installed to address COI plume changes.

Following full-scale implementation, it will be important to evaluate Groundwater Remedial Alternative 2 performance to determine if operational changes could result in greater efficiencies or shorter remediation time frames.

For example, additional extraction wells could be added to the remedial system to augment pumping or selected groundwater extraction wells could be repurposed and converted into clean water infiltration wells to augment infiltration provided by the infiltration galleries.

Groundwater Remedial Alternative 2 is readily amenable to other contingencies. The quantity of chemical amendments to be injected as a PRB along the southern portion of the ash basin dam will be estimated in the remedial design. A contingency would include whether there will be a need to have the amendments replenished one or more times to remain effective. However, bench-scale and field-scale pilot studies, as appropriate, prior to full-scale field implementation will help to quantify these uncertainties and assure that the remedy will be successful.

Sustainability

Sustainability analysis was completed as described in **Section 6.6**. The footprint was quantified based on energy use and associated emissions, during the construction phase (*e.g.,* material quantities and transportation), active remediation activities (*e.g.,* groundwater pumping and treatment) and groundwater monitoring activities (*e.g.,* transportation). The results of the footprint calculations for Remedial Alternative 2 are summarized in **Table 6-14**. A summary of sustainability calculations for Alternative 2 can be found in **Appendix L**.

The footprint of Alternative 2 is the most emission-intensive remedial alternative being considered. Alternative 1 (MNA) requires significantly less materials and energy than Alternative 2 and is therefore characterized by a dramatically smaller footprint. Conversely, Alternative 2 generates a dramatically larger footprint than Alternative 3. Compared to Alternative 3, Alternative 2 utilizes 33 fewer extraction wells, does not employ 24 clean water infiltration wells, but does propose the use of a 7.3-acre infiltration gallery and the in-situ placement of approximately 60 tons of reactive media through 143 drilled boreholes. The additional remediation system components required by Alternative 2 will

generate higher material-related footprint emissions for the construction phase than Alternative 3. Additionally, the increased timeframe of remediation system operation for Alternative 2 (30 years) when compared to Alternative 3 (9 years) produces air emissions more than five times the levels of Alternative 3. The quantitative analysis of the footprints of the remedial alternatives under consideration for this CAP Update indicates Alternative 2 to be the least sustainable option.

6.7.3 Remedial Alternative 3: Groundwater Extraction and Clean Water Infiltration

Protection of Human Health and the Environment

(CAP Content Section 6.D.a.iv.1)

Groundwater Remedial Alternative 3 is protective of human health and the environment. Groundwater COIs do not pose an unacceptable risk to potential receptors under conservative risk assessment exposure scenarios (**Appendix E**). Alternative exposure scenarios are not anticipated as long as Duke Energy owns and controls the property where groundwater COIs exist and institutional controls (*e.g.,* 15A NCAC 02L) remain in place. Furthermore, Lake Norman surface water immediately downgradient of the ash basin has been tested and comply with applicable 15A NCAC 02B standards (**Appendix J**). This conclusion is further supported by multiple water quality and biological assessments conducted by Duke Energy as part of the NDPES monitoring program. If implemented, Alternative 3 would be protective of human health and the environment.

The updated human health and ecological risk assessment concluded that there is no evidence of unacceptable risks to human and ecological receptors exposed to environmental media potentially affected by CCR constituents at MSS (**Appendix E**). Potential risks to human health and the environment are within acceptable levels prescribed by the USEPA.

Compliance with Applicable Regulations

(CAP Content Section 6.D.a.iv.2)

Remedial Alternative 3 can be fully implemented in compliance with applicable laws and regulations. Those regulations would include: CAMA, groundwater standards, extraction and infiltration well installation and permitting. Waste generated by Alternative 3 would include IDW (*e.g.,* soil cuttings, purge water) and extracted groundwater. IDW can be managed in compliance with applicable management standards.

Alternative 3 would be conducted with the goal of achieving 02L groundwater standards (15A NCAC 02L) beyond the compliance boundary. Monitoring well and groundwater extraction/clean water infiltration well installations must satisfy applicable requirements of NCAC Title 15A Subchapter 2C, Well Construction Standards, including 15A NCAC 02C .0108 (*Standards of Construction*) and 15A NCAC 02C .0112 (*Well Maintenance*). Permits would be needed for groundwater withdrawal and surface water withdrawals from Lake Norman greater than 100,000 gallons per day.

Discharge of extracted water would be in compliance with appropriate discharge requirements, such as pH or other COI limitations in the NPDES permit. However, the NPDES permit may need to be modified to allow for the discharge of groundwater through one of the outfalls. Any current requirements for a certified wastewater treatment plant operator for the influent to Outfall 002 would probably satisfy any future requirements for pretreatment/treatment of extracted groundwater prior to discharge via a permitted outfall.

The infiltration of clean water into the subsurface upgradient of the dam will aid in flushing COIs from unsaturated soils. Underground infiltration of water must comply with 15A NCAC 02C .0225 (*Groundwater Remediation Wells*).

Compliance with applicable regulations should not affect the implementability, effectiveness, or cost of Alternative 3.

Long-term Effectiveness and Permanence

(CAP Content Section 6.D.a.iv.3)

Groundwater extraction and clean water infiltration will contribute to be an effective and permanent achievement of groundwater standards by facilitating movement of impacted groundwater such that the COI plume is hydraulically controlled and COI mass is effectively removed as predicted by modeling results. Flow and transport modeling indicates that implementation of Groundwater Remedial Alternative 3 in conjunction with anticipated source control measures (basin closure) will achieve 02L compliance for boron within approximately 9 years after the remedial system is placed into service. Furthermore, the mass of concentrations of boron will be permanently reduced as a consequence of groundwater extraction and clean water infiltration.

Coal ash constituents within the compliance boundary should not pose a risk to human health since there should be no complete routes for potential exposure. Construction of water supply wells is prohibited within the compliance

boundary of an individually permitted disposal system (15A NCAC 02L .0107 (d)). Groundwater monitoring will continue at the compliance boundary in accordance with 02L.

The risk to human health and the environment is within acceptable levels prescribed by the USEPA. The risk to human health and the environment is expected to decrease over time following implementation of Alternative 3. Performance monitoring would be conducted in accordance with 02L the standard, or applicable federal regulations. Institutional controls, including 15A NCAC 02L .0107(d), restrict activities that could result in exposure to groundwater COIs.

NPDES discharge requirements are protective of human health and the environment. Extracted groundwater discharged via NPDES Outfall 005 or 002 must comply with applicable discharge requirements and will not pose an unacceptable risk to human health and the environment.

Reduction of Toxicity, Mobility, and Volume

(CAP Content Section 6.D.a.iv.4)

Implementation of Alternative 3 would help reduce COI concentrations and, therefore, the toxicity, mobility, and volume of affected groundwater by active groundwater extraction and clean water infiltration.

Constituents most amenable to groundwater extraction are those that are conservative/non-reactive COIs followed by variably reactive constituents. Groundwater extraction would have the least effect on non-conservative/reactive constituents.

Groundwater underlying the ash basin footprint also would be subject to the influences of natural attenuation. The mechanisms that naturally attenuate the concentrations of CCR inorganic constituents are dilution, dispersion, advection, sorption (including ion exchange and precipitation) and phyto-attenuation.

The volume of groundwater containing COIs at concentrations greater than groundwater standards would be reduced over a measurable time frame. For example, Groundwater Remedial Alternative 3 would permanently reduce the concentrations and areal extent of the boron plume in groundwater as defined by the 02L standard (700 μg/L).

Short-term Effectiveness

(CAP Content Section 6.D.a.iv.5)

The stability and limited areal extent of the COI plume, along with the absence of complete exposure pathways, indicates there are no short-term impacts to the environment, workers, or the local community. While there are areas with COI concentrations greater than 02L concentrations, the areas are not presenting unacceptable short-term risks.

Implementation of Groundwater Remedial Alternative 3 would be protective of communities adjacent to and near MSS. Installation of groundwater monitoring wells, groundwater extraction wells, clean water infiltration wells, discharge lines, collection tanks and related infrastructure are straight forward and routine tasks that can be conducted safely. Groundwater COIs do not pose an unacceptable risk to potential receptors under conservative risk assessment exposure scenarios (**Appendix E**).

Regardless, remediation worker exposure to COIs in groundwater should be minimal since they would be wearing personal protective equipment (PPE) if there is the potential for exposure to COIs in ash, soil, or groundwater.

Extracted groundwater will be managed via NPDES discharge. Compliance with NPDES Permit NC0004987 should make discharges of extracted groundwater protective of potential on-Site and off-Site receptors.

Hydraulic capture of groundwater near the groundwater extraction wells would be aided by the vertical infiltration wells and would occur soon after the groundwater extraction system is placed into service. Also, the advancement of the boron plume beyond the compliance boundary would be mitigated as long as hydraulic capture is sustained.

Technical and Logistical Feasibility

(CAP Content Section 6.D.a.iv.6)

Groundwater Remedial Alternative 3 is technically feasible and implementable with some challenges. Installation of the proposed clean water infiltration and extraction system would require significant efforts in planning, designing, and execution of site preparation. The extensive layout of groundwater remediation system wells, piping, and treatment system components, as well as site topography and access constraints pose significant challenges to constructability. However, with early awareness of the aforementioned complexities and effective

communications between the design, implementation and project management teams, successful construction of the system would be anticipated.

Alternative 3 might be implemented concurrent with source control measures (basin closure). Activities contemplated to implement Alternative 3 are routine with respect to the maturity of technologies used, material requirements and availability, and the availability of specialized services (*e.g.*, licensed drillers, electricians) and labor. Similarly, Remedial Alternative 3 is technically implementable with respect to the suitability and availability of extraction well and infiltration well installation locations and associated infrastructure.

Implementation of Remedial Alternative 3 can be achieved administratively. Obtaining a UIC permit to inject clean water should be a straightforward process. Likewise, obtaining groundwater and surface water withdrawal permits should be readily achievable. Modification to the NPDES permit to allow the discharge of groundwater, should be a straightforward process.

Consideration for dam safety is paramount; however, it appears that there are ample locations on the lower buttress of the dam for the safe installation of groundwater extraction wells and associated utilities. No well installations or construction will occur on the dam or lower buttress area without first obtaining the requisite permits from Duke Energy and North Carolina Environmental Quality Energy, Mineral and Land Resources.

In the area along the southern portion of the dam, rock, likely excavated or blasted during construction of the levee (dam) was used as fill. This may require drilling equipment used for bedrock drilling to install the extraction wells.

The area where infiltration is to be implemented slopes severely. This slope poses access challenges for construction. There is a challenge in construction of the vertical infiltration wells, but the challenge is not insurmountable. Also, the disturbance from construction activities should be manageable.

Time Required to Initiate and Implement Corrective Action Technologies and Alternatives

(CAP Content Section 6.D.a.iv.7)

Groundwater extraction proposed under Remedial Alternative 3 can be implemented concurrently with source control measures (basin closure). Some aspects of the alternative, (*e.g.*, hydraulic conductivity tests, design and permitting) could be started upon approval of the CAP, with some construction-

related activities phased in during ash basin closure. Hydraulic conductivity tests would be conducted to validate groundwater yields predicted by flow and transport modeling. Hydraulic conductivity test results would be used to refine predictive modeling, and adjustments would be made to the groundwater extraction system design if warranted.

Design of the groundwater extraction system proposed under Alternative 3 would be finalized following completion of hydraulic conductivity tests. Pre-design testing, preparation of the final design, preparation of bid documents, and submission of bid documents to prospective bidders could be accomplished within 22 months following NCDEQ approval of the CAP. No other prerequisites, such as permitting, are anticipated that would delay initiation of Groundwater Remedial Alternative 3. Full-scale operation of the groundwater extraction and clean water infiltration system could be accomplished within 14 months following the selection of a contractor.

Time Required to Achieve Remedial Goals

(CAP Content Section 6.D.a.iv.8)

Groundwater extraction and clean water infiltration performed under Alternative 3 can be fully implemented concurrent with the ash basin closure. Time to achieve the remediation goal of reducing the concentration of boron and variably reactive COIs beyond the compliance boundary to levels less than the 02L standard was estimated by predictive flow and transport modeling to be 9 years after full implementation of Remedial Alternative 3.

Cost

(CAP Content Section 6.D.a.iv.9)

Costs to implement, operate, and manage Groundwater Remedial Alternative 3 would include expenses associated with the design, permitting and construction management for the installation of 12 new monitoring wells, 66 groundwater extraction wells, and 24 vertical clean water infiltration wells.

Construction costs also include trenching for utilities and piping of infiltration water and extracted groundwater, equalization tanks, and piping infrastructure for the transfer of water to permitted outfall. O&M expenses would include costs to operate the groundwater infiltration/extraction system, groundwater monitoring program, extraction system performance monitoring, and periodic reporting for a 30-year period.

Costs for implementation, O&M, monitoring, and reporting for Remedial Alternative 3 are provided in **Appendix K**.

Community Acceptance

(CAP Content Section 6.D.a.iv.10)

It is expected that there will be positive and negative sentiment about implementation of a groundwater extraction system. No landowner is anticipated to be affected. It is anticipated that the extracted groundwater would be discharged through a NPDES permitted outfall that flows to Lake Norman and that the discharge would meet all permit limits. A groundwater extraction system that addresses potential COI plume expansion across the entire southern perimeter of the ash basin and east to the unnamed tributary may improve public perception.

It is anticipated that groundwater extraction and clean water infiltration under Alternative 3 would generally receive more positive community acceptance than MNA under Alternative 1 since Alternative 3 involves more active measures to attempt physical extraction of COI mass from groundwater and would likely be perceived as more robust than MNA. Additionally, it is anticipated that Alternative 3 may receive more positive community acceptance than Alternative 2 because Alternative 3 will not involve the infiltration of large quantities of chemical amendments into the subsurface for the purposes of in-situ treatment of COIs. The estimated remedial timeframe to reach the 02L standard for boron from implementation of the full system is significantly shorter for the implementation of Alternative 3 (9 years) than for Alternative 2 (30 years) and Alternative 1 (700 years).

It is possible that some community stakeholders might have concerns with potential exposure to discharged groundwater via NPDES permit. Assurances that any means of groundwater management will be permitted and monitored by NCDEQ should alleviate stakeholder concerns. Stakeholder concerns should be further alleviated when they understand that extracted groundwater would undergo treatment, if necessary, and that constituent concentrations in the discharged groundwater would be within permitted limits. Until the final Site remedy is developed and comments are received and reviewed, assessment of community acceptance will not be fully known.

Adaptive Site Management and Remediation Considerations

Groundwater extraction using conventional well technology is an adaptable process. It can be easily modified to address changes to COI plume configuration

or COI concentrations. Individual well pumping rates can be adjusted or eliminated or additional wells can be installed to address COI plume changes.

Following full-scale implementation, it will be important to evaluate Groundwater Remedial Alternative 3 performance to determine if operational changes could result in greater efficiencies or shorter remediation time frames.

For example, additional extraction wells could be added to the remedial system to augment pumping or selected groundwater extraction wells could be repurposed and converted into clean water infiltration wells to augment the infiltration and flushing provided by the network of infiltration wells.

Sustainability

Sustainability analysis was completed as described in **Section 6.6**. The footprint was quantified based on energy use and associated emissions, during the construction phase (*e.g.*, material quantities and transportation), active remediation activities (*e.g.*, groundwater pumping and treatment) and groundwater monitoring activities (*e.g.*, transportation). The results of the footprint calculations for Alternative 3 are summarized in **Table 6-14**. A summary of sustainability calculations for Alternative 3 can be found in **Appendix L.**

The footprint of Alternative 3 is the second-most emission-intensive remedial alternative being considered. Alternative 1 (MNA) requires significantly less materials and energy than Alternative 3 and is therefore characterized by a smaller footprint. Alternative 3 presents lower energy-consumption metrics when measured against Alternative 2. Alternative 3 utilizes twice the extraction wells (33) than Alternative 2 and a clean water infiltration system consisting of 24 wells not planned for Alternative 2. However, Alternative 2 utilizes a 7.3-acre clean water infiltration gallery and the in-situ placement of approximately 60 tons of reactive media, through drilled boreholes, which Alternative 3 does not employ. As a result, Alternative 3 will generate a lower material-related environmental footprint for the construction phase. Additionally, the shorter timeframe of remediation system operation for Alternative 3 (9 years) when compared to Alternative 2 (30 years) requires energy usage and produces air emissions far less than the levels of Alternative 2. The quantitative analysis of the footprints of the remedial alternatives under consideration for this CAP Update indicates Alternative 3 to be the second-most sustainable option after MNA. Opportunities for system optimization and energy savings could be pursued

throughout the remediation timeframe, as conditions change and component technologies possibly evolve.

6.8 Proposed Remedial Alternative Selected for Source Area
(CAP Content Section 6.E)

Based on the alternatives detailed analysis using criteria rankings presented in **Section 6.7** and summarized in **Appendix M**, the favored remedy for groundwater remediation is **Alternative 3, Groundwater Extraction and Clean Water Infiltration**.

To comply with 15A NCAC 02L .0106(h), corrective action plans must contain the following the following items, which are included in the following subsections:

- Specific plans, including engineering details where applicable, for restoring groundwater quality
- A schedule for the implementation and operations of the proposed plan
- A monitoring plan for evaluating the effectiveness of the proposed corrective action and the movement of the COI plume

6.8.1 Description of Proposed Remedial Alternative and Rationale for Selection
(CAP Content Section 6.E.a)

The favored remedy for groundwater remediation, Alternative 3, is intended to provide the remedial technology that has demonstrated to provide the most effective means for restoration of groundwater quality at or beyond the compliance boundary by returning COIs to acceptable concentrations (02L/IMAC or background, whichever is greater), or as closely thereto as is economically and technologically feasible, consistent with 15A NCAC 02L .0106(a), and to address 15A NCAC 02L .0106(j). In the future, alternative standards may be proposed as allowed under 02L .0106(k). This approach is considered reasonable given the documented lack of human health or ecological risk at the MSS.

Groundwater Remediation Alternatives 1, 2, and 3 are all protective of human health and the environment and will comply with applicable regulations. Alternatives 1 and 3 are readily implementable. Portions of Remediation Alternative 2 would have difficulty during implementation due to the steep embankment where the infiltration galley would have to be installed. Additionally, in-situ infiltration of chemical amendments in the dam buttress is anticipated to be difficult to the heterogeneity of the fill area. Groundwater Remediation Alternative 1, MNA, was not selected because it does restore ash

basin-affected groundwater at or beyond the compliance boundary within a reasonable (*i.e.* approximately 30 years) timeframe, and therefore does not meet the Duke Energy's corrective action goals. In contrast, Groundwater Remediation Alternative 2 is capable of achieving 02L compliance for boron and variably reactive COIs within approximately 30 years and Alternative 3 is capable of achieving compliance within approximately 9 years from implementation of the full system, assuming implementation is concurrent with source control measures (basin closure). Remediation Alternative 2 was not selected due to the anticipated difficulties with implementation of clean water infiltration galleries and in-situ application of chemical amendments.

Groundwater extraction and clean water infiltration proposed for Remediation Alternative 3 is an adaptable approach and less costly to implement than Alternative 2. The remedial system could be modified relatively easily if conditions change. The addition of wells, or adjusting well pumping schemes, can be readily accomplished. Treatment of extracted groundwater prior to discharge could be implemented if future permit requirements are required. The long-term effectiveness of Remedial Alternative 3 would be documented through an effectiveness monitoring program.

Groundwater extraction and clean water infiltration via a well network generates a larger footprint in the sustainability analysis over MNA (Alternative 1) but has a lower footprint than Remedial Alternative 2, which also includes in-situ treatment with chemical amendments and a longer timeframe to meet remedial objectives. The footprint of Alternative 3, however, is small in comparison to other elements of the ash basin closure process. During design phases of the groundwater remediation project, opportunities for energy efficiency and reduction of the project footprint can be evaluated.

Source control measures would mitigate the source of CCR COIs to groundwater and proposed Groundwater Remedial Alternative 3 would mitigate the migration of groundwater COIs beyond the compliance boundary. Groundwater Remedial Alternative 3 would reduce boron concentrations until groundwater remediation objectives are achieved.

Seep Corrective Action

As stated in the SOC, ash basin decanting is expected to substantially reduce or eliminate the seeps. After completion of decanting, remaining seeps, if not dispositioned in accordance with the SOC, would be characterized for determination of disposition. After seep characterization, an amendment to the

CAP and/or Closure Plan, may be required to address remaining seeps. Duke Energy is prepared to address those seeps through corrective action sufficient to protect public health, natural resources, and the environment. Non-constructed seeps, currently covered under the SOC, that have the potential to not be fully dispositioned post-decanting are listed on **Table 6-8**. No constructed seeps are present at the MSS. In summary, decanting, ash basin closure, and the proposed groundwater remediation alternative are the anticipated corrective action strategies to address each of the seeps.

Seep S-01 is located in the unnamed tributary east of the ash basin. As of December 2019, decanting has not observably reduced flow at this location. A re-assessment of this seep was conducted between September and November 2019 as a result of hardness levels greater than the interim action level (200 mg/L) established by the SOC. In accordance with the SOC, Duke Energy is conducting monthly monitoring of this seep. The findings of this re-assessment were submitted to NCDEQ in November 2019. The proposed remedial alternative within this CAP Update is expected to address water quality at this location, as groundwater extraction wells would be designed to maintain a water elevation less than the receiving waters (i.e., the unnamed tributary and Lake Norman). Groundwater flow and transport modeling simulations of groundwater extraction predict that the current hydraulic gradient toward the unnamed tributary would be reversed, inducing lake water infiltration into the groundwater system. Therefore, it could be expected that this location be dispositioned via dry conditions under the proposed remedial approach.

Seeps S-02 and S-04 are located east of the ash basin dam toward Lake Norman. Since the commencement of decanting, there has been no observable flow at these locations. This indicates that decanting has been an effective corrective measure and that it may be appropriate for S-02 and S-04 to be dispositioned in accordance with the SOC.

Final corrective action plans for non-constructed seeps that are not dispositioned post-decanting will be proposed in an amendment to this CAP Update, as needed, and submitted based on the schedule outlined in the SOC.

6.8.2 Design Details

(CAP Content Section 6.E.b)

Design of the proposed clean water infiltration and extraction system would require a pilot test (*i.e.,* installation of a portion of the system) to facilitate refinement of the final system design. A pilot test work plan will be prepared to

facilitate implementation of the system. As part of this process, the groundwater flow and transport model will likely be refined to determine the final number and locations of system wells. As the pilot testing and design process evolves, refinements to the systems and timeframe, including a potential reduction in the time needed to achieve compliance may occur compared to the model predictions presented in this CAP Update.

The intent of the design would be to maximize pore volume exchange and establish groundwater control in areas downgradient of the ash basin. Basic aspects of the Alternative 3 call for installation of:

- 24 clean water infiltration wells and flow appurtenances
- 66 extraction wells and appurtenances
- Well vault and wellhead piping, fittings, and instrumentation
- A system to control water level within each groundwater extraction well
- Groundwater extraction system discharge piping
- Clean water infiltration pre-treatment system
- Piping to transfer water from the infiltration water supply to the infiltration well system
- Clean water distribution system
- Electric power supply
- Groundwater remediation telemetry system

6.8.2.1 Process Flow Diagrams for all Major Components of Proposed Remedy
(CAP Content Section 6.E.b.i)

A conceptual process flow diagram for clean water infiltration is shown on **Figure 6-33** and a process flow diagram for a groundwater extraction system is shown on **Figure 6-34.** The detailed design elements presented below may be adjusted based on a final technical review.

Site Preparation (Step 1 – Create Access)

Installation of the proposed groundwater extraction and clean water infiltration system would require significant efforts in planning, designing, and execution of site preparation. The extensive layout of groundwater remediation system wells, piping, and treatment system components, as

well as haul road access constraints pose significant challenges to constructability. However, with early awareness of the implementability challenges and effective communications between the design, implementation and project management teams, successful construction of the system would be anticipated.

Safe access roads for mobile construction equipment (*e.g.,* drill rigs), as well as long-term operation and maintenance needs, will likely require clearing, grubbing, grading and access improvement.

A certain level of flexibility regarding well placement is expected to be required due to site conditions encountered during construction. Prior to construction and following the hydraulic conductivity test(s), an assessment of the precise locations of wells would be made in collaboration with the modeler. If the model predictions are not affected, relocation from the predetermined location due to terrain or other site-specific constraints would expedite construction. Land disturbance, anticipated to include somewhat extensive tree and brushy vegetation removal and grubbing, will require erosion and sedimentation control (ESC) to be implemented and likely reviewed and approved by a regulatory agency. Adaptable ESC should be planned to limit project delays by avoiding formal modifications of plans.

Pilot Test (Step 2a – To Finalize Design)

A pilot test would involve installation of a portion of the planned system to evaluate how the system performs and to make initial progress towards remediation at the same time. The results of the pilot test would be used to refine and scale up the final design thereby maximizing the likelihood of successful operation in the field. Extraction pilot test wells will be screened within or across a flow zone similar to model simulations to the extent feasible. Clean water infiltration tests would be conducted to determine the rates of groundwater infiltration wells screened across the saprolite, transition zone, and bedrock flow zones. The number of wells and their locations would be specified in the pilot test work plan.

Pilot test results will be used to:

- Determine site-specific well yields for each flow zone
- Validate predictive flow and transport modeling

- Refine predictive flow and transport modeling, as needed
- Confirm groundwater extraction well capture zones in the saprolite and transition zone flow zones beyond available data
- If warranted, make adjustments to the groundwater extraction system design
- If warranted, make design adjustments to conveyances for extracted groundwater
- If warranted, make design adjustments to the groundwater treatment system

Clean water infiltration test wells will be screened within or across flow zones similar to model simulations to the extent feasible. Clean water infiltration test results will be used to:

- Determine site-specific well infiltration rates
- Validate predictive flow and transport modeling
- Refine predictive flow and transport modeling, as needed
- If warranted, make adjustments to the groundwater infiltration system design
- If warranted, make design adjustments to conveyances for infiltration groundwater
- If warranted, make design adjustments to the infiltration water treatment system

The extraction and infiltration wells used for testing would be included in the final groundwater remediation system design.

Infiltration Water Quality and Treatment (Step 2b – To Finalize Design)

The Marshall facility does not have the capacity in the existing intake system to provide the 285 gpm that is projected for infiltration. The CAP included a proposed location for the new surface water intake to provide the water for infiltration based on the information that was available at that time. However, there is limited information on the quality of water from Lake Norman at the proposed location that will become infiltration water.

Prior to completing the design phase for the corrective action on groundwater at Marshall, the location for the new surface water intake will be evaluated and the location may be changed based on topography, depth of water in the lake, or other pertinent conditions at the site. Also, when the location of the surface water intake is finalized, an evaluation of the surface water quality at that location will be performed.

Based on the water quality and bench scale treatability studies, technologies for infiltration water treatment will be evaluated. The potential treatment technologies for infiltration water include, but are not limited to, the following:

- pH adjustment
- precipitation
- filtration (*i.e.,* sand filtration, reverse osmosis), and
- ion exchange

Clean Water Infiltration and Extraction Well Design (Step 3 – Install Wells)

The preliminary design for Groundwater Remedial Alternative 3 includes 66 extraction wells and 24 clean water infiltration wells. The new extraction wells would be installed along the southern portion of the dam, along north end of the ash basin dam, and along the eastern access road, between the ash basin and the tributary to Lake Norman (**Figure 6-30**). The locations are based on predicted COI plume configuration, with the intent of capturing groundwater to create groundwater flow control, COI mass removal, and reduced migration of potentially mobile COIs. The predicted effects of the wells are defined in detail in the flow and transport modeling results.

Clean water infiltration wells along the eastern access road will be used to flush residual COIs from shallow soils to the saturated portions of the aquifer where they can be captured by the extraction well network.

All groundwater extraction and clean water infiltration wells would be installed by a North Carolina licensed well driller in accordance with North Carolina Administrative Code Title 15A, Subchapter 2C – Well Construction Standards, Rule 108 Standards of Construction: Wells Other Than Water Supply (15A NCAC 02C .0108).

The infiltration and extraction wells might be drilled using hollow stem auger, air percussion/hammer, sonic methods, or a combination thereof. The drilling method would depend on Site conditions. Completed wells would be 6 inches in diameter to facilitate the installation of pumps and instrumentation (*e.g.,* level control) in groundwater extraction wells. The top of the sand pack would extend to approximately 2 feet above the top of well screens. A bentonite well seal at least 2 feet thick would be installed on top of the sand pack. Neat cement grout with 5 percent bentonite would be placed on top of the bentonite well seal and would fill the remaining well annulus to within 3 feet of the ground surface. All materials and installations would be in accordance with 15A NCAC 02C. Typical well construction schematics are included for extraction wells (**Figure 6-27**) and infiltration wells (**Figure 6-31**).

Infiltration Wells (Step 4A)

The clean water for infiltration would be stored in a tank near the well system and an HDPE distribution header would convey clean water from the infiltration water treatment system to each infiltration well (**Figure 6-33**). A seal at the top of the well through which the clean water infiltration-pipe and wiring would enter the well and would be designed to be leak free.

The hydraulic head at each clean water infiltration well would be controlled by a pressure control valve. The predictive flow and transport model assumed 0 pounds per square in gauge (psig) as the infiltration pressure, but the pressure could be increased or decreased to achieve performance objectives. The amount of water flowing into the infiltration well would be measured by a flow rate and flow totalizing meter. At startup, a ball valve at the top of the well would be opened to allow water to displace the air in the well and system piping. Also, pressure transducers installed at the top of each infiltration well would monitor well head pressures (**Figure 6-31**).

Other appurtenances in the piping system would include a pressure gauge, ball valves to isolate piping for maintenance, and a solenoid valve that would close to stop the flow of infiltration water in the event high water level in the vault.

Operational parameters, such as infiltration rate, totalized infiltration flow, and well head pressure, as well as critical malfunctions such as

accumulation of water in the well vault would be transmitted to the groundwater remediation system owner via telemetry system.

Extraction Wells (Step 4B)

A pump would be installed in each groundwater extraction well. Selection of pump type (*e.g.,* electric submersible or pneumatic) would be determined in the final design. If the water level in the well is above the top water level switch, the pump would run to pump the water to lower water level switch, which would cause the pump shut off. The flow of extracted groundwater from the pump would be measured using a flow rate and flow totalizer meter before being conveyed to groundwater discharge piping for treatment and discharge (**Figure 6-27**). Other appurtenances in the piping system would include a check valve to prevent back flow into the well, a sampling port, a pressure gauge to indicate the pressure generated by the pump, ball valves to isolate piping for maintenance, and a flow control valve such as a stainless steel globe or gate valve (**Figure 6-27**).

Operational parameters, such as flow and water level, and critical malfunctions, such as accumulation of water in the well vault, would be transmitted via telemetry system to inform the system operator of the status in the well and enclosure.

The collection system would consist of gravity sewers, eight duplex pump stations, and force main pipes to convey flow. Above ground piping, tanks, and pumps should be equipped with heating and insulation to prevent freezing in cold conditions.

Clean Water Infiltration Water Treatment (Step 5 – Build Infiltration Treatment)

Water used for clean water infiltration will be obtained from a water source such as Lake Norman. If the water quality is not suitable for infiltration, the groundwater would be treated in a modular treatment system if suspended solids are the only concern (**Figure 6-33**). The equalization tanks and the modular treatment systems would be located in the proximity of the infiltration system near the production well. The treatment system would condition the water, as necessary, prior to storage and distribution to the infiltration wells.

A modular flocculation, settling, and filtration treatment process may be used to reduce total suspended solids (TSS) to concentrations, if necessary.

A polymer could be added to the raw water in a rapid mix tank. The polymer would flocculate with total suspended solids (TSS). Treated water and flocculent would flow from the rapid mix tank to a modular sedimentation tank where the flocculent and particulates would settle. Sedimentation tank effluent would undergo filtration to remove suspended flocculent and particulates. The filtered water would be pumped to a holding tank where infiltration water would be stored prior to distribution to the infiltration wells.

Parallel treatment processes would facilitate infiltration system operation and maintenance and should achieve optimal runtime and performance. Individual system components (*e.g.,* vertical turbine pumps, equalization tanks, modular treatment system or transfer pumps) could be operated singularly or in parallel and achieve 100 percent groundwater infiltration capacity. Liquid waste materials generated as a result of maintenance (*e.g.,* filter backwash or wash water) would be directed to a wastewater treatment plant. The equalization tanks, treatment system, transfer pumps, and holding tank would be housed in an enclosed structure to prevent exposure to prevailing weather conditions.

Groundwater Extraction Water Treatment (Step 6 – Address Groundwater Treatment)

Extracted groundwater would flow to an equalization tank and then be conveyed to a water treatment system to address low pH and other COIs, as appropriate. Initially, the groundwater would propose to be discharged with the water from dewatering the ash basin. The pH would be adjusted in an existing system and the water would then be discharged through the permitted outfalls. Extracted groundwater would undergo any treatment processes necessary to satisfy applicable NPDES discharge requirements. Decanting of the ash basin is to be complete by March 2021. Prior to that time, options would be evaluated based on the actual groundwater quality and quantity. The options would include, but are not limited to, transfer to the new LRB, continue to operate the existing system for pH adjustment, or adding a new treatment system for extracted groundwater.

Clean Water Infiltration Well Distribution System (STEP 7 – Conceptual Infiltration System Considerations)

The purpose of the clean water infiltration distribution system is to convey water to the infiltration water treatment system and to convey water from the treatment system to the infiltration wells. The distribution system

design would have features similar to a drinking water distribution system. For example, distribution lines would be constructed with pressure relief valves so that the system may be flushed to remove buildup on piping walls.

Clean water would be transferred from the source to a treatment and storage plant. A booster pump would convey water from the storage tanks and provide the hydraulic head to the infiltration well network to maintain sufficient pressures to reach infiltration wells. Pressure regulating valves would be installed at each infiltration well to control infiltration rates.

Groundwater Extraction Well Discharge Piping (STEP 8 – Conceptual Extraction System Considerations)

The proposed groundwater extraction system would consist of 66 groundwater extraction wells. Based upon predictive groundwater flow and transport modeling, the groundwater extraction wells would generate on average 9.9 gpm of extracted groundwater per well or about 652 gpm of extracted groundwater collectively.

Each of the groundwater extraction wells would discharge into one of a series of headers. Extracted groundwater in these headers then would flow by gravity to one of several tanks. The collected groundwater in these tanks would be pumped to a conveyance line ultimately discharging to a groundwater treatment plant.

6.8.2.2 Engineering Designs with Assumptions, Calculations and Specifications

(CAP Content Section 6.E.b.ii)

Pipelines (STEP 9 – Pipeline Specifics)

High density polyethylene (HDPE) piping will be used for water conveyance in all areas where buried piping will be installed. Water conveyance will include:

- Groundwater pumped from extraction wells and conveyed to an NPDES permitted outfall
- Surface water pumped from the clean water source and conveyed to a infiltration water treatment system
- Infiltration water treatment system effluent to infiltration wells

HDPE piping will conform to standard HDPE pipe specifications such as the following:

- ASTM F714, "Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter,"
- ASTM D3035,"Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Controlled Outside Diameter."
- ANSI/AWWA C906, "Polyethylene (PE) Pressure Pipe and Fittings, 4" to 63", for Water Distribution and Transmission."
- Cell Classification PE445574C per ASTM D3350
- Plastics Pipe Institute (PPI) TR-4 Listing as PE4710 / PE3408
- Hydrostatic Design Basis 1,600 psi @ 73°F (23°C) and 1,000 psi @ 140°F (60°C) per ASTM D2837

Fittings will be molded from HDPE compound having cell classification equal to or exceeding the compound used in the pipe manufacture to ensure compatibility of polyethylene resins. Substitution may be allowed for approved material with use of flanged joint sections.

Heat fusion welding of the piping and fittings would be in accordance with Duke Procedure Number: CCP-ENGSTD-NA-QA-004, “Quality Assurance and Quality Control of HDPE Pipe Butt Fusion Joints Revision 3,” July 8, 2019. Only qualified operators trained in Duke Energy’s HDPE fusion standards would be allowed to perform fusion welding.

Flanged connections would be in accordance with Duke Procedure Number: CCP-ENGSTD-NA-QA-005, “Requirements for Installation of Polyethylene Flanged Joints Revision Number 0,” August 5, 2019.

The locations of the HDPE piping systems for extraction are generally in low traffic areas. The HDPE piping will be typically installed below grade in 3-foot deep excavated trenches constructed with compacted granular bedding material. The trenches will be backfilled with a minimum of 2-feet of excavated native soil and compacted. Pipe in areas with regular traffic of more than two axles will be installed in trenches designed to comply with AWWA M-55, “PE Pipe – Design and Installation” or an approved alternative design.

The design flow rate is 285 gpm for the clean water infiltration system and 652 gpm for the groundwater extraction system. Infiltration water distribution lines would connect to each well the clean water infiltration system. Likewise, each groundwater extraction well will be connected to a header that ultimately conveys extracted groundwater to a groundwater treatment plant. Preliminary calculations pertaining to the piping design (*e.g.,* pipe sizing, pressures, flow, friction losses, etc.) are provided in **Appendix N**.

Localized collection tanks and pumps or pump stations might be integrated into the piping system to allow for independent operation of various segments of the system.

Hydrostatic leak testing in accordance with the most current edition of *Handbook of Polyethylene Pipe***,** or an approved alternate method, will be performed and passed prior to the piping being placed into operation.

Pipe Network Calculations (STEP 10 – Pipeline Headloss Calculations)

The extraction and clean water infiltration networks for the proposed alternative were designed using Pipe Flow® Expert. Pipe Flow® Expert is a software package used to determine volumetric flow rates, pressure in pipes, friction losses, pump head, and other information. The calculated outputs and graphically represented conceptual network layouts are presented in **Appendix N**.

The extraction network consists of 66 extraction wells with trunk lines for conveyance and branching pipes providing connections to the wells. The network ultimately operates in gravity flow. The network was evaluated by generating a model with well elevations and depths, pipe lengths, etc. Once these values were incorporated, the calculations were performed using the model to determine the nature of flow in the network and to ensure that the desired movement in the pipe system was occurring. After the flow through the system was verified, pipe diameters and required pump head outputs were calculated. The calculation outputs took into account the interacting flows in the system and frictional losses from fittings and pipes to provide evidence of the efficacy of the proposed pipe network layout design.

Telemetry System Design

The groundwater remediation system would be managed using telemetry system that would enable remote monitoring and operational capabilities. The telemetry system would be designed to meet the system owner O&M requirements.

Electrical Design

It is unlikely that existing electrical capacity in the vicinity of the proposed groundwater remediation system would be sufficient to provide electrical power to 66 submersible pumps, the small transfer pump in the collection well, and other power requirements. Additional electrical capacity is anticipated to meet groundwater remediation system power requirements.

System Operation and Maintenance Issues

The effectiveness of the system would be dependent on maintaining adequate extraction flow rate through the wells, and stable water levels, for an extended period of time. This will necessitate effective operation and maintenance of the wells. As described above and in the Contingency Plan (**Section 6.8.8**), each well will be equipped with a control and monitoring system and monitored continuously by the control system, and an alert sent if the water level falls outside the prescribed range. Adjustments to pumping operations can be made if the root cause of the alert is determined to be system performance. Additionally, cleanouts will be installed on pipes to facilitate periodic maintenance, preventing mineral scaling or biological fouling on the conveyance pipe network.

Another factor in maintaining the effectiveness of the wells will be monitoring and maintaining the well screens to prevent a loss of efficiency due to mineral and/or biological fouling. If well performance monitoring indicates a decrease in flow rate, the well will be inspected for fouling and the screens will be cleaned as appropriate.

In addition to well performance monitoring and maintenance, other system elements, such as pumps controls, will receive routine maintenance in accordance with the manufacturer's recommendations.

6.8.2.3 Permits for Remedy and Schedule

(CAP Content Section 6.E.b.iii)

The design documents would provide the necessary plans and specifications for procurement and construction purposes. This would

include Site layout drawings, plans and profiles, well enclosure details, trench and discharge piping outlet details, well construction schematics, piping and instrumentation diagrams/drawings and complete equipment, materials and construction specifications.

Permit applications that may be needed for the proposed remedy include:

- Erosion and Sediment Control permit
- In Situ Groundwater Remediation Injection Well permit
- NPDES Stormwater permit
- Right-of-Way (ROW) encroachment agreement with North Carolina Department of Transportation
- Water Withdrawal and Transfer registration
- Wetlands permit

The schedule for obtaining permits is based off the project implementation schedule as discussed in **Section 6.8.2.4** and presented on **Figure 6-35**.

6.8.2.4 Schedule and Cost of Implementation
(CAP Content Section 6.E.b.iv)

A Gantt chart (**Figure 6-35**) is provided for outlining a general timeline of implementation tasks following CAP Update submittal. The exact timeline of the schedule milestones is dependent on various factors, including NCDEQ review and approval, permitting, weather, and field conditions.

Duke Energy will provide construction reports monthly from the beginning of construction until construction is complete and Duke Energy assumes full responsibility for operation of the groundwater remediation system.

Reporting will include:

- Health and Safety/Man Hours
- Tasks completed the prior month
- Problems affecting schedule (*e.g.,* inclement weather)
- Measures taken to achieve construction milestones (*e.g.*, increase number of drilling crews)
- Contingency actions employed, if any

- Tasks to be completed by next reporting period
- Provide updated schedule/Gantt chart

Duke Energy progress reports would be submitted to NCDEQ monthly.

A detailed cost estimate for this Alternative is provided in **Appendix K**. The cost estimate is based on capital costs for design and implementation, and the operations, maintenance (O&M) and monitoring costs. The design costs include work plans, design documents and reports necessary for implementation of the alternative. Implementation costs include procurement and construction. O&M costs are based on annual routine labor, materials and equipment to effectively conduct monitoring, routine annual and 5-year reporting, and routine and non-routine maintenance costs.

6.8.2.5 Measures to Ensure Health and Safety
(CAP Content Section 6.E.b.v)

There is no measurable difference between evaluated Site risks and risks indicated by background concentrations; therefore, no material increases in risks to human health related to the ash basin have been identified. The groundwater corrective action is being planned to address regulatory requirements. The risk assessment identified no current human health or ecological risk associated with groundwater downgradient of the ash basin. Water supply wells are located upgradient of the ash basin and alternate water supplies or water supply filtration systems have been provided to those who selected this option. Based on the absence of receptors, it is anticipated that groundwater extraction would create conditions that continue to be protective of human health and the environment because the COI concentrations will diminish with time.

6.8.2.6 Description of All Other Activities and Notifications Being Conducted to Ensure Compliance with 02L, CAMA, and Other Relevant Laws and Regulations
(CAP Content Section 6.E.b.vi)

This CAP Update is for the ash basin and the adjacent additional sources as identified in NCDEQs April 5, 2019 letter (**Appendix A**). The CAP Update addresses the requirements of G.S. Section 130A-309.211(b), complies with NCAC 15A Subchapter 02L. 0106 corrective action requirements, and follows the CAP guidance provided by NCDEQ in a letter to Duke Energy.

6.8.3 Requirements of 02L .0106(l) – MNA
(CAP Content Section 6.E.c)

The requirements for implementing corrective action by MNA, under 02L .0106(l), are provided in **Section 6.7.1** and **Appendix I**.

6.8.4 Requirements for 02L .0106(k) – Alternate Standards
(CAP Content Section 6.E.d)

Regulation 02L .0106(k), states that a request may be made for approval of a corrective action plan that uses standards other than the 02L groundwater quality standards. Duke Energy may request alternate standards for ash basin-related constituents, including boron, as allowed under 15A NCAC 02L .0106(k). Alternate standards are appropriate at the MSS given the lack of human health and ecological risks at the Site. G.S. Section 130A, Article 9, Part 8 allows risk-based remediation as a clean-up option where the use of remedial actions and land use controls can manage properties safely for intended use. Risk-based corrective action is where constituent concentrations are remediated to an alternative standard based on the actual posed risks rather than applicable background-levels or regulatory standards. The requirements for implementing corrective action by remediating to alternate standards, under 02L .0106(k), are as follows:

- *Sources are removed or controlled;*
- *Time and direction of contaminant travel can be predicted with reasonable certainty;*
- *COIs have and will not migrate onto adjacent properties unless specific conditions are met (i.e., alternative water sources, written property owner approval, etc.);*
- *Standards specified in Rule .0202 of this Subchapter will be met at a location no closer than one year time of travel upgradient of an existing or foreseeable receptor, based on travel time and the natural attenuation capacity of subsurface materials or on a physical barrier to groundwater migration that exists or will be installed by the person making the request;*
- *If contaminant plume is expected to intercept surface waters, the groundwater discharge will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 02B .0200;*
- *Public notice of the request has been provided in accordance with Rule .0114(b) of this Section; and*

- *Proposed corrective action plan would be consistent with all other environmental laws.*

Adaptive site management allows iterative review of site information and data to determine whether changing site conditions warrant adjustments to site management and monitoring approaches. Adaptive site management approaches may be adjusted over the site's life cycle as new information and technologies become available. This approach is particularly useful at complex sites where changes in site conditions may require an extended period of time or where NCDEQ approves alternate groundwater standards for COIs, such as 4,000 µg/l for boron, pursuant to its authority under G.S. Section 15A NCAC 02L .0106(k).

6.8.5 Sampling and Reporting

(CAP Content Section 6.E.e)

An effectiveness monitoring plan (EMP) has been developed as part of this CAP consistent with 02L. 0106(h)(4). The EMP is designed to monitor groundwater conditions at the MSS and document progress towards the remedial objectives over time. This plan is designed to be adaptive and can be modified as the groundwater remediation system design is prepared, completed, or evaluated for termination.

Duke Energy implemented an Interim Monitoring Plan (IMP) after the plan was that was submitted to NCDEQ on October 23, 2018 and subsequent additional modifications were agreed upon between Duke Energy and NCDEQ. The IMP includes the locations of groundwater wells sampled quarterly and semiannually.

The EMP is required by G.S. Section 130A-309.211(b)(1)(e). The IMP will be replaced by the EMP upon NCDEQ approval of the CAP Update. Either submittal of the EMP, or the pilot test work plan and permit applications (as applicable), will fulfill section G.S.130A-309.209(b)(3).

The EMP, presented in **Appendix O**, is designed to be adaptable and would target key areas where changes to groundwater conditions are most likely to occur due to corrective action and ash basin closure activities. EMP key areas for monitoring are based on the following considerations:

- Include background locations
- Include designated flow paths

- Within areas of observed or anticipated changing Site conditions, and/or have increasing constituent concentration trends
- Will effectively monitor COI plume stability and model simulation verification
- The EMP will be used to evaluate progress towards remediation

EMP elements include reporting evaluation and schedule, groundwater monitoring well systems, sampling protocol, frequency, and parameters (**Table 6-17**)**.** Effectiveness monitoring well locations are depicted on **Figure 6-36**. Thirty days after CAP approval, the EMP will be implemented at the Site and will continue until there is a total of three years of data confirming COIs are below applicable Standards at or beyond the compliance boundary, at which time a request for completion of active remediation will be filed with NCDEQ. If applicable standards are not met, the EMP will continue and transition to post-closure monitoring if necessary.

After ash basin closure and following closure certification, a post-closure groundwater monitoring plan equivalent to the long-term groundwater monitoring system well locations, parameters, and sampling frequency would be implemented at the Site for a minimum of 30 years in accordance with G.S. Section 130A-309.214(a)(4)k.2. If groundwater monitoring results are below applicable standards for three consecutive years, Duke Energy may request termination of the PCMP in accordance with G.S. Section 130A-309.214(a)(3)b. An EMP work flow and optimization process is outlined on a flow chart presented on **Figure 6-37**.

Optimization of the plan to help determine the remedy's performance, appropriate number of sample locations, sampling frequency, and laboratory analytes, and statistical analysis to evaluate the plume stability conditions will be conducted during EMP review periods. Optimization evaluation would be conducted using software designed to improve long-term groundwater monitoring programs such as Monitoring and Remediation Optimization System (MAROS).

6.8.5.1 Progress Reports and Schedule

(CAP Content Section 6.E.e.i)

After groundwater remediation implementation, evaluation of Site conditions, groundwater transport rates, and COI plume stability would be based on quantitative rationale using statistical, mathematical, modeling, or

empirical evidence. Existing data from historical monitoring and pilot testing would be used to provide baseline information prior to groundwater remediation implementation. Schedule and reporting of system quantitative evaluations, review and optimization would include:

- **Annual Reporting Evaluation:** The EMP will be evaluated annually for optimization and adaption for effective long term observations, using a data-need rationale for each location. The annual evaluation would include a comparison of observed concentrations compared to model predictions and an evaluation of statistical concentration trends, such as the Mann-Kendall test.

  Results of the evaluation would be reported in annual monitoring reports and are proposed to be submitted to NCDEQ annually. The reports would include the following:

  - Laboratory reports on electronic media,
  - Tables summarizing the past year's monitoring events,
  - Historical data tables,
  - Figures showing the historical data versus time for the designated monitoring locations and parameters,
  - Figures showing sample locations,
  - Statistical analysis (Mann-Kendall test) of data to determine if trends are present, if performed,
  - Identification of exceedances of comparative values,
  - Groundwater elevation contour maps in plan view and isoconcentration contour maps in plan view for one or more of the prior year's sampling events (as mutually agreed upon by Duke Energy and NCDEQ),
  - Any notable observations related to water level fluctuations or constituent concentration trends attributable to extraction system performance or water table drawdown, and
  - Recommendations regarding adjustments to the Plan

- **5-Year Review:** Similar to annual evaluation and reporting, the EMP would be re-evaluated and modified as part of each 5-year review

period as adaptive or, if necessary, additional corrective actions are implemented or water quality observations warrant adjustments of the plan. The annual evaluation would include elements of the annual evaluation, plus updated background analysis, confirmation of risk assessment, evaluation of statistical concentration trends, analytical result comparison and model verification. Flow and transport models could be updated as part of the 5-year review process to refine future predictions and the associated routine data needed to confirm the predictions.

Optimization of the monitoring network could be evaluated if the remedy is determined to be effective or when conditions re-stabilize after the implementation of closure or, if necessary, additional corrective action implementation. Optimization of the monitoring network could include a lesser monitoring frequency and/or parameter list. Flow and transport model predictions indicate very slow changes in conservative (boron) concentrations will occur over time. Geochemical model predictions indicate very little or much slower changes in the remaining COI distributions will occur. Therefore, a monitoring frequency consistent with these predictions would be proposed following confirmation of the models through site data.

If necessary, modifications to the corrective action approach would be proposed to achieve compliance within the target timeframe.

6.8.5.2 Sampling and Reporting Plan During Active Remediation

(CAP Content Section 6.E.e.ii)

Groundwater Monitoring Network

EMP monitoring will be conducted in coordination with required federal regulatory groundwater monitoring to provide an integrated and comprehensive monitoring strategy that (1) monitors the performance and effectiveness of the selected remedial alternative, (2) can provide adequate areal (horizontal) and vertical coverage to monitor plume status with regard to potential receptors, and (3) confirm flow and transport and geochemical model predictions. This monitoring would be implemented east of the ash basin (**Figure 6-36**). EMP groundwater well monitoring network objectives are outlined below:

- Compliance with 02L
- Measure and track the effectiveness of the proposed clean water infiltration and extraction system
- Monitor plume status (horizontally and vertically)
- Verify predictive model simulations
- Verify no unacceptable impact to downgradient receptors
- Verify attainment of active remedy objectives through validated model simulations
- Identify new potential releases of constituents into groundwater from changing site conditions
- Monitor approved background locations

The EMP would include 98 monitoring wells (**Table 6-17**). Several of the existing monitoring wells at the site might be abandoned from ash basin and landfill closure and related construction activities. In the event that closure activities extend to the proposed well locations, the layout of wells would be modified, if necessary.

Groundwater Monitoring Flow Paths - Trend Analysis

The monitoring program will provide adequate horizontal and vertical coverage to monitor:

- Changes in groundwater quality as Site conditions change (*e.g.*, groundwater extraction expands, ash basin closure commences, and the immediate groundwater flow and transport conditions respond),
- Transport rates, and
- Plume stability.

Horizontal and vertical coverage would be provided by using groundwater monitoring wells located along three primary groundwater flow paths within the corrective action area. To monitor performance, groundwater monitoring wells are located within the area of corrective action at specific intervals or as close as possible from the source area to a receptor as illustrated in **Figure 6-36** and described below:

1. At or near the source area

2. At waste boundary
3. 250 feet downgradient from waste boundary. If the waste boundary and compliance boundary are located sufficiently close to evaluate COI trends over time, this interval location would not be monitored.
4. 500 feet downgradient of waste boundary (CAMA compliance boundary)
5. No less than one year travel time upgradient of receptor or potential receptor and no greater than the distance groundwater is expected to travel in five years

Multi parameters sondes would be installed in 14 wells along the three primary flow paths in the remedy area (**Figure 6-36**). Daily monitoring of changes in groundwater quality on a real-time basis using multi-parameter sondes and telemetry technology would allow continuous monitoring and evaluation of geochemical conditions. Geochemical conditions, monitored using pH and Eh, would be compared to geochemical modeling results to evaluate changes that could potentially affect the mobility (K_d) of reactive and variably-reactive COIs. Water levels would also be monitored by the multi-parameter sondes to verify simulated changes to groundwater flow from groundwater remediation, and during and after ash basin closure. Having groundwater quality and water level data readily available will increase the response time to implement contingencies if field parameters significantly deviate from predicted responses. Contingency plans are included in **Section 6.8.8** of the CAP Update.

Plume stability evaluation would be based primarily on results of trend analyses. Trend analyses may be conducted using Mann-Kendall trend test. The Mann-Kendall trend test is a non-parametric test that calculates trends based on ranked data and has the flexibility to accommodate any data distribution and is insensitive to outliers and non-detects. The test is best used when large variations in the magnitude of concentrations may be present and may otherwise influence a time-series trend analysis.

Mann-Kendall trend tests would be conducted using data from EMP geochemically nonreactive, conservative constituents. These constituents include boron, chloride, and TDS, and best depict the areal extent of the plume and plume stability and physical attenuation, either from active remedy or natural dilution and dispersion. The test would be performed in

accordance with USEPA Guidance for Statistical Analysis of Groundwater Data (USEPA 2009).

Trend analysis of designated groundwater monitoring flow path wells (**Figure 6-36**) would be part of the decision metrics for determining termination of the active remedy.

Sampling Frequency

Multiple years of quarterly and semiannual monitoring data are available for use in trend analysis and to establish a baseline to evaluate corrective action performance. The comprehensive integrated monitoring plan sampling frequency is based on semi-annual sampling events to be consistent with long-term monitoring under applicable federal regulations.

Semi-annual monitoring following implementation of corrective action is recommended for the 98 monitoring wells to be included in the EMP. Over four years of quarterly monitoring data are available for existing wells, which will be used to supplement trend analysis and to establish a baseline to evaluate corrective action performance.

Newly installed wells to be added to the EMP would be monitored by quarterly sampling events. Quarterly sampling would target locations of proposed newly installed wells with fewer than four quarters of data. Quarterly monitoring of parameters outlined on **Table 6-17** is proposed for newly installed wells.

Quantitative evaluations would also determine additional data needs (*i.e.,* increased sampling frequency) for refining statistical and empirical model development. Additional monitoring described in the contingency plan would be implemented if significant geochemical condition changes are identified that could result in mobilization of reactive or variably-reactive COIs.

Sampling and Analysis Protocols

EMP sampling and analysis protocol will be similar to the existing IMP with some adjustment for anticipated changing site conditions. Detailed protocols are presented in the EMP (**Appendix O**). Samples would be analyzed by a North Carolina certified laboratory for the parameters listed in **Table 6-17**. Laboratory detection limits for each constituent are targeted to be at or less than applicable regulatory values (*i.e.*, 02L, IMAC, or 02B).

- **Groundwater Quality Parameters:** Conservative constituent analyses of boron, chloride, and TDS would be conducted, in addition to parameters listed on **Table 6-17**, to monitor corrective action performance using the designated wells along the groundwater flow paths. These constituents were selected because they are generally non-reactive to changing geochemical conditions and encompass the areal extent of the plume. Physical attenuation mechanisms of dilution and dispersion would be evaluated by comparing monitoring results with flow and transport model simulations. Changing geochemical conditions that could cause sorption or precipitation/co-precipitation mechanisms would be evaluated using multi parameter sondes.
- **Groundwater Field Parameters:** The following six field parameters will be monitored to confirm that monitoring well conditions have stabilized prior to sample collection and to evaluate data quality: water level, pH, specific conductance, temperature, dissolved oxygen, and oxidation reduction potential. For remedy performance monitoring, these parameters will be measured daily by a multi-parameter sondes installed in each flow path monitoring well and used to evaluate geochemical conditions from remedy effectiveness.

Major cations and anions would be analyzed to evaluate monitoring data quality (electrochemical charge balance). These include alkalinity, bicarbonate alkalinity, aluminum, calcium, iron, magnesium, manganese, nitrate + nitrite, potassium and sodium. Total organic carbon (TOC), ferrous iron, and sulfate analyses are also proposed as monitoring parameters. TOC is recommended to help determine if an organic compound is contributing to TDS, and ferrous iron and sulfate to monitor potential dissolution of iron oxides and sulfide precipitates as an indicator of changing conditions related to corrective action. These parameters are indicated on **Table 6-17** as water quality parameters.

6.8.6 Sampling and Reporting Plan After Termination of Active Remediation

(CAP Content Section 6.E.e.iii)

Termination of the proposed remedial alternative will be consistent with, and implemented in accordance with, 15A NCAC 02L .106 (m). A flow chart of the request and review timeline for termination is outlined on **Figure 6-38** *(CAP Content Section 6.E.e.iii.1)*. Completion of this phase might also provide

stakeholders with an opportunity to evaluate terminating the system, as appropriate, near the well or wells where groundwater restoration completion is being evaluated.

Trend analysis described in **Section 6.8.5** would be part of the decision metrics for determining termination of the active remedy *(CAP Content Section 6.E.e.iii.1.A and B).* Groundwater remediation effectiveness monitoring will transition to the attainment monitoring phase when NCDEQ determines that the remediation monitoring phase is complete at a particular well or area of the Site.

6.8.7 Proposed Interim Activities Prior to Implementation
(CAP Content Section 6.E.f)

In accordance with requirements of CAMA Section 130A-309.211(b)(3), implementation of the proposed corrective action will begin within 30 days of NCDEQ approval of the CAP Update.

Prior to pilot testing, the clean infiltration water will be sampled for geochemical and physical parameters for baseline conditions to evaluate the potential for biofouling and plugging of the clean water infiltration well screens. During pilot testing, extracted groundwater will be collected and analyzed for geochemical parameters consistent with the NPDES permit**.**

Additional interim activities to be conducted prior to implementation of the corrective action remedy include:

- Implementation of the EMP within 30 days of CAP approval
- Submittal of permit and registration applications to NCDEQ, as applicable.

6.8.8 Contingency Plan
(CAP Content Section 6.E.g)

The purpose of the contingency plan is to monitor changes in conditions and operations to effectively reach the remedial action objectives. The contingency plan addresses operations, groundwater conditions, and performance.

The Contingency Plan will be defined in greater detail as design elements of the system are finalized. A groundwater monitoring program to measure and track the effectiveness of the proposed comprehensive extraction and clean water infiltration system is described in **Section 6.8.5**. The plan is adaptive and can be modified as the final design is prepared.

6.8.8.1 Description of Contingency Plan
(CAP Content Section 6.E.g.i)

The contingency plan addresses the following areas:

- Operations (including extraction and infiltration wells, pumping, piping, electrical, and controls)
- Groundwater quality
- Groundwater levels
- Groundwater treatment
- Comparison to predicted concentrations and water levels

A health and safety plan and an operations manual will be prepared as part of the design. The health and safety plan address management of spills and other unplanned releases and the operations manual will address operational training including backup personnel, emergency response training, and reporting to appropriate authorities.

6.8.8.2 Decision Metrics for Contingency Plan Areas
(CAP Content Section 6.E.g.ii)

This section outlines decision metrics and possible contingency actions in support of a resilient groundwater corrective action strategy.

Operations

A remote telemetry system would be installed to monitor the groundwater extraction, infiltration, and treatment system. The telemetry system would be tied into a remote monitoring station that can be accessed by key personnel responsible for operation and maintenance of the groundwater remedial system. The telemetry system would alert key personnel if malfunctions or an emergency condition arises.

Several aspects of the monitoring system would be used to maintain safe and effective operations of the extraction and infiltration wells, and treatment system:

- Processes for maintenance of effective operation of each extraction and infiltration well include target flow rates and water levels for each well. Each well would be monitored continuously by the control system, with data being recorded, and an alert sent if the flow rate or water level is outside the prescribed range. In addition to automated

systems, each element of the system would be physically inspected and maintained as part of a routine operations and maintenance program.

- If a leak in the groundwater extraction or infiltration system is detected by the telemetry system, the affected portion of the system will be shut down, and an alert message will be immediately sent to the operator and to backup personnel. The potential leak will be inspected and repaired prior to restarting the system element.
- If pH adjustment or other water treatment technology is employed, continuous monitoring of key parameters would be used to maintain proper operation of the system. Variances between prescribed ranges would alert the operator and other key personnel and might result in an automatic system shutdown.
- The operator inspection schedule, completion, and notes for key systems would be documented.
- A system maintenance schedule would be established for effective operation. System elements would be maintained in accordance with manufacturer's recommendations, included in an Operation and Maintenance (O&M) Manual. Corrective measures, performed by appropriately skilled personnel, would be taken if mechanical issues are identified during routine maintenance monitoring.

Groundwater Quality

The EMP includes a primary network of wells that will provide focused monitoring in critical areas following corrective action implementation.

Data is maintained in a comprehensive database system following each sampling event. Trend analyses will be conducted, spatially and temporally, to evaluate COI plume changes. If groundwater quality field parameters, or constituent concentrations, significantly deviate from predicted responses, a focused investigation will be conducted to determine if the variation is due to system performance or other factors. Possible responses could include adding or removing extraction or infiltration wells, or changing flow rates or target water levels.

To assess the effectiveness of changes, or to determine if the unexpected data trends are temporary, increased monitoring frequency or additional monitoring locations might be conducted.

If subsequent results continue to show non-conformance, a more comprehensive assessment and corrective action plan for the specific non-conformance might be completed and implemented.

Groundwater Levels

Water levels in selected EMP monitoring wells will be monitored using downhole instrumentation until Site conditions have stabilized. Water-level data will be evaluated as part of the ongoing monitoring. Technical evaluations will include spatial and temporal trend analyses, drawdown calculations, and flow and transport model refinement to reflect pre-decanting conditions, as needed. If results conclude that water levels are not similar to predicted patterns, a focused investigation will be conducted that could include adjusting system pumping rates, refining the flow and transport model for infiltration and extraction rates, adding monitoring wells to the EMP monitoring network for greater resolution, installation of monitoring wells in key areas, and/or other activities.

If subsequent results from ongoing investigation continue to show non-conformance, a corrective action response with suggested approaches to determine possible reasons for the non-conformance would be implemented until resolution is achieved.

Groundwater Treatment

If extracted groundwater treatment is required prior to discharge through a permitted outfall, evaluation of that system will be part of the routine monitoring program.

If a treatment system is not meeting performance standards, or if trends suggest performance is not optimal, an analysis of the trends and an assessment of the system will be completed and corrective measures implemented.

Comparison to Predicted Concentrations and Water Levels

Many aspects of the proposed remediation approach are based on modeling and predicted groundwater conditions. As remedial efforts begin, hydraulic conditions change, and additional groundwater data are collected, the models will be updated. However, as conditions change, especially at the beginning of the process there might be deviations from existing data trends and model predictions. The models are anticipated to be updated to reflect changing conditions, as necessary, and changes in predicted results would

be analyzed to determine if the remedial approach needs to be modified to effectively address the changes.

Since clean water infiltration is an element of the remedial approach, there is a potential that soil might become saturated near the ground surface, with the potential to create surface discharges. If this occurs, reducing infiltration rates or increasing the extraction system would be used to control surficial saturation.

6.9 Summary and Conclusions

This CAP Update proposes remedies for COIs in groundwater associated with the MSS ash basin that are at or beyond the compliance boundary to the south and southeast of the ash basin. This CAP Update provides:

- A screening and ranking process of multiple potential groundwater corrective action alternatives that would address areas south and southeast of the ash basin where affected groundwater has migrated at or beyond the Site's compliance boundary.
- Additional source areas adjacent to the ash basin are being addressed through the closure plan (structural fill access road and ILF structural fill subgrade), groundwater remediation system (coal pile, Dry Ash Landfill Phase II, and PV Structural Fill) and/or through additional enhanced closure efforts with NCDEQ DWM (Dry Ash Landfill Phase I and Phase II, and PV Structural Fill).
- A selection and description of the proposed targeted corrective action **Alternative 3, Groundwater Extraction and Clean Water Infiltration.**
- Specific plans, including engineering details where applicable, for restoring groundwater quality.
- An EMP for evaluating the performance and effectiveness of the proposed corrective action and its effect on the movement of the affected groundwater plume. The EMP uses an optimized groundwater monitoring system with multiple groundwater flow paths in the area of corrective action that would monitor geochemical and physical conditions.
- A schedule for the implementation and operation of the proposed groundwater corrective action strategy.
- Planned activities prior to full-scale implementation include pilot testing in selected areas. Pilot test work plan(s) will be submitted to NCDEQ within 30 days of CAP Update approval to fulfill G.S. Section 130A-309.211(b)(3).

7.0 PROFESSIONAL CERTIFICATIONS

(CAP Content Section 7)

Certification for the Submittal of a Corrective Action Plan

Responsible Party and/or Permittee: Duke Energy Carolinas, LLC

Contact Person: Paul Draovitch

Address: 526 South Church Street

City: Charlotte **State:** NC **Zip Code:** 28202-1803

Site Name: Marshall Steam Station

Address: 8320 East Carolina Highway 150

City: Terrell **State:** NC **Zip Code:** 28682

Groundwater Incident Number (not applicable - Coal Ash Management Act CAP)

We, Brian D. Wilker a **Professional Geologist** and James E. Clemmer, a **Professional Engineer** for SynTerra Corporation (firm or company of employment) do hereby certify that the information contained herein is part of the required Corrective Action Plan (CAP) and that to the best of our knowledge the data, assessments, conclusions, recommendations and other associated materials are correct, complete and accurate.

(Affix Seal and Signature)

NORTH CAROLINA LICENSED GEOLOGIST SEAL 2546 BRIAN DENNIS

Brian D. Wilker, NC LG 2546
Project Manager

NORTH CAROLINA PROFESSIONAL ENGINEER SEAL 18675 JAMES E. CLEMMER

James E. Clemmer, NC PE 18675
Project Engineer

Sworn to and subscribed before me this 27 day of December, 20 19

DARNELL B. DELLINGER
Notary Public, State of South Carolina
My Commission Expires 12/22/2025

8.0 REFERENCES

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TABLES

(CAP Content Section 9)

Table ES-1

Summary of MSS Assessment Documentation

Included in Executive Summary text

Table ES-2

Summary of MSS Assessment Activities

Included in Executive Summary text

Table ES-3

Components of Source Control, Active Remediation, and Monitoring

Included in Executive Summary text

TABLE 1-1
SUMMARY OF ONSITE INCIDENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Station Name	Station Location	DEQ Section	Incident Number	Occurrence Date	Status	Closure Date	Release Type	Latitude	Longitude	Proximity to Ash Basin (ft)	Notes
Marshall	Terrell	UST	8601	4/19/1988	Closed	6/20/1989	Petroleum	35.598644	-80.971614	888	NA
Marshall	Terrell	AST	86354	NS	Open	NA	Petroleum	35.599043	-80.966393	1,345	NA
Marshall	Terrell	AST	91147	4/1/2011	Closed	6/15/2011	Petroleum	35.597493	-80.964849	2,036	Incident Name: Booster Fans
Marshall	Terrell	AST	91344	5/5/2015	Open	NA	Petroleum	35.599831	-80.964106	1,330	Incident Name: Diesel Spill

Prepared By: ECW Checked By: WCG

Notes:
Onsite incident records provided by Duke Energy
AST - Above Ground Storage Tank
DEQ - Department of Environmental Quality
ft - feet
UST - Underground Storage Tank
NA - Not Available
NS - Not Stated

TABLE 3-1
SUMMARY OF ONSITE FACILITIES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Facility Name	Evaluated as Source Area in CAP Update	CSA Schedule	Operational Status	Source Material	Area or Capacity	Rationale for Evaluation
Ash Basin	Yes	NA	Active	Coal Ash/NPDES Permitted waste streams	14,033,000 cy	CAMA-regulated unit
Dry Ash Landfill (Phase I)	Yes	NA	Inactive	Fly Ash	522,000 cy	Regulated via DWM; Adjacent to ash basin
Dry Ash Landfill (Phase II)	Yes	NA	Inactive	Fly Ash	4,064,000 cy	Regulated via DWM; adjacent to ash basin
Photovoltaic Structural Landfill	Yes	NA	Inactive	Coal Ash	5,410,000 cy	Coal ash structural fill; adjacent to ash basin
ILF sub-grade Structural Fill	Yes	NA	Inactive	Coal Ash	726,000 cy	Coal ash structural fill; adjacent to ash basin
Access Road Structural Fill	Yes	NA	Inactive	Fly Ash	127,982 cy	Coal ash structural fill; adjacent to ash basin
Coal Pile	Yes	Dec-19	Active	Coal	34 acres	Identified as additional source by NCDEQ
Gypsum Storage Pad	Yes	Dec-19	Active	Gypsum	4 acres	Identified as additional source by NCDEQ

Prepared by: WCG Checked by: ECW

Notes:

CSA Schedule - applicable only for units identified in the letter "Final Comprehensive Site Assessment and Corrective Action Plans Approvals for Duke Energy Coal Ash Facilities (April 5, 2019)

CAMA – North Carolina Coal Ash Management Act of 2014

CAP – Corrective Action Plan

CSA - Comprehensive Site Assessment

cy – cubic yards

DWM – Division of Waste Management

ILF – Industrial Landfill No. 1

NA – not applicable

NCDEQ – North Carolina Department of Environmental Quality

NPDES – National Pollutant Discharge Elimination System

TABLE 4-1
BACKGROUND SOIL SAMPLE SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Soil Boring	Depth Range (feet bgs)	Number of Sampled Intervals
BG-3D	(1- 12)	2
GWA-2DA	(3 - 10)	2
GWA-4D	(52 - 53)	1
GWA-5D	(27.5 - 29)	1
GWA-14S	(3 - 10)	2
BGSB-GWA-02	(2 - 20)	4
BGSB-GWA-04	(2 - 20)	5
BGSB-GWA-06	(2 - 20)	5

Prepared by: BDW Checked by: ECW

Note:

ft bgs – feet below ground surface

TABLE 4-2
BACKGROUND VALUES FOR SOIL
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	PSRG Protection of Groundwater	2018 Background Threshold Values[1]	2019 Updated Background Threshold Values[2]	Piedmont Background Threshold Value Range[3]
pH*	S.U.	NE	4.7 - 6.1	4.2 - 7.5	2.3 - 9.8
Aluminum	mg/kg	110,000	56,437	56,437	25,978 - 81,619
Antimony	mg/kg	0.9	0.65	0.64	0.177 - 0.9
Arsenic	mg/kg	5.8	4.697	8.237	1.2 - 43.13
Barium	mg/kg	580	819	1,063	122.2 - 1,063
Beryllium	mg/kg	63	3.9	3.897	1.2 - 4.52
Boron	mg/kg	45	8.7	15	14.4 - 56.3
Cadmium	mg/kg	3	0.11	0.72	0.03 - 1
Calcium	mg/kg	NE	1,500	1,660	410 - 8,769
Chloride	mg/kg	NE	13	293	12 - 423
Chromium	mg/kg	3.8	32.8	406	20 - 440
Cobalt	mg/kg	0.9	53.1	62.86	27 - 81.68
Copper	mg/kg	700	180	120	17.4 - 216
Iron	mg/kg	150	78,228	78,228	24,500 - 85,345
Lead	mg/kg	270	82.5	95.23	7.5 - 95.23
Magnesium	mg/kg	NE	32,462	49,637	760 - 51,829
Manganese	mg/kg	65	2,872	3,388	370 - 3,388
Mercury	mg/kg	1	0.1	0.1	0.04 - 0.113
Molybdenum	mg/kg	7.1	3.5	3.5	1.83 - 12
Nickel	mg/kg	130	18.6	237	9.2 - 237
Nitrate (as N)	mg/kg	NE	0.56	29.3	0.25 - 31.2
Nitrate	mg/kg	NE	---	43.7	40.3 - 48.8
Potassium	mg/kg	NE	10,698	18,117	427 - 35,600
Selenium	mg/kg	2.1	0.81	2.30	1.58 - 6.857
Sodium	mg/kg	NE	600	730	338 - 1,500
Strontium	mg/kg	1,500	31	28.73	7.1 - 200
Sulfate	mg/kg	1,438^	14	437	12 - 437
Thallium	mg/kg	0.28	0.48	0.48	0.166 - 2.132
Total Organic Carbon	mg/kg	NE	---	3,470	742 - 4,960
Vanadium	mg/kg	350	132	132	42 - 230.9
Zinc	mg/kg	1,200	72.3	80.8	60.5 - 325.5

Prepared by: ECW Checked by: BDW

Notes:

2018 background threshold values approved by North Carolina Department of Environmental Quality (NCDEQ) on May 23, 2018.

^ - PSRG Protection of Groundwater value was calculated using the equation presented on **Table 6-2**.

* - Upper and lower threshold values calculated for parameter

[1] - Background threshold values were calculated using data from background unsaturated soil samples collected May 2015 to March 2017.

[2] - Background threshold values were calculated using data from background unsaturated soil samples collected May 2015 to August 2018.

[3] - Piedmont background threshold value ranges include the Duke Energy calculated 2017[4] and 2019[5] background threshold values from 10 Duke Energy facilities located in the Piedmont physiographic region (Allen Steam Station[5], Belews Creek Steam Station[5], Buck Steam Station[4], Cape Fear Steam Electric Plant[4], Cliffside Steam Station[5], Dan River Steam Station[4], Marshall Steam Station[5], Mayo Steam Electric Plant[5], Riverbend Steam Station[4], and Roxboro Steam Electric Plant[5]).

--- - 2018 background threshold value was not calculated for constituent.

mg/kg - milligrams per kilogram

NE - not established

S.U. - standard unit

PSRG - Preliminary Soil Remediation Goals

TABLE 4-3
BACKGROUND VALUES FOR GROUNDWATER
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	15A NCAC 02L Standard	2018 Background Threshold Values[1]			2019 Updated Background Threshold Values[2]			Piedmont Background Threshold Value Range[3]
			Shallow Flow Zone	Deep Flow Zone	Bedrock Flow Zone	Shallow Flow Zone	Deep Flow Zone	Bedrock Flow Zone	
pH	S.U.	6.5 - 8.5	4.6 -6.4	5.7 - 6.9	5.6 - 7.6	3.6 - 6.6	5.5 - 8.1	5.7 - 7.8	3.6 - 9
Alkalinity	mg-$CaCO_3$/L	NE	63	204	108	69.4	145	110	19 - 379
Aluminum	µg/L	NE	757	128	300	1205	180	531.3	100 - 1,238
Antimony	µg/L	1*	0.5	0.5	0.5	0.79	0.62	1.0	0.5 - 2.9
Arsenic	µg/L	10	0.4	0.6	0.6	1.0	1.4	1.1	0.2 - 6.35
Barium	µg/L	700	310	127	435	580	138	840	10.52 - 840
Beryllium	µg/L	4*	0.2	0.1	0.2	0.223	0.2	1	0.0625 - 1
Bicarbonate	mg-$CaCO_3$/L	NE	63	204	108	71.4	145	110	19 - 388
Boron	µg/L	700	50	50	50	50	50	50	50 - 176.8
Cadmium	µg/L	2	0.08	0.08	0.08	1	0.08	1	0.08 - 1
Calcium	mg/L	NE	11	13	15	10.7	32.7	18.8	4 - 111
Carbonate	mg-$CaCO_3$/L	NE	5	5	5	5	5	5	5 - 10
Chloride	mg/L	250	5.5	4.7	4.5	5.0	4.2	3.6	3.34 - 250
Chromium	µg/L	10	16.5	7.6	8.3	16.8	4.3	11.2	1 - 26
Chromium (VI)	µg/L	NE	5.7	3.0	3.9	7.0	6.0	8.1	0.03 - 12
Cobalt	µg/L	1*	1.2	1.9	2.8	5.0	3.2	2.6	0.088 - 88.85
Copper	µg/L	1,000	3.8	2.8	4.2	5.0	10.15	3.356	0.5 - 17.15
Fluoride	mg/L	2	---	---	---	0.51	0.325	1.8	0.1 - 1.8
Iron	µg/L	300	744	272	792	1,095	225	1,220	56.3 - 37,500
Lead	µg/L	15	0.3	0.1	0.2	0.447	0.28	1.0	0 - 2
Lithium	µg/L	NE	---	---	---	4.8	10.0	11.4	2 - 95.39
Magnesium	mg/L	NE	2	14	13	9.98	7.68	14.8	1 - 45
Manganese	µg/L	50	75.3	141	26.6	155	142	330	7 - 9,170
Mercury	µg/L	1	0.2	0.2	0.2	0.2	0.2	0.2	0.05 - 0.5
Methane	µg/L	NE	10	10	10	10	10	16.4	1 - 2,505
Molybdenum	µg/L	NE	0.5	3.2	3.0	1.0	7.3	3.7	0.5 - 26.2
Nickel	µg/L	100	9.9	7.5	7.2	19.6	7.8	8.0	0.87 - 48
Nitrate + Nitrite	mg-N/L	NE	3	1	0.4	6.3	1.6	0.56	0.02 - 6.3
Potassium	mg/L	NE	5	8	1	5.0	5.27	9.57	1.609 - 18.8
Selenium	µg/L	20	0.5	0.5	0.5	1.0	2.4	1.0	0.5 - 2.4
Sodium	mg/L	NE	9	29	14	8.69	28.3	16.0	6 - 190
Strontium	µg/L	NE	303	665	253	210	727	313	27 - 2,120
Sulfate	mg/L	250	4.2	17.7	18.4	11.3	24.2	22.1	1.2 - 510
Sulfide	mg/L	NE	0.1	0.1	0.1	0.1	0.1	0.1	0.1 - 2
TDS	mg/L	500	140	183	216	152.4	200	195	50 - 1,200
Thallium	µg/L	0.2*	0.1	0.1	0.1	0.2	0.1	0.2	0.1 - 0.2
TOC	mg/L	NE	1.0	1.0	1.0	2.9	4.8	1.7	1 - 12.3
Total Radium	pCi/L	5^	3.0	2.8	5.7	5.33	7.46	6.43	0.494 - 35
Total Uranium	µg/mL	0.03^	0.0005	0.0005	0.0005	0.0005	0.0006	0.0005	0.0002 - 0.864

TABLE 4-3
BACKGROUND VALUES FOR GROUNDWATER
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	15A NCAC 02L Standard	2018 Background Threshold Values[1]			2019 Updated Background Threshold Values[2]			Piedmont Background Threshold Value Range[3]
			Shallow Flow Zone	Deep Flow Zone	Bedrock Flow Zone	Shallow Flow Zone	Deep Flow Zone	Bedrock Flow Zone	
Vanadium	µg/L	0.3*	5.6	3.8	16.0	13.0	3.9	25.8	0.33 - 25.8
Zinc	µg/L	1,000	19.2	17.0	11.9	31.8	29.9	21.0	5 - 140

Prepared by: JHG Checked by: HES / BDW

Notes:

[1] - BTVs were calculated using data from background groundwater samples collected September 2015 to October 2017

[2] - Updated BTVs were calculated using data from background groundwater samples collected February 2010 to December 2018

[3] - Piedmont background threshold value ranges include the Duke Energy calculated 2017[4] and 2019[5] background threshold values from 10 Duke Energy facilities located in the Piedmont physiographic region (Allen Steam Station[5], Belews Creek Steam Station[5], Buck Steam Station[4], Cape Fear Steam Electric Plant[4], Cliffside Steam Station[5], Dan River Steam Station[4], Marshall Steam Station[5], Mayo Steam Electric Plant[5], Riverbend Steam Station[4], and Roxboro Steam Electric Plant[5]).

Background threshold values (BTVs) have been rounded to similar levels of precision as 15A North Carolina Administrative Code (NCAC) 02L Standard or Interim Maximum Allowable Concentration (IMAC).

--- - BTV was not calculated for constituent.

* - IMAC of the 15A NCAC 02L Standard, Appendix 1, April 1, 2013.

^ - Federal Maximum Contaminant Level

µg/L - micrograms per liter

µg/mL - micrograms per milliliter

mg/L - milligrams per liter

mg-$CaCO_3$/L - milligrams calcium carbonate per liter

mg-N/L - milligrams nitrogen per liter

NE - not established

pCi/L - picocuries per liter

S.U. - standard units

TDS - total dissolved solids

TOC - total organic carbon

TABLE 4-4
BACKGROUND DATASET RANGES FOR SURFACE WATER
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	Comparison Criteria	Background Range
Constituents with 15A NCAC 02B (Class B, Water Supply: WS-IV)[1] Standards			
pH	S.U.	6.0-9.0	6.1 - 7.7
Dissolved Oxygen	mg/L	≥ 4	1.17 - 9.30
Temperature	deg C	≤ 32	10 - 33
Turbidity	NTU	≤ 25	1.2 - 46.9
Arsenic	µg/L	10	0.071 j - 1.4
Arsenic (Dissolved)	µg/L	acute: 340 chronic: 150	0.042 j - 0.92
Barium	µg/L	1000	9.7 - 60
Beryllium (Dissolved)	µg/L	acute: 65, chronic: 6.5	<0.1
Cadmium (Dissolved)[2]	µg/L	acute: 0.82, chronic: 0.15	<0.08
Chloride	mg/L	230	1.9 - 12
Chromium (III) (Dissolved)[2,3]	µg/L	acute: 180, chronic: 24	0.36 - 4.62
Chromium (VI) (Dissolved)	µg/L	acute: 16, chronic: 11	<0.025 - 2.1
Copper (Dissolved)[2]	µg/L	acute: 3.6, chronic: 2.7	<0.5 - 4.6
Fluoride	mg/L	1.8	<0.1
Lead (Dissolved)[2]	µg/L	acute: 14, chronic: 0.54	<0.1 - 0.32
Mercury	µg/L	chronic: 0.012	0.000514 - 0.00685
Nickel	µg/L	25	<0.5 - 5
Nickel (Dissolved)[2]	µg/L	acute:140, chronic: 16	<0.5 - 4.6
Nitrate + Nitrite	mg-N/L	10	<0.02 - 0.82
Selenium	µg/L	chronic: 5	<0.5
Silver (Dissolved)[2]	µg/L	acute: 0.3, chronic: 0.06	<0.5
Sulfate	mg/L	250	<1 - 31.7
Thallium	µg/L	2	0.015 - 0.12
Total Dissolved Solids	mg/L	500	<25 - 5680
Total Hardness	mg/L	100	11.8 - 28.8
Zinc (Dissolved)[2]	µg/L	acute: 36, chronic: 36	<10 - 24.9
Constituents with USEPA National Recommended Water Quality Criteria			
Alkalinity	mg/L	chronic: 20	10.8 - 33.9
Aluminum	µg/L	acute: 620, chronic: 300	<100 - 1830
Antimony	µg/L	5.6	<0.5
Iron	µg/L	1000	88.9 - 4,100
Manganese	µg/L	50	13.1 j - 674
Constituents without 02B or USEPA Criteria			
Bicarbonate	mg-$CaCO_3$/L	NE	10.8 - 33.9
Boron	µg/L	NE	27.8 j - 520
Cadmium	µg/L	NE	<0.08
Calcium	mg/L	NE	2.34 - 11.6
Carbonate Alkalinity	mg-$CaCO_3$/L	NE	<5
Chromium	µg/L	NE	<0.5 - 2 B
Chromium (VI)	µg/L	NE	<0.025 - 2.1
Cobalt	µg/L	NE	0.061 - 3.5
Copper	µg/L	NE	0.16 j - 2.9
Lead	µg/L	NE	<0.1 - 1
Lithium	µg/L	NE	0.67 B - 1.3
Magnesium	mg/L	NE	0.859 - 4.89
Methane	µg/L	NE	4.9 j+ - 159
Molybdenum	µg/L	NE	0.11 j - <0.5

TABLE 4-4
BACKGROUND DATASET RANGES FOR SURFACE WATER
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	Comparison Criteria	Background Range
Potassium	mg/L	NE	2.93 j - <5
Sodium	mg/L	NE	3.06 j - 8.69
Strontium	µg/L	NE	22.3 - 130
Sulfide	mg/L	NE	<0.1
Total Organic Carbon	mg/L	NE	0.74 j - 7.1
Total Radium	pCi/L	NE	NA
Total Uranium	µg/mL	NE	NA
Vanadium	µg/L	NE	0.27 j - 3.7
Zinc	µg/L	NE	2.6 j - 83.4

Prepared by: ECW Checked by: PPB

Notes:

Background locations, which were part of the evaluation of potential groundwater to surface water impacts, were approved by North Carolina Department of Environmental Quality (NCDEQ).

All samples collected from Lake Norman and its tributaries are subject to Class B, WS-IV water quality standards.

[1] 15A NCAC 02B .0101(c)(6) Class WS-IV - Waters protected as water supplies which are generally in moderately to high developed watersheds. Suitable for all Class C uses.

[2] Standard value dependent on hardness. Calculated hardness dependent metal standards represent most conservative value. Standards are calculated using 25 mg/L hardness, regardless if actual instream hardness values are greater than 25 mg/L.

[3] Chromium speciation is not performed for trivalent chromium (Cr(III)). Trivalent values are derived by subtracting hexavalent chromium values from dissolved chromium values. Where a dissolved chromium value is less than the detection limit ("<"), it is considered a whole number for purposes of deriving a trivalent chromium value.

Acute - "Compliance with acute instream metals standards shall only be evaluated using an average of two or more samples collected with one hour." Reference 15A NCAC 02B .0211
Chronic - "Compliance with chronic instream metals standards shall only be evaluated using averages of a minimum of four samples taken on consecutive days, or as a 96-hour average" Reference 15A NCAC 02B .0211.
NTU - Nephelometric Turbidity Unit
deg C - degrees Celcius
< - less than
mg/L - milligrams per liter
µg/L - micrograms per liter
µg/mL - micrograms per milliliter
mg-$CaCO_3$/L - milligrams calcium carbonate per liter
mg-N/L - milligram nitrogen per liter
NA - not available
NE - not established
pCi/L - picocuries per liter
S.U. - standard unit
B - Target analyte detected in method blank at or above the reporting limit. Target analyte concentration in sample is less than 10X the concentration in the method blank. Analyte concentration in sample could be due to blank contamination.
j - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.
j- - Estimated concentration, biased low.
j+ - Estimated concentration, biased high.

TABLE 4-5
BACKGROUND DATASET RANGES FOR SEDIMENT
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituent	Reporting Unit	Background Range
pH	S.U.	5.2 - 6.7
Aluminum	mg/kg	3,100 - 20,000
Antimony	mg/kg	<0.54 - <0.74
Arsenic	mg/kg	0.29 j - 1.4
Barium	mg/kg	4 - 74
Beryllium	mg/kg	0.055 j - 0.67
Boron	mg/kg	1.3 j - <3.2
Cadmium	mg/kg	<0.14 - <0.19
Calcium	mg/kg	42 j - 1,600
Chloride	mg/kg	3.4 j - <14
Chromium	mg/kg	0.68 -14
Chromium (III)	mg/kg	NE
Cobalt	mg/kg	<0.89 - 4.2
Copper	mg/kg	0.3 j - 15
Iron	mg/kg	710 M - 15,000
Lead	mg/kg	1.1 - 16
Magnesium	mg/kg	60 j,M - 3,800
Manganese	mg/kg	10 M - 230
Mercury	mg/kg	0.032 j - <0.099
Molybdenum	mg/kg	<2 - <2.5
Nickel	mg/kg	0.81 j - 4.8
Nitrate (as N)	mg/kg	<0.24 - <0.32
Nitrate	mg/kg	NE
Potassium	mg/kg	110 j - 4,100
Selenium	mg/kg	<1.4 - <1.9
Silver	mg/kg	<0.5 - <0.64
Sodium	mg/kg	37 j - 96 j
Strontium	mg/kg	0.62 j - 17
Sulfate	mg/kg	<12 - <16
Sulfide	mg/kg	19.2 j - <33.1
Thallium	mg/kg	0.054 j - 0.26
Total Organic Carbon	mg/kg	4,170 - 58,200
Vanadium	mg/kg	3.9 - 38
Zinc	mg/kg	1.7 j - 33

Prepared by: ECW Checked by: KHG

Notes:

Background locations, including SW-7, SW-8, SW-105, SW-106, which were part of the evaluation of potential groundwater to surface water impacts, were approved by North Carolina Department of Environmental Quality (NCDEQ).

< - Concentration not detected at or above the adjusted reporting limit.

j - estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

M - Matrix spike / matrix spike duplicate failure.

mg/kg - milligrams per kilogram

NE - not established

S.U. - standard unit

TABLE 5-1
MAY 2019 WATER LEVEL MEASUREMENTS AND ELEVATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Top of Casing Elevation (ft. NAVD 88)	Top of Screen Elevation (ft. NAVD 88)	Bottom of Screen Elevation (ft. NAVD 88)	May 2019 Measured Water Level[1] (ft. BTOC)	May 2019 Water Elevation (ft. NAVD 88)	Monitoring Flow Zone
AB-01BR	777.21	655.83	650.83	0.02	777.19	Bedrock
AB-01BRL[2]	776.78	615.77	610.77	-0.27	777.05	Bedrock
AB-01BRLL[2]	776.54	581.54	571.54	-0.55	777.09	Bedrock
AB-01BRLLL[2]	777.70	374.45	364.45	-0.27	777.97	Bedrock
AB-01D	777.09	683.69	678.69	3.16	773.93	Deep
AB-01S	777.27	769.06	754.06	6.02	771.25	Shallow
AB-02BR[2]	781.06	488.13	478.13	0.00	781.06	Bedrock
AB-02D	781.44	687.48	682.48	13.11	768.33	Deep
AB-02S	781.30	761.58	746.58	18.49	762.81	Shallow
AB-03D	815.03	682.14	677.14	21.96	793.07	Bedrock
AB-03S	815.08	804.00	789.00	23.50	791.58	Shallow
AB-04D	810.01	735.67	730.67	19.04	790.97	Deep
AB-04S	809.73	801.43	786.43	16.19	793.54	Shallow
AB-04SL	809.85	768.84	758.84	16.74	793.11	Shallow
AB-05BR	807.55	699.45	694.45	13.01	794.54	Bedrock
AB-05D	807.52	726.47	721.47	12.74	794.78	Deep
AB-05DU	807.58	749.92	739.92	12.65	794.93	Shallow
AB-05S	807.50	801.36	786.36	12.52	794.98	Shallow
AB-06BRA	836.70	733.77	731.70	11.30	825.40	Bedrock
AB-06BRL	836.76	679.14	674.14	12.80	823.96	Bedrock
AB-06D	835.36	770.40	765.40	9.42	825.94	Bedrock
AB-06S	835.38	825.77	810.77	7.70	827.68	Shallow
AB-07D	834.13	752.21	747.21	12.46	821.67	Deep
AB-07DU	834.08	786.62	776.62	12.40	821.68	Shallow
AB-07S	834.29	826.43	811.43	10.95	823.34	Shallow
AB-08D	800.50	702.50	697.50	7.33	793.17	Bedrock
AB-08DU	800.38	747.53	737.53	7.19	793.19	Shallow
AB-08S	800.33	794.42	784.42	7.42	792.91	Shallow
AB-09BR	797.64	716.94	711.94	6.61	791.03	Bedrock
AB-09D	797.26	746.76	741.76	6.88	790.38	Bedrock
AB-09S	797.78	792.38	782.38	6.50	791.28	Shallow
AB-10BR	802.54	679.53	674.53	11.04	791.50	Bedrock
AB-10BRL	801.59	549.35	539.35	5.59	796.00	Bedrock
AB-10D	802.68	728.58	723.58	11.56	791.12	Bedrock
AB-10S	802.41	790.54	775.54	9.81	792.60	Shallow
AB-10SL	802.52	759.52	749.52	10.97	791.55	Shallow
AB-11D	799.95	719.84	714.84	0.50	799.45	Bedrock
AB-11S	800.05	790.89	780.89	3.65	796.40	Shallow
AB-12BR[2]	797.43	694.09	689.09	-0.65	798.08	Bedrock
AB-12D	795.45	730.56	725.56	3.22	792.23	Bedrock
AB-12S	795.61	789.70	779.70	4.90	790.71	Shallow
AB-12SL	795.67	752.70	742.70	4.54	791.13	Shallow
AB-13D	824.55	740.59	735.59	24.57	799.98	Bedrock
AB-13S	823.73	806.41	791.41	21.23	802.50	Shallow
AB-14D	824.11	741.45	736.45	8.25	815.86	Deep

TABLE 5-1
MAY 2019 WATER LEVEL MEASUREMENTS AND ELEVATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Top of Casing Elevation (ft. NAVD 88)	Top of Screen Elevation (ft. NAVD 88)	Bottom of Screen Elevation (ft. NAVD 88)	May 2019 Measured Water Level[1] (ft. BTOC)	May 2019 Water Elevation (ft. NAVD 88)	Monitoring Flow Zone
AB-14DU	824.83	779.01	769.01	8.91	815.92	Shallow
AB-14S	824.71	816.03	801.03	10.01	814.70	Shallow
AB-15BR	823.01	713.04	708.04	15.44	807.57	Bedrock
AB-15D	823.04	756.26	751.26	19.12	803.92	Bedrock
AB-15S	823.27	815.14	800.14	17.96	805.31	Shallow
AB-15SL	823.17	780.02	770.02	21.48	801.69	Shallow
AB-16D	822.45	778.50	773.50	5.21	817.24	Bedrock
AB-16DU	823.00	802.00	792.00	5.69	817.31	Deep
AB-16S	822.08	815.82	805.82	5.02	817.06	Shallow
AB-20D	892.35	750.14	745.14	65.90	826.45	Bedrock
AB-20S	892.43	835.79	820.79	63.52	828.91	Shallow
AB-21D	810.23	747.61	742.61	16.78	793.45	Deep
AB-21S	810.66	794.95	779.95	18.70	791.96	Shallow
AL-01BR	818.07	693.02	688.02	40.11	777.96	Bedrock
AL-01BRL	815.41	548.29	538.29	35.41	780.00	Bedrock
AL-01D	817.94	735.45	730.45	42.25	775.69	Deep
AL-01S	817.97	783.43	768.43	37.06	780.91	Shallow
AL-02BR	915.10	709.18	704.18	111.27	803.83	Bedrock
AL-02BRL	915.39	658.09	653.09	115.10	800.29	Bedrock
AL-02BRLL	914.63	571.77	566.77	115.61	799.02	Bedrock
AL-02BRLLL	915.81	433.00	423.00	116.71	799.10	Bedrock
AL-02D	915.33	760.83	755.83	112.93	802.40	Deep
AL-02S	915.41	800.83	785.83	114.20	801.21	Shallow
AL-03BR	919.02	687.53	682.53	113.57	805.45	Bedrock
AL-03D	918.69	737.49	732.49	111.36	807.33	Deep
AL-03S	918.59	818.97	798.17	110.15	808.44	Shallow
AL-04BR	918.72	736.75	731.75	108.03	810.69	Bedrock
AL-04BRL	918.74	665.85	655.85	119.58	799.16	Bedrock
AL-04D	918.44	767.61	762.61	105.04	813.40	Deep
BG-01BRA	817.24	730.23	728.24	12.59	804.65	Bedrock
BG-01D	817.63	779.75	774.75	7.57	810.06	Deep
BG-01S	817.35	807.29	797.29	7.30	810.05	Shallow
BG-02BR	814.81	761.99	756.99	4.62	810.19	Bedrock
BG-02S	814.33	804.82	794.82	4.64	809.69	Shallow
BG-03BR	867.69	759.72	754.72	31.18	836.51	Bedrock
BG-03D	864.18	802.56	797.56	21.75	842.43	Deep
BG-03S	863.03	838.55	828.55	22.74	840.29	Shallow
CCR-01D	809.32	723.43	718.43	12.90	796.42	Deep
CCR-01S	810.31	787.40	772.40	11.12	799.19	Shallow
CCR-02D	806.89	729.93	724.93	14.67	792.22	Deep
CCR-02S	806.56	786.81	771.81	14.44	792.12	Shallow
CCR-03D	780.44	684.08	679.08	20.44	760.00	Deep
CCR-03S	780.28	759.05	744.05	20.93	759.35	Shallow
CCR-04D	783.82	683.57	678.57	21.39	762.43	Deep
CCR-04S	783.66	763.42	748.42	22.28	761.38	Shallow

TABLE 5-1
MAY 2019 WATER LEVEL MEASUREMENTS AND ELEVATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Top of Casing Elevation (ft. NAVD 88)	Top of Screen Elevation (ft. NAVD 88)	Bottom of Screen Elevation (ft. NAVD 88)	May 2019 Measured Water Level[1] (ft. BTOC)	May 2019 Water Elevation (ft. NAVD 88)	Monitoring Flow Zone
CCR-05D	776.97	696.83	691.83	13.78	763.19	Deep
CCR-05S	777.25	758.91	743.91	14.81	762.44	Shallow
CCR-09DA	799.77	685.67	680.67	28.72	771.05	Deep
CCR-09S	799.88	769.68	754.68	32.20	767.68	Shallow
CCR-11D	793.86	718.99	713.99	6.08	787.78	Deep
CCR-11S	794.24	786.43	771.43	6.63	787.61	Shallow
CCR-12D	793.84	709.18	704.18	5.46	788.38	Deep
CCR-12S	793.85	785.45	770.45	5.48	788.37	Shallow
CCR-13D	800.02	720.15	715.15	12.41	787.61	Deep
CCR-13S	799.68	740.57	725.57	12.14	787.54	Shallow
CCR-14D	796.11	736.52	731.52	8.15	787.96	Deep
CCR-14S	795.97	788.75	773.75	8.04	787.93	Shallow
CCR-15D	805.14	748.91	743.91	10.39	794.75	Deep
CCR-15S	804.76	798.25	783.25	10.12	794.64	Shallow
CCR-16D	819.37	772.92	767.92	20.45	798.92	Deep
CCR-16S	819.32	810.62	795.62	13.13	806.19	Shallow
CP-1D	806.40	744.66	734.66	14.62	791.78	Deep
CP-1S	806.32	793.47	783.47	14.27	792.05	Shallow
CP-2D	810.83	710.95	700.95	10.80	800.03	Deep
CP-2S	810.67	788.79	778.79	10.57	800.10	Shallow
CP-3D	810.58	738.69	728.69	13.52	797.06	Deep
CP-3S	810.47	794.81	784.81	14.12	796.35	Shallow
GP-1D	858.03	756.00	746.00	55.94	802.09	Deep
GP-1S	858.13	806.13	796.13	56.03	802.10	Shallow
GP-2D	833.68	731.73	721.73	28.50	805.18	Deep
GP-2S	833.45	805.52	795.52	27.73	805.72	Shallow
GP-3D	856.46	745.53	735.53	51.05	805.41	Deep
GP-3S	856.39	804.46	794.46	50.98	805.41	Shallow
GWA-01BR	806.10	651.65	646.65	40.27	765.83	Bedrock
GWA-01D	806.05	684.27	679.27	42.60	763.45	Deep
GWA-01S	805.97	765.16	750.16	43.40	762.57	Shallow
GWA-02DA	826.59	729.79	724.79	20.34	806.25	Deep
GWA-02S	826.97	813.47	794.41	20.05	806.92	Shallow
GWA-03D	839.44	800.48	795.48	3.54	835.90	Deep
GWA-03S	839.24	833.42	823.42	2.76	836.48	Shallow
GWA-04D	902.45	818.38	813.38	53.34	849.11	Deep
GWA-04S	901.97	849.78	834.78	53.92	848.05	Shallow
GWA-05D	847.17	800.86	795.86	33.66	813.51	Deep
GWA-06D	845.72	741.32	736.32	38.42	807.30	Bedrock
GWA-06S	845.37	805.29	795.29	37.96	807.41	Shallow
GWA-07D	812.50	784.05	779.05	5.59	806.91	Deep
GWA-07S	810.72	798.80	788.80	7.12	803.60	Shallow
GWA-08D	853.68	794.59	789.59	29.64	824.04	Bedrock
GWA-08S	852.90	826.75	811.75	28.25	824.65	Shallow
GWA-09BR[2]	850.45	763.53	758.53	-2.00	852.45	Bedrock

TABLE 5-1
MAY 2019 WATER LEVEL MEASUREMENTS AND ELEVATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Top of Casing Elevation (ft. NAVD 88)	Top of Screen Elevation (ft. NAVD 88)	Bottom of Screen Elevation (ft. NAVD 88)	May 2019 Measured Water Level[1] (ft. BTOC)	May 2019 Water Elevation (ft. NAVD 88)	Monitoring Flow Zone
GWA-10D	778.10	661.77	657.27	9.38	768.72	Deep
GWA-10S	777.65	770.32	755.32	11.59	766.06	Shallow
GWA-11BR	810.03	657.00	652.00	44.81	765.22	Bedrock
GWA-11D	811.24	698.44	693.44	45.80	765.44	Deep
GWA-11S	812.55	769.79	754.79	44.94	767.61	Shallow
GWA-12BR	875.65	763.02	758.02	10.10	865.55	Bedrock
GWA-12D	875.83	788.29	783.29	9.34	866.49	Bedrock
GWA-12S	887.87	878.41	863.41	10.50	877.37	Shallow
GWA-13DA	888.28	736.14	731.28	19.42	868.86	Deep
GWA-13S	887.87	873.51	858.51	10.52	877.35	Shallow
GWA-14D	911.41	806.98	801.98	38.32	873.09	Deep
GWA-14S	910.69	876.24	861.24	37.72	872.97	Shallow
GWA-15D	781.85	719.96	709.96	23.00	758.85	Deep
GWA-15S	781.39	757.73	742.73	22.69	758.70	Shallow
ILF-1BR	865.61	765.78	755.78	38.52	827.09	Bedrock
ILF-1D	865.32	792.59	782.59	38.28	827.04	Deep
ILF-1S	865.31	822.47	812.47	37.35	827.96	Shallow
ILF-2D	885.14	793.57	783.57	44.38	840.76	Deep
ILF-2S	884.79	843.21	833.21	47.09	837.7	Shallow
MS-08	872.34	849.35	839.35	41.95	830.39	Shallow
MS-09	868.04	825.36	815.36	38.92	829.12	Shallow
MS-10	851.29	834.95	824.95	15.34	835.95	Shallow
MS-11	859.78	824.15	814.15	31.20	828.58	Shallow
MS-12	835.66	811.61	801.61	20.14	815.52	Shallow
MS-13	841.90	807.67	797.67	28.57	813.33	Shallow
MS-14	844.07	806.89	796.89	32.36	811.71	Shallow
MS-15	861.47	805.34	795.34	38.23	823.24	Shallow
MS-16	836.98	806.79	796.79	23.60	813.38	Deep
MW-01	823.70	754.10	744.10	49.86	773.84	Shallow
MW-02	797.21	771.90	761.90	6.04	791.17	Shallow
MW-03	813.07	795.10	785.10	8.02	805.05	Shallow
MW-04	866.42	823.55	813.55	35.56	830.86	Shallow
MW-04D	866.74	807.87	802.87	35.68	831.06	Bedrock
MW-05	822.69	802.19	792.19	23.54	799.15	Shallow
MW-06D	791.19	705.62	700.62	17.30	773.89	Deep
MW-06S	790.35	772.58	762.58	18.71	771.64	Shallow
MW-07D	776.85	711.46	706.46	6.25	770.60	Deep
MW-07S	775.99	762.50	752.50	12.87	763.12	Shallow
MW-08D	775.18	678.64	673.64	13.79	761.39	Bedrock
MW-08S	775.34	754.42	744.42	15.78	759.56	Shallow
MW-09D	777.38	684.14	679.14	16.72	760.66	Deep
MW-09S	777.34	753.44	743.44	14.48	762.86	Shallow
MW-10D	772.04	687.53	682.53	13.87	758.17	Deep
MW-10S	772.05	755.53	740.53	14.12	757.93	Shallow
MW-11D	884.67	793.85	788.85	40.89	843.78	Deep

TABLE 5-1
MAY 2019 WATER LEVEL MEASUREMENTS AND ELEVATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Top of Casing Elevation (ft. NAVD 88)	Top of Screen Elevation (ft. NAVD 88)	Bottom of Screen Elevation (ft. NAVD 88)	May 2019 Measured Water Level[1] (ft. BTOC)	May 2019 Water Elevation (ft. NAVD 88)	Monitoring Flow Zone
MW-11S	884.99	842.89	827.89	41.14	843.85	Shallow
MW-12D	871.88	775.71	770.71	12.98	858.90	Deep
MW-12S	871.86	858.92	843.92	11.10	860.76	Shallow
MW-13D[2]	847.05	800.89	795.89	0.00	847.05	Deep
MW-13S	847.49	839.02	824.02	2.15	845.34	Shallow
MW-14BR	810.49	708.65	703.65	33.76	776.73	Bedrock
MW-14BRL	811.77	521.05	511.05	28.45	783.32	Bedrock
MW-14D	811.43	751.07	746.07	35.13	776.30	Deep
MW-14S	811.29	776.36	761.36	34.52	776.77	Shallow
MW-PZ1	851.30	819.70	809.70	33.78	817.52	Shallow
MW-PZ10	851.26	816.90	806.90	29.91	821.35	Shallow
MW-PZ2	836.62	828.70	818.70	17.73	818.89	Shallow
MW-PZ3	845.54	813.90	803.90	36.16	809.38	Shallow
MW-PZ4	832.64	815.20	805.20	22.87	809.77	Shallow
MW-PZ5	833.68	821.40	806.40	25.50	808.18	Shallow
MW-PZ6	845.33	815.10	805.10	36.56	808.77	Shallow
MW-PZ7	808.02	803.60	783.60	5.04	802.98	Shallow
MW-PZ8	849.70	830.10	820.10	Dry	--	Shallow
MW-PZ9	846.77	827.10	802.10	40.80	805.97	Shallow
OB-01 (Dry Ash Landfill)	825.85	770.40	760.40	44.82	781.03	Shallow
OB-1 (Ash Basin)	850.57	807.89	792.09	43.65	806.92	Shallow
(MW-6) OB-2	919.65	814.68	799.68	105.90	813.75	Shallow
MW-07 (OB-3)	859.16	817.56	802.56	43.94	815.22	Shallow
PVSF-1BR	880.17	712.36	697.36	53.48	826.69	Bedrock
PVSF-1D	880.28	800.55	790.55	52.75	827.53	Deep
PVSF-1S	880.27	825.62	815.62	52.46	827.81	Shallow
PVSF-2BR	833.36	738.48	723.48	12.13	821.23	Bedrock
PVSF-2D	833.20	778.44	768.44	11.62	821.58	Deep
PVSF-2S	833.15	818.44	808.44	11.48	821.67	Shallow
PVSF-3BR	838.22	657.88	647.88	15.61	822.61	Bedrock
PVSF-3D	838.02	698.44	688.44	14.08	823.94	Deep
PVSF-3S	838.18	818.17	808.17	17.17	821.01	Shallow
PVSF-4BR[3]	858.45	713.66	703.66	99.95	758.50	Bedrock
PVSF-4D[3]	858.58	788.78	778.78	10.40	848.18	Deep
PVSF-4S[3]	858.57	828.74	818.74	10.03	848.54	Shallow

Prepared by: ECW Checked by: BDW

Notes:

[1] - Manual water levels collected on May 20, 2019

[2] - Artesian conditions present

[3] - Water Levels measured on August 26, 2019, during the next quarterly sampling event after well installation.

ft. BTOC - feet below top of casing

ft. NAVD 88 - feet North American Vertical Datum of 1988

See Figures 5-4a through 5-4c for graphical representation of data

TABLE 5-2
HORIZONTAL HYDRAULIC GRADIENTS AND FLOW VELOCITIES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Shallow Flow Zone

Source Area	Upgradient Groundwater Level h (ft)[1]	Downgradient Groundwater Level h (ft)[2]	K (ft/day)[3]	Δh (ft)	Δl (ft)[4]	n_e[3]	v_s (ft/day)	v_s (ft/yr)	Gradient (Δh/Δl)
PV Structural Fill	850	820	1.0	30.00	1800	0.3	0.056	20.28	0.02
Ash Basin	805	765	1.0	40.00	5400	0.3	0.025	9.01	0.01
Dry Ash Landfill (Phase II)	815	795	1.0	20.00	1600	0.3	0.042	15.21	0.01
Dry Ash Landfill (Phase I)	785	765	1.0	20.00	600	0.3	0.111	40.56	0.03
Coal Pile	795	765	1.0	30.00	1850	0.3	0.054	19.73	0.02
Gypsum Pad	805	795	1.0	10.00	925	0.3	0.036	13.15	0.01

Shallow Flow Zone

Geometric Mean	0.048	17.6	0.01
Average	0.05	19.7	0.02

Deep Flow Zone

Source Area	Upgradient Groundwater Level h (ft)[1]	Downgradient Groundwater Level h (ft)[2]	K (ft/day)[3]	Δh (ft)	Δl (ft)[4]	n_e[3]	v_s (ft/day)	v_s (ft/yr)	Gradient (Δh/Δl)
PV Structural Fill	855	825	1.5	30.00	1550	0.3	0.097	35.32	0.02
Ash Basin	815	770	1.5	45.00	5250	0.3	0.043	15.64	0.01
Dry Ash Landfill (Phase II)	815	800	1.5	15.00	1600	0.3	0.047	17.11	0.01
Dry Ash Landfill (Phase I)	785	765	1.5	20.00	550	0.3	0.182	66.36	0.04
Coal Pile	800	765	1.5	35.00	1850	0.3	0.095	34.53	0.02
Gypsum Pad	805	800	1.5	5.00	850	0.3	0.029	10.74	0.01

Deep Flow Zone

Geometric Mean	0.068	24.8	0.01
Average	0.08	30.0	0.02

Bedrock Flow Zone

Source Area	Upgradient Groundwater Level h (ft)[1]	Downgradient Groundwater Level h (ft)[2]	K (ft/day)[3]	Δh (ft)	Δl (ft)[4]	n_e[3]	v_s (ft/day)	v_s (ft/yr)	Gradient (Δh/Δl)
PV Structural Fill	850	820	0.7	30.00	1450	0.01	1.448	528.62	0.02
Ash Basin	805	775	0.7	30.00	5200	0.01	0.404	147.40	0.01
Dry Ash Landfill (Phase II)	810	795	0.7	15.00	1900	0.01	0.553	201.71	0.01
Dry Ash Landfill (Phase I)	780	770	0.7	10.00	670	0.01	1.045	381.34	0.01

Bedrock Flow Zone

Geometric Mean	0.762	278.2	0.01
Average	0.86	314.8	0.01

Prepared by : GTC Checked by: BDW

Notes:

[1] - Groundwater level shown corresponds to upgradient groundwater contour on **Figures 5-4a** through **5-4c**

[2] - Groundwater level shown corresponds to downgradient groundwater contour on **Figures 5-4a** through **5-4c**

[3] - Values taken from Preliminary Updated Groundwater Flow and Transport Modeling Report for Marshall Steam Station, Terrell, NC, November 2018

[4] - The length of a flow path between an upgradient and downgradient groundwater contor within the same flow zone

ft - feet

h - water level height in feet

K - horizontal hydraulic conductivity

l - horizontal distance between wells

n_e - effective porosity

v_s - horizontal seepage velocity

Δh - difference in water level height between upgradient and downgradient locations

Δl - horizontal distance between upgradient and downgradient locations

TABLE 5-3
VERTICAL HYDRAULIC GRADIENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Monitoring Zone	Reference Cross-Section	Total Well Depth [1,2] (Ft-BGS)	Elevation mid-Point of Screened Interval	Water Level Elevation 5-20-2019	Vertical Gradient and Flow Direction	
Dry Ash Landfill (Phase II)							
AL-02S	Shallow	N/A	130.18	793.33	801.21	-0.03	Upward
AL-02D	Deep		164.50	758.33	802.40		
AL-02D	Deep	N/A	164.50	758.33	802.40	-0.03	Upward
AL-02BR	Bedrock		230.82	706.68	803.83		
AL-02BR	Bedrock	N/A	230.82	706.68	803.83	0.07	Downward
AL-02BRL	Bedrock		263.50	655.59	800.289		
AL-02BRL	Bedrock	N/A	263.50	655.59	800.289	0.01	Downward
AL-02BRLL	Bedrock		345.00	569.27	799.019		
AL-02BRLL	Bedrock	N/A	345.00	569.27	799.02	0.00	--
AL-02BRLLL	Bedrock		490.00	290.45	799.10		
AL-02S	Shallow	N/A	130.18	793.33	801.21	-0.03	Upward
AL-02BR	Bedrock		230.82	706.68	803.83		
AL-02S	Shallow	N/A	130.18	793.33	801.21	0.01	Downward
AL-02BRL	Bedrock		263.50	655.59	800.289		
AL-02S	Shallow	N/A	130.18	793.33	801.21	0.01	Downward
AL-02BRLL	Bedrock		345.00	569.27	799.019		
AL-02S	Shallow	N/A	130.18	793.33	801.21	0.00	--
AL-02BRLLL	Bedrock		490.00	290.45	799.10		
AL-03S	Ash Pore Water	N/A	120.42	808.57	808.44	0.02	Downward
AL-03D	Deep		189.70	734.99	807.33		
AL-03D	Deep	N/A	189.70	734.99	807.33	0.04	Downward
AL-03BR	Bedrock		239.30	685.03	805.45		
AL-04D	Deep	N/A	159.83	765.11	813.40	0.03	Downward
AL-04BR	Bedrock		211.00	660.85	810.69		
AL-04BR	Bedrock	N/A	211.00	660.85	810.685	-0.16	Upward
AL-04BRL	Bedrock		260.00	734.25	799.161		
AB-10S	Shallow	C-C'	27.87	783.04	792.60	0.04	Downward
AB-10SL	Shallow		56.00	754.52	791.55		
AB-10SL	Shallow	C-C'	56.00	754.52	791.55	-0.17	Upward
AB-10D	Deep		84.20	757.02	791.12		
AB-10D	Deep	C-C'	84.20	757.02	791.12	0.00	--
AB-10BR	Bedrock		134.00	677.03	791.50		
Dry Ash Landfill (Phase I)							
AL-01S	Shallow	N/A	50.34	775.93	780.91	0.12	Downward
AL-01D	Deep		92.29	732.95	775.69		

TABLE 5-3
VERTICAL HYDRAULIC GRADIENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Monitoring Zone	Reference Cross-Section	Total Well Depth [1,2] (Ft-BGS)	Elevation mid-Point of Screened Interval	Water Level Elevation 5-20-2019	Vertical Gradient and Flow Direction	
Dry Ash Landfill (Phase I) (Continued)							
AL-01D	Deep	N/A	92.29	732.95	775.69	-0.05	Upward
AL-01BR	Bedrock		132.00	690.52	777.96		
GWA-11S	Shallow	N/A	78.96	762.29	767.61	0.03	Downward
GWA-11D	Deep		129.00	695.94	765.44		
GWA-11D	Deep	N/A	129.00	695.94	765.44	0.01	Downward
GWA-11BR	Bedrock		155.00	654.50	765.22		
Downgradient of Ash Basin Dam							
AB-01S	Shallow	N/A	23.71	761.56	771.25	-0.03	Upward
AB-01D	Deep		99.90	681.19	773.93		
AB-01D	Deep	N/A	99.90	681.19	773.93	-0.12	Upward
AB-01BR	Bedrock		134.38	653.33	777.19		
AB-01BR	Bedrock	N/A	134.38	653.33	777.19	0.05	Downward
AB-01BRL	Bedrock		166.00	611.27	775.05		
AB-01BRL	Bedrock	N/A	166.00	611.27	775.05	0.00	--
AB-01BRLL	Bedrock		205.00	574.79	775.09		
AB-01BRLL	Bedrock	N/A	205.00	574.79	775.09	0.00	--
AB-01BRLLL	Bedrock		413.00	367.45	775.97		
AB-01S	Shallow	N/A	23.71	761.56	771.25	-0.05	Upward
AB-01BR	Bedrock		134.38	653.33	777.19		
AB-01S	Shallow	N/A	23.71	761.56	771.25	-0.03	Upward
AB-01BRL	Bedrock		166.00	611.27	775.05		
AB-01S	Shallow	N/A	23.71	761.56	771.25	-0.02	Upward
AB-01BRLL	Bedrock		205.00	574.79	775.09		
AB-01S	Shallow	N/A	23.71	761.56	771.25	-0.01	Upward
AB-01BRLLL	Bedrock		413.00	367.45	775.97		
PV Structural Fill							
PVSF-1S	Shallow	N/A	62.00	820.62	827.81	0.01	Downward
PVSF-1D	Deep		87.00	795.55	827.53		
PVSF-1D	Deep	N/A	87.00	795.55	827.53	0.01	Downward
PVSF-1BR	Bedrock		180.00	704.86	826.69		
PVSF-1S	Shallow	N/A	62.00	820.62	827.81	0.01	Downward
PVSF-1BR	Bedrock		180.00	704.86	826.69		
PVSF-2S	Shallow	N/A	22.00	813.44	821.67	0.00	--
PVSF-2D	Deep		62.00	773.44	821.58		

TABLE 5-3
VERTICAL HYDRAULIC GRADIENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Monitoring Zone	Reference Cross-Section	Total Well Depth [1,2] (Ft-BGS)	Elevation mid-Point of Screened Interval	Water Level Elevation 5-20-2019	Vertical Gradient and Flow Direction	
PV Structural Fill (Continued)							
PVSF-2D	Deep	N/A	62.00	773.44	821.58	0.01	Downward
PVSF-2BR	Bedrock		107.00	730.99	821.23		
PVSF-2S	Shallow	N/A	22.00	813.44	821.67	0.01	Downward
PVSF-2BR	Bedrock		107.00	730.99	821.23		
PVSF-3S	Shallow	N/A	27.00	813.17	821.01	-0.02	Upward
PVSF-3D	Deep		147.00	693.44	823.94		
PVSF-3D	Deep	N/A	147.00	693.44	823.94	0.03	Downward
PVSF-3BR	Bedrock		187.50	652.88	822.61		
PVSF-3S	Shallow	N/A	27.00	813.17	821.01	-0.01	Upward
PVSF-3BR	Bedrock		187.50	652.88	822.61		
PVSF-4S	Shallow	N/A	40.00	823.74	848.54	0.01	Downward
PVSF-4D	Deep		80.00	783.78	848.18		
PVSF-4D	Deep	N/A	80.00	783.78	848.18	1.19	Downward
PVSF-4BR	Bedrock		155.00	708.66	758.50		
PVSF-4S	Shallow	N/A	40.00	823.74	848.54	0.78	Downward
PVSF-4BR	Bedrock		155.00	708.66	758.5		
Structural Fill Access Road							
AB-06S	Ash Pore Water	C-C'	24.61	818.27	827.68	0.03	Downward
AB-06D	Bedrock		78.26	767.90	825.94		
AB-06D	Bedrock	C-C'	78.26	767.90	825.94	0.01	Downward
AB-06BRA	Bedrock		112.93	725.34	825.40		
Coal Pile							
CP-1S	Shallow	N/A	20.00	788.47	792.05	0.01	Downward
CP-1D	Deep		69.00	739.66	791.78		
CP-2S	Shallow	N/A	29.00	783.79	800.10	0.00	--
CP-2D	Deep		107.00	705.95	800.03		
CP-3S	Shallow	N/A	79.00	733.81	796.35	0.01	Downward
CP-3D	Deep		23.00	789.69	797.06		
Gypsum Pad							
GP-1S	Shallow	N/A	59.00	801.13	802.10	0.00	--
GP-1D	Deep		109.00	751.00	802.09		
GP-2S	Shallow	N/A	35.00	800.52	805.72	0.01	Downward
GP-2D	Deep		109.00	726.73	805.18		
GP-3S	Shallow	N/A	59.00	799.46	805.41	0.00	--
GP-3D	Deep		118.00	740.53	805.41		

TABLE 5-3
VERTICAL HYDRAULIC GRADIENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Monitoring Zone	Reference Cross-Section	Total Well Depth [1,2] (Ft-BGS)	Elevation mid-Point of Screened Interval	Water Level Elevation 5-20-2019	Vertical Gradient and Flow Direction	
Middle of Ash Basin							
AB-12S	Ash Pore Water	A-A'/C-C'	15.91	784.70	790.71	-0.01	Upward
AB-12SL	Ash Pore Water		54.97	747.70	791.13		
AB-12SL	Ash Pore Water	A-A'	54.97	747.70	791.13	-0.06	Upward
AB-12D	Bedrock		73.69	728.06	792.23		
AB-12D	Bedrock	A-A'	73.69	728.06	792.23	-0.10	Upward
AB-12BR	Bedrock		114.60	689.59	796.08		

Prepared by: GTC Checked by: BDW

Notes:

[1] - "Total Well Depth" is the depth to the bottom of the filter pack.

[2] - Values measured during well installation

BGS - Below ground surface

ft - feet

NAVD 88 - North American Vertical Datum 1988

TABLE 5-4
GROUNDWATER BALANCE SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Modeling Scenario	Pre-Decanting		Post-Decanting		Closure-in-Place		Closure-by-Excavation	
Water Balance Components	Flow in (gpm)	Flow out (gpm)	Flow in (gpm)	Flow out (gpm)	Flow in (gpm)	Flow out (gpm)	Flow in (gpm)	Flow out (gpm)
Direct recharge to the ash basin	136		170				112	
Direct recharge to the watershed outside of the ash basin	346		346		336		308	
Ash basin pond	80			16				157
Drainage inside the ash basin[1]		270		284		158		127
Drainage outside the ash basin		75		66		43		20
Domestic water supply wells	2	2	2	2	2	2	2	2
Flow through and under the dam		217		150		135		117

Prepared by: YAG Checked by: WCG

Notes:

1) Drainage includes streams, seeps, ditch, channel, canal, etc. Drainage streams depend on the closure scenario, where the pre-decanting scenario includes streams present prior to closure and closure-by excavation includes streams that form within the excavated ash basin footprint after closure.

Flow in refers to recharge to the groundwater system

Flow out refers to discharge from the groundwater system

gpm - gallons per minute

TABLE 5-5
SURFACE WATER CLASSIFICATION
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Adjacent Surface Water Body	Surface Water Classification (15A NCAC 02B .0300)
Lake Norman	Class B, WS-IV; CA

Notes:

1. Class B waters are protected for primary recreation, which includes swimming on a frequent or organized basis and all Class C uses.

2. Class WS-IV waters are protected as water supplies that are generally in moderately to highly developed watersheds. WS-IV waters are also subject to Class C water quality standards.

3. CA – Critical area refers to an area adjacent to a water supply intake or reservoir where risk associated with impacts is greater than from other areas of the watershed

NCAC – North Carolina Administrative Code

WS – Water Supply

TABLE 6-1
BORON CONCENTRATIONS IN GROUNDWATER BELOW SOURCE AREA
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well Beneath Ash (Flow Zone)	Number of Sample Events	Time Period of Record	Boron Concentration Range in Groundwater	Boron Concentration Range in Overlying Pore Water
AB-03D (bedrock)	16	07/2015 – 2/2019	34.6 j – 190 (Note: One anomalous concentration of 4,370 ug/L (06/2016) was not confirmed through dissolved result)	220 – 1,700 Saturated Ash: 55'
AB-04D (transition zone)	14	07/2015 – 11/2018	344 – 390	146 – 850 Saturated Ash: 45'
AB-05D (transition zone)	14	10/2015 – 2/2019	27.3 j - <50	1,100 j+ – 2,750 M1 Saturated Ash: 38'
AB-05DU (saprolite)	3	08/2018 – 2/2019	33.4 j,B – 44.2 j	
AB-05BR (bedrock)	15	07/2015 – 2/2019	<50	
AB-06D (bedrock)	15	07/2015 – 2/2019	5,050 – 6,270	235 – 8,140 Saturated Ash: 42'
AB-06BRA (bedrock)	8	06/2017 – 2/2019	244 – 1,210 (Time series shows a spike and return to ~300 ug/L range; currently <2L)	
AB-06BRL (bedrock)	6	10/2017 – 2/2019	46.9 j - <250	
AB-07D (transition zone)	13	07/2015 – 11/2018	25 – 107	9,390 – 29,900 Saturated Ash: 10'
AB-07DU (saprolite)	3	08/2018 – 2/2019	27.4 j - 236	
AB-08D (bedrock)	12	09/2015 – 11/2018	30.6 j – 225	405 – 1,500 Saturated Ash: 18'
AB-08DU (saprolite)	3	08/2018 – 2/2019	45.3 j – 111	
AB-10D (bedrock)	15	07/2015 – 2/2019	1,070 – 1,580	9,350 – 27,400 Saturated Ash: 43'
AB-10BR (bedrock)	10	12/2016 – 2/2019	216 – 383	
AB-12D (bedrock)	15	07/2015 – 2/2019	928 – 3,500	2,860 – 103,000 Saturated Ash: 48'
AB-12BR (bedrock)	10	03/2017 – 2/2019	37.4 j – 94.6 B, 1g	
AB-13D (bedrock)	12	09/2015 – 11/2018	26 j - <50	697 – 1,310 Saturated Ash: 40'
AB-14D (transition zone)	14	07/2015 – 2/2019	130 – 502	1,300 – 20,500 Saturated Ash: 30'
AB-14DU (saprolite)	3	08/2018 – 2/2019	61.4 – 130	
AB-15D (bedrock)	15	07/2015 – 2/2019	27.1 j – 55.9	214 – 4,140 Saturated Ash: 33'
AB-15BR (bedrock)	15	07/2015 – 2/2019	<50 – 54.2	
AB-16D (bedrock)	12	09/2015 – 11/2018	26.3 j – 96.9	<50 – 166 Saturated Ash: 2'
AB-16DU (saprolite)	3	08/2018 – 2/2019	<50	
AB-17D (bedrock)	13	10/2015 – 11/2018	<50 – 179	6,000 – 27,600 Saturated Ash: 20'

TABLE 6-1
BORON CONCENTRATIONS IN GROUNDWATER BELOW SOURCE AREA
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well Beneath Ash (Flow Zone)	Number of Sample Events	Time Period of Record	Boron Concentration Range in Groundwater	Boron Concentration Range in Overlying Pore Water
AB-18D (bedrock)	12	04/2016 – 11/2018	<50 – 61	1,260 – 2,520 Saturated Ash: 24’
AB-18DU (saprolite)	2	08/2018 – 11/2018	<50	
AB-20D (bedrock)	14	07/2015 – 2/2019	25.6 j – 129	48,500 M6 – 80,600 Saturated Ash: 28’
AB-21D (transition zone)	14	07/2015 – 2/2019	26 j - <50	1,100 – 5,770 Saturated Ash: 15’

Prepared by: BDW Checked by: ECW

Notes:

< - less than

j - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

j+ - Estimated concentration, biased high.

M1 - Matrix spike recovery was high: the associated Laboratory Control Spike (LCS) was acceptable.

M6 - Matrix spike and Matrix spike duplicate recovery not evaluated against control limits due to sample dilution.

B - Target analyte detected in method blank at or above the reporting limit.

Target analyte concentration in sample is less than 10X the concentration in the method blank.

Analyte concentration in sample could be due to blank contamination.

1g - Result confirmed by second analysis performed out of hold time.

TABLE 6-2
SOIL PSRG POG STANDARD EQUATION PARAMETERS AND VALUES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

$$C_{soil} = C_{gw} [K_d + (\theta_w + \theta_a H') / P_b] df$$

Inorganic Parameters	Parameter Definition	Default Values	Units
C_{soil}	Calculated source concentration for soil	NA	mg/kg - soil
C_{gw}	Applicable groundwater target concentration: 15A NCAC 02L Standard	15A NCAC 02L Standard	mg/L - water
df	Dilution factor[1] (0.5 acre source size)	20	unitless
K_d	Soil -water partition coefficient for inorganics (range)	Constituent Specific[4]	L/kg
θ_w	Water filled soil porosity - vadose soils[2]	0.3	L_{water}/L_{soil}
θ_a	Air filled soil porosity - vadose soils[3]	0.13	L_{air}/L_{soil}
P_b	Dry bulk density[2]	1.6	kg/L
H'	Henry's law constant-dimensionless where: H' = Henry's law constant (atm - m3/mole) x conversion factor of 41	Constituent Specific[3,5]	unitless

Prepared by: BDW Checked by: ECW

Notes:

[1] - Default value from Soil Screening Guidance: Technical Background Document (USEPA, 1996)

[2] - Site specific value (Falta et al., 2018). Effective porosity represents unconsolidated material

[3] - DEQ default value appropriate for North Carolina

[4] - Constituent Specific- Soil water partition coefficients (K_d) were obtained from the Groundwater Quality Signatures for Assessing Potential Impacts from Coal Combustion Product Leachate (EPRI, 2012). Chloride K_d ranges from 0 to 0.5, based on 0.25 soil, 0.5 for sand and 0-0.5 for sands, sediments. Sulfate K_d ranges from 0.1 to 2.1, based on sands/sediments and a pH range of 4.6 to 7.2

[5] - a value of 0 is used for chloride and sulfate

NA - Not applicable

TABLE 6-3
SUMMARY OF UNSATURATED SOIL SAMPLE ANALYTICAL RESULTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium*	Cobalt	Iron	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Vanadium
Reporting Units		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PSRG Protection of Groundwater		**0.9**	5.8	580	**63**	**45**	**3**	**938** [1]	3.8	0.9	150	65	**7.1**	130	2.1	**1500**	**1438** [1]	0.28	**350**
2017 Background Threshold Values[1]		0.65	4.7	819	3.9	8.7	0.11	13	32.8	53	78,228	2,872	3.5	18.6	1.77	7.53	36	1.1	210
2019 Background Threshold Values[2]		0.64	**8.2**	**1,063**	3.9	15	0.72	293	**406**	**63**	**78,228**	**3,388**	3.5	**237**	**3.7**	200	293	**2.1**	210
Sample ID	**Sample Collection Date**	**Analytical Results**																	
Background																			
BG-3D (1-2)	6/9/2015	~~<5.7~~	**8.4**	649	1.3	~~<57.3~~	<0.69	<278	**420**	27.4	37,600	243	<2.9	237	**6.7**	213	<278	~~<5.7~~	81.9
BG-3D (10-12)	6/9/2015	~~<5.3~~	5.7	1,030	0.34	~~<52.9~~	<0.63	<262	406	28	34,300	412	<2.6	**267**	3.7 j	200	<262	~~<5.3~~	83.3
BGSB-GWA-02 (2-4)	8/16/2017	0.12 j,B,M	0.52 j,B	270	1.4	<15	<0.03	<2.6	19	28	44,000 M	1,300 M	~~<12 M~~	16	0.39 j	7.8	36 M	0.54	140 M
BGSB-GWA-02 (8-10)	8/16/2017	<0.5	0.58 B	140	1.7	5.4 j	0.016 j	4 j,M	23	32	59,000	1,200	<2	10	<1.3	2.8	21	0.53	150
BGSB-GWA-02 (13-15)	8/16/2017	<0.59	0.63 B	180	1.6	<14	0.019 j	4.5 j	17	45	43,000	2,600	<2.2	17	<1.5	2.4	28	0.51	120
BGSB-GWA-02 (18-20)	8/16/2017	<0.59	0.47 j,B	180	1.5	1.6 j	0.031	3.9 j	15	**70**	27,000	1,900	<2.2	10	<1.5	5.3	18	0.75	120
BGSB-GWA-04 (2-4)	8/16/2017	<0.63	2.9 B	26	1.3	6.2 j	<0.032	<13	13	3.2	53,000	120	2.3 j	<12	0.44 j	0.9 j	<13	0.32	120
BGSB-GWA-04 (8-10)	8/16/2017	<0.63	1.5 B	62	2.8	5.7 j	<0.031	<13	16	6.4	61,000	240	~~<11~~	<11	0.49 j	<5.3	<13	0.23	150
BGSB-GWA-04 (13-15)	8/16/2017	<0.59	0.44 j,B	230	2.7	5.9 j	<0.03	<12	14	36	56,000	1,700	~~<11~~	5.8 j	0.38 j	<5.6	<12	0.58	140
BGSB-GWA-04 (15-17)	8/16/2017	<0.64	1.8 B	72	3.5	<14	<0.032	1.3 j	25	23	51,000	400	~~<11~~	<11	0.55 j	<5.5	<13	0.19	170
BGSB-GWA-04 (18-20)	8/16/2017	<0.56	0.94 B	140	3.2	<15	0.11	<13	16	41	65,000	1,200	~~<12~~	<12	0.55 j	<6	<13	0.86	160
BGSB-GWA-06 (2-4)	8/16/2017	0.24 j,B	2.1 B	20	0.58	2.6 j	<0.03	<12	28	2.9	22,000	75	0.74 j	5.6	0.34 j	3.4	<12	0.31	54
BGSB-GWA-06 (8-10)	8/16/2017	<0.37	0.93 B	110	1.1	1.5 j	<0.018	<12	6.9	15	18,000	400	1.1 j	6.7	0.38 j	1.8	<12	0.63	29
BGSB-GWA-06 (11-13)	8/16/2017	<0.54	1.9 B	99	1.9	1.2 j	<0.027	1.3 j	21	21	20,000	270	0.83 j	9.6	0.63 j	4.3	<13	1.6	86
BGSB-GWA-06 (13-15)	8/16/2017	<0.46	0.68 B	33	0.59	<2.6	0.051	<11	11	40	6,000	770	3.5	4.2	<1.2	4.1	<11	0.32	5.4
BGSB-GWA-06 (18-20)	8/16/2017	<0.42	0.25 j,B	11	0.21	<2.6	<0.021	<11	0.38 j	6.3	170	32	<2.1	1 j	<1.1	2.6	<11	0.06 j	<1.1
GWA-2DA (3-5)	3/13/2017	~~<2.9~~	1 j	159	2.2	<6.6	<0.17	<63.1	10.8	22.6	38,900	361	<0.66	11.1	0.92 j	3.1	91.4	~~<1.4~~	97
GWA-2DA (8-10)	3/13/2017	~~<2.7~~	1.2 j	270	2.9	<7.2	<0.16	<59.7	16	16.7	33,400	734	<0.72	14.3	1.2 j	6	79	0.78 j	112
GWA-4D (52-53)	5/19/2015	~~<6~~	~~<6~~	345 j+	1.8 j-	~~<59.8~~	<0.72	<293	15	23.2 j-	42,300 j-	810 j-	<3	7.1 j-	~~<6~~	16.5	<293	~~<6~~	128 j-
GWA-5D (27.5-29.0)	7/1/2015	~~<7.9~~	~~<7.9~~	490	2.6	<19.7	<0.94	<384	3.1	8.3	31,500	509	<3.9	4.5	~~<7.9~~	60.7	<384	~~<7.9~~	67.7
GWA-14S (3-5)	3/9/2017	~~<2.6~~	1.6	94.4	1.7	<6.4	<0.16	<56.1	2.4	4	18,300	334	<0.64	2.7	1.1 j	1.5	<56.1	~~<1.3~~	34
GWA-14S (8-10)	3/9/2017	~~<3.2~~	3.8	45.1	1.3	<7.8	<0.19	<63.1	23.2	2	46,500	219	0.4 j	11.5	1.4 j	2.3	56.5 j	~~<1.6~~	72.2
MAR 145 CCR Removal Verification Samples - West Finger Pond																			
B-04 (0-1)	05/02/2019	<0.52	0.36 j	27	0.24	<2.6	<0.13	1.8 j	11	1.1	6,600	29	<2.1	3.1	<1.3	4.4	6.9 j	0.13	29
B-04 (2-3)	05/02/2019	<0.54	<0.54	48	0.48	<2.7	<0.14	<12	13	1.3	4,000	40	<2.2	3.4	0.63 j	10	<12	0.13 j	50
B-11 (0-1)	05/02/2019	<0.53	0.99	100	0.65	<5.3	0.029 j	3.8 j	52	5.2	37,000	230	4.7	19	1.7	2.9	<12	0.3	130
B-11 (2-3)	05/02/2019	<0.48	1.2	160	0.92	<19	0.034 j	<12	72	8	57,000	370	4.4	32	1.6	2.7	<12	0.59	110
B-11 (6.5-7.5)	05/02/2019	<0.45	2.2	**1,100**	1.3	<8.9	0.12	3 j	53	**160**	66,000	**5,400**	2.8	56	1.2	2.3	<12	**3.9**	78
C-06 (0-1)	05/02/2019	<0.58	0.62	91	1	<2.9	0.031 j	4.1 j	11	9.9	16,000	650	<2.3	17	<1.5	3	8 j	0.19	31
C-06 (2-3)	05/02/2019	<0.54	0.26 j	160	0.88	<2.7	0.067 j	1.9 j	13	9.4	10,000	890	<2.1	27	0.62 j	6.2	<12	0.33	21
C-08 (0-1)	05/02/2019	<0.62	<0.62	190	1.3	<3.1	0.14 j	1.4 j	27	9.6	21,000	220	<2.5	21	0.64 j	14	7.7 j	0.14 j	59
C-08 (2-3)	05/02/2019	<0.6	<0.6	200	1	<3	0.081 j	3.4 j	34	11	29,000	290	<2.4	15	<1.6	19	<14	0.19	49
C-08 (7-8)	05/02/2019	<0.57	<0.57	270	0.96	<2.9	0.23	2.3 j	11	14	28,000	800	<2.3	11	<1.5	19	<15	0.26	54
D-10 (0-1)	05/02/2019	<0.55	<0.55	610	0.93	<5.5	<0.14	7.2 j	36	14	52,000	440	<2.2	29	0.76 j	2.1	<13	0.36	82
D-10 (2-3)	05/02/2019	<0.56	0.25 j	380	0.76	<5.6	<0.14	6.7 j	51	13	52,000	360	<2.2	21	0.81 j	2.2	7.3 j	0.21	76
D-10 (7-8)	05/02/2019	<0.51	<0.51	440	1.3	<5.1	0.061 j	3.6 j	27	11	35,000	540	<2.1	18	<1.3	4.7	6.4 j	0.28	50
D-10 (12-13)	05/02/2019	--	<0.59	780	1.9	<8.8	0.15	3 j	49	24	56,000	2,000	<2.3	35	<1.5	3.4	<13	0.65	79
D-11 (0-1)	05/02/2019	<0.5	<0.5	190	0.73	<20	<0.13	4.8 j	41	15	**85,000**	350	<2	26	0.66 j	4	<14	0.43	93
D-11 (2-3)	05/02/2019	<0.6	<0.6	320	1.3	<9	<0.16	4.3 j	44	17	49,000	460	<2.4	27	<1.6	2.5	<15	0.59	85
D-11 (7-8)	05/02/2019	<0.56	<0.56	250	1.2	<5.6	<0.15	2.3 j	68	14	48,000	290	<2.3	43	<1.5	2.4	<13	0.38	57

TABLE 6-3
SUMMARY OF UNSATURATED SOIL SAMPLE ANALYTICAL RESULTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium*	Cobalt	Iron	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Vanadium
Reporting Units		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PSRG Protection of Groundwater		**0.9**	5.8	580	**63**	**45**	**3**	**938** [1]	3.8	0.9	150	65	**7.1**	130	2.1	**1500**	**1438** [1]	0.28	**350**
2017 Background Threshold Values[1]		0.65	4.7	819	3.9	8.7	0.11	13	32.8	53	78,228	2,872	3.5	18.6	1.77	7.53	36	1.1	210
2019 Background Threshold Values[2]		0.64	**8.2**	**1,063**	3.9	15	0.72	293	**406**	**63**	**78,228**	**3,388**	3.5	**237**	**3.7**	200	293	**2.1**	210
Sample ID	**Sample Collection Date**	**Analytical Results**																	
CAMA/Data Gap/Additional Source Areas Assessment Samples																			
AB-02S (6-7)	07/01/2015	<5.5	2.8 j	74	0.79	<13.7	<0.66	<262	5.3	3.4 j	10,600	125	<2.7	1.6	<5.5	24.1	<262	<5.5	21.7
AL-01 (0.5-1)	04/12/2019	<0.44	3.4	150	0.58	1.2 j	<0.11	<12	12	6.5	17,000	260	0.5 j	11	0.8 j	30	<12	0.24	38
AL-01 (2-3)	04/12/2019	<0.5	3.2	220	1.7	<7.4	0.025 j	<12	20	7.8	37,000	230	<2	15	0.82 j	74	84	0.69	77
AL-01D (32-34)	06/30/2015	<5.9	**10.5**	319	2.4	<14.6	<0.7	<294	1 j	6.4 j	26,200	566	<2.9	1.5 j	**7.1**	82.6	<294	<5.9	54
CCR-05 (0.5-1)	04/16/2019	<0.41	0.61	190	0.77	0.98 j	0.077 j	<11	14	11	20,000	540	<1.6	8.1	<1.1	26	41	0.33	47
CCR-05 (2-3)	04/16/2019	<0.41	0.54	260	0.38	1.7 j	0.065 j	10 j	14	14	38,000	780	<1.7	12	0.49 j	19	59	0.71	76
CCR-09 (0.5-1)	04/12/2019	<0.51	3.9	90	0.77	<5.1	<0.13	4.4 j	48	2.9	44,000	85	1.7 j	8	1.6	27	130	0.45	81
CCR-09 (2-3)	04/12/2019	<0.54	2.9	83	0.95	<8.1	<0.14	17	18	3.4	45,000	120	1.9 j	10	1.4	42	120	0.54	93
CP-01D (2-3)	03/15/2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CP-01D (2-4)	03/15/2019	<0.59	1.7	170	1.3	<2.9	<0.15	11 j	14	7.8	25,000	350	<2.3	8.8	<1.5	34	65	0.48	57
CP-01D (4-6)	03/15/2019	<0.45	2	76	0.66	<2.3	<0.12	7.8 j	13	3.5	19,000	130	<1.8	6.3	<1.2	12	13	0.36	39
CP-01D (6-8)	03/15/2019	<0.61	1.9	44	0.8	<3	<0.16	13	16	3.1	26,000	130	<2.4	8.1	<1.6	10	77	0.4	52
CP-01D (8-10)	03/15/2019	<0.57	1.9	96	1	<2.8	<0.15	12 j	16	5.8	25,000	260	<2.3	8.5	<1.5	15	200	0.42	53
CP-02D (6-8)	03/18/2019	<0.45	0.98	130	1.2	<4.5	<0.12	2.7 j	16	8.5	25,000	730	<1.8	9.1	<1.2	21	14	0.42	49
CP-03D (0-2)	03/19/2019	0.22 j,M	4.7	100	0.73	3.6 j	0.074 j	<11	20	7.6	66,000 M	400 M	4.1	17	<1.4	27	160	0.34	32
CP-03D (2-3)	03/19/2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CP-03D (2-4)	03/19/2019	<0.5	0.24 j	160	1.2	<2.5	<0.13	4.1 j	4.2	5.8	19,000	420	<2	5.4	<1.3	13	260	0.45	46
CP-03D (4-6)	03/19/2019	<0.58	1.2	140	2.3	<2.9	0.031 j	7 j	25	15	25,000	380	<2.3	10	<1.5	12	<12	0.45	60
CP-03D (6-8)	03/19/2019	<0.56	2.1	70	2.3	<2.8	0.03 j	4.3 j	5.8	6.9	21,000	310	<2.3	2.6	<1.5	6.9	<12	0.29	41
CP-03D (8-10)	03/19/2019	<0.48	0.44 j	310	1.9	<4.8	0.05 j	4.1 j	74	12	34,000	720	<1.9	40	<1.3	16	230	0.72	75
GP-01D (0-5)	03/22/2019	<0.61	5.3	310	1.1	<6.1	<0.16	4.3 j	41	6.3	36,000	170	<2.4	24	1.2 j	130	**1,500**	0.4	84
GP-01D (2-3)	03/20/2019	NA	<0.6	200	NA	NA	NA	8.3 j	1.9	2.7	6,800	120	NA	2.6	0.6 j	NA	<13	0.18	NA
GP-01D (5-10)	03/22/2019	<0.69	0.37 j	330	2.1	<6.9	<0.18	6.7 j	76	18	52,000	400	<2.8	76	1.2 j	130	<13	0.65	97
GP-01D (10-15)	03/22/2019	<0.6	<0.62	970	1	<3	<0.16	5.9 j	130	18	38,000	390	<2.4	90	1.4 j	88	<13	0.77	16
GP-01D (15-20)	03/22/2019	<0.56	NA	NA	2.2	<8.4	<0.15	NA	NA	NA	NA	NA	<2.3	NA	NA	72	NA	NA	99
GP-01D (20-25)	03/22/2019	<0.62	0.56	300	3.4	<9.3	<0.16	3.5 j	110	45	33,000	880	<2.5	120	<1.5	390	<12 M	0.77	80
GP-01D (25-30)	03/22/2019	<0.56	0.33 j	400	2.3	<5.6	0.091 j	3.3 j	170	23	47,000	540	<2.2	120	<1.4	73	<11	0.82	79
GP-01D (30-35)	03/22/2019	<0.53	0.42 j	330	2.1	<7.9	0.04 j	2.9 j	160	16	49,000	330	<2.1	110	0.59 j	76	<13	0.65	82
GP-01D (35-40)	03/22/2019	<0.61	0.29 j	530	2.3	<9.1	<0.16	3.2 j	12	14	31,000	580	<2.4	16	0.87 j	75	<12	0.79	87
GP-01D (40-45)	03/22/2019	<0.49	0.47 j	210	3.5	<4.9	0.041 j	<12	53	7.9	21,000	430	<2	32	0.52 j	200	<12	0.41	87
GP-01D (45-50)	03/22/2019	<0.48	NA	NA	2.2	1.1 j	0.086 j	NA	NA	NA	NA	NA	<1.9	NA	NA	120	NA	NA	56
GP-01D (47-49)	03/22/2019	NA	1.6	460	NA	NA	NA	14 j	16	8.5	46,000	420	NA	14	1.4 j	NA	300	0.72	NA
GP-02D (0-5)	03/29/2019	<0.6	0.89	100	1.1	<9	<0.16	3.3 j	18	4	39,000	250	<2.4	11	0.81 j	28	390	0.34	91
GP-02D (5-10)	03/29/2019	<0.57	<0.59	590	1.7	<5.7	<0.15	7 j	46	11	30,000	750	<2.3	34	<1.5	130	270	0.73	90
GP-02D (15-20)	03/29/2019	<0.59	<0.49	240	3.4	<5.9	0.086 j	<12	8.3	2.6	13,000	500	<2.4	4.7	0.68 j	280	110	0.33	66
GP-02D (20-25)	03/29/2019	<0.49	0.61	280	1.6	1.4 j	0.033 j	9.4 j	13	8.8	39,000	520	<2	10	1.2 j	150	11 j	0.53	24

TABLE 6-3
SUMMARY OF UNSATURATED SOIL SAMPLE ANALYTICAL RESULTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium*	Cobalt	Iron	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Vanadium
Reporting Units		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PSRG Protection of Groundwater		**0.9**	5.8	580	**63**	**45**	**3**	**938** [1]	3.8	0.9	150	65	**7.1**	130	2.1	**1500**	**1438** [1]	0.28	**350**
2017 Background Threshold Values[1]		0.65	4.7	819	3.9	8.7	0.11	13	32.8	53	78,228	2,872	3.5	18.6	1.77	7.53	36	1.1	210
2019 Background Threshold Values[2]		0.64	**8.2**	**1,063**	3.9	15	0.72	293	**406**	**63**	**78,228**	**3,388**	3.5	**237**	**3.7**	200	293	**2.1**	210
Sample ID	**Sample Collection Date**	**Analytical Results**																	
GP-03D (0-5)	03/25/2019	<0.56 M	0.28 j	320	1.4	<5.9	<0.14	2.8 j	4.6 B	7	36,000 B,M	470	<2.4	3.9	1.6	75	110 M	0.75	76
GP-03D (2-3)	03/25/2019	NA	<0.64	**1100**	NA	NA	NA	6.6 j	57 B	39	23,000 B	1,100	NA	50	2.8	NA	860	0.71	NA
GP-03D (5-10)	03/25/2019	<0.62	0.8	720	2.3	4 j	<0.16	9.1 j	62 B	**140**	28,000 B	**4,300**	<2.5	58	1.5 j	30	670	1.9	120
GP-03D (10-15)	03/25/2019	<0.64	0.99	320	3.1	<3.2	0.049 j	6.9 j	180 B	16	38,000 B	610	<2.6	49	1.7	320	680	0.44	56
GP-03D (15-20)	03/25/2019	<0.6	NA	NA	2.5	<3	0.25	NA	NA	NA	NA	NA	<2.4	NA	NA	180	NA	NA	71
GP-03D (20-25)	03/25/2019	<0.57	<0.62	450	2.9	2.6 j	0.053 j	6.1 j	290 B	23	65,000 B	480	<2.3	160	3.4	110	670	0.96	64
GWA-01BR (8-10)	06/26/2015	<5.7	NA	NA	1.9	<14.3	<0.69	NA	NA	NA	NA	NA	<2.9	NA	NA	19.8	NA	NA	30.4
GWA-01BR (14-15.5)	06/26/2015	NA	<6.2	118	NA	NA	NA	<297	13.4	7.1	18,100	192	NA	9.5	<6.2	NA	<297	<6.2	NA
GWA-01BR (18-20)	06/26/2015	<6.2	<5.7	128	1.4	<15.5	<0.74	<302	6	9.1	16,000	529	<3.1	5.3	<5.7	12.2	<302	<5.7	46.7
GWA-07 (0.5-1)	04/12/2019	<0.43	0.76	99	0.68	<2.1	<0.11	<11	51	11	13,000	550	<1.7	24	0.49 j	28	<11	0.21	30
GWA-07 (2-3)	04/12/2019	<0.51	2	140	0.8	<2.5	<0.13	<12	92	13	22,000	500	<2	41	0.49 j	46	41	0.37	52
ILF-01BR (0-5)	03/13/2019	<0.63 M	1.9	150	2	3.3	<0.16	8.7 j	22	6.6	28,000 M	220	0.68 j	11	0.62 j,M	64 M	49	0.41	70
ILF-01BR (5-10)	03/13/2019	<0.56	<0.47	82	1.2	2.7 j	<0.15	1.9 j	2	3.7	14,000	460	0.59 j	1.3 j	<1.2	22	<11	0.26	50
ILF-01BR (10-15)	03/13/2019	<0.47	<0.47	100	1.1	<2.3	<0.12	3 j	2.1	3.8	16,000	360	<1.9	1.4 j	<1.2	27	<11	0.31	23
ILF-01BR (15-20)	03/13/2019	<0.47	0.5	140	0.91	0.96 j	0.028 j	2.1 j	12	4	19,000	400	<1.9	5.5	<1.3	25	<11	0.38	26
ILF-01BR (20-25)	03/13/2019	<0.49	0.23 j	220	0.85	1.1 j	0.024 j	3.3 j	11	6.5	22,000	380	<2	5.2	<1.3	33	<11	0.47	32
ILF-01BR (25-30)	03/13/2019	<0.49	0.47	300	0.53	1.4 j	0.065 j	2.5 j	17	9.7	32,000	420	<1.9	7.8	<1.2	33	<11	0.55	56
ILF-01BR (30-35)	03/13/2019	<0.47	0.66	160	0.77	<4.7	0.041 j	5.7 j	12	6.1	23,000	380	<1.9	7.3	<1.5	63	6.3 j	0.36	71
ILF-02D (7-10)	03/31/2019	<0.59	<0.58	340	1.5	<5.9	<0.15	5.3 j	21	14	38,000	760	<2.4	8.3	0.61 j	22	<13	0.91	72
ILF-02D (10-15)	03/31/2019	<0.58	0.3 j	370	1.6	<5.8	0.049 j	6.3 j	20	12	29,000	590	<2.3	14	<1.6	20	<13	0.61	76
ILF-02D (15-20)	03/31/2019	<0.63	<0.53	310	1.1	2.9 j	<0.16	3.2 j	15	8.1	29,000	460	<2.5	6.7	0.52 j	25	<11	0.77	67
ILF-02D (20-25)	03/31/2019	<0.53	0.46 j	180	1.6	<7.9	0.026 j	<12	13	8	30,000	620	<2.1	5	<1.4	26	<12	0.32	66
ILF-02D (25-30)	03/31/2019	<0.55	<0.58	320	2.4	<8.2	0.1 j	3.2 j	18	9.8	34,000	510	<2.2	7.3	<1.5	44	<12	0.63	62
ILF-02D (30-35)	03/31/2019	<0.58	<0.55	290	2.1	<5.8	0.056 j	2.9 j	16	8.1	28,000	490	<2.3	6.3	<1.4	44	<12	0.56	67
ILF-02D (35-40)	03/31/2019	<0.55	<0.59	280	2.3	<5.5	0.14	6.7 j	21	9.7	34,000	530	<2.2	8.9	0.66 j	39	<13	0.85	62
MW-05 (0.5-1)	04/12/2019	<0.59	3.1	160	1.6	<8.8	<0.15	3.3 j	22	8.3	38,000	150	<2.4	15	0.75 j	120	100	0.42	79
MW-05 (2-3)	04/12/2019	<0.49	1.5	170	1.4	<7.4	<0.13	11 j	12	6.3	32,000	220	<2	9.3	0.64 j	120	<13 M	0.41	50
MW-10 (0.5-1)	04/12/2019	<0.6	1.7	88	1.3	<6	<0.16	2.8 j	110	6	35,000	190	<2.4	79	0.98 j	9.5	56	0.45	68
MW-10 (2-3)	04/12/2019	<0.63 M	0.91 M	150	1.3	<5.7	<0.16	14	61	6.4	33,000 M	360 M	<2.3 M	48	0.79 j	6.9	<13	0.65	64 M
MW-14BR (31.5-33)	07/10/2015	<6.5	<6.5	828	6.3	<3.3	<0.78	<329	61.9	16.8	50,400	421	3	45.2	<6.5	19.1	<329	<6.5	128
PVSF-01BR (2-4)	03/18/2019	<0.46	0.53 j	630	1.3	<6.9	<0.12	3.2 j	3.7	17	42,000	650	<1.8	5.7	<1.4	450	130	0.68	86
PVSF-01BR (4-6)	03/18/2019	<0.46	0.7	530	1	<6.9	<0.12	3.8 j	8.6	11	53,000	490	<1.8	7.4	<1.4	120	150	0.66	94
PVSF-01BR (8-10)	03/18/2019	<0.64 M	0.67	570	1.2	<5.1	<0.17	5.9 j	2	13	50,000	530	<2.1	4.5	0.49 j	310 M	85 M	0.6	69
PVSF-01BR (10-12)	03/18/2019	<0.55	0.39 j	730	1	<8.3	0.041 j	5.7 j	6.1	11	39,000	440	<2.2	6.5	<1.3	290	<12	0.5	93
PVSF-01BR (12-14)	03/18/2019	<0.55	0.37 j	740	1.3	<8.2	<0.14	4.5 j	4.3	21	35,000	710	<2.2	5.5	0.51 j	160	<11 M	0.55	120
PVSF-01BR (14-16)	03/18/2019	<0.49	0.44 j	500	1.2	<7.4	<0.13	6.7 j	1.8	13	43,000	520	<2	3.7	<1.3	230	<12	0.7	110
PVSF-01BR (16-18)	03/18/2019	<0.5	0.52	590	2	<5	<0.13	5.3 j	4.1	15	44,000	580	<2	5	<1.1	260	<12	0.61	96
PVSF-01BR (18-20)	03/18/2019	<0.45	1.4	630	1.9	<4.5	0.041 j	3.6 j	10	6.5	45,000	360	<1.8	12	0.72 j	290	330	0.5	75
PVSF-01BR (20-22)	03/18/2019	<0.5	0.48	690	1.6	<7.5	<0.13	5.5 j	1.9	58	37,000	2,500	<2	3.4	<1.2	70	<11 M	0.72	92
PVSF-01BR (22-24)	03/18/2019	<0.43	0.37 j	780	1.7	<6.4	0.027 j	8.6 j	2.9	14	40,000	530	<1.7	4	<1.3	160	<13	0.6	92
PVSF-01BR (24-26)	03/18/2019	<0.47	0.56	680	1.9	<7.1	0.031 j	5.8 j	1.6	42	53,000	1,900	0.52 j	8.1	<1.2	260	<11	1.1	80

TABLE 6-3
SUMMARY OF UNSATURATED SOIL SAMPLE ANALYTICAL RESULTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium*	Cobalt	Iron	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Vanadium
Reporting Units		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PSRG Protection of Groundwater		**0.9**	5.8	580	**63**	**45**	**3**	**938** [1]	3.8	0.9	150	65	**7.1**	130	2.1	**1500**	**1438** [1]	0.28	**350**
2017 Background Threshold Values[1]		0.65	4.7	819	3.9	8.7	0.11	13	32.8	53	78,228	2,872	3.5	18.6	1.77	7.53	36	1.1	210
2019 Background Threshold Values[2]		0.64	**8.2**	**1,063**	3.9	15	0.72	293	**406**	**63**	**78,228**	**3,388**	3.5	**237**	**3.7**	200	293	**2.1**	210
Sample ID	**Sample Collection Date**	**Analytical Results**																	
PVSF-01BR (26-28)	03/18/2019	<0.49	0.33 j	520	1.7	<7.4	0.025 j	6.1 j	4.7	9.7	41,000	470	<2	3.5	<1.4	350	<13	0.5	89
PVSF-01BR (28-30)	03/18/2019	<0.47	0.51	570	1.6	<12	0.12	5.2 j	5	11	41,000	510	0.6 j	4.1	<1.2	160	<11 M	0.49	100
PVSF-01BR (30-32)	03/18/2019	<0.52	0.52	520	1.6	<5.2	<0.14	3.9 j	2.6	12	41,000	610	<2.1	3.5	<1.1	170	<11	0.55	85
PVSF-01BR (32-34)	03/18/2019	<0.46	0.79	420	1.6	<6.8	0.024 j	11 j	6.1	8.7	48,000	390	<1.8	7.5	0.49 j	200	<12	0.57	82
PVSF-01BR (34-36)	03/18/2019	<0.44	4.9	560	1.5	<6.6	0.047 j	7.6 j	3.8	6.6	35,000 M	320 M	<1.8	5.1	1 j	160	150	0.45	84
PVSF-03BR (0-2)	03/26/2019	<0.64	2.9	64	1.2	5.9 j	0.039 j	NA	47	5.6	67,000	130	2.7	21	1.1 j	3.1	130	0.35	180
PVSF-03BR (2-3)	03/26/2019	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PVSF-03BR (2-4)	03/26/2019	<0.7	1.3	83	1.2	5.5 j	0.036 j	NA	35	7	**79,000**	350	0.7 j	18	0.93 j	1.1 j	11 j	0.25	180
PVSF-03BR (4-6)	03/26/2019	<0.66	0.95	73	1.1	5.6 j	0.049 j	NA	37	9.3	76,000	290	<2.6	18	0.69 j	0.61 j	<15	0.16 j	190
PVSF-03BR (6-8)	03/26/2019	<0.74	0.56 j	63	1.2	<18	0.08 j	NA	38	20	**85,000**	600	<2.9	16	<1.9	0.38 j	9.4 j	0.1 j	190
PVSF-03BR (8-10)	03/26/2019	<0.75	0.54 j	66	1.3	4.4 j	0.096 j	NA	32	29	67,000	850	<3	17	<1.9	<1.5	12 j	0.095 j	180
PVSF-04D (2-3)	07/24/2019	<0.57	0.79	190	1.2	<8.7	<0.15	2.7 j	62	5	53,000	68	1 j	23	0.61 j	2.7	<12 M	0.9	81
PVSF-04D (7-8)	07/24/2019	<0.58	0.27 j	440	3	<12	0.047 j	6.6 j	59	12	54,000	390	4.3	41	0.77 j	3.8	<12	1.1	130
PVSF-04D (12-13)	07/24/2019	<0.58	0.91	350	2.3	<6.1	0.034 j	4.5 j	60	14	52,000	320	2.3 j	27	<1.5	7.4	6.6 j	1.2	90
PVSF-04S (15-16)	07/24/2019	<0.55	0.34 j	130	1.1	<2.4	<0.14	<12	4.8	3.6	11,000	230	0.54 j	4.9	<1.4	46	75	0.42	20
SS-01 (0.5-1)	04/16/2019	<0.5 M	0.5	340	2.6	<5.6	0.036 j	5.3 j	27	9	36,000 M	510 M	<2.3	17	1.3	120	63	0.5	81
SS-01 (2-3)	04/16/2019	<0.6 M	0.32 j,M	310	1.9	<4.8	0.041 j	16	11	23 M	36,000 M	570 M	<1.9 M	11	0.62 j	86	480	0.58	78 M

Prepared by: BDW/ECW Checked by: KHG

Prepared by: BDW/ECW Checked by: KHG

Notes:

[1] - Background threshold values were calculated using data from background unsaturated soil samples collected May 2015 to March 2017.

[2] - Background threshold values were calculated using data from background unsaturated soil samples collected May 2015 to August 2018.

[3] - The PSRG POG displayed was calculated in accordance with **Table 6-2** presented in the CAP Update Report text.

- bold highlighted concentration indicates value is greater than applicable regulatory standard (PSRG POG)

- bold highlighted concentration indicates value is greater than greatest background threshold value where there is no regulatory standard, or background threshold values are greater than regulatory standard

- highlighted concentration indicates value is either within range of background threshold values for constituents where there is no regulatory standard/background threshold values are greater than regulatory standard, or within range of background threshold value and the regulatory standard

PSRG - Preliminary Soil Remediation Goals for the Protection of Groundwater (POG); NCDEQ Inactive Hazardous Sites Branch (IHSB) Preliminary Soil Remediation Goals Table (February 2018)

* - North Carolina PSRG POG is for hexavalent chromium, soil analytical is for total chromium.

< - Concentration not detected at or above the adjusted reporting limit.

mg/kg - milligrams per kilogram

~~<7.9~~ - Strike-through indicates that the non-detect was omitted from the dataset because the reporting limit for the non-detect was greater than the protection of groundwater preliminary soil remediation goal.

B - Target analyte detected in method blank at or above the reporting limit. Target analyte concentration in sample is less than 10X the concentration in the method blank. Analyte concentration in sample could be due to blank contamination.

j - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

j- - Estimated concentration, biased low.

j+ - Estimated concentration, biased high.

M - Matrix spike / matrix spike dup failure.

TABLE 6-4
SOURCE AREA INTERIM ACTIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Groundwater Remedy Component	Rationale
Ash Basin Decanting	Active source remediation by removing ponded water in the ash basin. Decanting will lower the hydraulic head within the coal ash basin and reduce hydraulic gradients, reducing groundwater seepage velocities and COI transport potential. Decanting will return the groundwater flow system to its approximate natural condition, flowing toward the axis of the perennial stream valley, then east.
Permanent Water Supply Solution for Water Well Users	Groundwater data at the Site indicates that surrounding water supply wells are not affected by Site-related COIs. However, Duke Energy installed 62 connections to public water supply and maintains 3 water filtration systems for qualifying occupied households. Six additional properties, including businesses and churches, within a 0.5-mile radius of the MSS compliance boundary were also provided permanent water solutions by Duke Energy, although they did not meet the eligibility requirements outlined in G.S. Section 130A-309.211(c1). Duke Energy's actions were approved by NCDEQ, which addresses stakeholder concerns.
Source Area Stabilization	Dam modifications include tree removal, installation of an aggregate seepage collection and filter overlay system, and installation of flumes, riprap channels, and storm water culverts, riprap lined ditches, seepage collection berm and a concrete ditch.

Prepared by: WCG Checked by: ECW

Notes:

COI – Constituent of Interest

NCDEQ - North Carolina Department of Environmental Quality

TABLE 6-5
MEANS OF GROUNDWATER COIs - FEBRUARY 2018 TO MAY 2019
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L
15A NCAC 02L Standard		1*	10	700	4*	700	2	250	10	10	1*	300	NE	50	NE	100	20	NE	250	0.2*	500	5^	0.3*
2018 Background Threshold Values (Shallow Flow Zone)[1]		0.5	0.4	310	0.2	50	0.08	5.5	5.7	16.5	1.2	744	---	75.3	0.5	9.9	1	303	4.2	0.1	140	3.0	5.6
2019 Background Threshold Values (Shallow Flow Zone)[2]		0.79	1	580	0.223	50	1.0	5.0	7.0	16.8	5.0	1095	4.8	155	1.0	19.6	1.0	210	11.3	0.2	152.4	5.33	13.0
Background Data Set Range (Shallow Flow Zone)[2]		0.1 j - 1.12	0.043 j - 1.7	22.2 - 730	0.012 j - 0.61	3.3 - 56.7	0.052 j - 0.101	0.92 - 5.4	0.076 j - 7.1	0.1 j - 39.2	0.041 j - 5.2	28 - 3440	0.19 j - 5.6	1.46 j - 390	0.076 j - 1.4	0.28 j - 21.9	0.092 - 0.72	9 - 223	0.0447 j - 12.8	0.015 j - 0.024	10 - 144	0.049 - 6.73	0.077 j - 15.4
2018 Background Threshold Values (Deep Flow Zone)[1]		0.5	0.6	127	0.1	50	0.08	4.7	3	7.6	1.9	272	---	141	3.2	7.5	1	665	17.7	0.1	183	2.8	3.8
2019 Background Threshold Values (Deep Flow Zone)[2]		0.62	1.4	138	0.2	50	0.08	4.2	6.0	4.3	3.2	225	10.0	142	7.3	7.8	2.4	727	24.2	0.1	200	7.46	3.9
Background Data Set Range (Deep Flow Zone)[2]		0.14 j - 1.3	0.088 j - 1.9	15.1 - 146	0.012 j - 0.095 j	2.3 j - 43 j	0.03 j - 0.054 j	1.2 - 4.8	0.01 j - 2.7	0.15 j - 3.1	0.013 j - 3.3	30.4 j - 310	2.5 - 10.9	7.4 - 154	0.19 j - 10.5	0.13 j - 7.9	0.17 j - 2.9	81.4 - 732	2.3 - 35.4	0.018 j - 0.054 j	41 - 202	0.2587 - 11.14	0.74 - 4
2018 Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0
2019 Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	840	1.0	50	1.0	3.6	8.1	11.2	2.6	1,220	11.4	330	3.7	8.0	1.0	313	22.1	0.2	195	6.43	25.8
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6
Sample ID	Flow Zone	Analytical Results																					
Background Locations																							
BG-01S	Shallow	< 0.5	0.10	48	< 0.1	< 50	< 0.08	3.0	3.3	4.3	0.20	324	< 0.5	7.5	< 0.5	3.8	< 0.5	111	8.3	< 0.1	88	0.51	0.88
BG-01D	Deep	< 0.5	0.16	132	< 0.1	< 50	< 0.08	3.1	2.7	2.8	0.20	81	10.0	11	< 0.5	5.0	2.3	689	9.1	< 0.1	137	2.3	3.5
BG-01BRA	Bedrock	< 0.5	0.18	441	< 0.1	< 50	< 0.08	2.4	2.4	2.9	0.26	110	6.6	22	0.59	2.3	< 0.5	197	2.1	< 0.1	146	2.3	18
BG-02S	Shallow	< 0.5	0.14	294	< 0.1	< 50	< 0.08	1.7	4.7	5.6	0.10	407	4.5	5.5	< 0.5	3.9	< 0.5	179	5.8	< 0.1	115	1.2	8.3
BG-02BR	Bedrock	< 0.5	0.17	468	< 0.1	< 50	< 0.08	2.4	7.9	7.1	< 0.1	< 50	8.3	< 5	< 0.5	1.0	< 0.5	239	2.9	< 0.1	153	5.1	14
BG-03S	Shallow	< 0.5	0.23	426	< 0.1	< 50	< 0.08	1.8	5.9	8.9	0.25	414	4.3	6.7	< 0.5	11	< 0.5	126	8.5	< 0.1	122	0.85	6.3
BG-03D	Bedrock	< 0.5	0.38	788	< 0.1	< 50	< 0.08	2.6	5.3	5.1	< 0.1	52	7.3	< 5	< 0.5	4.7	< 0.5	156	11	< 0.1	181	0.99	25
BG-03BR	Bedrock	< 0.5	0.46	65	< 0.1	< 50	0.08	2.5	3.8	5.7	0.41	620	10	11	1.8	5.2	< 0.5	180	11	< 0.1	181	1.4	16
GWA-04D	Deep	< 0.5	0.81	27	< 0.1	< 50	< 0.08	3.3	0.10	0.57	< 0.1	51	3.7	66	4.3	0.59	< 0.5	139	7.8	< 0.1	179	1.2	1.3
GWA-04S	Shallow	< 0.5	0.13	33	< 0.1	< 50	< 0.08	3.6	0.93	2.0	0.15	394	0.86	12	< 0.5	1.0	< 0.5	40	< 1	< 0.1	61	0.55	0.50
GWA-05D	Deep	< 0.5	0.12	17	< 0.1	< 50	< 0.08	1.5	0.42	0.57	< 0.1	< 50	3.0	< 5	< 0.5	< 0.5	< 0.5	84	2.6	< 0.1	66	1.1	1.5
GWA-06D	Bedrock	< 0.5	0.17	25	< 0.1	56	< 0.08	2.9	0.66	0.94	0.54	116	6.1	24	0.73	0.89	< 0.5	234	7.6	< 0.1	104	0.38	1.5
GWA-06S	Shallow	< 0.5	0.23	62	0.12	51	< 0.08	2.9	0.45	1.1	< 0.1	393	0.63	11	< 0.5	1.0	< 0.5	56	< 1	< 0.1	54	0.77	0.54
GWA-08D	Bedrock	< 0.5	0.22	31	< 0.1	< 50	< 0.08	2.7	0.42	0.88	< 0.1	190	5.7	11	< 0.5	0.54	< 0.5	176	< 1	< 0.1	83	-	3.4
GWA-08S	Shallow	< 0.5	0.11	27	< 0.1	< 50	< 0.08	4.7	1.0	4.6	0.14	268	3.1	7.6	< 0.5	1.2	0.57	203	3.4	< 0.1	77	-	3.5
GWA-12BR	Bedrock	< 0.5	0.34	29	< 0.1	< 50	< 0.08	1.5	0.04	< 0.5	1.2	328	9.1	250	2.2	2.0	< 0.5	180	21	< 0.1	112	1.4	< 0.3
GWA-12S	Shallow	< 0.5	0.11	44	< 0.1	< 50	< 0.08	2.6	0.58	0.83	0.35	73	0.59	16	< 0.5	1.2	< 0.5	10	3.9	< 0.1	30	1.1	< 0.3
MS-10	Shallow	< 0.5	< 0.1	111	0.22	< 50	< 0.08	1.2	0.70	1.0	0.62	236	2.3	22	< 0.5	1.4	< 0.5	16	< 1	< 0.1	28	1.5	0.54
MW-04	Shallow	< 0.5	0.15	52	< 0.1	< 50	< 0.08	1.9	1.6	2.3	< 0.1	73	0.86	< 5	< 0.5	0.8	< 0.5	103	< 1	< 0.1	55	0.88	1.1
MW-04D	Bedrock	< 0.5	0.13	41	< 0.1	< 50	< 0.08	1.4	0.38	0.54	< 0.1	58	4.3	< 5	< 0.5	< 0.5	< 0.5	195	1.3	< 0.1	84	0.79	2.6
Shallow Flow Zone																							
AB-01S	Shallow	< 0.5	1.9	58	0.72	3978	0.28	169	0.06	0.92	14	715	1.4	2819	0.64	1.5	1.7	711	106	0.34	556	3.1	1.6
AB-02S	Shallow	< 0.5	0.18	33	< 0.1	< 50	< 0.08	3.1	0.03	0.96	16	1298	< 0.5	845	< 0.5	0.96	< 0.5	12	3.0	0.19	36	1.0	< 0.3
AB-05DU	Shallow	< 0.5	0.29	302	< 0.1	40	0.20	3.9	< 0.025	0.63	44	2765	9.9	4220	0.24	13	< 0.5	1595	52	< 0.1	248	1.4	1.5
AB-07DU	Shallow	< 0.5	1.3	166	0.06	107	< 0.08	2.8	< 0.025	2.7	8.5	3088	5.1	397	0.81	11	< 0.5	916	14	< 0.1	169	0.91	1.3
AB-08DU	Shallow	< 0.5	0.37	190	< 0.1	78	< 0.08	3.9	0.06	1.4	2.6	1156	3.4	466	0.51	9.4	< 0.5	1223	68	< 0.1	219	0.77	0.34
AB-09S	Shallow	< 0.5	0.50	37	< 0.1	48	< 0.08	1.7	0.50	4.7	1.1	1095	< 0.5	143	< 0.5	4.4	< 0.5	72	11	0.14	78	-	1.2
AB-11S	Shallow	< 0.5	0.24	12	< 0.1	< 50	< 0.08	1.9	0.34	0.64	0.66	166	0.97	62	< 0.5	< 0.5	< 0.5	43	< 1	< 0.1	35	-	0.58
AB-14DU	Shallow	< 0.5	0.19	118	< 0.1	95	< 0.08	1.8	0.97	3.1	1.2	178	2.3	214	0.49	1.3	< 0.5	281	17	< 0.1	109	0.47	1.8
AB-16DU	Shallow	< 0.5	0.75	182	< 0.1	< 50	< 0.08	8.2	0.03	1.1	15	1211	5.4	623	2.0	7.3	< 0.5	776	18	< 0.1	232	0.64	1.5
AB-16S	Shallow	< 0.5	7.4	107	< 0.1	99	< 0.08	2.3	0.03	0.54	18	60900	0.55	1940	0.53	3.7	0.57	302.5	21	< 0.1	179	-	0.74
AL-01S	Shallow	< 0.5	1.2	83	4.6	3978	0.45	190	0.16	3.3	6.0	374	7.1	1796	< 0.5	2.7	1.4	2182	94	0.20	511	2.3	0.39
AL-02S	Shallow	< 0.5	0.30	40	1.0	12633	0.91	1.9	1.1	2.5	0.29	124	5.6	282	0.51	19	87	5530	1433	< 0.1	2422	-	0.87
CCR-01S	Shallow	< 0.5	0.18	99	0.35	< 25	< 0.08	4.0	< 0.025	< 0.5	2.9	81	< 2.5	382	< 0.5	1.3	< 0.5	125	0.87	< 0.1	81	0.85	1.2
CCR-02S	Shallow	< 0.5	0.12	68	0.13	125	0.09	6.3	0.05	< 0.5	8.2	43	< 2.5	684	< 0.5	1.2	< 0.5	59	9.4	0.11	62	0.93	0.87
CCR-03S	Shallow	< 0.5	0.11	32	0.13	< 50	0.09	3.1	0.37	0.70	0.21	25	< 2.5	1.2	< 0.5	< 0.5	< 0.5	543	< 1	< 0.1	39	0.79	0.73
CCR-04S	Shallow	< 0.5	0.74	88	0.74	287	0.65	9.3	-	< 0.5	116	-	1.6	-	< 0.5	-	0.52	-	136	0.70	277	1.5	-
CCR-05S	Shallow	< 0.5	0.66	110	0.06	177	< 0.08	12	-	< 0.5	0.92	-	0.44	-	0.31	-	< 0.5	-	80	< 0.1	284	1.5	-
CCR-09S	Shallow	0.52	1.0	129	2.2	3805	0.70	174	1.4	3.0	111	68	6.8	3835	< 0.5	3.7	1.2	116	88	0.27	464	1.2	< 0.3
CCR-11S	Shallow	< 0.5	2.5	49	1.1	5037	0.17	201	-	0.88	62	-	6.9	-	< 0.5	-	1.5	-	98	3.0	343	2.4	-
CCR-12S	Shallow	< 0.5	1.2	965	5.0	3897	0.89	226	-	1.3	83	-	1.7	-	< 0.5	-	0.61	-	24	0.70	476	7.6	-
CCR-13S	Shallow	< 0.5	50	109	< 0.1	3263	< 0.08	136	< 0.025	0.72	9.8	7050	37	2910	42	2.7	< 0.5	2040	167	0.37	824	1.9	< 0.3
CCR-14S	Shallow	< 0.5	0.64	499	0.89	3780	0.18	235	-	1.1	9.9	-	0.71	-	< 0.5	-	< 0.5	-	59	0.15	491	5.8	-
CCR-15S	Shallow	< 0.5	0.16	12	0.16	5.6	< 0.08	1.8	-	2.4	0.38	-	0.43	-	< 0.5	-	< 0.5	-	0.87	< 0.1	36	0.63	-
CCR-16S	Shallow	< 0.5	0.19	45	0.15	10	< 0.08	4.3	-	1.3	0.63	-	0.73	-	< 0.5	-	0.60	-	20	< 0.1	78	0.44	-
CP-01S	Shallow	0.11	3.2	30	5.4	218	0.86	11	0.07	0.58	274	69167	8.9	4383	< 0.5	56	2.8	514	304	1.3	638	0.80	0.50
CP-02S	Shallow	< 0.5	0.16	21	< 0.1	< 50	< 0.08	2.9	0.05	< 0.5	27	12313	< 2.5	1877	1.5	2.0	< 0.5	65	1.5	0.06	277	0.94	0.31
CP-03S	Shallow	< 0.5	0.11	93	0.10	111	< 0.08	12	0.45	2.2	0.51	73	2.7	91	0.44	1.9	0.38	97	39	< 0.1	135	0.73	0.24
GP-01S	Shallow	0.18	0.20	80	0.07	< 50	< 0.08	1.9	0.64	5.3	0.94	128	< 2.5	94	0.66	9.5	< 0.5	223	5.5	< 0.1	95	1.1	1.8
GP-02S	Shallow	< 0.5	0.12	124	0.10	< 50	< 0.08	1.8	1.9	2.7	0.89	263	< 2.5	54	0.21	0.93	0.97	609	19	< 0.1	111	1.7	0.77
GP-03S	Shallow	< 0.5	0.08	49	< 0.1	< 50	< 0.08	2.9	0.04	< 0.5	0.48	< 50	< 2.5	52	0.53	0.74	< 0.5	106	2.3	< 0.1	66	1.0	0.45
GWA-01S	Shallow	0.52	< 0.1	49	0.71	< 50	< 0.08	2.9	0.48	0.89	0.54	116	1.3	16	< 0.5	0.62	1.5	33	9.4	< 0.1	60	0.88	0.41
GWA-02S	Shallow	< 0.5	0.15	68	0.18	< 50	0.08	1.5	2.5	3.5	0.58	78	< 2.5	44	< 0.5	1.3	0.90	29	34	0.11	111	0.52	0.33
GWA-03S	Shallow	< 0.5	< 0.1	32	0.10	< 50	< 0.08	2.1	0.31	0.53	< 0.1	147	1.6	12	< 0.5	< 0.5	< 0.5	41	0.85	< 0.1	67	-	0.63

TABLE 6-5
MEANS OF GROUNDWATER COIs - FEBRUARY 2018 TO MAY 2019
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L
15A NCAC 02L Standard		1*	10	700	4*	700	2	250	10	10	1*	300	NE	50	NE	100	20	NE	250	0.2*	500	5^	0.3*
2018 Background Threshold Values (Shallow Flow Zone)[1]		0.5	0.4	310	0.2	50	0.08	5.5	5.7	16.5	1.2	744	---	75.3	0.5	9.9	1	303	4.2	0.1	140	3.0	5.6
2019 Background Threshold Values (Shallow Flow Zone)[2]		0.79	1	580	0.223	50	1.0	5.0	7.0	16.8	5.0	1095	4.8	155	1.0	19.6	1.0	210	11.3	0.2	152.4	5.33	13.0
Background Data Set Range (Shallow Flow Zone)[2]		0.1 j - 1.12	0.043 j - 1.7	22.2 - 730	0.012 j - 0.61	3.3 - 56.7	0.052 j - 0.101	0.92 - 5.4	0.076 j - 7.1	0.1 j - 39.2	0.041 j - 5.2	28 - 3440	0.19 j - 5.6	1.46 j - 390	0.076 j - 1.4	0.28 j - 21.9	0.092 - 0.72	9 - 223	0.0447 j - 12.8	0.015 j - 0.024	10 - 144	0.049 - 6.73	0.077 j - 15.4
2018 Background Threshold Values (Deep Flow Zone)[1]		0.5	0.6	127	0.1	50	0.08	4.7	3	7.6	1.9	272	---	141	3.2	7.5	1	665	17.7	0.1	183	2.8	3.8
2019 Background Threshold Values (Deep Flow Zone)[2]		0.62	1.4	138	0.2	50	0.08	4.2	6.0	4.3	3.2	225	10.0	142	7.3	7.8	2.4	727	24.2	0.1	200	7.46	3.9
Background Data Set Range (Deep Flow Zone)[2]		0.14 j - 1.3	0.088 j - 1.9	15.1 - 146	0.012 j - 0.095 j	2.3 j - 43 j	0.03 j - 0.054 j	1.2 - 4.8	0.01 j - 2.7	0.15 j - 3.1	0.013 j - 3.3	30.4 j - 310	2.5 - 10.9	7.4 - 154	0.19 j - 10.5	0.13 j - 7.9	0.17 j - 2.9	81.4 - 732	2.3 - 35.4	0.018 j - 0.054 j	41 - 202	0.2587 - 11.14	0.74 - 4
2018 Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0
2019 Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	840	1.0	50	1.0	3.6	8.1	11.2	2.6	1,220	11.4	330	3.7	8.0	1.0	313	22.1	0.2	195	6.43	25.8
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6
Sample ID	Flow Zone	Analytical Results																					
GWA-07S	Shallow	< 0.5	0.17	226	< 0.1	< 50	< 0.08	3.9	1.0	3.6	8.1	823	5.1	271	0.99	6.0	< 0.5	197	11	< 0.1	123	-	0.46
GWA-10S	Shallow	< 0.5	0.27	58	0.12	93	< 0.08	1.6	1.5	2.4	0.17	499	< 2.5	41	< 0.5	4.5	2.0	777	57	< 0.1	153	-	3.0
GWA-11S	Shallow	< 0.5	0.16	53	0.17	2746	0.24	6.0	0.21	0.65	0.26	305	2.1	18	0.88	1.5	21	1064	265	< 0.1	498	0.65	0.36
GWA-13S	Shallow	< 0.5	0.12	89	< 0.1	< 50	< 0.08	3.2	0.88	1.5	0.16	136	1.7	42	< 0.5	3.0	< 0.5	8.2	1.9	< 0.1	38	-	0.35
GWA-14S	Shallow	< 0.5	0.19	37	< 0.1	< 50	< 0.08	1.2	0.37	0.73	0.20	157	1.5	54	1.0	0.56	< 0.5	14	< 1	< 0.1	27	-	< 0.3
GWA-15S	Shallow	< 0.5	0.13	154	0.16	1660	0.29	155	0.16	0.70	1.6	397	5.8	698	< 0.5	2.0	6.3	1687	87	< 0.1	488	2.4	0.36
ILF-01S	Shallow	< 0.5	0.22	87	< 0.1	26	< 0.08	30	0.09	0.74	1.4	250	5.6	408	4.3	4.5	0.68	632	48	< 0.1	209	1.4	1.1
ILF-02S	Shallow	0.30	0.08	58	< 0.1	< 50	< 0.08	1.8	0.45	1.9	0.33	74	1.5	51	0.36	2.9	< 0.5	73	1.0	< 0.1	96	0.13	0.91
MS-08	Shallow	< 0.5	0.11	38	0.14	< 50	< 0.08	1.1	3.1	5.2	0.33	801	1.3	9.3	< 0.5	2.0	< 0.5	94	< 1	< 0.1	54	-	4.9
MS-09	Shallow	0.18	0.15	40	2.8	< 50	-	1.2	-	2.2	3.1	185	-	37	-	3.2	-	-	0.32	0.08	69	-	2.7
MS-11	Shallow	< 0.5	0.10	83	< 0.1	< 50	< 0.08	4.4	0.47	2.8	0.28	372	0.74	16	< 0.5	1.5	< 0.5	80	1.1	< 0.1	42	-	0.41
MS-12	Shallow	-	-	74	-	< 50	-	3.2	-	0.90	1.2	117	-	18	-	0.75	-	-	0.5	0.08	32	-	0.62
MS-13	Shallow	< 0.5	0.09	97	0.27	< 50	< 0.08	2.5	0.22	0.67	0.13	< 50	0.94	12	< 0.5	0.66	< 0.5	376	< 1	< 0.1	45	-	0.62
MS-14	Shallow	-	0.22	47	-	< 50	-	1.0	-	0.44	-	60	-	< 5	-	0.99	-	-	0.1	-	65	-	2.4
MS-15	Shallow	0.39	0.15	105	-	< 50	-	2.2	-	17	0.40	129	-	6.5	-	2.5	0.60	-	0.99	-	103	-	6.6
MS-16	Shallow	-	0.16	96	-	< 50	-	1.5	-	3.0	0.40	297	-	8.4	-	1.5	-	-	0.3	-	86	-	4.1
MW-01	Shallow	< 0.5	0.13	387	0.19	200	0.16	159	3.6	4.4	0.18	269	2.2	39	< 0.5	2.3	0.98	2608	15	< 0.1	399	-	1.6
MW-02	Shallow	< 0.5	0.18	49	0.15	3036	0.09	4.8	0.10	< 0.5	< 0.1	< 50	1.4	15	< 0.5	0.4	28	1663	152	< 0.1	295	-	1.0
MW-03	Shallow	< 0.5	< 0.1	270	0.58	< 50	< 0.08	9.2	1.0	1.9	8.7	141	1.5	48	< 0.5	2.1	< 0.5	59	< 1	< 0.1	55	-	0.60
MW-05	Shallow	< 0.5	0.25	57	0.35	< 50	< 0.08	2.4	0.27	1.2	0.16	623	0.79	15	0.65	1.2	< 0.5	139	1.0	< 0.1	61	-	0.72
MW-06S	Shallow	< 0.5	0.21	58	0.34	405	0.16	14	0.09	0.73	27	106	< 2.5	1055	< 0.5	1.9	0.56	21	23	0.11	94	1.7	< 0.3
MW-07 (OB-03)	Shallow	< 0.5	0.21	37	0.06	< 50	< 0.08	1.7	0.22	14	0.16	103	-	7.8	0.44	8.0	< 0.5	83	< 1	< 0.1	63	-	0.83
MW-07S	Shallow	< 0.5	3.0	109	1.1	4250	0.15	191	0.03	4.4	42	86	3.1	4382	0.50	3.7	1.6	396	93	0.45	475	1.6	< 0.3
MW-08S	Shallow	< 0.5	0.22	144	< 0.1	238	< 0.08	1.9	0.06	< 0.5	1.2	333	< 2.5	3058	2.2	1.5	1.3	1705	37	< 0.1	539	1.1	0.36
MW-09S	Shallow	< 0.5	< 0.1	254	< 0.1	< 50	< 0.08	14	0.42	0.66	< 0.1	< 50	< 2.5	12	< 0.5	< 0.5	0.51	1105	86	< 0.1	444	0.71	1.8
MW-10S	Shallow	< 0.5	< 0.1	43	< 0.1	< 50	< 0.08	1.0	0.15	< 0.5	0.11	55	0.86	7.7	< 0.5	1.3	< 0.5	< 5	< 1	< 0.1	28	0.85	< 0.3
MW-11S	Shallow	< 0.5	0.14	61	< 0.1	< 50	< 0.08	2.8	5.7	5.8	< 0.1	80	< 0.5	5.2	< 0.5	< 0.5	< 0.5	83	< 1	< 0.1	50	-	2.1
MW-12S	Shallow	< 0.5	< 0.1	52	< 0.1	< 50	< 0.08	1.5	0.52	0.66	1.2	122	0.71	17	< 0.5	1.3	< 0.5	33	< 1	< 0.1	31	-	0.41
MW-13S	Shallow	< 0.5	0.12	36	< 0.1	< 50	< 0.08	4.0	0.62	1.1	0.16	534	1.5	8.9	0.59	< 0.5	< 0.5	53	1.3	< 0.1	93	-	4.1
MW-14S	Shallow	< 0.5	< 0.1	35	0.67	2490	0.13	107	0.64	3.7	4.8	871	2.3	51	0.54	50	6.6	2350	217	< 0.1	563	1.1	0.77
OB-01 (Ash Basin)	Shallow	< 0.5	< 0.1	40	0.07	< 50	< 0.08	1.7	0.18	1.9	0.73	198	0.51	25	< 0.5	1.3	< 0.5	19	< 1	< 0.1	27	-	< 0.3
B-01 (Dry Ash Landfi	Shallow	< 0.5	0.18	1080	0.17	2850	0.22	252	1.1	30	2.5	281	1.4	39	6.2	64	0.55	3275	11	< 0.1	593	-	1.4
PVSF-01S	Shallow	< 0.5	0.20	37	< 0.1	< 50	< 0.08	2.0	0.08	1.8	0.80	266	4.1	141	4.7	3.9	< 0.5	220	2.2	< 0.1	87	0.28	1.6
PVSF-02S	Shallow	< 0.5	1.1	62	0.81	3507	1.1	8.9	0.05	0.60	21	1737	-	22400	0.20	4.9	3.2	382	495	< 0.1	729	0.86	0.96
PVSF-03S	Shallow	< 0.5	0.44	107	1.4	7487	0.33	6.2	0.76	1.3	133	< 50	4.6	600	0.79	25	17	13	174	< 0.1	418	0.95	0.47
Deep Flow Zone																							
AB-01D	Deep	< 0.5	0.19	431	< 0.1	1257	< 0.08	222	0.03	0.83	23	703	20	26	< 0.5	1.4	< 0.5	2615	40	< 0.1	606	2.1	1.1
AB-02D	Deep	< 0.5	0.21	28	< 0.1	399	< 0.08	4.9	0.22	0.83	0.43	338	7.7	43	< 0.5	0.65	< 0.5	681	171	< 0.1	380	3.3	0.41
AB-04D	Deep	< 0.5	0.18	72	< 0.1	360	< 0.08	8.4	0.03	< 0.5	0.35	1330	12	55	< 0.5	2.2	< 0.5	239	34	< 0.1	136	-	< 0.3
AB-05D	Deep	< 0.5	0.88	101	< 0.1	< 50	< 0.08	2.8	0.03	< 0.5	7.3	755	15	869	< 0.5	10	< 0.5	2662	109	< 0.1	319	0.8	0.63
AB-07D	Deep	< 0.5	0.85	142	< 0.1	< 50	< 0.08	2.2	1.0	1.3	0.17	129	10	21	< 0.5	3.0	< 0.5	468	< 1	< 0.1	114	-	6.7
AB-14D	Deep	< 0.5	0.17	169	< 0.1	442	< 0.08	1.9	2.1	1.5	< 0.1	52	3.0	5.4	0.62	0.70	0.77	524	55	< 0.1	161	-	1.2
AB-18DU	Deep	< 0.5	2.8	91	< 0.1	< 50	< 0.08	1.9	< 0.025	0.48	4.8	19100	1.4	1820	1.2	0.67	< 0.5	141	1.1	< 0.1	122	1.1	0.62
AB-21D	Deep	< 0.5	0.15	181	< 0.1	< 50	< 0.08	12	< 0.025	1.0	0.72	1058	13	88	1.3	3.7	< 0.5	512	17	< 0.1	177	-	0.61
AL-01D	Deep	< 0.5	0.12	879	< 0.1	3148	< 0.08	265	0.05	1.7	0.26	96	12	22	< 0.5	3.0	< 0.5	5537	16	< 0.1	661	10	0.81
AL-02D	Deep	< 0.5	0.23	44	< 0.1	11633	< 0.08	2.4	0.57	1.7	3.1	252	31	437	2.0	18	94	2770	916	< 0.1	1587	-	1.0
AL-03D	Deep	0.39	0.20	67	< 0.1	5297	< 0.08	2.9	0.09	2.3	0.33	218	17	46	0.98	3.4	52	2875	452	< 0.1	888	-	0.59
AL-04D	Deep	< 0.5	0.26	87	< 0.1	16242	0.09	2.8	0.67	2.8	0.65	440	123	60	1.7	8.8	10	4544	594	< 0.1	1072	-	3.7
CCR-01D	Deep	< 0.5	0.45	51	< 0.1	< 50	< 0.08	1.6	0.06	< 0.5	0.09	< 50	3.1	29	0.41	0.51	< 0.5	670	4.0	< 0.1	131	0.64	13
CCR-02D	Deep	< 0.5	0.10	33	0.10	140	< 0.08	5.0	0.98	0.89	< 0.1	< 50	1.8	32	< 0.5	< 0.5	< 0.5	116	5.0	< 0.1	68	0.75	1.5
CCR-03D	Deep	< 0.5	0.10	39	< 0.1	< 50	< 0.08	1.1	0.09	< 0.5	< 0.1	41	7.7	1.6	0.26	-	0.56	556	94	< 0.1	234	0.76	2.9
CCR-04D	Deep	< 0.5	0.10	51	< 0.1	16	< 0.08	0.8	-	0.66	1.3	-	21	-	0.49	-	< 0.5	-	73	< 0.1	227	0.84	-
CCR-05D	Deep	1.3	0.20	130	< 0.1	8.0	< 0.08	2.9	-	0.54	0.61	-	62	-	0.81	-	< 0.5	-	34	0.13	232	3.0	-
CCR-09DA	Deep	0.42	0.58	83	< 0.1	26	< 0.08	81	0.04	2.9	0.19	144	21	16	1.5	1.7	< 0.5	776	20	< 0.1	284	2.9	0.78
CCR-11D	Deep	< 0.5	< 0.1	900	0.56	2917	1.3	270	-	3.0	4.7	-	6.3	-	< 0.5	-	< 0.5	-	14	0.27	215	6.4	-

TABLE 6-5
MEANS OF GROUNDWATER COIs - FEBRUARY 2018 TO MAY 2019
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L
15A NCAC 02L Standard		1*	10	700	4*	700	2	250	10	10	1*	300	NE	50	NE	100	20	NE	250	0.2*	500	5^	0.3*
2018 Background Threshold Values (Shallow Flow Zone)[1]		0.5	0.4	310	0.2	50	0.08	5.5	5.7	16.5	1.2	744	---	75.3	0.5	9.9	1	303	4.2	0.1	140	3.0	5.6
2019 Background Threshold Values (Shallow Flow Zone)[2]		0.79	1	580	0.223	50	1.0	5.0	7.0	16.8	5.0	1095	4.8	155	1.0	19.6	1.0	210	11.3	0.2	152.4	5.33	13.0
Background Data Set Range (Shallow Flow Zone)[2]		0.1 j - 1.12	0.043 j - 1.7	22.2 - 730	0.012 j - 0.61	3.3 - 56.7	0.052 j - 0.101	0.92 - 5.4	0.076 j - 7.1	0.1 j - 39.2	0.041 j - 5.2	28 - 3440	0.19 j - 5.6	1.46 j - 390	0.076 j - 1.4	0.28 j - 21.9	0.092 - 0.72	9 - 223	0.0447 j - 12.8	0.015 j - 0.024	10 - 144	0.049 - 6.73	0.077 j - 15.4
2018 Background Threshold Values (Deep Flow Zone)[1]		0.5	0.6	127	0.1	50	0.08	4.7	3	7.6	1.9	272	---	141	3.2	7.5	1	665	17.7	0.1	183	2.8	3.8
2019 Background Threshold Values (Deep Flow Zone)[2]		0.62	1.4	138	0.2	50	0.08	4.2	6.0	4.3	3.2	225	10.0	142	7.3	7.8	2.4	727	24.2	0.1	200	7.46	3.9
Background Data Set Range (Deep Flow Zone)[2]		0.14 j - 1.3	0.088 j - 1.9	15.1 - 146	0.012 j - 0.095 j	2.3 j - 43 j	0.03 j - 0.054 j	1.2 - 4.8	0.01 j - 2.7	0.15 j - 3.1	0.013 j - 3.3	30.4 j - 310	2.5 - 10.9	7.4 - 154	0.19 j - 10.5	0.13 j - 7.9	0.17 j - 2.9	81.4 - 732	2.3 - 35.4	0.018 j - 0.054 j	41 - 202	0.2587 - 11.14	0.74 - 4
2018 Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0
2019 Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	840	1.0	50	1.0	3.6	8.1	11.2	2.6	1,220	11.4	330	3.7	8.0	1.0	313	22.1	0.2	195	6.43	25.8
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6
Sample ID	Flow Zone	Analytical Results																					
CCR-12D	Deep	< 0.5	0.07	58	< 0.1	12	< 0.08	3.0	-	0.63	0.05	-	1.9	-	< 0.5	-	< 0.5	-	7.6	< 0.1	116	0.97	-
CCR-13D	Deep	< 0.5	< 0.1	299	< 0.1	202	< 0.08	165	< 0.025	< 0.5	< 0.1	< 50	10	18	< 0.5	< 0.5	< 0.5	2950	2.6	< 0.1	427	6.5	0.90
CCR-14D	Deep	< 0.5	< 0.1	532	< 0.1	2220	< 0.08	238	-	0.53	< 0.1	-	16	-	< 0.5	-	< 0.5	-	10	< 0.1	565	5.4	-
CCR-15D	Deep	< 0.5	0.55	352	< 0.1	3.2	< 0.08	2.7	-	3.1	0.11	-	7.0	-	0.32	-	0.93	-	5.3	< 0.1	119	2.3	-
CCR-16D	Deep	< 0.5	0.49	41	< 0.1	3.5	< 0.08	3.5	-	0.78	< 0.1	-	14	-	1.3	-	0.41	-	8.2	< 0.1	145	1.8	-
CP-01D	Deep	0.11	0.27	70	1.7	< 50	4.5	10	0.13	< 0.5	91	383	42	24200	2.9	61	1.5	1183	825	< 0.1	1337	1.8	1.3
CP-02D	Deep	0.17	0.20	25	< 0.1	< 50	< 0.08	1.4	0.92	1.8	1.7	318	2.9	370	3.2	2.7	< 0.5	142	< 1	< 0.1	233	0.94	4.0
CP-03D	Deep	< 0.5	0.21	47	< 0.1	< 50	< 0.08	2.1	0.36	1.2	0.21	178	3.7	42	0.85	1.2	< 0.5	99	1.2	< 0.1	341	1.2	3.7
GP-01D	Deep	< 0.5	0.21	185	< 0.1	< 50	< 0.08	1.9	1.4	2.1	0.67	71	5.1	58	0.82	1.4	1.2	779	77	< 0.1	189	1.7	3.0
GP-02D	Deep	< 0.5	0.17	89	< 0.1	< 50	< 0.08	2.1	0.83	1.4	0.33	54	5.3	29	0.95	1.5	0.50	858	30	< 0.1	156	1.3	2.1
GP-03D	Deep	< 0.5	0.31	32	< 0.1	< 50	< 0.08	1.9	0.61	2.3	0.45	275	< 2.5	54	2.6	2.5	< 0.5	235	5.1	< 0.1	94	0.94	1.8
GWA-01D	Deep	< 0.5	0.26	50	< 0.1	< 50	< 0.08	2.3	< 0.025	0.98	0.38	305	18	48	11	4.1	< 0.5	886	214	< 0.1	434	2.2	0.73
GWA-03D	Deep	< 0.5	< 0.1	31	< 0.1	< 50	< 0.08	2.0	0.33	0.60	< 0.1	55	3.9	11	2.4	< 0.5	< 0.5	67	2.3	< 0.1	97	-	1.1
GWA-07D	Deep	< 0.5	0.19	355	< 0.1	< 50	< 0.08	2.6	6.0	5.8	0.19	106	7.5	6.2	0.63	4.5	< 0.5	189	8.9	< 0.1	135	-	4.5
GWA-10D	Deep	< 0.5	0.15	64	0.10	< 50	< 0.08	1.3	< 0.025	0.42	0.28	699	9.1	14	0.88	1.1	< 0.5	1740	220	< 0.1	428	-	0.94
GWA-11D	Deep	< 0.5	0.12	102	< 0.1	1069	< 0.08	5.2	1.9	2.4	0.15	130	8.1	83	< 0.5	0.86	10	1664	112	< 0.1	273	1.5	2.1
GWA-13DA	Deep	1.5	1.1	13	< 0.1	< 50	< 0.08	2.2	0.13	1.1	0.06	345	30	8.2	1.9	0.86	< 0.5	110	2.8	< 0.1	143	-	6.1
GWA-14D	Deep	0.67	0.57	24	< 0.1	< 50	0.10	1.6	0.36	1.6	0.16	204	2.9	24	1.1	1.2	< 0.5	70	1.6	< 0.1	103	-	2.9
GWA-15D	Deep	< 0.5	0.16	94	< 0.1	66	0.09	39	< 0.025	0.64	1.4	1033	8.7	486	2.6	5.2	< 0.5	1025	108	< 0.1	334	11	0.84
ILF-01D	Deep	< 0.5	0.18	52	< 0.1	< 50	< 0.08	4.2	0.61	1.1	0.41	57	4.0	121	1.5	1.3	< 0.5	230	6.2	< 0.1	111	0.76	2.4
ILF-02D	Deep	< 0.5	0.09	22	< 0.1	< 50	< 0.08	2.6	0.33	1.4	1.4	74	4.0	17	0.61	2.2	< 0.5	77	1.3	< 0.1	97	0.70	2.4
MW-06D	Deep	< 0.5	< 0.1	369	< 0.1	175	0.16	143	0.09	1.1	0.22	117	3.1	8.2	< 0.5	3.0	< 0.5	1828	5.6	< 0.1	414	3.3	0.38
MW-07D	Deep	< 0.5	0.18	85	< 0.1	378	< 0.08	115	0.03	0.53	< 0.1	990	8.5	747	< 0.5	< 0.5	< 0.5	1485	74	< 0.1	490	5.9	< 0.3
MW-09D	Deep	< 0.5	< 0.1	87	< 0.1	468	0.13	6.6	0.03	< 0.5	1.4	51	5.1	989	< 0.5	4.6	< 0.5	1175	172	< 0.1	351	< 1.4	0.62
MW-10D	Deep	< 0.5	< 0.1	18	< 0.1	< 50	< 0.08	1.3	0.42	0.59	< 0.1	63	2.1	< 5	< 0.5	< 0.5	< 0.5	99	3.8	< 0.1	72	< 0.49	2.9
MW-11D	Deep	< 0.5	0.20	57	< 0.1	< 50	< 0.08	1.9	8.4	8.8	< 0.1	< 50	3.5	< 5	< 0.5	0.59	< 0.5	94	< 1	< 0.1	66	-	14
MW-12D	Deep	< 0.5	0.13	19	< 0.1	51	< 0.08	< 1	0.45	0.66	0.37	147	3.2	7.0	0.76	0.94	< 0.5	170	4.5	< 0.1	73	-	1.0
MW-13D	Deep	< 0.5	< 0.1	48	< 0.1	< 50	< 0.08	4.4	0.99	1.5	< 0.1	< 50	2.4	< 5	0.65	0.54	< 0.5	69	< 1	< 0.1	89	-	4.9
MW-14D	Deep	< 0.5	0.11	35	0.34	2115	< 0.08	56	0.07	< 0.5	1.8	< 50	4.5	42	< 0.5	20	3.0	2128	160	< 0.1	423	0.53	< 0.3
PVSF-01D	Deep	< 0.5	0.24	74	< 0.1	< 50	< 0.08	1.8	0.18	0.61	0.35	64	2.9	35	1.1	1.6	< 0.5	269	3.4	< 0.1	103	1.2	2.7
PVSF-02D	Deep	< 0.5	0.19	48	0.36	4500	0.88	5.7	0.41	3.1	10	152	-	933	0.68	7.6	12	689	450	< 0.1	927	2.3	1.1
PVSF-03D	Deep	< 0.5	0.22	11	< 0.1	< 50	< 0.08	3.8	0.32	2.1	0.28	239	6.2	65	1.4	1.4	0.71	121	17	< 0.1	135	0.74	2.3
Bedrock Flow Zone																							
AB-01BR	Bedrock	< 0.5	0.23	79	< 0.1	2818	< 0.08	240	0.03	< 0.5	2.5	8090	21	595	< 0.5	1.0	< 0.5	2217	54	< 0.1	677	17	0.35
AB-01BRL	Bedrock	< 0.5	0.15	289	< 0.1	2213	< 0.08	282	< 0.025	0.67	< 0.1	7961	16	927	0.68	0.66	< 0.5	2054	39	< 0.1	799	16	0.35
AB-01BRLL	Bedrock	< 0.5	0.15	270	< 0.1	2022	< 0.08	288	< 0.025	0.66	0.12	6938	13	1398	0.17	0.84	< 0.5	1783	40	< 0.1	752	4.8	< 0.3
AB-01BRLLL	Bedrock	< 0.5	1.5	80	< 0.1	60	< 0.08	5.8	< 0.025	< 0.5	0.17	122	8.2	304	0.73	0.66	< 0.5	1090	85	< 0.1	340	5.6	0.42
AB-02BR	Bedrock	< 0.5	0.42	5	< 0.1	< 50	< 0.08	2.6	< 0.025	< 0.5	0.16	< 50	3.9	24	0.94	< 0.5	< 0.5	1140	101	< 0.1	353	3.9	< 0.3
AB-03D	Bedrock	< 0.5	0.14	115	< 0.1	165	< 0.08	4.5	0.04	1.0	0.13	124	12	48	< 0.5	1.4	< 0.5	1246	95	< 0.1	277	-	2.4
AB-05BR	Bedrock	< 0.5	0.36	83	< 0.1	< 50	< 0.08	1.8	0.16	1.3	0.98	294	48	127	< 0.5	13	< 0.5	3648	281	< 0.1	537	3.0	< 0.3
AB-06BRA	Bedrock	0.12	179	73	< 0.1	512	< 0.08	2.5	0.03	< 0.5	< 0.1	214	59	71	5.7	< 0.5	< 0.5	3273	109	< 0.1	376	-	0.46
AB-06BRL	Bedrock	< 0.5	0.51	30	< 0.1	< 50	< 0.08	2.4	0.03	< 0.5	< 0.1	256	3.0	58	4.4	0.77	< 0.5	6013	281	< 0.1	551	1.5	< 0.3
AB-06D	Bedrock	< 0.5	1.9	92	0.60	5325	< 0.08	3.6	< 0.025	< 0.5	1.9	5473	15	457	< 0.5	50	< 0.5	4140	43	< 0.1	326	-	< 0.3
AB-08D	Bedrock	< 0.5	0.35	51	< 0.1	< 50	< 0.08	2.4	< 0.025	< 0.5	0.14	89	7.0	329	2.1	< 0.5	< 0.5	2248	76	< 0.1	277	-	< 0.3
AB-09BR	Bedrock	< 0.5	0.63	198	< 0.1	< 50	< 0.08	1.4	0.04	< 0.5	0.14	712	25	92	4.8	1.5	< 0.5	259	16	< 0.1	187	-	0.33
AB-09D	Bedrock	< 0.5	0.41	255	< 0.1	< 50	< 0.08	1.7	< 0.025	0.60	2.4	1006	15	51	2.6	23	< 0.5	228	8.2	< 0.1	147	-	< 0.3
AB-10BR	Bedrock	< 0.5	0.37	217	< 0.1	276	< 0.08	2.9	< 0.025	< 0.5	0.13	251	22	27	0.62	1.8	< 0.5	4668	20	< 0.1	377	-	< 0.3
AB-10BRL	Bedrock	< 0.5	6.7	33	< 0.1	< 50	< 0.08	6.2	0.04	< 0.5	< 0.1	64	2.6	39	2.2	< 0.5	< 0.5	3773	89	< 0.1	341	8.2	0.42
AB-10D	Bedrock	< 0.5	0.74	426	< 0.1	1430	< 0.08	5.2	< 0.025	< 0.5	10	4338	7.7	4197	1.5	25	< 0.5	2857	9.2	< 0.1	332	-	0.66
AB-11D	Bedrock	< 0.5	0.15	17	< 0.1	57	< 0.08	1.7	0.08	< 0.5	< 0.1	118	5.3	5.3	0.68	< 0.5	< 0.5	1198	3.2	< 0.1	106	-	0.60
AB-12BR	Bedrock	< 0.5	0.84	28	< 0.1	51	< 0.08	1.4	0.03	< 0.5	< 0.1	115	5.8	29	2.0	0.62	< 0.5	2756	165	< 0.1	395	8.2	< 0.3
AB-12D	Bedrock	0.57	2.8	49	< 0.1	1118	< 0.08	127	0.18	2.2	< 0.1	108	6.1	104	0.60	2.9	< 0.5	10332	174	< 0.1	689	6.4	< 0.3
AB-13D	Bedrock	< 0.5	0.56	218	< 0.1	< 50	< 0.08	1.8	0.05	1.2	2.1	952	8.1	227	1.4	0.74	< 0.5	691	14	< 0.1	222	-	< 0.3
AB-15BR	Bedrock	< 0.5	0.11	106	< 0.1	< 50	< 0.08	2.2	< 0.025	< 0.5	< 0.1	2412	4.4	270	0.95	0.68	0.55	1064	69	< 0.1	286	-	0.31
AB-15D	Bedrock	< 0.5	0.11	253	< 0.1	< 50	< 0.08	2.6	0.03	0.55	< 0.1	2612	5.1	260	0.75	0.53	< 0.5	652	34	< 0.1	271	-	< 0.3

TABLE 6-5
MEANS OF GROUNDWATER COIs - FEBRUARY 2018 TO MAY 2019
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L
15A NCAC 02L Standard		1*	10	700	4*	700	2	250	10	10	1*	300	NE	50	NE	100	20	NE	250	0.2*	500	5^	0.3*
2018 Background Threshold Values (Shallow Flow Zone)[1]		0.5	0.4	310	0.2	50	0.08	5.5	5.7	16.5	1.2	744	---	75.3	0.5	9.9	1	303	4.2	0.1	140	3.0	5.6
2019 Background Threshold Values (Shallow Flow Zone)[2]		0.79	1	580	0.223	50	1.0	5.0	7.0	16.8	5.0	1095	4.8	155	1.0	19.6	1.0	210	11.3	0.2	152.4	5.33	13.0
Background Data Set Range (Shallow Flow Zone)[2]		0.1 j - 1.12	0.043 j - 1.7	22.2 - 730	0.012 j - 0.61	3.3 - 56.7	0.052 j - 0.101	0.92 - 5.4	0.076 j - 7.1	0.1 j - 39.2	0.041 j - 5.2	28 - 3440	0.19 j - 5.6	1.46 j - 390	0.076 j - 1.4	0.28 j - 21.9	0.092 - 0.72	9 - 223	0.0447 j - 12.8	0.015 j - 0.024	10 - 144	0.049 - 6.73	0.077 j - 15.4
2018 Background Threshold Values (Deep Flow Zone)[1]		0.5	0.6	127	0.1	50	0.08	4.7	3	7.6	1.9	272	---	141	3.2	7.5	1	665	17.7	0.1	183	2.8	3.8
2019 Background Threshold Values (Deep Flow Zone)[2]		0.62	1.4	138	0.2	50	0.08	4.2	6.0	4.3	3.2	225	10.0	142	7.3	7.8	2.4	727	24.2	0.1	200	7.46	3.9
Background Data Set Range (Deep Flow Zone)[2]		0.14 j - 1.3	0.088 j - 1.9	15.1 - 146	0.012 j - 0.095 j	2.3 j - 43 j	0.03 j - 0.054 j	1.2 - 4.8	0.01 j - 2.7	0.15 j - 3.1	0.013 j - 3.3	30.4 j - 310	2.5 - 10.9	7.4 - 154	0.19 j - 10.5	0.13 j - 7.9	0.17 j - 2.9	81.4 - 732	2.3 - 35.4	0.018 j - 0.054 j	41 - 202	0.2587 - 11.14	0.74 - 4
2018 Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0
2019 Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	840	1.0	50	1.0	3.6	8.1	11.2	2.6	1,220	11.4	330	3.7	8.0	1.0	313	22.1	0.2	195	6.43	25.8
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6
Sample ID	Flow Zone	Analytical Results																					
AB-16D	Bedrock	< 0.5	0.86	183	< 0.1	< 50	< 0.08	3.4	0.03	0.53	0.25	1390	23	201	1.0	1.8	< 0.5	404	25	< 0.1	199	-	< 0.3
AB-17D	Bedrock	< 0.5	0.16	26	< 0.1	< 50	< 0.08	1.2	1.0	1.4	0.11	< 50	5.0	< 5	< 0.5	0.98	< 0.5	107	< 1	< 0.1	89	-	4.5
AB-18D	Bedrock	< 0.5	0.34	37	< 0.1	< 50	< 0.08	1.7	0.17	0.56	0.10	62	4.1	76	1.0	2.0	< 0.5	185	4.8	< 0.1	99	-	2.8
AB-20D	Bedrock	< 0.5	0.57	56	< 0.1	80	< 0.08	1.9	0.04	1.3	< 0.1	262	1.4	10	14	1.5	< 0.5	496	19	< 0.1	132	-	0.76
AL-01BR	Bedrock	< 0.5	< 0.1	368	< 0.1	622	< 0.08	173	0.10	2.9	0.16	81	18	9.7	0.60	7.2	< 0.5	3230	7.8	< 0.1	492	11	0.84
AL-01BRL	Bedrock	< 0.5	1.4	91	< 0.1	< 50	< 0.08	3.8	< 0.025	< 0.5	0.18	165	9.9	365	5.7	0.69	< 0.5	1400	224	< 0.1	474	33	0.80
AL-02BR	Bedrock	0.27	0.40	138	< 0.1	4308	< 0.08	< 1	0.45	1.9	0.75	101	17	41	4.8	6.7	20	3227	254	< 0.1	551	-	2.8
AL-02BRL	Bedrock	< 0.5	0.20	108	< 0.1	1401	< 0.08	1.1	0.28	1.7	0.05	< 50	43	15	1.4	0.63	5.5	1595	203	< 0.1	439	< 0.567	0.29
AL-02BRLL	Bedrock	< 0.5	0.25	76	< 0.1	10084	< 0.08	4.5	0.03	0.80	0.12	321	60	414	1.2	1.2	0.88	3710	520	< 0.1	1013	5.8	< 0.3
AL-02BRLLL	Bedrock	< 0.5	6.1	171	< 0.1	< 50	< 0.08	21	0.03	0.87	0.18	437	3.6	176	1.6	0.86	< 0.5	1023	129	< 0.1	402	4.0	0.83
AL-03BR	Bedrock	< 0.5	0.52	114	< 0.1	1114	< 0.08	2.1	0.07	2.4	0.09	< 50	119	35	4.0	2.2	7.3	1160	178	< 0.1	422	-	< 0.3
AL-04BR	Bedrock	< 0.5	0.14	96	0.11	8992	0.08	1.7	0.47	1.9	0.15	137	33	6.7	0.66	5.1	6.4	2842	225	< 0.1	456	-	3.2
AL-04BRL	Bedrock	< 0.5	0.34	124	< 0.1	< 50	< 0.08	2.3	< 0.025	0.82	< 0.1	582	27	56	1.7	0.54	< 0.5	413	5.6	< 0.1	134	-	0.38
GWA-01BR	Bedrock	< 0.5	0.11	38	< 0.1	< 50	< 0.08	3.0	2.4	2.8	0.82	72	6.2	< 5	< 0.5	0.57	< 0.5	276	50	< 0.1	159	1.2	4.1
GWA-09BR	Bedrock	< 0.5	< 0.1	17	< 0.1	< 50	< 0.08	4.3	0.64	0.84	< 0.1	< 50	3.8	< 5	< 0.5	0.55	< 0.5	52	< 1	< 0.1	98	-	3.1
GWA-11BR	Bedrock	0.73	0.13	52	< 0.1	< 50	< 0.08	3.7	< 0.025	1.9	< 0.1	223	5.4	8.0	1.1	2.3	< 0.5	566	48	< 0.1	201	1.3	2.3
GWA-12D	Bedrock	< 0.5	0.35	42	< 0.1	< 50	< 0.08	3.4	< 0.025	< 0.5	0.10	72	-	9.2	12	0.76	< 0.5	285	11	< 0.1	150	< 0.601	0.32
ILF-01BR	Bedrock	0.48	0.34	8	< 0.1	< 50	< 0.08	2.7	0.21	1.8	16	199	4.7	39	5.9	3.1	< 0.5	160	4.7	< 0.1	126	0.53	2.4
MW-08D	Bedrock	< 0.5	0.11	14	0.11	277	< 0.08	8.5	< 0.025	< 0.5	0.31	832	6.6	111	< 0.5	< 0.5	< 0.5	1693	97	< 0.1	383	2.3	< 0.3
MW-14BR	Bedrock	< 0.5	0.13	43	< 0.1	144	< 0.08	53	0.41	3.0	0.17	90	12	5.7	0.69	4.2	1.2	819	9.8	< 0.1	158	3.0	3.2
MW-14BRL	Bedrock	< 0.5	0.47	227	< 0.1	< 50	< 0.08	2.2	< 0.025	0.62	< 0.1	90	5.1	6.8	1.4	0.58	< 0.5	280	10	< 0.1	209	5.6	6.3
PVSF-01BR	Bedrock	0.53	0.47	96	< 0.1	< 50	< 0.08	6.2	0.06	1.6	0.16	518	6.0	82	5.5	1.3	< 0.5	306	12	< 0.1	158	1.9	0.81
PVSF-02BR	Bedrock	< 0.5	0.16	54	< 0.1	2900	< 0.08	5.6	0.10	< 0.5	4.3	182	5.8	462	3.9	1.9	6.8	1028	341	< 0.1	704	0.51	1.1
PVSF-03BR	Bedrock	0.25	0.74	40	< 0.1	< 50	< 0.08	4.9	0.04	2.8	0.46	105	< 2.5	26	14	4.6	< 0.5	619	14	< 0.1	196	0.64	0.86

Prepared by: WCG Checked by: ECW

Notes:

[1] - Background threshold values were calculated using data from background groundwater samples collected September 2015 to October 2017.

[2] - Background threshold values were calculated using data from background groundwater samples collected February 2010 to December 2018.

Statistical mean calculated from data ranging from January 2018 to June 2019. Ash pore water results are not compared to groundwater standards or criteria.

For wells with datasets containing fewer than four valid results, the most recent valid sample data was used.

Means were calculated for wells with four or more valid sample results. Sample results were excluded from calculations:

1) if turbidity >10 NTU (for COIs other than boron)

2) for unusable data (R0 qualified)

3) if a result was non-detect at a reporting limit (RL) greater than the normal laboratory RL

Bold text - greatest comparative value

- bold highlighted concentration indicates value is greater than the 15A NCAC 02L .0202 Standard or the IMAC. (Effective date for 15A NCAC 02L .0202 Standard and IMAC is April 1, 2013)

- bold highlighted concentration indicates value is greater than greatest background threshold value where there is no regulatory standard, or background threshold values are greater than regulatory standard

- highlighted concentration indicates value is either within range of background threshold values for constituents where there is no regulatory standard/background threshold values are greater than regulatory standard, or within range of background threshold value and the regulatory standard

* - Interim Maximum Allowable Concentrations (IMACs) of the 15A NCAC 02L Standard, Appendix 1, April 1, 2013.

< - concentration not detected at or above the adjusted reporting limit.

- - no available data to conduct mean analysis

NE - not established

mg/L - milligrams per liter

µg/L - micrograms per liter

TABLE 6-6
COI MANAGEMENT MATRIX
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituents of Interest[1]	Reporting Unit	02L, IMAC, or MCL Criteria	Groundwater Zone Statistically Derived Background Value			Marshall Steam Station Background Data Set Range	Piedmont Background Value Range	Maximum Mean Concentration Near or Beyond of Compliance Boundary[7]	Groundwater Exceedance Ratio[4,7]	Number of Wells Above Criterion Near or Beyond Compliance Boundary[7]	Groundwater Monitoring Wells With COI Concentration Greater Than Comparative Criteria[7]	Present in Ash Pore Water Above Comparative Criteria (2018 APW Means)[5]	Exceeds Flow Zone Background Range	Exceeds Site-Specific Background Range	Exceeds Piedmont Provence Background Range	Downgradient of Source Area	Geochemical Mobility[6]	Rationale for Selection of COIs for Corrective Action (a constituent is not warranted for corrective action if no means are greater than comparative criteria in all flow zones and/or lines of evidence support that the constituents's occurrances are not related to the source area)
			Flow Zone	2018 [2]	2019 [3]													
Constituent Standards and Values - 02L Criterion												**Lines of Evidence (LOE) - 02L Criterion**						**Rationale for Exclusion/Inclusion for Corrective Action**
Arsenic	µg/L	10	Shallow	0.4	1	0.043 - 5	0.1 - 6.35	3.0	0.3	0	-	Y	0	0	0	N	Variable	No means exceed comparative criteria
			Transition Zone	0.6	1	0.088 - 1.9		0.6	0.1	0	-		0	0	0	N		No means exceed comparative criteria
			Bedrock	0.6	1	0.071 - 2.3		0.2	0.0	0	-		0	0	0	N		No means exceed comparative criteria
Barium	µg/L	700	Shallow	310	580	22.2 - 730	11 - 840	254	0.4	0	-	Y	0	0	0	N	Variable	No means exceed comparative criteria
			Transition Zone	127	138	15.1 - 146		879	1.3	1	AL-1D		4	1	1	Y		Single location with detection of barium above 02L standard. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Bedrock	435	840	23 - 857		368	0.4	0	-		0	0	0	N		No means exceed comparative criteria
Boron	µg/L	700	Shallow	50	50	3.3 - 56.7	49.1 - 176.8	4,250	6.1	7	AB-1S, AL-1S, CCR-9S, GWA-11S, GWA-15S, MW-7S, MW-14S	Y	12	12	11	Y	Conservative	Exceedances depict a plume-like distribution likely attributed to the ash basin
			Transition Zone	50	50	2.3 - 50		3,148.33	4.5	4	AB-1D, AL-1D, GWA-11D, MW-14D		9	9	7	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	50	50	25.9 - 50		2,818.33	4.0	3	AB-1BR, AB-1BRL, AB-1BRLL		6	6	5	Y		Single location (three intervals) with detection of boron about 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
Cadmium	µg/L	2	Shallow	0.08	1	0.052 - 1	0.08 - 1	0.7	0.4	0	-	Y	0	0	0	N	Variable	No means exceed comparative criteria
			Transition Zone	0.08	0.08	0.03 - 0.08		0.2	0.1	0	-		3	0	0	N		No means exceed comparative criteria
			Bedrock	0.08	1	0.054 - 1.9		< 0.08	0	0	-		0	0	0	N		No means exceed comparative criteria
Chloride	mg/L	250	Shallow	5.5	5	0.92 - 5.4	3 - 250	191	0.8	0	-	Y	11	11	0	N	Conservative	No means exceed comparative criteria
			Transition Zone	4.7	4	1.2 - 4.8		265	1.1	1	AL-1D		10	8	1	Y		Single location with detection of chloride above 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Bedrock	4.5	4	1.2 - 4		288	1.2	2	AB-1BRL, AB-1BRLL		6	6	2	Y		Single location (two intervals) with detection of chloride about 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
Chromium (Total)	µg/L	10	Shallow	16.5	17	0.23 - 39.2	1 - 26	4	0.3	0	-	Y	0	0	0	N	Non-Conservative	No means exceed comparative criteria
			Transition Zone	7.6	4	0.15 - 3.1		6	0.6	0	-		1	0	0	N		No means exceed comparative criteria
			Bedrock	8.3	11	0.23 - 31		3	0.3	0	-		0	0	0	N		No means exceed comparative criteria
Iron	µg/L	300	Shallow	744	1,095	26.9 - 3440	56.3 - 37500	1,298	1.2	1	AB-2S	Y	0	0	0	Y	Variable	Single location with detection of iron above 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	272	225	30.4 - 310		1,032.50	3.4	5	AB-1D, AB-2D, GWA-10D, GWA-15D, MW-7D		5	0	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	792	1,220	10 - 1530		8,090	6.6	3	AB-1BR, AB-1BRL, AB-1BRLL		3	3	0	Y		Single location (three intervals) with detection of iron about 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
Manganese	µg/L	50	Shallow	75.3	155	2.2 - 390	7 -9170	4,381.67	28.3	9	AB-1S, AB-2S, AL-1S, CCR-9S, GWA-7S, GWA-15S, MW-6S, MW-7S, MW-8S	Y	8	8	0	Y	Variable	Exceedances depict a plume-like distribution likely attributed to the ash basin
			Transition Zone	141	142	2.8 - 154		989	7.0	3	GWA-15D, MW-7D, MW-9D		3	3	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	26.6	330	2.7 - 385		1,397.50	4.2	3	AB-1BR, AB-1BRL, AB-1BRLL		3	3	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
Nickel	µg/L	100	Shallow	9.9	20	0.28 - 21.9	1.98 - 20	50	0.5	0	-	Y	1	1	1	N	Variable	No means exceed comparative criteria
			Transition Zone	7.5	8	0.13 - 7.9		20	0.2	0	-		1	0	0	N		No means exceed comparative criteria
			Bedrock	7.2	8	0.33 - 22.8		7	0.1	0	-		0	0	0	N		No means exceed comparative criteria
Selenium	µg/L	20	Shallow	0.5	1	0.092 - 10	0.5 - 2	21	1.1	1	GWA-11S	Y	1	1	1	Y	Variable	Single location with detection of selenium above 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	0.5	2.4	0.17 - 2.9		10	0.5	0	-		2	0	2	N		No means exceed comparative criteria
			Bedrock	0.5	1	0.17 - 2.3		1	0.1	0	-		0	0	0	N		No means exceed comparative criteria
Sulfate	mg/L	250	Shallow	4.2	11	0.0589 - 12.8	1.2 - 510	265	1.1	1	GWA-11S	Y	13	12	0	Y	Conservative	Single location with detection of sulfate above 02L. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	17.7	24	2.3 - 35.4		220	0.9	0	-		10	10	0	N		No means exceed comparative criteria
			Bedrock	18.4	22	0.42 - 23.9		97	0.4	0	-		6	6	0	N		No means exceed comparative criteria
Total Dissolved Solids	mg/L	500	Shallow	140	152	10 - 144	50 - 1200	563	1.1	4	AB-1S, AL-1S, MW-8S, MW-14S	Y	12	11	0	Y	Conservative	Exceedances depict a plume-like distribution likely attributed to the ash basin
			Transition Zone	183	200	41 - 202		661	1.3	2	AB-1D, AL-1D		15	12	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	216	195	42 - 240		799	1.6	3	AB-1BR, AB-1BRL, AB-1BRLL		5	5	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
Constituent Standards and Values - IMAC Criterion												**Lines of Evidence (LOE) - IMAC Criterion**						**Rationale for Exclusion - IMAC Criterion**
Antimony	µg/L	1	Shallow	0.5	1	0.1 - 1.12	0.5 - 4.2	0.5	0.5	0	-	Y	0	0	0	N	Conservative	No means exceed comparative criteria
			Transition Zone	0.5	1	0.11 - 1.3		1.325	1.3	1	CCR-5D		1	0	0	Y		Single location with detection of antimony above IMAC. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Bedrock	0.5	1	0.11 - 2.5		0.726	0.7	0	-		0	0	0	N		No means exceed comparative criteria
Beryllium	µg/L	4	Shallow	0.2	0.2	0.012 - 0.61	0.053 - 1	4.6	1.2	1	AL-1S	Y	7	2	2	Y	Non-Conservative	Single location with detection of beryllium above IMAC. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	0.1	0.2	0.012 - 0.2		0.34	0.1	0	-		1	0	0	N		No means exceed comparative criteria
			Bedrock	0.2	0.2	0.01 - 1.8		0.1	0.0	0	-		0	0	0	N		No means exceed comparative criteria

TABLE 6-6
COI MANAGEMENT MATRIX
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Constituents of Interest[1]	Reporting Unit	02L, IMAC, or MCL Criteria	Groundwater Zone Statistically Derived Background Value			Marshall Steam Station Background Data Set Range	Piedmont Background Value Range	Maximum Mean Concentration Near or Beyond of Compliance Boundary[7]	Groundwater Exceedance Ratio[4,7]	Number of Wells Above Criterion Near or Beyond Compliance Boundary[7]	Groundwater Monitoring Wells With COI Concentration Greater Than Comparative Criteria[7]	Present in Ash Pore Water Above Comparative Criteria (2018 APW Means)[5]	Exceeds Flow Zone Background Range	Exceeds Site-Specific Background Range[6]	Exceeds Piedmont Provence Background Range	Downgradient of Source Area	Geochemical Mobility[5]	Rationale for Selection of COIs for Corrective Action (a constituent is not warranted for corrective action if no means are greater than comparative criteria in all flow zones and/or lines of evidence support that the constituents's occurrances are not related to the source area)
Cobalt	µg/L	1	Shallow	1.2	5	0.041 - 5.2	0.2 - 88.85	116.4	23.3	8	AB-1S, AB-2S, AL-1S, CCR-4S, CCR-9S, GWA-7S, MW-6S, MW-7S	Y	8	8	2	Y	Variable	Exceedances depict a plume-like distribution likely attributed to the ash basin
			Transition Zone	1.9	3.2	0.013 - 3.3		23.1	7.2	1	AB-1D		1	1	0	Y		Single location with detection of cobalt above IMAC. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Bedrock	2.8	2.6	0.026 - 3.9		2.5	0.9	0	-		0	0	0	N		No means exceed comparative criteria
Thallium	µg/L	0.2	Shallow	0.1	0.2	0.015 - 0.2	0.1 - 0.2	0.7	3.5	4	AB-1S, CCR-4S, CCR-9S, MW-7S	Y	4	4	4	Y	Variable	Four locations with detection of thallium above 02L. Two locations depict a plume-like distribution attributed to the ash basin
			Transition Zone	0.1	0.1	0.018 - 0.1		0.1	0.7	0	-		1	0	0	N		No means exceed comparative criteria
			Bedrock	0.1	0.2	0.015 - 0.2		< 0.1	0	0	-		0	0	0	N		No means exceed comparative criteria
Total Radium	pCi/L	5^	Shallow	3	5	(-0.112) - 6.73	0.825 - 35	3.1	0.6	0	-	N	0	0	0	N	Variable	No means exceed comparative criteria
			Transition Zone	2.8	7	0.2587 - 11.14		10.8	1.5	2	AL-1D, GWA-15D		0	0	0	Y		Two locations with detection of total radium above IMAC. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Bedrock	5.7	6	0.573 - 7.43		16.7	2.8	3	AB-1BR, AB-1BRL, AL-1BR		3	2	0	Y		Single location (three intervals) with detection of chloride about IMAC. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
Vanadium	µg/L	0.3	Shallow	5.6	13	0.093 - 15.4	0.657 - 26	3.0	0.2	0	-	Y	0	0	0	N	Non-Conservative	No means exceed comparative criteria
			Transition Zone	3.8	4	0.74 - 4		4.5	1.1	1	GWA-7D		1	0	0	N		Single location with detection of vanadium above IMAC. Does not exhibit a discernible plume. Concentrations are within range of Piedmont background datasets. Groundwater flow direction derived from water elevations collected over 30 monitoring events and velocity vectors derived from groundwater flow and transport modeling simultations indicate this location is beyond the downgradient flow path from the source area.
			Bedrock	16	26	0.11 - 26.6		4.1	0.2	0	-		0	0	0	N		No means exceed comparative criteria
Constituent Standards and Values - Background Criterion												**Lines of Evidence (LOE) - Background Criterion**						**Rationale for Exclusion - Background Criterion**
Chromium (Hexavalent)	µg/L	NE	Shallow	5.7	7	0.076 - 7.1	0.03 - 12	1.5	0.2	0	-	Y	0	0	0	N	Variable	No means exceed comparative criteria
			Transition Zone	3	6	0.01 - 3.3		6.0	0.9	0	-		1	0	0	N		No means exceed comparative criteria
			Bedrock	3.9	8	0.012 - 11.8		2.4	0.3	0	-		0	0	0	N		No means exceed comparative criteria
Lithium	µg/L	NE	Shallow	NE	5	0.19 - 5.6	2 - 95.39	7.1	1.4	3	AL-1S, CCR-9S, GWA-15S	Y	3	0	0	Y	Conservative	Three locations with detection of lithium above background. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	NE	10	2.5 - 10.9		61.7	6.2	6	AB-1D, AL-1D, CCR-4D, CCR-5D, CCR-9DA, GWA-1D		6	6	0	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	NE	11	3.8 - 11		20.8	1.9	5	AB-1BR, AB-1BRL, AB-1BRLL, AL-1BR, MW-14BR		5	5	0	Y		Three locations (one location with three intervals) with detection of lithium above background. Two locations depict a plume-like distribution attributed to the ash basin
Molybdenum	µg/L	NE	Shallow	0.5	1	0.084 - 1.4	0.5 - 26	2.16	2.2	1	MW-8S	Y	1	0	0	Y	Variable	Single location with detection of molybdenum above background. Does not exhibit a discernible plume; however, other CCR-related constituents present above comparative criteria
			Transition Zone	3.2	7	0.19 - 10.5		11.17	1.6	1	GWA-1D		1	1	0	N		Single location with detection of molybdenum above background. Does not exhibit a discernible plume. Concentrations are within range of Piedmont background datasets. Groundwater flow direction derived from water elevations collected over 30 monitoring events and velocity vectors derived from groundwater flow and transport modeling simultations indicate this location is beyond the downgradient flow path from the source area.
			Bedrock	3	4	0.13 - 6.2		1.1	0.3	0	-		0	0	0	Y		No means exceed comparative criteria
Strontium	µg/L	NE	Shallow	303	303	9 - 223	27 - 2,272	2,350	7.8	10	AB-1S, AL-1S, CCR-3S, GWA-10S, GWA-11S, GWA-15S, MW-7S, MW-8S, MW-9S, MW-14S	Y	10	7	1	Y	Non-Conservative	Exceedances depict a plume-like distribution likely attributed to the ash basin
			Transition Zone	665	665	81.4 - 732		5,537	8.3	11	AB-1D, AL-1D, CCR-9DA, GWA-1D, GWA-10D, GWA-11D, GWA-15D, MW-6D		11	11	2	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin
			Bedrock	253	253	140 - 407		3,230	12.8	7	AB-1BR, AB-1BRL, AB-1BRLL, AL-1BR, GWA-11BR, MW-8BR, MW-14BR		7	6	1	Y		Exceedances depict a plume-like distribution likely attributed to the ash basin

Prepared by: ECW Checked by: VJH

Notes:

- Reference Criterion
- Evidence warrants COI inclusion for corrective action
- Evidence does not warrant COI inclusion for corrective action

[1] - Constituent list reflects the COIs identified in the 2018 CSA Update report (SynTerra, January 2018), in addition to CCR Rule Appendix IV constituents with statistically significant increases above the groundwater protection standards, and constituents requested for inclusion by NCDEQ.

[2] - Background values include groundwater data collected September 2015 through October 2017.

[3] - Updated background values include groundwater data collected February 2010 through December 2018.

[4] - Exceedance ratio = calculated COI mean concentration divided by criterion concentration.

[5] - Assignment of conservative, non-conservative, or variable behavior is based on geochemical modeling results.

[6] - The following wells were used to calculate mean concentrations for ash pore water: AB-3S, AB-4S/SL, AB-5S, AB-6S, AB-7S, AB-8S, AB-10S/SL, AB-12S/SL, AB-13S, AB-14S, AB-15S/SL, AB-17S, AB-18S, AB-20S, AB-21S, AL-3S

[7] - The following wells were used to calculate mean concentrations near or beyond compliance boundary: AB-1S/D/BR/BRL/BRLL, AB-2S/D, AL-1S/D/BR, CCR-3S/D, CCR-4S/D, CCR-5S/D, CCR-9S/DA, GWA-1S/D/BR, GWA-7S/D, GWA-10S/D, GWA-11S/D/BR, GWA-15S/D, MW-6S/D, MW-7S/D, MW-8S/D, MW-9S/D, MW-10S/D, MW-14S/D/BR

> - greater than

< - less than

COI - constituent of interest

CSA - Comprehensive Site Assessment

IMAC - interim maximum allowable concentration

MCL - maximum contaminant level

µg/L - micrograms per liter

mg/L - milligrams per liter

pCi/L - picocuries per liter

NA - Not Applicable

NE - Not Established

Y - Yes

N - No

TABLE 6-7
SUMMARY TREND ANALYSIS RESULTS FOR
GROUNDWATER MONITORING WELLS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Wells Within the Waste Boundary			
Well ID	Boron	Lithium	Total Dissolved Solids
Shallow Flow Zone			
AB-09S	I	S	I
AB-11S	ND	ND	NT
Deep Flow Zone			
AB-03D	NT	S	S
AB-04D	S	S	S
AB-05D	ND	S	NT
AB-08D	ND	S	S
AB-09D	ND	S	S
AB-10D	I	D	I
AB-11D	ND	S	S
AB-12D	D	D	D
AB-21D	ND	S	S
Bedrock Flow Zone			
AB-05BR	ND	NT	I
AB-09BR	ND	S	S
AB-10BR	S	D	S
AB-12BR	ND	S	S

Wells Between Waste Boundary and Compliance Boundary			
Well ID	Boron	Lithium	Total Dissolved Solids
Shallow Flow Zone			
CCR-12S	I	D	S
CCR-13S	S	I	NT
CCR-14S	I	NT	D
CCR-15S	ND	NT	S
CCR-16S	ND	NT	S
CCR-01S	ND	S	S
CCR-02S	I	S	S
MW-01	D	S	I
OB-01 (Dry Ash Landfill)	NE	NE	NE
Deep Flow Zone			
CCR-12D	ND	D	S
CCR-13D	I	D	I
CCR-14D	I	S	D
CCR-15D	ND	D	S
CCR-16D	ND	S	S
CCR-01D	ND	NT	NT
CCR-02D	S	I	S

Wells Near or Beyond Compliance Boundary			
Well ID	Boron	Lithium	Total Dissolved Solids
Shallow Flow Zone			
AB-01S	S	I	S
AB-02S	ND	S	NT
AL-01S	S	S	NT
CCR-03S	ND	NT	S
CCR-04S	I	I	S
CCR-05S	I	D	I
CCR-09S	D	S	D
GWA-01S	ND	S	I
GWA-07S	ND	S	S
GWA-10S	I	S	I
GWA-11S	S	S	I
GWA-15S	I	S	S
MW-06S	D	D	D
MW-07S	NT	NT	D
MW-08S	I	S	I
MW-09S	ND	NT	I
MW-10S	ND	S	ND
MW-14S	D	S	S
Deep Flow Zone			
AB-01D	I	S	NT
AB-02D	S	S	I
AL-01D	I	S	S
CCR-03D	ND	S	S
CCR-04D	ND	NT	S
CCR-05D	ND	I	S
CCR-09DA	S	S	I
GWA-01D	ND	NT	I
GWA-07D	ND	D	S
GWA-10D	ND	S	I
GWA-11D	I	S	I

Wells Near or Beyond Compliance Boundary			
Well ID	Boron	Lithium	Total Dissolved Solids
Deep Flow Zone			
GWA-15D	NT	S	S
MW-06D	I	S	I
MW-07D	I	S	I
MW-09D	I	NT	I
MW-10D	ND	S	S
MW-14D	D	S	D
Bedrock Wells			
AB-01BR	I	S	I
AB-01BRL	I	S	S
AB-01BRLL	S	S	I
AL-01BR	I	S	I
GWA-01BR	ND	S	NT
GWA-11BR	ND	S	S
MW-08D	I	D	S
MW-14BR	I	S	I

Mann-Kendall trend analysis and results prepared by: Arcadis U.S. Inc. Checked by: MRC

Notes:

1. Summary of results and trends are presented for samples collected from 2011 - 2019.
2. Trend results are presented when at least four samples were available and frequency of detection was >50%. Statistically significant trends are reported at the 95% confidence level.
3. Variability Index (VI) is calculated as the (maximum - minimum) / median concentration and is calculated using detected concentrations only. Values less than 1 indicate low variability in the dataset.

ND	= Greater than 50 percent of constituent concentrations were non-detect
D	= Statistically significant, decreasing concentration trend
S	= Stable. No significant trend and variability is low (VI ≤ 1)
NT	= No significant trend and variability is high (VI > 1)
I	= Statistically significant, increasing concentration trend.
NE	= Insufficient number of samples to evaluate trend (n < 4)

TABLE 6-8
SEEPS CORRECTIVE ACTION STRATEGY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Seep ID	Regulatory Program	General Location	Approximate Average Present Flow (cfs)	Anticipated Seep Corrective Action Strategy
S-01	SOC	Just NE of active basin and flows to intake canal	0.02	Duke Energy anticipates flow will remain. As of November 2019 Duke Energy is conducting additional evaluations of the S-1 and is prepared to manage corrective action for this location. Active remediation and source control are anticipated to reduce COI migration to the area.
S-02	SOC	Just east of active basin near shoreline of intake canal	NDF	Flow could become negligible, however, Duke Energy is prepared to manage corrective action for this location if the seep is not dispositioned through source control measures. Active remediation and source control are anticipated to reduce COI migration to the area.
S-04	SOC	Just east of active basin near shoreline of intake canal	NDF	Flow could become negligible, however, Duke Energy is prepared to manage corrective action for this location if the seep is not dispositioned through source control measures. Active remediation and source control are anticipated to reduce COI migration to the area.

Prepared by: BDW Checked by: WCG

Notes:

cfs- cubic feet per second

COI - Constituent of Interest

SOC – Special Order by Consent

NDF - no discernable flow present

TABLE 6-9
WATER SUPPLY WELL ANALYTICAL RESULTS SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium	Impacted by Coal Ash?	Comments
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L		
15A NCAC 02L Standard		1*	10	700	4*	700	2	250	10	10	1*	300	NE	50	NE	100	20	NE	250	0.2*	500	5^	0.3*		
Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0		
Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	**840**	1.0	50	1.0	3.6	8.1	**11.2**	**2.6**	**1220**	**11.4**	**330**	**3.7**	8.0	1	**313**	22.1	0.2	195	**6.43**	**25.8**		
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6		
Sample ID	**Sample Collection Date**	**Analytical Results**																							
MR1	03/03/2015	0.29 j	<1	13	<1	<500	0.84 j	7.2	<10	<10	<1	28 j	NA	0.68 j	0.11 j	<2	<1	28	11	<1	58	NA	<5	N	All COIs are below comparative criteria
MR10	04/30/2015	<0.5	<0.5	38.8	<0.2	<5	<0.08	2.4	0.43	0.99	<0.5	260	NA	1.7	<0.5	<0.5	<0.5	59	<2	<0.1	65	NA	1.5	N	All COIs are below comparative criteria
MR-1000	10/12/2016	<0.5	0.17	36	<0.1	<25	0.54	2.2	0.7	1.4	<0.1	<50	NA	0.76	<0.5	1.6	<0.5	95.4	<2	NA	91	NA	1.9	N	All COIs are below comparative criteria
MR-1001	10/11/2016	<0.5	<0.1	47.7	<0.1	<25	<0.08	4.8	1.2	1.8	<0.1	<50	NA	1.3	<0.5	0.86	<0.5	140	<2	NA	67	NA	1.1	N	All COIs are below comparative criteria
MR-1002	09/23/2016	<0.5	<0.1	23.1	<0.1	<25	<0.08	1	6.2	7.2	<0.1	<50	NA	0.62	<0.5	<0.5	<0.5	68.5	<2	NA	66	NA	5	N	All COIs are below comparative criteria
MR-1003	10/18/2016	<0.5	0.23	34.3	0.12	<25	<0.08	7.6	2.4	2.6	<0.1	<50	NA	10.5	<0.5	0.59	<0.5	111	3.8	NA	81	NA	1	N	All COIs are below comparative criteria
MR-1004	09/23/2016	<0.5	<0.1	44.9	<0.1	<25	0.24	1.1	2	2.3	<0.1	<50	NA	1.1	<0.5	<0.5	<0.5	160	<2	NA	35	NA	3.7	N	All COIs are below comparative criteria
MR-1005	01/05/2017	<0.5	<0.1	45.2	<0.1	<25	<0.08	2.1	2.5	1.6	<0.1	<50	NA	0.85	<0.5	<0.5	<0.5	103	<2	NA	67	NA	4.4	N	All COIs are below comparative criteria
MR-1006	01/05/2017	<0.5	<0.1	48.6	<0.1	<25	<0.08	3.8	0.77	1.1	<0.1	<50	NA	1.2	<0.5	1	<0.5	**563**	<2	NA	107	NA	2.3	N	Located west and sidegradient of ash basin. Strontium exceedance possible from natural source.
MR-1007	02/21/2017	<0.5	<0.1	412	0.2	<25	<0.08	6.4	1.1	1.5	0.34	<50	NA	6.2	<0.5	3.2	<0.5	156	<2	NA	115	NA	0.42	N	All COIs are below comparative criteria
MR-1008	02/21/2017	<0.5	<0.1	30.8	<0.1	<25	<0.08	1.4	1.7	2.2	<0.1	<50	NA	0.59	<0.5	<0.5	<0.5	98.9	<2	NA	55	NA	3.1	N	All COIs are below comparative criteria
MR-1009	02/21/2017	<0.5	<0.1	20.5	<0.1	<25	<0.08	2	0.63	0.93	<0.1	268	NA	3.6	<0.5	<0.5	<0.5	75.5	<2	NA	84	NA	3.4	N	All COIs are below comparative criteria
MR-1010	04/26/2017	<0.5	<0.1	30.1	<0.1	<25	<0.08	4	5.8	3.1	<0.1	<50	NA	0.91	<0.5	<0.5	<0.5	172	1.2	NA	91	NA	5.8	N	All COIs are below comparative criteria
MR11	04/30/2015	<0.5	<0.5	48.5	<0.2	<5	<0.08	1.3	0.52	0.87	<0.5	<50	NA	0.72	<0.5	<0.5	<0.5	78.2	2	<0.1	71	NA	1	N	All COIs are below comparative criteria
MR12	02/05/2015	<1	2.9 j	34	<2	<130	<0.1	2.3	<20	<25	<25	330	NA	53 B	0.088 j	10 j	<5	99	<1	<0.5	93 B	NA	12 j	N	All COIs are below comparative criteria
MR13	03/03/2015	<3	<10	11.4	<1	<100	<1	1.9	<20	<10	<5	<50	NA	<10	<10	<10	<10	106	<10	<1	56	NA	1.97	N	All COIs are below comparative criteria
MR13	07/31/2015	<0.5	<0.5	32.1	<0.2	<5	<0.08	1.1	0.18	0.56	<0.5	<50	NA	0.79	**4.7**	<0.5	<0.5	**353**	8.4	<0.1	85	NA	2.8		Located west and sidegradient of ash basin. Molybdenum and Strontium exceedances possible from natural source.
MR14	02/05/2015	<1	<1	49	<0.4	<25	<0.1	2.3	<20	<5	<5	210	NA	<5	<10	<5	<1	77	<1	<0.5	67	NA	<5	N	All COIs are below comparative criteria
MR14	05/22/2015	<0.5	<0.5	49.5	<0.2	<5	<0.08	2.3	0.65	0.82	<0.5	<50	NA	1.5	<0.5	<0.5	<0.5	85.3	<2	<0.1	38	NA	1.1		
MR16	02/18/2015	<0.5	<2	86.8	<0.5	<50	<0.15	7	<5	<2	<1	969	NA	131	<2	<0.5	<2	103	16	<0.5	125	NA	0.36	N	All COIs are below comparative criteria
MR16	08/13/2015	<0.5	<0.5	86.5	<0.2	<5	<0.08	10.2	<0.03	<0.5	<0.5	718	NA	112	<0.5	<0.5	<0.5	101	18.7	<0.1	140	NA	<1		
MR17	02/05/2015	<1	<1	12	<0.4	<25	<0.1	1.4	<20	<5	<5	240	NA	<5	<10	<5	<1	160	<1	<0.5	45	NA	<5	N	All COIs are below comparative criteria
MR17	05/20/2015	<0.5	<0.5	10.6	<0.2	<5	<0.08	1.3	0.25	<0.5	<0.5	<50	NA	<0.5	<0.5	<0.5	<0.5	189	<2	<0.1	46 D6	NA	2.6		
MR18	02/05/2015	<5	<5	<25	<2	<130	<0.5	3.3	<20	<25	<25	500	NA	<25	<50	<25	<5	240	1.6	<2.5	88	NA	<25	N	All COIs are below comparative criteria
MR18	05/20/2015	<0.5	<0.5	17	<0.2	<5	<0.08	3.5	0.037	<0.5	<0.5	<50	NA	2	<0.5	<0.5	<0.5	201	2.8	<0.1	82	NA	1.8		
MR2 Office	03/03/2015	<1	<1	31	<1	<500	<1	1.2	<10	4.5	<1	82	NA	<5	<2	<2	<1	100	<1	<1	68	NA	5.5	N	All COIs are below comparative criteria
MR2 Office	08/03/2015	<0.5	<0.5	90.2	<0.2	<5	0.086	1.1	<0.03	<0.5	<0.5	109	NA	17.2	2.1	3.2	<0.5	**378**	3.4	<0.1	92	NA	2.8		Located south and sidegradient of ash basin. Outside half-mile radius from basin. Strontium exceedance possible from natural source.
MR2 Plant	03/03/2015	<1	<1	130	<1	<500	<1	<1	<10	2.1	<1	**3,700**	NA	50	<2	<2	<1	260	4	<1	130	NA	<5	N	Located south and sidegradient of ash basin. Outside half-mile radius from basin. Iron exceedance possible from natural source.
MR20	02/05/2015	<1	<5	14	<2	<130	<0.1	3.3	<20	<25	<25	1100	NA	<25	<10	<25	<5	170	1.3	<0.5	100	NA	<25	N	All COIs are below comparative criteria
MR20	07/31/2015	<0.5	<0.5	14	<0.2	<5	<0.08	3.1	0.43	0.96	<0.5	<50	NA	<0.5	2.2	<0.5	<0.5	132	2.2	<0.1	107	NA	2.8		
MR21	02/05/2015	<1	<5	82	<2	<130	<0.5	4	<20	<25	<25	190	NA	34	<50	<25	<5	<50	<1	<0.5	49	NA	<25	N	All COIs are below comparative criteria
MR21	05/21/2015	<0.5	<0.5	74.6	<0.2	<5	<0.08	4.1	0.15	<0.5	0.75	<50	NA	17.9	<0.5	0.66	<0.5	9.7	<2	<0.1	26	NA	<1		All COIs are below comparative criteria
MR22	04/30/2015	<0.5	<0.5	79.3	<0.2	<5	<0.08	2.3	0.56	0.91	<0.5	<50	NA	3.8	<0.5	0.55	<0.5	34.1	<2	<0.1	55	NA	<1	N	All COIs are below comparative criteria
MR23	02/12/2015	<1	<5	110	<1	<100	<0.1	<5	<10	1	<1	<50	NA	<5	<5	<5	<5	270	<1	<0.1	<25	NA	3	N	All COIs are below comparative criteria
MR23	08/13/2015	<0.5	<0.5	121	<0.2	<5	<0.08	27.6	1.1	1.5	<0.5	<50	NA	1.2	<0.5	<0.5	<0.5	278	2.7	<0.1	194	NA	2.6		
MR23 (State Well)	02/12/2015	<10	<2	130	<5	<50	<0.5	25	<50	<10	<50	<50	NA	<10	<10	<2	<5	280	<2	<2	155	NA	<25	N	All COIs are below comparative criteria
MR25	03/03/2015	<1	<1	47	<1	<500	<1	7.8	<10	<1	<1	<50	NA	<5	<2	<2	<1	110	<1	<1	150	NA	<5	N	All COIs are below comparative criteria
MR25	08/13/2015	<0.5	<0.5	53.8	<0.2	<5	<0.08	6.5	0.96	1.1	<0.5	<50	NA	1.2	<0.5	<0.5	<0.5	110	3.1	<0.1	108	NA	2		
MR26	02/12/2015	<1	<5	56	<1	<100	<0.1	2.68	<10	1	<1	<50	NA	<5	<5	<5	<5	170	1.12	<0.1	80	NA	3	N	All COIs are below comparative criteria
MR26	08/14/2015	<0.5	<0.5	52	<0.2	<5	<0.08	3	1.2 M1	1.4	<0.5	<50	NA	<0.5	<0.5	<0.5	<0.5	149	2	<0.1	66	NA	2.9		
MR26 (State Well)	02/12/2015	<10	<2	57	<5	<50	<0.5	3.4	<50	<10	<50	<50	NA	<10	<10	<2	<5	160	<2	<2	76	NA	<25	N	All COIs are below comparative criteria
MR28	04/30/2015	<0.5	<0.5	44.5	<0.2	<5	<0.08	14 M1	0.064	1	<0.5	114	NA	4.4	<0.5	1.1	<0.5	162	2.4	<0.1	105	NA	1.9	N	All COIs are below comparative criteria
MR29	04/30/2015	<0.5	<0.5	37	<0.2	<5	<0.08	1.5	1.5	2.9	<0.5	<50	NA	3.2	<0.5	0.69	<0.5	106	<2	<0.1	59	NA	2.9	N	All COIs are below comparative criteria
MR30	02/18/2015	<0.4	0.39 j	30.5	<0.11	<20	<0.06	1	2.74	3.22	<0.03	27	NA	<2	0.67 j	0.61	0.43 j	163	5	<0.06	68	NA	2.24	N	All COIs are below comparative criteria
MR31	07/31/2015	<0.5	<0.5	23.3	<0.2	<5	<0.08	1.6	1.4	1.5	<0.5	<50	NA	0.81	<0.5	<0.5	<0.5	46	<2	<0.1	68	NA	4.7	N	All COIs are below comparative criteria
MR32	02/23/2015	<1	<5	130	<1	<100	<0.1	5.72	<10	2	**2**	**3100**	NA	**130**	<5	<5	<5	110	<1	0.1	106	NA	**8**	**NA**	Invalid dataset; turbidity greater than 10 NTUs
MR32	08/03/2015	<0.5	<0.5	107	<0.2	<5	<0.08	5.7	0.41	0.88	<0.5	428	NA	26.9	<0.5	<0.5	<0.5	99.6	<2	<0.1	74	NA	2.2	N	All COIs are below comparative criteria
MR33	05/21/2015	<0.5	<0.5	26.7	<0.2	<5	<0.08	2.9	0.9	1	<0.5	<50	NA	<0.5	<0.5	<0.5	<0.5	46.7	<2	<0.1	57 D6	NA	1.7	N	All COIs are below comparative criteria
MR35	05/21/2015	<0.5	<0.5	18	<0.2	<5	<0.08	1.4	<0.03	<0.5	<0.5	65.4	NA	23.5	1.3	<0.5	<0.5	95	5	<0.1	96	NA	2	N	All COIs are below comparative criteria
MR36	05/22/2015	<0.5	<0.5	<0.3	<0.2	<5	<0.08	2.7	<0.03	<0.5	<0.5	105	NA	0.54	<0.5	<0.5	<0.5	<0.5	11.7	<0.1	75	NA	<1	N	All COIs are below comparative criteria
MR37	05/21/2015	<0.5	<0.5	32.3	<0.2	<5	<0.08	5.3	2.7	2.8	<0.5	<50	NA	4.1	<0.5	<0.5	<0.5	21.9	<2	<0.1	**2,040**	NA	<1	N	Located northwest and upgradient of ash basin. Total dissolved solution exceedance possible from natural source.
MR38	05/22/2015	<0.5	<0.5	91.7	0.21	<5	<0.08	1.5	1.3	1.7	<0.5	<50	NA	5.3	<0.5	0.51	<0.5	36	<2	<0.1	224	NA	<1	N	All COIs are below comparative criteria
MR4	02/05/2015	<1	0.66 j	370	0.19 j	<25	0.12 B	55	<20	<5	0.36 j	1,200	NA	30 B	<10	3.5 j	0.3 j	**580**	<1	<0.5	200 B	NA	<5	N	Located north and upgradient of ash basin. Strontium exceedance possible from natural source.
MR40	07/31/2015	<0.5	<0.5	17.4	<0.2	<5	0.09	2.8	0.5	0.56	<0.5	<50	NA	5.1	<0.5	<0.5	<0.5	100	<2	<0.1	97	NA	1.5	N	All COIs are below comparative criteria
MR42	07/31/2015	<0.5	<0.5	35	<0.2	<5	<0.08	4.1	0.63	0.96	<0.5	<50	NA	<0.5	<0.5	<0.5	<0.5	60.3	<2	<0.1	47	NA	<1	N	All COIs are below comparative criteria
MR43	05/28/2015	<0.5	<0.5	43	<0.2	<5	<0.08	1.6	2.4	4.8	<0.5	190	NA	1.9	<0.5	1.2	<0.5	76.3	<2	<0.1	90	NA	3.9	N	All COIs are below comparative criteria
MR44	04/30/2015	<0.5	<0.5	33	<0.2	5.1	<0.08	1.6	0.54	1.2	<0.5	327	NA	0.96	<0.5	<0.5	<0.5	196	<2	<0.1	93	NA	5.1	N	All COIs are below comparative criteria

TABLE 6-9
WATER SUPPLY WELL ANALYTICAL RESULTS SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Analytical Parameter		Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chloride	Chromium (VI)	Chromium	Cobalt	Iron	Lithium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Sulfate	Thallium	Total Dissolved Solids	Total Radium	Vanadium	Impacted by Coal Ash?	Comments
Reporting Units		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	pCi/L	µg/L		
15A NCAC 02L Standard		**1***	**10**	700	**4***	**700**	**2**	**250**	**10**	10	1*	300	NE	50	NE	**100**	**20**	NE	**250**	**0.2***	**500**	5^	0.3*		
Background Threshold Values (Bedrock Flow Zone)[1]		0.5	0.6	435	0.2	50	0.08	4.5	3.9	8.3	2.8	792	---	26.6	3.0	7.2	1	253	18.4	0.1	216	5.7	16.0		
Background Threshold Values (Bedrock Flow Zone)[2]		1.0	1.1	**840**	1.0	50	1.0	3.6	8.1	**11.2**	**2.6**	**1220**	**11.4**	**330**	**3.7**	8.0	1	**313**	22.1	0.2	195	**6.43**	**25.8**		
Background Data Set Range (Bedrock Flow Zone)[2]		0.11 - 1.25	0.071 j - 2.3	23 - 857	0.01 j - 1.8	25.9 j - 49.1 j	0.054 j - 1.9	1.2 - 4	0.012 j - 11.8	0.23 j - 31	0.026 j - 3.9	16 - 1530	3.8 - 11	2.8 j - 385	0.13 j - 6.2	0.33 j - 22.8	0.17 j - 2.3	140 - 407	0.42 j - 23.9	0.016 j - 0.069 j	42 - 240	4.6E-05 j - 1.5E-04 j	0.099 j -26.6		
Sample ID	**Sample Collection Date**	**Analytical Results**																							
MR45	05/28/2015	<0.5	<0.5	127	<0.2	<5	<0.08	6.2	0.73	1	<0.5	<50	NA	12	<0.5	0.97	<0.5	37.4	<2	<0.1	65	NA	<1	N	All COIs are below comparative criteria
MR46	07/31/2015	<0.5	<0.5	38.7	<0.2	<5	<0.08	1.6	0.6	0.97	<0.5	<50	NA	10.2	<0.5	<0.5	<0.5	45.7	2.3	<0.1	55	NA	1.2	N	All COIs are below comparative criteria
MR47	08/04/2015	<0.5	<0.5	83.5	<0.2	<5	<0.08	1.1	1.3	1.6	<0.5	<50	NA	0.86	<0.5	0.72	<0.5	129	<2	<0.1	50 D6	NA	1.7	N	All COIs are below comparative criteria
MR48	10/23/2015	<0.5	<0.5	58.4	<0.2	<5	<0.08	2.5	0.98 H3	1.4	<0.5	<50	NA	5.4	<0.5	0.52	<0.5	55.8	<2	<0.1	49	NA	1.1	N	All COIs are below comparative criteria
MR6	02/18/2015	<0.5	<2	52.9	<0.5	<50	<0.15	4	<5	<2	<1	<25	NA	<2	<2	<0.5	<2	309	<5	<0.5	119	NA	1.29	N	All COIs are below comparative criteria
MR6	08/07/2015	<0.5	<0.5	50.5	<0.2	<5	<0.08	4.7	0.83	1	<0.5	<50	NA	0.92	<0.5	<0.5	<0.5	291	<2	<0.1	103	NA	1.5		
MR8	02/18/2015	<0.5	<2	12.7	<0.5	<50	<0.15	2	<5	<2	<1	<25	NA	<2	2.8	<0.5	<2	50	<5	<0.5	95	NA	2.65	N	All COIs are below comparative criteria
MR8	08/05/2015	<0.5	<0.5	14	<0.2	<5	<0.08	2.2	0.56	0.81	<0.5	<50	NA	1.8	1.9	<0.5	<0.5	44.1	2.6	<0.1	98	NA	2.4		
MR9	02/05/2015	<1	<1	18	<0.4	<25	<0.1	1.3	<20	<5	<5	180	NA	<5	<10	<5	<1	81	<1	<0.5	88	NA	5.8	N	All COIs are below comparative criteria
MR9	05/20/2015	<0.5	<0.5	17.6	<0.2	<5	<0.08	1	0.68	0.92	<0.5	<50	NA	<0.5	<0.5	<0.5	<0.5	83.5	<2	<0.1	83	NA	6.4		

Prepared By: ECW Checked By: CMH

Notes:

[1] - Background threshold values were calculated using data from background groundwater samples collected June 2015 to September 2017.

[2] - Background threshold values were calculated using data from background groundwater samples collected March 2011 to December 2018.

Bold text - greatest comparative value

- bold highlighted concentration indicates value is greater than the 15A NCAC 02L .0202 Standard or the IMAC. (Effective date for 15A NCAC 02L .0202 Standard and IMAC is April 1, 2013)
- bold highlighted concentration indicates value is greater than greatest background threshold value where there is no regulatory standard, or background threshold values are greater than regulatory standard
- highlighted concentration indicates value is either within range of background threshold values for constituents where there is no regulatory standard/background threshold values are greater than regulatory standard, or within range of background threshold value and the regulatory standard
- highlighted concentration indicates turbidity value is out of range [>10 Nephelometric Turbidity Units (NTUs)] or pH value was not measured. Results are deemed invalid.

* - Interim Maximum Allowable Concentrations (IMACs) of the 15A NCAC 02L Standard, Appendix 1, April 1, 2013.

< - concentration not detected at or above the adjusted reporting limit.

NE - not established

NA - not available

mg/L - milligrams per liter

µg/L - micrograms per liter

pCi/L - picocuries per liter

j - Estimated concentration above the adjusted method detection limit and below the adjusted reporting limit.

H3 - Sample was received or analysis requested beyond the recognized method holding time.

B - Target analyte detected in method blank at or above the reporting limit. Target analyte concentration in sample is less than 10X the concentration in the method blank. Analyte concentration in sample could be due to blank contamination.

D6 - The precision between the sample and sample duplicate exceeded laboratory control limits.

M1 - Matrix spike recovery was high: the associated Laboratory Control Spike (LCS) was acceptable.

TABLE 6-10
NPDES PERMITS LIMITS AND ANTICIPATED GROUNDWATER REMEDIATION PARAMETER LEVELS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

NPDES Permit Parameter	Outfall 002[10]		Outfall 005		Geomean Concentration of Anticipated Groundwater Discharge [9]
	Monthly Average	Daily Maximum	Monthly Average	Daily Maximum	
Flow (million gallons/day)	Not specified	1	Monitor and Report		Not applicable
Oil & Grease	9.0 mg/L	12.0 mg/L	15.0 mg/L	20.0 mg/L	Not applicable
Total Suspended Solids (TSS) [1]	20.0 mg/L	50.0 mg/L	30.0 mg/L	50.0 mg/L	3.7 mg/L
Total Arsenic	397.1 µg/L	11,121 µg/L	Monitor and Report		0.3 µg/L
Total Cadmium, µg/L	Not applicable		Monitor and Report		Not applicable
Total Copper [3]	1.0 mg/L	1.0 mg/L	68.8 µg/L	76.8 µg/L	0.9 mg/L
Total Chromium, µg/L	-		Monitor and Report		Not applicable
Total Iron [3]	1.0 mg/L	1.0 mg/L	1.0 mg/L	1.0 mg/L	0.252 mg/L
Total Lead, µg/L	-		Monitor and Report		Not applicable
Total Mercury, ng/L	Monitor and Report		Monitor and Report		Not applicable
Total Nickel, µg/L	-		Monitor and Report		Not applicable
Total Selenium, µg/L	Monitor and Report		Monitor and Report		1.0 µg/L
Total Silver, µg/L	-		Monitor and Report		Not applicable
Total Zinc, µg/L	-		Monitor and Report		Not applicable
BOD, 5-day, 20°C [2]	30.0 mg/L	45.0 mg/L	-		Not applicable
Nitrate/nitrite as N, mg/L	Monitor and Report		-		Not applicable
Sulfate, mg/L	-		Monitor and Report		32.2 µg/L
Chloride, mg/L	-		Monitor and Report		41.4 mg/L
Bromide, mg/L	Monitor and Report		Monitor and Report		Not applicable
Fluoride, mg/L	-		-		Not applicable
TDS, mg/L	-		Monitor and Report		322 mg/L
Hardness, mg/L	Monitor and Report		Monitor and Report		Not applicable
Total Nitrogen (NO_2+NO_3+TKN), mg/L	Monitor and Report		Monitor and Report		Not applicable
Total Phosphorus, mg/L	Monitor and Report		Monitor and Report		Not applicable
Chronic Toxicity	See Part I, Section A. (17.)		See Part I, Section A. (17.)		Not applicable
pH [7]	Between 6.0 and 9.0 S.U.		Between 6.0 and 9.0 S.U.		5.8 S.U.
Other COIs Not Specified in the NPDES Permit					
Barium	Not applicable	Not applicable	Not applicable	Not applicable	107.2 µg/L
Beryllium	Not applicable	Not applicable	Not applicable	Not applicable	0.18 µg/L
Boron	Not applicable	Not applicable	Not applicable	Not applicable	533 µg/L
Cobalt	Not applicable	Not applicable	Not applicable	Not applicable	0.75 µg/L
Hexavalent Chromium	Not applicable	Not applicable	Not applicable	Not applicable	0.09 µg/L
Lithium	Not applicable	Not applicable	Not applicable	Not applicable	5.1 µg/L
Manganese	Not applicable	Not applicable	Not applicable	Not applicable	96.0 µg/L
Molybdenum	Not applicable	Not applicable	Not applicable	Not applicable	0.57 µg/L
Radium (total)[8]	Not applicable	Not applicable	Not applicable	Not applicable	4.13 pCi/L
Strontium	Not applicable	Not applicable	Not applicable	Not applicable	945 µg/L
Thallium	Not applicable	Not applicable	Not applicable	Not applicable	0.13 µg/L

Prepared by: WCG Checked by: BDW

Notes:

Constituents indicated as "not applicable" are not constituents of interest associated with the source area

µg/L - Micrograms per liter mg/L - Milligrams per S.U. - Standard Unit

[1] – Effluent sampling shall be conducted at the discharge from the ash settling basin prior to mixing with any other waste stream(s).

[2] - The facility shall continuously monitor TSS concentrations when the dewatering process commences and the dewatering pump shall be shut off automatically when one half of the Daily Maximum limit (15 minutes average) is exceeded. Pumping will be allowed to continue if interruption might result in a dam failure or damage. The continuous TSS monitoring only required when the pumps are employed for dewatering.

[3] – The limits for total copper and total iron only apply when chemical metal cleaning wastewaters are being discharged.

[7] – The facility shall continuously monitor pH when the dewatering process commences and the dewatering pump shall be shut off automatically when 15 minutes running average pH falls below 6.1 S.U., or rises above 8.9 S.U. Pumping will be allowed to continue if interruption might result in a dam failure or damage. Continuous pH monitoring is only required when the pumps are employed for dewatering.

[8] – Arithmetic average, the geomean is not applicable for data sets containing non-positive numbers.

[9] – Groundwater quality data from 2018 and 2019 quarterly sampling events from the following wells completed in the shallow, deep, and bedrock flow zones. The monitoring wells are located near proposed extraction wells in the ash basin vicinity and north of the ash basin dam:

- AB-01BR, -01BRL, -01BRLL;
- AB-01D, -01S;
- AL-01BR, -01BRL, -01D, -01S;
- CCR-09DA, -09S;
- CCR-11D, -11S;
- CCR-13D, -13S;
- CCR-14D, -14S;
- CCR-15D, -15S;
- CCR-16D, -16S;
- GWA-11BR, -11D, -11S;
- GWA-15D, -15S;
- MW-01;
- MW-02;
- MW-06D, -06S;
- MW-07D, -07S;
- MW-08D, -08S;
- MW-10D, -10S; and
- MW-14BR, -14BRL, -14D, -14S.

[10] - Outfall 002 effluent limitations during dewatering phase

TABLE 6-11
FEATURE IRRIGATION SYSTEM SETBACK
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Feature	Irrigation System Setback (feet)	
	Spray	Drip
Private residence	400	100
Place of assembly owned by permittee	200	15
Surface waters	100	100
Property line	150	50

Prepared by: WCG Checked by: ECW

Notes:

Reference: 15A NCAC 02T .056

TABLE 6-12
REMEDIAL TECHNOLOGY SCREENING SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Summary of Remedial Technology Screening	Retain Technology for Further Consideration	
Technology	Yes/No	Rationale
Monitored Natural Attenuation (MNA)	Yes	COIs pose no unacceptable risk to human health or the environment under conservative exposure scenarios. MNA could be implemented in conjunction with source control measures.
In-Situ Technologies		
Low Permeability Barriers (LPB)	No	Technically challenging and costly. The saprolite and transition zone is too thick and bedrock is too deep to be feasible. Implementation could cause groundwater mounding and alternate flow paths.
Groundwater Infiltration and Flushing	Yes	Possible application to enhance capture of mobile COIs (*e.g.,* boron).
Encapsulation	No	Volume of CCR waste in the ash basin is too great to implement as a groundwater corrective measure. Varied site conditions may make uniform application difficult.
Permeable Reactive Barrier (PRB)	Yes	The saprolite and transition zone is too thick and bedrock is too deep to be feasible for implementation by open trenching. Injection of chemical amendments through a line of offset boreholes is technically feasible.
Groundwater Extraction		
Vertical Extraction Wells	Yes	Would have potential application for alternatives involving groundwater extraction.
Horizontal/Angular Extraction Wells	No	Vertical extraction wells are deemed more cost effective. Might have potential application for alternatives involving groundwater extraction where vertical wells are not feasible.
Extraction Trenches	No	The saprolite and transition zone is too thick and bedrock is too deep to be effective.
Hydraulic Fracturing	No	COI occurrence be bedrock is limited. Contingent option based on observed yield of extraction wells.
Phytoremediation	No	Effectiveness is variable with the growing season. Flow and Transport modeling indicates that the flow rates needed to meet remedial objectives are too great to be achieved by phytoremediation.
Groundwater Treatment		
pH Adjustment	Yes	Retained for remedial alternatives that include groundwater extraction, if needed to meet discharge requirements.

TABLE 6-12
REMEDIAL TECHNOLOGY SCREENING SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Summary of Remedial Technology Screening	Retain Technology for Further Consideration	
Technology	Yes/No	Rationale
Groundwater Treatment Technologies (Continued)		
Precipitation	No	Extracted groundwater is not expected to cause violations of the NPDES permit when discharged; therefore, precipitation technologies are not retained for further consideration.
Ion Exchange	No	Requires a feasible and economical method to dispose of the regeneration effluent. Susceptible to geochemical interferences.
Membrane Filtration	No	Pretreatment and a high volume of reject effluent that requires additional treatment prior to disposal.
Groundwater Disposal		
NPDES Permitted Discharge	Yes	Existing permitted discharges for wastewater are already in place. Permit modification would be required for the discharge of treated groundwater.
Publically Owned Treatment Works (POTW)	No	Acceptance of industrial waste water by the Sewer Authority is doubtful. Additional construction of sewer line along public ROW and monthly utility charges might be cost prohibitive.
Non-Discharge Permit		
Infiltration Gallery	No	Soil type might be amenable to long term infiltration. Will help to mobilize residual COIs in the vadose zone, however, extracted groundwater would require treatment prior to infiltration to meet 02L standards.
Land Application	No	Potential application to maintain vegetative cover following basin closure.
Beneficial Reuse		
Fire Protection	No	Potential but limited application. Not feasible for long-term application.
Non-Contact Cooling Water	No	Alkalinity and TDS may cause scaling problems for some applications.
Dust Suppression and Truck Wash	No	Potential application, but not recommended at this time.

Prepared by: WCG Checked by: BDW

TABLE 6-13
ALTERNATIVE 3 GROUNDWATER EXTRACTION AND CLEAN WATER INFILTRATION WELL SUMMARY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Extraction Well System		
Number of Wells	**Flow Zone**	**Total Depth (ft bgs)**
42	transition zone / upper bedrock	125 - 165
24	upper bedrock	230 - 245
Total Extraction Well Count: 66		
System Flow and operation assumptions: Average flow rate: 9.8 gpm per well. Total system extraction flow rate = 652 gpm. Extraction wells operate to maintain water level between 125 to 150 feet below ground surface. Average screen length: 100 feet		
Vertical Clean Water Infiltration Wells		
Number of Wells	**Flow Zone**	**Total Depth (ft bgs)**
24	saprolite zone	40 - 70
Total Infiltration Well Count: 24		
System Flow and operation assumptions: Average infiltration rate: 11.5 gpm per well. Total system infiltration flow rate = 285 gpm. Infiltration wells operate to maintain water level at about 2 feet below ground surface. Average screen length: 15 feet		

Prepared by: WCG Checked by: ECW

Notes:

ft bgs - feet below ground surface

gpm - gallons per minute

TABLE 6-14
ENVIRONMENTAL SUSTAINABILITY COMPARISONS FOR REMEDIATION ALTERNATIVES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Remedial Alternative		Remedial Alternative 1 – Groundwater Remediation by MNA	Remedial Alternative 2 – Groundwater Remediation by Extraction, Clean Water Infiltration, and In-Situ Treatment	Remedial Alternative 3 – Groundwater Remediation by Extraction and Clean Water Infiltration
Emissions	**Units**			
CO_2 Emissions	metric ton	9.66E+01	6.64E+04	1.17E+04
Onsite NO_x Emissions	metric ton	1.46E-01	1.90E+00	4.73E+00
Onsite SO_x Emissions	metric ton	1.49E-02	1.37E-01	4.83E-01
Onsite PM_{10} Emissions	metric ton	1.31E-02	1.10E-01	4.26E-01
Total NO_x Emissions	metric ton	2.00E-01	1.87E+02	3.91E+01
Total SO_x Emissions	metric ton	7.50E-02	1.79E+02	2.87E+01
Total PM_{10} Emissions	metric ton	2.24E-02	3.43E+01	1.40E+01
Total Energy Used	MMBTU	2.29E+04	3.87E+07	4.26E+06
Total Emissions	**metric ton**	**9.70E+01**	**6.68E+04**	**1.18E+04**

Prepared by: GTC Checked by: CBC

Notes:

CO_2 - Airborne emissions of carbon dioxide

MMBTU - Million British Thermal Units

MNA - Monitored Natural Attenuation

NO_X - Airborne emissions of nitrogen oxides (combination of nitrogen monoxide and nitrogen dioxide)

SO_X - Airborne emissions of sulfur oxides (combination of sulfur monoxide, sulfur dioxide, sulfur trioxide, and others)

PM_{10} - Airborne emissions of particulate matter that is 10 micrometers or less in diameter

TABLE 6-15
MODELED CLEAN WATER INFILTRATION WELL DETAILS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Easting (ft NAD 83)	Northing (ft NAD 83)	Approximate Ground Surface Elevation (feet)	Operational DTW Maintained In Well (ft BGS)	Well Depth (ft BGS)	Targeted Flow Zone	Total Simulated Flow (gpm)
Vertical Clean Water Infiltration Wells							
IW-01	1,417,021.17	683,539.53	819	2	55	Saprolite	11.9
IW-02	1,417,053.64	683,477.46	809	2	48	Saprolite	11.9
IW-03	1,417,080.43	683,402.72	809	2	53	Saprolite	11.9
IW-04	1,417,095.94	683,322.35	811	2	54	Saprolite	11.9
IW-05	1,417,124.01	683,252.59	802	2	70	Saprolite	11.9
IW-06	1,417,140.93	683,193.37	807	2	53	Saprolite	11.9
IW-07	1,417,156.44	683,125.68	812	2	59	Saprolite	11.9
IW-08	1,417,174.78	683,058.00	813	2	62	Saprolite	11.9
IW-09	1,417,223.85	682,988.28	816	2	69	Saprolite	11.9
IW-10	1,417,277.55	682,929.54	814	2	72	Saprolite	11.9
IW-11	1,417,353.76	682,873.46	803	2	71	Saprolite	11.9
IW-12	1,417,411.94	682,767.47	807	2	73	Saprolite	11.9
IW-13	1,417,479.14	682,694.35	804	2	70	Saprolite	11.9
IW-14	1,417,565.41	682,638.94	803	2	70	Saprolite	11.9
IW-15	1,417,209.60	683,350.10	789	2	41	Saprolite	11.9
IW-16	1,417,238.10	683,238.30	788	2	39	Saprolite	11.9
IW-17	1,417,261.30	683,138.80	801	2	56	Saprolite	11.9
IW-18	1,417,327.70	683,047.60	799	2	59	Saprolite	11.9
IW-19	1,417,397.30	682,948.00	797	2	64	Saprolite	11.9
IW-20	1,417,455.70	682,871.00	796	2	64	Saprolite	11.9
IW-21	1,417,506.80	682,789.40	802	2	72	Saprolite	11.9
IW-22	1,417,557.30	682,745.60	793	2	63	Saprolite	11.9
IW-23	1,417,621.40	682,722.00	790	2	63	Saprolite	11.9
IW-24	1,417,687.20	682,686.60	773	2	50	Saprolite	11.9

Prepared by: GTC Checked by: YG

Notes:
All depths are approximated and may change depending on site conditions.
Flowrates are approximate and may change depending on site conditions.
Screen bottom elevation assumes screen goes to top of competent bedrock and open bore below.
25 foot screen assumption for vertical infiltration wells
DTW - depth to water
ft - feet
ft BGS - feet below ground surface
gpm - gallons per minute
NAD 83 - North American Datum 1983

TABLE 6-16
MODELED GROUNDWATER EXTRACTION WELL DETAILS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Easting (ft NAD 83)	Northing (ft NAD 83)	Approximate Ground Surface Elevation (feet)	Operational DTW Maintained In Well (ft BGS)	Well Depth (ft BGS)	Targeted Flow Zones	Total Simulated Flow (gpm)
Vertical Groundwater Extraction Wells							
EX-01	1,415,623.10	683,524.60	791	106	126	Saprolite/Transition Zone/Bedrock	8.5
EX-02	1,415,670.40	683,584.40	799	114	139	Saprolite/Transition Zone/Bedrock	8.5
EX-03	1,415,727.10	683,666.30	801	115	140	Saprolite/Transition Zone/Bedrock	8.5
EX-04	1,415,786.90	683,738.70	808	121	146	Saprolite/Transition Zone/Bedrock	8.5
EX-05	1,415,849.90	683,779.60	821	132	158	Saprolite/Transition Zone/Bedrock	8.5
EX-06	1,415,906.50	683,826.90	813	122	148	Saprolite/Transition Zone/Bedrock	8.5
EX-07	1,415,947.50	683,886.70	817	124	149	Saprolite/Transition Zone/Bedrock	8.5
EX-08	1,415,988.40	683,940.20	827	132	156	Saprolite/Transition Zone/Bedrock	8.5
EX-09	1,416,161.45	683,645.80	795	99	127	Saprolite/Transition Zone/Bedrock	10.1
EX-10	1,416,607.39	683,660.09	835	145	162	Saprolite/Transition Zone/Bedrock	10.1
EX-11	1,416,848.67	683,558.02	828	146	165	Saprolite/Transition Zone/Bedrock	10.1
EX-12	1,416,894.13	683,451.30	824	141	163	Saprolite/Transition Zone/Bedrock	10.1
EX-13	1,416,921.80	683,336.67	826	145	166	Saprolite/Transition Zone/Bedrock	10.1
EX-14	1,416,945.52	683,229.95	817	137	157	Saprolite/Transition Zone/Bedrock	10.1
EX-15	1,416,981.09	683,119.27	817	138	160	Saprolite/Transition Zone/Bedrock	10.1
EX-16	1,417,056.19	683,024.40	818	148	171	Saprolite/Transition Zone/Bedrock	10.1
EX-17	1,417,131.30	682,927.56	819	157	183	Saprolite/Transition Zone/Bedrock	10.1
EX-18	1,417,218.26	682,822.81	820	164	190	Saprolite/Transition Zone/Bedrock	10.1
EX-19	1,417,273.59	682,741.78	816	166	190	Saprolite/Transition Zone/Bedrock	10.1
EX-20	1,417,340.95	682,633.90	818	166	193	Saprolite/Transition Zone/Bedrock	10.1
EX-21	1,417,457.40	682,556.00	805	157	180	Saprolite/Transition Zone/Bedrock	10.1
EX-22	1,417,514.71	682,445.32	803	155	177	Saprolite/Transition Zone/Bedrock	10.1
EX-23	1,417,593.77	682,575.76	801	153	177	Saprolite/Transition Zone/Bedrock	10.1
EX-24	1,417,698.05	682,466.57	799	150	175	Saprolite/Transition Zone/Bedrock	10.1
EX-25	1,417,703.80	682,624.30	781	134	159	Saprolite/Transition Zone/Bedrock	10.1
EX-26	1,417,745.64	682,529.29	780	133	158	Saprolite/Transition Zone/Bedrock	10.1
EX-27	1,417,946.79	682,397.36	761	115	142	Saprolite/Transition Zone/Bedrock	10.1
EX-28	1,417,992.21	682,356.26	769	122	151	Saprolite/Transition Zone/Bedrock	10.1
EX-29	1,418,057.09	682,282.72	772	130	158	Saprolite/Transition Zone/Bedrock	10.1
EX-30	1,418,096.77	682,214.61	780	143	168	Saprolite/Transition Zone/Bedrock	10.1
EX-31	1,418,162.86	682,191.28	780	145	245	Bedrock	10.1
EX-32	1,418,180.10	682,109.50	785	149	250	Bedrock	10.4
EX-33	1,418,229.20	682,029.00	783	149	249	Bedrock	10.4
EX-34	1,418,233.11	681,907.25	781	149	249	Bedrock	10.4
EX-35	1,418,229.18	681,795.31	781	150	250	Bedrock	10.4
EX-36	1,418,187.94	681,673.55	784	153	253	Bedrock	10.4
EX-37	1,418,178.12	681,567.50	785	157	257	Bedrock	10.4
EX-38	1,418,123.13	681,404.50	777	152	252	Bedrock	10.4
EX-39	1,417,977.80	681,400.57	777	145	244	Bedrock	10.4
EX-40	1,417,889.43	681,481.09	780	140	240	Bedrock	10.4
EX-41	1,417,808.91	681,516.44	777	132	233	Bedrock	10.4
EX-42	1,417,667.70	681,436.50	771	119	218	Bedrock	10.4
EX-43	1,417,611.60	681,342.20	765	113	215	Bedrock	10.4
EX-44	1,417,552.90	681,227.40	764	126	224	Bedrock	10.4
EX-45	1,417,508.00	681,115.00	764	132	234	Bedrock	10.4
EX-46	1,417,444.00	681,029.00	760	132	236	Bedrock	10.4
EX-47	1,417,383.00	680,933.00	758	132	236	Bedrock	10.4
EX-48	1,417,343.30	680,813.20	743	118	222	Bedrock	10.2
EX-49	1,417,298.00	680,684.00	730	102	207	Bedrock	10.2
EX-50	1,417,261.01	680,586.11	719	92	196	Bedrock	10.2
EX-51	1,417,210.19	680,461.04	713	86	189	Bedrock	10.2
EX-52	1,417,144.50	680,351.60	715	87	189	Bedrock	10.2
EX-53	1,417,080.00	680,219.00	736	104	207	Bedrock	10.2
EX-54	1,417,019.63	680,140.34	753	121	222	Bedrock	10.2
EX-55	1,416,959.80	680,028.50	763	129	230	Bedrock	10.2

TABLE 6-16
MODELED GROUNDWATER EXTRACTION WELL DETAILS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

Well ID	Easting (ft NAD 83)	Northing (ft NAD 83)	Approximate Ground Surface Elevation (feet)	Operational DTW Maintained In Well (ft BGS)	Well Depth (ft BGS)	Targeted Flow Zones	Total Simulated Flow (gpm)
EX-56	1,417,165.00	683,479.00	794	113	138	Saprolite/Transition Zone/Bedrock	9.4
EX-57	1,417,197.00	683,387.00	789	111	135	Saprolite/Transition Zone/Bedrock	9.4
EX-58	1,417,217.00	683,291.00	791	115	141	Saprolite/Transition Zone/Bedrock	9.4
EX-59	1,417,249.00	683,183.00	795	127	152	Saprolite/Transition Zone/Bedrock	9.4
EX-60	1,417,277.00	683,087.00	806	144	169	Saprolite/Transition Zone/Bedrock	9.4
EX-61	1,417,365.00	682,991.00	793	134	166	Saprolite/Transition Zone/Bedrock	9.4
EX-62	1,417,429.00	682,903.00	796	145	169	Saprolite/Transition Zone/Bedrock	9.4
EX-63	1,417,492.60	682,823.40	800	152	176	Saprolite/Transition Zone/Bedrock	9.4
EX-64	1,417,529.00	682,759.00	793	144	170	Saprolite/Transition Zone/Bedrock	9.4
EX-65	1,417,653.00	682,723.00	773	125	151	Saprolite/Transition Zone/Bedrock	9.4
EX-66	1,417,587.60	682,732.70	782	135	161	Saprolite/Transition Zone/Bedrock	9.4

Prepared by: GTC Checked by: YG

Notes:

All depths are approximated and may change depending on site conditions.
Flowrates are approximate and may change depending on site conditions.
Screen bottom elevation assumes screen goes to top of competent bedrock and open bore below.
15 ft screen assumption for vertical extraction wells
DTW - depth to water
ft - feet
ft BGS - feet below ground surface
gpm - gallons per minute
NAD 83 - North American Datum 1983

TABLE 6-17
EFFECTIVENESS MONITORING PLAN ELEMENTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
DUKE ENERGY CAROLINAS, LLC, TERRELL, NC

	Effectiveness Monitoring Plan (EMP) Implemented 30 days after CAP approval	Post-Closure Monitoring Plan (PCMP) Implemented after completion of ash basin closure activities
Groundwater Monitoring Network	**Remedial Action Groundwater Performance Monitoring Well Network**	**PCMP Groundwater Monitoring Well Network (background, downgradient of ash basin)**

AB-1BR	CCR-14D[4]	MW-6D	PVSF-3S	Upgradient/ Background Wells[3]	Geochemical Transect Wells[1]
AB-1BRL	CP-1S	MW-7S[1]	PVSF-3D	BG-1S	AB-1S
AB-1BRLL	CP-1D	MW-7D[1]	PVSF-3BR	BG-1D	AB-1D
AB-1BRLLL	CP-1BR[5]	MW-8S	PVSF-4S	BG-1BRA	AB-2S
AB-2BR	EMP-01BR[2]	MW-8D	PVSF-4D	BG-2S	AB-2D
AL-1S	EMP-02BR[2]	MW-9S	PVSF-4BR	BG-2BR	EMP-01S[2]
AL-1D	EMP-03S[2]	MW-9D		BG-3S	EMP-01D[2]
AL-1BR	EMP-03D[2]	MW-12S		BG-3D	EMP-02S[2]
AL-1BRL	EMP-03BR[2]	MW-12D		BG-3BR	EMP-02D[2]
CCR-4S	EMP-04S[2]	MW-14S		GWA-4S	CCR-5S
CCR-4D	EMP-04D[2]	MW-14D		GWA-4D	CCR-5D
CCR-9S	EMP-04BR[2]	MW-14BR		GWA-5S	GWA-15S
CCR-9DA	ILF-2S	MW-14BRL		GWA-5D	GWA-15D
CCR-11S[4]	ILF-2D	PVSF-1S		GWA-6S	MW-10S
CCR-11D[4]	GWA-10S	PVSF-1D		GWA-6D	MW-10D
CCR-12S[4]	GWA-10D	PVSF-1BR		GWA-8S	
CCR-12D[4]	GWA-11S	PVSF-2S		GWA-8D	
CCR-13S[4]	GWA-11D	PVSF-2D		GWA-12S	
CCR-13D[4]	GWA-11BR	PVSF-2BR		GWA-12D	
CCR-14S[4]	MW-6S	PVSF-2BRL[5]			

A PCMP will be implemented at the Site in accordance with G.S. 130A-309.214(a)(4)k.2 after completion of ash basin closure activities.

Sampling Parameters and Frequency

EMP Groundwater Quality[7,8] (Semi-Annual Sampling Frequency)		
Alkalinity	Cobalt	Selenium
Aluminum	*Ferrous Iron*	Strontium
Antimony	*Iron*	*Sodium*
Barium	Lithium[6]	*Sulfate*
Beryllium	*Magnesium*	Thallium
Bicarbonate Alkalinity	*Manganese*	Total Dissolved Solids (TDS)[6]
Boron[6]	Molybdenum	Radium (total)[9]
Calcium	*Nitrate + Nitrite*	*Total Organic Carbon*
Chloride[6]	*Potassium*	Vanadium

PCMP Groundwater Quality (Sampling frequency to be determined)

Parameters and sampling frequency to be included in the PCMP in accordance with G.S. 130A-309.214(a)(4)k.2 when submitted.

EMP and PCMP Groundwater Field Parameters

Water Level	Specific Conductivity	Temperature
pH	Oxidation Reduction Potential	Dissolved Oxygen

Review and Reporting

EMP Duration

Annual Effectiveness Monitoring Evaluation and Reporting
1) Summary of annual groundwater monitoring results
2) Evaluate statistical concentration trends
3) Comparison of observed concentrations to model predictions
4) Evaluation of compliance with applicable Standards
5) Evaluation of system performance and effectiveness
6) Recommend plan adjustments, if applicable, to optimize the remedial action

5-Year Performance Review Reporting
1) Update background analysis
2) Confirm Risk Assessment assumptions remain valid
3) Re-evaluate effectiveness of technology
4) Verify modeling results, update model if needed
5) Modify corrective action approach, as needed, to achieve compliance goal established

PCMP Duration

Annual Evaluation and Reporting
1) Summary of annual groundwater monitoring results
2) Evaluate statistical concentration trends
3) Comparison of observed concentrations to model predictions
4) Evaluation 02L compliance
5) Recommend plan adjustments, if applicable

At a frequency no greater than 5 years
1) Update background analysis
2) Confirm Risk Assessment assumptions remain valid
3) Verify model results, update if needed

Monitoring Program Duration

EMP Review

30 days after CAP approval, the EMP will be implemented at the Site and will continue until there is a total of three years of data confirming COIs are below applicable Standards at or beyond the compliance boundary, at which time a request for completion of active remediation will be filed with NCDEQ.

If applicable standards are not met, the EMP will continue and transition to post-closure monitoring if necessary.

PCMP Review

After ash basin closure and following ash basin closure certification, a PCMP will be implemented at the Site for a minimum of 30 years in accordance with G. S. 130A-309.214(4)(k)(2).
Early termination:
If groundwater monitoring results are below applicable Standards at the compliance boundary for three years, Duke Energy will request completion of corrective action in accordance with G.S. 130A-309.214(a)(3)b. If groundwater monitoring results are above applicable Standards, the PCMP will continue.

Prepared by: ECW Checked by: BDW

Notes:

1) Select flow path groundwater wells would have geochemical sondes installed for telemetry monitoring of the six groundwater field parameters. See Appendix O, Figure 2.

2) New EMP groundwater well proposed for performance monitoring. All other wells listed are existing groundwater monitoring wells.

3) Approved background groundwater monitoring location.

4) Groundwater monitoring well assumed to be abandoned from closure activities. Groundwater well location proposed to be replaced post-closure.

5) Proposed well to be installed in Quarter 4 - 2019.

6) Geochemically non-reactive constituents (*i.e.*, conservative corrective action COIs) that best depict the areal extent of the plume; and monitor plume stability and physical attenuation either from active remedy or natural dilution/dispersion.

7) The number of monitoring wells and parameters may be adjusted based on additional data and the effects of corrective action.

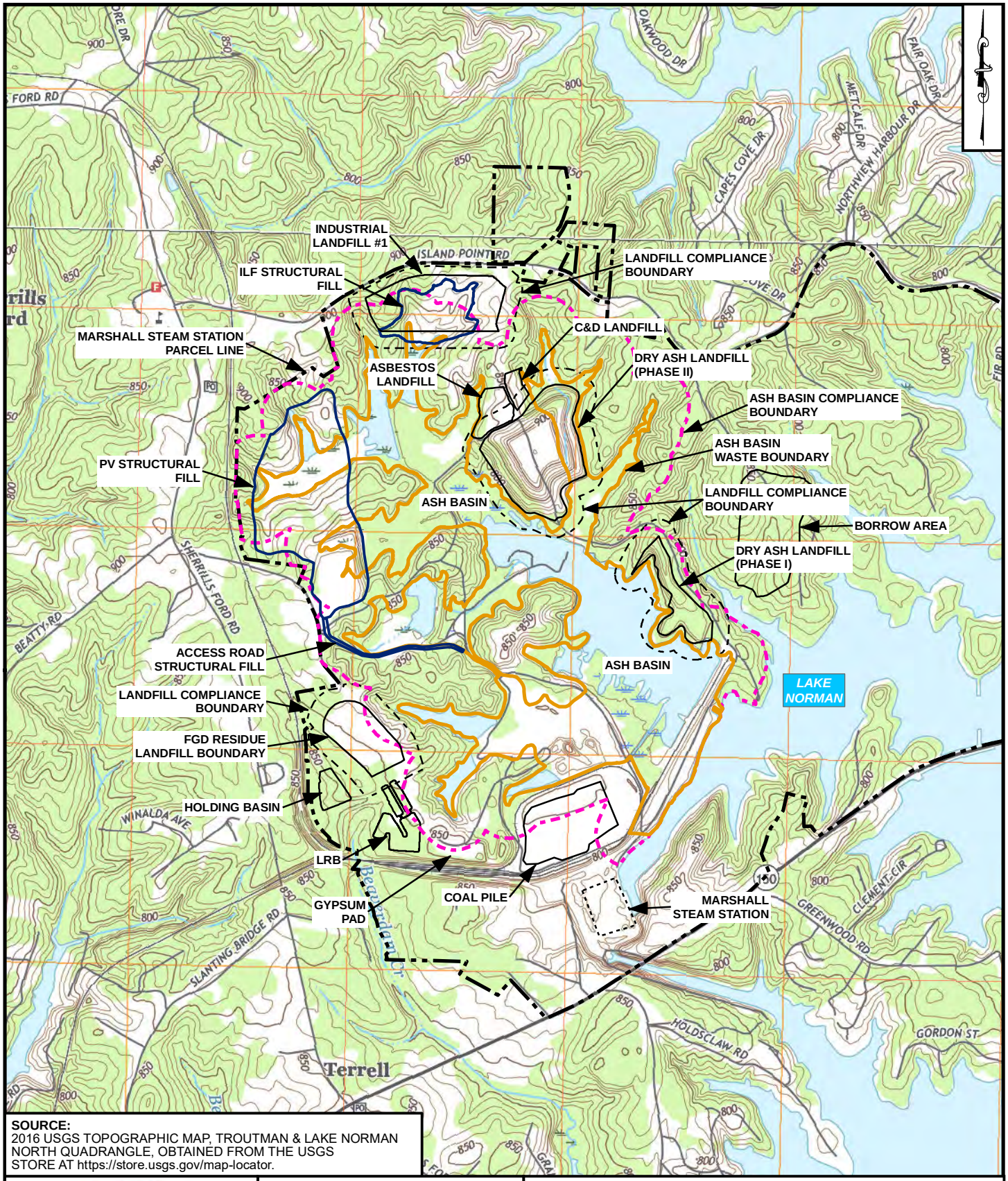
8) Groundwater standards may be modified over time in accordance with 02L .0106(k).

9) Total radium to be monitored at select well locations, in general agreement with well currently monitored for radium under the Interim Monitoring Plan

Italicized parameters - parameters for general water quality to evaluate monitoring data quality (electrochemical charge balance).

FIGURES

(CAP Content Section 10)



SOURCE:
2016 USGS TOPOGRAPHIC MAP, TROUTMAN & LAKE NORMAN NORTH QUADRANGLE, OBTAINED FROM THE USGS STORE AT https://store.usgs.gov/map-locator.

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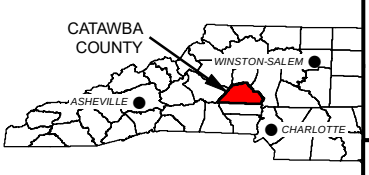

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FIGURE ES-1
USGS LOCATION MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

DRAWN BY: B. YOUNG	DATE: 05/15/2019
REVISED BY: B. YOUNG	DATE: 12/10/2019
CHECKED BY: E. WEBSTER	DATE: 12/10/2019
APPROVED BY: B. WILKER	DATE: 12/10/2019
PROJECT MANAGER: B. WILKER	

GRAPHIC SCALE
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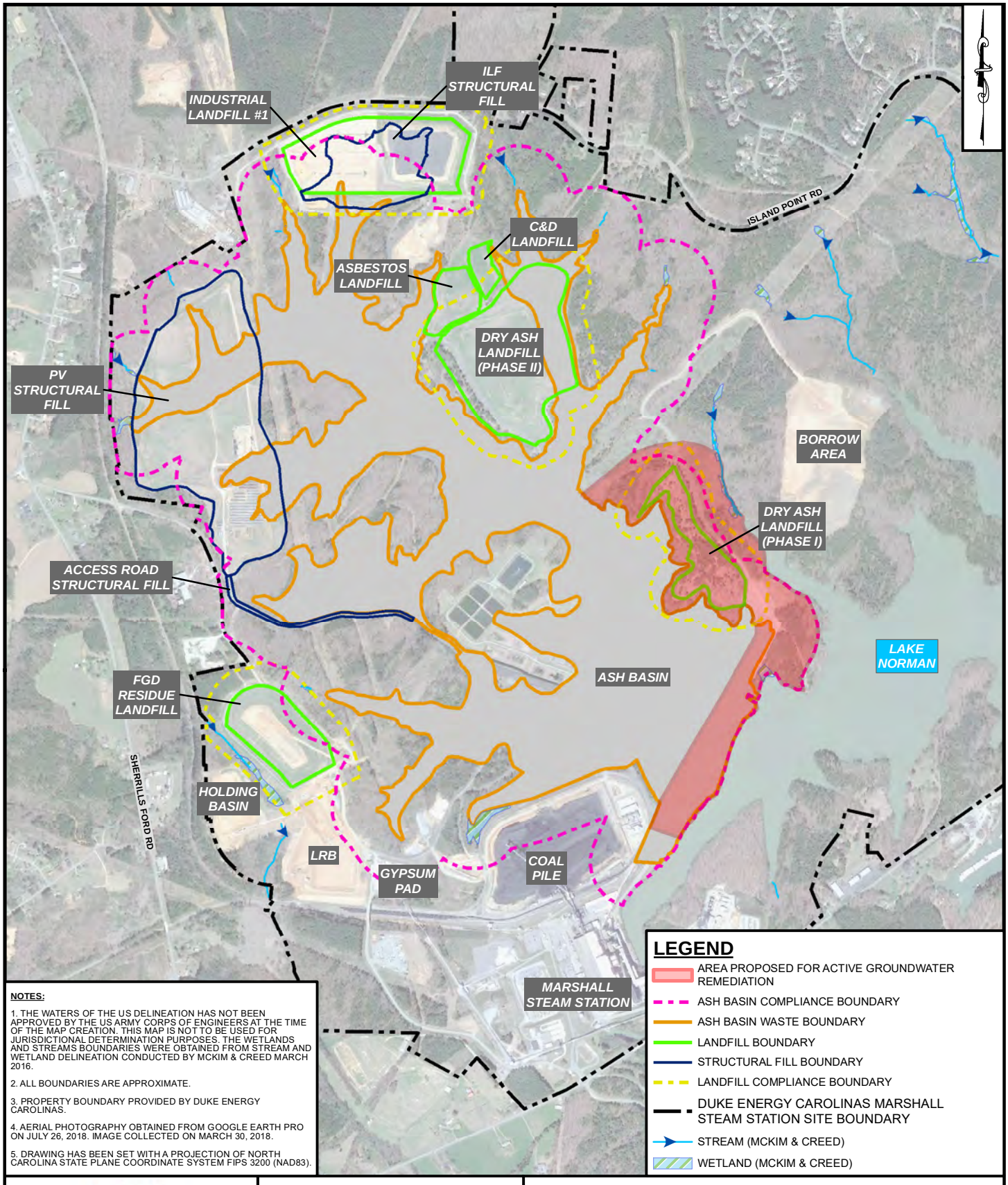
(IN FEET)



NOTES:

1. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
2. ALL BOUNDARIES ARE APPROXIMATE.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

LEGEND

- AREA PROPOSED FOR ACTIVE GROUNDWATER REMEDIATION
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS MARSHALL STEAM STATION SITE BOUNDARY
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

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GRAPHIC SCALE
750 0 750 1,500
(IN FEET)

DRAWN BY: B. YOUNG	DATE: 08/27/2019
REVISED BY: C. WYATT	DATE: 12/18/2019
CHECKED BY: E. WEBSTER	DATE: 12/18/2019
APPROVED BY: B. WILKER	DATE: 12/18/2019
PROJECT MANAGER: B. WILKER	

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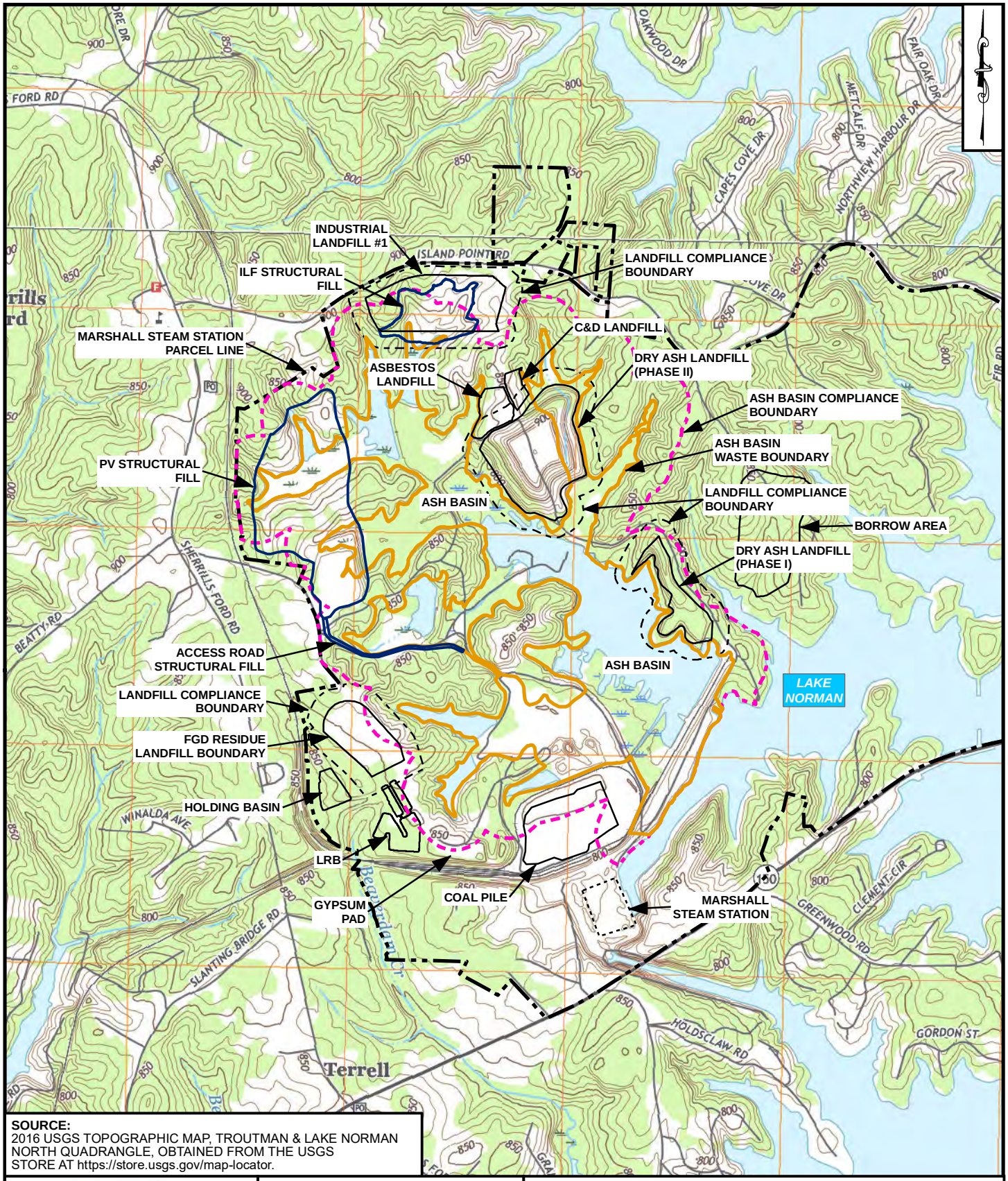
FIGURE ES-2
AREAS PROPOSED FOR CORRECTIVE ACTION
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure ES-3

Proposed Corrective Action Approach

Provided in separate electronic figure file as a large sheet size



SOURCE:
2016 USGS TOPOGRAPHIC MAP, TROUTMAN & LAKE NORMAN NORTH QUADRANGLE, OBTAINED FROM THE USGS STORE AT https://store.usgs.gov/map-locator.

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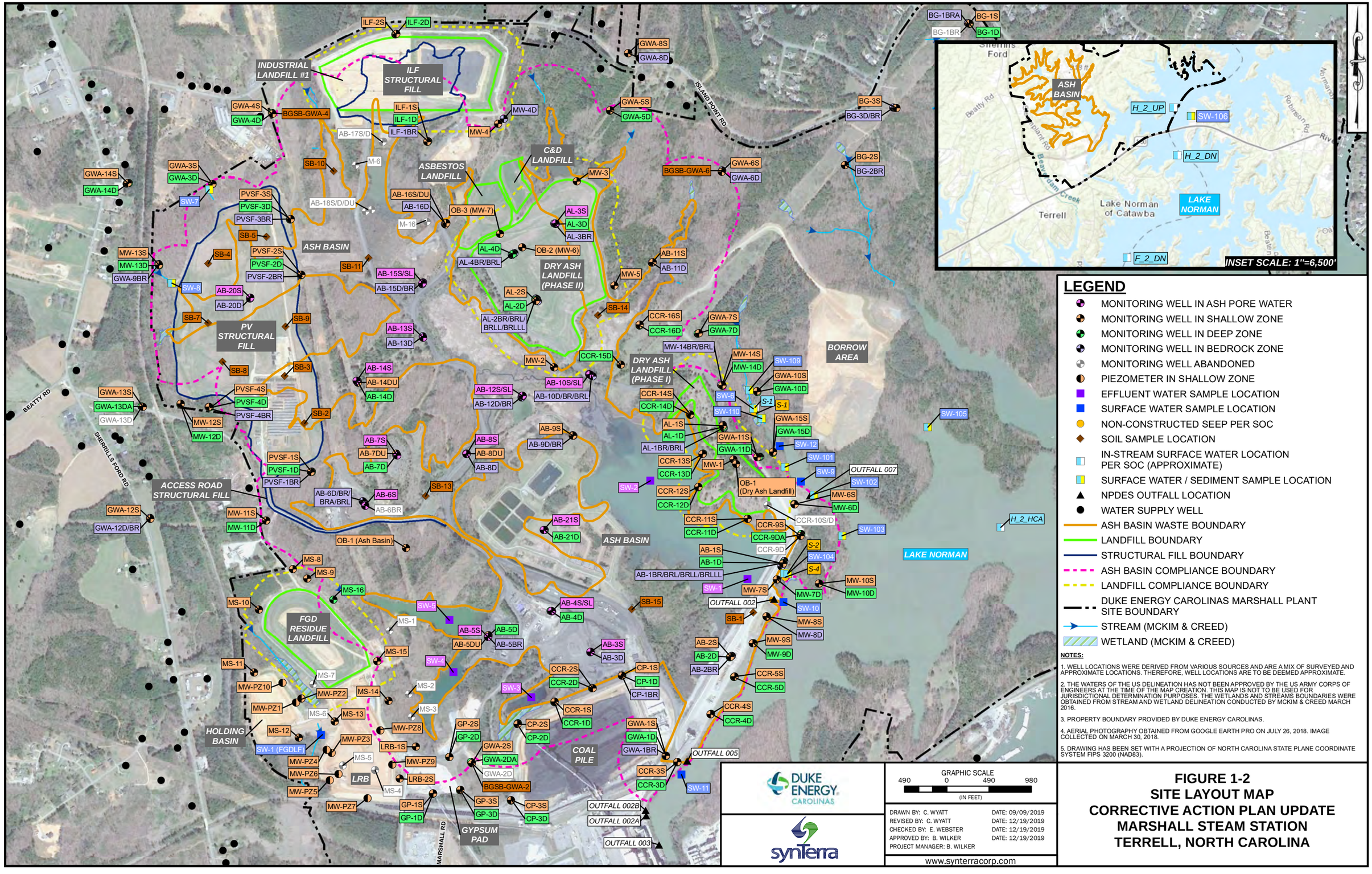
FIGURE 1-1
USGS LOCATION MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

DRAWN BY: B. YOUNG	DATE: 05/15/2019	
REVISED BY: B. YOUNG	DATE: 12/10/2019	
CHECKED BY: E. WEBSTER	DATE: 12/10/2019	
APPROVED BY: B. WILKER	DATE: 12/10/2019	
PROJECT MANAGER: B. WILKER		

GRAPHIC SCALE
1,000 0 1,000 2,000
(IN FEET)



LEGEND

- MONITORING WELL IN ASH PORE WATER
- MONITORING WELL IN SHALLOW ZONE
- MONITORING WELL IN DEEP ZONE
- MONITORING WELL IN BEDROCK ZONE
- MONITORING WELL ABANDONED
- PIEZOMETER IN SHALLOW ZONE
- EFFLUENT WATER SAMPLE LOCATION
- SURFACE WATER SAMPLE LOCATION
- NON-CONSTRUCTED SEEP PER SOC
- SOIL SAMPLE LOCATION
- IN-STREAM SURFACE WATER LOCATION PER SOC (APPROXIMATE)
- SURFACE WATER / SEDIMENT SAMPLE LOCATION
- NPDES OUTFALL LOCATION
- WATER SUPPLY WELL
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS MARSHALL PLANT SITE BOUNDARY
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. WELL LOCATIONS WERE DERIVED FROM VARIOUS SOURCES AND ARE A MIX OF SURVEYED AND APPROXIMATE LOCATIONS. THEREFORE, WELL LOCATIONS ARE TO BE DEEMED APPROXIMATE.
2. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
490 0 490 980
(IN FEET)

DRAWN BY: C. WYATT	DATE: 09/09/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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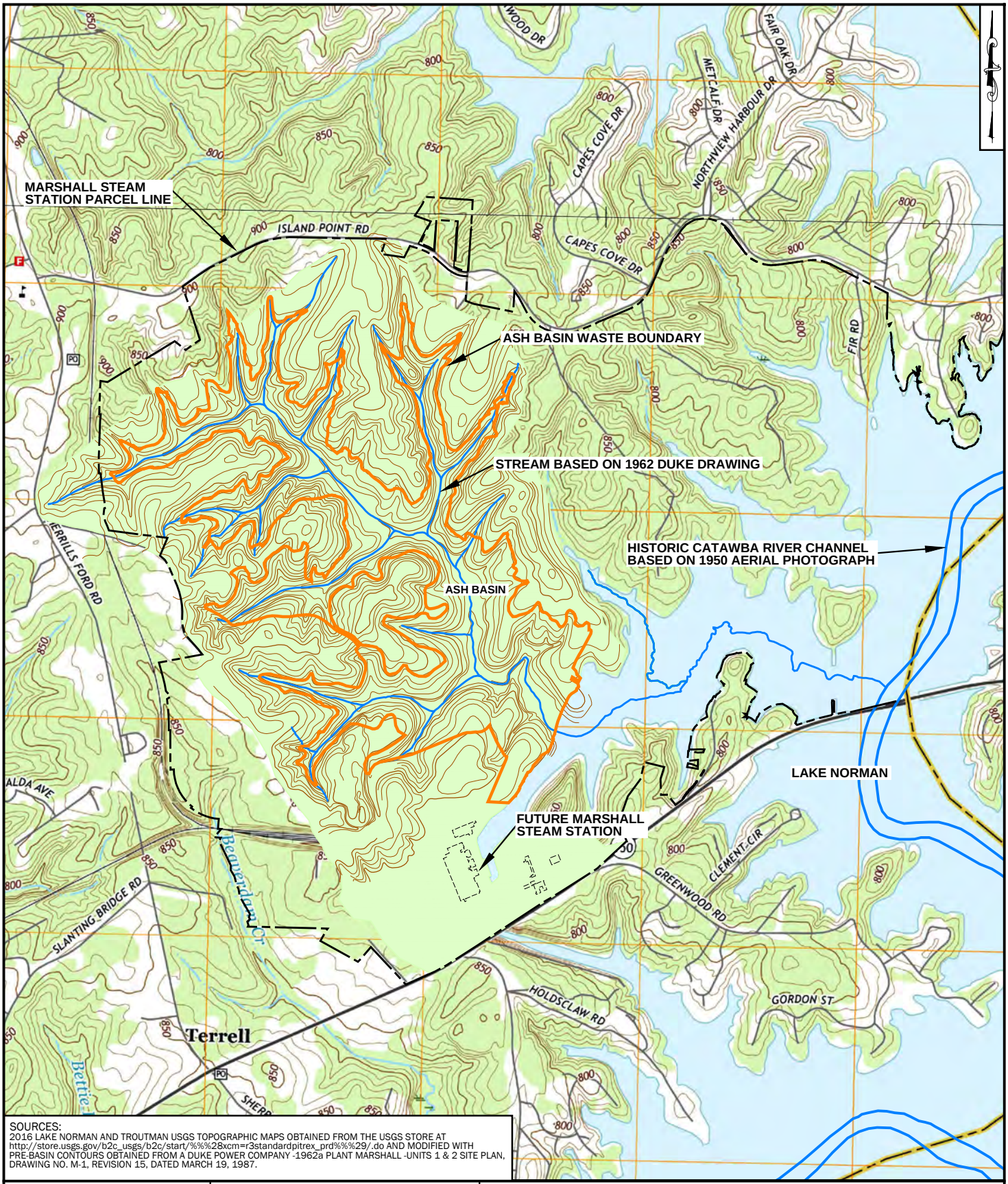
FIGURE 1-2
SITE LAYOUT MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



SOURCES:
2016 LAKE NORMAN AND TROUTMAN USGS TOPOGRAPHIC MAPS OBTAINED FROM THE USGS STORE AT http://store.usgs.gov/b2c_usgs/b2c/start/%%%28xcm=r3standardpitrex_prd%%%29/.do AND MODIFIED WITH PRE-BASIN CONTOURS OBTAINED FROM A DUKE POWER COMPANY -1962a PLANT MARSHALL -UNITS 1 & 2 SITE PLAN, DRAWING NO. M-1, REVISION 15, DATED MARCH 19, 1987.

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GRAPHIC SCALE
1000 0 1000 2000
IN FEET

DRAWN BY: J. CHASTAIN	DATE: 4/16/2019
REVISED BY: C. NEWELL	DATE: 9/3/2019
CHECKED BY: W. GERALD	DATE: 9/3/2019
APPROVED BY: B. WILKER	DATE: 9/3/2019
PROJECT MANGER: B. WILKER	
LAYOUT: FIG 1-3-1962 (USGS)	

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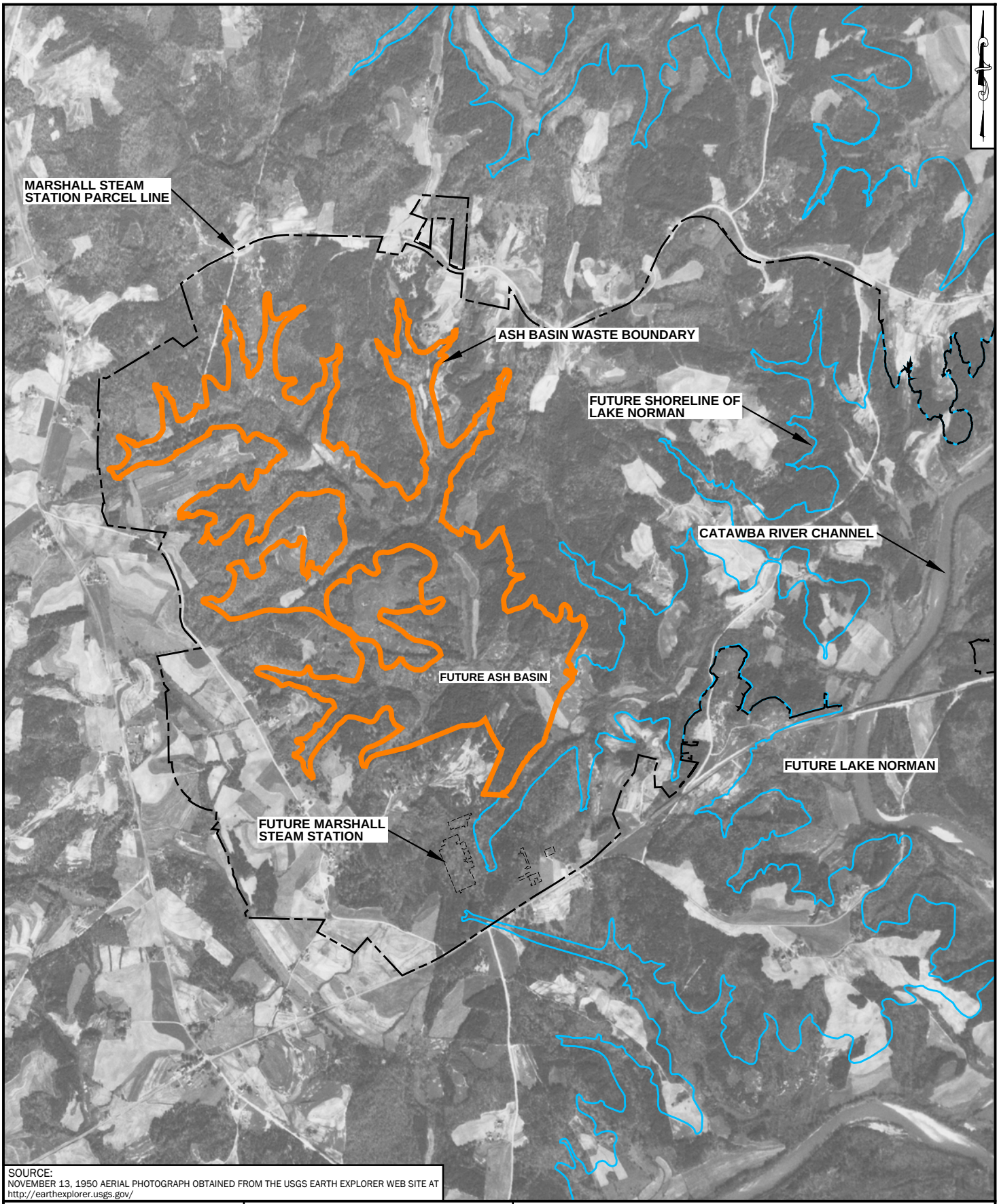
FIGURE 1-3
1962 TOPOGRAPHIC SURVEY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



SOURCE:
NOVEMBER 13, 1950 AERIAL PHOTOGRAPH OBTAINED FROM THE USGS EARTH EXPLORER WEB SITE AT http://earthexplorer.usgs.gov/

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GRAPHIC SCALE
1000 0 1000 2000
IN FEET

DRAWN BY: J. CHASTAIN	DATE: 7/8/2019
REVISED BY: C. NEWELL	DATE: 8/27/2019
CHECKED BY: E. WEBSTER	DATE: 8/27/2019
APPROVED BY: B.WILKER	DATE: 8/27/2019
PROJECT MANAGER: B WILKER	

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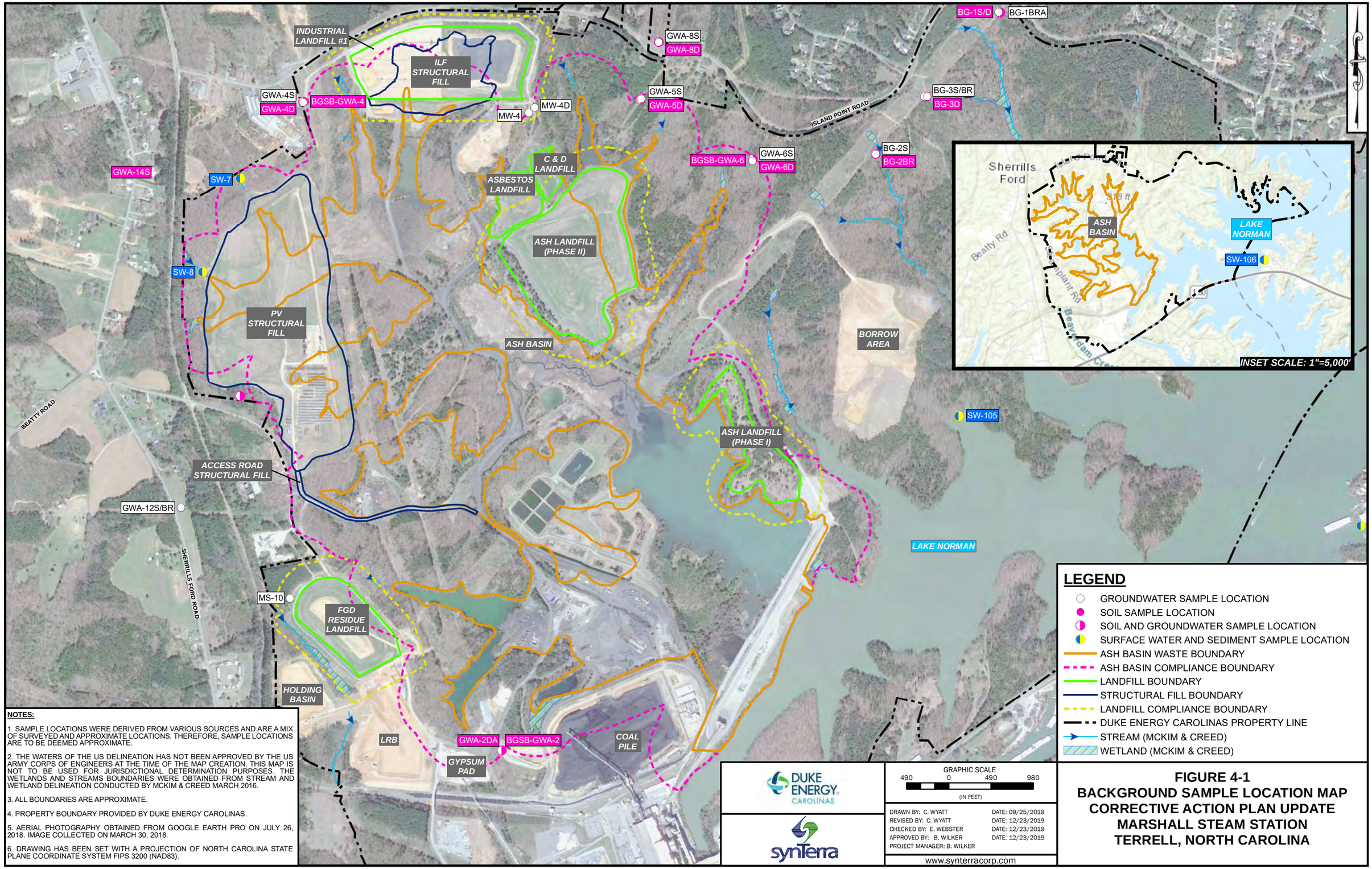
FIGURE 1-4
1950 AERIAL PHOTOGRAPH
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. SAMPLE LOCATIONS WERE DERIVED FROM VARIOUS SOURCES AND ARE A MIX OF SURVEYED AND APPROXIMATE LOCATIONS. THEREFORE, SAMPLE LOCATIONS ARE TO BE DEEMED APPROXIMATE.
2. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
5. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
6. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

LEGEND

- GROUNDWATER SAMPLE LOCATION
- SOIL SAMPLE LOCATION
- SOIL AND GROUNDWATER SAMPLE LOCATION
- SURFACE WATER AND SEDIMENT SAMPLE LOCATION
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
490 0 490 980
(IN FEET)

DRAWN BY: C. WYATT	DATE: 09/25/2019
REVISED BY: C. WYATT	DATE: 12/23/2019
CHECKED BY: E. WEBSTER	DATE: 12/23/2019
APPROVED BY: B. WILKER	DATE: 12/23/2019
PROJECT MANAGER: B. WILKER	

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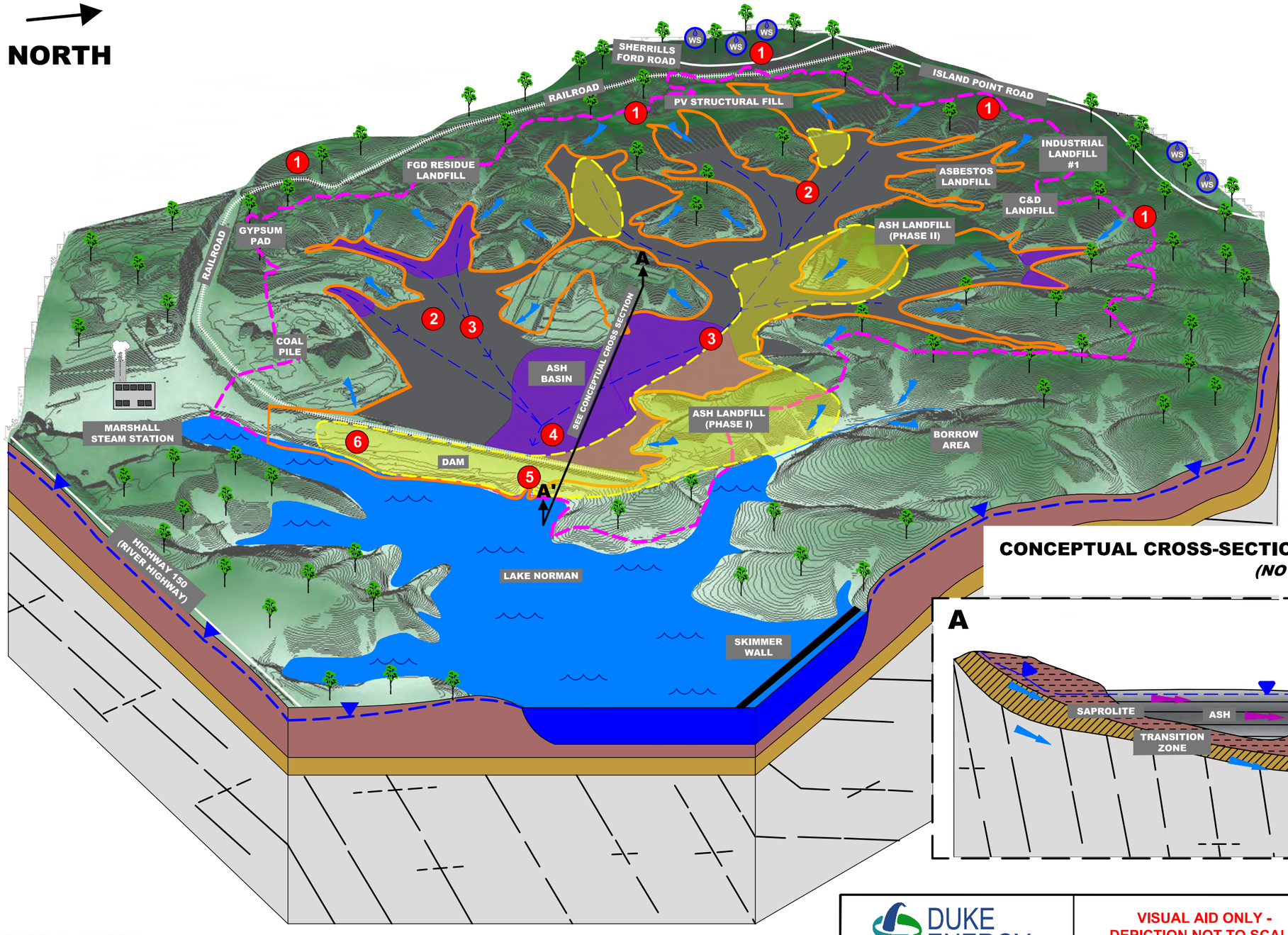
FIGURE 4-1
BACKGROUND SAMPLE LOCATION MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

NORTH



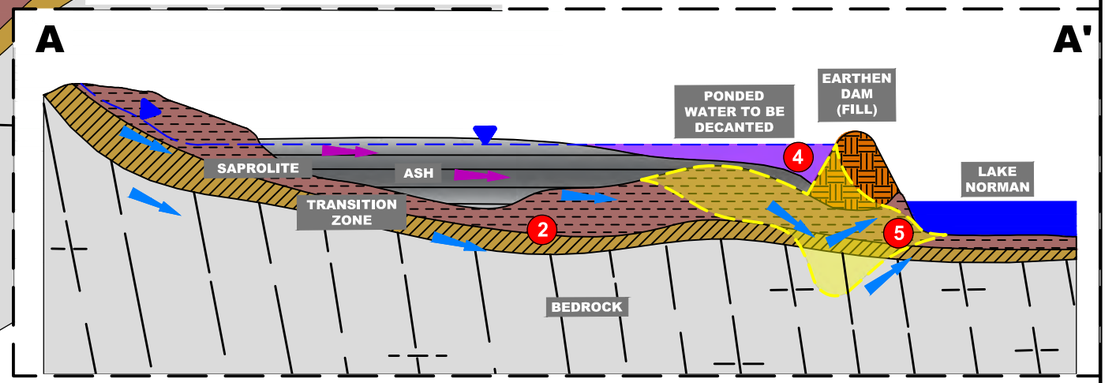
SITE FEATURES KEY

1. GROUNDWATER FLOWS FROM RIDGES THAT COINCIDE WITH GROUNDWATER DIVIDES, WHICH PROVIDE HYDRAULIC CONTROL KEEPING CONSTITUENT MIGRATION WITHIN FORMER STREAM VALLEYS AND AWAY FROM WATER SUPPLY WELLS
2. LIMITED CONSTITUENT MIGRATION THROUGH THE SAPROLITE, TRANSITION ZONE, AND INTERCONNECTED BEDROCK FRACTURES BENEATH THE ASH BASIN
3. FORMER STREAM CHANNELS IN ASH BASIN
4. PONDED WATER IN THE ASH BASIN CAUSES LIMITED AREA OF DOWNWARD VERTICAL MIGRATION OF CONSTITUENTS NEAR THE DAM DUE TO ELEVATED HYDRAULIC HEAD
5. UPWARD VERTICAL GRADIENTS IN GROUNDWATER IMMEDIATELY DOWNGRADIENT OF THE ASH BASIN DAM LIMIT VERTICAL MIGRATION OF CONSTITUENTS AS GROUNDWATER MIGRATES TOWARD LAKE NORMAN
6. AREA OF COI CONCENTRATION GREATER THAN CRITERIA BEYOND THE 02L BORON PLUME

- AREA OF COI CONCENTRATION IN GROUNDWATER GREATER THAN CRITERIA (SEE GENERAL NOTE 1)
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- STREAM
- APPROXIMATE FORMER STREAM WITH FLOW DIRECTION
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- GENERAL AREA OF WATER SUPPLY WELL USERS (SEE GENERAL NOTE 2)
- PREDOMINANT BEDROCK FRACTURE ORIENTATION

CONCEPTUAL CROSS-SECTION OF PRE-DECANTING CONDITIONS

(NOT TO SCALE)



GENERAL NOTES

1) GENERALIZED AREAL EXTENT OF MIGRATION REPRESENTED BY CONSTITUENT CONCENTRATIONS GREATER THAN NCAC 02L, IMAC, OR BACKGROUND IN MULTIPLE FLOW ZONES.
2) PERMANENT WATER SUPPLY HAS BEEN IMPLEMENTED PROVIDING 65 SURROUNDING WELL USERS WITH CONNECTIONS TO PUBLIC WATER SUPPLY OR WATER TREATMENT SYSTEMS. THIS WORK WAS COMPLETED IN ACCORDANCE WITH HB630 AND SUBSEQUENTLY APPROVED BY NCDEQ ON OCTOBER 12, 2018.
3) ALL BOUNDARIES ARE APPROXIMATE.

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VISUAL AID ONLY - DEPICTION NOT TO SCALE

DRAWN BY: A. FEIGL	DATE: 8/19/2019
REVISED BY: C. NEWELL	DATE: 12/13/2019
CHECKED BY: E. WEBSTER	DATE: 12/13/2019
APPROVED BY: W. GERALD	DATE: 12/13/2019
PROJECT MANAGER: B. WILKER	

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FIGURE 5-1
CONCEPTUAL SITE MODEL - PRE-DECANTING CONDITIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure 5-2

LeGrand Slope Aquifer System

Included in Section 5 text

Figure 5-3

Generalized Profile of Ash Basin Pre-Decanting Flow Conditions in the Piedmont

Included in Section 5 text

Figure 5-4a

Water Level Map – Shallow Flow Zone (May 2019)

Provided in separate electronic figure file as a large sheet size

Figure 5-4b

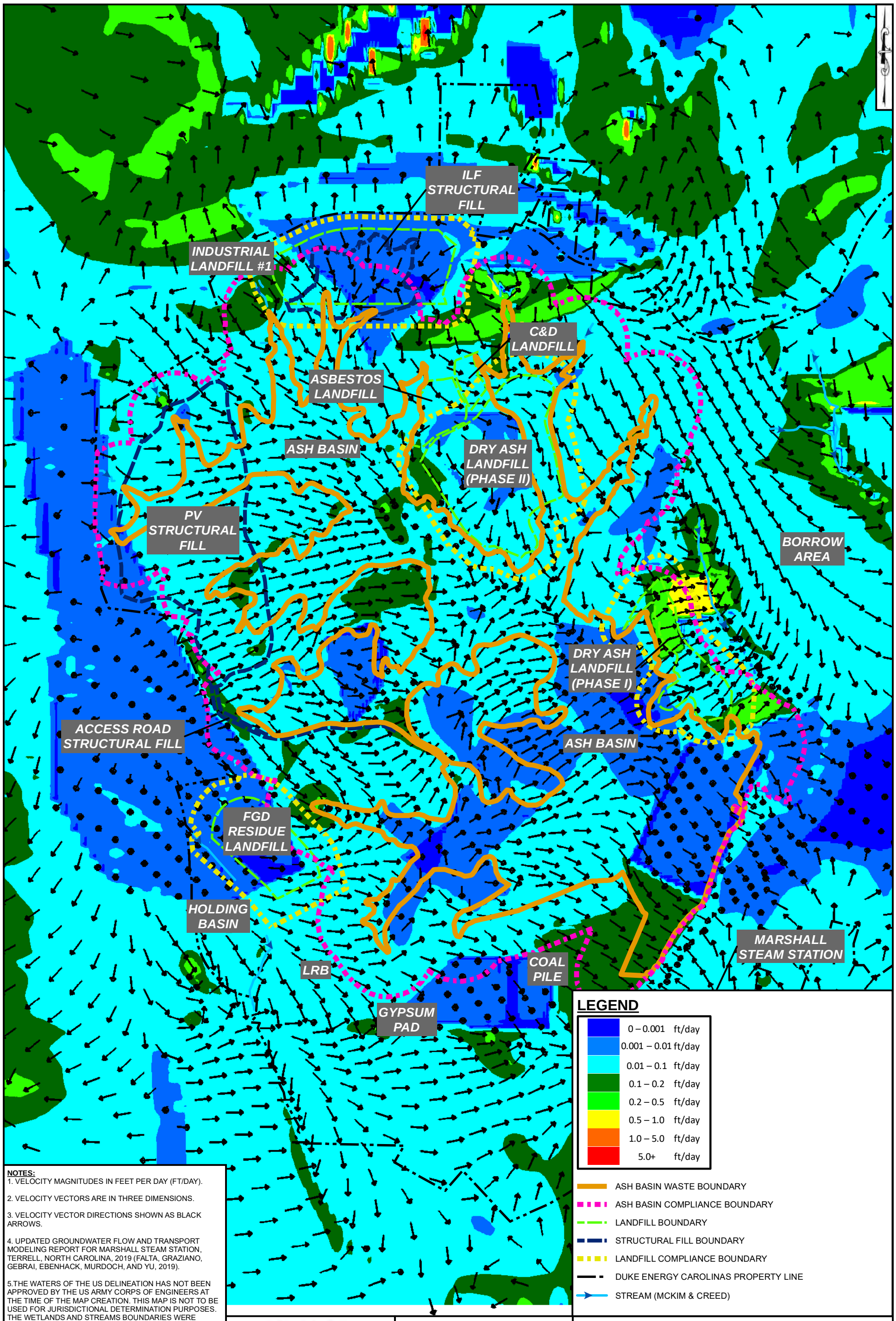
Water Level Map – Deep Flow Zone (May 2019)

Provided in separate electronic figure file as a large sheet size

Figure 5-4c

Water Level Map – Bedrock Flow Zone (May 2019)

Provided in separate electronic figure file as a large sheet size



NOTES:

1. VELOCITY MAGNITUDES IN FEET PER DAY (FT/DAY).
2. VELOCITY VECTORS ARE IN THREE DIMENSIONS.
3. VELOCITY VECTOR DIRECTIONS SHOWN AS BLACK ARROWS.
4. UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT FOR MARSHALL STEAM STATION, TERRELL, NORTH CAROLINA, 2019 (FALTA, GRAZIANO, GEBRAI, EBENHACK, MURDOCH, AND YU, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
7. ALL BOUNDARIES ARE APPROXIMATE.
8. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

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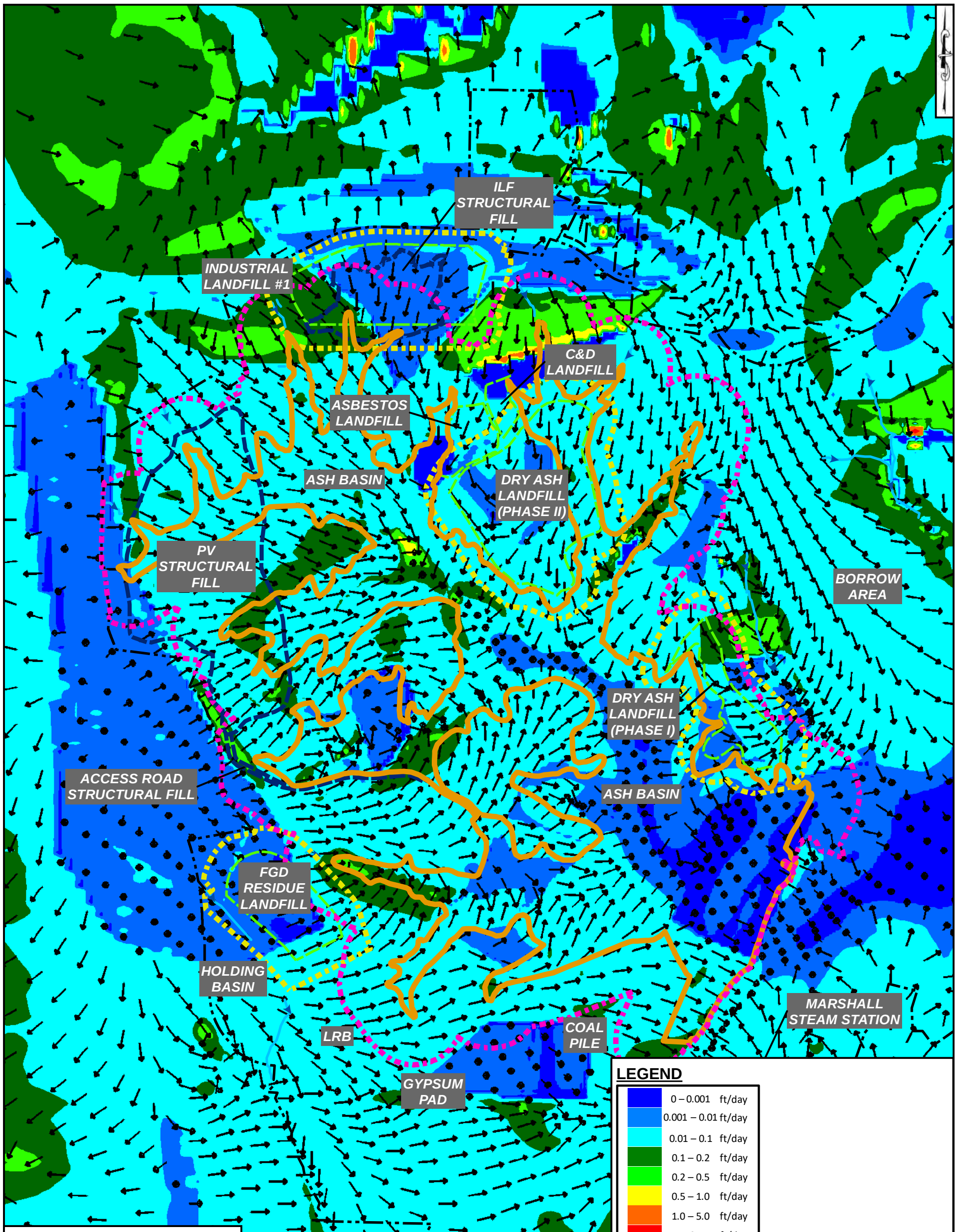
FIGURE 5-5a
VELOCITY VECTOR MAP
FOR PRE-DECANTING CONDITIONS
DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. VELOCITY MAGNITUDES IN FEET PER DAY (FT/DAY).
2. VELOCITY VECTORS ARE IN THREE DIMENSIONS.
3. VELOCITY VECTOR DIRECTIONS SHOWN AS BLACK ARROWS.
4. UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT FOR MARSHALL STEAM STATION, TERRELL, NORTH CAROLINA, 2019 (FALTA, GRAZIANO, GEBRAI, EBENHACK, MURDOCH, AND YU, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
7. ALL BOUNDARIES ARE APPROXIMATE.
8. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

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PROJECT MANAGER: B. WILKER	

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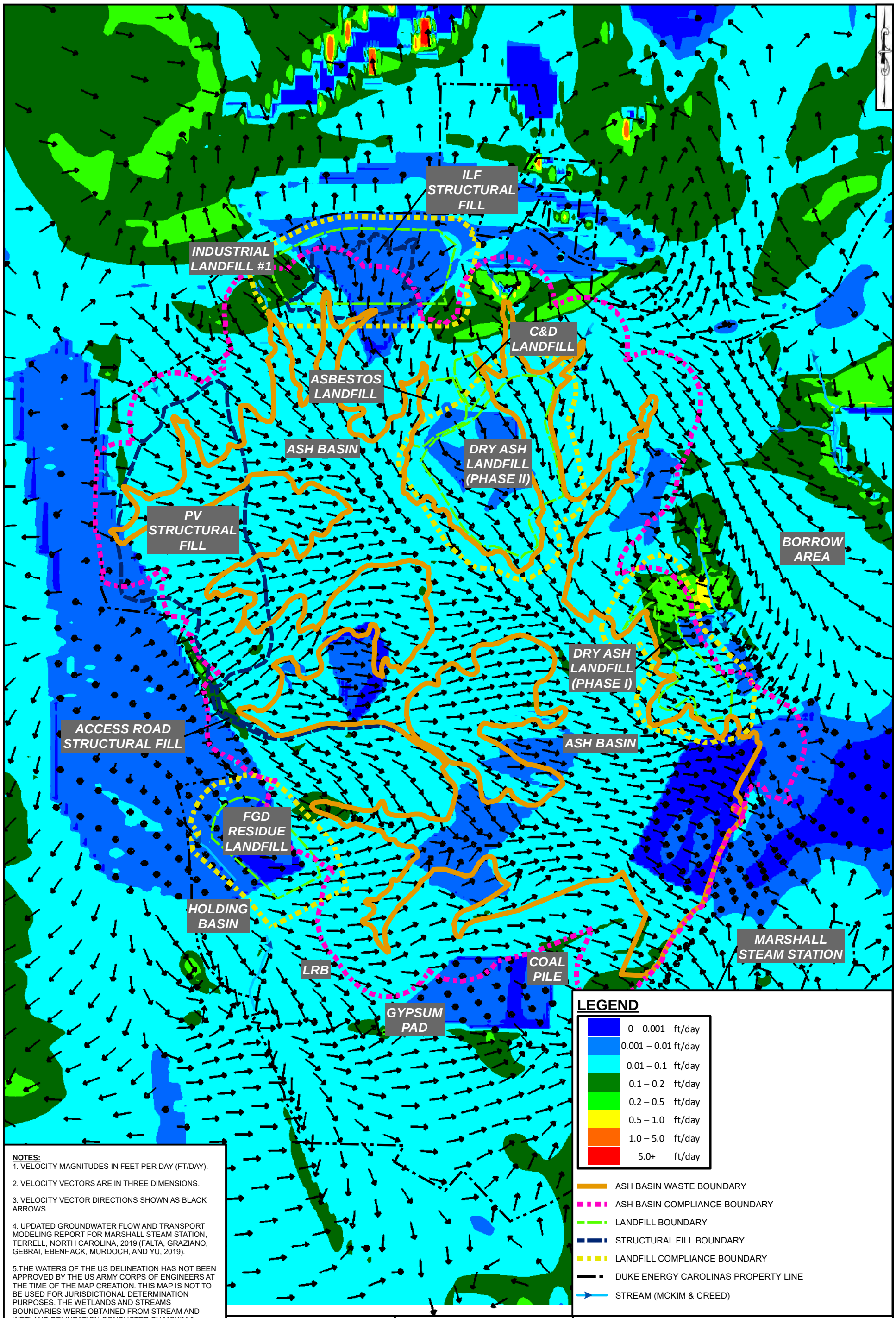
FIGURE 5-5b
VELOCITY VECTOR MAP
FOR CLOSURE-BY-EXCAVATION CONDITIONS
DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. VELOCITY MAGNITUDES IN FEET PER DAY (FT/DAY).
2. VELOCITY VECTORS ARE IN THREE DIMENSIONS.
3. VELOCITY VECTOR DIRECTIONS SHOWN AS BLACK ARROWS.
4. UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT FOR MARSHALL STEAM STATION, TERRELL, NORTH CAROLINA, 2019 (FALTA, GRAZIANO, GEBRAI, EBENHACK, MURDOCH, AND YU, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
7. ALL BOUNDARIES ARE APPROXIMATE.
8. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	

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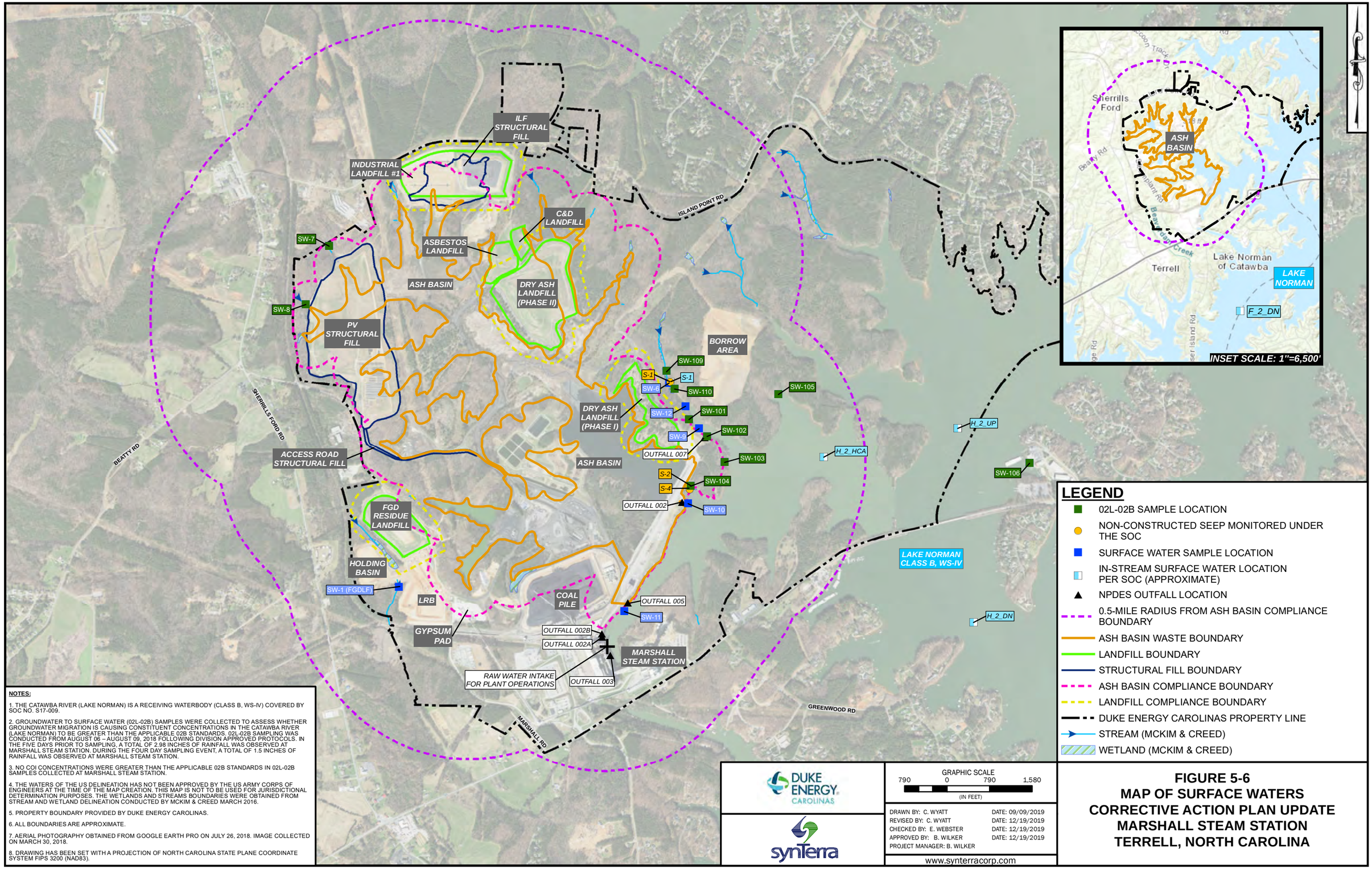
FIGURE 5-5c
VELOCITY VECTOR MAP
FOR CLOSURE-IN-PLACE CONDITIONS
DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. THE CATAWBA RIVER (LAKE NORMAN) IS A RECEIVING WATERBODY (CLASS B, WS-IV) COVERED BY SOC NO. S17-009.

2. GROUNDWATER TO SURFACE WATER (02L-02B) SAMPLES WERE COLLECTED TO ASSESS WHETHER GROUNDWATER MIGRATION IS CAUSING CONSTITUENT CONCENTRATIONS IN THE CATAWBA RIVER (LAKE NORMAN) TO BE GREATER THAN THE APPLICABLE 02B STANDARDS. 02L-02B SAMPLING WAS CONDUCTED FROM AUGUST 06 – AUGUST 09, 2018 FOLLOWING DIVISION APPROVED PROTOCOLS. IN THE FIVE DAYS PRIOR TO SAMPLING, A TOTAL OF 2.98 INCHES OF RAINFALL WAS OBSERVED AT MARSHALL STEAM STATION. DURING THE FOUR DAY SAMPLING EVENT, A TOTAL OF 1.5 INCHES OF RAINFALL WAS OBSERVED AT MARSHALL STEAM STATION.

3. NO COI CONCENTRATIONS WERE GREATER THAN THE APPLICABLE 02B STANDARDS IN 02L-02B SAMPLES COLLECTED AT MARSHALL STEAM STATION.

4. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

5. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

6. ALL BOUNDARIES ARE APPROXIMATE.

7. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

8. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

LEGEND

- 02L-02B SAMPLE LOCATION
- NON-CONSTRUCTED SEEP MONITORED UNDER THE SOC
- SURFACE WATER SAMPLE LOCATION
- IN-STREAM SURFACE WATER LOCATION PER SOC (APPROXIMATE)
- NPDES OUTFALL LOCATION
- 0.5-MILE RADIUS FROM ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

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GRAPHIC SCALE
790 0 790 1,580
(IN FEET)

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REVISED BY: C. WYATT	DATE: 12/19/2019
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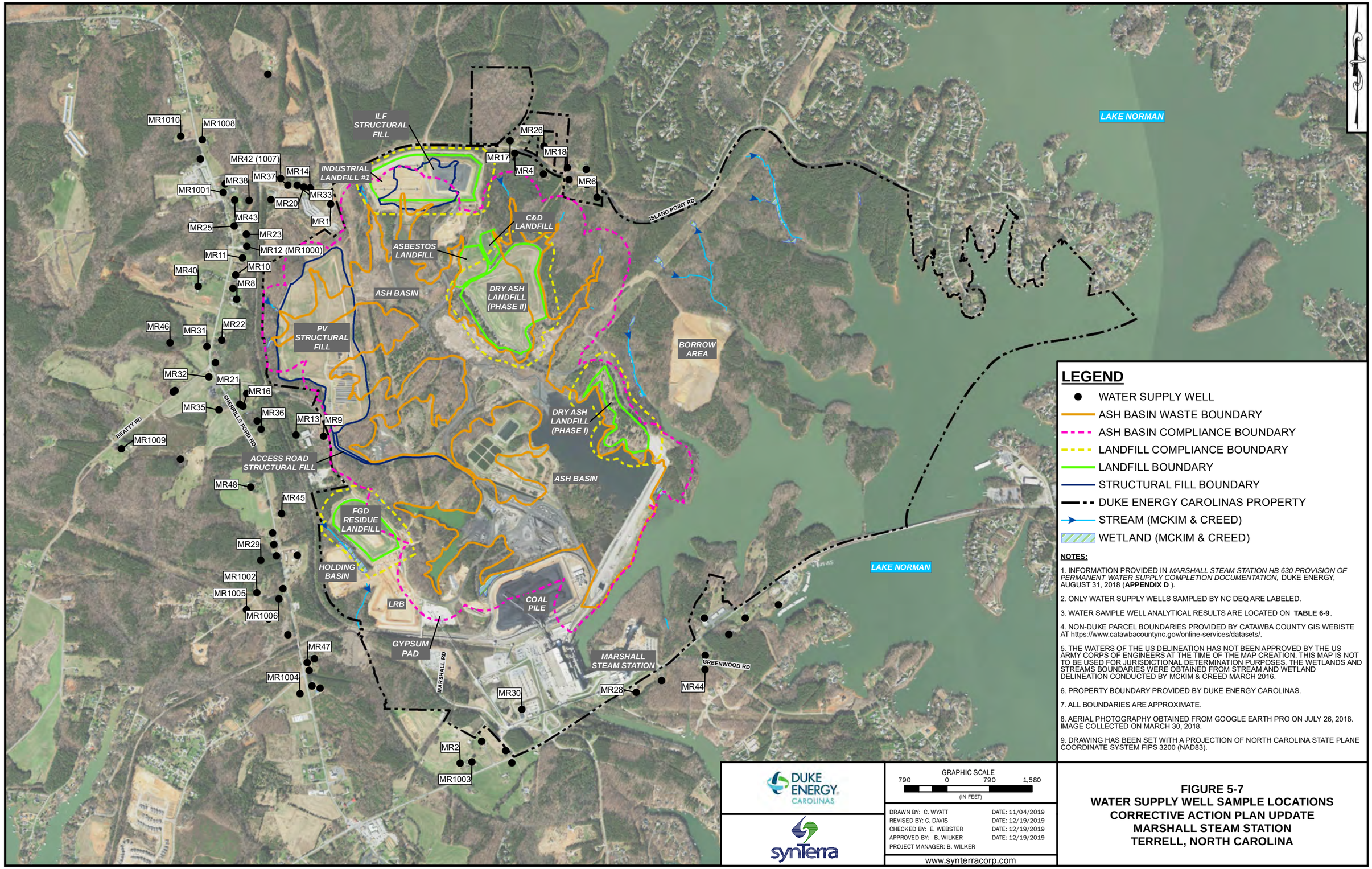
FIGURE 5-6
MAP OF SURFACE WATERS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- WATER SUPPLY WELL
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. INFORMATION PROVIDED IN *MARSHALL STEAM STATION HB 630 PROVISION OF PERMANENT WATER SUPPLY COMPLETION DOCUMENTATION,* DUKE ENERGY, AUGUST 31, 2018 (**APPENDIX D**).
2. ONLY WATER SUPPLY WELLS SAMPLED BY NC DEQ ARE LABELED.
3. WATER SAMPLE WELL ANALYTICAL RESULTS ARE LOCATED ON **TABLE 6-9**.
4. NON-DUKE PARCEL BOUNDARIES PROVIDED BY CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
7. ALL BOUNDARIES ARE APPROXIMATE.
8. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
9. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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790 0 790 1,580
(IN FEET)

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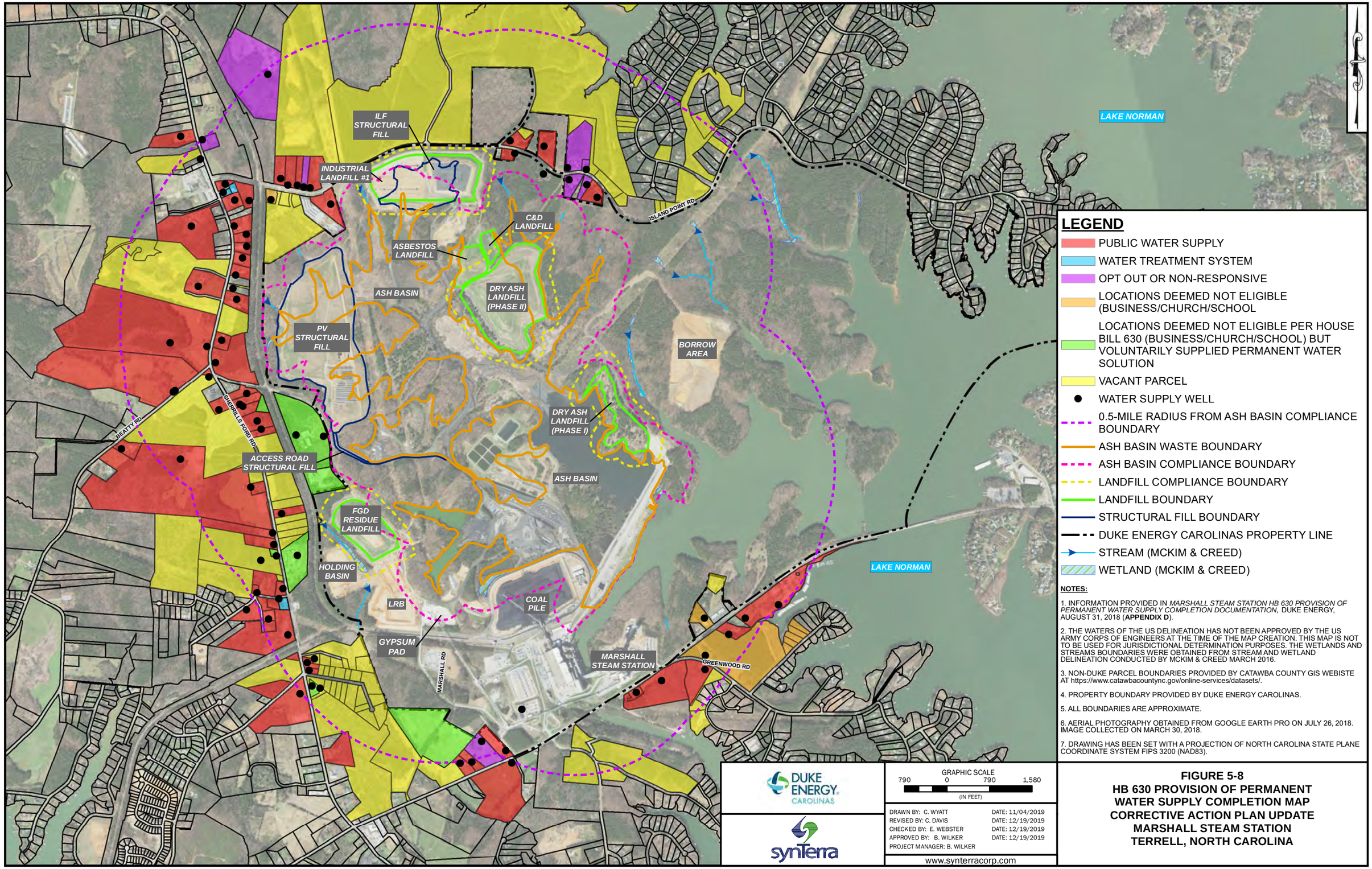
FIGURE 5-7
WATER SUPPLY WELL SAMPLE LOCATIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- PUBLIC WATER SUPPLY
- WATER TREATMENT SYSTEM
- OPT OUT OR NON-RESPONSIVE
- LOCATIONS DEEMED NOT ELIGIBLE (BUSINESS/CHURCH/SCHOOL
- LOCATIONS DEEMED NOT ELIGIBLE PER HOUSE BILL 630 (BUSINESS/CHURCH/SCHOOL) BUT VOLUNTARILY SUPPLIED PERMANENT WATER SOLUTION
- VACANT PARCEL
- WATER SUPPLY WELL
- 0.5-MILE RADIUS FROM ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. INFORMATION PROVIDED IN *MARSHALL STEAM STATION HB 630 PROVISION OF PERMANENT WATER SUPPLY COMPLETION DOCUMENTATION,* DUKE ENERGY, AUGUST 31, 2018 (**APPENDIX D**).
2. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
3. NON-DUKE PARCEL BOUNDARIES PROVIDED BY CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
4. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
5. ALL BOUNDARIES ARE APPROXIMATE.
6. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
7. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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790 0 790 1,580
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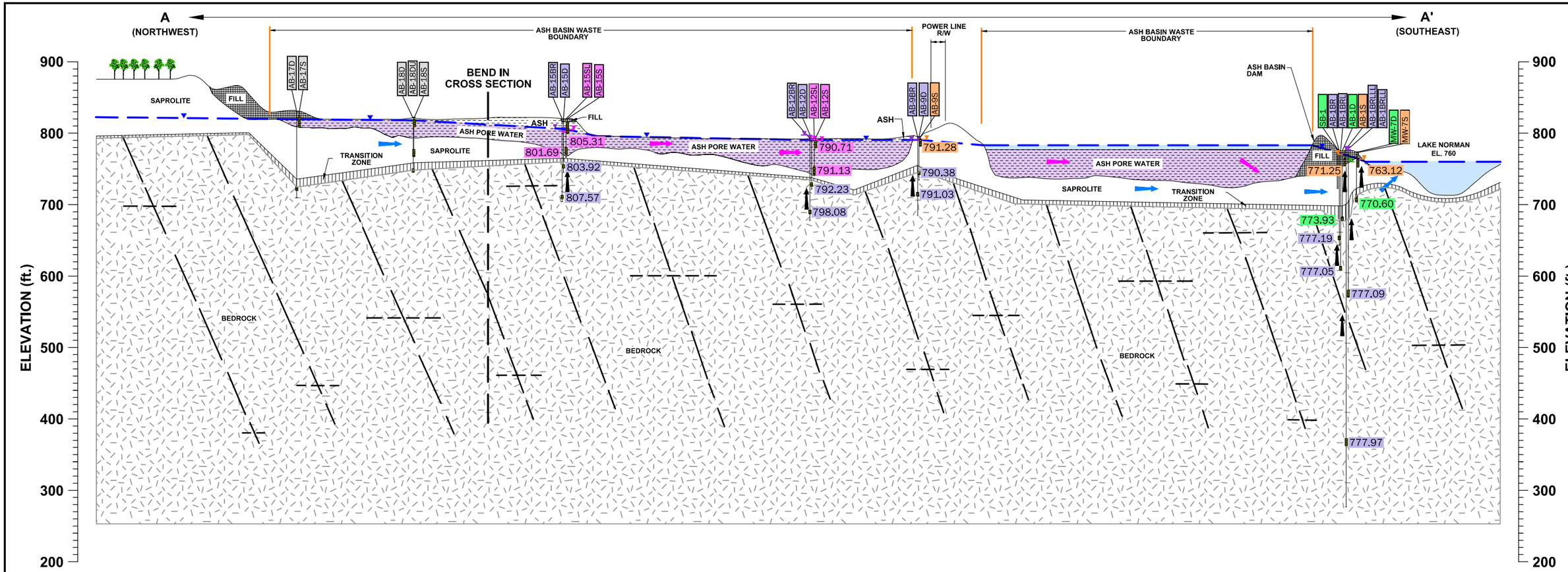
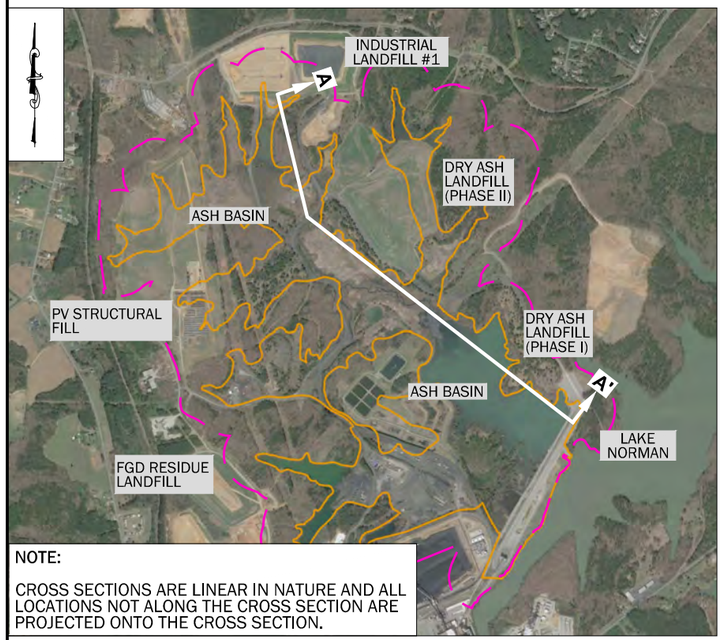
FIGURE 5-8
HB 630 PROVISION OF PERMANENT WATER SUPPLY COMPLETION MAP
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure 6-1

Fly Ash and Bottom Ash Interbedded Depiction

Included in Section 6 text





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- AB-9S — WELL IN SAPROLITE MATERIAL
- AB-1D — WELL IN TRANSITION ZONE
- AB-15BR — WELL IN BEDROCK
- AB-15S — WELL IN ASH PORE WATER
- AB-18D — ABANDONED WELL
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- FILL
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- SURFACE WATER
- 803.04 — WATER LEVEL ELEVATION - MAY 2019 (NAVD-88) (LABEL COLORING BY FLOW ZONE)
- GENERALIZED VERTICAL HYDRAULIC GRADIENT
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS ARE FROM THE MAY 2019 GAUGING EVENT. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE TWO MOST PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

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GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

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REVISED BY: D. KREFSKI	DATE: 12/11/2019
CHECKED BY: B. WILKER	DATE: 12/11/2019
APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	DATE: 12/11/2019

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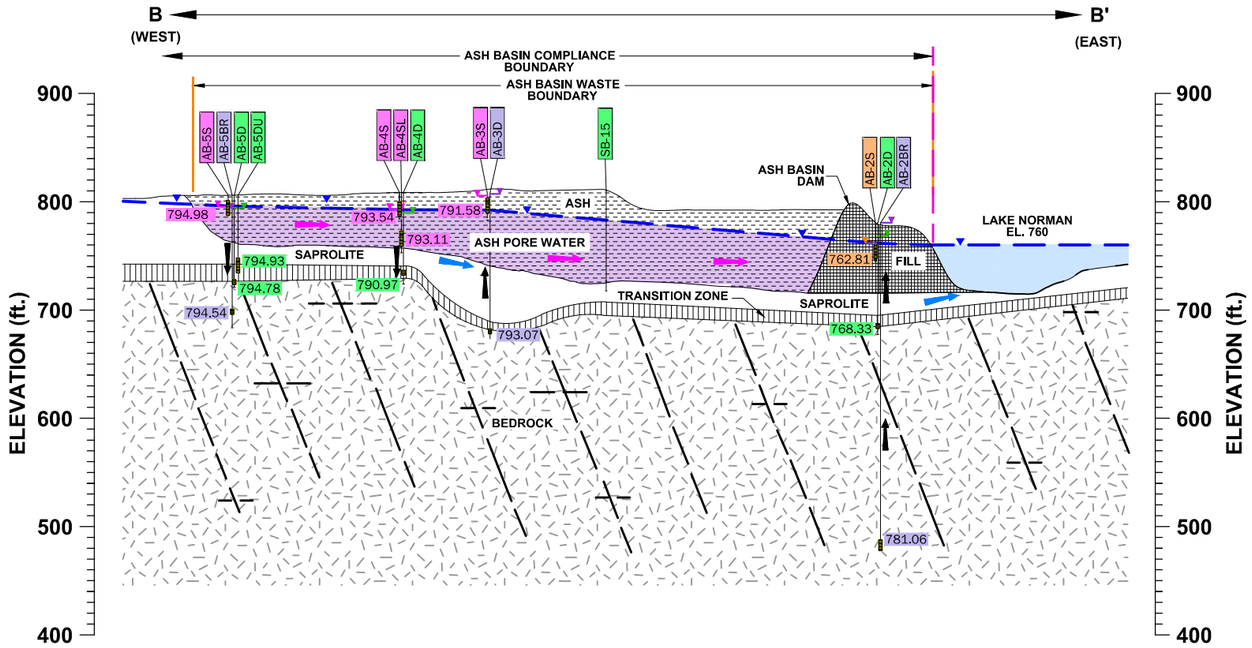
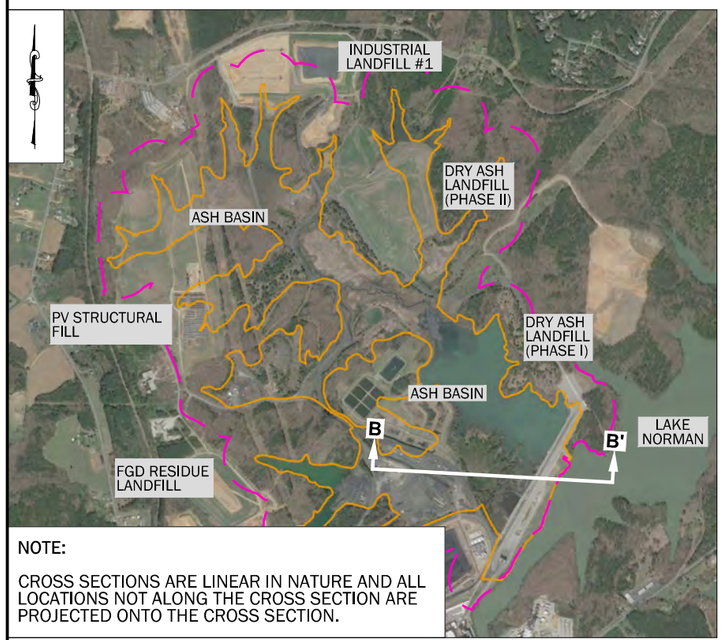
FIGURE 6-2
GENERAL CROSS SECTION A-A'
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- AB-2S — WELL IN SAPROLITE MATERIAL
- AB-4D — WELL IN TRANSITION ZONE
- AB-5BR — WELL IN BEDROCK
- AB-3S — WELL IN ASH PORE WATER
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- FILL
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- SURFACE WATER
- 794.54 — WATER LEVEL ELEVATION - MAY 2019 (NAVD-88) (LABEL COLORING BY FLOW ZONE)
- GENERALIZED VERTICAL HYDRAULIC GRADIENT
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS ARE FROM THE MAY 2019 GAUGING EVENT. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE TWO MOST PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/11/2019
CHECKED BY: B. WILKER	DATE: 12/11/2019
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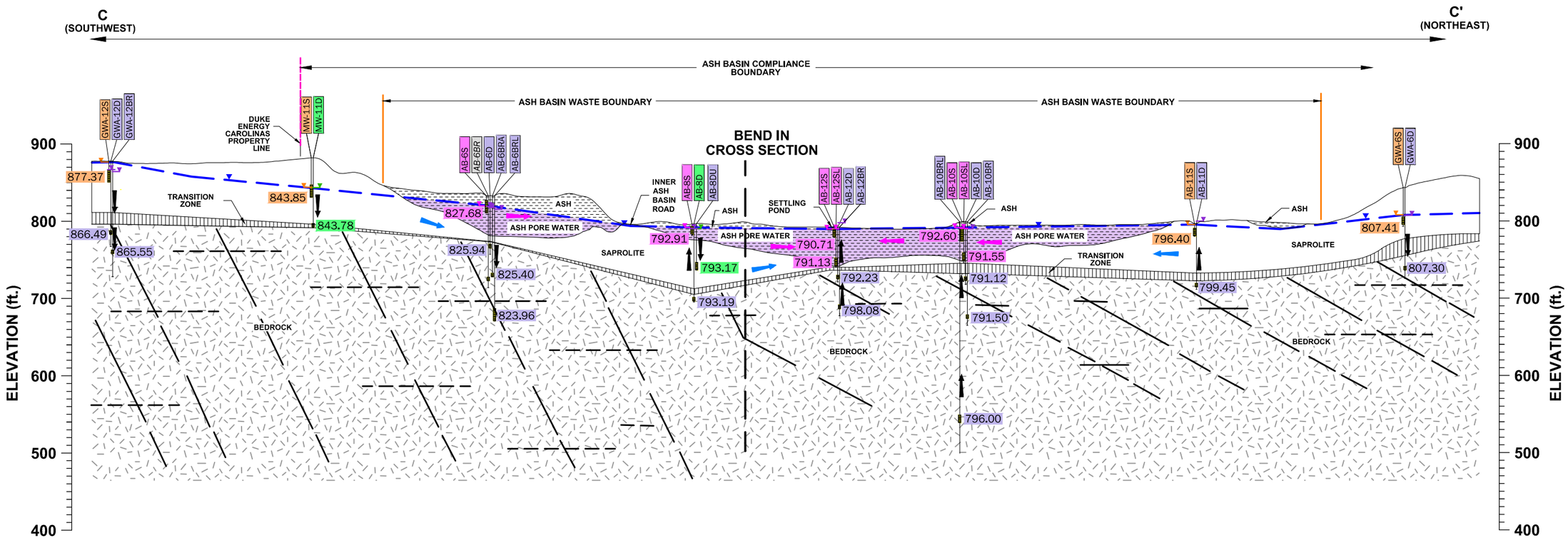
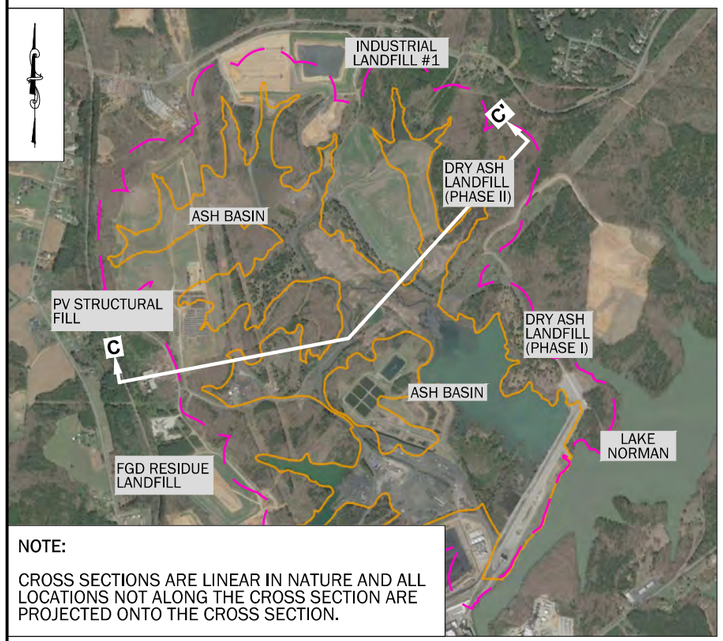
FIGURE 6-3
GENERAL CROSS SECTION B-B'
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- MW-12S — WELL IN SAPROLITE MATERIAL
- MW-16D — WELL IN TRANSITION ZONE
- MW-16BR — WELL IN BEDROCK
- ABMW-2 — WELL IN ASH PORE WATER
- AB-18D — ABANDONED WELL
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- 823.96 — WATER LEVEL ELEVATION - MAY 2019 (NAVD-88) (LABEL COLORING BY FLOW ZONE)
- GENERALIZED VERTICAL HYDRAULIC GRADIENT
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS ARE FROM THE MAY 2019 GAUGING EVENT. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE TWO MOST PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/11/2019
CHECKED BY: B. WILKER	DATE: 12/11/2019
APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	DATE: 12/11/2019

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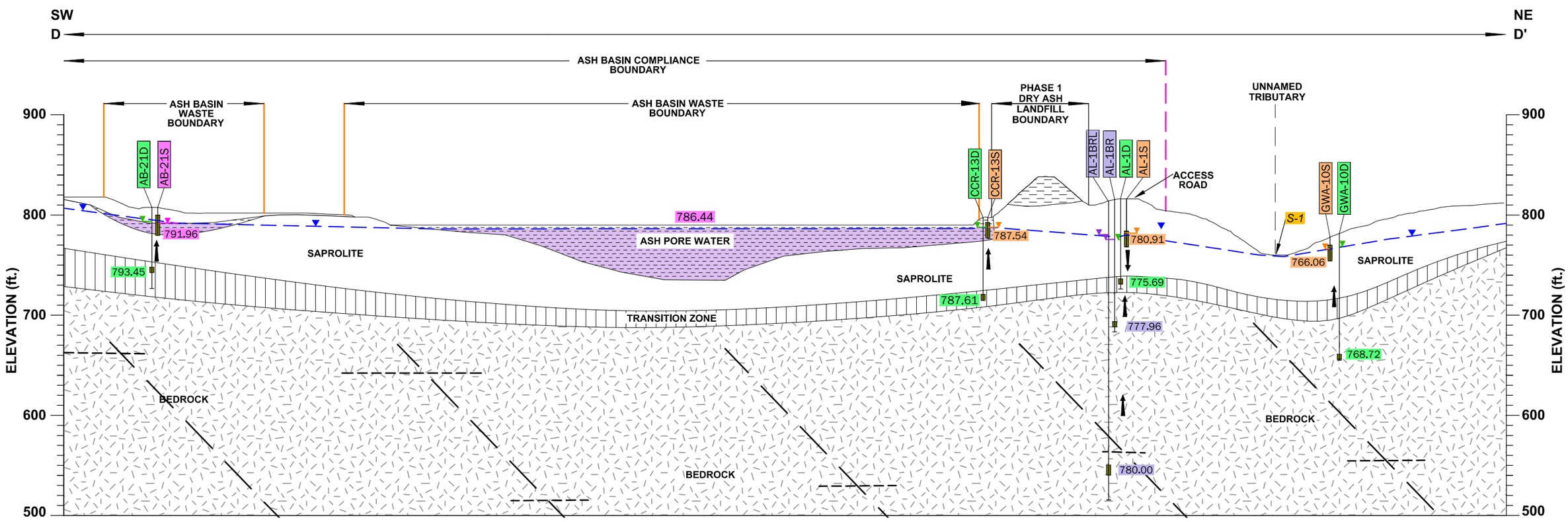
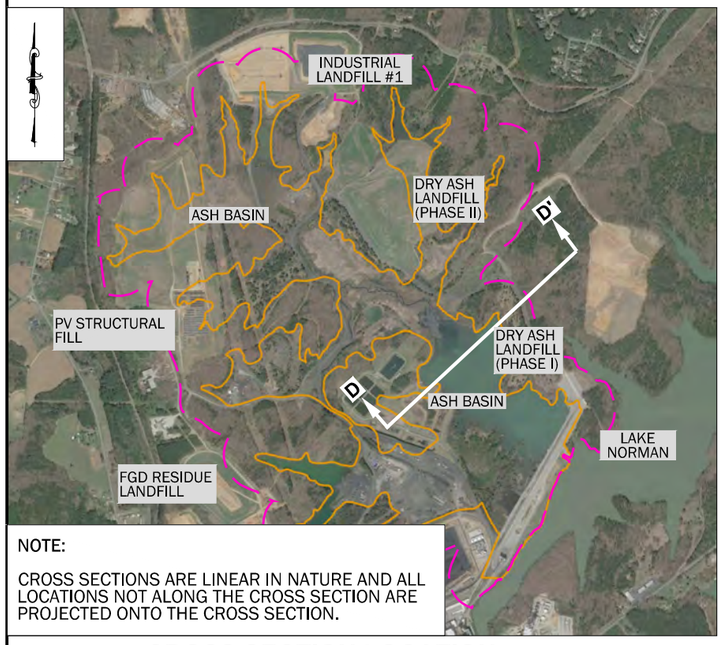
FIGURE 6-4
GENERAL CROSS SECTION C-C'
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- MW-12S — WELL IN SAPROLITE MATERIAL
- MW-16D — WELL IN TRANSITION ZONE
- MW-16BR — WELL IN BEDROCK
- ABMW-2 — WELL IN ASH PORE WATER
- S-1 — NON-CONSTRUCTED SEEP MONITORED UNDER THE SPECIAL ORDER BY CONSENT S17-009 (SOC)
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- 823.96 — WATER LEVEL ELEVATION - MAY 2019 (NAVD-88) (LABEL COLORING BY FLOW ZONE)
- GENERALIZED VERTICAL HYDRAULIC GRADIENT
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS ARE FROM THE MAY 2019 GAUGING EVENT. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS FROM CROSS SECTION C-C'. DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTHS ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
0 125 250
HORIZONTAL SCALE: 1" = 250'
VERTICAL SCALE: 1" = 100'
2.5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/11/2019
CHECKED BY: B. WILKER	DATE: 12/11/2019
APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	DATE: 12/11/2019

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FIGURE 6-5
GENERAL CROSS SECTION D-D'
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

PRE-DECANTING CONDITIONS

POST CLOSURE CONDITIONS
FOR CLOSURE-IN-PLACE

ILF STRUCTURAL FILL
INDUSTRIAL LANDFILL #1
ASBESTOS LANDFILL
DRY ASH LANDFILL (PHASE II)
DRY ASH LANDFILL (PHASE I)
ASH BASIN
PV STRUCTURAL FILL
BORROW AREA
ACCESS ROAD STRUCTURAL FILL
FGD RESIDUE LANDFILL
HOLDING BASIN
LRB
COAL PILE
GYPSUM PAD
MARSHALL STEAM STATION

70 FEET
0 FEET

LEGEND

- APPROXIMATE SATURATED ASH THICKNESS ISOPACH
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. SATURATED ASH THICKNESS BASED ON CLOSURE MODEL RESULTS WITH UNDERDRAINS.
2. ASH THICKNESS ISOPACH SURFACES FROM FLOW AND TRANSPORT MODELS (FALTA AND OTHERS, 2019)
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM ESRI ONLINE ON JUNE 10, 2019. AERIAL WAS COLLECTED ON FEBRUARY 6, 2017.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. DAVIS	DATE: 11/08/2019
REVISED BY: C. DAVIS	DATE: 12/12/2019
CHECKED BY: E. WEBSTER	DATE: 12/12/2019
APPROVED BY: E. WEBSTER	DATE: 12/12/2019
PROJECT MANAGER: B. WILKER	

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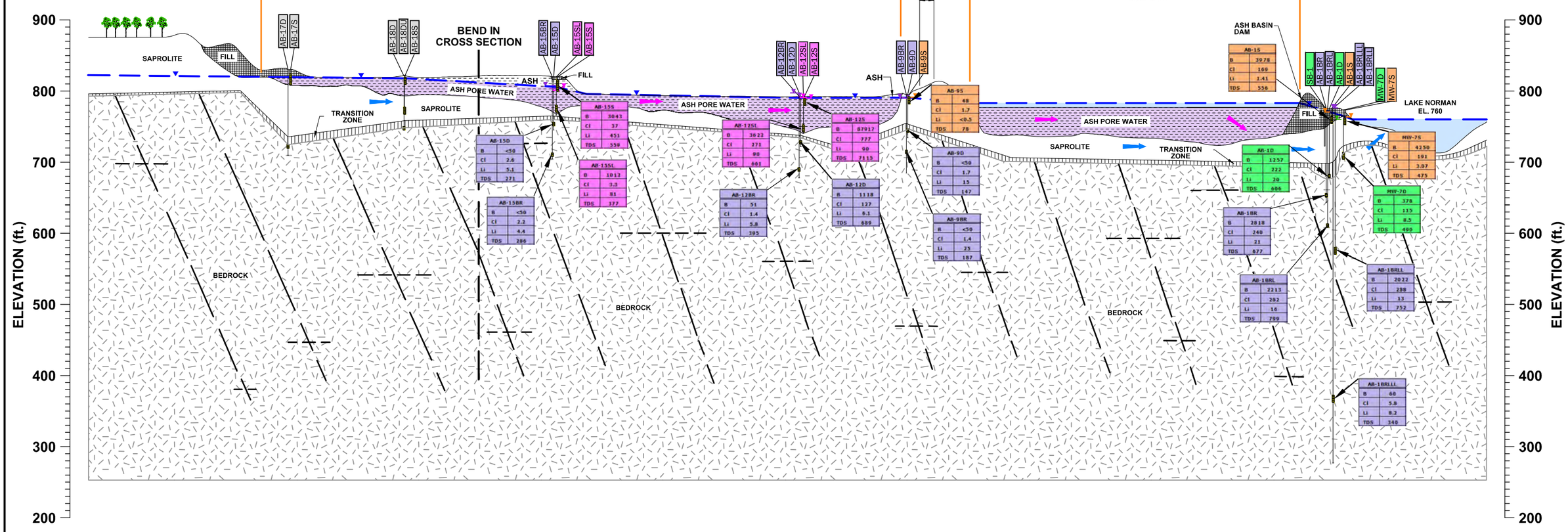
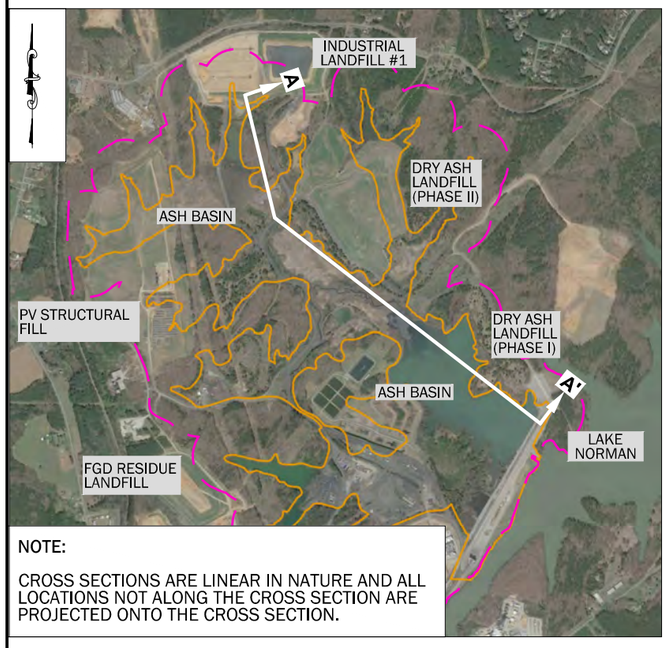
FIGURE 6-6
SATURATED ASH THICKNESS MAP FOR PRE-DECANTING AND POST-CLOSURE CONDITIONS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- AB-9S — WELL IN SAPROLITE MATERIAL
- AB-1D — WELL IN TRANSITION ZONE
- AB-15BR — WELL IN BEDROCK
- AB-15S — WELL IN ASH PORE WATER
- AB-18D — ABANDONED WELL
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- FILL
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- SURFACE WATER

- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- MEAN BORON (B) CONCENTRATION (µg/L)
  MEAN CHLORIDE (Cl) CONCENTRATION (mg/L)
  MEAN LITHIUM (Li) CONCENTRATION (µg/L)
  MEAN TOTAL DISSOLVED SOLIDS (TDS) CONCENTRATION (mg/L)
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS REPRESENT THE MAY, 2019 GAUGING EVENT FOR EACH WELL. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED IN THE SAME DAY. REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THIS CROSS SECTION IS APPROXIMATELY PARALLEL TO THE PREDOMINANT FRACTURE STRIKE DIRECTION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

COI NOTES:

1. ALL CONCENTRATIONS SHOWN ARE STATISTICAL MEANS CALCULATED BASED ON CENTRAL TENDANCY OF DATASET USING DATA RANGING FROM JANUARY 2018 TO MAY 2019.
2. BORON (B) AND LITHIUM (Li) CONCENTRATIONS ARE IN MICROGRAMS PER LITER (µg/L).
3. CHLORIDE (Cl) AND TOTAL DISSOLVED SOLIDS (TDS) CONCENTRATIONS ARE IN MILLIGRAMS PER LITER (mg/L).
4. WELLS WITH DATASETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA UP TO JUNE 2019 WAS USED.

ANALYTICAL PARAMETER	B	Cl	Li	TDS
REPORTING UNITS	µg/L	mg/L	µg/L	mg/L
15A NCAC 02L Standard	700	250	NE	500
Background Threshold Values (Shallow Flow Zone)[1]	50	5.0	4.8	152
Background Threshold Values (Deep Flow Zone)[1]	50	4.2	10	200
Background Threshold Values (Bedrock Flow Zone)[1]	50	3.6	11.4	195

[1] - UPDATED BACKGROUND THRESHOLD VALUES (BTVs) WERE CALCULATED USING DATA FROM BACKGROUND GROUNDWATER SAMPLES COLLECTED FEBRUARY 2010 TO DECEMBER 2018.

DUKE ENERGY CAROLINAS

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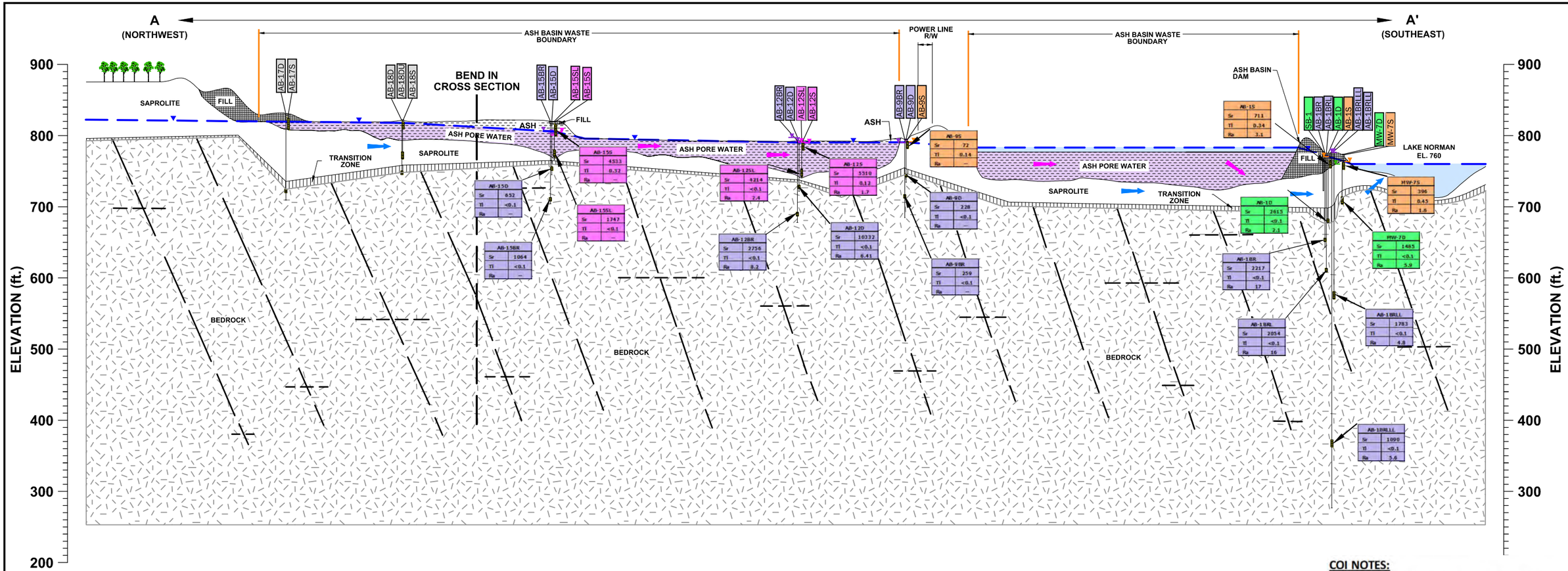
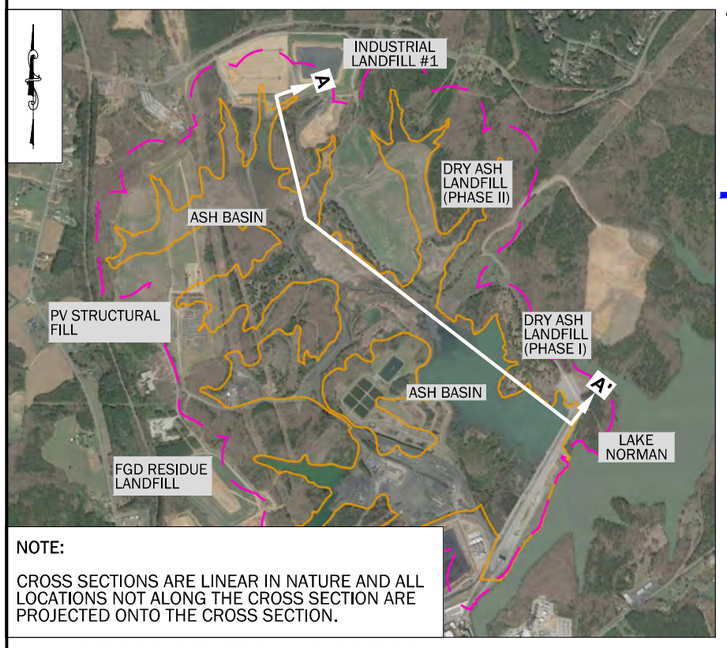
GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/24/2019
CHECKED BY: B. WILKER	DATE: 12/24/2019
APPROVED BY: B. WILKER	DATE: 12/24/2019
PROJECT MANAGER: B. WILKER	DATE: 12/24/2019

FIGURE 6-7a
GENERAL CROSS SECTION A-A'
CONSERVATIVE GROUP
MEAN OF BORON, CHLORIDE, LITHIUM, TOTAL DISSOLVED SOLIDS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- AB-9S — WELL IN SAPROLITE MATERIAL
- AB-1D — WELL IN TRANSITION ZONE
- AB-15BR — WELL IN BEDROCK
- AB-15S — WELL IN ASH PORE WATER
- AB-18D — ABANDONED WELL
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- FILL
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- SURFACE WATER
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- MEAN STRONTIUM (Sr) CONCENTRATION (µg/L)
  MEAN THALLIUM (Tl) CONCENTRATION (µg/L)
  MEAN TOTAL RADIUM (Ra) CONCENTRATION (pCi/L)

AB-1BRL	
Sr	2054
Tl	<0.1
Ra	16

- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS REPRESENT THE MAY, 2019 GAUGING EVENT FOR EACH WELL. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED IN THE SAME DAY. REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THIS CROSS SECTION IS APPROXIMATELY PARALLEL TO THE PREDOMINANT FRACTURE STRIKE DIRECTION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

COI NOTES:

1. ALL CONCENTRATIONS SHOWN ARE STATISTICAL MEANS CALCULATED BASED ON CENTRAL TENDANCY OF DATASET USING DATA RANGING FROM JANUARY 2018 TO MAY 2019.
2. STRONTIUM (Sr) AND THALLIUM (TI) ARE IN MICROGRAMS PER LITER (µg/L).
3. TOTAL RADIUM CONCENTRATIONS ARE IN PICOCURIES PER LITER OF AIR (pCi/L).
4. WELLS WITH DATASETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA UP TO JUNE 2019 WAS USED.

- NO DATA AVAILABLE

ANALYTICAL PARAMETER	Sr	Tl	Ra
REPORTING UNITS	µg/L	µg/L	pCi/L
15A NCAC 02L Standard	NE	0.2*	5^
Background Threshold Values (Shallow Flow Zone)[1]	210	0.2	5.33
Background Threshold Values (Deep Flow Zone)[1]	727	0.1	7.46
Background Threshold Values (Bedrock Flow Zone)[1]	313	0.2	6.43

[1]- UPDATED BACKGROUND THRESHOLD VALUES (BTVs) WERE CALCULATED USING DATA FROM BACKGROUND GROUNDWATER SAMPLES COLLECTED FEBRUARY 2010 TO DECEMBER 2018.

* - INTERIM MAXIMUM ALLOWABLE CONCENTRATION (IMAC) OF THE 15A NCAC 02L STANDARD, APPENDIX 1, APRIL 1, 2013.

^ - FEDERAL MAXIMUM CONTAMINANT LEVEL.

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/24/2019
CHECKED BY: B. WILKER	DATE: 12/24/2019
APPROVED BY: B. WILKER	DATE: 12/24/2019
PROJECT MANAGER: B. WILKER	DATE: 12/24/2019

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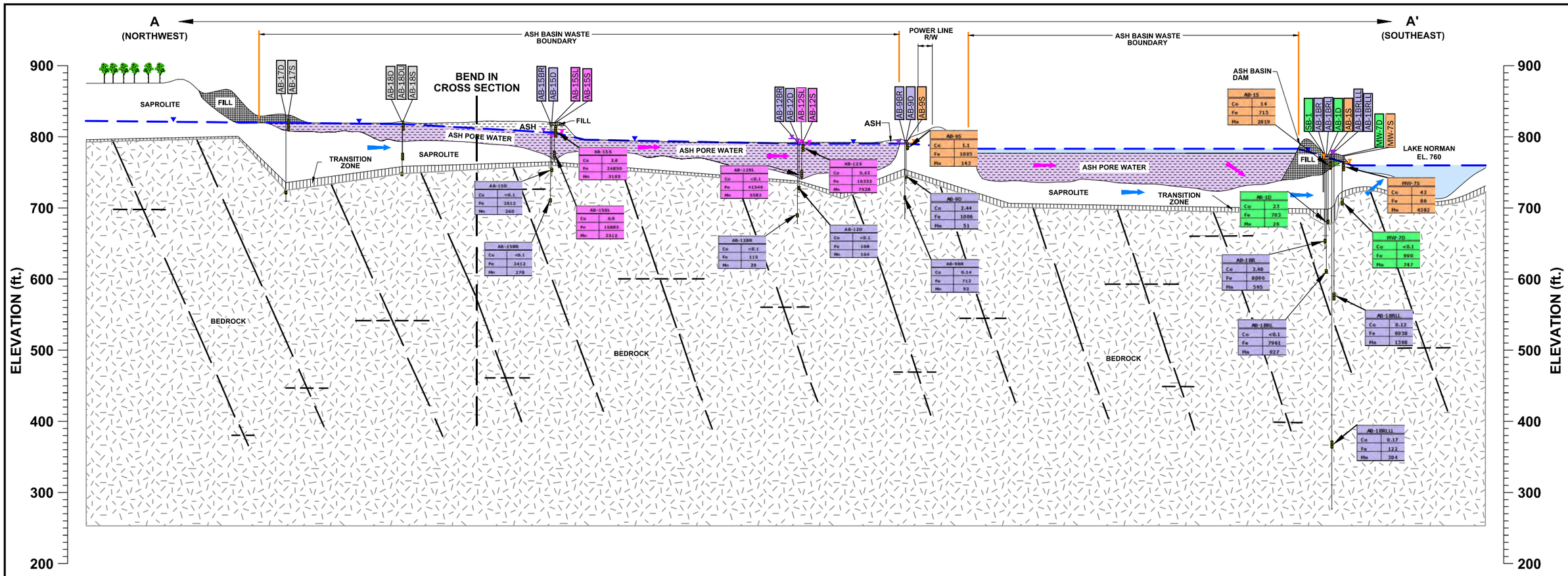
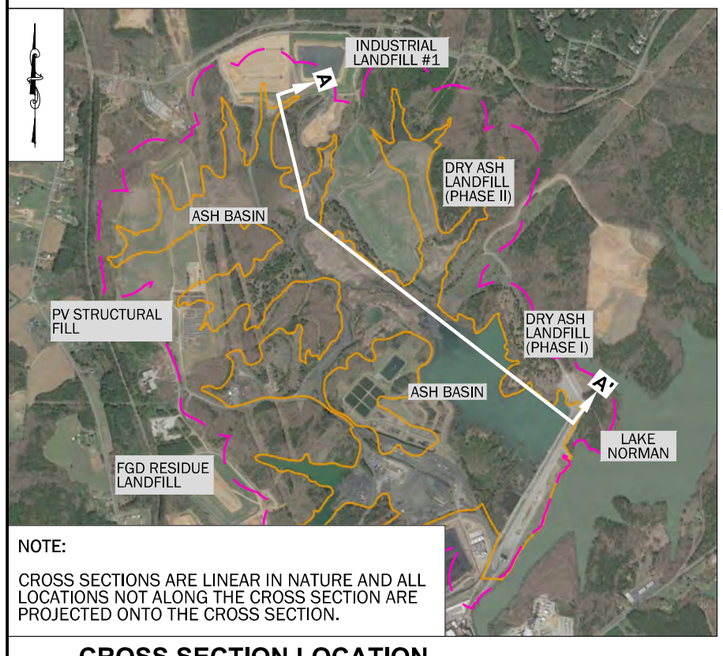
FIGURE 6-7b
GENERAL CROSS SECTION A-A'
NON-CONSERVATIVE GROUP
MEAN OF STRONTIUM, THALLIUM, TOTAL RADIUM
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA





NOTE:

CROSS SECTIONS ARE LINEAR IN NATURE AND ALL LOCATIONS NOT ALONG THE CROSS SECTION ARE PROJECTED ONTO THE CROSS SECTION.

CROSS SECTION LOCATION

LEGEND

- AB-9S — WELL IN SAPROLITE MATERIAL
- AB-1D — WELL IN TRANSITION ZONE
- AB-15BR — WELL IN BEDROCK
- AB-15S — WELL IN ASH PORE WATER
- AB-18D — ABANDONED WELL
- GENERALIZED WATER TABLE
- GENERALIZED GROUNDWATER FLOW DIRECTION
- GENERALIZED ASH PORE WATER FLOW DIRECTION
- PREDOMINANT BEDROCK FRACTURE ORIENTATION
- ASH
- ASH PORE WATER
- FILL
- SAPROLITE
- TRANSITION ZONE
- BEDROCK
- SURFACE WATER
- SHALLOW FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- DEEP FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- BEDROCK FLOW LAYER GROUNDWATER WELL WATER LEVEL ELEVATION
- ASH PORE WATER FLOW LAYER WATER LEVEL ELEVATION
- MEAN COBALT (Co) CONCENTRATION (µg/L)
  MEAN IRON (Fe) CONCENTRATION (µg/L)
  MEAN MANGANESE (Mn) CONCENTRATION (µg/L)
- WELL SCREEN
- ASH BASIN COMPLIANCE BOUNDARY
- ASH BASIN WASTE BOUNDARY

NOTES

1. WATER ELEVATIONS REPRESENT THE MAY, 2019 GAUGING EVENT FOR EACH WELL. NOTE ELEVATIONS WITHIN EACH CLUSTER ARE MEASURED IN THE SAME DAY. REFERENCED TO NORTH AMERICAN VERTICAL DATUM 1988.
2. FRACTURES DEPICTED ON THIS CROSS SECTION REPRESENT THE GENERALIZED ORIENTATIONS OF THE PREVALENT FRACTURE SETS OBSERVED AT THE SITE BASED ON TELEVIEWER LOGGING AT SITE-SPECIFIC BOREHOLES. THEY ARE SHOWN WITH APPROPRIATE APPARENT DIP, WITH VERTICAL EXAGGERATION. THIS CROSS SECTION IS APPROXIMATELY PARALLEL TO THE PREDOMINANT FRACTURE STRIKE DIRECTION. THE ACTUAL NUMBER OF FRACTURES IS FAR TOO NUMEROUS TO ILLUSTRATE AT THIS SCALE. IN ADDITION, THE DEPTHS AND LENGTHS OF FRACTURES VERSUS DEPTH ARE CONCEPTUAL ONLY.
3. ALL BOUNDARIES ARE APPROXIMATE.
4. CROSS SECTION REPRESENTATIVE OF PRE-DECANTING CONDITIONS.

COI NOTES:

1. ALL CONCENTRATIONS SHOWN ARE STATISTICAL MEANS CALCULATED BASED ON CENTRAL TENDANCY OF DATASET USING DATA RANGING FROM JANUARY 2018 TO MAY 2019.
2. COBALT (Co), IRON (Fe), AND MANGANESE (Mn) CONCENTRATIONS ARE IN MICROGRAMS PER LITER (µg/L).
3. WELLS WITH DATASETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA UP TO JUNE 2019 WAS USED.

ANALYTICAL PARAMETER	Co	Fe	Mn
REPORTING UNITS	µg/L	µg/L	µg/L
15A NCAC 02L Standard	1*	300	50
Background Threshold Values (Shallow Flow Zone)[1]	5.0	1095	155
Background Threshold Values (Deep Flow Zone)[1]	3.2	225	142
Background Threshold Values (Bedrock Flow Zone)[1]	2.6	1220	330

[1] - UPDATED BACKGROUND THRESHOLD VALUES (BTVS) WERE CALCULATED USING DATA FROM BACKGROUND GROUNDWATER SAMPLES COLLECTED FEBRUARY 2010 TO DECEMBER 2018.
* - INTERIM MAXIMUM ALLOWABLE CONCENTRATION (IMAC) OF THE 15A NCAC 02L STANDARD, APPENDIX 1, APRIL 1, 2013.

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
0 350 700
HORIZONTAL SCALE: 1" = 700'
VERTICAL SCALE: 1" = 140'
5X VERTICAL EXAGGERATION

DRAWN BY: J. CHASTAIN	DATE: 08/01/2019
REVISED BY: D. KREFSKI	DATE: 12/24/2019
CHECKED BY: B. WILKER	DATE: 12/24/2019
APPROVED BY: B. WILKER	DATE: 12/24/2019
PROJECT MANAGER: B. WILKER	DATE: 12/24/2019

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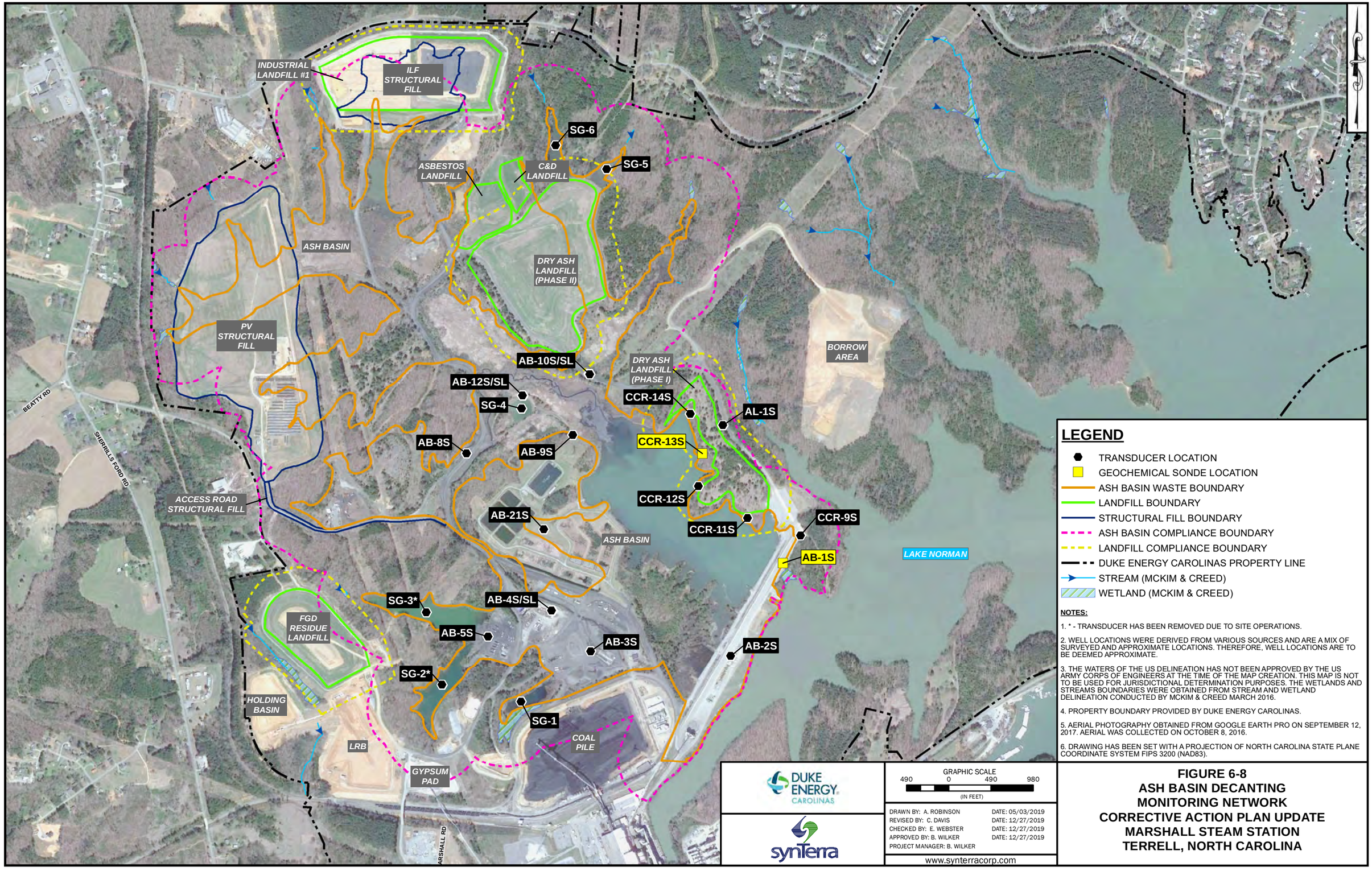
FIGURE 6-7c
GENERAL CROSS SECTION A-A'
VARIABLE GROUP
MEANS OF COBALT, IRON, MANGANESE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. * - TRANSDUCER HAS BEEN REMOVED DUE TO SITE OPERATIONS.
2. WELL LOCATIONS WERE DERIVED FROM VARIOUS SOURCES AND ARE A MIX OF SURVEYED AND APPROXIMATE LOCATIONS. THEREFORE, WELL LOCATIONS ARE TO BE DEEMED APPROXIMATE.
3. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
4. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
5. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON SEPTEMBER 12, 2017. AERIAL WAS COLLECTED ON OCTOBER 8, 2016.
6. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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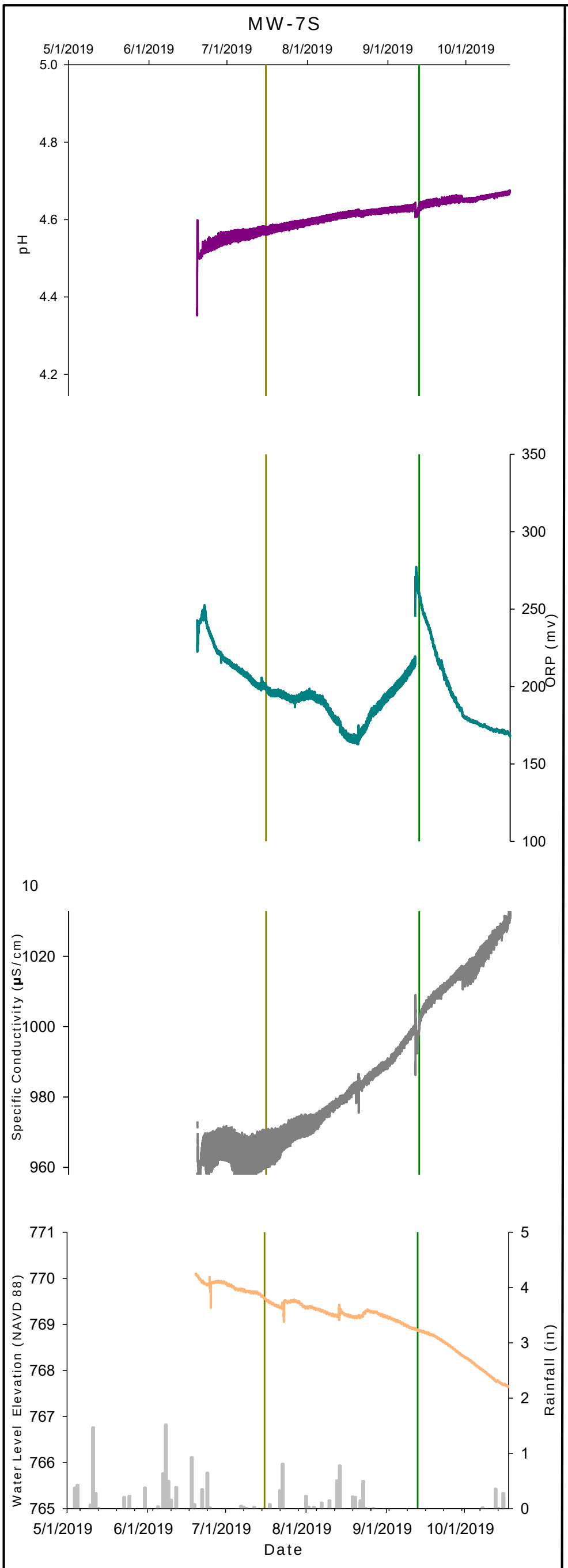
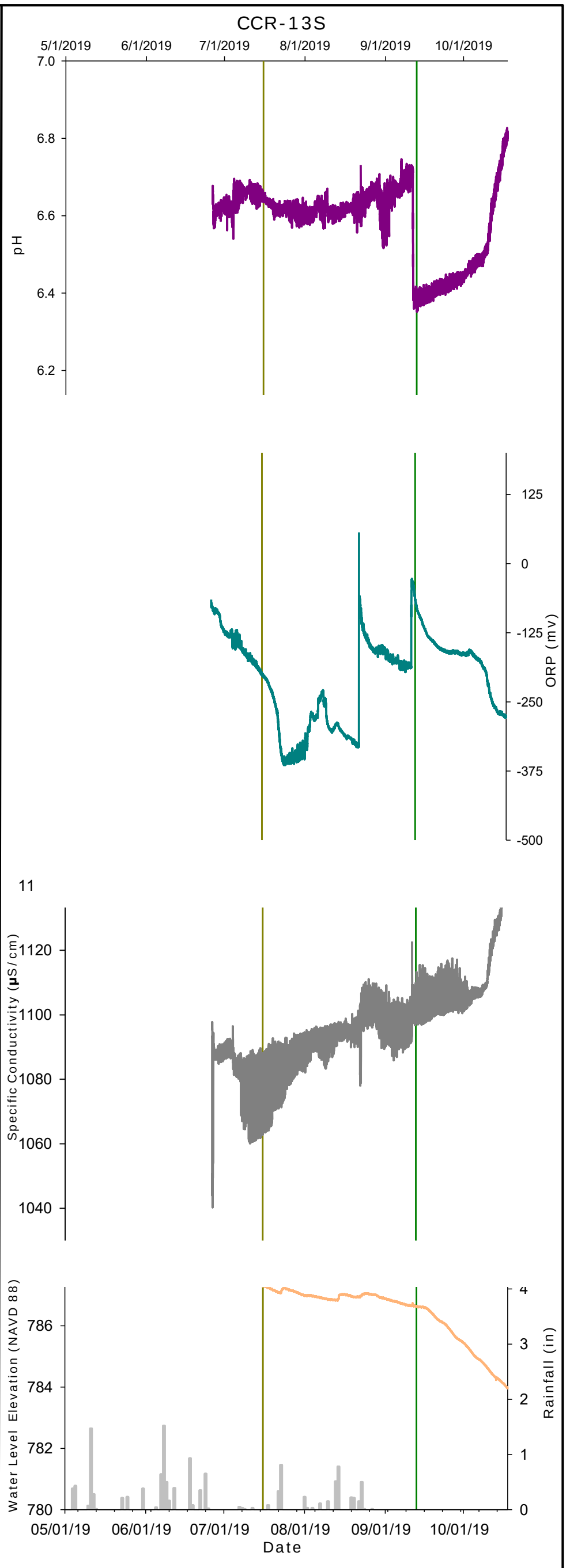
GRAPHIC SCALE
490 0 490 980
(IN FEET)

DRAWN BY: A. ROBINSON	DATE: 05/03/2019
REVISED BY: C. DAVIS	DATE: 12/27/2019
CHECKED BY: E. WEBSTER	DATE: 12/27/2019
APPROVED BY: B. WILKER	DATE: 12/27/2019
PROJECT MANAGER: B. WILKER	

FIGURE 6-8
ASH BASIN DECANTING MONITORING NETWORK
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



MW-7S: Shallow flow zone monitoring well located within the



CCR-13S: Deep flow zone well located downgradient of the ash

LEGEND

- pH (S.U.)
- Oxidation Reduction Potential (ORP) (mV)
- Specific Conductivity (mS/cm)
- Gravity Flow Decanting Start (07/16/2019)
- Mechanical Decanting Start (09/13/2019)
- Daily Total (inches)

Notes:
NAVD 88 – North American Vertical Datum
in – inches
µS/cm – micro Siemens per centimeter
mv – millivolts
SU – standard unit

DUKE ENERGY CAROLINAS

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DRAWN BY: D. AVARD
DATE: 10/31/2019
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CHECKED BY: E. WEBSTER
APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER

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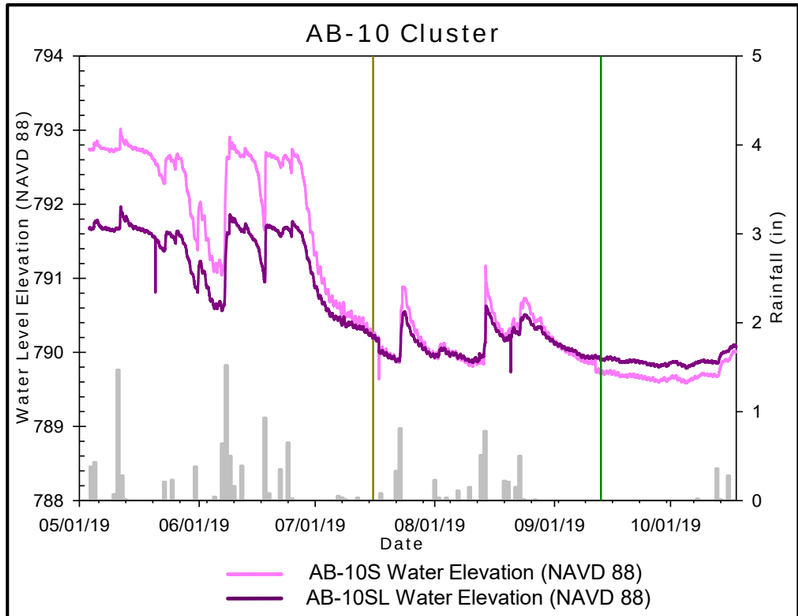
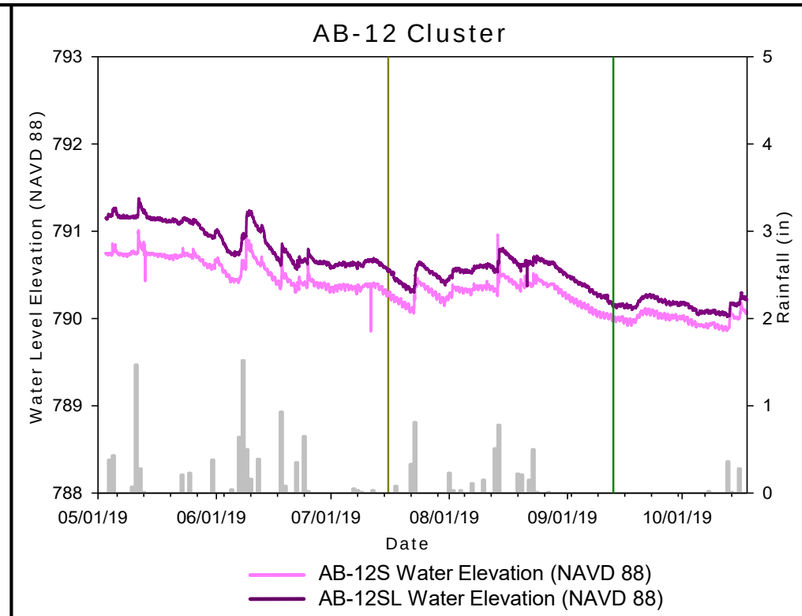
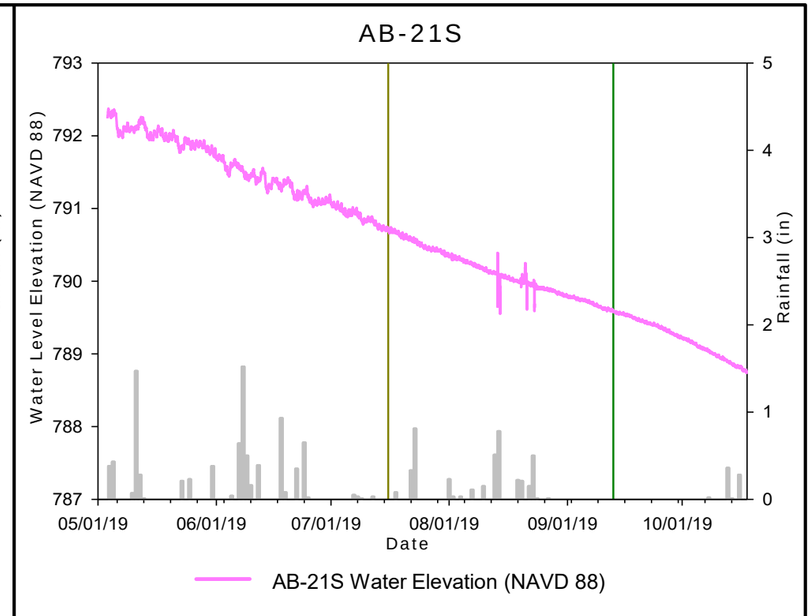
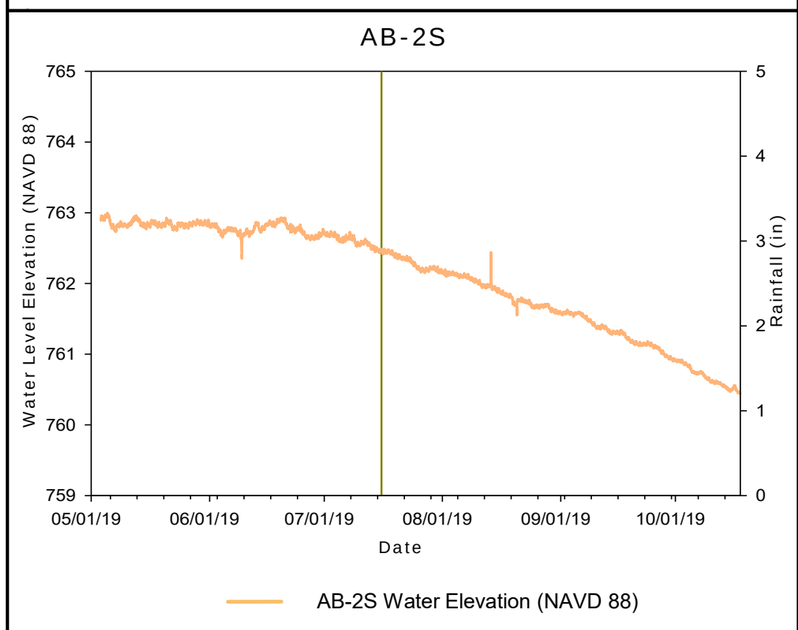
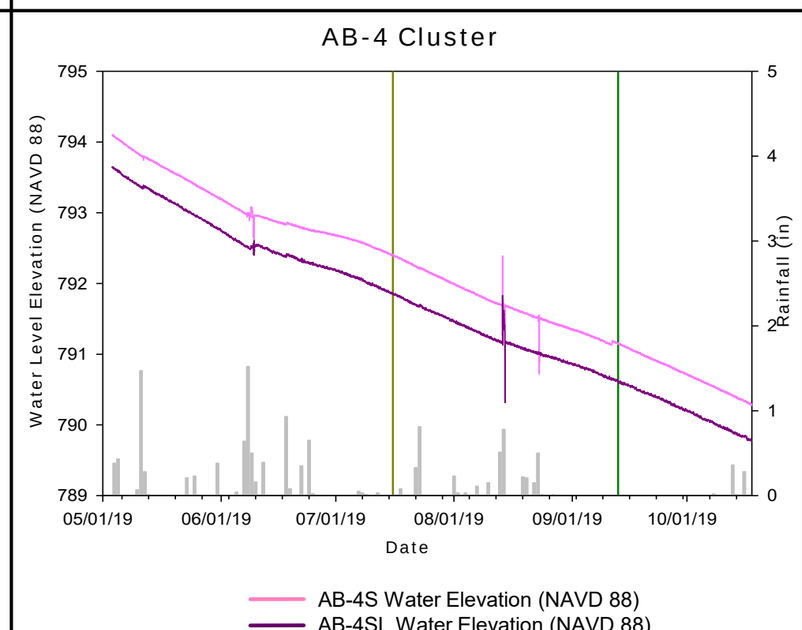
FIGURE 6-9
GEOCHEMICAL WATER QUALITY PLOTS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NC

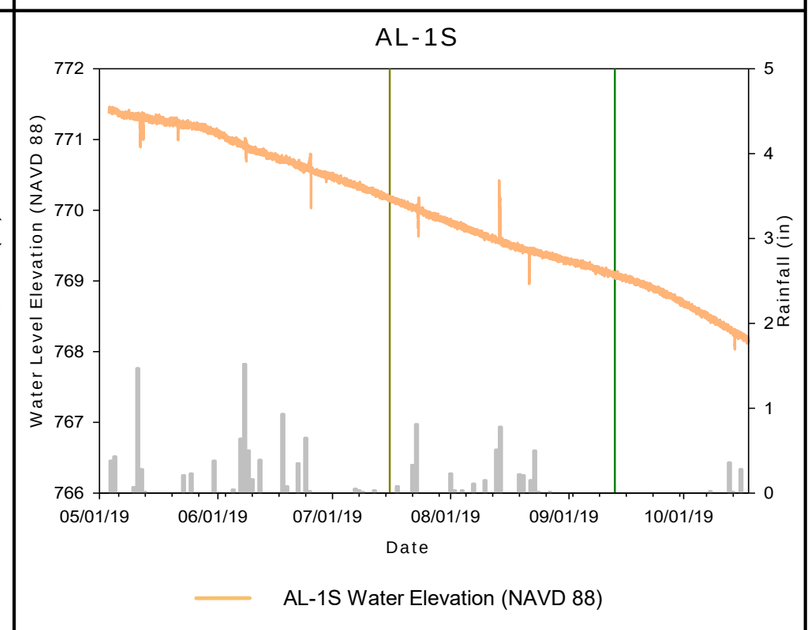












LEGEND

- Gravity Flow Decanting Start (07/16/2019)
- Mechanical Decanting Start (09/13/2019)
- Daily Total Rainfall (inches)
- Ash Pore Water
- Lower Ash Pore Water
- Shallow Flow Zone

Notes:
NAVD 88 – North American Vertical Datum 1988
in – inches
See Figure 6-8 for monitoring locations

DUKE ENERGY CAROLINAS

synTerra

DRAWN BY: D. AVARD DATE: 11/05/2019
REVISED BY: E. WEBSTER
CHECKED BY: E. WEBSTER
APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER

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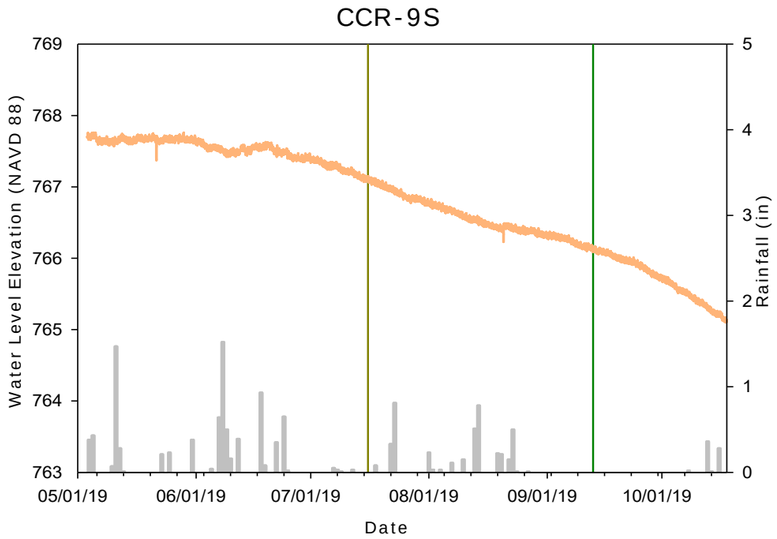
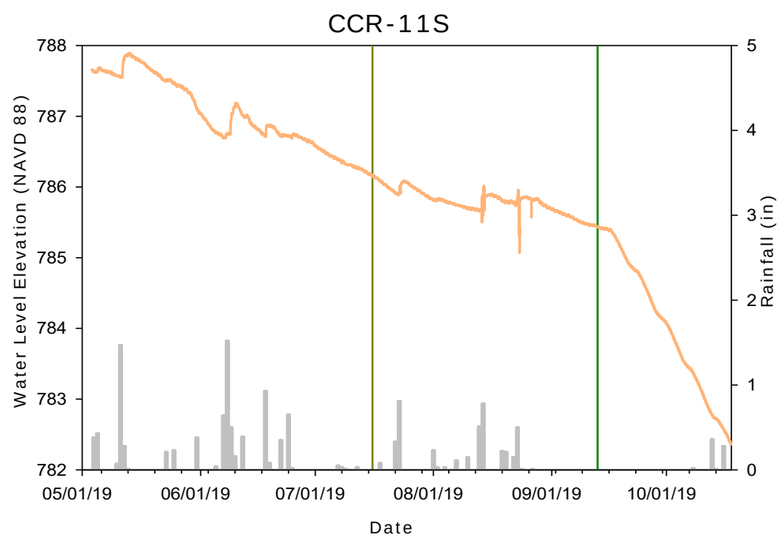
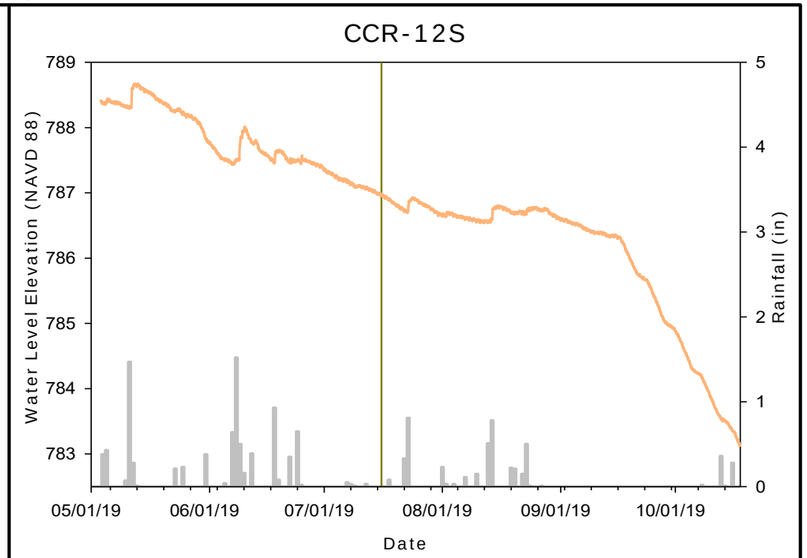
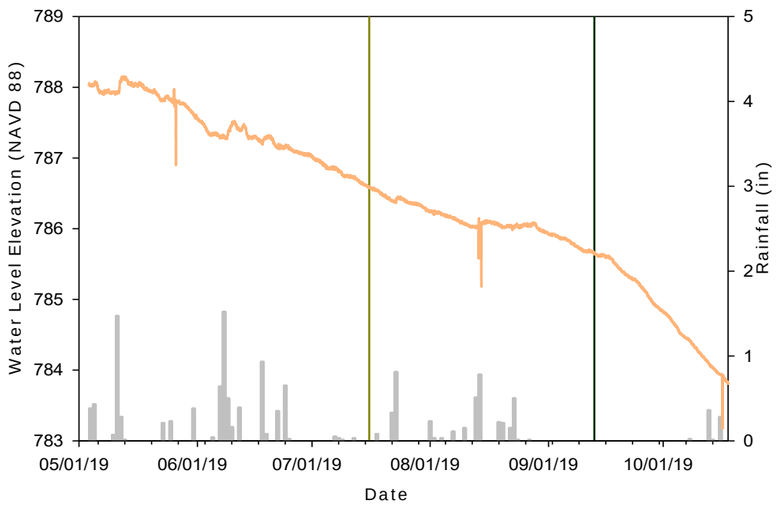
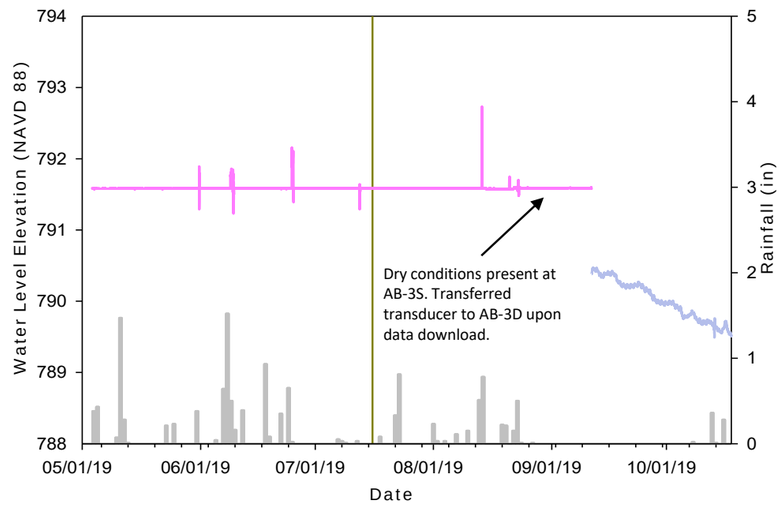
FIGURE 6-10a
HYDROGRAPHS – ASH BASIN AND VICINITY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

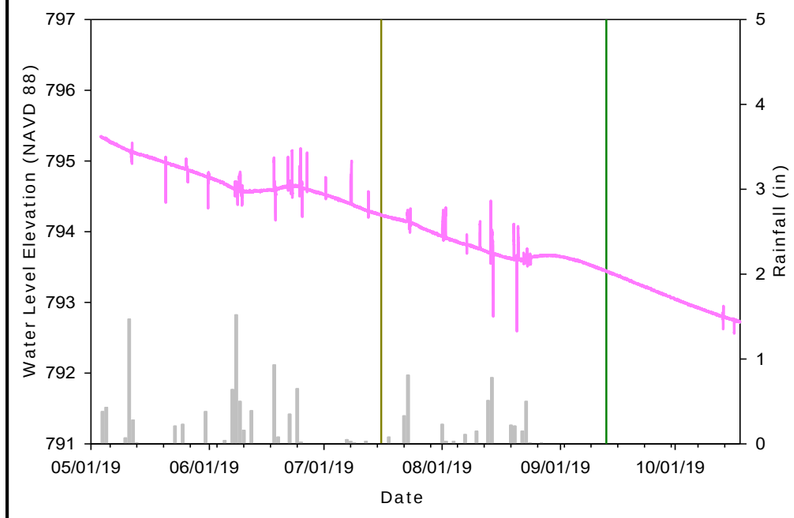












LEGEND

- Gravity Flow Decanting Start (07/16/2019)
- Mechanical Decanting Start (09/13/2019)
- Daily Total Rainfall (inches)
- Ash Pore Water
- Shallow Flow Zone
- Bedrock Flow Zone

Notes:
NAVD 88 – North American Vertical Datum 1988
in – inches
See Figure 6-8 for monitoring locations

DUKE ENERGY CAROLINAS

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DRAWN BY: D. AVARD DATE: 11/05/2019
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CHECKED BY: E. WEBSTER
APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER
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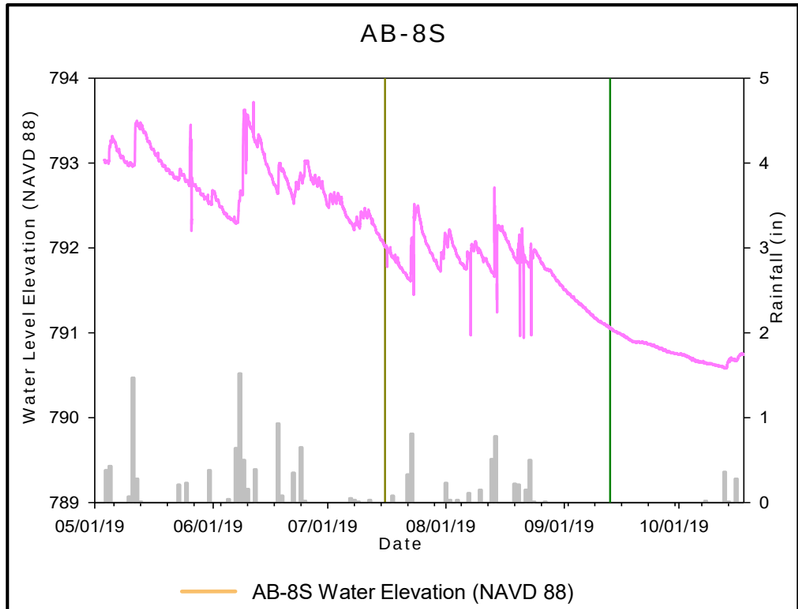
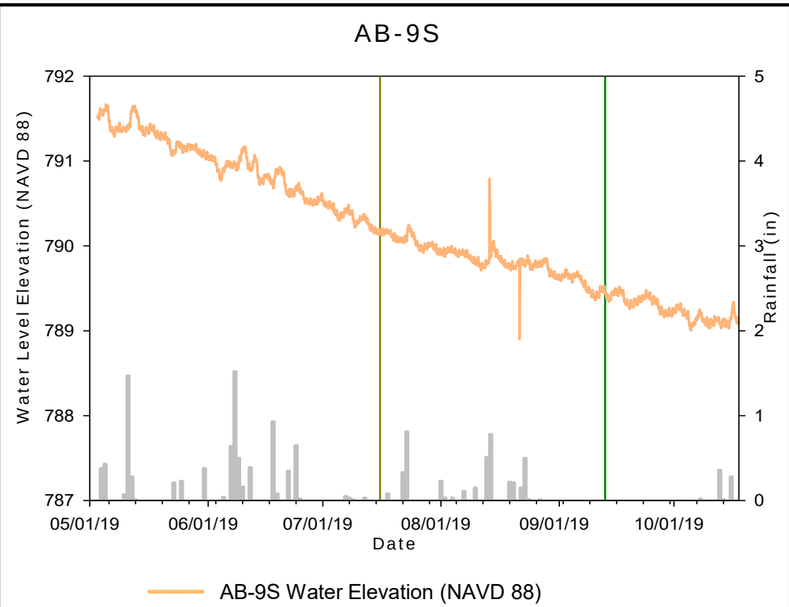
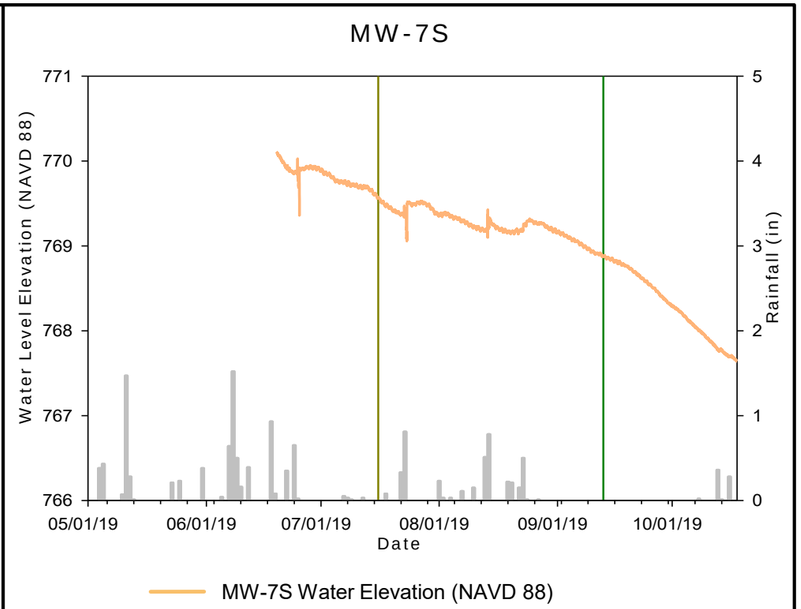
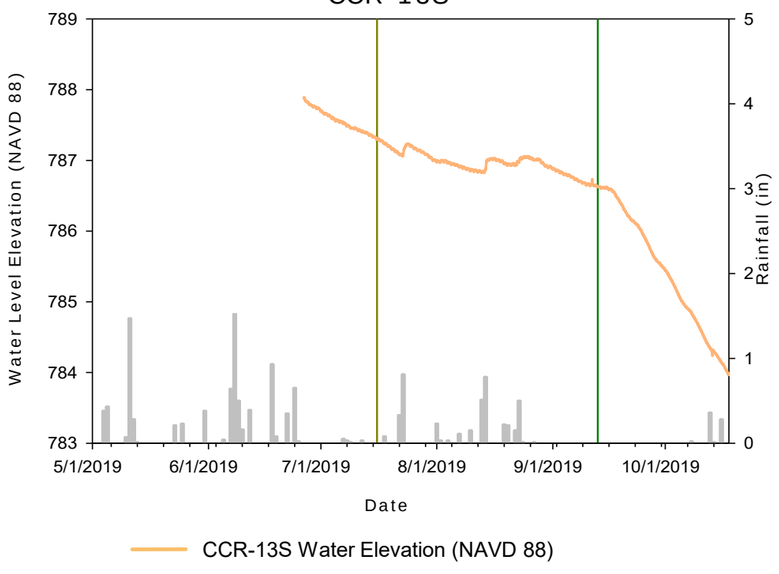
FIGURE 6-10b
HYDROGRAPHS – ASH BASIN AND VICINITY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA









LEGEND

- Gravity Flow Decanting Start (07/16/2019)
- Mechanical Decanting Start (09/13/2019)
- Daily Total Rainfall (inches)
- Ash Pore Water
- Shallow Flow Zone

Notes:
NAVD 88 – North American Vertical Datum 1988
in – inches
See Figure 6-8 for monitoring locations

DUKE ENERGY CAROLINAS

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REVISED BY: E. WEBSTER
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APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER

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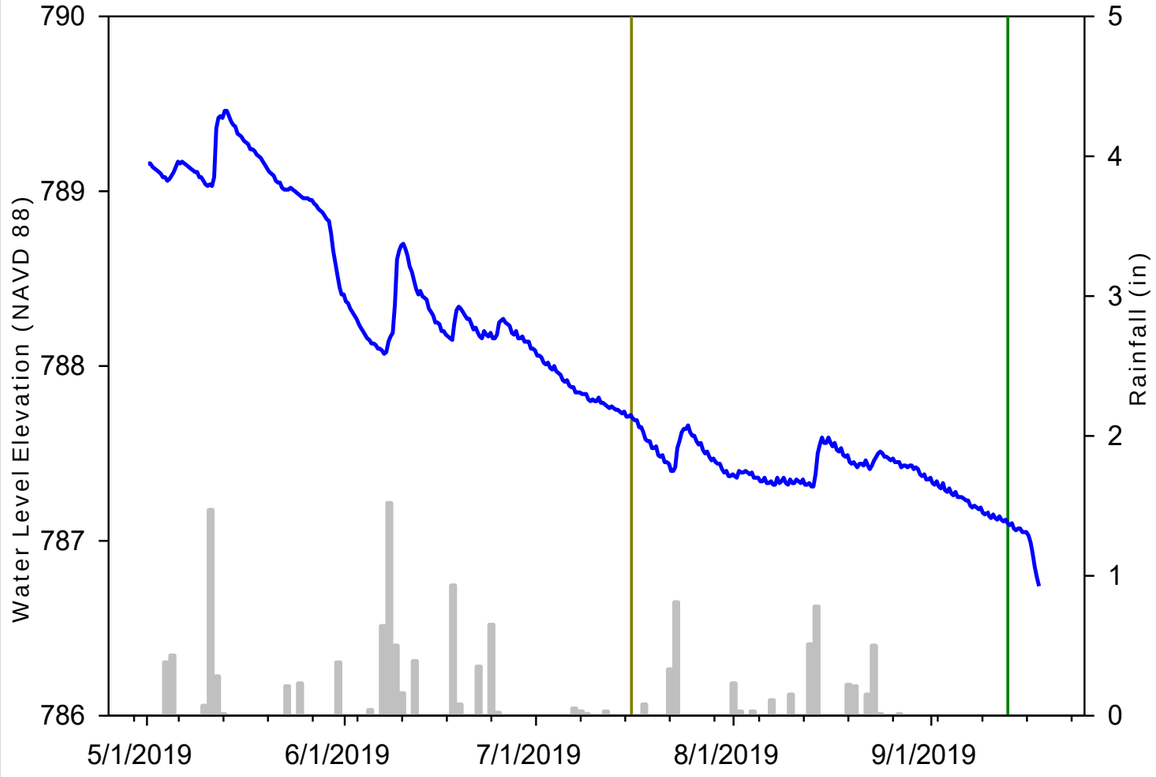
FIGURE 6-10c
HYDROGRAPHS – ASH BASIN AND VICINITY
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

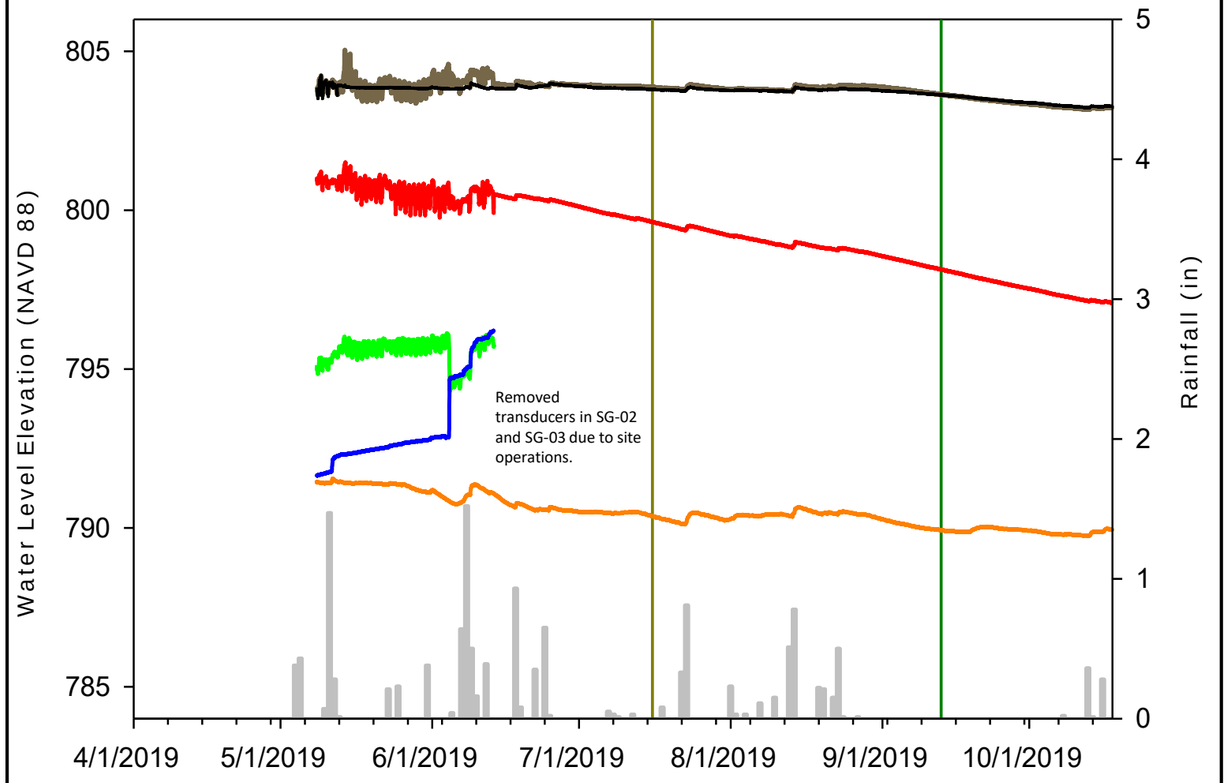
Ash Basin Pond



Date

Ash Basin Pond Level Elevation (NAVD 88)

Ash Basin Ponded Water Monitoring



Date

SG-01 Water Elevation (NAVD 88)
SG-02 Water Elevation (NAVD 88)
SG-03 Water Elevation (NAVD 88)
SG-04 Water Elevation (NAVD 88)
SG-05 Water Elevation (NAVD 88)
SG-06 Water Elevation (NAVD 88)

LEGEND

- Gravity Flow Decanting Start (07/16/2019)
- Mechanical Decanting Start (09/13/2019)
- Daily Total Rainfall (inches)

Notes:
NAVD 88 – North American Vertical Datum 1988
in – inches
See Figure 6-8 for monitoring locations

DUKE ENERGY CAROLINAS

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DRAWN BY: D. AVARD DATE: 11/05/2019
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APPROVED BY: E. WEBSTER
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FIGURE 6-10d
HYDROGRAPHS – ASH BASIN PONDED WATER
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Ash Pore Water Legend

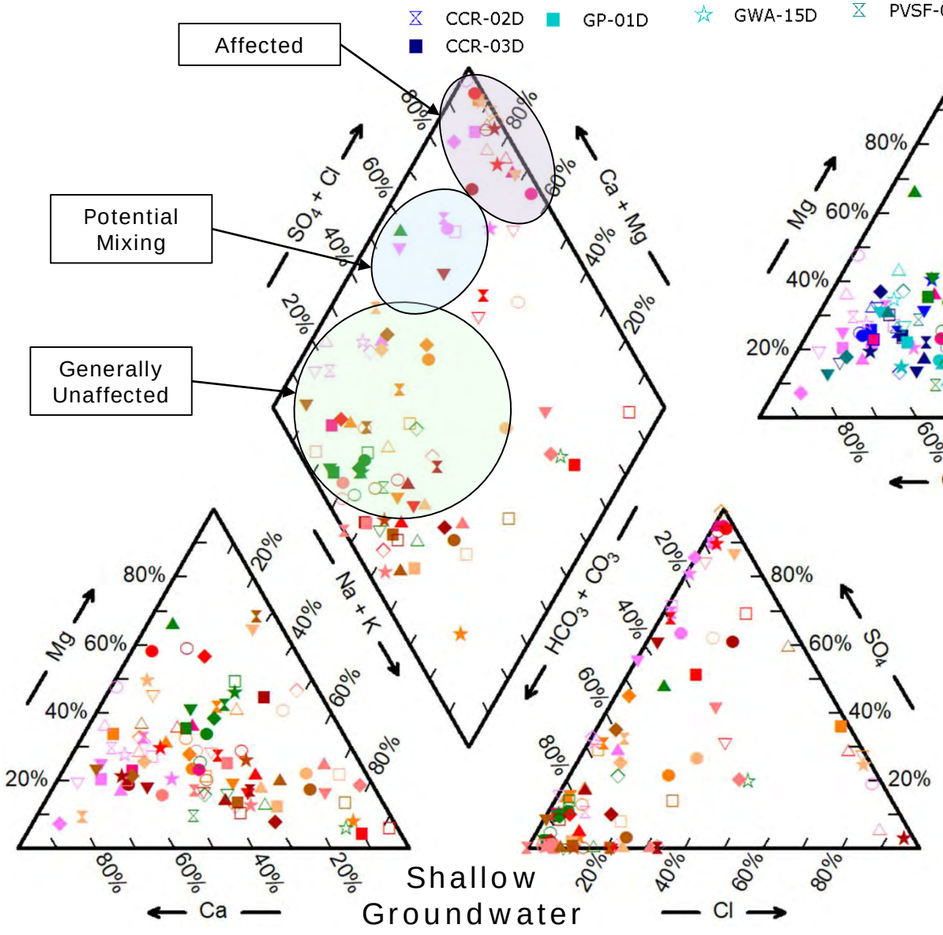
AB-03S, AB-04S, AB-04SL, AB-06S, AB-07S, AB-08S, AB-10S, AB-10SL, AB-12S, AB-12SL, AB-13S, AB-14S, AB-15S, AB-15SL, AB-18S, AB-20S, AL-03S

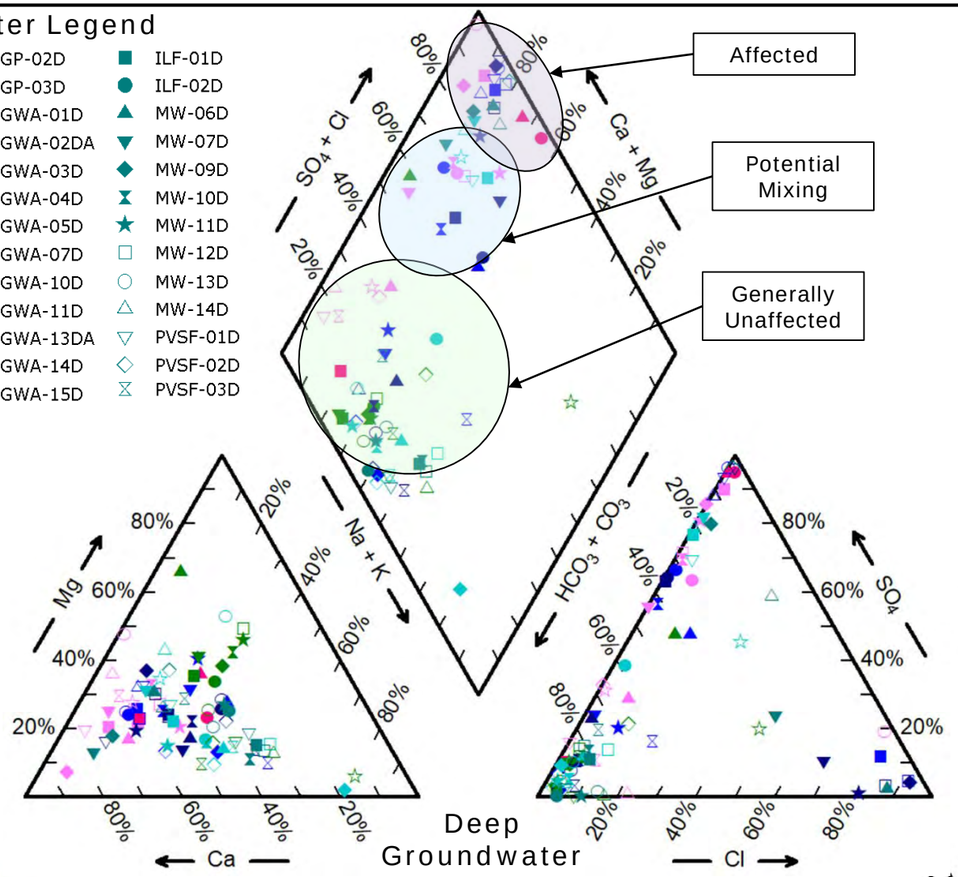
Deep Groundwater Legend

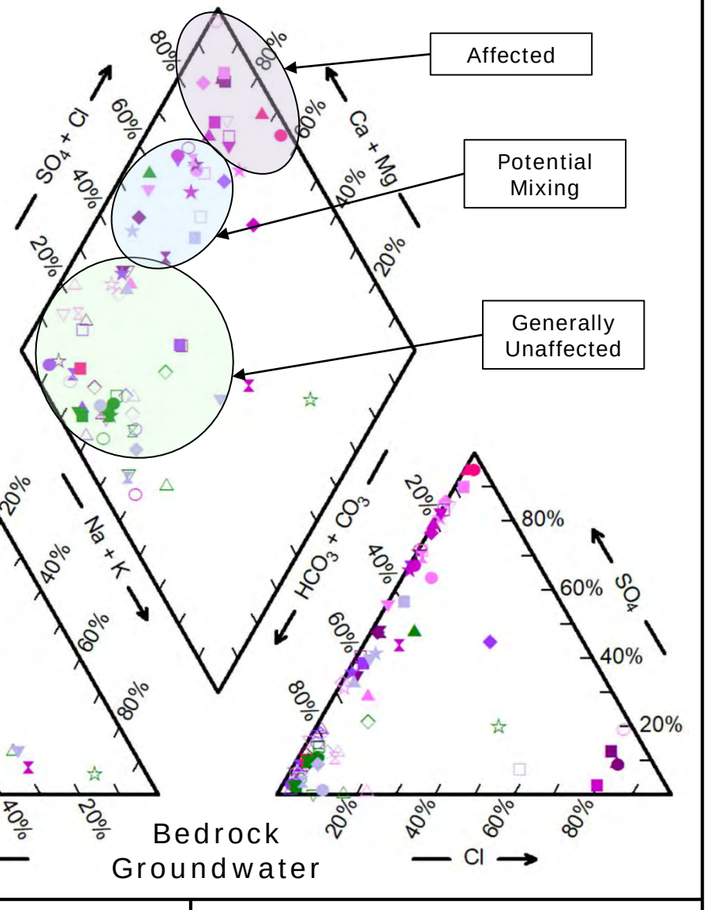
AB-01D, AB-02D, AB-04D, AB-05D, AB-07D, AB-14D, AB-21D, AL-01D, AL-02D, AL-03D, AL-04D, CCR-01D, CCR-02D, CCR-03D, CCR-04D, CCR-05D, CCR-09DA, CCR-11D, CCR-12D, CCR-13D, CCR-14D, CCR-15D, CCR-16D, CP-01D, CP-02D, CP-03D, GP-01D, GP-02D, GP-03D, GWA-01D, GWA-02DA, GWA-03D, GWA-04D, GWA-05D, GWA-07D, GWA-10D, GWA-11D, GWA-13DA, GWA-14D, GWA-15D, ILF-01D, ILF-02D, MW-06D, MW-07D, MW-09D, MW-10D, MW-11D, MW-12D, MW-13D, MW-14D, PVSF-01D, PVSF-02D, PVSF-03D

Bedrock Groundwater Legend

AB-01BR, AB-01BRL, AB-01BRLL, AB-01BRLLL, AB-02BR, AB-03D, AB-05BR, AB-06BRA, AB-06BRL, AB-06D, AB-08D, AB-09BR, AB-09D, AB-10BR, AB-10BRL, AB-10D, AB-11D, AB-12BR, AB-12D, AB-13D, AB-15BR, AB-15D, AB-16D, AB-17D, AB-18D, AB-20D, AL-01BR, AL-01BRL, AL-02BR, AL-02BRL, AL-02BRLL, AL-02BRLLL, AL-03BR, AL-04BR, AL-04BRL, GWA-01BR, GWA-09BR, GWA-11BR, GWA-12BR, ILF-01BR, MW-04D, MW-08D, MW-14BR, MW-14BRL, PVSF-01BR, PVSF-02BR, PVSF-03BR







Background Monitoring Well Legend

BG-01BRA, BG-01D, BG-01S, BG-02BR, BG-02S, BG-03BR, BG-03D, BG-03S, GWA-06D, GWA-06S, GWA-08D, GWA-08S, GWA-12D, GWA-12S

AB-01S, AB-02S, AB-05DU, AB-07DU, AB-08DU, AB-09S, AB-11S, AB-14DU, AB-16DU, AB-16S, AL-01S, AL-02S, CCR-01S, CCR-02S, CCR-03S, CCR-04S, CCR-05S, CCR-13S, CCR-14S, CCR-15S, CCR-16S, GWA-01S, GWA-02S, GWA-03S, GWA-04S, GWA-07S, GWA-10S, GWA-11S, GWA-13S, GWA-14S, GWA-15S, ILF-01S, ILF-02S, MS-08, MS-09, MS-10, MS-11, MS-12, MS-13, MS-14, MS-15, MS-16, MW-01, MW-02, MW-03, MW-04, MW-05, MW-07 (OB-03), MW-08S, MW-09S, MW-10S, MW-11S, MW-12S, MW-13S, MW-14S, CP-02S, CP-03S, GP-01S, GP-02S, GP-03S, OB-01 (Ash Basin), OB-01 (Dry Ash Landfill), PVSF-01S, PVSF-02S

DUKE ENERGY CAROLINAS

synTerra

DRAWN BY: R. BADUM DATE: 11/5/2019
REVISED BY: R. BADUM
CHECKED BY: W. GERALD
APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER

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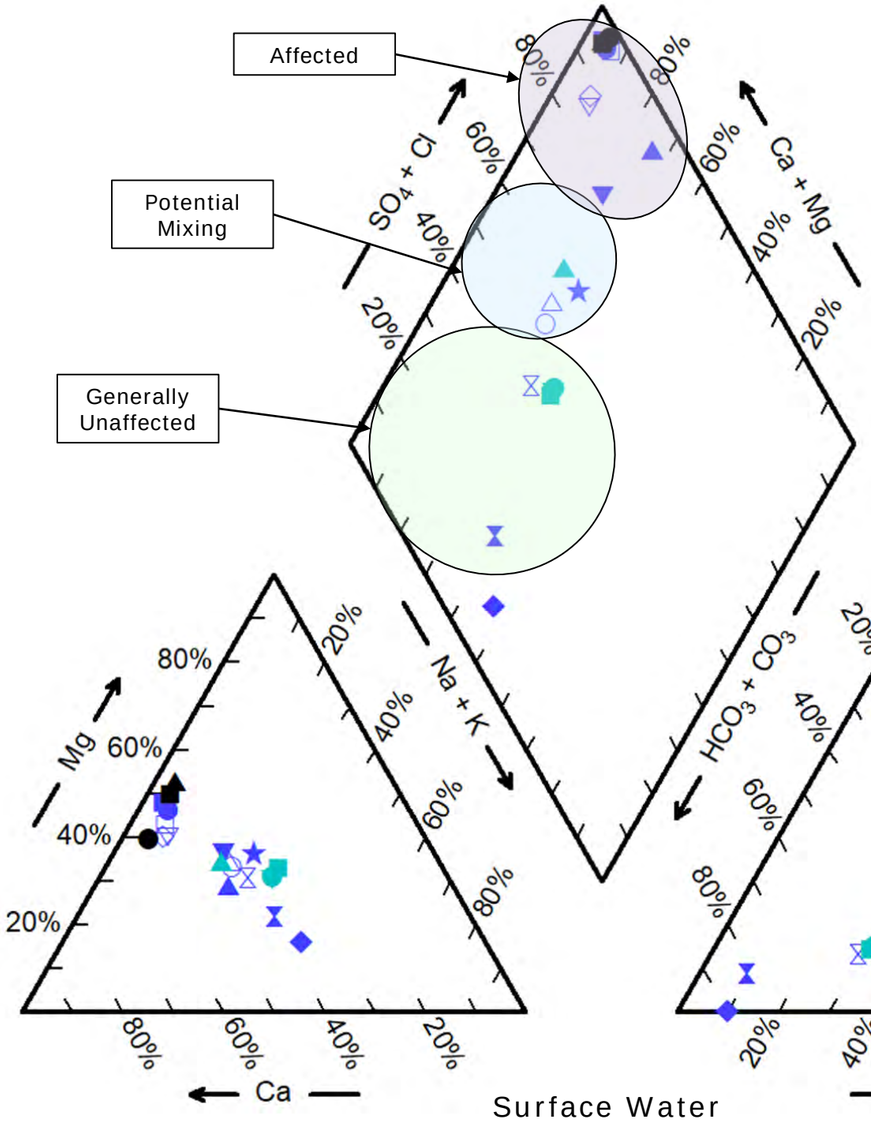
FIGURE 6-11
WATER QUALITY PIPER DIAGRAMS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Note:
*Samples taken before 1/1/2018

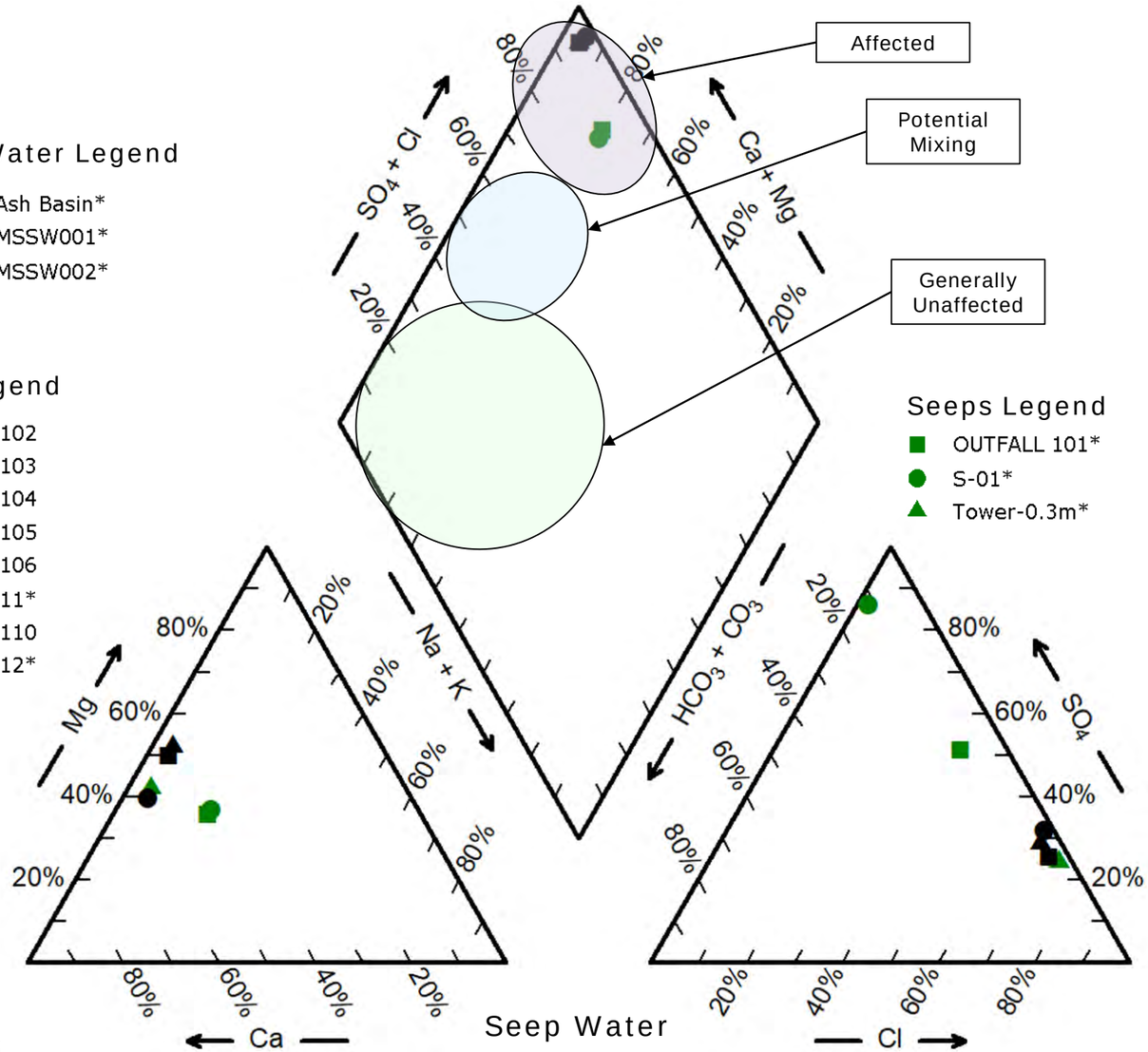
Source Water Legend
- Ash Basin*
- MSSW001*
- MSSW002*

Surface Water Legend
- SW-01
- SW-02*
- SW-03*
- SW-06*
- SW-07
- SW-08
- SW-09*
- SW-10
- SW-101
- SW-102
- SW-103
- SW-104
- SW-105
- SW-106
- SW-11*
- SW-110
- SW-12*

Seeps Legend
- OUTFALL 101*
- S-01*
- Tower-0.3m*



Surface Water



Seep Water

DUKE ENERGY CAROLINAS

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DRAWN BY: R. BADUM DATE: 11/8/2019
REVISED BY: R. BADUM
CHECKED BY: W. GERALD
APPROVED BY: E. WEBSTER
PROJECT MANAGER: B. WILKER

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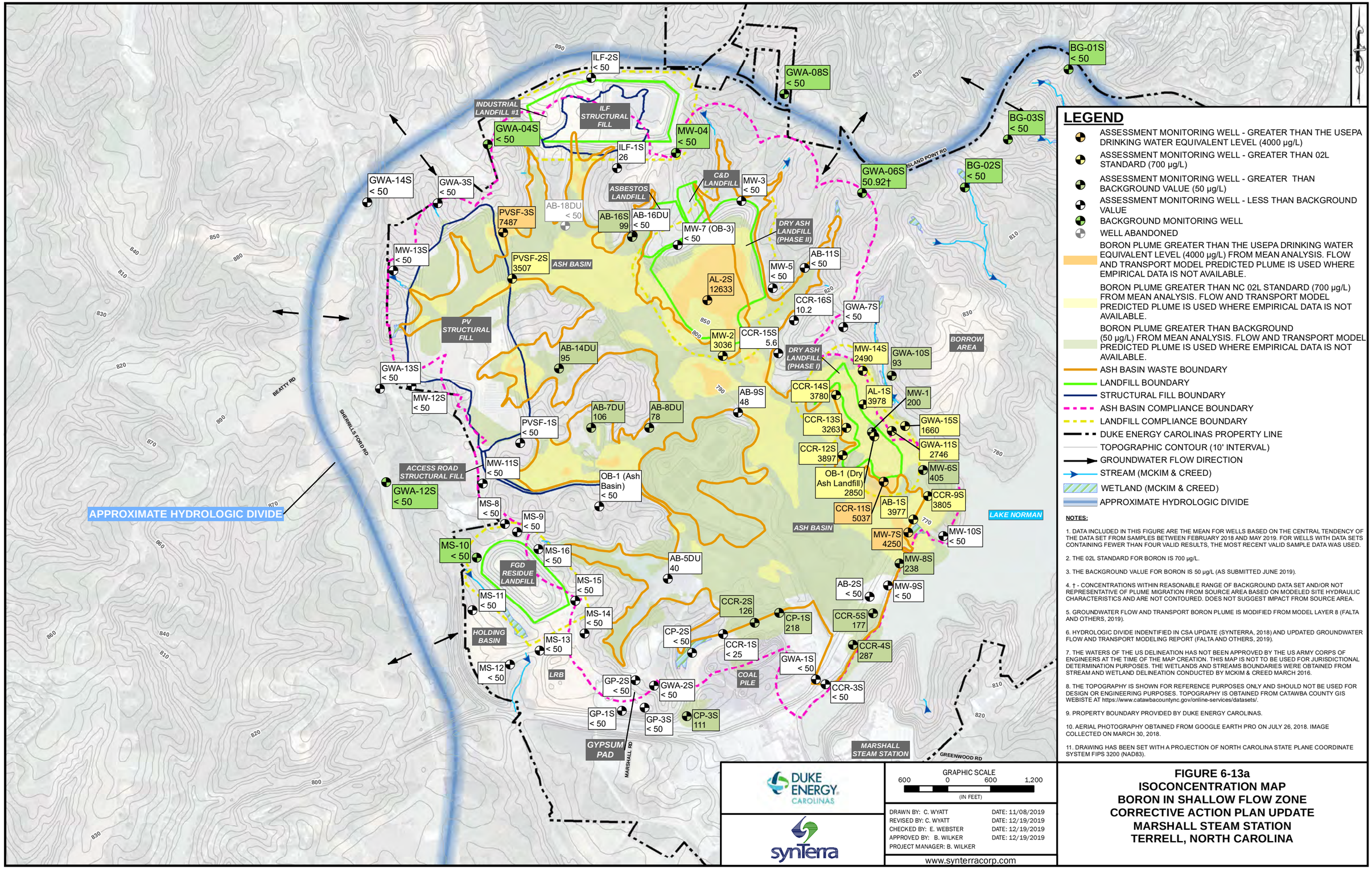
FIGURE 6-12
SURFACE WATER
QUALITY PIPER DIAGRAMS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN 02L STANDARD (700 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (50 µg/L)
- ASSESSMENT MONITORING WELL - LESS THAN BACKGROUND VALUE
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- BORON PLUME GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN NC 02L STANDARD (700 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN BACKGROUND (50 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR BORON IS 700 µg/L.
3. THE BACKGROUND VALUE FOR BORON IS 50 µg/L (AS SUBMITTED JUNE 2019).
4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
5. GROUNDWATER FLOW AND TRANSPORT BORON PLUME IS MODIFIED FROM MODEL LAYER 8 (FALTA AND OTHERS, 2019).
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 11/08/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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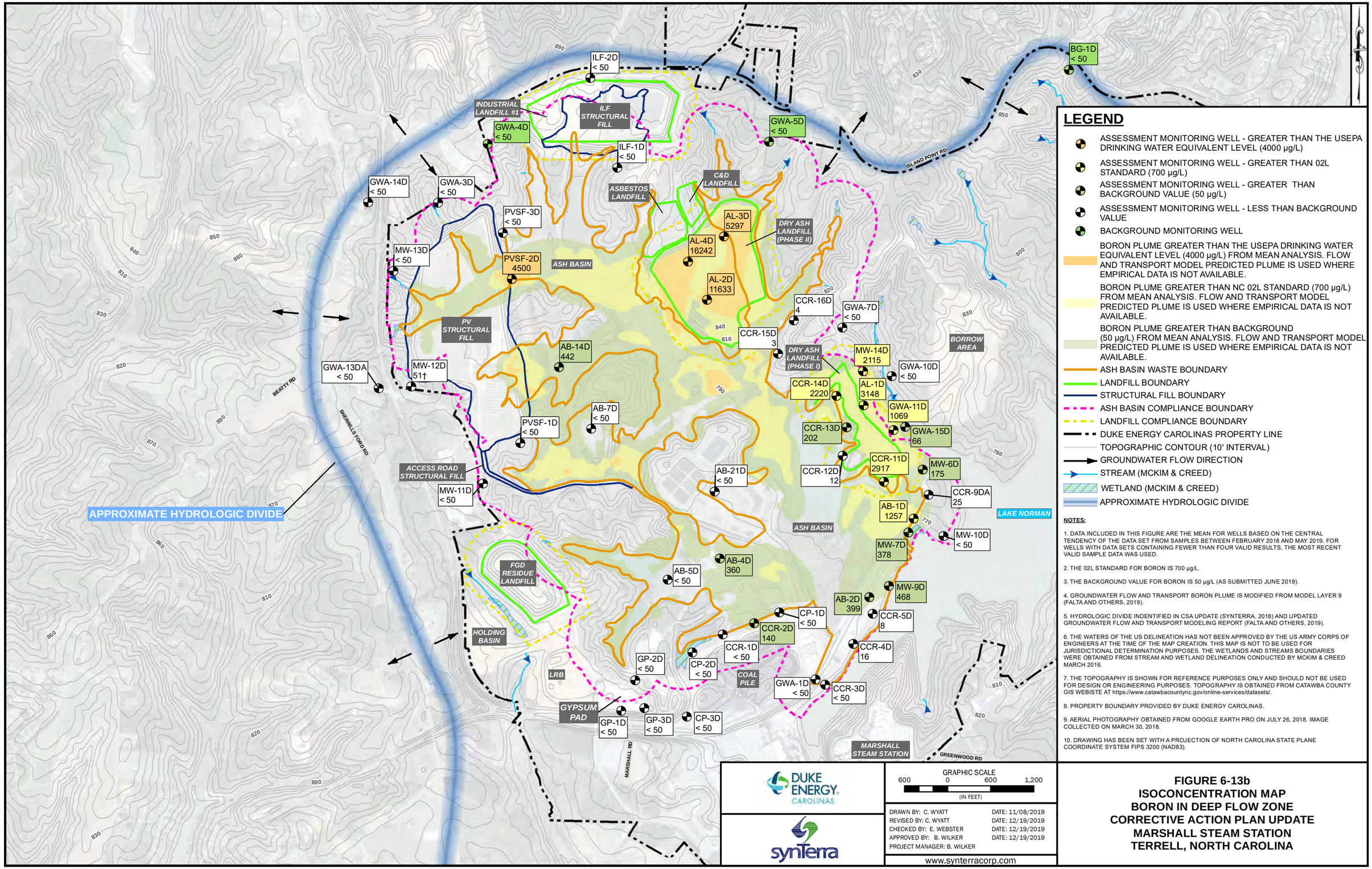
FIGURE 6-13a
ISOCONCENTRATION MAP
BORON IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN 02L STANDARD (700 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (50 µg/L)
- ASSESSMENT MONITORING WELL - LESS THAN BACKGROUND VALUE
- BACKGROUND MONITORING WELL
- BORON PLUME GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN NC 02L STANDARD (700 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN BACKGROUND (50 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR BORON IS 700 µg/L.
3. THE BACKGROUND VALUE FOR BORON IS 50 µg/L (AS SUBMITTED JUNE 2019).
4. GROUNDWATER FLOW AND TRANSPORT BORON PLUME IS MODIFIED FROM MODEL LAYER 9 (FALTA AND OTHERS, 2019).
5. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
6. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
7. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
8. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 11/08/2019
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APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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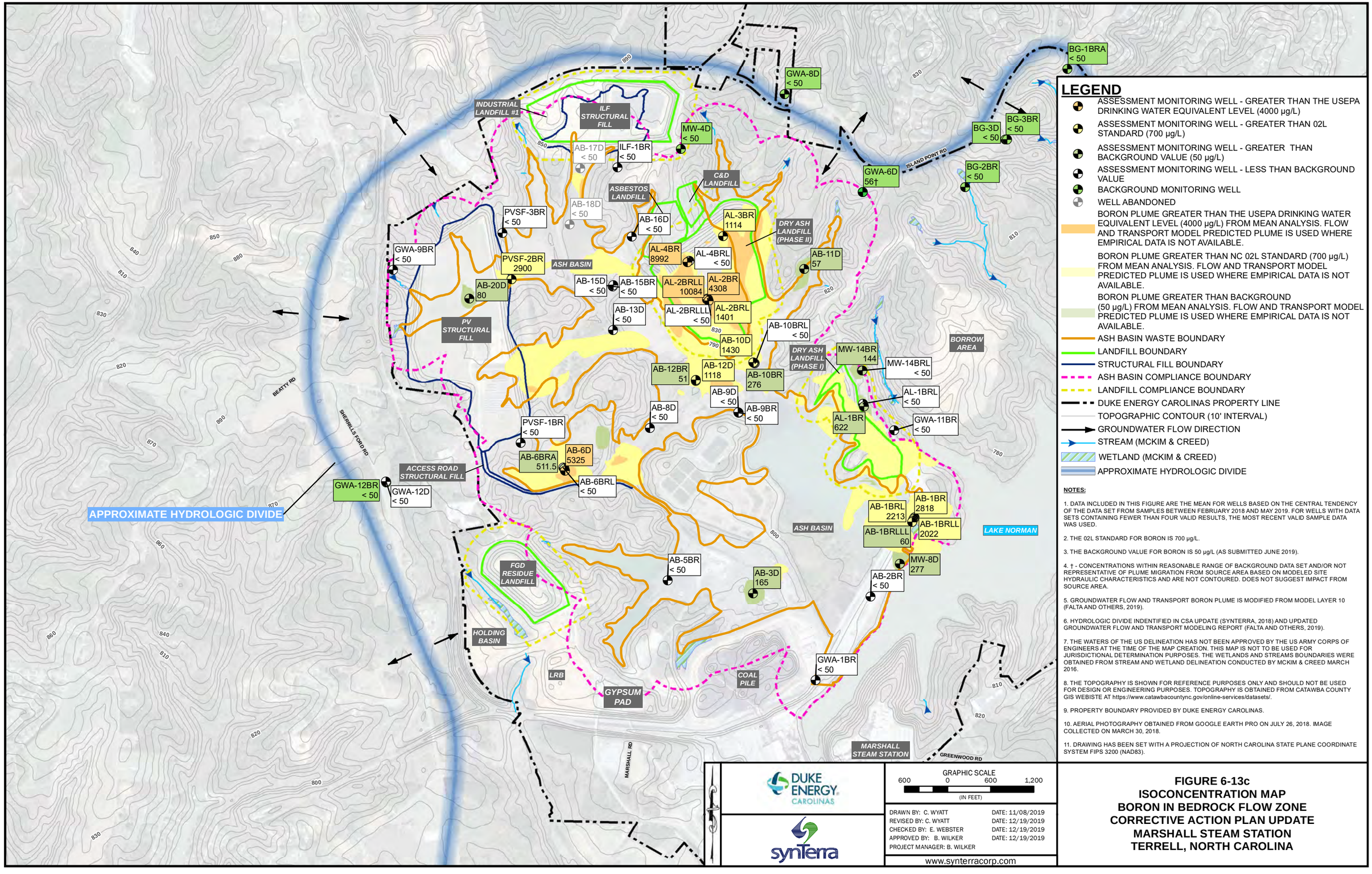
FIGURE 6-13b
ISOCONCENTRATION MAP
BORON IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN 02L STANDARD (700 µg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (50 µg/L)
- ASSESSMENT MONITORING WELL - LESS THAN BACKGROUND VALUE
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- BORON PLUME GREATER THAN THE USEPA DRINKING WATER EQUIVALENT LEVEL (4000 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN NC 02L STANDARD (700 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- BORON PLUME GREATER THAN BACKGROUND (50 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR BORON IS 700 µg/L.
3. THE BACKGROUND VALUE FOR BORON IS 50 µg/L (AS SUBMITTED JUNE 2019).
4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
5. GROUNDWATER FLOW AND TRANSPORT BORON PLUME IS MODIFIED FROM MODEL LAYER 10 (FALTA AND OTHERS, 2019).
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 11/08/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
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APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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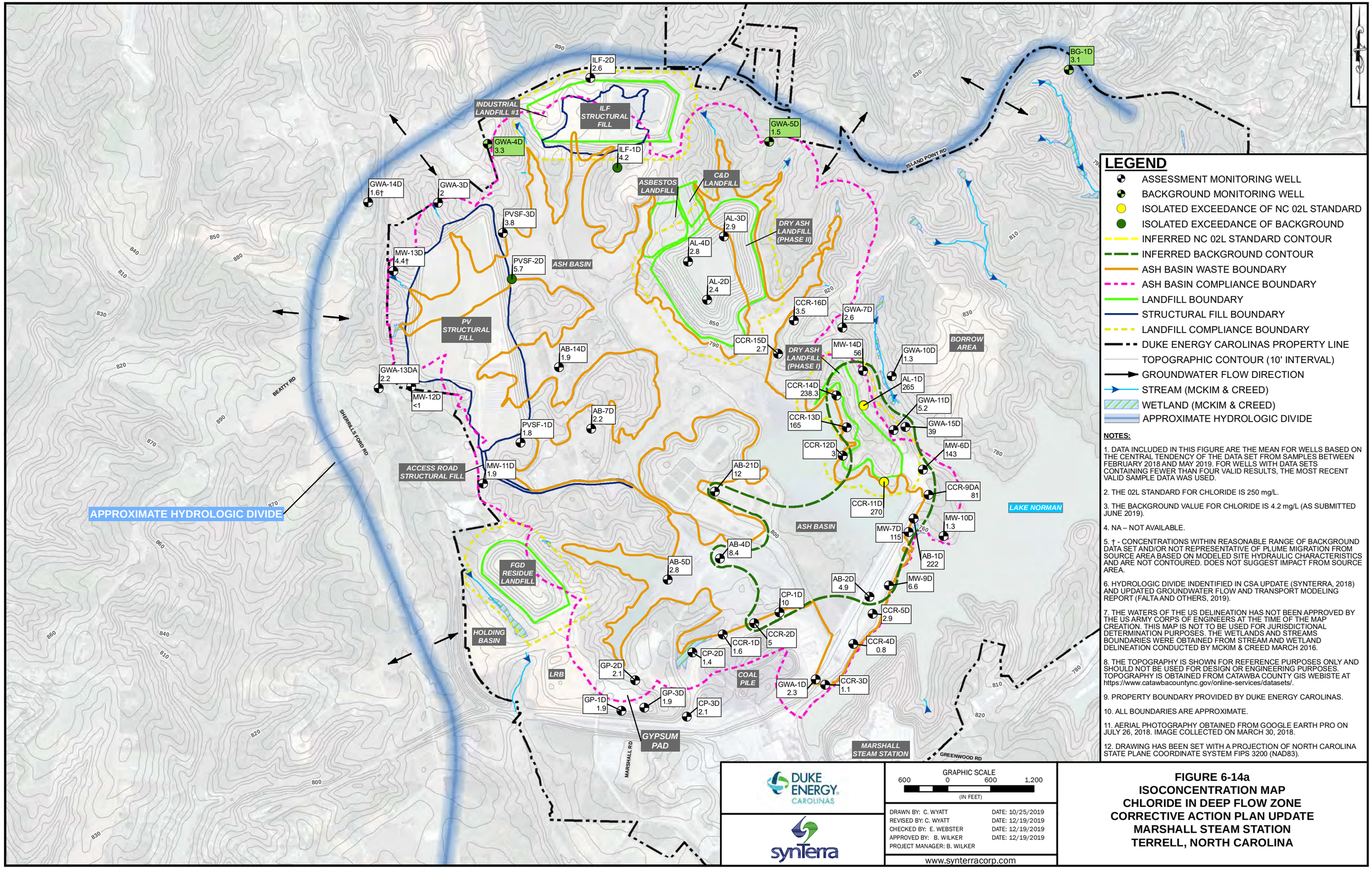
FIGURE 6-13c
ISOCONCENTRATION MAP
BORON IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- ISOLATED EXCEEDANCE OF NC 02L STANDARD
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED NC 02L STANDARD CONTOUR
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.

2. THE 02L STANDARD FOR CHLORIDE IS 250 mg/L.

3. THE BACKGROUND VALUE FOR CHLORIDE IS 4.2 mg/L (AS SUBMITTED JUNE 2019).

4. NA – NOT AVAILABLE.

5. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.

6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

10. ALL BOUNDARIES ARE APPROXIMATE.

11. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

12. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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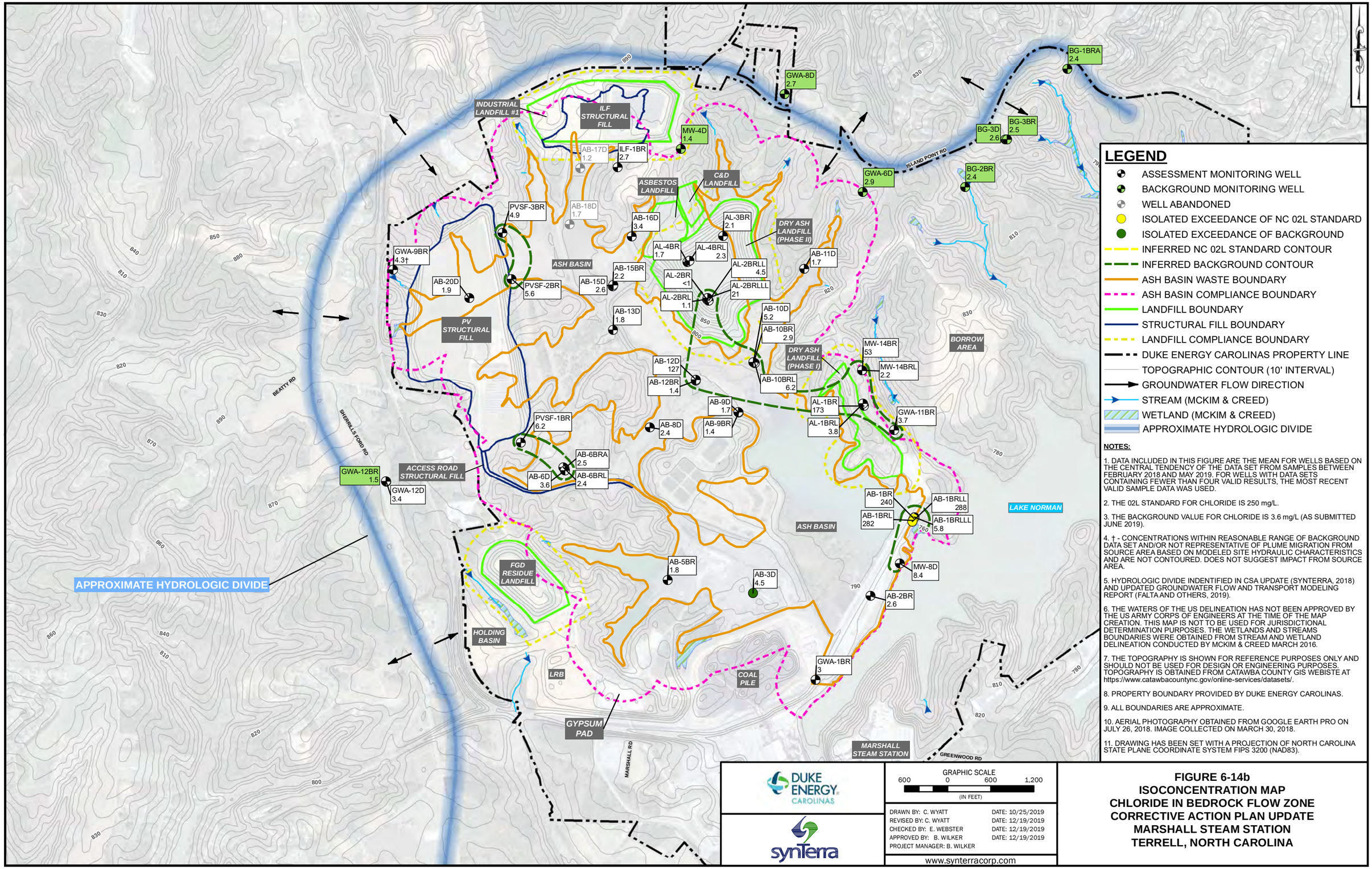
FIGURE 6-14a
ISOCONCENTRATION MAP
CHLORIDE IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF NC 02L STANDARD
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED NC 02L STANDARD CONTOUR
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

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2. THE 02L STANDARD FOR CHLORIDE IS 250 mg/L.

3. THE BACKGROUND VALUE FOR CHLORIDE IS 3.6 mg/L (AS SUBMITTED JUNE 2019).

4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.

5. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

6. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

7. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

8. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

9. ALL BOUNDARIES ARE APPROXIMATE.

10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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PROJECT MANAGER: B. WILKER	

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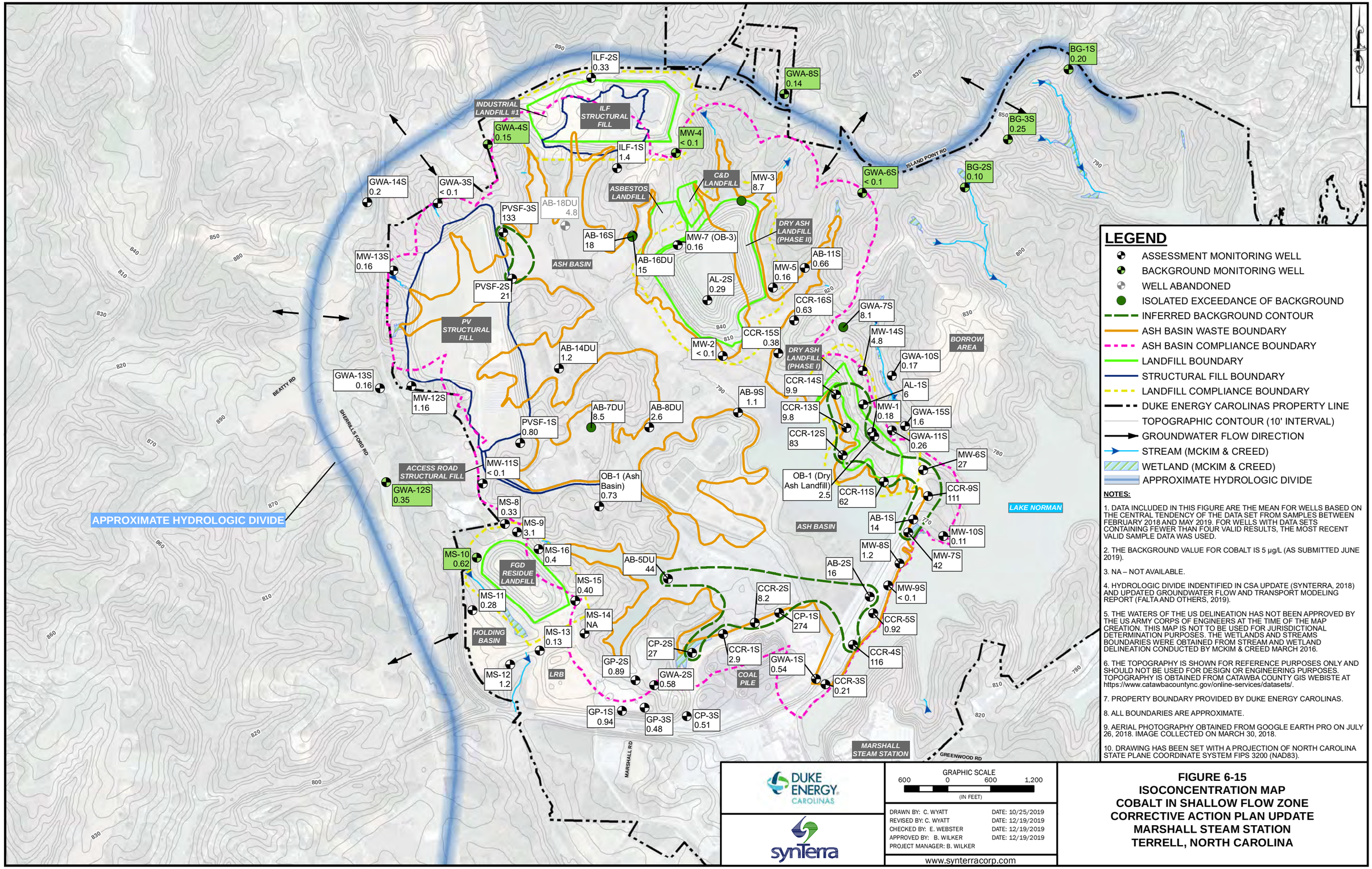
FIGURE 6-14b
ISOCONCENTRATION MAP
CHLORIDE IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

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2. THE BACKGROUND VALUE FOR COBALT IS 5 µg/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
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7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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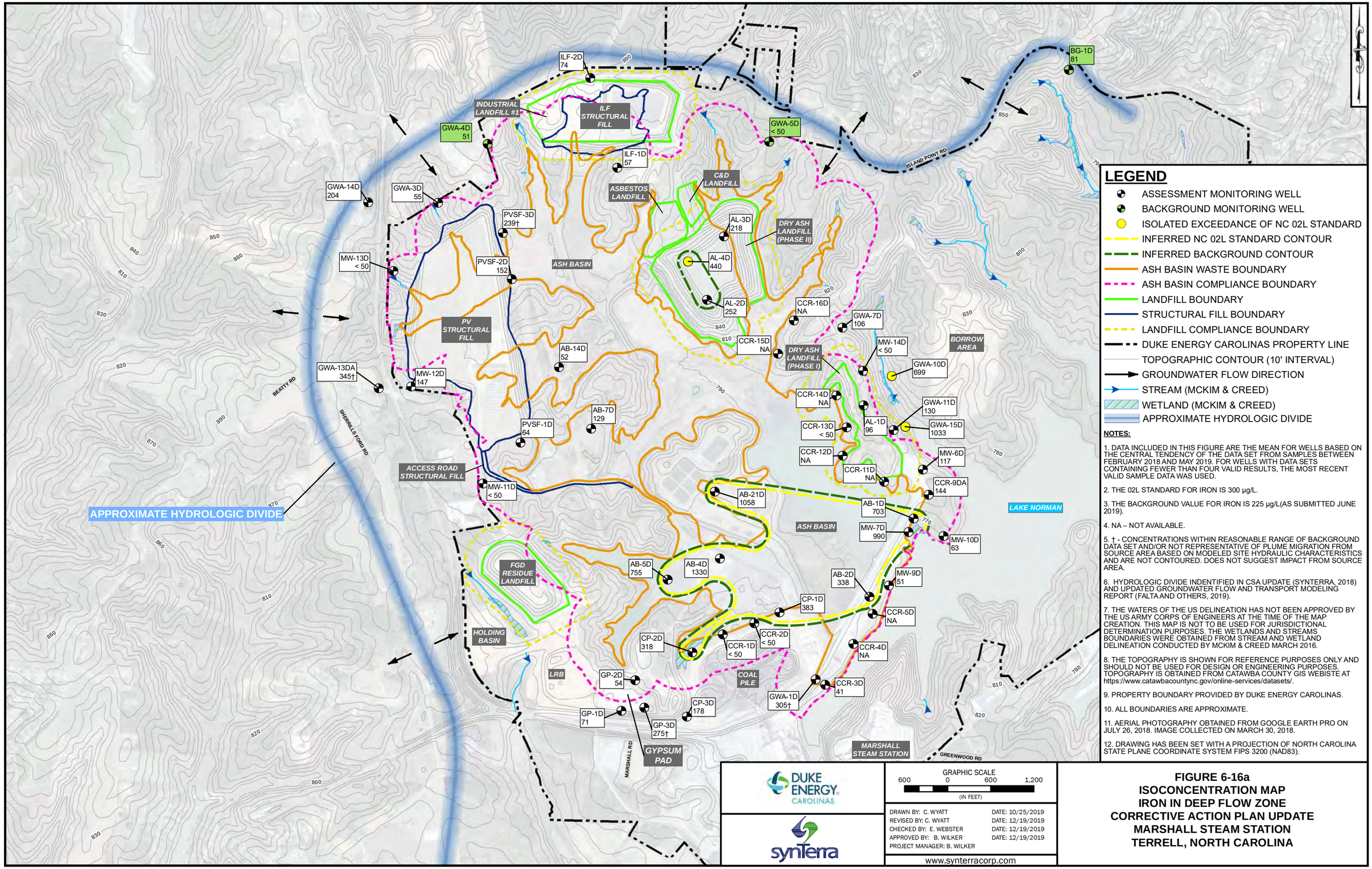
FIGURE 6-15
ISOCONCENTRATION MAP
COBALT IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- ISOLATED EXCEEDANCE OF NC 02L STANDARD
- INFERRED NC 02L STANDARD CONTOUR
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR IRON IS 300 µg/L.
3. THE BACKGROUND VALUE FOR IRON IS 225 µg/L(AS SUBMITTED JUNE 2019).
4. NA – NOT AVAILABLE.
5. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
10. ALL BOUNDARIES ARE APPROXIMATE.
11. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
12. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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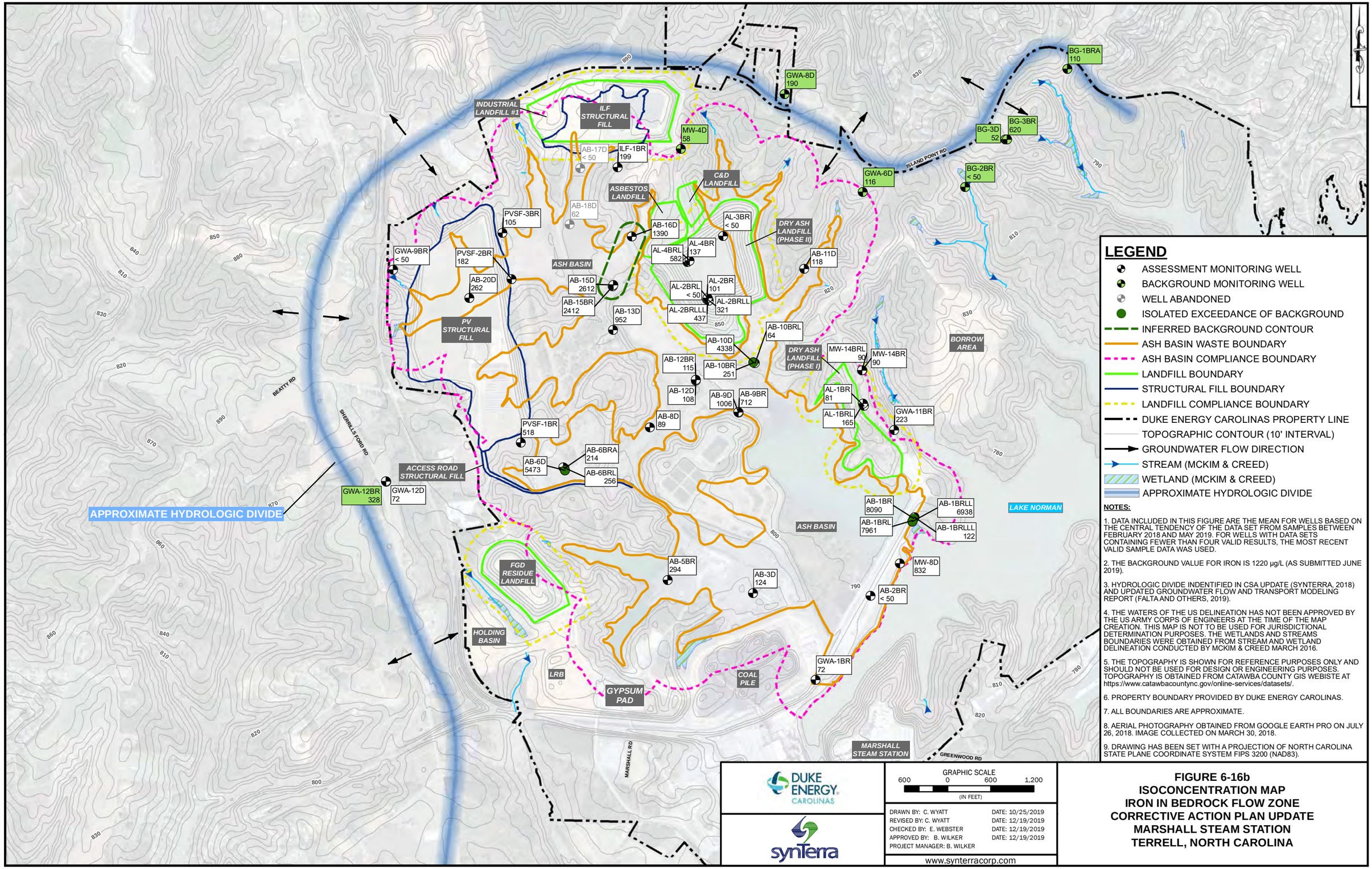
FIGURE 6-16a
ISOCONCENTRATION MAP
IRON IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.

2. THE BACKGROUND VALUE FOR IRON IS 1220 µg/L (AS SUBMITTED JUNE 2019).

3. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

4. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

5. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

7. ALL BOUNDARIES ARE APPROXIMATE.

8. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

9. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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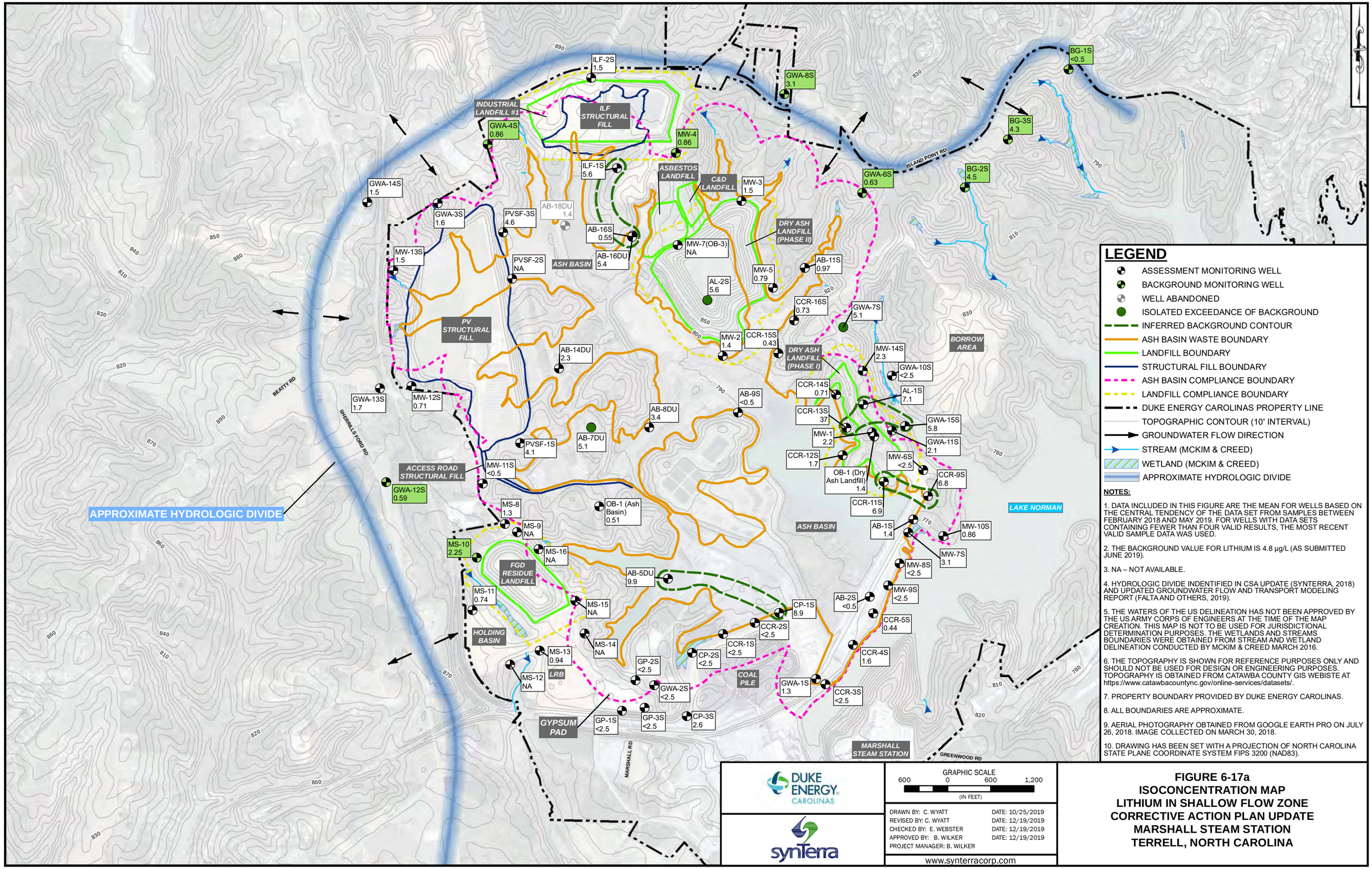
FIGURE 6-16b
ISOCONCENTRATION MAP
IRON IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR LITHIUM IS 4.8 µg/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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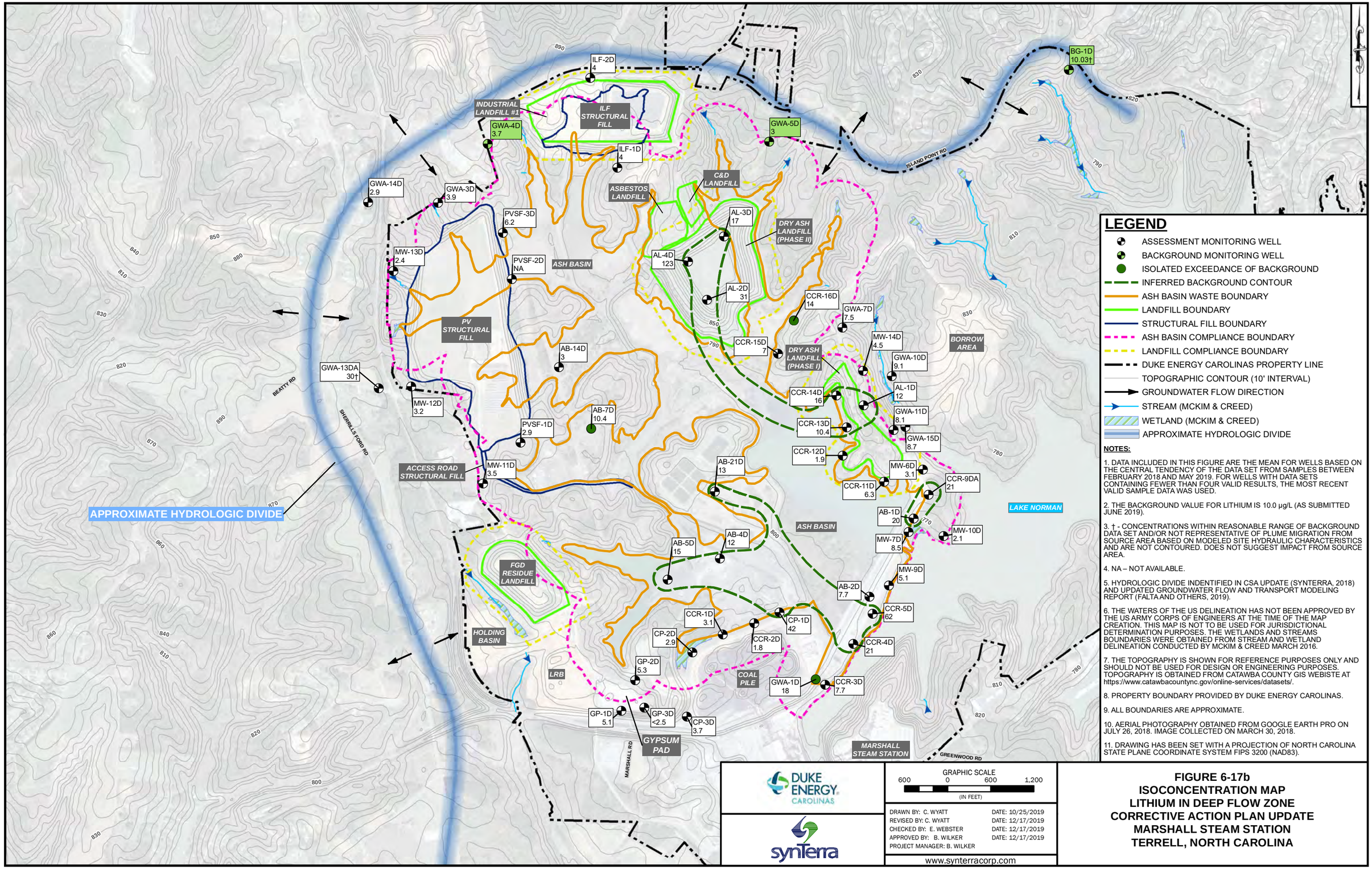
FIGURE 6-17a
ISOCONCENTRATION MAP
LITHIUM IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.

2. THE BACKGROUND VALUE FOR LITHIUM IS 10.0 µg/L (AS SUBMITTED JUNE 2019).

3. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.

4. NA – NOT AVAILABLE.

5. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

6. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

7. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

8. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

9. ALL BOUNDARIES ARE APPROXIMATE.

10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/17/2019
CHECKED BY: E. WEBSTER	DATE: 12/17/2019
APPROVED BY: B. WILKER	DATE: 12/17/2019
PROJECT MANAGER: B. WILKER	

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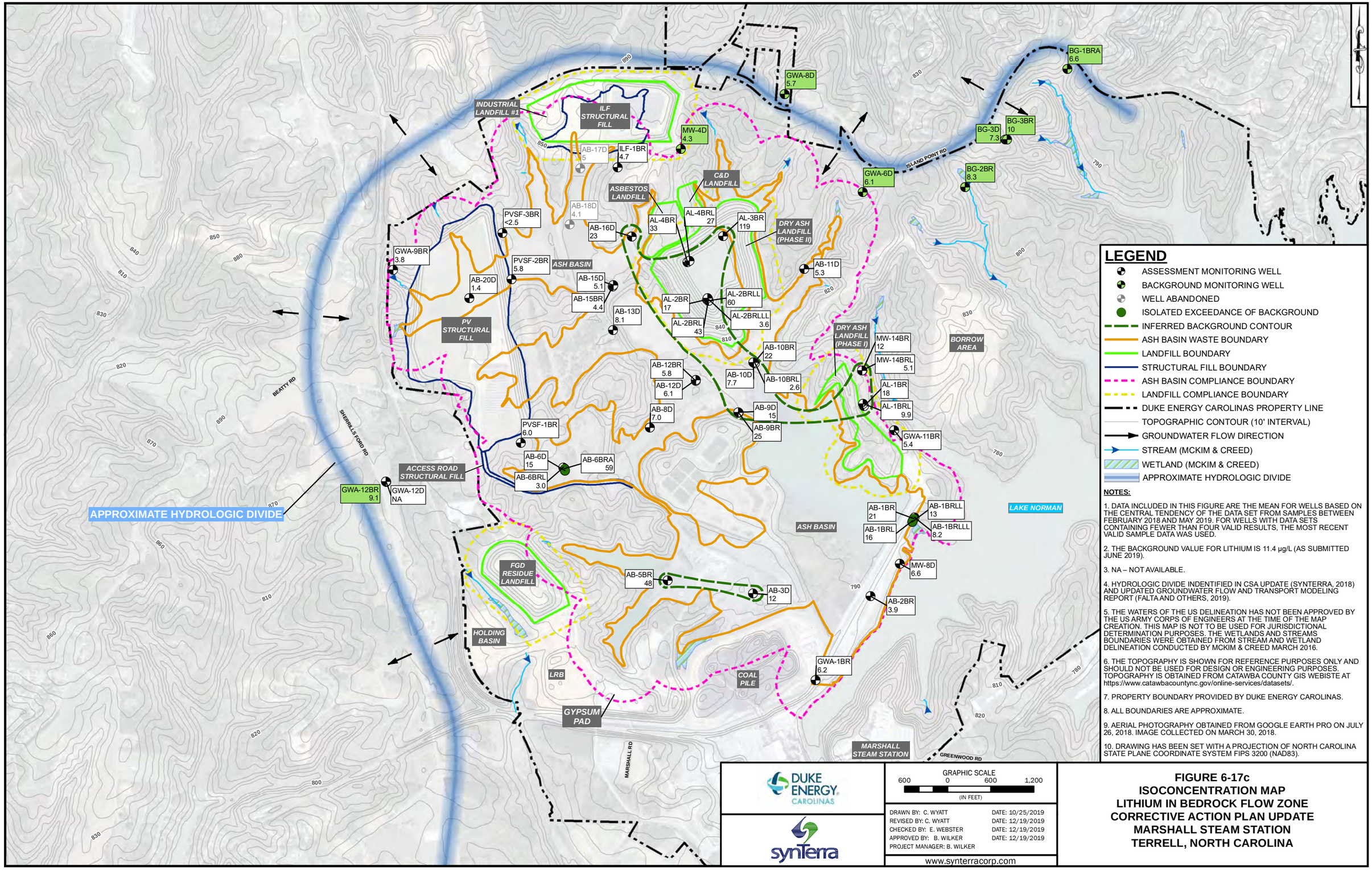
FIGURE 6-17b
ISOCONCENTRATION MAP
LITHIUM IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.

2. THE BACKGROUND VALUE FOR LITHIUM IS 11.4 µg/L (AS SUBMITTED JUNE 2019).

3. NA – NOT AVAILABLE.

4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

8. ALL BOUNDARIES ARE APPROXIMATE.

9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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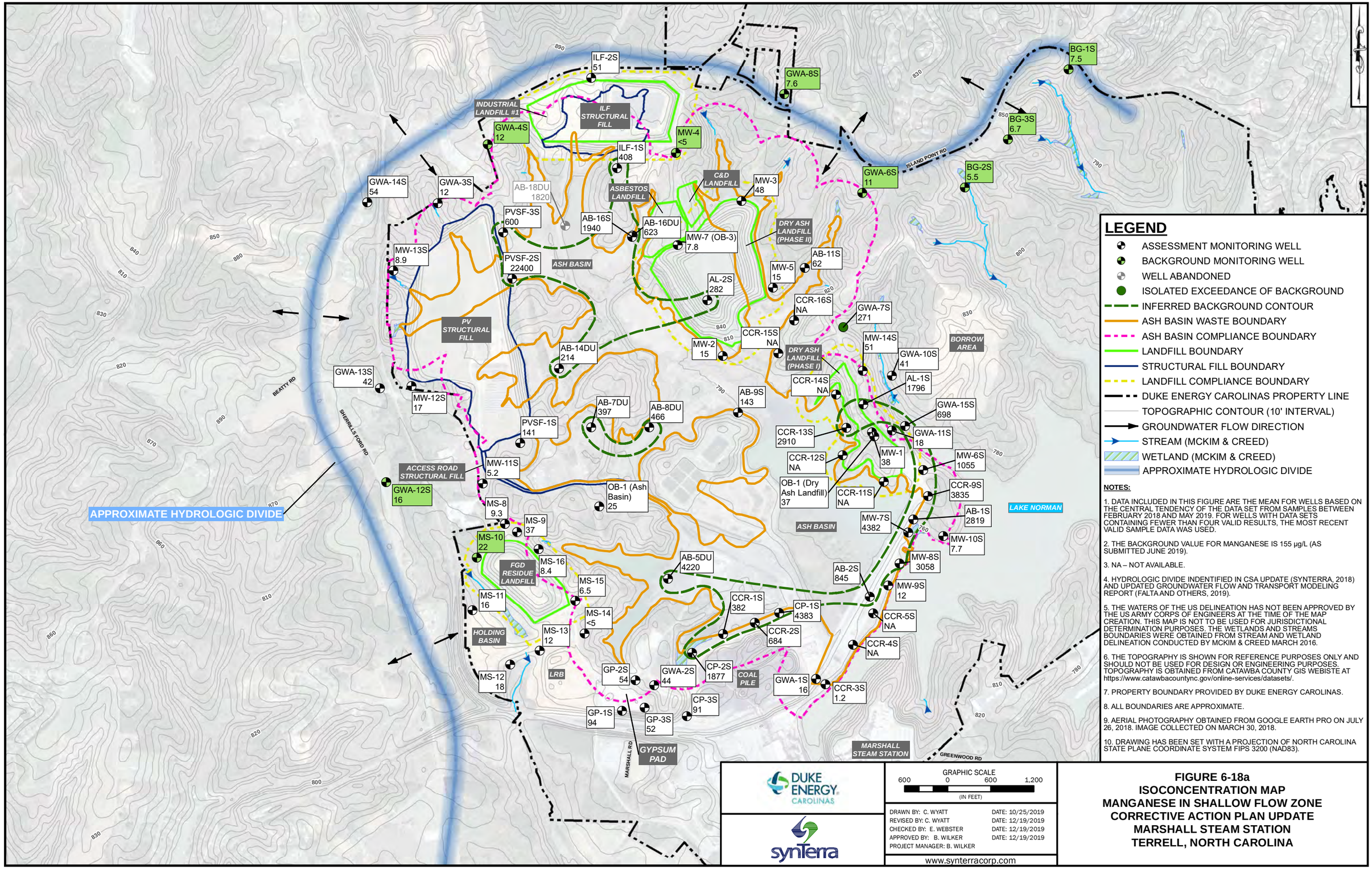
FIGURE 6-17c
ISOCONCENTRATION MAP
LITHIUM IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR MANGANESE IS 155 µg/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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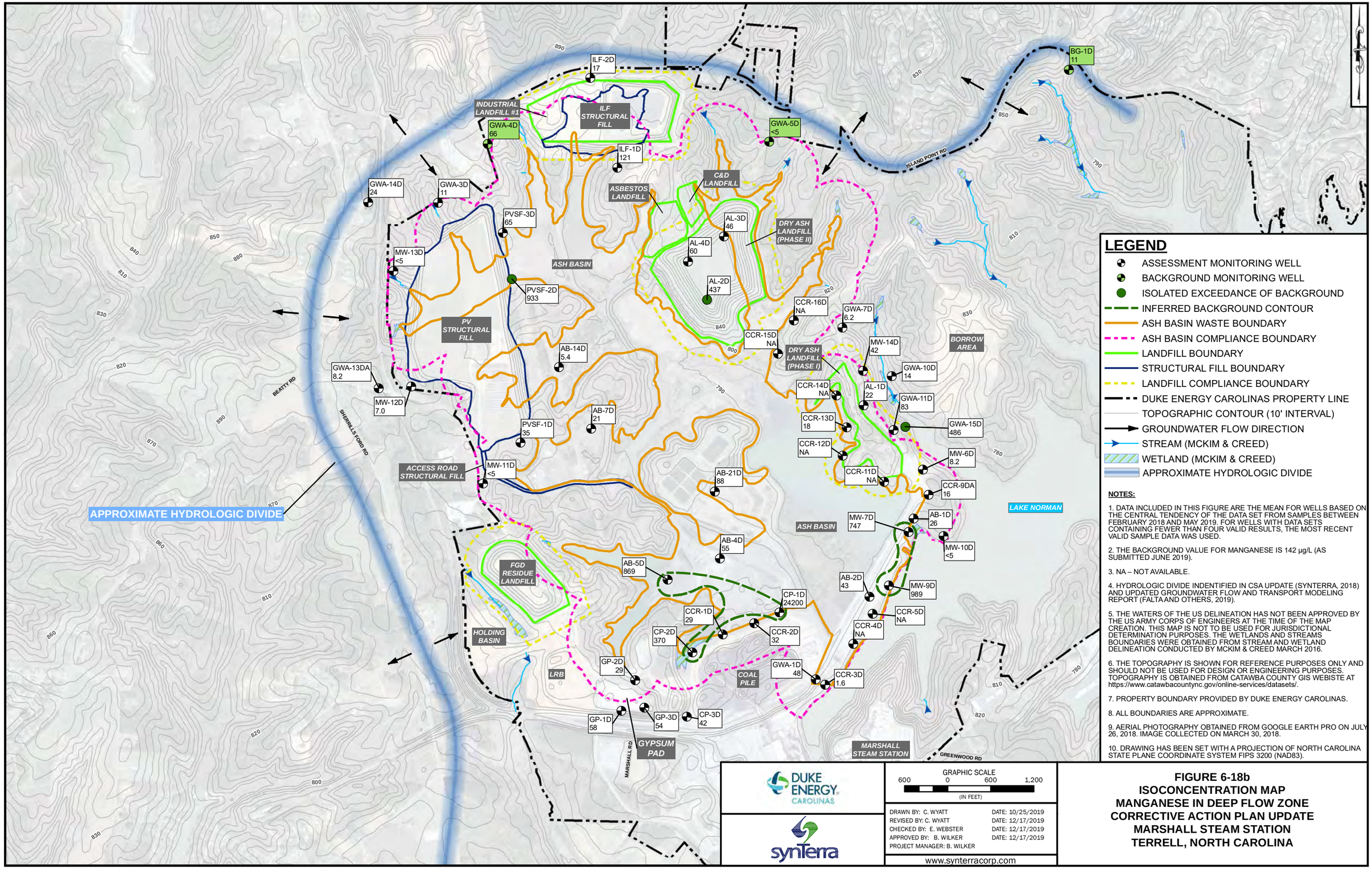
FIGURE 6-18a
ISOCONCENTRATION MAP
MANGANESE IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR MANGANESE IS 142 µg/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/17/2019
CHECKED BY: E. WEBSTER	DATE: 12/17/2019
APPROVED BY: B. WILKER	DATE: 12/17/2019
PROJECT MANAGER: B. WILKER	

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FIGURE 6-18b
ISOCONCENTRATION MAP
MANGANESE IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

INDUSTRIAL LANDFILL #1
ILF STRUCTURAL FILL
ASBESTOS LANDFILL
C&D LANDFILL
DRY ASH LANDFILL (PHASE II)
DRY ASH LANDFILL (PHASE I)
ASH BASIN
PV STRUCTURAL FILL
ACCESS ROAD STRUCTURAL FILL
FGD RESIDUE LANDFILL
HOLDING BASIN
LRB
GYPSUM PAD
COAL PILE
BORROW AREA
MARSHALL STEAM STATION
LAKE NORMAN
ISLAND POINT RD
BEATTY RD
SHERRILLS FORD RD
MARSHALL RD
GREENWOOD RD
APPROXIMATE HYDROLOGIC DIVIDE

GWA-8D 11
MW-4D <5
ILF-1BR 39
AB-17D* <5
AB-18D* 76
GWA-6D 24
BG-1BRA 22
BG-3D <5
BG-3BR 11
BG-2BR <5
PVSF-3BR 26
GWA-9BR <5
PVSF-2BR 462
AB-20D 10
AB-15D 260
AB-15BR 270
AB-16D 201
AL-3BR 35
AL-4BR 6.7
AL-4BRL 56
AB-11D 5.3
AL-2BR 41
AL-2BRLL 414
AL-2BRLLL 176
AL-2BRL 15
AB-13D 227
AB-10BRL 39
AB-12BR 29
AB-10D 4197
AB-12D 104
AB-10BR 27
AB-9D 51
AB-9BR 92
AB-8D 329
MW-14BR 5.7
MW-14BRL 6.8
AL-1BR 9.1
AL-1BRL 365
GWA-11BR 8.0
PVSF-1BR 82
AB-6BRL 58
AB-6BRA 71
AB-6D 457
GWA-12D 9.2
GWA-12BR 250
AB-1BR 595
AB-1BRLL 1398
AB-1BRL 927
AB-1BRLLL 304
MW-8D 111
AB-2BR 24
AB-5BR 127
AB-3D 48
GWA-1BR <5

LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.

2. THE BACKGROUND VALUE FOR MANGANESE IS 330 µg/L (AS SUBMITTED JUNE 2019).

3. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).

4. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

5. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.

6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

7. ALL BOUNDARIES ARE APPROXIMATE.

8. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

9. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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FIGURE 6-18c
ISOCONCENTRATION MAP
MANGANESE IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

ILF-2D 0.70
INDUSTRIAL LANDFILL #1
ILF STRUCTURAL FILL
GWA-4D 1.2
ILF-1D 0.76
GWA-5D 1.1
BG-1D 2.3
ISLAND POINT RD
GWA-14D NA
GWA-3D NA
ASBESTOS LANDFILL
C&D LANDFILL
PVSF-3D 0.74
AL-3D NA
DRY ASH LANDFILL (PHASE II)
MW-13D NA
PVSF-2D 2.3
ASH BASIN
AL-4D NA
AL-2D NA
CCR-16D 1.8
GWA-7D NA
PV STRUCTURAL FILL
CCR-15D 2.3
MW-14D 0.53
BORROW AREA
AB-14D NA
DRY ASH LANDFILL (PHASE I)
GWA-10D NA
GWA-13DA NA
AL-1D 10
CCR-14D 5.4
MW-12D NA
BEATTY RD
SHERRILLS FORD RD
GWA-11D 1.5
PVSF-1D 1.2
AB-7D NA
CCR-13D 6.5
GWA-15D 11
CCR-12D 0.97
MW-6D 3.3
MW-11D NA
ACCESS ROAD STRUCTURAL FILL
CCR-11D 6.4
CCR-9DA 2.9
AB-21D NA
AB-1D 2.1
APPROXIMATE HYDROLOGIC DIVIDE
LAKE NORMAN
ASH BASIN
MW-7D 5.9
MW-10D <0.49
AB-4D NA
FGD RESIDUE LANDFILL
AB-5D 0.82
AB-2D 3.3
MW-9D <1.4
CCR-5D 3.0
CP-1D 1.8
CCR-1D 0.64
CCR-2D 0.75
HOLDING BASIN
CP-2D 0.94
CCR-4D 0.84
GP-2D 1.3
LRB
COAL PILE
GWA-1D 2.2
CCR-3D 0.76
GP-1D 1.7
GP-3D 0.94
CP-3D 1.2
GYPSUM PAD
MARSHALL RD
MARSHALL STEAM STATION
GREENWOOD RD

LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR TOTAL RADIUM IS 7.46 pCi/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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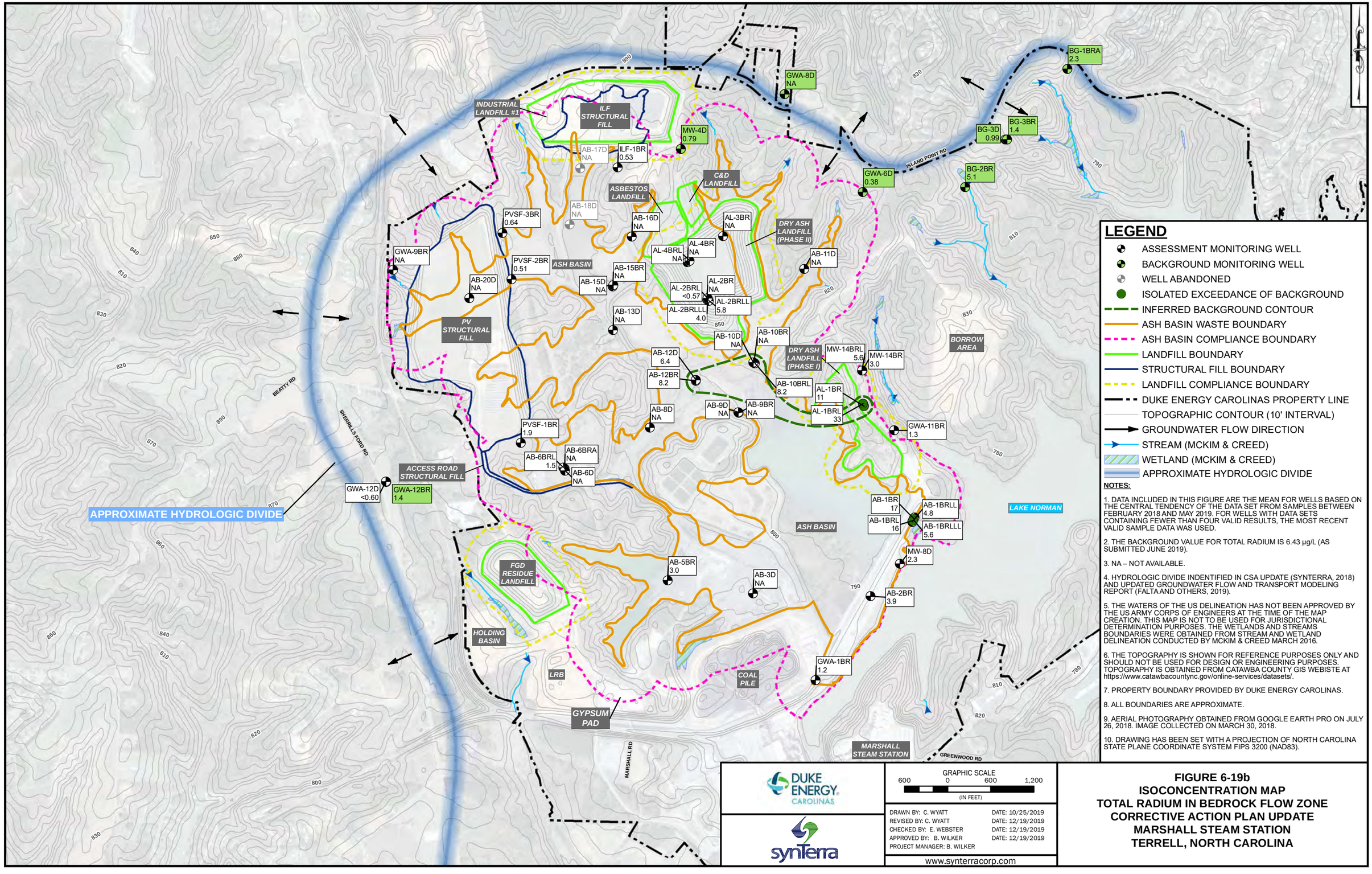
FIGURE 6-19a
ISOCONCENTRATION MAP
TOTAL RADIUM IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- ISOLATED EXCEEDANCE OF BACKGROUND
- INFERRED BACKGROUND CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR TOTAL RADIUM IS 6.43 µg/L (AS SUBMITTED JUNE 2019).
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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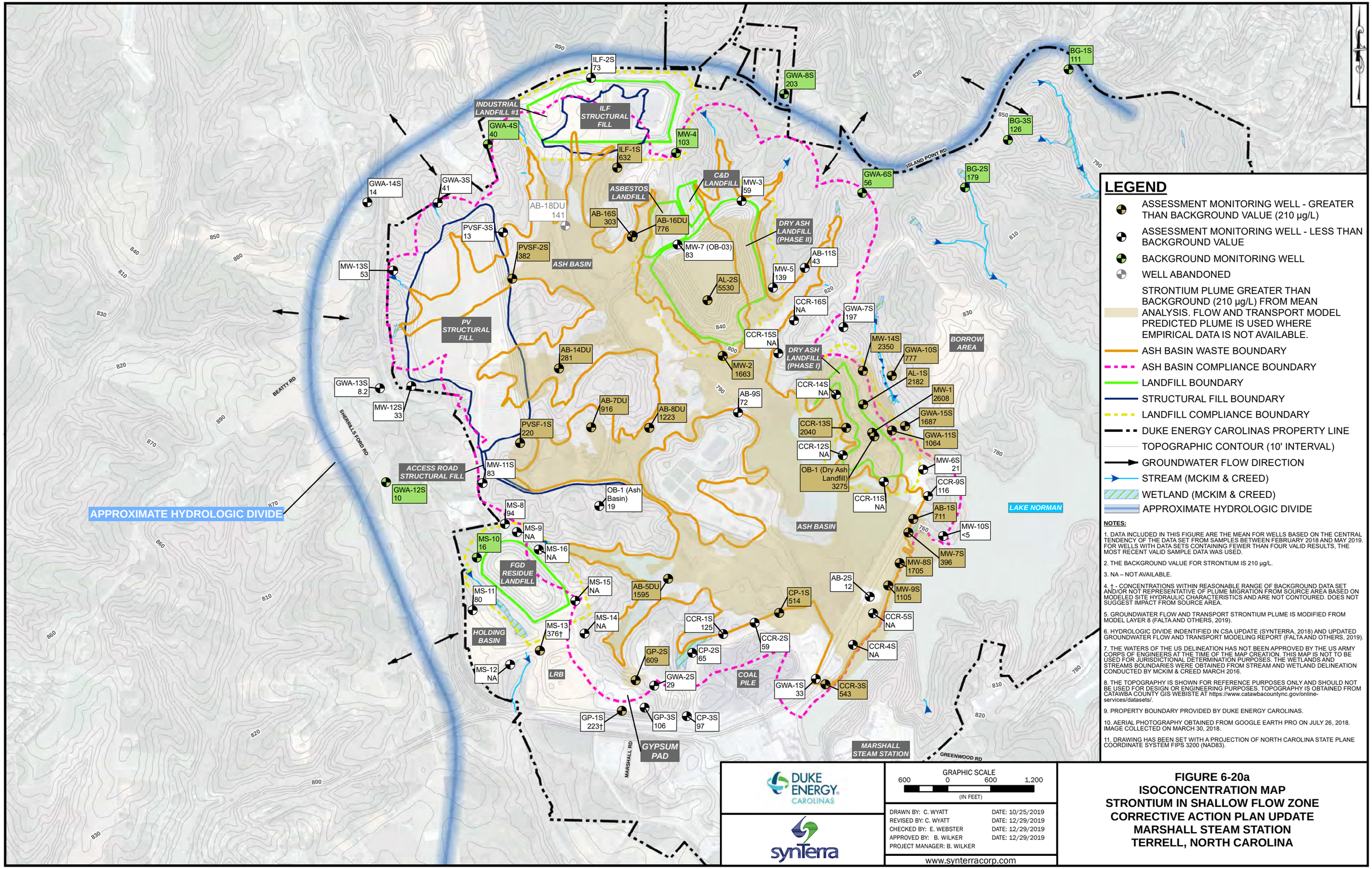
FIGURE 6-19b
ISOCONCENTRATION MAP
TOTAL RADIUM IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (210 µg/L)
- ASSESSMENT MONITORING WELL - LESS THAN BACKGROUND VALUE
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- STRONTIUM PLUME GREATER THAN BACKGROUND (210 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR STRONTIUM IS 210 µg/L.
3. NA – NOT AVAILABLE.
4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
5. GROUNDWATER FLOW AND TRANSPORT STRONTIUM PLUME IS MODIFIED FROM MODEL LAYER 8 (FALTA AND OTHERS, 2019).
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/29/2019
PROJECT MANAGER: B. WILKER	

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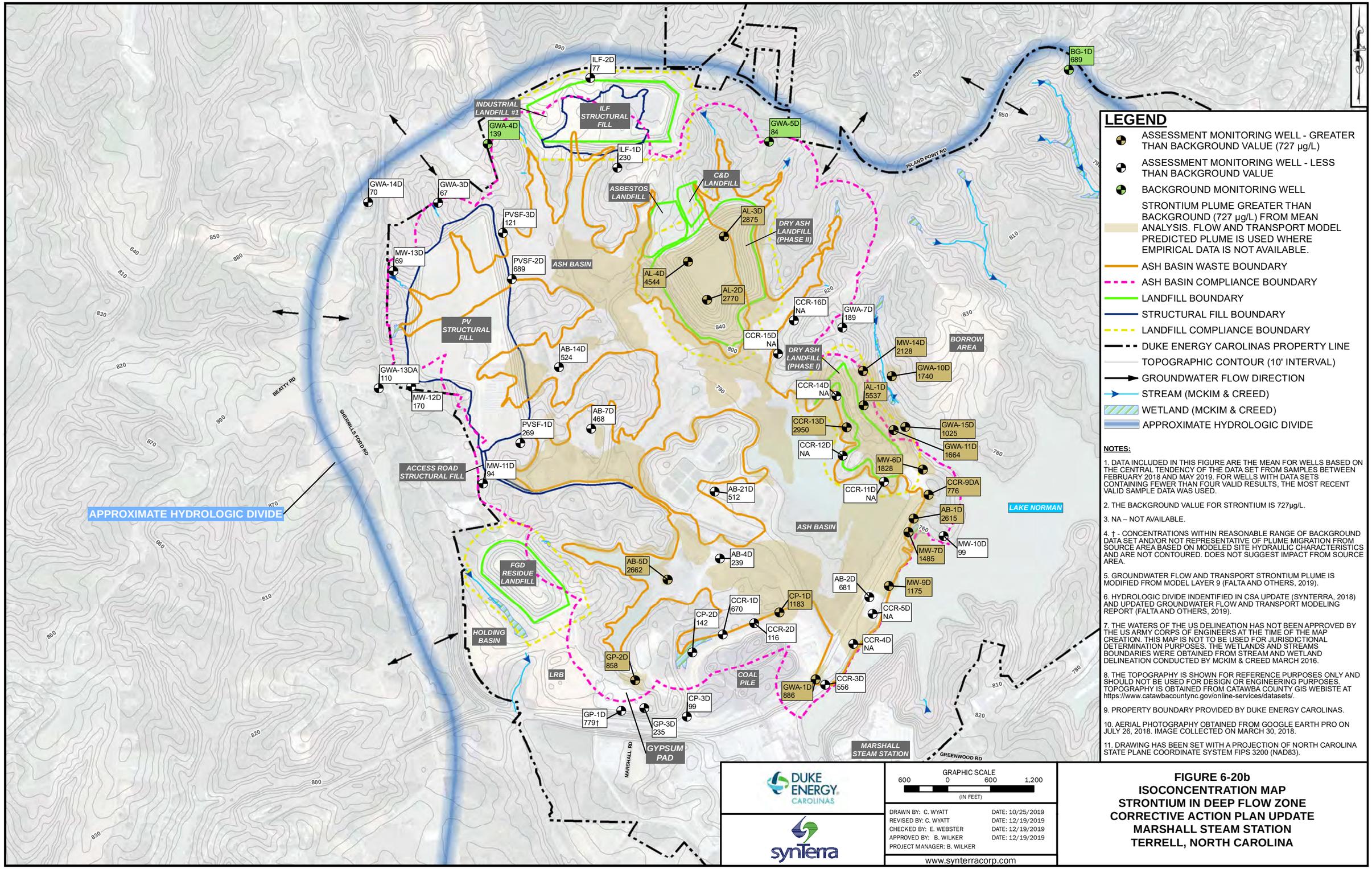
FIGURE 6-20a
ISOCONCENTRATION MAP
STRONTIUM IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (727 µg/L)
- ASSESSMENT MONITORING WELL - LESS THAN BACKGROUND VALUE
- BACKGROUND MONITORING WELL
- STRONTIUM PLUME GREATER THAN BACKGROUND (727 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR STRONTIUM IS 727µg/L.
3. NA – NOT AVAILABLE.
4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
5. GROUNDWATER FLOW AND TRANSPORT STRONTIUM PLUME IS MODIFIED FROM MODEL LAYER 9 (FALTA AND OTHERS, 2019).
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
8. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
9. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
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(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/19/2019
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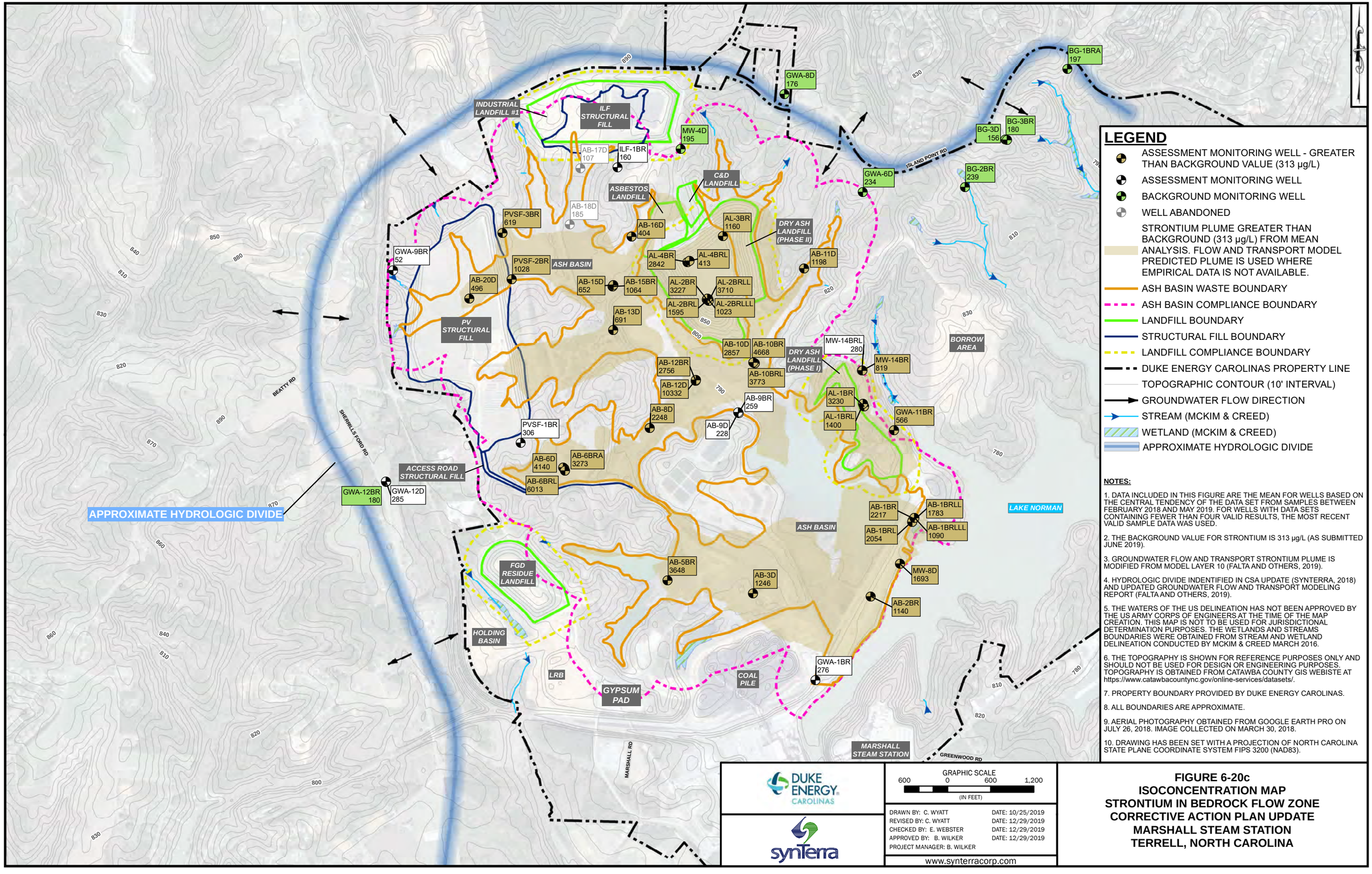
FIGURE 6-20b
ISOCONCENTRATION MAP
STRONTIUM IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (313 µg/L)
- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- STRONTIUM PLUME GREATER THAN BACKGROUND (313 µg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE BACKGROUND VALUE FOR STRONTIUM IS 313 µg/L (AS SUBMITTED JUNE 2019).
3. GROUNDWATER FLOW AND TRANSPORT STRONTIUM PLUME IS MODIFIED FROM MODEL LAYER 10 (FALTA AND OTHERS, 2019).
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

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PROJECT MANAGER: B. WILKER	

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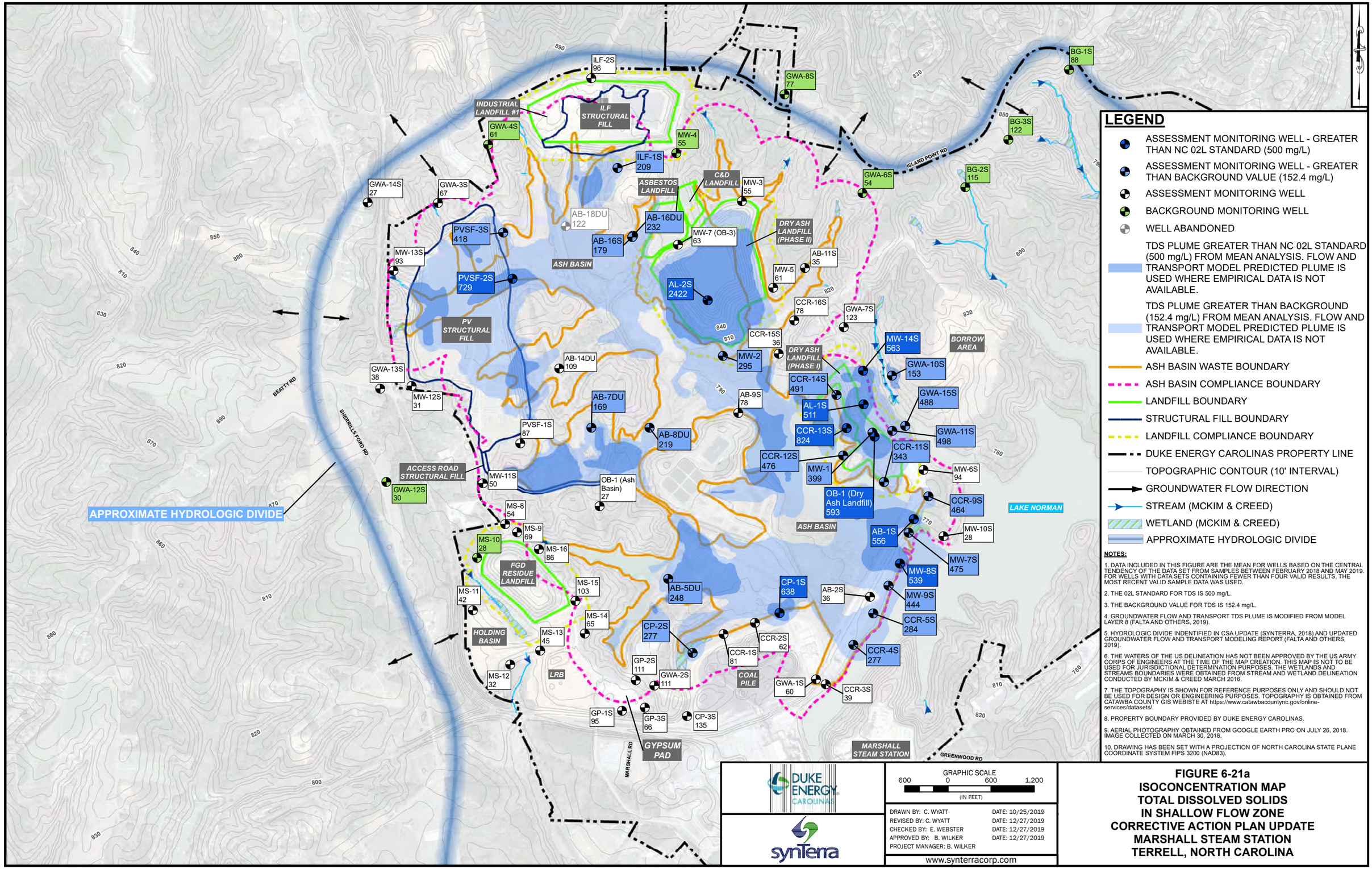
FIGURE 6-20c
ISOCONCENTRATION MAP
STRONTIUM IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN NC 02L STANDARD (500 mg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (152.4 mg/L)
- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- TDS PLUME GREATER THAN NC 02L STANDARD (500 mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- TDS PLUME GREATER THAN BACKGROUND (152.4 mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR TDS IS 500 mg/L.
3. THE BACKGROUND VALUE FOR TDS IS 152.4 mg/L.
4. GROUNDWATER FLOW AND TRANSPORT TDS PLUME IS MODIFIED FROM MODEL LAYER 8 (FALTA AND OTHERS, 2019).
5. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
6. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
7. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
8. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
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DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
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(IN FEET)

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APPROVED BY: B. WILKER	DATE: 12/27/2019
PROJECT MANAGER: B. WILKER	

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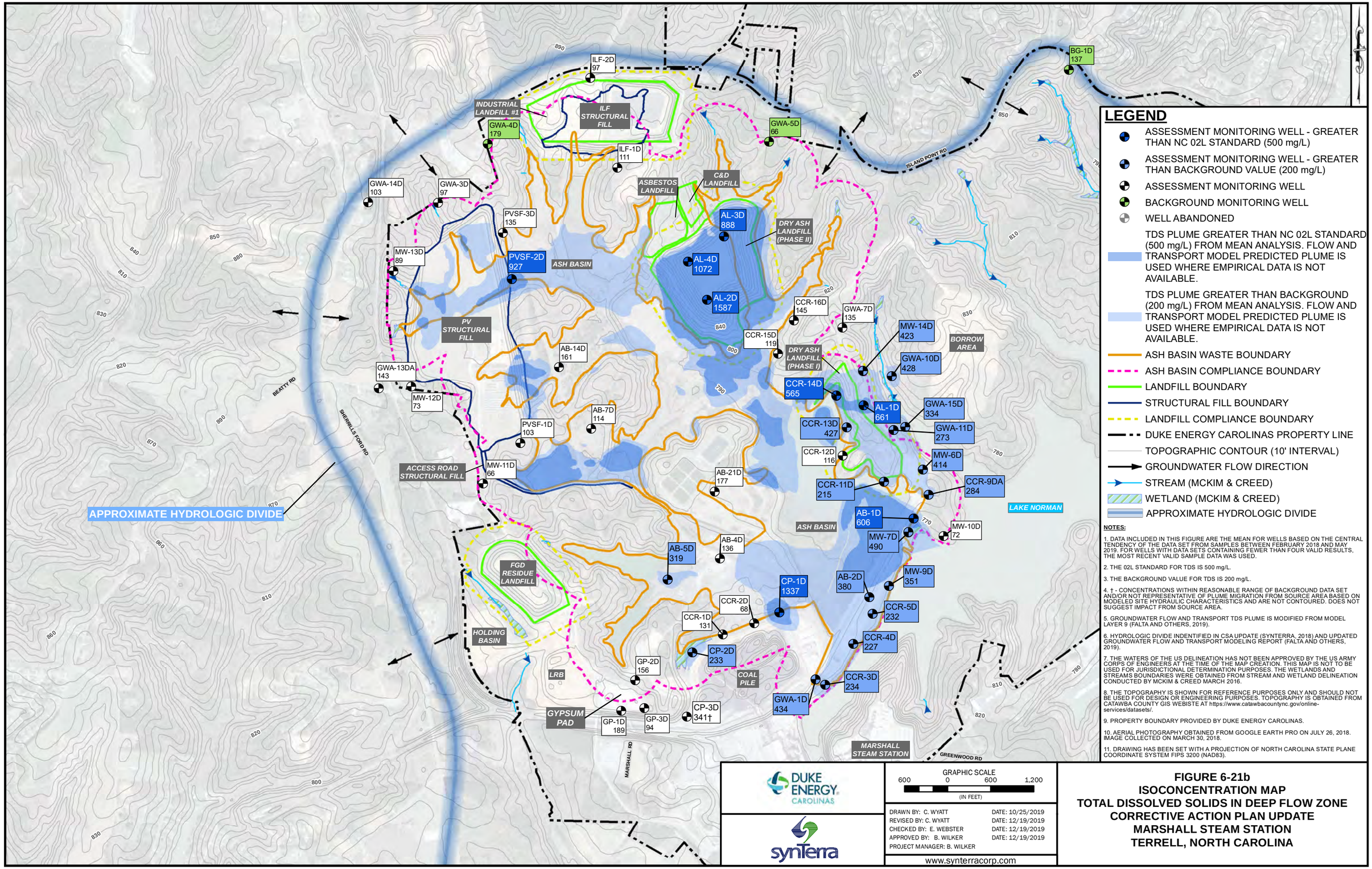
FIGURE 6-21a
ISOCONCENTRATION MAP
TOTAL DISSOLVED SOLIDS
IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN NC 02L STANDARD (500 mg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (200 mg/L)
- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- TDS PLUME GREATER THAN NC 02L STANDARD (500 mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- TDS PLUME GREATER THAN BACKGROUND (200 mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR TDS IS 500 mg/L.
3. THE BACKGROUND VALUE FOR TDS IS 200 mg/L.
4. † - CONCENTRATIONS WITHIN REASONABLE RANGE OF BACKGROUND DATA SET AND/OR NOT REPRESENTATIVE OF PLUME MIGRATION FROM SOURCE AREA BASED ON MODELED SITE HYDRAULIC CHARACTERISTICS AND ARE NOT CONTOURED. DOES NOT SUGGEST IMPACT FROM SOURCE AREA.
5. GROUNDWATER FLOW AND TRANSPORT TDS PLUME IS MODIFIED FROM MODEL LAYER 9 (FALTA AND OTHERS, 2019).
6. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
7. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
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10. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
11. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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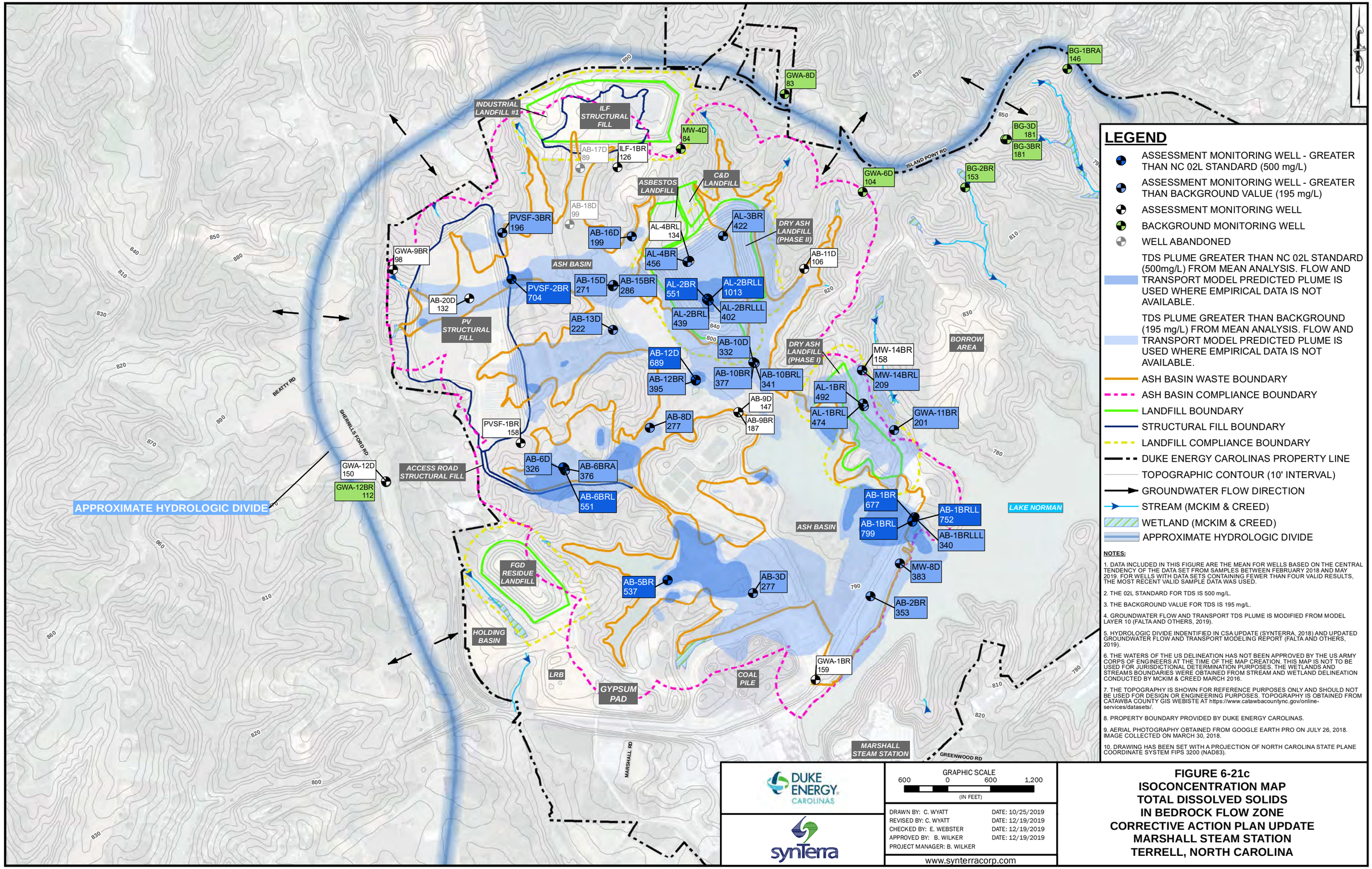
FIGURE 6-21b
ISOCONCENTRATION MAP
TOTAL DISSOLVED SOLIDS IN DEEP FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL - GREATER THAN NC 02L STANDARD (500 mg/L)
- ASSESSMENT MONITORING WELL - GREATER THAN BACKGROUND VALUE (195 mg/L)
- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- TDS PLUME GREATER THAN NC 02L STANDARD (500mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- TDS PLUME GREATER THAN BACKGROUND (195 mg/L) FROM MEAN ANALYSIS. FLOW AND TRANSPORT MODEL PREDICTED PLUME IS USED WHERE EMPIRICAL DATA IS NOT AVAILABLE.
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR TDS IS 500 mg/L.
3. THE BACKGROUND VALUE FOR TDS IS 195 mg/L.
4. GROUNDWATER FLOW AND TRANSPORT TDS PLUME IS MODIFIED FROM MODEL LAYER 10 (FALTA AND OTHERS, 2019).
5. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
6. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
7. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
8. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/19/2019
CHECKED BY: E. WEBSTER	DATE: 12/19/2019
APPROVED BY: B. WILKER	DATE: 12/19/2019
PROJECT MANAGER: B. WILKER	

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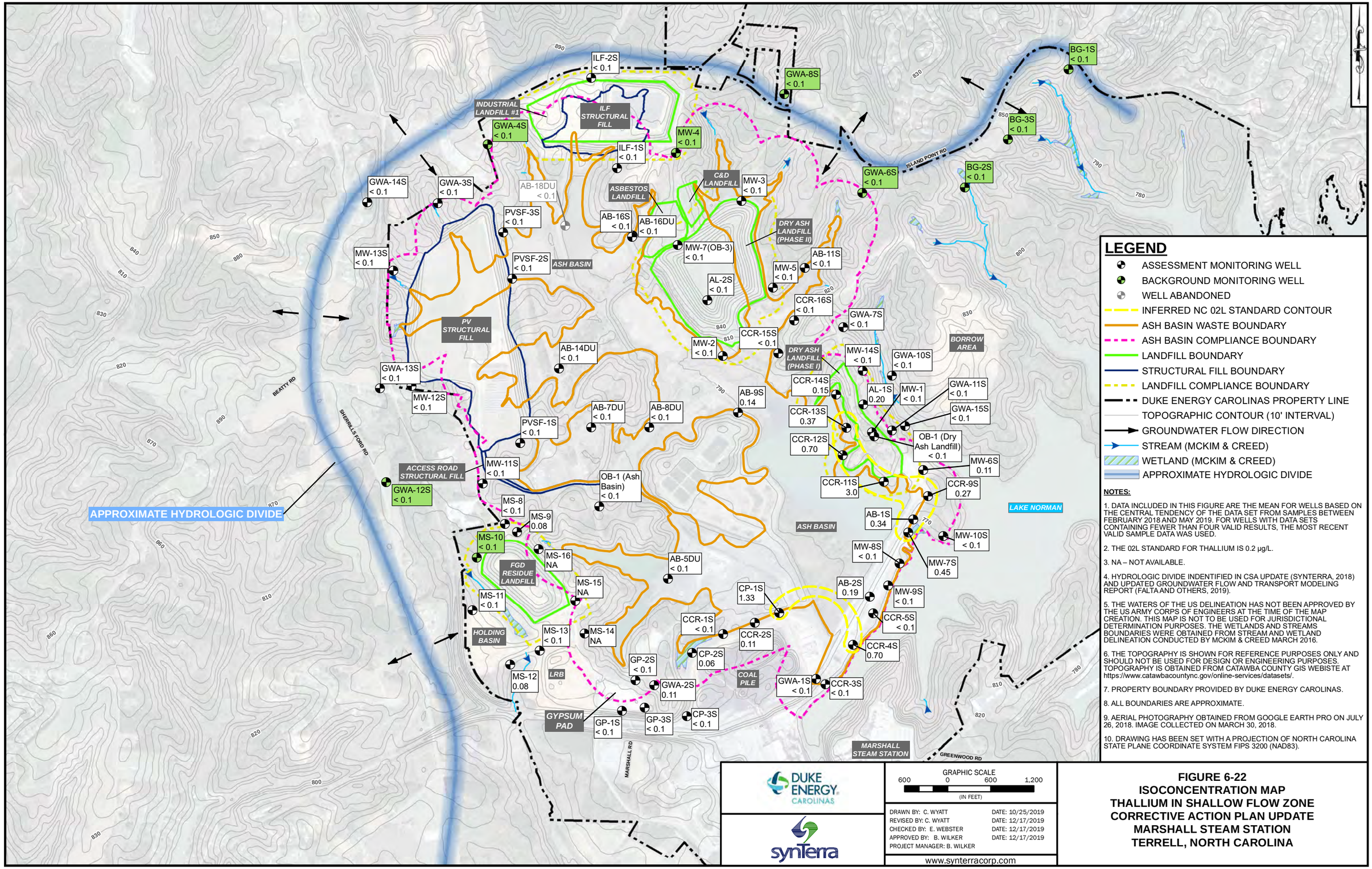
FIGURE 6-21c
ISOCONCENTRATION MAP
TOTAL DISSOLVED SOLIDS
IN BEDROCK FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- ASSESSMENT MONITORING WELL
- BACKGROUND MONITORING WELL
- WELL ABANDONED
- INFERRED NC 02L STANDARD CONTOUR
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- TOPOGRAPHIC CONTOUR (10' INTERVAL)
- GROUNDWATER FLOW DIRECTION
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)
- APPROXIMATE HYDROLOGIC DIVIDE

NOTES:

1. DATA INCLUDED IN THIS FIGURE ARE THE MEAN FOR WELLS BASED ON THE CENTRAL TENDENCY OF THE DATA SET FROM SAMPLES BETWEEN FEBRUARY 2018 AND MAY 2019. FOR WELLS WITH DATA SETS CONTAINING FEWER THAN FOUR VALID RESULTS, THE MOST RECENT VALID SAMPLE DATA WAS USED.
2. THE 02L STANDARD FOR THALLIUM IS 0.2 µg/L.
3. NA – NOT AVAILABLE.
4. HYDROLOGIC DIVIDE INDENTIFIED IN CSA UPDATE (SYNTERRA, 2018) AND UPDATED GROUNDWATER FLOW AND TRANSPORT MODELING REPORT (FALTA AND OTHERS, 2019).
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS OBTAINED FROM CATAWBA COUNTY GIS WEBISTE AT https://www.catawbacountync.gov/online-services/datasets/.
7. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
8. ALL BOUNDARIES ARE APPROXIMATE.
9. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
10. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
600 0 600 1,200
(IN FEET)

DRAWN BY: C. WYATT	DATE: 10/25/2019
REVISED BY: C. WYATT	DATE: 12/17/2019
CHECKED BY: E. WEBSTER	DATE: 12/17/2019
APPROVED BY: B. WILKER	DATE: 12/17/2019
PROJECT MANAGER: B. WILKER	

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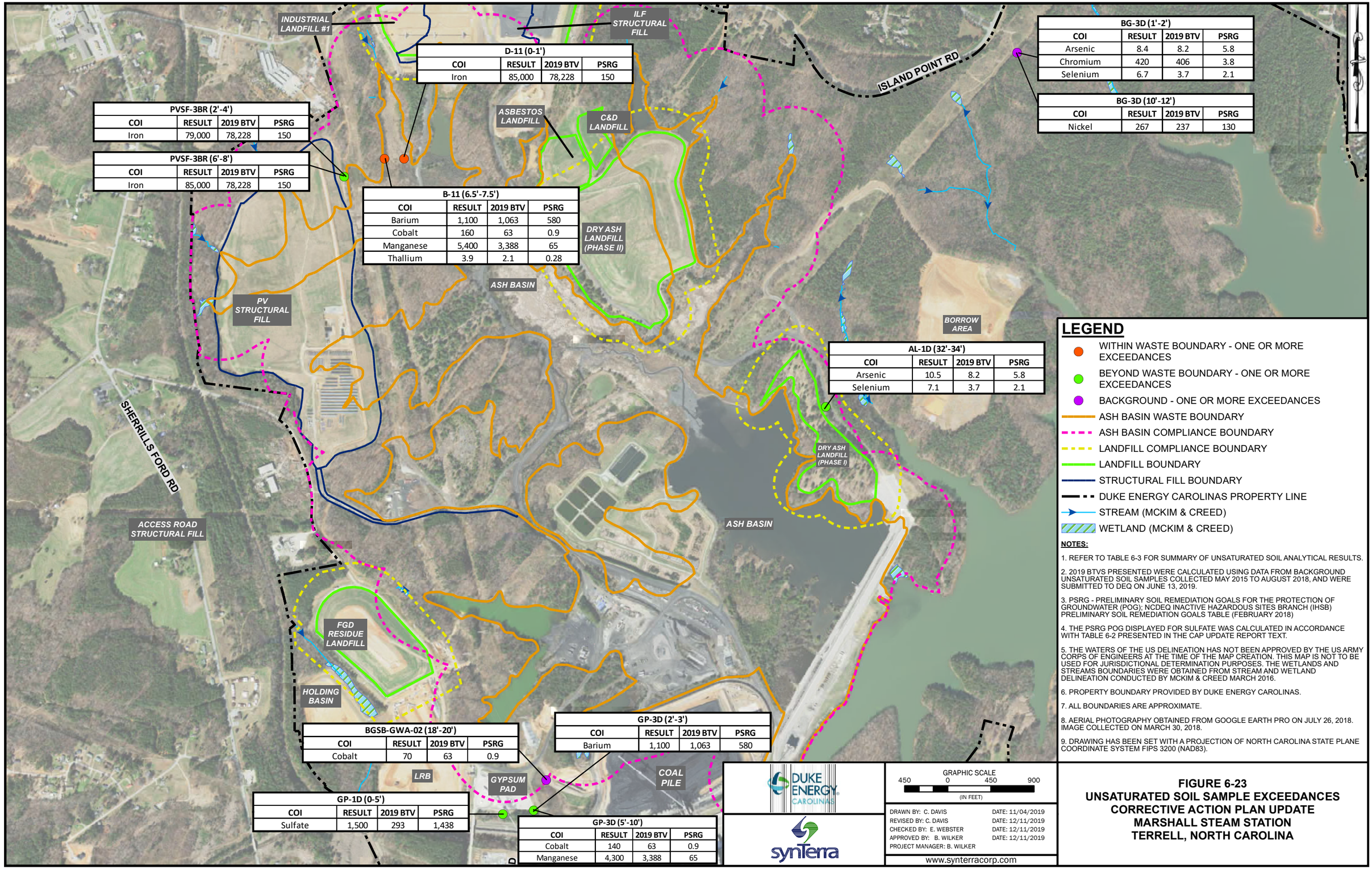
FIGURE 6-22
ISOCONCENTRATION MAP
THALLIUM IN SHALLOW FLOW ZONE
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



D-11 (0-1')			
COI	RESULT	2019 BTV	PSRG
Iron	85,000	78,228	150

PVSF-3BR (2'-4')			
COI	RESULT	2019 BTV	PSRG
Iron	79,000	78,228	150

PVSF-3BR (6'-8')			
COI	RESULT	2019 BTV	PSRG
Iron	85,000	78,228	150

B-11 (6.5'-7.5')			
COI	RESULT	2019 BTV	PSRG
Barium	1,100	1,063	580
Cobalt	160	63	0.9
Manganese	5,400	3,388	65
Thallium	3.9	2.1	0.28

BG-3D (1'-2')			
COI	RESULT	2019 BTV	PSRG
Arsenic	8.4	8.2	5.8
Chromium	420	406	3.8
Selenium	6.7	3.7	2.1

BG-3D (10'-12')			
COI	RESULT	2019 BTV	PSRG
Nickel	267	237	130

AL-1D (32'-34')			
COI	RESULT	2019 BTV	PSRG
Arsenic	10.5	8.2	5.8
Selenium	7.1	3.7	2.1

BGSB-GWA-02 (18'-20')			
COI	RESULT	2019 BTV	PSRG
Cobalt	70	63	0.9

GP-3D (2'-3')			
COI	RESULT	2019 BTV	PSRG
Barium	1,100	1,063	580

GP-1D (0-5')			
COI	RESULT	2019 BTV	PSRG
Sulfate	1,500	293	1,438

GP-3D (5'-10')			
COI	RESULT	2019 BTV	PSRG
Cobalt	140	63	0.9
Manganese	4,300	3,388	65

LEGEND

- WITHIN WASTE BOUNDARY - ONE OR MORE EXCEEDANCES
- BEYOND WASTE BOUNDARY - ONE OR MORE EXCEEDANCES
- BACKGROUND - ONE OR MORE EXCEEDANCES
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- STRUCTURAL FILL BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. REFER TO TABLE 6-3 FOR SUMMARY OF UNSATURATED SOIL ANALYTICAL RESULTS.
2. 2019 BTVS PRESENTED WERE CALCULATED USING DATA FROM BACKGROUND UNSATURATED SOIL SAMPLES COLLECTED MAY 2015 TO AUGUST 2018, AND WERE SUBMITTED TO DEQ ON JUNE 13, 2019.
3. PSRG - PRELIMINARY SOIL REMEDIATION GOALS FOR THE PROTECTION OF GROUNDWATER (POG); NCDEQ INACTIVE HAZARDOUS SITES BRANCH (IHSB) PRELIMINARY SOIL REMEDIATION GOALS TABLE (FEBRUARY 2018)
4. THE PSRG POG DISPLAYED FOR SULFATE WAS CALCULATED IN ACCORDANCE WITH TABLE 6-2 PRESENTED IN THE CAP UPDATE REPORT TEXT.
5. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
6. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
7. ALL BOUNDARIES ARE APPROXIMATE.
8. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
9. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
450 0 450 900
(IN FEET)

DRAWN BY: C. DAVIS	DATE: 11/04/2019
REVISED BY: C. DAVIS	DATE: 12/11/2019
CHECKED BY: E. WEBSTER	DATE: 12/11/2019
APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	

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FIGURE 6-23
UNSATURATED SOIL SAMPLE EXCEEDANCES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure 6-24

Simplified Pourbaix Diagram

Included in Section 6 text

PRE-DECANTING CONDITIONS

APPROXIMATE MODEL YEAR 2720
CLOSURE-IN-PLACE

APPROXIMATE MODEL YEAR 2720
CLOSURE-BY-EXCAVATION

ASBESTOS LANDFILL
C&D LANDFILL
DRY ASH LANDFILL (PHASE II)
DRY ASH LANDFILL (PHASE I)
BORROW AREA
LAKE NORMAN
COAL PILE
MARSHALL STEAM STATION

LEGEND

- BORON CONCENTRATION RANGE (>4,000 µg/L)
- BORON CONCENTRATION RANGE (700 - 4,000 µg/L)
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
2. ALL BOUNDARIES ARE APPROXIMATE.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

DRAWN BY: C. WYATT	DATE: 11/11/2019
REVISED BY: C. DAVIS	DATE: 12/27/2019
CHECKED BY: E. WEBSTER	DATE: 12/27/2019
APPROVED BY: B. WILKER	DATE: 12/27/2019
PROJECT MANAGER: A. ALBERT	

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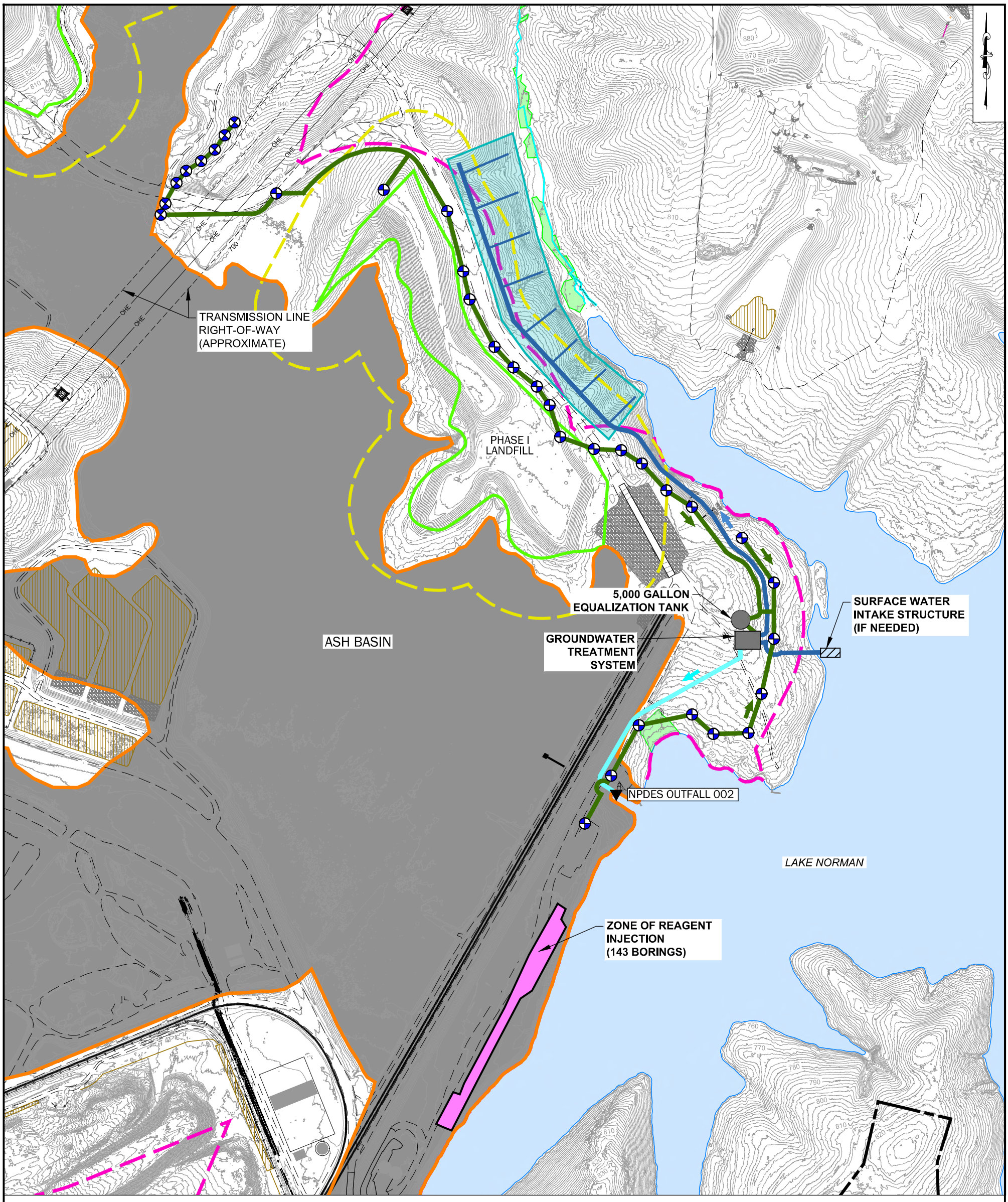
FIGURE 6-25
SIMULATED BORON CONCENTRATIONS IN ALL FLOW ZONES
REMEDIAL ALTERNATIVE 1, MNA
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



NOTES:

1. NOT ALL UTILITIES ARE IDENTIFIED ON THIS DRAWING. THE UTILITIES SHOWN ON THIS DRAWING ARE VISUAL AIDS. THE HORIZONTAL AND VERTICAL LOCATION HAVE NOT BEEN FIELD VERIFIED AND ARE APPROXIMATE.
2. THE TOPOGRAPHY IS SHOWN FOR REFERENCE PURPOSES ONLY AND SHOULD NOT BE USED FOR DESIGN OR ENGINEERING PURPOSES. TOPOGRAPHY IS BASED ON LIDAR BARE EARTH DATA OBTAINED FROM THE NORTH CAROLINA SPATIAL DATA SITE https://sdd.nc.gov/sdd/DataDownload.aspx.
3. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS A PRELIMINARY JURISDICTIONAL DETERMINATION ONLY. THE PRELIMINARY WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM MCKIM&CREED DRAWINGS FOR MARSHALL STEAM PLANT DATED MARCH, 2016.
4. ALL BOUNDARIES ARE APPROXIMATE.

LEGEND

PROPOSED CORRECTIVE ACTION INFRASTRUCTURE

- INFLUENT PIPE
- INFILTRATION PIPE
- DISCHARGE PIPE
- EXTRACTION WELLS
- ZONE OF REAGENT INJECTIONS (143 BORINGS)
- TANK
- GROUNDWATER TREATMENT SYSTEM
- INFILTRATION GALLERY
- PIPING FLOW DIRECTION
- FORMER ASH BASIN FOOTPRINT
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- STREAM (NOT USACE APPROVED) [AMEC 2015]
- SURFACE WATER (AERIAL PHOTOGRAPH & TOPOGRAPHIC MAP BASED)
- WETLAND BY McKIM & CREED
- OHE — OVERHEAD POWER
- 800 — TOPOGRAPHIC CONTOUR (10' INTERVAL)
- TOPOGRAPHIC CONTOUR (2' INTERVAL)
- NPDES OUTFALL 002 — NPDES OUTFALL (APPROXIMATE)

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
200 0 200 400
IN FEET

DRAWN BY: J. CHASTAIN	DATE: 8/15/2019
REVISED BY: J. CHASTAIN	DATE: 12/24/2019
CHECKED BY: W. GERALD	DATE: 12/24/2019
APPROVED BY: W. GERALD	DATE: 12/24/2019
PROJECT MANGER: B. WILKER	
LAYOUT: FIGURE 6-19	

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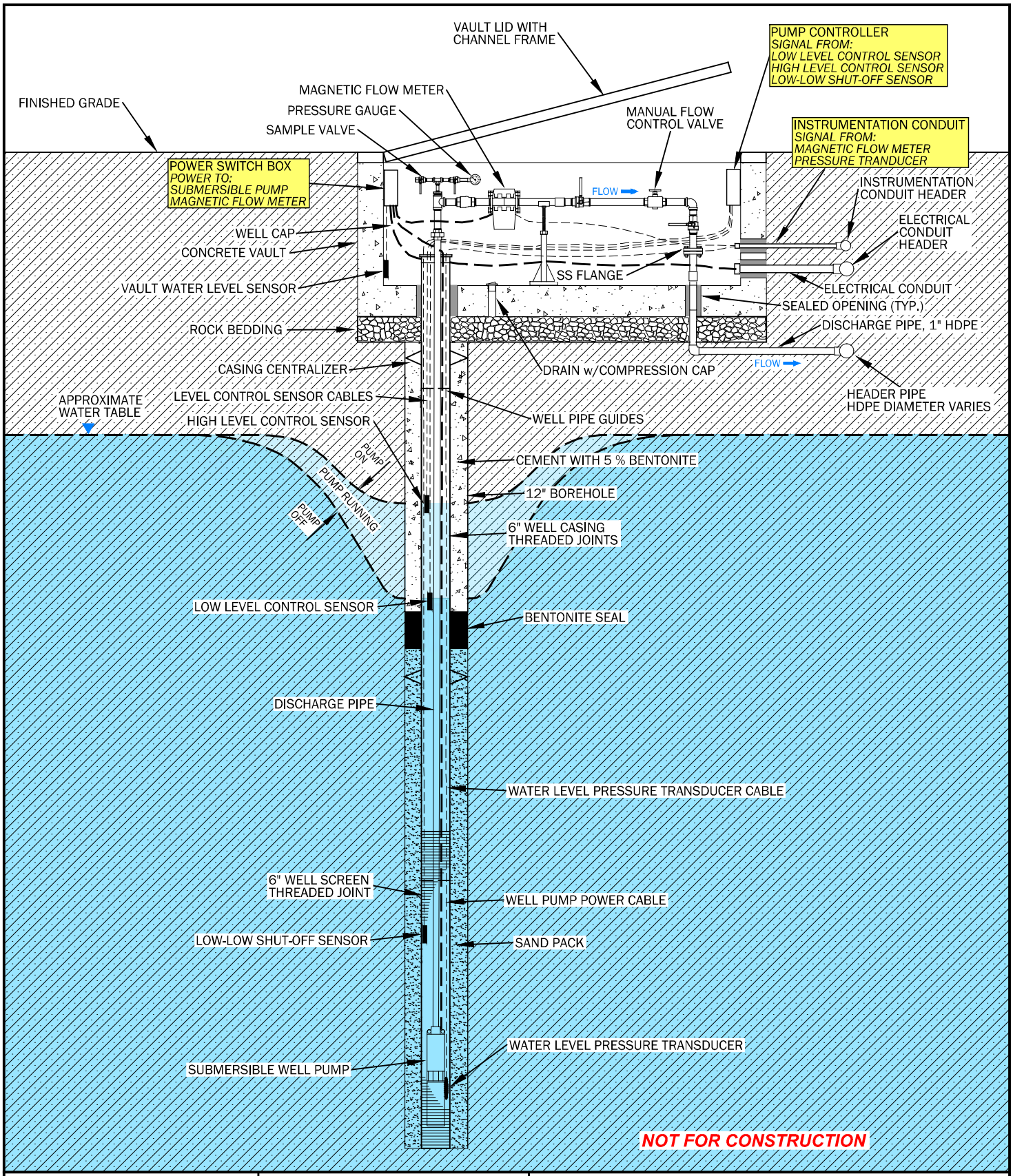
FIGURE 6-26
CONCEPTUAL GROUNDWATER REMEDIAL SYSTEM LAYOUT ALTERNATIVE 2
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



DUKE ENERGY CAROLINAS

synTerra

NOT TO SCALE

DRAWN BY: J. CHASTAIN DATE: 12/21/2019
REVISED BY: DATE: -
CHECKED BY: J. CLEMMER DATE: 12/21/2019
APPROVED BY: W. GERALD DATE: 12/21/2019
PROJECT MANAGER: B. WILKER

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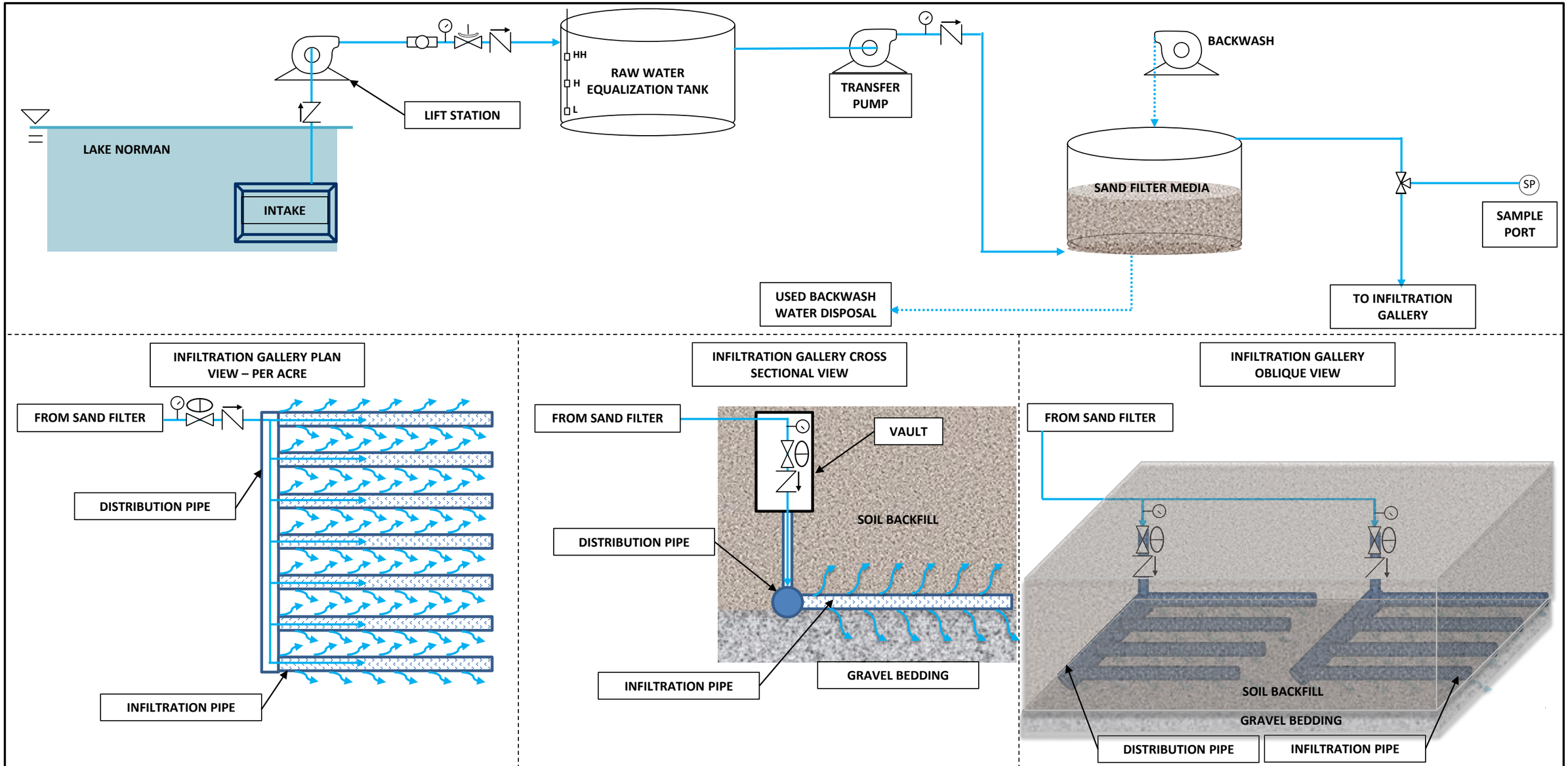
FIGURE 6-27
EXTRACTION WELL SCHEMATIC
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



Not to Scale

LEGEND

HH - High high
H - High low
L - Low

- Flow totalizer
- Pressure gauge
- Sampling port
- Check valve
- Three-way valve
- Ball valve, normally closed
- Rotameter
- Ball valve, normally open
- Diaphragm valve, normally open
- Diaphragm valve, normally closed

DUKE ENERGY CAROLINAS

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DRAWN BY: T. COLTON
REVISED BY:
CHECKED BY: W. GERALD
APPROVED BY: B. WILKER
PROJECT MANAGER: B. WILKER
DATE: 7/17/2019

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FIGURE 6-28
CONCEPTUAL PROCESS FLOW DIAGRAM
WATER INFILTRATION GALLERIES
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

PRE-DECANTING CONDITIONS

APPROXIMATE MODEL YEAR 2050
CLOSURE-IN-PLACE

APPROXIMATE MODEL YEAR 2050
CLOSURE-BY-EXCAVATION

ASBESTOS LANDFILL
C&D LANDFILL
DRY ASH LANDFILL (PHASE II)
DRY ASH LANDFILL (PHASE I)
BORROW AREA
LAKE NORMAN
COAL PILE
MARSHALL STEAM STATION

LEGEND

- BORON CONCENTRATION RANGE (>4,000 µg/L)
- BORON CONCENTRATION RANGE (700 - 4,000 µg/L)
- INFILTRATION GALLERY
- EXTRACTION WELL
- INJECTION WELL
- ASH BASIN WASTE BOUNDARY
- LANDFILL BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
2. ALL BOUNDARIES ARE APPROXIMATE.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

DRAWN BY: B. YOUNG	DATE: 08/09/2019
REVISED BY: C. WYATT	DATE: 12/26/2019
CHECKED BY: E. WEBSTER	DATE: 12/26/2019
APPROVED BY: B. WILKER	DATE: 12/26/2019
PROJECT MANAGER: B. WILKER	

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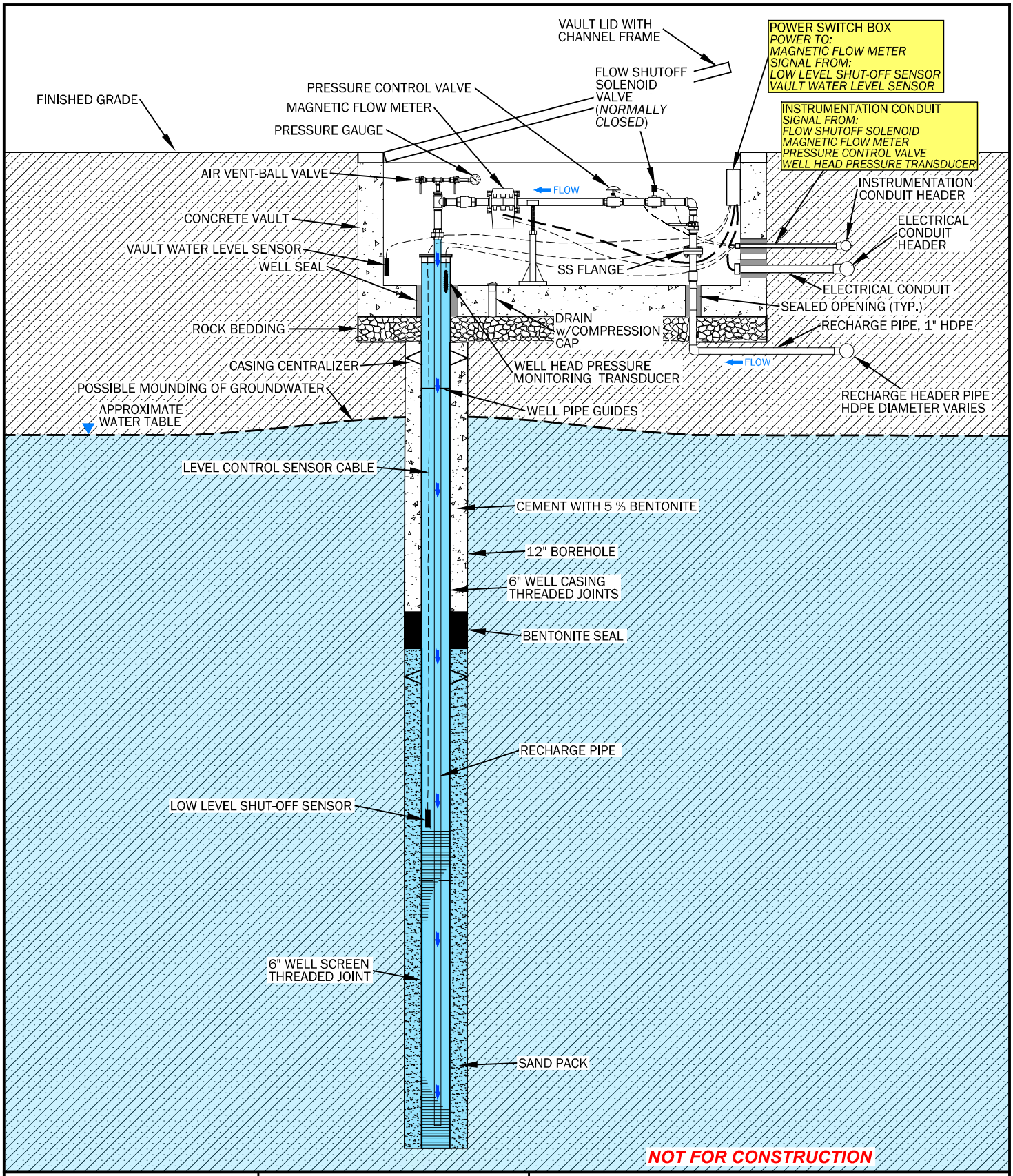
FIGURE 6-29
SIMULATED BORON CONCENTRATIONS IN ALL FLOW ZONES
REMEDIAL ALTERNATIVE 2
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

Figure 6-30

Groundwater Remedial System Layout – Alternative 3

Provided in separate electronic figure file as a large sheet size



DUKE ENERGY CAROLINAS

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NOT TO SCALE

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REVISED BY: DATE: -
CHECKED BY: J. CLEMMER DATE: 12/21/2019
APPROVED BY: W. GERALD DATE: 12/21/2019
PROJECT MANAGER: B. WILKER

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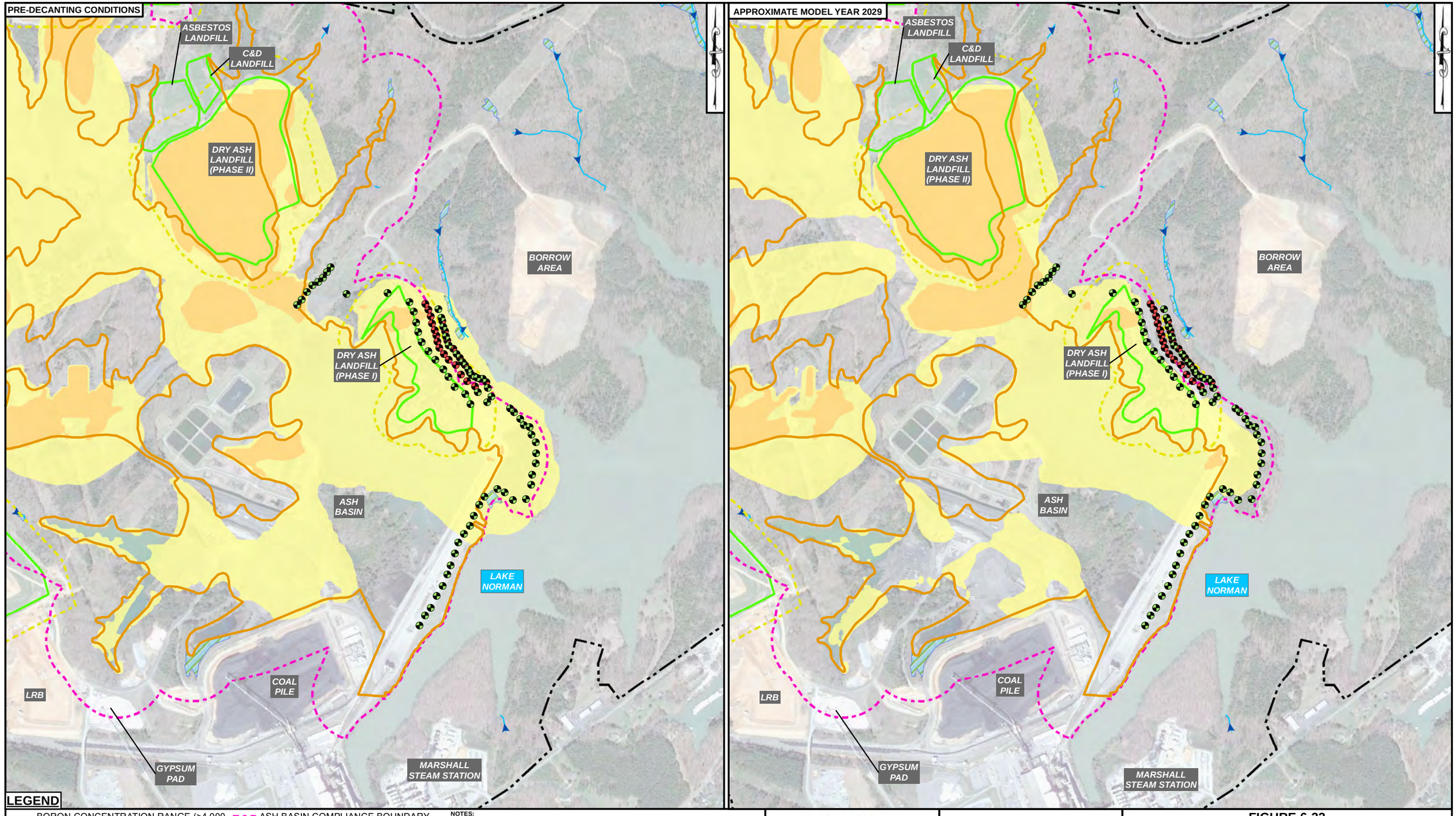
FIGURE 6-31
CLEAN WATER INFILTRATION WELL SCHEMATIC
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



LEGEND

- BORON CONCENTRATION RANGE (>4,000 µg/L)
- BORON CONCENTRATION RANGE (700 - 4,000 µg/L)
- EXTRACTION WELL
- CLEAN WATER INFILTRATION WELL
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- LANDFILL BOUNDARY
- LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.
2. ALL BOUNDARIES ARE APPROXIMATE.
3. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.
4. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.
5. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

synTerra

GRAPHIC SCALE
500 0 500 1,000
(IN FEET)

DRAWN BY: C. WYATT	DATE: 09/09/2019
REVISED BY: C. DAVIS	DATE: 12/11/2019
CHECKED BY: E. WEBSTER	DATE: 12/11/2019
APPROVED BY: B. WILKER	DATE: 12/11/2019
PROJECT MANAGER: B. WILKER	

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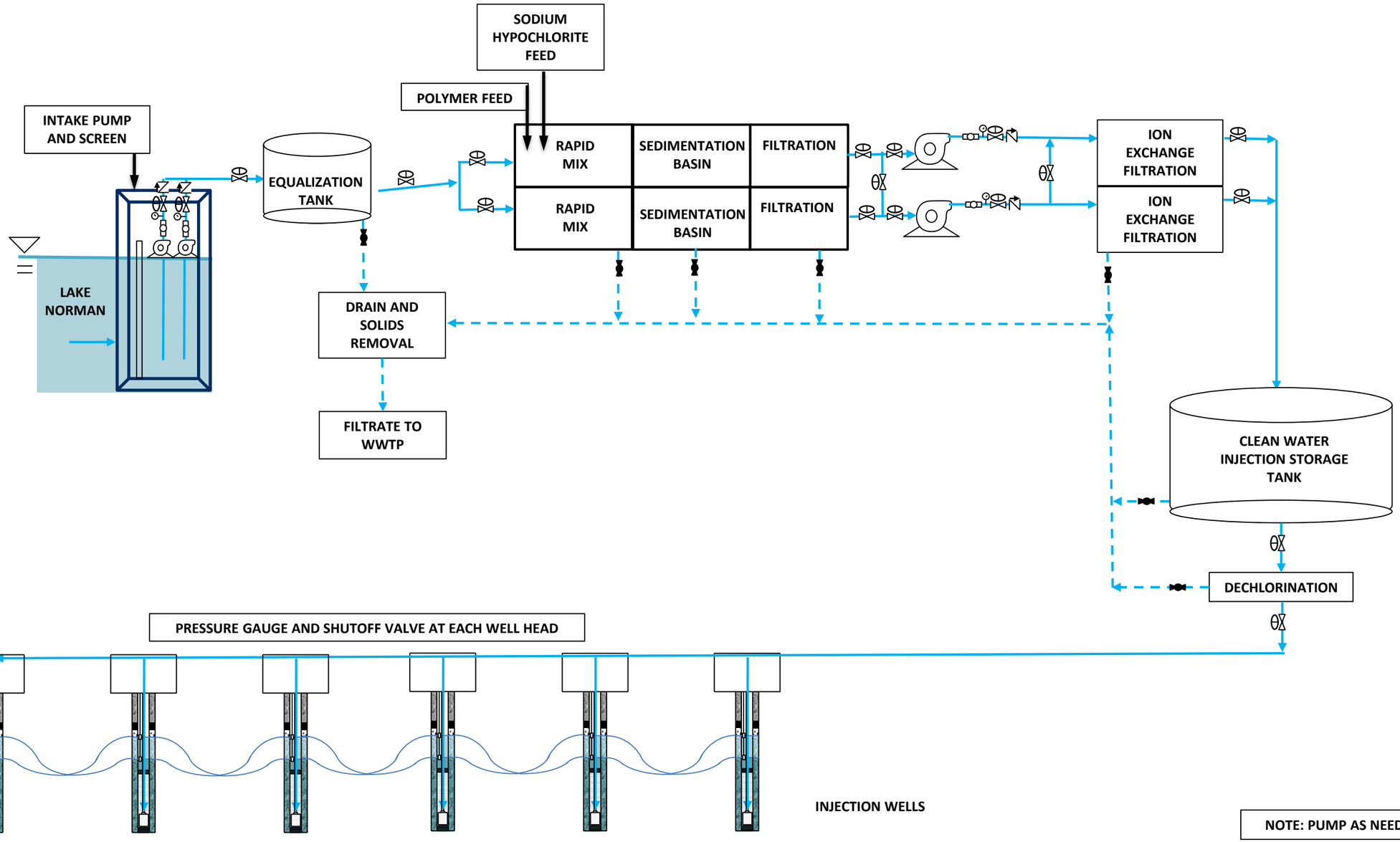
FIGURE 6-32
SIMULATED BORON CONCENTRATIONS IN ALL FLOW ZONES
REMEDIAL ALTERNATIVE 3
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



Not to Scale

LEGEND

HH - High high
H - High low
L – Low
TYP - Typical

- Flow totalizer
- Pressure gauge
- Sampling port (SP)
- Check valve
- Three-way valve
- Ball valve, normally closed
- Rotameter
- Ball valve, normally open
- Diaphragm valve, normally open
- Diaphragm valve, normally closed

DUKE ENERGY CAROLINAS

synterra

DRAWN BY: B. GREEN
REVISED BY: B. GREEN
CHECKED BY: T. COLTON
APPROVED BY: W. GERALD
PROJECT MANAGER: B. WILKER
DATE: 11/7/2019

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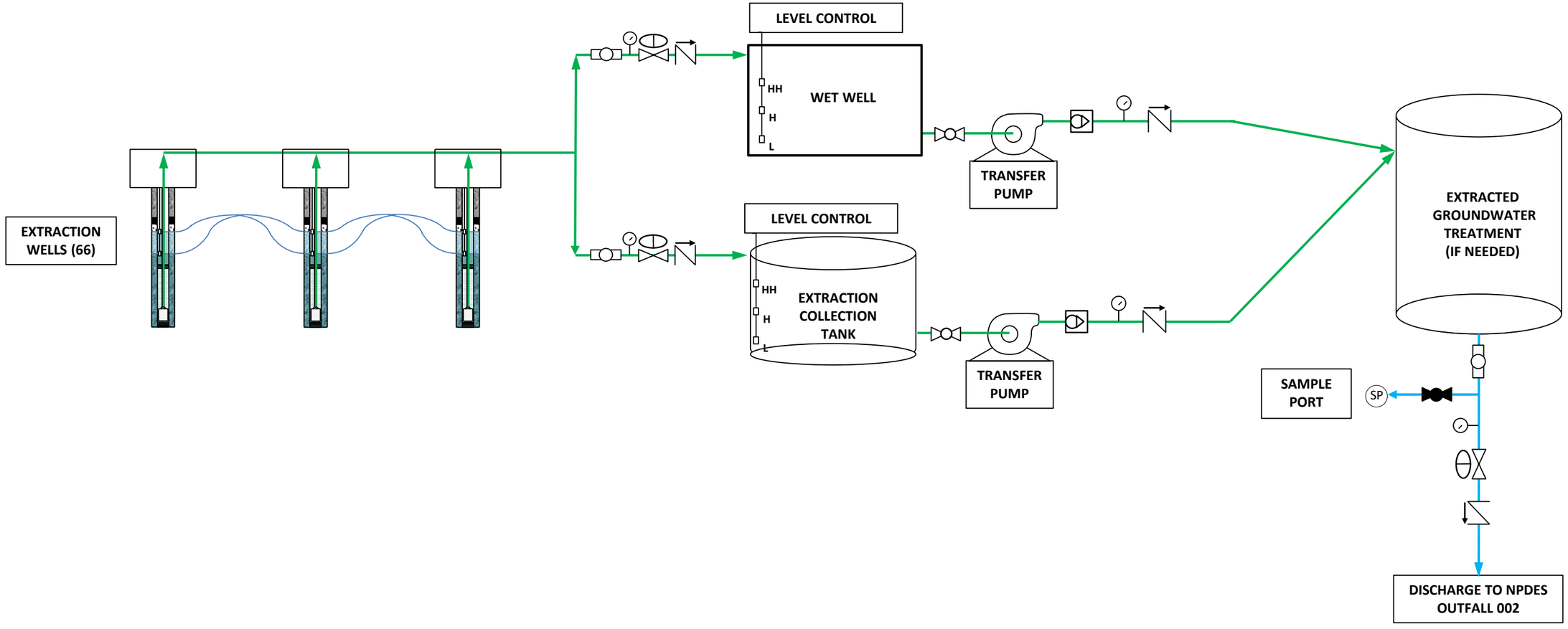
FIGURE 6-33
CONCEPTUAL PROCESS FLOW DIAGRAM
CLEAN WATER INFILTRATION
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



Not to Scale

LEGEND

HH - High high
H - High low
L – Low
TYP - Typical

- Flow totalizer
- Pressure gauge
- Sampling port
- Check valve
- Three-way valve
- Ball valve, normally closed
- Rotameter
- Ball valve, normally open
- Diaphragm valve, normally open
- Diaphragm valve, normally closed

DUKE ENERGY CAROLINAS

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DRAWN BY: B. GREEN DATE: 11/07/2019
REVISED BY: B. GREEN
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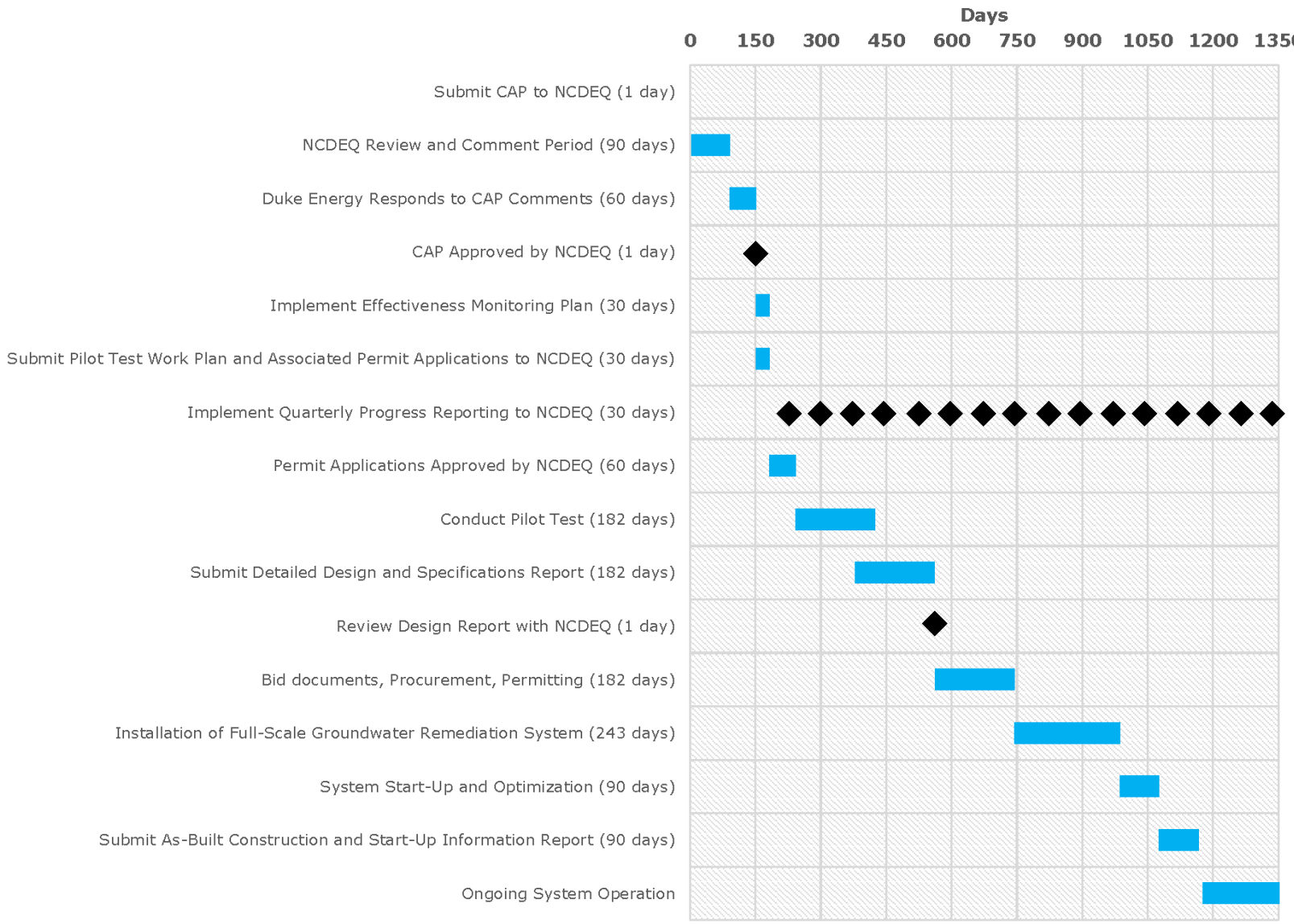
FIGURE 6-34
CONCEPTUAL PROCESS FLOW DIAGRAM
GROUNDWATER EXTRACTON SYSTEM
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



Notes:

* - Either submittal of the Effectiveness Monitoring Plan or the pilot test work plan and permit applications (as applicable) will fulfill section G.S.130A-309.209.(b)(3).

** - Actual time may vary due to a variety of factors including agency review and approvals, weather delays, equipment availability, etc.

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FIGURE 6-35
CAP IMPLEMENTATION GANTT CHART
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA

ILF-2S/D
INDUSTRIAL LANDFILL #1
ILF STRUCTURAL FILL
GWA-8S/D
PROPOSED NEW LANDFILL BOUNDARY
BG-1S/D/BRA
ISLAND POINT RD
BG-3S/D/BR
BG-2S/BR
GWA-6S/D
C&D LANDFILL
ASBESTOS LANDFILL
PVSF-3S/D/BR
ASH BASIN
DRY ASH LANDFILL (PHASE II)
PVSF-2S/D/BR/BRL
PV STRUCTURAL FILL
DRY ASH LANDFILL (PHASE I)
BORROW AREA
MW-14S/D/BR/BRL
GWA-10S/D
AL-1S/D/BR/BRL
CCR-14S/D
EMP-4S/D/BR
PVSF-4S/D/BR
MW-12S/D
BEATTY RD
SHERRILLS FORD RD
CCR-13S/D
GWA-15S/D
GWA-11S/D/BR
EMP-1S/D/BR
PVSF-1S/D/BR
CCR-12S/D
MW-6S/D
CCR-11S/D
EMP-3S/D/BR
ACCESS ROAD STRUCTURAL FILL
GWA-12S/BR
ASH BASIN
CCR-9S/DA
LAKE NORMAN
AB-1S/D/BR/BRL/ BRLL/BRLLL
EMP-2S/D/BR
MW-7S/D
MW-10S/D
MW-8S/D
FGD RESIDUE LANDFILL
MW-9S/D
AB-2S/D/BR
CP-1S/D/BR
CCR-5S/D
HOLDING BASIN
CCR-4S/D
COAL PILE
LRB
GYPSUM PAD
MARSHALL RD

LEGEND

- PROPOSED PERFORMANCE MONITORING WELL (NEW)
- ACTIVE REMEDY PERFORMANCE MONITORING WELL (EXISTING)
- APPROVED BACKGROUND GROUNDWATER MONITORING LOCATION
- ASSUMED WELL ABANDONMENT DURING CLOSURE AND REPLACEMENT POST-CLOSURE
- EFFECTIVENESS MONITORING FLOW PATH
- PROPOSED LANDFILL BOUNDARY
- CURRENT ASH BASIN WASTE BOUNDARY
- CURRENT LANDFILL BOUNDARY
- CURRENT STRUCTURAL FILL BOUNDARY
- CURRENT ASH BASIN COMPLIANCE BOUNDARY
- CURRENT LANDFILL COMPLIANCE BOUNDARY
- DUKE ENERGY CAROLINAS PROPERTY LINE
- STREAM (MCKIM & CREED)
- WETLAND (MCKIM & CREED)

NOTES:

1. FLOW PATH MONITORING LOCATIONS INCLUDE:
1) SOURCE AREA WELLS,
2) WASTE BOUNDARY WELLS,
3) 250' FROM WASTE BOUNDARY WELLS,
4) 500' CAMA COMPLIANCE BOUNDARY WELLS,
5) WELLS NO LESS THAN ONE YEAR TRAVEL TIME UPGRADIENT OF RECEPTOR AND NO GREATER THAN THE DISTANCE GROUNDWATER IS EXPECTED TO TRAVEL IN FIVE YEARS.

2. IF THE WASTE BOUNDARY AND COMPLIANCE BOUNDARY ARE LOCATED SUFFICIENTLY CLOSE TO EVALUATE COI TRENDS OVER TIME, THE 250' INTERVAL LOCATION WOULD NOT BE MONITORED.

3. FLOW PATH GROUNDWATER WELLS WOULD HAVE GEOCHEMICAL SONDES INSTALLED FOR TELEMETRY MONITORING OF THE SIX GROUNDWATER FIELD PARAMETERS. SEE **TABLE 6-21** FOR GROUNDWATER FIELD PARAMETERS.

4. THE WATERS OF THE US DELINEATION HAS NOT BEEN APPROVED BY THE US ARMY CORPS OF ENGINEERS AT THE TIME OF THE MAP CREATION. THIS MAP IS NOT TO BE USED FOR JURISDICTIONAL DETERMINATION PURPOSES. THE WETLANDS AND STREAMS BOUNDARIES WERE OBTAINED FROM STREAM AND WETLAND DELINEATION CONDUCTED BY MCKIM & CREED MARCH 2016.

5. PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY CAROLINAS.

6. AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON JULY 26, 2018. IMAGE COLLECTED ON MARCH 30, 2018.

7. DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83).

DUKE ENERGY CAROLINAS

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GRAPHIC SCALE
490 0 490 980
(IN FEET)

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PROJECT MANAGER: B. WILKER	

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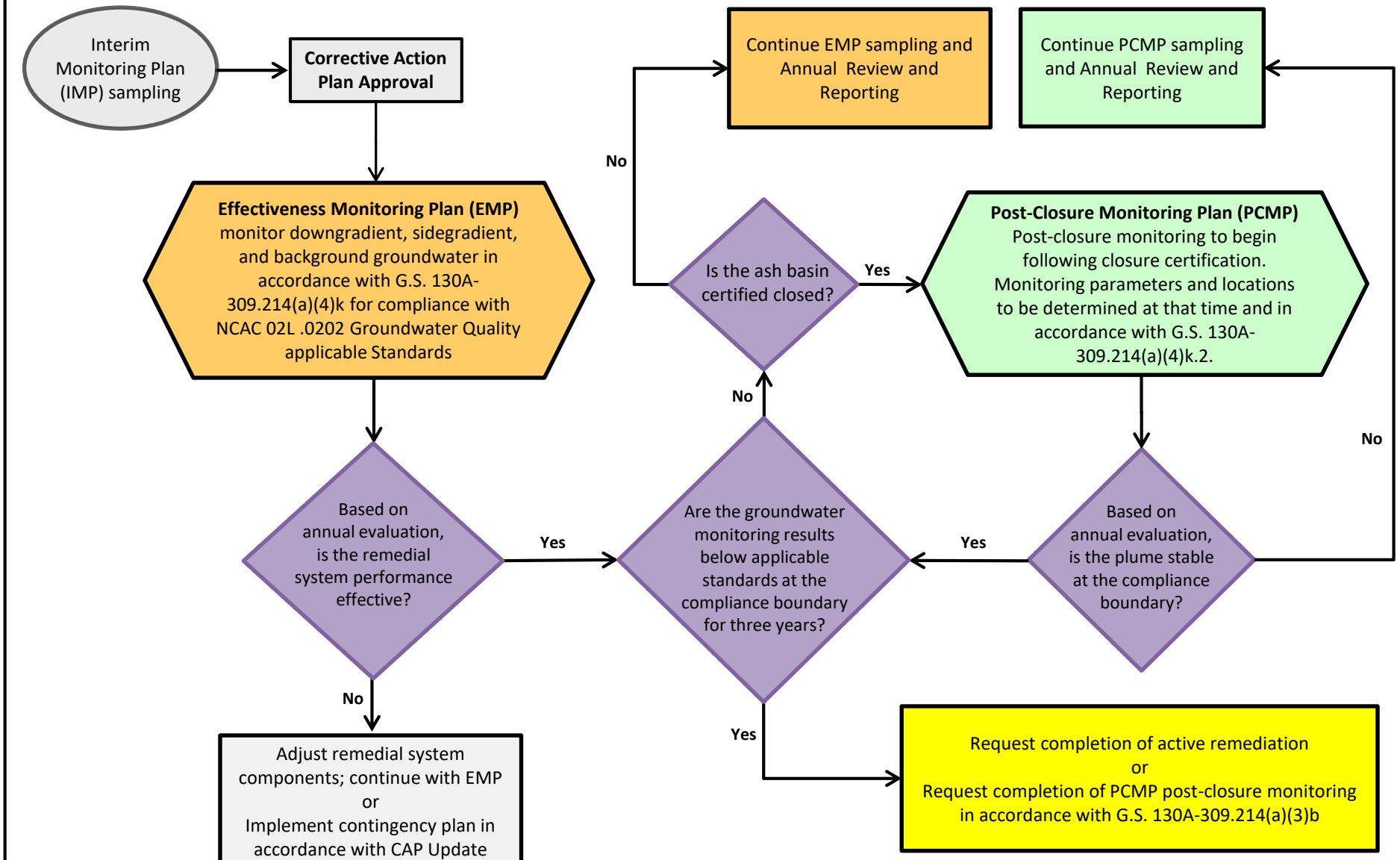
FIGURE 6-36
EFFECTIVENESS MONITORING WELL NETWORK AND FLOW PATHS
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



Notes:

NCAC - North Carolina Administrative Code
02L - NCAC Title 15A, Subchapter 02L. Groundwater Classification and Standards

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APPROVED BY: J. WYLIE	DATE: 12/16/2019
PROJECT MANAGER: B. WILKER	

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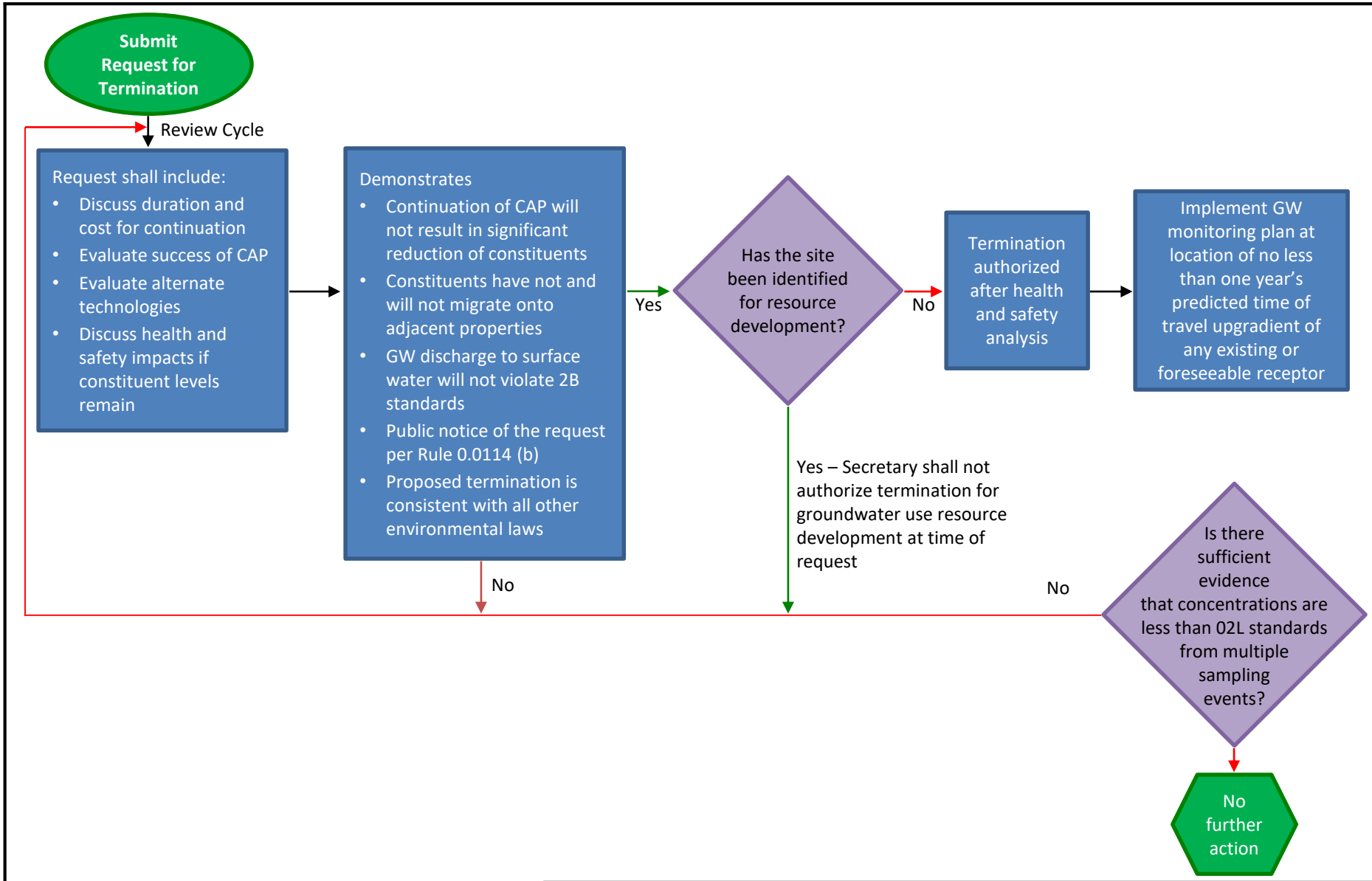
FIGURE 6-37
WORK FLOW FOR EFFECTIVENESS MONITORING AND OPTIMIZATION
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA



DUKE ENERGY CAROLINAS

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CHECKED BY: W. GERALD
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FIGURE 6-38
WORK FLOW FOR TERMINATION OF GROUNDWATER REMEDIATION PROGRAM
CORRECTIVE ACTION PLAN UPDATE
MARSHALL STEAM STATION
TERRELL, NORTH CAROLINA