MAYO STEAM ELECTRIC PLANT
EXECUTIVE SUMMARY

North Carolina General Assembly Session Law 2014-122, the Coal Ash Management Act (CAMA) of 2014, requires the owner of a coal combustion residuals surface impoundment to submit a Groundwater Assessment Plan (GAP) to the North Carolina Department of Environment and Natural Resources (NCDENR) no later than December 31, 2014 and a Groundwater Assessment Report [herein referred to as a Comprehensive Site Assessment (CSA)] no later than 180 days after approval of the GAP. Data generated by this CSA will be used in development of a Corrective Action Plan (CAP) for each regulated facility. This report addresses the Mayo Steam Electric Plant (Mayo Plant, Plant or Site) owned by Duke Energy Progress, LLC (Duke Energy). The assessment was performed within 180 days of the approval of the GAP by NCDENR dated March 6, 2015.

The purpose of the CSA is to characterize the extent of impact resulting from historical production and storage of coal ash, evaluate the chemical and physical characteristics of detected constituents, investigate the geology and hydrogeology of the Site including factors relating to contaminant transport, and examine risk to potential receptors and exposure pathways.

NCDENR prescribed the list of monitoring parameters to be measured at the Mayo Plant. Following receipt of the data, parameters were evaluated to assess those most relevant for the Site. These parameters were determined by examining data from monitoring wells installed in ash pore water and groundwater, and then by comparing these results to the North Carolina Groundwater Quality Standards found in the North Carolina Administrative Code (NCAC) Title 15A, Subchapter 2L.0202 (2L or 2L Standards) and the Interim Maximum Allowable Concentrations (IMAC) established by NCDENR pursuant to 15A NCAC 02L.0202(c). If a constituent concentration exceeded the North Carolina Groundwater Quality Standards in ash pore water wells, as specified in the 2L Standards or the IMACs, it has been designated as a "Constituent of Interest" (COI). COIs are constituents that display correlation to ash basin influence. Some COIs are also present in background monitoring wells and thus require careful examination to determine whether their presence on the downgradient side of the basin is from natural sources (*e.g.*, rock and soil) or the ash basin.

The IMACs were issued in 2010, 2011 and 2012; however, NCDENR has not established a 2L for these constituents as described in 15A NCAC 02L.0202(c). For this reason, IMACs noted in this report are for reference only.

The assessment addresses the horizontal and vertical extent of COIs in soil and groundwater. Significant factors affecting constituent transport and the geological and hydrogeological features influencing the movement, as well as the chemical and physical character of the COIs, were evaluated.

Data presented in this assessment report will be the basis for the CAP required within 270 days of the approved GAP to identify alternative strategies to address groundwater impacts at the Site.

Duke Energy recently stated that future actions concerning the Mayo Plant ash basin were continuing to be studied to determine the best options going forward (http://www.duke-energy.com/news/releases/2015062301.asp). The CAP, as required by CAMA, will include groundwater model results of potential ash removal and capping closure options to assess the impact to groundwater. A groundwater monitoring plan will be provided to assess changes in groundwater conditions over time. Duke Energy is investigating a hybrid closure approach to address the Mayo ash basin where a portion of the basin may be capped and the remainder may be excavated. The excavated material may be re-positioned within the basin footprint in accordance with the hybrid cap-in-place design, or safely recycled, or reused in a lined structural fill, or disposed in a lined landfill.

Based on scientific evaluation of historical and new groundwater assessment data presented in this report, the following conclusions can be drawn:

- No imminent hazard to human health or the environment has been identified as a result of COI migration from the ash basin.
- Recent groundwater assessment results are consistent with previous results from historical and routine compliance boundary monitoring well data.
- Upgradient (background) monitoring wells contain naturally occurring metals and other COIs at concentrations greater than 2L or IMAC. This information is used to evaluate whether concentrations in groundwater downgradient of the basin are also naturally occurring or might be influenced by migration of constituents from the ash basin. Examples include antimony, cobalt, iron, manganese, pH, thallium, and vanadium, all present in background groundwater samples at concentrations greater than 2L or IMAC.
- Groundwater beneath the ash basin flows to the north-northeast and discharges into the Crutchfield Branch stream valley. This flow direction is away from the

nearest public and private water wells. There are no water supply wells located between the ash basin and Crutchfield Branch.

- Boron is the primary constituent in groundwater detected at concentrations greater than background concentrations and 2L. Boron is detected at concentrations greater than 2L within a three-dimensional area beneath and downgradient of the ash basin in the alluvium, transition zone, and shallow bedrock, primarily to the north-northeast of the ash basin and the Site. Boron is highly soluble and was identified by the USEPA as one of the leading indicators for releases of contaminants from ash.

- Vertical migration of constituents is generally limited by underlying bedrock. Based on available data, groundwater exceedances of 2L from ash basin-related constituents have not been detected beyond the boundary of the Site.

- Boron was not detected in the wells installed downgradient of the boundary of the Site in the Crutchfield Branch stream valley in the alluvium, regolith/bedrock transition zone, or shallow bedrock.

- Surface water flowing north off of the Site downstream of the dam in Crutchfield Branch contains boron. There is no North Carolina Surface Water 2B Standard in Title 15A, NCAC Subchapter 2B for boron, and this concentration is further reduced by the convergence with other streams, such as Mayo Creek, north of the state line.

- Cobalt, iron, manganese, pH, and vanadium are also present in groundwater greater than 2L off-site and downgradient of the ash basin. However, these constituents are also present in background samples in one or more background wells at greater than 2L concentrations.

- The CSA serves to characterize the horizontal and vertical extent of COIs, and the groundwater gradients which facilitate development of the Site Conceptual Model (SCM), *i.e.* the groundwater flow and contaminant migration model. This then facilitates identification of corrective actions due in 90 days under the CAP.

- Groundwater modeling to be provided with the CAP will allow an evaluation of potential ash removal and capping closure options to assess the impact to groundwater.

Brief summaries of the essential portions of the CSA are presented in the following sections.

ES1. Source Information

Duke Energy Progress, LLC (Duke Energy) owns and operates the Mayo Steam Electric Plant, located in Person County, near Roxboro, North Carolina. The Mayo Plant began operations in 1983 and is presently in service. Mineralogical, physical, and chemical properties of the Mayo Plant ash basin have been characterized for use in the SCM. A single ash basin has historically been used to manage coal combustion residuals (CCR) at the Mayo Plant and has been active from Plant start-up in 1983. Mayo Plant has recently implemented dry ash handling. CCR is only placed into the ash basin when the dry system is undergoing maintenance.

The CSA found that CCR accumulated in the ash basin, through leaching of CCRs into underlying groundwater, is a source of impact detected in the vicinity of the ash basin as shown on **Figure ES-1**. Water within the ash basin is hydraulically higher (upgradient) than the surrounding land surface to the north and northeast beyond the ash basin dam. When water is present below the ash surface, it is referred to as ash pore water. Ash pore water from the ash drains through the soil, saprolite, and shallow bedrock into groundwater. Groundwater and seeps are the primary mechanisms for migration of COI's to the environment.

ES2. Initial Abatement and Emergency Response

The Mayo Plant is an active, power generating facility. The ash basin and other industrial features of the Plant are actively monitored and maintained. The CSA found no imminent hazard to public health or the environment; therefore, no actions to mitigate or abate imminent hazards are required.

ES3. Receptor Information

The requirement contained in the NORR and CAMA concerning receptors was completed with the results provided in **Section 4.0**. A screening level HHRA and SLERA were conducted with the results provided in **Section 12.0**.

Land use surrounding the Mayo Plant includes mostly rural, rural residential, agricultural, and forest land. Duke Energy-owned and maintained land borders the Mayo Plant to the west, east (Mayo Lake), and north (with the exception of two large parcels between the Site and the state line). A small residential area borders the Site to the south-southwest.

ES.3-1 Public Water Supply Wells

Surveys of public and private water supply wells within a ½ mile radius of the ash basin compliance boundaries have been conducted. Available information is provided in **Section 4.0**. Bethel Hill Baptist Church, located approximately 0.5

miles south and upgradient of the Site, maintains a public water supply provided by a groundwater well.

ES.3-2 Private Water Supply Wells

Inventories of public and private water supply wells have been compiled. NCDENR contacted nearby residents regarding private wells and managed the sampling of the wells in accordance with CAMA. NCDENR has reported analytical data for two private wells in the vicinity of the Mayo Plant. No constituents were detected above the 2L in the wells with the exception of iron (both wells), manganese (one well), lead (one well), and vanadium (one well). Both wells are located in positions upgradient from the ash basin. No lead detections have been noted in Site groundwater. Elevated concentrations of iron and manganese are cited in a USGS report as being the most common water quality issue in the Piedmont (Daniel and Dahlen, 2002). The NCDENR water well data is provided herein.

ES.3-3 Human and Ecological Receptors

The exposure media for human receptors includes potentially impacted groundwater, soil, surface water and sediments. The exposure routes associated with the potentially completed exposure pathways evaluated for the Site include ingestion, inhalation and dermal contact of environmental media. Potential human receptors include current or future recreational users; current or future construction/industrial workers; and future residents.

The potential exposure media for ecological receptors includes impacted soil, surface water, and sediments. Direct contact with groundwater does not present a complete exposure pathway to ecological receptors. Exposure routes associated with potentially completed exposure pathways include dermal contact, incidental ingestion, and ingestion of prey or plants.

ES4. Sampling / Investigation Results

The approximate extent of horizontal migration of boron, the COI that appears to be most attributable to migration from the ash basin, is shown on **Figure ES-1**.

ES.4-1 Nature and Extent of Contamination

Antimony, arsenic, barium, boron, cobalt, iron, manganese, pH, thallium, TDS, and vanadium were detected in ash pore water at concentrations greater than the 2L or IMAC.

Boron was detected above the 2L at the compliance boundary to the north-northeast active basin in surficial (alluvium) groundwater, transition zone

groundwater, and bedrock groundwater. The horizontal extent of migration is controlled by Crutchfield Branch which serves as a groundwater to surface water discharge zone (**Figure ES-1**). The vertical extent of migration is impeded by the paucity of interconnected fractures in the bedrock.

In addition, antimony, arsenic, barium, cobalt, iron, manganese, pH, thallium, total dissolved solids (TDS), and vanadium were detected in the ash basin (pore) water, near the bottom of the ash, at concentrations greater than 2L or IMAC. Of these constituents, all but arsenic, barium, and TDS were also detected in Site background wells upgradient of the ash basin at concentrations greater than 2L or IMAC. Neither arsenic nor barium was detected greater than 2L or IMAC outside of the ash basin.

Cobalt, iron, manganese, and vanadium are commonly detected in shallow groundwater in the Piedmont of North Carolina. Site background concentration ranges for some of these constituents are available from routine monitoring of the upgradient compliance boundary monitoring wells and newly installed background wells.

ES.4-2 Maximum Contaminant Concentrations

For the COIs identified on the basis of ash basin pore water concentrations, boron, cobalt, and TDS are the only COIs in groundwater detected downgradient or otherwise outside of the ash basin (refer to figures and tables in **Section 10.0**). The highest detected concentration for boron occurs in a shallow well (MW-3) previously installed immediately downgradient of the ash basin. The second highest boron detection occurs in a NPDES compliance boundary well completed in the regolith/bedrock transition zone downgradient of the ash basin. The occurrence of boron in groundwater is limited in area (**Figure ES-1**), and groundwater affected by boron discharges to Crutchfield Branch.

The highest detection of cobalt occurred in MW-16S, a well screened in the alluvium of Crutchfield Branch. The highest concentration of TDS in groundwater occurs in areas downgradient of the active ash basin in shallow bedrock (CW-6, MW-3BR, and MW-8BR).

Other constituents that exceed the 2L or IMAC in groundwater outside of the ash basin include antimony, iron, manganese, pH, thallium, and vanadium. The highest concentrations of antimony, thallium, and vanadium occurred in groundwater collected from background wells. Values for pH across the Site generally range from 5 to 8.

The highest iron concentration was observed in upgradient bedrock well MW-5BR. Manganese was highest in bedrock well MW-8BR, likely outside of the hydrogeological influence of the ash basin.

Elevated COI occurrences in soil ranged from background areas to soil beneath the ash basin. The maximum concentration of boron in soil was detected in a sample collected 33 to 35 feet below the ash basin. The highest concentrations of aluminum, cobalt, iron, manganese, selenium, and zinc were from soils beyond the ash basin. Only arsenic and lead had higher concentrations in ash than Site soils. For some constituents, including boron, chromium, copper, molybdenum, nickel, strontium, and zinc, detected concentrations were similar regardless of whether the samples were ash or soil outside of the ash basin.

ES.4-3 Source Characterization

COIs that leached from ash into ash basin pore water at concentrations greater than 2L or IMAC include antimony, arsenic, barium, boron, cobalt, iron, manganese, pH, TDS, thallium, and vanadium. Ash pore water may discharge through the toe of the basin dam via the engineered toe drains, via groundwater beneath the dam into the Crutchfield Branch stream valley, or through NPDES Outfall 002.

ES.4-4 Receptor Survey

The area to the south of the plant is serviced by a municipal water line which terminates near the intersection of the Plant entrance road and US 501. The area north of the plant is not serviced by public water. Up to 22 private supply wells may be located within one half mile of the Site, including three water supply wells, inactive for years, located on the Mayo Plant. The majority of these private wells are upgradient of the Mayo Plant. NCDENR has managed the sampling of water supply wells in the area, and data have been reported for two private wells. No constituents were detected above 2L in the private supply wells with the exception of iron (both wells), manganese (one well), lead (one well), and vanadium (one well). Both wells are located in positions upgradient from the ash basin. Bethel Hill Baptist Church, located approximately 0.5 miles south and upgradient of the Site, reportedly maintains a public water supply provided by a groundwater well.

Constituents of potential concern (COPCs) for human and ecological receptors identified using screening level risk assessment methodology for receiving areas at the Site include pH, aluminum, arsenic, boron, chromium, cobalt, copper, iron, manganese, mercury, selenium, vanadium, and zinc. This list is longer than the

list of site-specific COIs due to the conservative approach of comparing analytical results to published reference criterion in the risk assessment screening process.

ES.4-5 Regional Geology and Hydrogeology

The Mayo Plant is situated in the north-central Piedmont of North Carolina. Geologically, the Plant is located near the contact between two regional zones of metamorphic rocks. The rocks in the area include volcanic and sedimentary rocks that have been metamorphosed, intruded by coarse-grained granitic rocks, and subjected to regional structural deformation. The characteristics and genesis of the rocks within these regional metamorphic belts have been the subject of intense study for over a century to describe the mineral resources of the area and the geologic character of the region.

The upper portions of rocks in the Piedmont are typically fractured and weathered and are covered with unconsolidated material known as regolith. The regolith includes residual soil and saprolite zones and, where present, alluvium. Saprolite is typically composed of clay and coarser granular material and reflects the texture and structure of the rock from which it was formed as a result of in-situ chemical weathering. Beneath the saprolite, partially weathered/fractured bedrock occurs with depth until competent bedrock is encountered. Groundwater is typically stored in and moves through these units.

ES.4-6 Site Geology and Hydrogeology

Geology beneath the Mayo Plant can be classified into three units. Regolith (surficial soils, fill and reworked soil, alluvium along the Crutchfield Branch stream valley, and saprolite) is the shallowest geologic unit. Saprolite is mostly thin (ranging from non-existent to around 25 feet deep) and almost entirely unsaturated except in the southern, upland parts of the Site and certain locations beneath the ash basin. A transition zone of partially weathered rock underlies the regolith (where present, the saprolite is the lowest portion of the regolith) and is generally continuous throughout the Mayo Plant area. The transition zone is comprised of partially weathered rock that is gradational between saprolite and competent bedrock. The change from partially weathered rock to the third unit, competent bedrock, is subjective and at Mayo Plant is defined by subtle changes in weathering, secondary staining and mineralization, core recovery, and the degree of fracturing in the rock. Only mildly productive fractures (providing water to wells) were observed within the top 50 feet of competent rock.

In general, three hydrogeologic units or zones of groundwater flow can be described for the Mayo Plant. The zone closest to the surface is the shallow or surficial flow zone encompassing saturated conditions, where present, in the residual soil, saprolite, or alluvium beneath the Site. A transition zone is encountered below the surficial zone and the bedrock as is characterized primarily by partially weathered rock of variable thickness. The transition zone is not consistently saturated across the Site. The bedrock flow zone occurs below the transition zone and is characterized by the storage and transmission of groundwater in water-bearing fractures.

The primary feature that influences migration of COIs at the Mayo Plant is the topography of the area and location of the ash basin in the former Crutchfield Branch stream valley. The Mayo Plant ash basin occupies the former stream valley of Crutchfield Branch. The basin acts as an elongated bowl-like feature towards which groundwater flows from the northwest, west, south, and east. Groundwater flows from the ash basin into the small valley formed by Crutchfield Branch. Crutchfield Branch flows north off of the Site and into Virginia. The regolith/bedrock transition zone, where saturated, and shallow bedrock fractures contain the first occurrence of groundwater.

ES.4-7 Existing Groundwater Monitoring Data

NPDES compliance groundwater monitoring data indicate that elevated concentrations of boron, iron, manganese, and TDS have been detected at the compliance boundary.

ES.4-8 Development of Site Conceptual Model

A hydrogeological SCM was developed from data generated during previous assessments, existing groundwater monitoring data, and 2015 groundwater assessment activities. Ash pore water may discharge through the toe of the basin dam via the engineered toe drains, via groundwater beneath the dam into the Crutchfield Branch stream valley, or through NPDES Outfall 002. Groundwater flows north-northeast into the Crutchfield Branch stream valley. Arsenic is found in ash pore water; however, arsenic was only detected at a very low concentration in downgradient groundwater (MW-16BR). Boron, detected in ash pore water, was detected in downgradient wells on the Site and in Crutchfield Branch.

ES5. Identification of Data Gaps

The horizontal and vertical extent of COIs occurring at or above the appropriate regulatory standards have been determined for soil and groundwater. Source area and

groundwater characterization data have been used to develop hydrogeologic and geochemical SCMs that will support preparation of flow and transport groundwater modeling for the Site. There are no data gaps that will be limiting factors in the execution of the groundwater model or development of the CAP.

ES6. Conclusions

1. The CSA found no imminent hazard to human health or the environment as a result of groundwater migration from the ash basin.

2. Boron is the primary constituent in groundwater detected at concentrations greater than background concentrations and 2L. Boron is detected at concentrations greater than 2L beneath and downgradient of the ash basin in the alluvium, transition zone, and shallow bedrock, primarily to the north-northeast of the ash basin (as shown of **Figure ES-1**). Boron was not detected in the wells installed downgradient of the boundary of the Site in the Crutchfield Branch stream valley in the alluvium, regolith/bedrock transition zone, or shallow bedrock.

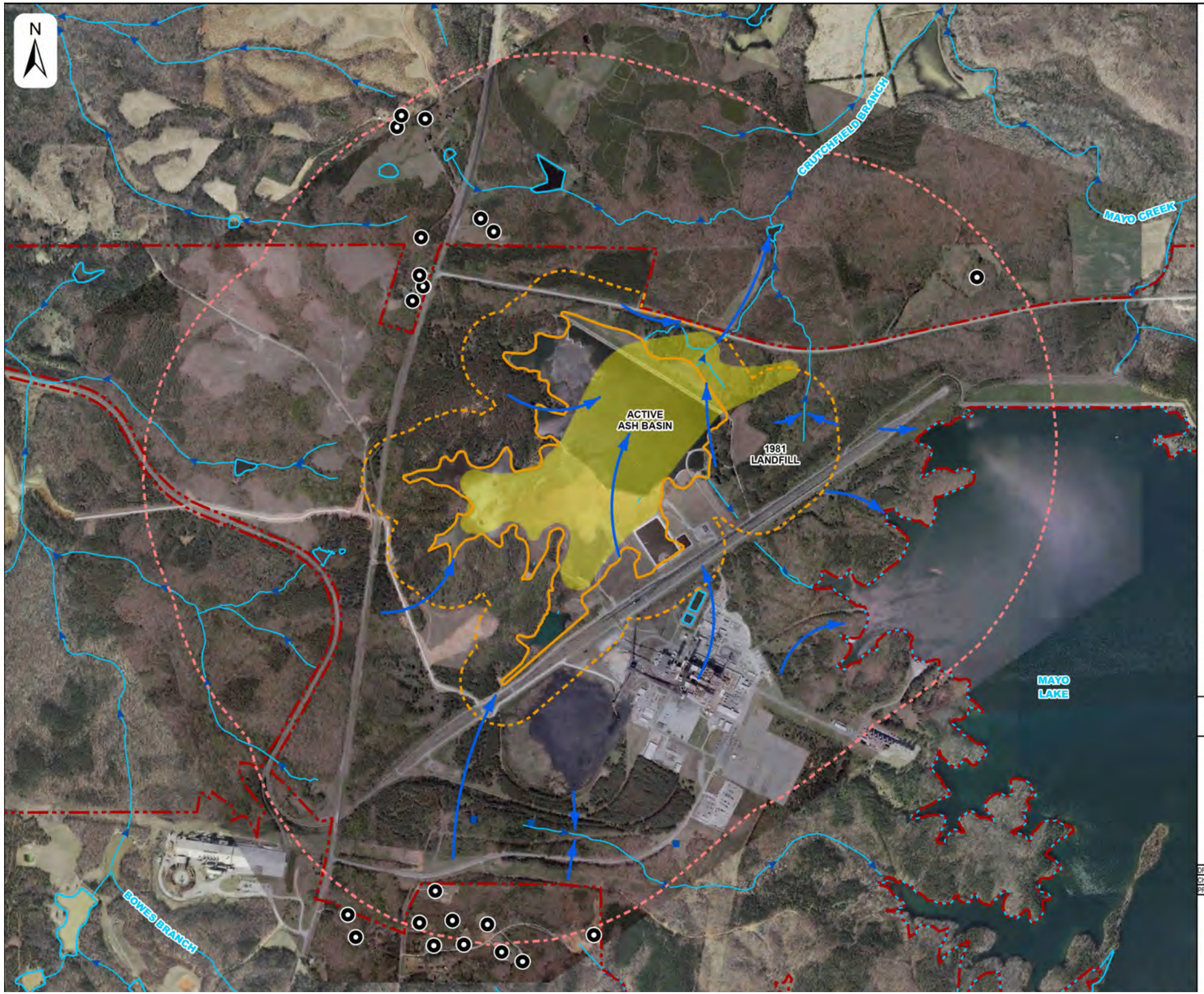
3. Cobalt, iron, manganese, pH, and vanadium are present in downgradient groundwater at levels above the IMAC or 2L; however, these constituents are also present in background wells at concentrations that exceed the 2L.

4. Surface water flowing north off of the Site in Crutchfield Branch contains boron. There is no 2B standard for boron. Other constituents present in surface water are aluminum, cobalt, iron, and manganese. The concentrations of these constituents exceed the North Carolina Surface Water 2B Standard (except iron which has no 2B); however, these constituents are also present in background samples.

5. Duke Energy is investigating a hybrid closure approach to address the Mayo ash basin where a portion of the basin may be capped and the remainder may be excavated.

6. An interim groundwater monitoring plan is presented in **Section 16.0** of this report. A performance monitoring plan to support the remedy in the proposed CAP will be submitted within 90 days of September 2, 2015.

7. The CSA and the groundwater modeling work will allow for completion of a CAP within 90 days of submittal of this report.



LEGEND

- WATER SUPPLY WELL[1]
- DUKE ENERGY PRODUCTION WELL[1]
- AREA OF CONCENTRATIONS IN GROUNDWATER ABOVE NC2L[2]
- GENERALIZED GROUNDWATER FLOW DIRECTION
- ACTIVE ASH
- ASH BASIN COMPLIANCE
- HALF-MILE OFFSET FROM COMPLIANCE
- DUKE ENERGY PROGRESS MAYO PLANT SITE
- STREAM

NOTES:

[1] FROM DRINKING WATER WELL AND RECEPTOR STUDY (APPENDIX B).

[2] BORON AND TOTAL DISSOLVED SOLIDS (TDS) EXHIBITS THE GREATEST THREE-DIMENSIONAL EXTENT OF MIGRATION FROM THE MAYO PLANT ASH BASIN. THE NORTH CAROLINA 2L (NC2L) FOR BORON IS 700 µg/L. THE NORTH CAROLINA 2L (NC2L) FOR TDS IS 500 mg/L.

[3] APRIL 17, 2014 AERIAL ORTHOPHOTOGRAPHY OBTAINED FROM WSP.

[4] 2013 AERIAL ORTHOPHOTOGRAPHY OBTAINED FROM THE NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS. (http://services.nconemap.gov/)

[5] PARCEL BOUNDARY WAS OBTAINED FROM THE NC CENTER FOR GEOGRAPHIC INFORMATION AND ANALYSIS. (http://services.nconemap.gov/)

GRAPHIC SCALE

600 0 600 1,200 1,800 2,400

IN FEET

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DRAWN BY: B. RHODE	DATE: 09/01/2015
CHECKED BY: J. MEADOWS	DATE: 09/01/2015
PROJECT MANAGER: J. WYLIE	

FIGURE ES-1
SITE CONCEPTUAL MODEL - PLAN VIEW
MAYO STEAM ELECTRIC POWER PLANT