# Community Impact Analysis of Ash Basin Closure Options at the Mayo Steam Electric Plant

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Prepared on behalf of Duke Energy Progress, LLC

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November 15, 2018



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# Acronyms and Abbreviations

| | |
|---|---|
| AADT | annual average daily traffic |
| CAMA | North Carolina Coal Ash Management Act |
| CAP | corrective action plan |
| CCR | coal combustion residuals |
| CCR Rule | EPA Coal Combustion Residuals Rule of 2015 |
| CERCLA | Comprehensive Environmental Response, Compensation and Liability Act |
| CIP | cap in place |
| COI | constituent of interest |
| COPC | chemical of potential concern |
| CSA | comprehensive site assessment |
| DPM | diesel particulate matter |
| Duke Energy | Duke Energy Progress, LLC |
| DSAY | discounted service acre-year |
| ELCR | excess lifetime cancer risk |
| EPA | U.S. Environmental Protection Agency |
| ERA | ecological risk assessment |
| GIS | geographic information system |
| HEA | habitat equivalency analysis |
| HHRA | human health risk assessment |
| HI | hazard index |
| HQ | hazard quotient |
| LOAEL | lowest-observed-adverse-effects level |
| Mayo Plant | Mayo Steam Electric Plant |
| MOVES | Mobile Vehicle Emissions Simulator |
| NEBA | net environmental benefit analysis |
| NCDEQ | North Carolina Department of Environmental Quality |
| NCDOT | North Carolina Department of Transportation |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAEL | no-observed-adverse-effects level |
| NPDES | National Pollutant Discharge Elimination System |
| NPP | net primary productivity |
| NRDA | natural resource damage assessment |
| OSAT-2 | Operational Science Advisory Team-2 |
| RCRA | Resource Conservation and Recovery Act |
| REL | reference exposure level |
| SOC | Special Order by Consent |
| TRV | toxicity reference value |
| TVA | Tennessee Valley Authority |

# Limitations

This report sets forth my conclusions, which are based on my education, training, and experience; field work; established scientific methods; and information reviewed by me or under my direction and supervision. These conclusions are expressed to a reasonable degree of scientific certainty. The focus of this report is on local community impacts. I have, therefore, not attempted to evaluate broader environmental impacts, such as impacts from greenhouse gas emissions, that would be associated with each closure option.

The conclusions in this report are based on the documents made available to me by Duke Energy Progress, LLC (Duke Energy) or collected as part of my investigation. I reserve the right to supplement my conclusions if new or different information becomes available to me. As an example, the excavation option presented in this report assumes that landfilling of excavated ash can be accommodated within the boundaries of the currently permitted landfill space. The currently permitted landfill space was sized to accommodate future ash production and did not include the addition of excavated ash from the Mayo Steam Electric Plant (Mayo Plant) ash basin. If additional landfill space is required to accommodate both excavated ash and future ash production, then additional habitat destruction would be necessary, and that impact has not been factored into this analysis.

# Executive Summary[1]

In 2015, the U.S. Environmental Protection Agency (EPA) issued a rule called the "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals [CCR] from Electric Utilities" (CCR Rule), which, among other things, regulates closure of coal ash impoundments in the United States. Closure of coal ash impoundments in North Carolina is further regulated by the North Carolina Coal Ash Management Act of 2014 (CAMA) as amended by H.B. 630, Sess. L. 2016-95. Under both the North Carolina CAMA and the federal CCR Rule, there are two primary alternatives for closure of an ash impoundment:

- "Cap in place" (CIP) closure involves decanting the impoundment and placing a low-permeability liner topped by appropriate cap material, soil, and grass vegetation over the footprint of the ash to restrict vertical transport of water through the ash, as well as a minimum of 30 years of post-closure care, which requires the implementation of corrective action measures if and as necessary;
- Excavation closure involves decanting the impoundment, excavating all ash in the basin, transporting the ash to an appropriate, permitted, lined landfill, and restoring the site.

Duke Energy Progress, LLC's (Duke Energy's) Mayo Steam Electric Plant (Mayo Plant) has one onsite ash basin and a separate onsite, lined landfill. Duke Energy has evaluated three representative types of closure for the ash impoundment at the Mayo Plant: CIP; excavation to the existing (expanded) onsite, lined landfall; and a hybrid closure, which involves excavating and consolidating ash within the basin footprint to reduce the spatial area of CIP closure (Duke Energy 2018b). The administrative process for selecting an appropriate closure plan is ongoing.

[1] Note that this Executive Summary does not contain all of the technical evaluations and analyses that support the conclusions. Hence, the main body of this report is at all times the controlling document.

The purpose of my report is to examine how the local community's environmental health and environmental services[2] are differently affected by each closure option as currently defined and to evaluate these differences in a structured framework that can support decision-making in this matter.

## Environmental Decision-Making

Environmental decision-making involves understanding complex issues that concern multiple stakeholders. Identifying the best management alternative often requires tradeoffs among stakeholder values. These tradeoffs necessitate a transparent and systematic method to compare alternative actions and support the decision-making process. My analyses in this matter have used a net environmental benefit analysis (NEBA) framework (Efroymson et al. 2003, 2004) to compare the relative risks and benefits from CIP closure, excavation closure, or a hybrid CIP and excavation closure of the ash basin at the Mayo Plant. The NEBA framework relies on scientifically supported estimates of risk to compare the reduction of risk associated with chemicals of potential concern (COPCs)[3] under different remediation and closure alternatives alongside the creation of any risk during the remediation and closure, providing an objective, scientifically structured foundation for weighing the tradeoffs between remedial and closure alternatives.

Despite the scientific basis of the risk characterization process used in NEBA, stakeholders in any environmental decision-making scenario may place different values on different types of risk (i.e., stakeholders may have different priorities for the remediation and closure). NEBA does not, by design, elevate, or increase the value of, any specific risk or benefit in the framework. The purpose of NEBA is to simultaneously and systematically examine all tradeoffs that affect the services provided to humans and the ecosystem by the environment under

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[2] Environmental services, or ecosystem services, are ecological processes and functions that provide value to individuals or society (Efroymson et al. 2003, 2004).

[3] COPCs are "any physical, chemical, biological, or radiological substance found in air, water, soil or biological matter that has a harmful effect on plants or animals" (https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Eco%20Risk%20Assessment%20Glossary).

remediation and closure, allowing decision-makers to more fully understand all potential benefits and risks of each alternative.

NEBA and similar frameworks have been used extensively by regulatory agencies such as the National Oceanic and Atmospheric Administration (NOAA) and EPA to support evaluating tradeoffs in mitigation (e.g., NOAA 1990), remediation (e.g., U.S. EPA 1988, 1994), and restoration (e.g., NOAA 1996). The National Environmental Policy Act (40 CFR § 1502) relies on a structured framework to conduct environmental assessments and produce environmental impact statements; these analyses evaluate potential adverse effects from development projects and identify alternatives to minimize environmental impacts and/or select mitigation measures. Natural resource damage assessment (NRDA) utilizes a structured process to estimate environmental injury and lost services and identify projects that restore the impacted environment and compensate the public for the lost environmental services (e.g., NOAA 1996). The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation/feasibility study process uses a set of evaluation criteria to identify remediation projects for contaminated Superfund sites that meet remediation objectives for effectiveness, implementability, and cost (U.S. EPA 1988). Within the Superfund Program, EPA has also recognized the importance of remediation that comprehensively evaluates cleanup actions "to ensure protection of human health and the environment and to reduce the environmental footprint of cleanup activities to the maximum extent possible" (U.S EPA 2010).

The Tennessee Valley Authority (TVA) recently used a structured framework to compare the impacts and benefits of ash basin closure alternatives at ten of its facilities (TVA 2016). Through a NEBA-like analysis, the TVA identified "issue areas," such as air quality, groundwater, vegetation, wildlife, transportation, and noise and created a summary table that provided a side-by-side comparison of the impacts of "no action," "closure-in-place," and "closure-by-removal" actions. As a result of this analysis, TVA identified "closure-in-place" as "its preferred alternative" for all ten facilities stating, "[t]his alternative would achieve the purpose and need for TVA's proposed actions and compared to Closure-by-Removal with less environmental impact, shorter schedules, and less cost" (TVA 2016). The Mayo ash basin closure presents similar “issue areas” that can benefit from a similar, systematic analysis of net benefits resulting from closure activities.

## Linking Stakeholder Concerns to NEBA

To better understand stakeholder concerns related to closure of the ash basin at Mayo, I reviewed written communications about ash pond closure plans for the Mayo Plant submitted to and summarized by the North Carolina Department of Environmental Quality (NCDEQ 2016). From this review, I identified the following categories of stakeholder concerns:

- Drinking water quality
- Groundwater quality
- Surface water quality
- Fish and wildlife
- Maintaining property value
- Preservation of natural beauty
- Recreational value
- Swimming safety
- Failure of the ash impoundment
- Risk created by the closure option outweighing risk from contamination.

The primary concerns expressed by community stakeholders involve perceived risks from exposure to CCR constituents that could negatively affect environmental services that benefit the local community: provision of safe drinking water and food, safe recreational enjoyment (hunting, fishing, swimming), and protection of natural beauty and biodiversity.[4] Potential hazards to the community associated with closure activities include physical disturbance of existing habitats; air pollution from diesel emissions resulting from transportation activities; and traffic, noise, and accidents that could result in property damage, injuries, and fatalities. Table

4 Biodiversity is the variety of plants and animals present at a location. Protection of biodiversity refers to provision of habitat and related functions capable of sustaining biological populations.

ES-1 links concerns over CCR exposure and potential hazards created by ash basin closure to environmental services that could be affected by closure activities.

**Table ES-1. Relationships between environmental services and concerns to the local community associated with CCR and ash basin closure hazards**

| | Environmental Services | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Safe drinking water quality | Safe surface water quality | Safe air quality | Safe food quality | Protection of biodiversity | Recreation | Natural beauty | Safe community environment |
| **CCR Concerns** | | | | | | | | |
| Drinking water contamination | X | X | | | | | | X |
| Groundwater contamination | X | X | | | | | | X |
| Surface water contamination | X | X | | X | X | X | X | X |
| Fish/wildlife contamination | | | | X | X | X | X | X |
| Contamination impacting property value | X | X | | X | X | X | X | X |
| Contamination impacting natural beauty | | | | | X | | X | X |
| Contamination impacting recreational enjoyment | | X | | | X | X | X | X |
| Contamination impacting swimming safety | | X | | | | X | X | X |
| Failure of the ash impoundment | X | X | | X | X | X | X | X |
| **Closure Hazards** | | | | | | | | |
| Habitat loss | | X | X | | X | X | X | |
| Contamination of air | | | X | | X | X | | X |
| Noise, Traffic, Accidents | | | | | | X | | X |

In recognition of the potential discrepancy between stakeholder priorities and the broad and balanced treatment of service risks and benefits in NEBA, I organized the NEBA analysis around the following five objectives for ash basin closure that recognize local stakeholder concerns while being consistent with the methods and purpose of NEBA:

1. Protect human health from CCR constituent exposure
2. Protect ecological health from CCR constituent exposure
3. Minimize risk and disturbance to humans from closure
4. Minimize risk and disturbance to the local environment from closure
5. Maximize local environmental services.

In my analysis, I linked environmental services to the local community that could be potentially impacted by ash basin closure and the identified objectives of ash basin closure, and I identified attributes and comparative metrics[5] that characterize the condition of the environmental services (Efroymson et al. 2003, 2004).

I used human health attributes (e.g., risk to onsite construction workers, risk to offsite swimmers) and risk quotients (hazard index [HI], excess lifetime cancer risk [ELCR]) to evaluate whether there would be a potential impact to environmental services related to safe water, air, and food under each ash basin closure option. I also used human health attributes to evaluate whether there would be an impact to air quality during closure activities. I used ecological health attributes (e.g., risk to birds, mammals) and risk quotients (hazard quotients [HQs]) to evaluate whether there would be a potential impact to environmental services related to safe surface water and food and protection of biodiversity and natural beauty under the ash basin closure options. I evaluated risk and disturbance associated with traffic and accidents using transportation metrics and trucking logistics (e.g., number of truck miles driven) associated with each closure option to evaluate potential impacts to community safety. I used

[5] For purposes of this analysis, an attribute is a feature that characterizes environmental services and may be impacted by a closure option. Comparative metrics are features of the attribute (e.g., risk quotients, acreage of habitat) that can be measured and compared between closure options.

net primary productivity (NPP)[6] and discounted service acre-years (DSAYs)[7] to characterize differences in the environmental services that derive from habitats (e.g., protection of biodiversity, natural beauty) and that would be impacted by ash basin closure activities. Finally, I assembled all attributes, services, and objectives within a full NEBA to examine which of the closure options best maximizes environmental services for the local community. The metrics I used are scientifically appropriate and commonly applied metrics to evaluate risk to humans and the environment (U.S. EPA 1989, 1997, 2000; NHTSA 2016) and to quantitatively measure differences in environmental services associated with impact and restoration (Dunford et al. 2004; Desvousges et al. 2018; Penn undated; Efroymson et al. 2003, 2004).

Of note, my analysis did not consider the risks involved with onsite construction activities. For example, I did not attempt to evaluate occupational accidents created by onsite construction and excavation. Nor did I attempt to evaluate emissions associated with onsite construction activities. Finally, I did not attempt to consider the risk created by disturbing the ash basin and exposing it to the elements during excavation activities.

Some stakeholders also expressed concern over safety of the ash impoundment dam (NCDEQ 2016). The most recent dam safety report produced by Amec Foster Wheeler and submitted to NCDEQ indicates "the construction, design, operation, and maintenance of the CCR surface impoundments have been sufficiently consistent with recognized and generally accepted engineering standards for protection of public safety and the environment" (Williams and Tice 2018).

Three possible options for closure of the ash basin at the Mayo Plant were identified by Duke Energy (Duke Energy 2018b) and summarized in (Table ES-2). I used these options in the

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6 NPP represents the mass of chemically fixed carbon produced by a plant community during a given time interval. It reflects the rate at which different ecosystems are able to sequester carbon, which is related to mitigating climate change (https://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD17A2_M_PSN).

7 DSAYs are derived from habitat equivalency analysis (HEA). HEA is an assessment method that calculates debits based on services lost and credits for services gained from a remediation action (Dunford et al. 2004; Desvousges et al. 2018; Penn undated). A discount rate is used to standardize the different time intervals in which the debits and credits occur, and in doing so, present the service debits and credits at present value. The present value of the services is usually expressed in terms of discounted service acre-years of equivalent habitat, or DSAYs, which provide a means to compare the different service levels of affected habitat acres (Dunford et al. 2004; Desvousges et al. 2018; Penn undated).

NEBA to examine how different closure possibilities impact environmental services to the local community.

**Table ES-2. Ash basin closure options provided by Duke Energy (2018)**

| Closure option | Description | Closure Duration (years)[a] | Construction Duration (years)[b] |
|---|---|---|---|
| CIP | CIP | 6 | 4 |
| Excavation | Excavate to expanded Mayo landfill | 10 | 7 |
| Hybrid | Partially excavate to consolidate ash and CIP consolidated ash | 8 | 5 |

[a] Includes pre-design investigation, design and permitting, site preparation, construction, and site restoration.
[b] Includes only site preparation, construction, and site restoration.

## NEBA Risk Ratings

NEBA organizes environmental hazard and benefit information into a unitless metric that represents the degree and the duration of impact from remediation and closure alternatives. One approach to structure this analysis is to create a risk-ranking matrix that maps the proportional impact of a hazard (i.e., risk) with the duration of the impact, which is directly related to the time to recovery (Robberson 2006). The risk-ranking matrix used for this application of NEBA is provided in Table ES-3. In this application, the matrix uses alphanumeric coding to indicate the severity of an impact: higher numbers and higher letters (e.g., 4F) indicate a greater extent and a longer duration of impact. Shading of cells within the matrix supports visualization of the magnitude of the effect according to the extent and duration of impact.[8] When there is no meaningful risk, the cell is not given an alphanumeric code. Relative risk ratings for each attribute and closure option examined were assembled into objective-specific summaries to compare the net benefits of the closure options. All closure options in the NEBA were evaluated against current conditions as a "baseline" for comparison.

[8] Categories and shading as defined in the risk-ranking matrix are based on best professional judgment and used for discussion of the relative differences in relative risk ratings. Alternative risk matrices and resulting NEBA classifications are explored in Appendix E.

**Table ES-3. Risk-ranking matrix for impacts and risk from closure activities. Darker shading and higher codes indicate greater impact.**

| | | Duration of Impact (years) | | | |
|---|---|---|---|---|---|
| | | 10–15 **(4)** | 5–9 **(3)** | 1–4 **(2)** | <1 **(1)** |
| **% Impact** | No meaningful risk | -- | -- | -- | -- |
| | <5% **(A)** | **4A** | **3A** | **2A** | **1A** |
| | 5–19% **(B)** | **4B** | **3B** | **2B** | **1B** |
| | 20–39% **(C)** | **4C** | **3C** | **2C** | **1C** |
| | 40–59% **(D)** | **4D** | **3D** | **2D** | **1D** |
| | 60–79% **(E)** | **4E** | **3E** | **2E** | **1E** |
| | >80% **(F)** | **4F** | **3F** | **2F** | **1F** |

NEBA analysis of possible closure options for the ash basin at the Mayo Plant helps both Duke Energy and other stakeholders understand the net environmental benefits from the closure option configurations that were examined. If a closure option that is preferred for reasons not considered in the NEBA does not rate as one of the options that best maximizes environmental services to the local community, closure plans for that option can be re-examined, and opportunities to better maximize environmental benefits can be identified (e.g., including an offsite habitat mitigation project to offset environmental services lost from habitat alteration). The NEBA can then be re-run with the updated plan to compare the revised closure plan with other closure options.

The following is a summary of my conclusions and supporting analyses, which are structured around the five objectives identified above.

## Conclusion 1: All closure options for the Mayo ash basin are protective of human health.

The first objective for ash basin closure, *to protect human health from CCR constituent exposure*, is represented by environmental services that provide safe drinking water, safe groundwater, safe surface water, safe food consumption, and safe recreation. For purposes of the NEBA, these safety considerations were evaluated based on the following:

1. Provision of permanent alternative drinking water supplies to private well water supply users within a 0.5-mile radius of the Mayo ash basin compliance boundary (Holman 2018);
2. Concentrations of CCR constituents of interest (COIs)[9] in drinking water wells that could potentially affect local residents and visitors, as characterized by SynTerra (2015a, 2016b, 2017) in the Comprehensive Site Assessment (CSA); and
3. Risk to various human populations from CCR exposure, as characterized in the updated human health and ecological risk assessment conducted by SynTerra (2018; Appendix B).

Based on these analyses, no CCR impacts to drinking water and no meaningful risk to humans from CCR exposure were found under current conditions[10] or under any closure option. Using the NEBA framework and relative risk ratings, these results are summarized in Table ES-4 within the objective of protecting human health from exposure to CCR constituents.

[9] COIs are constituents relevant to analysis of potential exposure to CCR constituents but are not necessarily associated with risk to human or ecological receptors.

[10] SynTerra's updated human health risk assessment (HHRA) considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps (or areas of wetness [AOWs]) at Mayo was not evaluated in the HHRA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable Special Order by Consent (SOC) that Duke Energy entered with the North Carolina Environmental Management Commission on August 15, 2018 (EMC SOC WQ S18-005; See Section 4.2). The SOC requires Duke Energy to accelerate the schedule for decanting the ash basin to "substantially reduce or eliminate" seeps that may be affecting state or federal waters; the SOC also requires Duke Energy to take appropriate corrective actions for any seeps remaining after decanting is complete to ensure the remaining seeps are managed "in a manner that will be sufficient to protect public health, safety, and welfare, the environment, and natural resources" (EMC SOC WQ S18-005).

**Table ES-4. Summary of relative risk ratings for attributes that characterize potential hazards to humans from CCR exposure in drinking water, surface water, groundwater, food, and recreation**

| **Objective** | Protect Human Health from CCR | | |
|---|---|---|---|
| **Hazard** | Exposure to CCR | | |
| **Potentially Affected Populations** | Local Residents/Visitors | Onsite Trespassers | Offsite Recreational Waders |
| **Scenario** | | | |
| Baseline | **--** | **--** | **--** |
| CIP | **--** | **--** | **--** |
| Excavation | **--** | **--** | **--** |
| Hybrid | **--** | **--** | **--** |

"--" indicates "no meaningful risk."

Current conditions and conditions under all closure options support provision of safe drinking water, safe surface water, safe food, and safe recreation, satisfying the first objective of ash basin closure—*to protect human health from CCR constituent exposure*.

## Conclusion 2: All closure options for the Mayo ash basin are protective of ecological health.

The second objective for ash basin closure, *to protect ecological health from CCR constituent exposure*, is represented by environmental services that provide safe surface water, safe food consumption, and protection of biodiversity and natural beauty. For purposes of the NEBA, these considerations were evaluated based on the following:

1. Risk to ecological receptors from CCR constituent exposure, as characterized by SynTerra (2018; Appendix B) in the updated human health and ecological risk assessment; and
2. Aquatic community health in Mayo Lake as reported in the 2017 environmental monitoring report (Duke Energy 2018a).

From my review of these analyses, no evidence of impacts to ecological receptors from CCR constituent exposure was identified under current conditions[11] or under any closure option, and Mayo Lake continues to support a healthy aquatic community (Duke Energy 2018a). Using the NEBA framework and relative risk ratings, these results are summarized in Table ES-5 within the objective of protecting environmental health from exposure to CCR constituents.

Current conditions and conditions under all closure options support provision of safe surface water, safe food consumption, and protection of biodiversity and natural beauty, satisfying the second objective of ash basin closure—*to protect ecological health from CCR constituent exposure.*

[11] SynTerra's updated ecological risk assessment (ERA) considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps (or AOWs) at Mayo was not evaluated in the ERA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable SOC that Duke entered with the North Carolina Environmental Management Commission on August 15, 2018 (EMC SOC WQ S18-005; See Section 4.2). The SOC requires Duke Energy to accelerate the schedule for decanting the ash basin to "substantially reduce or eliminate" seeps that may be affecting state or federal waters; the SOC also requires Duke Energy to take appropriate corrective actions for any seeps remaining after decanting is complete to ensure the remaining seeps are managed "in a manner that will be sufficient to protect public health, safety, and welfare, the environment, and natural resources" (EMC SOC WQ S18-005).

**Table ES-5. Summary of relative risk ratings for attributes that characterize potential hazards to ecological resources from CCR exposure in surface water, soil, sediment, and food**

| **Objective** | Protect Ecological Health from CCR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hazard** | Exposure to CCR | | | | | | | | | |
| **Potentially Affected Populations** | Fish Populations | Aquatic Omnivore Birds (mallard) | Aquatic Piscivore Birds (great blue heron) | Aquatic Carnivore Birds (bald eagle) | Aquatic Herbivore Mammals (muskrat) | Aquatic Piscivore Mammals (river otter) | Terrestrial Omnivore Birds (robin) | Terrestrial Carnivore Birds (red tail hawk) | Terrestrial Herbivore Mammals (meadow vole) | Terrestrial Carnivore Mammals (red fox) |
| **Scenario** | | | | | | | | | | |
| Baseline | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| CIP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Excavation | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Hybrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

"--" indicates "no meaningful risk."

## Conclusion 3: All closure options for the Mayo ash basin create low levels of community disturbance.

The third objective for ash basin closure, *to minimize risk and disturbance to humans from closure*, is represented by environmental services that provide safe air quality and a safe community environment. For purposes of the NEBA, these considerations were evaluated based on the following:

1. Health risks from diesel exhaust emissions to the community living and working along transportation corridors during trucking operations to haul materials to and from the ash basin, as evaluated through the application of diesel truck air emissions modeling and human health risk assessment; and

2. The relative risk for disturbance and accidents resulting from trucking operations affecting residents living and working along transportation corridors during construction operations, as evaluated by comparing the relative differences in trucking operations among the closure options.

From these analyses, no meaningful health risk is expected from diesel exhaust emissions under any closure option, but all closure options are expected to produce different levels of community disturbance in the form of noise and traffic congestion and risk from traffic accidents.

I used the number of trucks per day passing[12] a receptor along a near-site transportation corridor to examine the differences in noise and traffic congestion under the closure options. I compared the increase in the average number of trucks hauling materials to Mayo under the closure options[13] to the current number of truck passes for the same receptor. I specified a baseline level of truck passes[14] on the transportation corridor under current conditions of 314 passes per day. Based on the assumed 314-truck-per-day baseline level and the number of truck trips per day from Duke Energy's projections (Duke Energy 2018b), all options would have a less than 3% impact (CIP = 2.9%, excavation = 0.01 %, hybrid = 2.3%) on noise and traffic congestion. I input these percent changes to the risk-ranking matrix (Table ES-3) along with the total duration of construction activities (4 years CIP; 7 years excavation; and 5 years hybrid) to evaluate which of the closure options best minimizes human disturbances.

I also evaluated risk of traffic accidents by comparing the average number of annual offsite road miles driven between closure options relative to an estimate of the current road miles driven in Person County, North Carolina. I specified a current, or baseline, level of annual road miles

[12] Truck passes per day resulting from closure activities are calculated as the total number of loads required to transport earthen fill, geosynthetic materials, and other materials multiplied by two to account for return trips. The resulting total number of passes is then divided evenly among the total number of months of construction time multiplied by 26 working days per month.

[13] Truck trips to haul ash were not included in the estimate for Mayo ash basin closure because, with the exception of crossing U.S. Highway 501, trucks hauling ash would not leave the Mayo Plant property and would not affect community receptors along the transportation corridors.

[14] A baseline estimate of trucking passes per day for transportation corridors near Mayo was derived from North Carolina Department of Transportation (NCDOT) data of annual average daily traffic (AADT) at thousands of locations across the state and the proportion of road miles driven by large trucks in North Carolina (See Appendix E for details).

driven along the transportation corridor near the Mayo Plant of 33.5 million miles,[15] and the road miles driven under the closure options are from the trucking projections provided by Duke Energy (2018b). Using the 33.5-million-truck-miles baseline assumption, CIP has a 0.13% impact; excavation has a 0.01% impact; and the hybrid closure option has a 0.09% impact. All closure options have a relative risk rating of <5%. These relative risk ratings appear to be insensitive to lower assumed baseline annual truck miles (Appendix E).

Table ES-6 summarizes the NEBA relative risk ratings based on the trucking projections and implementation schedules provided by Duke Energy (2018b) for the objective of minimizing disturbance to humans during closure. Disturbance and risk created by all closure options are low (i.e., risk rating of A). While the excavation and hybrid closure options have a longer duration (i.e., risk rating of 3 compared to 2 for CIP), the impact levels for the excavation and hybrid closure options are less than the impacts created by CIP closure on a daily or annual basis.

15 To estimate the number of baseline truck miles, I multiplied the number of total vehicle miles traveled in Person County (NCDMV 2017) by the Person County average 9.5% contribution of trucks to total AADT (NCDOT 2015).

**Table ES-6. Summary of relative risk ratings for attributes that characterize potential hazards to communities during closure activities. Darker shading and higher codes indicate greater impact.**

| **Objective** | Minimize Human Disturbance | | |
|---|---|---|---|
| **Hazard** | Noise and Traffic Congestion | Traffic Accidents | Air Pollution |
| **Potentially Affected Populations** | Local Residents/Visitors | Local Residents/Visitors | Reasonable Maximum Exposure |
| **Scenario** | | | |
| Baseline | baseline | baseline | baseline |
| CIP | **2A** | **2A** | **--** |
| Excavation | **3A** | **3A** | **--** |
| Hybrid | **3A** | **3A** | **--** |

"--" indicates "no meaningful risk."

All closure options support safe air quality from diesel truck emissions along the transportation routes and create minimal disturbance to community safety. Thus, all closure options comparably satisfy the third objective of ash basin closure—*to minimize risk and disturbance to humans from closure*.

## Conclusion 4: Most closure options for the Mayo ash basin produce no net environmental disturbance.

The fourth objective for ash basin closure, *to minimize risk and disturbance to the environment from closure,* is represented by two environmental services: protection of biodiversity and natural beauty. For purposes of the NEBA, these considerations were evaluated based on differences in the NPP of impacted habitats under the closure options, as estimated by the number of DSAYs calculated by a habitat equivalency analysis (HEA).

The results of the HEA indicate that all but one closure option produce a net gain in environmental services as indicated by a positive DSAY total. Only CIP closure results in a net loss of environmental services due primarily to reduced NPP services provided by grass cap,[16] such that environmental services produced after closure will not compensate for the service losses resulting from the closure. The differences in NPP services are summarized in Table ES-7. A full description of the methods, assumptions, results, and sensitivity analyses for the HEA are provided in Appendix D and E.

**Table ES-7. Summary of NPP DSAYs for closure options**

| | | CIP | Excavation | Hybrid |
|---|---|---|---|---|
| **Ash basin losses** | Open Field | | | |
| | Grass Cap | −27 | −26 | −26 |
| | Open Water | −167 | −162 | −162 |
| | Stream | | | |
| | Wetland | | | |
| | Wooded | −161 | −156 | −156 |
| | **Total losses** | −356 | −344 | −344 |
| **Ash basin post-closure gains** | Open Field | | 127 | 26 |
| | Grass Cap | 295 | | 148 |
| | Open Water | | | |
| | Stream | | 8 | 3 |
| | Wetland | | 16 | 3 |
| | Wooded | | 2,438 | 1,305 |
| | **Total gains** | 295 | 2,589 | 1,486 |
| **Landfill/borrow losses** | Forest | −371 | −590 | |
| | Open field | | −151 | |
| | Grass Cap | | | −9 |
| | Wetland | | | |
| | **Total losses** | −371 | -741 | −9 |
| **Landfill/borrow post-closure gains** | Forest | 265 | | |
| | Grass Cap | | 56 | 9 |
| | **Total gains** | 265 | 56 | 9 |
| **Net Gain/Loss per Option** | | **−166** | **1,559** | **1,142** |

[16] An open field provides a relatively lower NPP service level than forest habitat (40% of forest NPP; Ricklefs 2008), and since a grass cap requires periodic maintenance mowing, for purposes of the HEA it was assumed never to reach a level of NPP service equivalent to an open field. Grass cap was assigned a post-closure service level of 8%, with full service attained in 2 years.

The impact of closure on environmental services was computed as the percentage difference in net DSAYs produced by the closure option and the baseline DSAYs (or the absolute value of the DSAY losses). The DSAY losses represent the NPP services that would have been produced by the ash basin, borrow areas, and landfills but for the project closure. The DSAY gains represent the NPP services restored after project closure plus any future gains realized from existing habitats before remediation begins. The sum of DSAY losses and gains represents the net change of NPP services for the project resulting from closure. Dividing the closure option net DSAYs by the absolute value of the DSAY losses provides a percentage of the impact. From these calculations, CIP closure as currently defined will have a 23% impact, [17] while all other closure options will have no net adverse impact on NPP services and will, in fact, increase net NPP services. These percent impacts were input to the risk-ranking matrix (Table ES-3) along with the duration of the closure activities (4 years CIP; 7 years excavation; and 5 years hybrid) to visualize, within the NEBA framework, which of the closure options best minimizes environmental disturbances (Table ES-8).

**Table ES-8. Summary of relative risk ratings for habitat changes that affect protection of biodiversity and natural beauty. Darker shading and higher codes indicate greater impact.**

| **Objective** | **Minimize Environmental Disturbance** |
|---|---|
| **Hazard** | Habitat Change |
| Attribute | DSAYs |
| **Scenario** | |
| Baseline | baseline |
| CIP | **2C** |
| Excavation | **--** |
| Hybrid | **--** |

Within the objective of minimizing environmental disturbance from closure, my analyses indicate that excavation and hybrid closure options produce a net benefit in habitat-derived environmental services; however, CIP closure as currently defined decreases habitat-derived environmental services. Thus, all closure options except CIP satisfy the fourth objective of ash basin closure—*to minimize risk and disturbance to the local environment from closure*.

[17] As discussed below, this habitat impact could be offset with an appropriate reforestation project.

## Conclusion 5: Most closure options for the Mayo ash basin produce comparable environmental services.

Identifying environmental actions that maximize environmental services (the fifth objective for ash basin closure) is a function of NEBA (Efroymson et al. 2003, 2004) and the overarching objective that encompasses each of the other four objectives and all of the environmental services that have been considered to this point.

I organized my analyses around the following five objectives for ash basin closure, and I found the following:

1. Protect human health from CCR constituent exposure
   *All closure options for the Mayo ash basin are protective of human health.*
2. Protect ecological health from CCR constituent exposure
   *All closure options for the Mayo ash basin are protective of ecological health.*
3. Minimize risk and disturbance to humans from closure
   *All closure options for the Mayo ash basin create low levels of community disturbance.*
4. Minimize risk and disturbance to the local environment from closure
   *Most closure options for the Mayo ash basin produce no net environmental disturbance.*
5. Maximize local environmental services
   *Most closure options for the Mayo ash basin produce comparable environmental services.*

Table ES-9 summarizes the relative risk ratings for all attributes and objectives that have been considered. From this analysis, which is based on a scientific definition of risk acceptability and includes no value weighting, all closure options except CIP closure produce comparable environmental benefits, similarly satisfying the fifth objective of ash basin closure—*to maximize environmental services*.

As noted previously, NEBA analysis also provides an opportunity to better understand the net environmental benefits of possible closure options. If Duke Energy's preferred closure option for reasons not considered in the NEBA does not best maximize environmental services to the local community as currently defined, the NEBA results provide insight into how environmental services could be improved for that closure option. For instance, if Duke Energy's preferred closure option for the Mayo Plant is CIP closure but the HEA results for the currently defined CIP closure option estimate a net environmental service loss of an approximate 166 DSAYs, Duke Energy could consider incorporating into an updated CIP closure plan for the Mayo Plant a mitigation project that compensates for the net environmental service losses projected from the currently defined CIP closure option. As an example, if Duke Energy started a reforestation project outside of the ash basin in 2021 (when onsite preparation of the ash basin begins), the reforestation project would gain 25.1 DSAYs/acre over the lifetime of the site (150 years in the HEA), requiring an approximate 6.6 acre project to compensate for the 166 DSAY loss projected from the HEA based on the current CIP closure plan. Re-analysis of the HEA component of the NEBA for the updated possible closure options would then result in no net environmental losses (as NPP services) from habitat alteration of the basin under any closure option.

By looking at a wide variety of attributes that represent a number of different environmental services that directly link to local stakeholder concerns for the Mayo ash basin, I conclude, with a reasonable degree of scientific certainty, that all closure options except CIP provide similar net environmental services and disturbance to the community and the environment.

**Table ES-9. NEBA for closure of the ash basin at the Mayo Plant. Darker shading and higher alphanumeric codes indicate greater impact.**

| **Objective** | **Protect Human Health from CCR** | | | | **Protect Ecological Health from CCR** | | | | | | | | | | **Minimize Human Disturbance** | | | **Minimize Environmental Disturbance** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hazard** | Exposure to CCR | | | | Exposure to CCR | | | | | | | | | | Noise and Traffic Congestion | Traffic Accidents | Air Pollution | Habitat Change |
| **Potentially Affected Populations** | Local Residents/Visitors | Onsite Trespassers | Onsite Construction Workers | Offsite Recreational Waders | Fish Populations | Aquatic Omnivore Birds (mallard) | Aquatic Piscivore Birds (great blue heron) | Aquatic Carnivore Birds (bald eagle) | Aquatic Herbivore Mammals (muskrat) | Aquatic Piscivore Mammals (river otter) | Terrestrial Omnivore Birds (robin) | Terrestrial Carnivore Birds (red tail hawk) | Terrestrial Herbivore Mammals (meadow vole) | Terrestrial Carnivore Mammals (red fox) | Local Residents/Visitors | Local Residents/Visitors | Reasonable Maximum Exposure | DSAYs |
| **Scenario** | | | | | | | | | | | | | | | | | | |
| Baseline | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | baseline | baseline | baseline | baseline |
| CIP | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **2A** | **2A** | -- | **2C** |
| Excavation | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **3A** | **3A** | -- | **--** |
| Hybrid | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **3A** | **3A** | -- | -- |

"--" indicates "no meaningful risk."

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# 1 Qualifications

I am a senior managing scientist in the Ecological and Biological Sciences Practice at Exponent, a scientific and engineering consulting firm. I am a professional ecologist, toxicologist, and biologist with more than 20 years of experience studying the relationship between human activities and effects on natural resources and people. I have Doctor of Science and Master of Science degrees in environmental health from the Harvard University School of Public Health. I have a Bachelor of Science degree in biology from Rhodes College. My academic and professional training includes a broad background in topics ranging from biology, ecology, toxicology, epidemiology, pollution fate and transport, and statistical analysis. Key areas of my practice involve the use of structured frameworks for evaluating multiple lines of evidence to assess causation of environmental impacts and to weigh the benefits and consequences of decisions that affect ecological and human health.

Decision support projects I have conducted include the following:

- Net environmental benefit analysis (NEBA) to facilitate the selection of a remediation plan for a lead contaminated river and to support closure option analysis for several coal ash basins;
- Developing beach management tools to improve public advisories related to elevated fecal bacteria from sewage contamination at recreational beaches;
- Selecting cleanup thresholds for sediment remediation that quantitatively weigh the tradeoff between sensitivity and specificity of potential thresholds to meet cleanup objectives;
- Natural resource damage assessment (NRDA) to support injury quantification and restoration selection; and
- Review and testimony on the sufficiency of environmental impact analysis to support development planning.

Projects I have been involved in have concerned coal ash basin closures, oil spills, sewage releases, heavy metal contamination, development planning, and various industrial and municipal facilities that have generated complex releases to the aquatic environment. A list of my publications, presentations, and cases for which I have written expert reports, been deposed, and/or provided trial testimony is provided in my *curriculum vitae*, included as Appendix A of this report.

## 2 Assignment and Retention

I was asked to examine how local environmental health and environmental services are differently affected under potential closure options for the coal ash basin at Duke Energy Progress, LLC's (Duke Energy's) Mayo Steam Electric Plant (Mayo Plant) and to evaluate these differences in a structured framework that can support decision-making. My assignment included review of the comprehensive site assessment (CSA) and corrective action plan (CAP) documents for the Mayo Plant, as well as documents available through the North Carolina Department of Environmental Quality's (NCDEQ's) website and documents prepared as part of Duke Energy's National Pollutant Discharge Elimination System (NPDES) permitting. I visited the Mayo Plant on October 30, 2017, and I reviewed expert reports prepared for related matters involving the Mayo Plant. A list of the primary documents I relied upon in formulating my conclusions is provided in Section 3 of this report.

# 3 Reliance Materials

In the process of formulating my conclusions in this matter, I have reviewed many documents. Of those, I have relied most on the following reports and documents. Technical (scientific literature) references are cited in subsequent sections of this report and listed in Section 12.

- Comprehensive Site Assessment (CSA) for the Mayo Steam Electric Plant (SynTerra 2015a, 2016b, 2017)
- Corrective Action Plan (CAP) for the Mayo Steam Electric Plant (SynTerra 2015b, 2016a)
    - Baseline Human Health and Ecological Risk Assessment for the Mayo Steam Electric Plant (SynTerra 2016c [Appendix E of CAP 2])
- 2017 environmental monitoring report for Mayo Lake (Duke Energy 2018a)
- NCDEQ Mayo Meeting Officer Report (NCDEQ 2016)
    - Attachment V. Written Public Comments Received
    - Attachment VIII. Public Comment Summary Spreadsheet
- Human Health and Ecological Risk Assessment Summary Update for the Mayo Steam Electric Plant (SynTerra 2018; Appendix B)
- Closure logistics estimates (Duke Energy 2018b).

# 4 Introduction

In 2015, the U.S. Environmental Protection Agency (EPA) issued a rule called the "Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals [CCR] from Electric Utilities" (CCR Rule), which, among other things, regulates closure of coal ash impoundments in the United States. Closure of coal ash impoundments in North Carolina is further regulated by the North Carolina Coal Ash Management Act of 2014 (CAMA), as amended by H.B. 630, Sess. L. 2016-95. Under both the North Carolina CAMA and the federal CCR Rule, there are two primary alternatives for closure of an ash impoundment:

- "Cap in place" (CIP) closure involves decanting the impoundment and placing a low permeability liner topped by appropriate cap material, soil, and grass vegetation over the footprint of the ash to restrict vertical transport of water through the ash, as well as a minimum of 30 years of post-closure care, which requires the implementation of corrective action measures if and as necessary;
- Excavation closure involves decanting the impoundment, excavating all ash in the basin, transporting the ash to an appropriate, permitted, lined landfill, and restoring the site.

Duke Energy has evaluated three representative types of closure for the ash impoundment at the Mayo Plant: CIP; excavation to the existing (expanded) onsite, lined landfall; and a hybrid closure, which involves excavating and consolidating ash within the basin footprint to reduce the spatial area of CIP closure (Duke Energy 2018b). The administrative process for selecting an appropriate closure plan is ongoing.

The purpose of my report is to examine how the local community's environmental health and environmental services[18] are differently affected by each closure option as currently defined and

[18] Environmental services, or ecosystem services, are ecological processes and functions that provide value to individuals or society (Efroymson et al. 2003, 2004).

to evaluate these differences in a structured framework that can support decision-making in this matter.

## 4.1 Site Setting

The Mayo Plant is a coal-fired power plant that began operation in 1983. It is located in Person County in north-central North Carolina on the North Carolina/Virginia border, approximately 10 miles northeast of the town of Roxboro, North Carolina (Figure 4-1). Bisected by U.S. Highway 501, the eastern portion of the plant encompasses 460 acres, excluding Mayo Lake, and includes the majority of the operational facilities and equipment as well as the coal ash basin. A newly operational lined ash monofill is located on the western portion of the Mayo Plant property, across U.S. Highway 501.[19]

Coal ash from historical operations of the Mayo Plant is stored in an unlined, impounded basin. The ash basin received all ash waste from the Mayo Plant until 2013 when the plant began conversion to a dry-ash waste system. Since 2014, dry ash from the Mayo Plant has been deposited in the lined onsite monofill located approximately one mile west of the ash basin. The last ash received in the ash basin at Mayo was in 2016. The ash basin now holds approximately 6.6 million tons of CCR and covers approximately 140 acres of open water and exposed ash (SynTerra 2017). Effluent from Mayo's active ash basin is discharged under NPDES (NPDES Outfall 002) to Mayo Lake (SynTerra 2017).

[19] Information presented in this section was derived from reviews of the CSA documents prepared by SynTerra (2015a, 2016b, 2017).

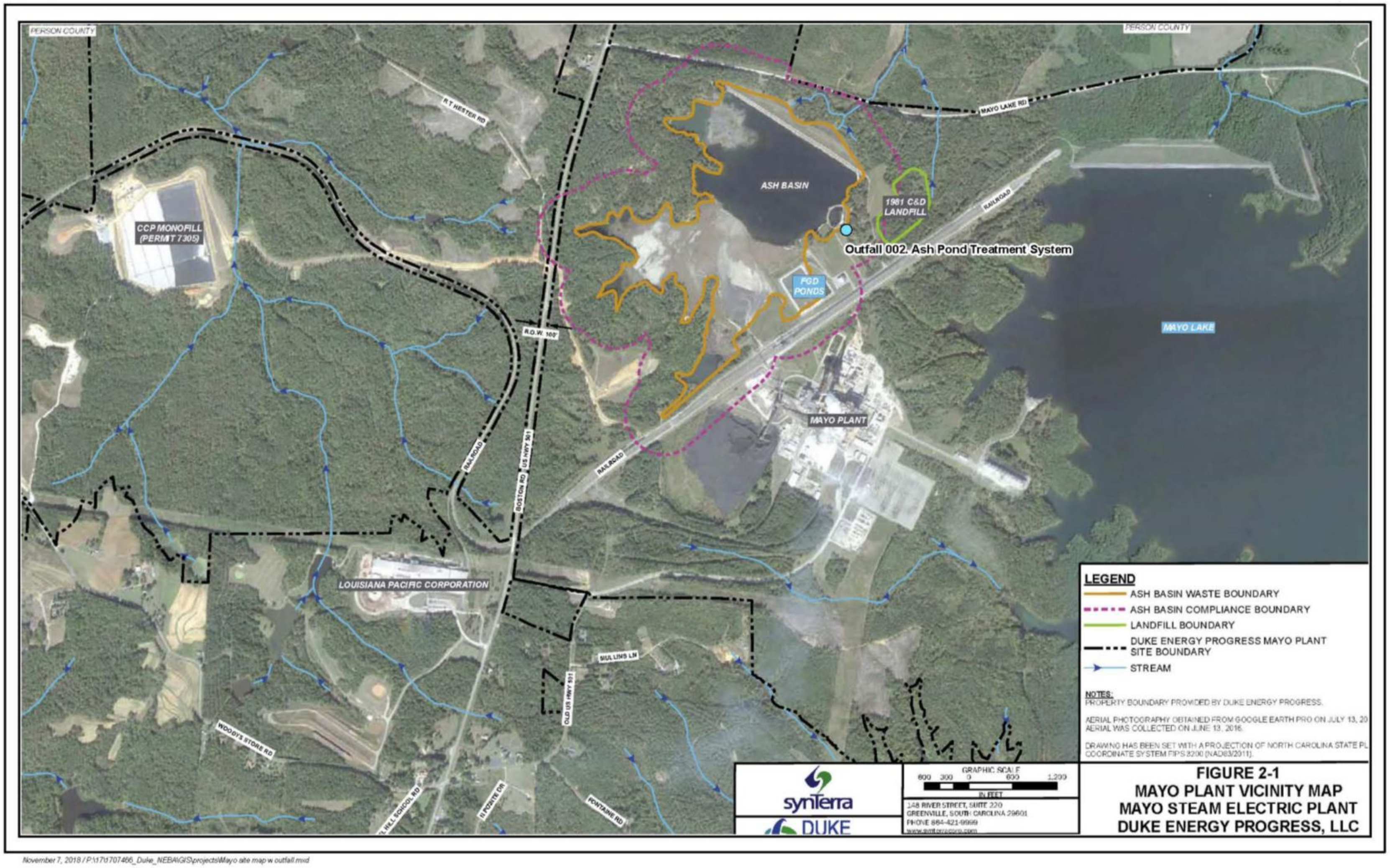


Figure 4-1. Map of the Mayo Plant. Reproduced and adapted from Figure 2-1 of the 2017 CSA Supplement (SynTerra 2017). The location of ash basin discharge to Mayo Lake was added (NPDES outfall 002).

The region surrounding the Mayo Plant is an ecological transitional zone between the Appalachian Mountains and the Atlantic coastal plain. Much of the region was transformed historically from oak-hickory-pine forests to farmland and more recently from farmland again to woodlands characterized by successional pine and hardwood forest (Griffith et al. 2002). Current aerial imagery and onsite observations show that approximately 80% of the Mayo Plant property is forested,[20] and I observed extensive forest habitat areas at the Mayo Plant and near the facility during my October 30, 2017 site visit (Figure 4-2). The many acres of game lands adjacent to the Mayo Plant and Mayo Lake support annual hunting harvests of deer (*Odocoileus virginianus*), turkey (*Meleagris gallopavo silvestris*), and black bear (*Ursus americanus*).[21]


Figure 4-2. Images of forest habitat at the Mayo Plant, October 30, 2017. (a) Primarily broadleaf forest canopy looking north over Crutchfield Branch from the ash basin dam. (b) Forest understory looking north along Crutchfield Branch. (c) Primarily coniferous forest along the banks of the Mayo ash basin.

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[20] Based on interpretation of aerial satellite imagery and geographic information system (GIS) layers provided by SynTerra for the Mayo Plant.

[21] http://www.ncwildlife.org/Hunting/Seasons-Limits/Harvest-Statistics

Mayo Lake is an approximately 2,880-acre impoundment of Mayo Creek. The reservoir was constructed by Carolina Power & Light Co., a predecessor to Duke Energy, to provide cooling water to the power station and receiving waters for heated water discharge[22] and has since become a popular location for recreational boating and fishing activities.[23] Duke Energy owns all shoreline property around Mayo Lake to the 450-foot contour elevation above mean sea level, and per the 1987 permit from the U.S. Army Corps of Engineers, Duke Energy is required to maintain the shoreline surrounding Mayo Lake in a natural and undisturbed condition, which supports local wildlife and protects the lake. Game and Fish Magazine included Mayo Lake on its list of four "less-pressured" high-quality fall bass lakes in North Carolina in October 2010.[24] Figure 4-3 includes images of Mayo Lake.

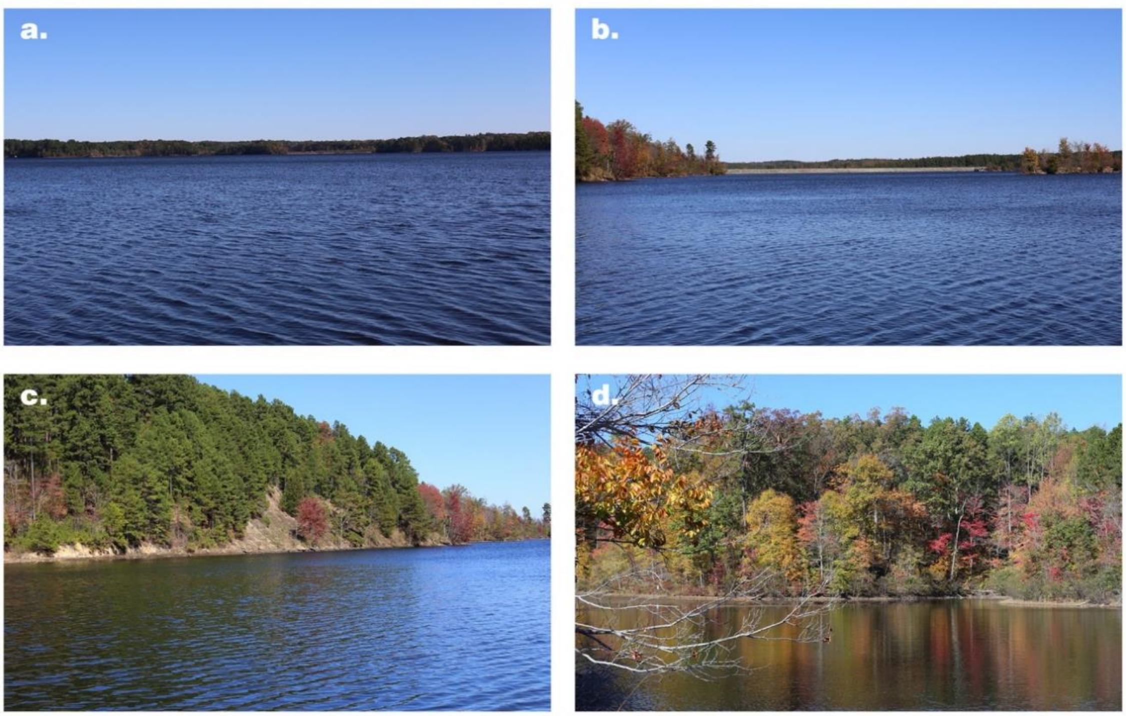


Figure 4-3. Images of Mayo Lake, October 30, 2017.
(a) Looking east across Mayo Lake from the Mayo Plant. (b) Looking north toward the Mayo Reservoir dam from the Mayo Plant. (c, d) Undisturbed shoreline along Mayo Lake near the Mayo Plant.

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[22] Discharge of runoff from the ash basin into Mayo Lake is regulated by NCDEQ Division of Water Resources under NPDES Permit NC0038377 at outfall 002.

[23] For example: http://www.personcounty.net/departments-services/departments-i-z/parks-recreation/mayo-park-and-lake.

[24] http://www.gameandfishmag.com/fishing/fishing_bass-fishing_nc_0905_02/

## 4.2 Closure of the Ash Impoundment at the Mayo Plant

Coal ash, or CCR, includes fly ash, bottom ash, boiler slag, and flue gas desulfurization material (U.S. EPA 2017c). CCR are derived from the inorganic minerals in coal, which include quartz, clays, and metal oxides (EPRI 2009). Fine-grained, amorphous particles that travel upward with flue gas are called fly ash, while the coarser and heavier particles that fall to the bottom of the furnace are called bottom ash (EPRI 2009). The chemical composition of coal ash is similar to natural geologic materials found in the earth's crust, but the physical and chemical properties of coal ash vary depending on the coal source and the conditions of coal combustion and cooling of the flue gas (EPRI 2009). The majority of both fly ash and bottom ash are composed of silicon, aluminum, iron, and calcium, similar to volcanic ash and shale (Figure 4-4). Trace elements such as arsenic, cadmium, lead, mercury, selenium, and chromium generally constitute less than 1% of total CCR composition (EPRI 2009; USGS 2015). CCR are classified as a non-hazardous solid waste under the Resource Conservation and Recovery Act (RCRA).[25]

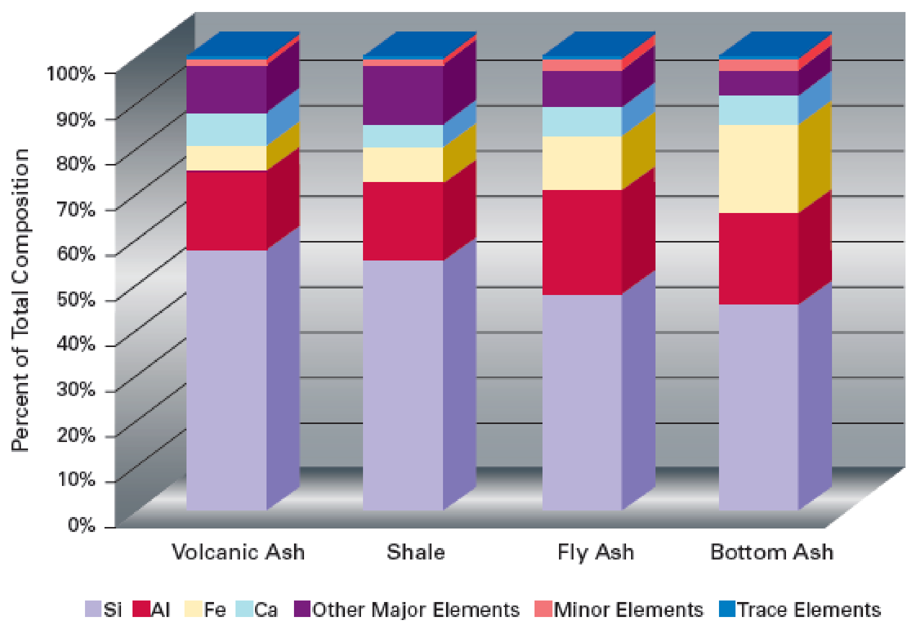


Figure 4-4. Elemental composition of bottom ash, fly ash, shale, and volcanic ash. Excerpt from EPRI (2009).

25 https://www.epa.gov/coalash/coal-ash-rule

EPA's 2015 CCR Rule (40 CFR §§ 257 and 261) requires groundwater monitoring[26] of CCR landfills and surface impoundments and for corrective action, including closure, of CCR sites under certain circumstances. Owners and operators of CCR landfills and impoundments that are required to close under the regulation must conduct an analysis of the effectiveness of potential corrective measures (a corrective measures assessment) and select a strategy that involves either excavation or capping the "waste-in-place." Per § 257.97(b), the selected strategy must at a minimum be protective of human health and the environment, attain groundwater protection standards, control the source of releases so as to reduce or eliminate further releases of certain CCR constituents into the environment, remove from the environment as much of the contaminated material that was released from the CCR unit as is feasible, taking into account factors such as avoiding inappropriate disturbance of sensitive ecosystems, and comply with the standards for management of wastes in § 257.98(d).

The CCR Rule does not provide criteria for selecting between these closure alternatives because they are both considered effective closure methods. The CCR Rule states both methods of closure "can be equally protective, provided they are conducted properly." Hence, the final CCR Rule allows the owner or operator to determine whether excavation or closure in place is appropriate for their particular unit (80 FR 21412).

For the last several years, Duke Energy has been evaluating all of its ash impoundments and remains in the midst of further evaluating each one, including at Mayo, under the CCR Rule and pursuant to the administrative process set forth in CAMA. Ultimately, a final closure plan will be approved by NCDEQ.

Three possible options for closure of the ash basin at the Mayo Plant were identified by Duke Energy and are summarized in (Table 4-1). These options were used in the NEBA to examine how different closure possibilities impact environmental services to the local community.

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[26] According to the CCR rule, groundwater must be evaluated for boron, calcium, fluoride, pH, sulfate, and total dissolved solids, which are defined as the constituents for detection monitoring in Appendix III of the Rule. When a statistically significant increase in Appendix III constituents over background concentrations is detected, monitoring of assessment monitoring constituents (Appendix IV) is required. Assessment Monitoring constituents are antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, fluoride, lead, lithium, mercury, molybdenum, selenium, thallium, and radium 226 and 228, combined.

**Table 4-1. Ash basin closure options provided by Duke Energy (2018b)**

| Closure Option | Description | Closure Duration (years)[a] | Construction Duration (years)[b] |
|---|---|---|---|
| CIP | CIP | 6 | 4 |
| Excavation | Excavate to expanded Mayo landfill | 10 | 7 |
| Hybrid | Partially excavate to consolidate ash and CIP consolidated ash | 8 | 5 |

[a] Includes pre-design investigation, design and permitting, site preparation, construction, and site restoration.
[b] Includes only site preparation, construction, and site restoration.

Table 4-2 provides a summary of some of the logistical differences between the closure options. Key among these are the following: (1) a longer period of time is necessary to complete excavation closure; (2) substantially more deforestation is required under an excavation closure;[27] and (3) substantially less average daily truck traffic results from excavation closure. Considering logistics alone, however, does not provide a complete understanding of the potential benefits and hazards associated with each closure option, and an integrated analysis is necessary to place stakeholder concerns regarding risk from CCR in the larger context of risks and benefits to environmental services.

**Table 4-2. Overview of some key logistical differences between CIP and excavation closure of the Mayo Plant ash basin. Data provided by Duke Energy (2018).**

| Closure Option | Closure Completion Time (years)[a] | Deforested Acres[b] | Average Truck trips/day[c] |
|---|---|---|---|
| CIP | 6 | 12 | 5 |
| Excavation | 10 | 30 | 0.02 |
| Hybrid | 8 | 0 | 4 |

[a] Includes pre-design investigations, design and permitting, site preparation, construction, and site restoration.
[b] Includes areas deforested to create borrow pits and/or landfill.
[c] Includes the total number of offsite round trip truck trips to haul earthen, ash, and geosynthetic material to and from the ash basin.

[27] The Mayo Plant has an onsite, lined landfill that could accept some excavated ash from the Mayo ash basin; however, there is insufficient capacity in the currently configured landfill to accept all of the coal ash from the ash basin under an excavation closure. Forest would need to be cleared to expand the landfill capacity beyond its current footprint to create this capacity. Deforestation is also likely under a CIP closure to access surface soil for capping activities.

Closure of the ash basin at Mayo involves decanting any overlying water in the basin and excavating or capping in place the underlying ash, as specified under CAMA and the federal CCR Rule. Additional activities related to, but separate from, closure under CAMA and the CCR Rule concern constructed[28] and non-constructed[29] seeps associated with the ash basin.[30] A Special Order by Consent (SOC; EMC SOC WQ S18-005) was signed by the North Carolina Environmental Management Commission and Duke Energy on August 15, 2018, to "address issues related to the elimination of seeps" from Duke Energy's coal ash basins. The SOC requires Duke Energy to accelerate the schedule for decanting the ash basin to "substantially reduce or eliminate" seeps that may be affecting state or federal waters; the SOC also requires Duke Energy to take appropriate corrective actions for any seeps remaining after decanting is complete to ensure the remaining seeps are managed "in a manner that will be sufficient to protect public health, safety, and welfare, the environment, and natural resources" (EMC SOC WQ S18-005). Given the court-enforceable requirement for Duke Energy to remediate any seeps remaining after decanting the ash basin to meet standards for the protection of public and environmental health, for purposes of my analyses, seeps (or areas of wetness [AOWs]) are assumed to contribute no meaningful risk to humans or the environment following any closure option since all closure options will entail decanting the basins and remediating any risk associated with remaining seeps as required by the SOC (EMC SOC WQ S18-005).

28 Constructed seeps are features within the dam structure, such as toe drains or filter blankets, that collect seepage of liquid through the dam and discharge the seepage through a discrete, identifiable point source to a receiving water.

29 Non-constructed seeps are not on or within the dam structure and do not convey liquid through a pipe or constructed channel; non-constructed seeps at Mayo that require monitoring (and potentially action if they are not eliminated after ash basin decanting) are listed in the SOC (EMC SOC WQ S18-005).

30 In 2014, Duke Energy provided a comprehensive evaluation of all areas of wetness (AOWs or seeps) on Duke Energy property and formally applied for NPDES coverage for all seeps (EMC SOC WQ S18-005).

# 5 Approach to Forming Conclusions

Environmental decision-making involves complex issues that concern multiple stakeholders. Identifying the best management alternative often requires tradeoffs among stakeholder values. For example, remediation management alternatives can decrease potential risks to human health and the environment from contaminants, but such benefits can also have unintended consequences, such as adverse impacts to other functions of the environment (e.g., destruction of habitat) or create other forms of risk (e.g., contamination of other environmental media). These tradeoffs between existing and future environmental services necessitate a transparent and systematic method to compare alternative actions and support the decision-making process.

Structured frameworks or processes are commonly used to weigh evidence and support requirements for environmental decision-making. Examples include:

- Environmental assessment (EA) and environmental impact statement (EIS) process that supports National Environmental Policy Act requirements for evaluating impacts from development projects and selecting mitigation measures (40 CFR § 1502);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigation/feasibility study process that characterizes risk from contaminants at a site and then evaluates remediation alternatives (U.S. EPA 1988);
- RCRA corrective measures study that supports identification, development, and evaluation of potential remedial alternatives for corrective action (U.S. EPA 1994);
- EPA's causal analysis/diagnosis decision information system (CADDIS) that supports stressor identification and selection of appropriate mitigation actions under the Clean Water Act (Cormier et al. 2000);
- NRDA that characterizes injury and lost human services to support selection of restoration projects under a number of environmental laws, including CERCLA and the Oil Pollution Act of 1990 (e.g., NOAA 1996); and

- NEBA that evaluates the tradeoffs in environmental impacts and benefits from remediation alternatives (NOAA 1990; Efroymson et al. 2003, 2004).

These frameworks have different regulatory origins and somewhat different approaches to accomplishing their specific objectives, but they all rely on a common core of analyses, including characterization of exposures, identification of adverse effects, definition of complete pathways between exposures and effects, characterization of risk or impact to exposed receptors (i.e., human and ecological populations), and weight-of-evidence analysis.

My analyses in this matter have used a NEBA framework to compare the relative risks and benefits derived from the closure options under consideration for the ash basin at the Mayo Plant. NEBA was originally developed to examine impacts and benefits to ecological resources and habitats excluding impacts and risk to humans (Efroymson et al. 2004); however, as noted by U.S. EPA (2009), remediation and closure actions can also have both direct and indirect consequences to humans. To support a more thorough analysis of the net benefits of each closure option in this matter, I have included comparative analyses in the NEBA that consider environmental health more broadly, including risks and benefits to both ecological and human populations in the vicinity. My analyses draw on the core principles of the environmental decision support frameworks discussed above and follow a pragmatic and transparent process.

In assembling information for the NEBA and forming my conclusions, I have relied on analyses reported in the CSA and CAP documents, as well as information provided by Duke Energy. Because a NEBA of environmental health necessarily encompasses a variety of scientific disciplines, I assembled a team of professionals within Exponent with expertise in ecological risk assessment (ERA), human health risk assessment (HHRA), contaminant fate and transport, decision support analysis, and statistics to review documents and, where indicated, conduct analyses at my direction. The results of these efforts are included in this report and have been reviewed by me.

## 5.1 Net Environmental Benefit Analysis

Net environmental benefits are defined as "the gains in environmental services or other ecological properties attained by remediation or ecological restoration, minus the environmental injuries caused by those actions" (Efroymson et al. 2003, 2004). Environmental services, or ecosystem services, are ecological processes and functions that produce value to individuals or society. A NEBA, as discussed above, is a structured framework for comparing impacts and benefits to environmental services and support decision-making (Efroymson et al. 2003, 2004). NEBA can be useful in evaluating and communicating the short-term and long-term impacts of remedial alternatives but does not make a determination of which alternative is best; that decision must be made by stakeholders and decision-makers and may ultimately involve weighing or prioritizing some values or objectives over others (Efroymson et al. 2003, 2004).

NEBA relies on scientifically supported estimates of risk to compare the reduction of risk associated with chemicals of potential concern (COPCs)[31] under different remediation and closure alternatives alongside the creation of any risk during the remediation and closure, providing an objective, scientifically structured foundation for weighing the tradeoffs among remedial and closure alternatives. Despite the scientific basis of the risk characterization process, however, stakeholders in any environmental decision-making scenario may place different values on different types of risk. In other words, stakeholders may have different priorities for the remediation and closure. NEBA does not, by design, elevate, or increase the value of, any specific risk or benefit in the framework. The purpose of NEBA is to simultaneously and systematically examine all tradeoffs that affect the services (e.g., provision of safe drinking water, protection of biodiversity[32]) provided to humans and the ecosystem by the environment under remediation and closure, allowing decision-makers to more fully understand all potential benefits and risks of each alternative.

[31] COPCs are "any physical, chemical, biological, or radiological substance found in air, water, soil or biological matter that has a harmful effect on plants or animals" (https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Eco%20Risk%20Assessment%20Glossary).

[32] Biodiversity is the variety of plants and animals present at a location. Protection of biodiversity refers to provision of habitat and related functions capable of sustaining biological populations.

EPA supports the use of NEBA (U.S. EPA 2009) as a means to compare remediation and redevelopment alternatives "based on their contributions to human well-being." EPA and the National Oceanic and Atmospheric Administration (NOAA) also use NEBA to support oil spill response decision-making (Robberson 2006; NOAA 1990). Examples of NEBA in oil-spill decision-making include:

- *Exxon Valdez* Oil Spill: NEBA was first applied to weigh the net environmental benefits of rock-washing to remove beached oil versus leaving the oil in place to naturally degrade (NOAA 1990).
- *Deepwater Horizon* Oil Spill: NEBA was used by the Operational Science Advisory Team-2 (OSAT-2) to "compare the environmental consequences of the defined cleanup endpoints for the oil and beach types considered, and the consequences of cleanup beyond those endpoints," specifically noting, "It is at this juncture that the concept of continued remedial efforts doing 'more harm than good' becomes a concern" (OSAT 2011).

I have personally applied NEBA to evaluate the net environmental benefits associated with two alternative sediment remediation cleanup goals for lead contamination in a tidal river. At that site, the river had been contaminated with lead from a battery manufacturing facility, and the state required removal of contaminated sediment that could potentially pose a health risk to people and the environment. The responsible party conducted human and ecological risk assessments, toxicity tests, and benthic community analyses to support the selection of an appropriate cleanup threshold for lead that would be protective of humans and the natural environment. Uncertainty in the results, however, led to two different remediation threshold concentrations being proposed by the state and by the responsible party. The NEBA was conducted to examine the tradeoffs in environmental impacts associated with the two cleanup thresholds. For one segment of the river, the footprint of remediation, including the size and types of habitat impacted, was substantially different under the alternative cleanup goals. The lower remediation threshold caused much greater impacts to submerged aquatic vegetation and riparian (shoreline) habitat that had cascading consequences to animals that rely on those environments. NEBA was able to demonstrate that remediation to the lower threshold would cause greater ecological harm and disturbance to the local community with little or no decrease in risk to benthic invertebrates (the ecological receptor at issue).[33] Consequently, the higher remediation goal was applied to that segment of the river.

These examples of NEBA are particularly relevant to the issues at the Mayo Plant. Remediation and closure of coal ash basins is specifically addressed in CAMA and the CCR Rule, and both CIP and excavation closure satisfy defined cleanup endpoints. At issue is whether removal of the coal ash under an excavation closure crosses the "juncture," as noted by OSAT-2, where the action would do more harm than good (OSAT 2011).

## 5.2 Linking Stakeholder Concerns to NEBA

To better understand stakeholder concerns related to closure of the ash basin at the Mayo Plant, I reviewed written communications about ash basin closure plans for the Mayo Plant submitted to and summarized by NCDEQ (NCDEQ 2016). From this review, I identified the following categories of stakeholder concerns:

- Drinking water quality
- Groundwater quality
- Surface water quality
- Fish and wildlife
- Maintaining property value
- Preservation of natural beauty
- Recreational value
- Swimming safety
- Failure of the ash impoundment
- Risk created by the closure option outweighing risk from contamination.

The primary concerns expressed by community stakeholders involve perceived risks from exposure to CCR constituents that could negatively affect environmental services that benefit

[33] Both remediation goals were found to be protective of human, fish, bird, and mammal health. Uncertainty in toxicity test results and concern for protection of benthic macroinvertebrates (e.g., insect larvae and crustaceans) led the state to propose a lower remediation threshold for lead.

the community: provision of safe drinking water and food, safe recreational enjoyment (e.g., hunting, fishing, swimming), protection of natural beauty, and biodiversity. Potential hazards to the community associated with closure activities include physical disturbance of existing habitats; air pollution from diesel emissions; and traffic, noise, and accidents that could result in property damage, injuries, and fatalities. Table 5-1 links concerns over CCR exposure and potential hazards created by ash basin closure to environmental services that could be affected by closure activities.

**Table 5-1. Relationships between environmental services and concerns to the local community associated with CCR and ash basin closure hazards**

| | Environmental Services | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Safe drinking water quality | Safe surface water quality | Safe air quality | Safe food quality | Protection of biodiversity | Recreation | Natural beauty | Safe community environment |
| **CCR Concerns** | | | | | | | | |
| Drinking water contamination | X | X | | | | | | X |
| Groundwater contamination | X | X | | | | | | X |
| Surface water contamination | X | X | | X | X | X | X | X |
| Fish/wildlife contamination | | | | X | X | X | X | X |
| Contamination impacting property value | X | X | | X | X | X | X | X |
| Contamination impacting natural beauty | | | | | X | | X | X |
| Contamination impacting recreational enjoyment | | X | | | X | X | X | X |
| Contamination impacting swimming safety | | X | | | | X | X | X |
| Failure of the ash impoundment | X | X | | X | X | X | X | X |
| **Closure Hazards** | | | | | | | | |
| Habitat alteration | | X | X | | X | X | X | |
| Contamination of air | | | X | | X | X | | X |
| Noise, Traffic, Accidents | | | | | | X | | X |

In recognition of the potential discrepancy between stakeholder priorities and the broad and balanced treatment of service risks and benefits in NEBA, I organized the NEBA in this matter around the following five objectives for ash basin closure that recognize stakeholder concerns while being consistent with the methods and purpose of NEBA:

1. Protect human health from CCR constituent exposure
2. Protect ecological health from CCR constituent exposure
3. Minimize risk and disturbance to humans from closure
4. Minimize risk and disturbance to the local environment from closure
5. Maximize local environmental services.

Associations between environmental services to the local community that could be potentially impacted by ash basin closure and the identified objectives of ash basin remediation are shown in Table 5-2.

**Table 5-2. Associations between objectives for closure and remediation of the Mayo ash basin and environmental services**

| | **Ash Basin Closure Objectives** | | | | |
|---|---|---|---|---|---|
| **Environmental Services** | Protect human health from CCR constituent exposure | Protect ecological health from CCR constituent exposure | Minimize risk and disturbance to humans from closure | Minimize risk and disturbance to the local environment from closure | Maximize local environmental services |
| Safe drinking water quality | X | X | | | X |
| Safe surface water quality | X | X | | | X |
| Safe air quality | | | X | | X |
| Safe food quality | X | X | | | X |
| Recreation | X | | | | X |
| Natural beauty | | X | | X | X |
| Protection of biodiversity | | X | | X | X |
| Safe community environment | | | X | | X |

NEBA relies on comparative metrics for specific attributes of the environment to examine the potential impacts and benefits from remediation and closure alternatives (Efroymson et al. 2003, 2004). NEBA methodology is not, however, prescriptive in defining attributes or comparative metrics because each application of NEBA is unique to contaminant exposure, remediation and closure alternatives, available data, and stakeholder concerns. NEBA is an extension of the risk assessment process (Efroymson et al. 2004). As a result, receptors, exposure pathways, and risks identified in a site risk assessment are key inputs to a NEBA. The links between key environmental services, attributes that represent those services, and comparative metrics used in this NEBA are summarized in Table 5-3.

**Table 5-3. Matrix of key environmental services, attributes, and comparative metrics applied in the NEBA**

| | Attributes | | | |
|---|---|---|---|---|
| **Environmental Services** | Human Health Risk | Ecological Health Risk | Net Primary Productivity | Transportation Metrics |
| Safe ground water quality | HI/ELCR | -- | -- | |
| Safe surface water quality | HI/ELCR | HQ | | |
| Safe soil and sediment quality | HI/ELCR | HQ | -- | |
| Safe air quality | HI/ELCR | -- | -- | |
| Safe food quality | HI/ELCR | HQ | -- | |
| Protection of biodiversity | | HQ | DSAYs | |
| Recreation | HI/ELCR[a] | -- | DSAYs | |
| Natural beauty | | HQ | DSAYs | |
| Safe community environment | | -- | | Trucking Logistics |

Notes:

DSAYs – discounted service acre-years
ELCR – excess lifetime cancer risk
HI – hazard index
HQ – hazard quotient

[a] Estimated from health risks from consumption of fish.

I used human health attributes (e.g., risk to onsite construction workers, risk to offsite swimmers) and risk quotients (hazard index [HI], excess lifetime cancer risk [ELCR]) to evaluate whether there would be a potential impact to environmental services related to safe water, air, and food under each ash basin closure option. I also used human health attributes to evaluate whether there would be an impact to air quality during closure activities. I used ecological health attributes (e.g., risk to birds, mammals) and risk quotients (hazard quotient [HQ]) to evaluate whether there would be a potential impact to environmental services related to safe surface water and food and protection of biodiversity and natural beauty under the ash basin closure options. I evaluated risk and disturbance associated with traffic and accidents using transportation metrics and trucking logistics (e.g., number of truck miles driven) associated with each closure option to evaluate impacts to community safety. I used net primary productivity (NPP)[34] and discounted service acre-years (DSAYs)[35] to characterize differences in the environmental services that derive from habitats (e.g., protection of biodiversity, natural beauty) and that would be impacted by ash basin closure activities. Finally, I assembled all attributes, services, and objectives within a full NEBA to examine which of the closure options best maximizes environmental services to the local community. These metrics represent scientifically appropriate and commonly applied metrics to evaluate risk to humans and the environment (U.S. EPA 1989, 1997, 2000; NHTSA 2016) and to quantitatively measure differences in environmental services associated with impact and restoration (Dunford et al. 2004; Desvousges et al. 2018; Penn undated; Efroymson et al. 2003, 2004).

Of note, my analysis did not consider the risks involved with onsite construction activities. For example, I did not attempt to evaluate occupational accidents created by onsite construction and excavation. Nor did I attempt to evaluate emissions associated with onsite construction activities. Finally, I did not attempt to consider the risk created by disturbing the ash basin and exposing it to the elements during excavation activities.

Some stakeholders also expressed concern over safety of the ash impoundment dam (NCDEQ 2016). The most recent dam safety report produced by Amec Foster Wheeler and submitted to

34 NPP represents the mass of chemically fixed carbon produced by a plant community during a given time interval. It reflects the rate at which different ecosystems are able to sequester carbon, which is related to mitigating climate change (https://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD17A2_M_PSN).

35 DSAYs are derived from habitat equivalency analysis (HEA). HEA is an assessment method that calculates debits based on services lost and credits for services gained from a remediation and closure action (Dunford et al. 2004; Desvousges et al. 2018; Penn undated). A discount rate is used to standardize the different time intervals in which the debits and credits occur, and in doing so, present the service debits and credits at present value. The present value of the services is usually expressed in terms of discounted service acre-years of equivalent habitat, or DSAYs, which provide a means to compare the different service levels of affected habitat acres (Dunford et al. 2004; Desvousges et al. 2018; Penn undated).

NCDEQ indicates "the construction, design, operation, and maintenance of the CCR surface impoundments have been sufficiently consistent with recognized and generally accepted engineering standards for protection of public safety and the environment" (Williams and Tice 2018).

## 5.3 NEBA Risk Ratings

NEBA organizes environmental hazard and benefit information into a unitless metric that represents the degree and the duration of impact from a remediation and closure alternative (Efroymson et al. 2003, 2004). One approach to structure this analysis is to create a risk-ranking matrix that maps the proportional impact of a hazard (i.e., risk) with the duration of the impact (Robberson 2006). The risk-ranking matrix used for this application of NEBA is provided in Table 5-4. The matrix uses alphanumeric coding to indicate the severity of an impact: higher numbers and higher letters (e.g., 4F) indicate a greater extent and a longer duration of impact, respectively. Shading of cells within the matrix supports visualization of the magnitude of the effect according to the extent and duration of an impact.[36] When there is no meaningful risk, the cell is not given an alphanumeric code. Risk ratings generated from the risk-ranking matrix for each attribute and closure option examined were assembled into objective-specific summaries to compare the net benefits of the closure options. All closure options in the NEBA were evaluated against current conditions as a "baseline" for comparison.

[36] Categories and shading as defined in the risk-ranking matrix are based on best professional judgment and used for discussion of the relative differences in relative risk ratings. Alternative risk matrices and resulting NEBA classifications are explored in Appendix E.

**Table 5-4. Risk-ranking matrix for impacts and risk from remediation and closure activities. Darker shading/higher codes indicate greater impact.**

| | | Duration of Impact (years) | | | |
|---|---|---|---|---|---|
| | | 10–15 **(4)** | 5–9 **(3)** | 1–4 **(2)** | <1 **(1)** |
| **% Impact** | No meaningful risk | -- | -- | -- | -- |
| | <5% **(A)** | **4A** | **3A** | **2A** | **1A** |
| | 5–19% **(B)** | **4B** | **3B** | **2B** | **1B** |
| | 20–39% **(C)** | **4C** | **3C** | **2C** | **1C** |
| | 40–59% **(D)** | **4D** | **3D** | **2D** | **1D** |
| | 60–79% **(E)** | **4E** | **3E** | **2E** | **1E** |
| | >80% **(F)** | **4F** | **3F** | **2F** | **1F** |

NEBA analysis of possible closure options for the ash basin at the Mayo Plant helps both Duke Energy and other stakeholders understand the net environmental benefits from the closure option configurations that were examined. If a closure option that is preferred for reasons not considered in the NEBA does not rate as one of the options that best maximizes environmental services to the local community, closure plans for that option can be re-examined, and opportunities to better maximize environmental benefits can be identified (e.g., including an offsite habitat mitigation project to offset environmental services lost from habitat alteration). The NEBA can then be re-run with the updated plan to compare the revised closure plan with other closure options.

## 5.4 Risk Acceptability

Selecting any remediation, mitigation, restoration, or closure alternative involves considerations of risk—risk posed by contamination in place, risk created by the action, risk remaining after the action—and all of these risk considerations must be placed in some contextual framework if informed decisions are to be made. Hunter and Fewtrell (2001) state, “The notion that there is some level of risk that everyone will find acceptable is a difficult idea to reconcile and yet, without such a baseline, how can it ever be possible to set guideline values and standards, given that life can never be risk free?”

EPA defines risk as "the chance of harmful effects to human health or to ecological systems resulting from exposure to an environmental stressor" (U.S. EPA 2017a). In accordance with EPA guidance for conducting ERAs (U.S. EPA 1997) and HHRAs (U.S. EPA 1989), risk to a receptor (e.g., person, animal) exists when exposure to a stressor or stressors occur(s) at some level of effect; however, because not all exposures produce *adverse* effects in humans or ecological species, the exposure concentrations need to overlap with adverse effect thresholds for there to be the potential for meaningful risk. The science supporting individual benchmarks or levels of concern differs by the specific exposure at issue and the receptor at risk; however, such benchmarks are considered by regulatory authorities to represent the best scientific information available to create a baseline for risk (U.S. EPA 2017b).

The potential for risk associated with contamination is often evaluated using HQs, HIs, and ELCRs to screen environmental media (e.g., water, soil) and identify the potential risk associated with contamination (U.S. EPA 1989, 1997, 2000). The HQ is the ratio of an exposure point concentration[37] divided by an appropriate toxicity benchmark for the receptor, chemical, and exposure scenario. An HI, which is used in HHRA, is the sum of the HQs for several chemicals that share the same target organ. If the HQ or HI is less than 1, exposure to that chemical (HQ) or group of chemicals (HI) is expected to result in no adverse effects to even the most sensitive receptors. Cancer risk to humans is typically evaluated using a probabilistic approach that considers an acceptable risk benchmark range of $10^{-4}$ to $10^{-6}$, meaning that a person's ELCR from the exposure being assessed is less than 1 in 10,000 to 1 in 1,000,000 (U.S. EPA 1989, 2000).

NEBA relies on scientifically supported estimates of risk; however, regardless of the scientific acceptability of the risk characterization process, stakeholders may place different values on different types of risk.

[37] A conservative estimate of the chemical concentration available from a particular media and exposure pathway.

# 6 Summary of Conclusions

Based on my review and analyses, I developed the following conclusions in this matter, which are structured around the five objectives identified previously:

**Conclusion 1: All closure options for the Mayo ash basin are protective of human health.** Current conditions[38] and conditions under all closure options support provision of safe drinking water, safe surface water, safe food, and safe recreation, satisfying the first objective of ash basin closure—to protect human health from CCR constituent exposure.

**Conclusion 2: All closure options for the Mayo ash basin are protective of ecological health.** Current conditions[39] and conditions under all closure options support provision of safe surface water, safe food consumption, and protection of biodiversity and natural beauty, satisfying the second objective of ash basin closure—to protect ecological health from CCR constituent exposure.

**Conclusion 3: All closure options for the Mayo ash basin create low levels of community disturbance.** All closure options support safe air quality from diesel truck emissions along the transportation routes and create minimal risk and disturbance to community safety. Thus, all closure options similarly satisfy the third objective of ash basin closure—to minimize risk and disturbance to humans from closure.

**Conclusion 4: Most closure options for the Mayo ash basin produce no net environmental disturbance.** All closure options, except CIP, improve habitat-derived environmental services

[38] SynTerra's updated HHRA considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps at Mayo was not evaluated in the HHRA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable SOC that Duke entered with the North Carolina Environmental Management Commission on August 15, 2018 (EMC SOC WQ S18-005; See Section 4.2).

[39] SynTerra's updated ERA considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps at Mayo was not evaluated in the ERA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable SOC that Duke entered with the North Carolina Environmental Management Commission on August 15, 2018 (EMC SOC WQ S18-005; See Section 4.2).

over baseline conditions. Therefore, all closure options, except CIP,[40] have no net impacts to the protection of biodiversity and natural beauty, satisfying the fourth objective of ash basin closure—to minimize risk and disturbance to the local environment from closure.

**Conclusion 5: Most closure options for the Mayo ash basin produce comparable environmental services.** All closure options, except CIP, produce comparable environmental benefits with equivalent protection of human and ecological health from CCR exposure, similar levels of disturbance to humans, and net gains in habitat-derived environmental services, similarly satisfying the fifth objective of ash basin closure—to maximize local environmental services.

Each will be discussed in detail in the following sections.

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[40] As noted in Section 5 and further discussed in Section 11, the loss of habitat-derived environmental services could be offset with an appropriate reforestation project.

# 7 Conclusion 1: All closure options for the Mayo ash basin are protective of human health.

The first objective for ash basin closure, to protect human health from CCR constituent exposure, is represented by environmental services that provide safe drinking water, safe groundwater, safe surface water, safe food consumption, and safe recreation. For purposes of the NEBA, these safety considerations were evaluated based on the following:

1. Provision of permanent alternative drinking water supplies to private well water supply users within a 0.5-mile radius of the Mayo ash basin compliance boundary (Holman 2018);
2. Concentrations of CCR constituents of interest (COIs)[41] in drinking water wells that could potentially affect local residents and visitors, as characterized by SynTerra (2015a, 2016b, 2017) in the CSA; and
3. Risk to various human populations from CCR exposure, as characterized in the updated human health and ecological risk assessment conducted by SynTerra (2018).

Through these lines of evidence, I evaluated whether CCR constituents are currently impacting drinking water wells, whether they will in the future, and whether other exposures to CCR constituents pose a risk to human populations now or with ash basin closure.

## 7.1 Private water supply wells pose no meaningful risk to the community around Mayo.

Per H.B. 630, Sess. L. 2016-95, all residents with drinking water supply wells within a 0.5-mile radius of the Mayo ash basin compliance boundary have been provided with permanent alternative drinking water supplies (i.e., filter systems; Draovitch 2018),[42] eliminating drinking water as a potential CCR exposure pathway for local residents or visitors. Additionally,

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41 COIs are constituents relevant to analysis of potential exposure to CCR constituents but are not necessarily associated with risk to human or ecological receptors.

42 NCDEQ determined Duke Energy had satisfactorily completed the permanent alternative water provision under CAMA General Statute (G.S.) 130A-309.21 l(cl) on October 12, 2108 (Holman 2018).

available data indicate that private well water conditions are not impacted by CCR constituents and groundwater flow paths from the ash basin are away from residential areas (SynTerra 2017). One public well (Bethel Hill Baptist Church) and 20 private wells are located near, but upgradient or cross-gradient, of the 0.5-mile radius around the ash basin (SynTerra 2017), and no private wells are located downgradient of the ash basin within 0.5 miles. In 2015, two of these private wells were found to have exceedances of the North Carolina Groundwater Quality Standards (2L)[43] for iron, manganese, and vanadium among the constituents of interest (COIs). These constituents are naturally occurring but have also been associated with CCR (SynTerra 2015a). In this case, however, background concentrations of these constituents were also elevated compared to the 2L standard (SynTerra 2017). In fact, exceedances of these constituents were below estimates of background concentrations for the area.[44] A study of private drinking water wells within 0.5 miles of Mayo as well as private drinking water wells located within a 2–10-mile radius of the Mayo Plant also detected some constituents that can been associated with CCR, but sample concentrations were less than background concentrations (SynTerra 2017).

## 7.2 CCR constituents from the Mayo ash basin pose no meaningful risk to human populations.

To assess potential risk to humans both onsite and offsite using the most recent and comprehensive data available, SynTerra updated the baseline HHRA (SynTerra 2018) originally conducted by SynTerra (2016c) as a component of the CAP part 2 (SynTerra 2016a). The updated HHRA included updates[45] to the conceptual site model, exposure point concentrations for human receptors with complete exposure pathways, screening level risk assessments for

43 North Carolina Administrative code 15A NCAC 02L Groundwater Rules.

44 Samples were below the bedrock groundwater provisional background threshold value (PBTV), which was developed by SynTerra in the 2017 CSA Supplement (SynTerra 2017).

45 Updates to risk assessments are a natural part of the risk analysis process. EPA guidance for ecological risk assessment notes, "The [risk assessment] process is more often iterative than linear, since the evaluation of new data or information may require revisiting a part of the process or conducting a new assessment as more information about a site is gained through site investigations, the risk assessment must be updated to reflect the best knowledge of potential risk at a site" (U.S. EPA 1998). EPA similarly describes human health risk characterization as an iterative process (U.S. EPA 2000).

human receptors with complete exposure pathways, and hazard calculations (HI, ELCR) for receptors and COPCs with plausible complete exposure pathways.

Consistent with the 2016 baseline human health and ecological risk assessment (SynTerra 2016c), the updated HHRA (SynTerra 2018) examined CCR constituent exposure to a range of human populations, including onsite trespassers, construction workers, and waders, under different pathways (i.e., exposure to sediment, surface water, or groundwater). HIs and ELCRs were estimated for scenarios with plausible complete exposure pathways.

CCR exposure pathways considered complete and evaluated in the updated HHRA included the following (SynTerra 2018):[46]

- Onsite trespassers via onsite sediment and surface water
- Offsite recreational waders via offsite surface water and sediment
- Onsite construction workers via groundwater.[47]

Since all households with drinking water supply wells within a 0.5-mile radius of the Mayo ash basin compliance boundary have received permanent alternative water supplies (Holman 2018) and no potable water wells are located downgradient of the Mayo Plant (SynTerra 2017), drinking water risks were not further evaluated because there was no complete exposure pathway. A summary of the risk assessment results from the updated HHRA (SynTerra 2018) is provided in Table 7-1.

[46] The 2016 HHRA (SynTerra 2016c) considered exposure to offsite recreational users of Crutchfield Branch (e.g., offsite recreational swimmers, offsite recreational waders, offsite recreational boaters, offsite recreational and subsistence fishers), onsite trespassers, onsite construction workers, and onsite commercial and industrial workers. Several of these receptors were removed in the updated HHRA (SynTerra 2018). SynTerra (2018) explains that the updated HHRA did not include onsite commercial and industrial workers because "use of personal protective equipment (*e.g.*, boots, gloves, safety glasses) and other safety behaviors exhibited by Site workers limits exposure to CCR constituents," and did not include offsite swimmers, boaters, or fishers because "updated modeling and data collection demonstrate that groundwater migration from the ash basin does not influence Mayo Lake, and observations of Crutchfield Branch confirms that it is not of sufficient size to support these recreational uses."

[47] Groundwater exposure to onsite construction workers was evaluated in the updated HHRA, though a pathway for exposure was considered incomplete by SynTerra (2018).

**Table 7-1. Summary of human health risk assessment hazard index (HI) and excess lifetime cancer risk (ELCR) from SynTerra (2018)**

| Media | Receptor | HI | ELCR |
|---|---|---|---|
| Sediment | Trespasser | 0.002 | NC |
| Surface Water | Trespasser | 0.008 | $1.4\times10^{-7}$ |
| Groundwater (Surficial Aquifer) | Construction Worker | 0.001 | NC |
| Groundwater (Transition/Bedrock) | Construction Worker | 0.001 | NC |
| Sediment | Recreational Wader | 0.002 | NC |
| Surface Water | Recreational Wader | 0.04 | $1.9\times10^{-6}$ |

Notes:
NC - Risk based concentration based on non-cancer HI.

All exposure scenarios assessed by SynTerra (2018) indicated that exposure to CCR poses no meaningful risks to humans.

## 7.3 NEBA – Protection of Human Health from CCR Exposure

Based on these analyses, there is no CCR risk from drinking water supplies, no evidence of CCR impacts to drinking water wells, and no meaningful risk to humans from CCR exposure under current conditions[48] or under any closure option. Using the NEBA framework and relative risk ratings, these results are summarized in Table 7-2 within the objective of protecting human health from exposure to CCR constituents.

48 SynTerra's updated HHRA considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps at Mayo was not evaluated in the HHRA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable SOC that Duke entered with the North Carolina Environmental Management Commission on August 15, 2018 (EMC SOC WQ S18-005; See Section 4.2).

**Table 7-2. Summary of relative risk ratings for attributes that characterize potential hazards to humans from CCR exposure in drinking water, surface water, groundwater, soil, sediment, food, and through recreation**

| **Objective** | Protect Human Health from CCR | | |
|---|---|---|---|
| **Hazard** | Exposure to CCR | | |
| **Potentially Affected Populations** | Local Residents/Visitors | Onsite Trespassers | Offsite Recreational Waders |
| **Scenario** | | | |
| Baseline | -- | -- | -- |
| CIP | -- | -- | -- |
| Excavation | -- | -- | -- |
| Hybrid | -- | -- | -- |

"--" indicates "no meaningful risk."

Current conditions and conditions under all closure options support provision of safe drinking water, safe surface water, safe food, and safe recreation, satisfying the first objective of ash basin closure—to protect human health from CCR constituent exposure.

# 8 Conclusion 2: All closure options for the Mayo ash basin are protective of ecological health.

The second objective for ash basin closure, to protect ecological health from CCR constituent exposure, is represented by environmental services that provide safe surface water, safe food consumption, and protection of biodiversity and natural beauty. For purposes of the NEBA, these considerations were evaluated based on the following:

1. Risk to ecological receptors from CCR exposure, as characterized by SynTerra (2018; Appendix B) in the updated human health and ecological risk assessment; and
2. Aquatic community health in Mayo Lake as reported in the 2017 environmental monitoring report (Duke Energy 2018a).

Through these two lines of evidence, I evaluated whether CCR constituents pose a risk to ecological populations now or after ash basin closure.

## 8.1 No meaningful risks to ecological receptors from CCR exposure exist under current conditions or any closure option.

To assess potential risk to ecological receptors both onsite and offsite using the most recent and comprehensive data available, SynTerra (2018) updated the baseline human health and ecological risk assessment that was originally performed by SynTerra (2016c) as a component of the CAP part 2 (SynTerra 2016a). The updated ERA included updates to the conceptual site model, exposure point concentrations for receptors with potentially complete exposure pathways, and screening level risk assessments for ecological receptors with potentially complete exposure pathways. Updated HQs were estimated for receptors with plausible potentially complete exposure pathways to CCR related COPCs (SynTerra 2018).

The ecological receptors evaluated in an ERA are common representatives of particular groups of organisms inhabiting different habitats and aspects of the food web. Key receptors in

SynTerra's updated ERA (SynTerra 2018) and their pathways for exposure included the following:

- **Birds:** Avifauna species may be exposed by ingestion of food and surface water and by incidental ingestion of sediment and soil. Aquatic/wetland species included were mallard duck (omnivore), great blue heron (piscivore), and bald eagle (carnivore)[49]; terrestrial species included were American robin (omnivore) and red-tailed hawk (carnivore).
- **Mammals:** Aquatic/wetland or terrestrial species may be exposed by ingestion of food and surface water and by incidental ingestion of sediment and soil. Aquatic/wetland species included were muskrat (omnivore) and river otter (piscivore), and terrestrial species included were meadow vole (herbivore) and red fox (carnivore).

Ecological risk for these indicator species was characterized by SynTerra (2018) using a risk-based screening approach that compared chemical exposure levels to chemical toxicity reference values (TRVs) to calculate HQs for COPCs. TRVs in the ERA included no-observed-adverse-effects levels (NOAELs)[50] and lowest-observed-adverse-effects levels (LOAELs)[51] derived from the literature for each COPC.

[49] The bald eagle was added to this risk assessment model because the species is federally protected and represents a raptor that preys upon fish, primarily, while the red-tailed hawk primarily preys upon small terrestrial vertebrates (e.g., rodents, snakes, etc.). Hazard quotient calculations for the bald eagle include hypothetical consumption of fish that inhabit adjacent surface water areas in addition to terrestrial vertebrates that inhabit upland areas.

[50] A NOAEL is a concentration below which no adverse effects have been observed for a specific receptor and pathway of exposure. NOAELs are typically estimated from laboratory toxicity tests.

[51] A LOAEL is a concentration associated with the lowest concentration level at which adverse effects have been observed for a specific receptor and pathway of exposure. LOAELs are typically estimated from laboratory toxicity tests.

HQ results for the site were evaluated for one area of Mayo[52] (Figure 8-1). HQs less than 1 indicate no meaningful risk to ecological receptor species associated with exposure to the COPCs evaluated.

- **Crutchfield Branch:** All HQs <1, indicating no meaningful risk to ecological receptors in this area.

Additionally, the 2017 environmental monitoring report (Duke Energy 2018a) for Mayo Lake reported results from biological sampling and water chemistry analyses conducted in 2017. The report concluded that impacts from the Mayo Plant to water quality and aquatic life are minimal. Based on analyses of fish community composition, the fish community was reported to be balanced and "[s]uccessful reproduction of Bluegill and Largemouth Bass was evident throughout the reservoir" (Duke Energy 2018a).

Given the lack of meaningful ecological risk from CCR exposure under current conditions based on the lines of evidence evaluated, all closure options would be protective of ecological receptors since all closure options reduce or eliminate potential exposure pathways following closure.

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52 The baseline ecological risk assessment conducted by SynTerra in 2016 (SynTerra 2016c) included four exposure areas. The ash basin exposure area, the ash basin downgradient exposure area, and the South Creek exposure area were not evaluated for the updated ERA because they represent the ash basin, AOWs (seeps), or upgradient locations (SynTerra 2018). The separate Crutchfield Branch downgradient and Crutchfield Branch exposure areas were evaluated as one exposure unit, Crutchfield Branch, in the updated ERA (SynTerra 2018).

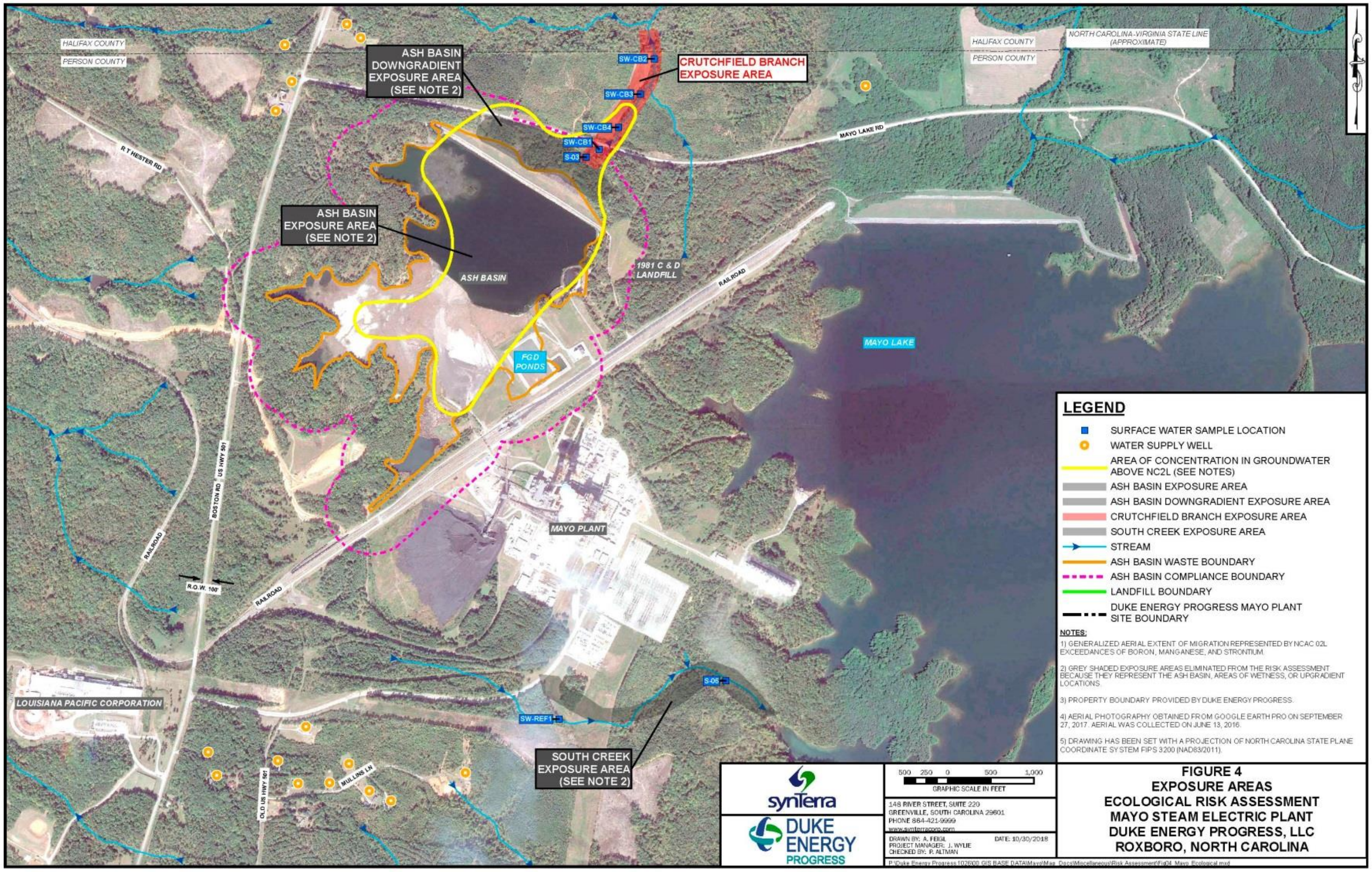


Figure 8-1. Exposure areas evaluated in the 2018 Ecological Risk Assessment update. Reproduced from SynTerra (2018).

## 8.2 NEBA – Protection of Ecological Health from CCR Exposure

Based on these analyses, no meaningful risk to ecological receptors from CCR exposure was found under current conditions[53] or under any closure option. Using the NEBA framework and relative risk ratings, within the objective of protecting ecological health from exposure to CCR constituents, these results are summarized in Table 8-1.

**Table 8-1. Summary of relative risk rating for attributes that characterize potential hazards to ecological resources from CCR exposure in surface water, soil, sediment, and food**

| **Objective** | Protect Ecological Health from CCR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Hazard** | Exposure to CCR | | | | | | | | | |
| **Potentially Affected Populations** | Fish Populations | Aquatic Omnivore Birds (mallard) | Aquatic Piscivore Birds (great blue heron) | Aquatic Carnivore Birds (bald eagle) | Aquatic Herbivore Mammals (muskrat) | Aquatic Piscivore Mammals (river otter) | Terrestrial Omnivore Birds (robin) | Terrestrial Carnivore Birds (red tail hawk) | Terrestrial Herbivore Mammals (meadow vole) | Terrestrial Carnivore Mammals (red fox) |
| **Scenario** | | | | | | | | | | |
| Baseline | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| CIP | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Excavation | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Hybrid | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

"--" indicates "no meaningful risk."

53 SynTerra's updated ERA considered only potential exposure pathways that currently exist and could remain after ash basin closure under any closure option. Any potential risk currently associated with seeps at Mayo was not evaluated in the ERA or considered in this analysis because any risk resulting from seeps will be eliminated, reduced, or mitigated per the court-enforceable SOC that Duke entered with the North Carolina Environmental Management Commission on April 18, 2018 (EMC SOC WQ S17-009; See Section 4.2).

Current conditions and conditions under all closure options support provision of safe surface water, safe food consumption, and protection of biodiversity and natural beauty, satisfying the second objective of ash basin closure—to protect ecological health from CCR constituent exposure.

# 9 Conclusion 3: All closure options for the Mayo ash basin create low levels of community disturbance.

The third objective for ash basin closure, to minimize human disturbance and risk from closure, is represented by environmental services that provide safe air quality and a safe community environment. For purposes of the NEBA, these considerations were evaluated based on the following:

1. Health risks from diesel exhaust emissions to the community living and working along transportation corridors during trucking operations to haul materials to and from the ash basin, as evaluated through the application of diesel truck air emissions modeling and HHRA; and
2. The relative risk for disturbance and accidents resulting from trucking operations affecting residents living and working along transportation corridors during construction operations, as evaluated by comparing the relative differences in trucking operations between the closure options.

All closure options require increased trucking activity to haul materials to the site (e.g., transport cap material to the ash basin). These activities involve the use of diesel-powered dump trucks, which increase local diesel exhaust emissions and traffic, both of which present potential hazards to local populations in the form of air pollution and roadway hazards. Table 9-1 summarizes the transportation logistics associated with each of the closure options Duke Energy is considering for the Mayo Plant (Duke Energy 2018b). Obvious from these numbers is that the amount of trucking involved in CIP and hybrid closure is substantially greater than that involved in excavation closure because there is only a small amount of offsite cover (i.e., geosynthetic material for capping new landfill area) needed for excavation closure; fill, cover, and topsoil requirements are expected to be met onsite from excavated portions of dams and embankments. All ash hauling under the excavation and hybrid options occurs on site. These differences are reflected in the number of truck loads required and the number of miles driven.

**Table 9-1. Summary of offsite transportation logistics associated with each closure option (Duke Energy 2018b)**

| Logistics | CIP | Excavation | Hybrid |
|---|---|---|---|
| Closure Duration (years)[a] | 6 | 10 | 8 |
| Construction Duration (years)[b] | 4 | 7 | 5 |
| Offsite truck loads to haul cap & fill material[c] | 5,740 | 50 | 5,709 |
| Offsite miles driven to haul cap & fill material[c] | 175,560 | 27,500 | 156,049 |

[a] Includes design and permitting, decanting, site preparation, construction, and site restoration.
[b] Includes site preparation, construction, and site restoration.
[c] Includes cover soil, top soil, and geosynthetic material.
[d] Includes ash, over-excavated soil, and removed dams and embankments.

Costs to society associated with trucking include accidents (fatalities, injuries, and property damage), emissions (air pollution and greenhouse gases), noise, and the provision, operation, and maintenance of public roads and bridges (Forkenbrock 1999). Generally, the magnitude of these impacts scales with the frequency, duration, and intensity of trucking operations (Forkenbrock 1999). Figure 9-1 illustrates the normalized differences between offsite transportation activities under the closure options. From these results, it is clear that risk and disturbance associated with transportation activities will be substantially greater under a CIP or hybrid closure compared to the excavation option because most materials for excavation closure are available onsite and do not require offsite transportation.

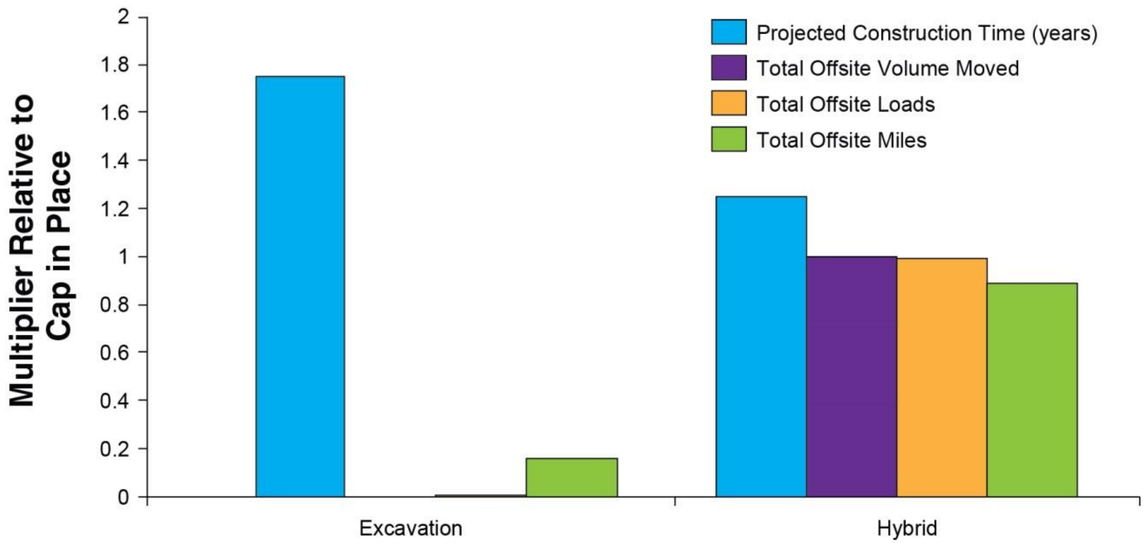


Figure 9-1. Normalized differences between offsite transportation activities under CIP, excavation, and hybrid closure options.
Bars represent the increased activity under closure options compared to CIP.

## 9.1 There is no meaningful risk from diesel emissions to people living and working along the transportation corridor.

The types of large dump trucks that will be used in closure activities at the Mayo Plant are generally diesel powered, and diesel exhaust includes a variety of different particulates and gases, including more than 40 toxic air contaminants.[54] North Carolina does not have a diesel-specific health-based toxicity threshold because diesel exhaust is not currently regulated as a toxic air pollutant. North Carolina also does not regulate $PM_{2.5}$ or $PM_{10}$[55] as toxic air pollutants. North Carolina defers to EPA's chronic non-cancer reference concentration (RfC) for diesel particulate matter (DPM) of 5 µg/m$^3$ based on diesel engine exhaust to estimate risk from diesel emissions.[56] California is, to my knowledge, the only state that currently regulates diesel as a toxic air contaminant and has identified both an inhalation non-cancer chronic reference exposure level (REL)[57] of 5 µg/m$^3$ and a range of inhalation potency factors indicating that a

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54 https://oehha.ca.gov/air/health-effects-diesel-exhaust

55 $PM_{2.5}$ and $PM_{10}$ are airborne particulate matter sizes. $PM_{2.5}$ is particulate matter that is 2.5 µm or less in size; $PM_{10}$ is particulate matter that is 10 µm or less in size.

56 Integrated Risk Information System (IRIS). U.S. EPA. Diesel engine exhaust.

57 A chronic REL is a concentration level (expressed in units of micrograms per cubic meter [µg/m$^3$]) for inhalation exposure at or below which no adverse health effects are anticipated following long-term exposure.

"reasonable estimate" for the inhalation unit risk is $3.0\times10^{-4}$ $(\mu g/m^3)^{-1}$ "until more definitive mechanisms of toxicity become available" (OEHHA 2015). California bases the non-cancer and cancer health factors on the whole (gas and particulate matter) diesel exhaust and uses $PM_{10}$ as a surrogate measure.

As $PM_{10}$ is the basis for both the non-cancer and inhalation risk factors for diesel exhaust exposure in California, I relied on a $PM_{10}$ exposure model to evaluate potential non-cancer and cancer health risks from diesel exhaust.[58]

A representative segment of road was simulated using EPA's AERMOD model[59] to quantify air concentrations at set distances away from the road (U.S. EPA 2016). Diesel truck emissions were configured in the model in a manner consistent with the recommendations from EPA's Haul Road Working Group (U.S. EPA 2011). The emission rate for diesel trucks was calculated using the U.S. EPA Mobile Vehicle Emissions Simulator (MOVES) model (U.S. EPA 2015).[60] Emission factors were then applied to the average number of anticipated offsite truck trips each year to define the average annual amount of DPM emitted along the representative road segment, and these exposures were then summed over seventy years.[61] AERMOD simulations were run for four transportation orientation directions and used five years of local meteorological data to estimate exposure point concentrations at regular intervals from 10 to 150 m perpendicular to either side of the road. The results of the model were translated into average $PM_{10}$ exposure ($\mu g/m^3$) and excess cancer risk over a 70-year period using reasonable

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EPA has defined long-term exposure for these purposes as at least 12% of a lifetime, or about eight years for humans.

58 California regulations and guidance indicate that when comparing whole diesel exhaust to speciated components of diesel (e.g., polycyclic aromatic hydrocarbons, metals) the cancer risk from inhalation of whole diesel exhaust will outweigh the multi-pathway analysis for speciated components.

59 AERMOD will calculate both the downwind transport and the dispersion of pollutants emitted from a source. Both transport and dispersion are calculated based on the observed meteorology and characteristics of the surrounding land. AERMOD is maintained by EPA and is the regulatory guideline model for short-range applications (transport within 50 km).

60 The MOVES model allows a user to determine fleet average emission factors (in units of grams of pollutant per mile traveled) for specific classes of vehicles and specific years. In this application, factors defined by MOVES for single-unit short-haul diesel truck were used.

61 For the cancer risk analysis, emissions were calculated as an average over the regulatory default 70-year residential exposure duration. If the truck activity for a closure option occurs over a shorter period of time, the duration of the truck activity exposure is factored into the 70-year averaging time (OEHHA 2015).

maximum exposure.[62] Results of the exposure modeling are provided in Table 9-2. Full results and a more detailed description of the model are provided in Appendix C.

**Table 9-2. Hazard indices (HI) and excess lifetime cancer risk (ELCR) from exposure to diesel exhaust emissions along transportation corridors in northern North Carolina. Results are for the maximum exposures modeled.**

| Perpendicular Distance from the Road | CIP | | Excavation | | Hybrid | |
|---|---|---|---|---|---|---|
| | ELCR | HI | ELCR | HI | ELCR | HI |
| *10 m* | 2.77E-09 | 0.0000 | 1.50E-11 | 0.0000 | 1.95E-09 | 0.0000 |
| *20 m* | 2.25E-09 | 0.0000 | 1.22E-11 | 0.0000 | 1.59E-09 | 0.0000 |
| *30 m* | 1.77E-09 | 0.0000 | 9.61E-12 | 0.0000 | 1.25E-09 | 0.0000 |
| *40 m* | 1.46E-09 | 0.0000 | 7.90E-12 | 0.0000 | 1.03E-09 | 0.0000 |
| *50 m* | 1.23E-09 | 0.0000 | 6.69E-12 | 0.0000 | 8.69E-10 | 0.0000 |
| *60 m* | 1.08E-09 | 0.0000 | 5.85E-12 | 0.0000 | 7.60E-10 | 0.0000 |
| *70 m* | 9.60E-10 | 0.0000 | 5.21E-12 | 0.0000 | 6.77E-10 | 0.0000 |
| *80 m* | 8.64E-10 | 0.0000 | 4.69E-12 | 0.0000 | 6.09E-10 | 0.0000 |
| *90 m* | 7.85E-10 | 0.0000 | 4.26E-12 | 0.0000 | 5.54E-10 | 0.0000 |
| *100 m* | 7.19E-10 | 0.0000 | 3.90E-12 | 0.0000 | 5.07E-10 | 0.0000 |
| *110 m* | 6.63E-10 | 0.0000 | 3.60E-12 | 0.0000 | 4.67E-10 | 0.0000 |
| *120 m* | 6.14E-10 | 0.0000 | 3.33E-12 | 0.0000 | 4.33E-10 | 0.0000 |
| *130 m* | 5.72E-10 | 0.0000 | 3.10E-12 | 0.0000 | 4.03E-10 | 0.0000 |
| *140 m* | 5.34E-10 | 0.0000 | 2.90E-12 | 0.0000 | 3.77E-10 | 0.0000 |
| *150 m* | 5.01E-10 | 0.0000 | 2.72E-12 | 0.0000 | 3.53E-10 | 0.0000 |

Based on the assumptions applied in the air model, no meaningful risk from diesel emissions associated with ash basin closure trucking operations was identified for people living and working along the transportation corridor. The exposure model and risk assessment applied here represent a simple approach to estimate risk. A more refined estimate of risk could be computed with a more sophisticated air and risk model; however, it is unlikely to change the conclusion that there is no meaningful risk to people living and working along the transportation corridor from diesel emissions associated with ash basin closure construction operations.

[62] Long-term exposure was incorporated into the air simulation as the average exposure given estimated trucking rates for 12 hours per day—7am to 7 pm—6 days a week for the duration of the project trucking time.

## 9.2 The likelihood of noise, traffic, and accidents from transportation activities is comparable under all closure options.

Increased trucking increases noise and traffic congestion and creates a statistically based risk for increased traffic accidents that could result in fatalities, injuries, and/or property damage (Forkenbrock 1999; NHTSA 2016). The primary public intersection along the transportation route between the ash impoundment and the onsite lined landfill occurs at U.S. Highway 501 (see Figure 4-1). There will be an increase in trucking traffic under the excavation option at this intersection, with a statistically increased likelihood of traffic accidents (NHTSA 2016). There will also be an increased likelihood of accidents along the transportation corridor through which earthen and geosynthetic material is brought to the Mayo Plant under each closure option. These accidents and associated risks to life, health, and property will generally scale with the frequency and duration of trucking, total number of truckloads, number of roundtrip truck trips per day, and duration of the closure.

For purposes of the NEBA two attributes of offsite truck traffic that create disturbance to local communities were considered: (1) noise and congestion and (2) accidents. Noise and congestion were evaluated by comparing the number of times a construction truck would be expected to pass a given location along the transportation corridor during closure construction activities. The difference in the likelihood of traffic accidents between the closure options was assumed to be a function of the number of offsite road miles driven by construction trucks (NHTSA 2016).

### 9.2.1 Noise and Congestion

Regardless of the option, closure of the ash basin at Mayo will result in an increased number of large trucks[63] on local roads (Table 9-1). Noise from these trucks includes engine and braking noise, which can be disruptive to the communities through which they are passing,[64] and trucks frequently passing through rural communities may pose additional disturbance from roadway

[63] Twenty-ton dump trucks, or similar vehicles for bulk transport, are assumed to be the primary vehicles that will be involved in transporting materials during closure construction activities.

[64] A typical construction dump truck noise level is approximately 88 decibels 50 ft. from the truck. (https://www.fhwa.dot.gov/ENVIRONMENT/noise/construction_noise/handbook/handbook09.cfm)

congestion. To compare the disturbance of trucking noise and congestion between closure options, I used the average daily number of truck passes for trucks carrying earthen fill and geosynthetic material to the construction site (Table 9-1). The number of passes of trucks hauling ash from the ash basin to the landfill was not considered because these trucks do not leave the site except for crossing U.S. Highway 501, and community noise receptors are not present at this location. For the CIP option, it is estimated that a total of 11,480 truck passes hauling cover material would occur at locations along the transportation corridor within 11 miles of the facility over the 48-month course of construction, for an average of 9 passes per day, or one truck every 65 minutes, assuming a 10-hour work day.[65] For the hybrid option, there would be 11,418 total truck passes hauling cover material along the transportation corridor for 60 months for an average of 7 passes per day, or one truck every 82 minutes. The excavation option does not require offsite cover material except geosynthetics and, therefore, employs only 100 total truck passes for 84 months, or less than one truck per month on average. These results and their relative differences (as the ratio to CIP closure) are summarized in Table 9-3.

### 9.2.2 Traffic Accidents

Traffic accidents are assumed to be a function of the total number of offsite road miles driven by construction trucks (NHTSA 2016). As with noise and congestion, only the miles driven hauling earthen fill and cap materials were considered because ash-hauling vehicles will only cross U.S. Highway 501 in one location, and I have assumed that a traffic control method would be implemented to reduce accidents to baseline levels at this location.[66] The CIP option requires a total of approximately 175,500 miles of driving, while the excavation option requires approximately 27,500 miles of driving. The difference in distance driven between the CIP and excavation option is equivalent to more than six round trips to the moon. Table 9-3 summarizes the results for all disturbances considered.

[65] All closure options assume 10-hour work days, 6-day work weeks, and 26 working days per month.

[66] This assumption likely minimizes the risk for traffic accidents at the U.S. Highway 501 intersection because the increased traffic would likely increase accident risk even with a traffic control measure.

**Table 9-3. Comparative metrics for increased noise and congestion and traffic accidents**

| Closure option | Months of trucking | Noise and congestion | | Traffic Accidents | |
|---|---|---|---|---|---|
| | | Average truck passes per day | Ratio to CIP | Total offsite road miles driven | Ratio to CIP |
| CIP | 48 | 9 | 1 | 175,560 | 1 |
| Excavation | 84 | 0.05 | 0.005 | 27,500 | 0.16 |
| Hybrid | 60 | 7 | 0.80 | 156,049 | 0.89 |

## 9.3 NEBA – Minimize Human Disturbance

From these analyses, no meaningful health risk is expected from diesel exhaust emissions under any closure option, but the closure options are expected to produce different levels of community disturbance in the form of noise and traffic congestion and risk from traffic accidents.

I used the number of trucks per day passing[67] a receptor along a near-site transportation corridor to examine the differences in noise and traffic congestion under the closure options. I compared the increase in the average number of trucks hauling earthen fill, geosynthetic material, and other materials under the closure options to the current number of truck passes for the same receptor. I specified a baseline, or current, level of truck passes on the transportation corridor, and the number of truck passes per day under the closure options derive directly from the trucking projections and implementation schedules provided by Duke Energy (2018b).

A baseline estimate of trucking passes per day for transportation corridors near the Mayo Plant was derived from North Carolina Department of Transportation (NCDOT) data of annual average daily traffic (AADT) at thousands of locations across the state[68] and the proportion of

[67] Truck passes per day is calculated as the total number of loads required to transport earthen fill, geosynthetic material, and other materials multiplied by two to account for return trips. The resulting total number of passes is then divided evenly among the total number of months of trucking time multiplied by 26 working days per month.

[68] Annual average daily traffic (AADT) values are derived from counts of axle pairs in every lane travelling in both directions using a pneumatic tube counter. At each monitoring station, raw data is collected for two days, and these raw counts are adjusted using axle and seasonal correction factors to estimate the AADT. AADT results are compared to historical values at the same location and values at nearby stations to provide temporal

road miles driven by large trucks in Person County.[69] Based on the assumed 314 truck per day baseline level and the number of truck trips per day from Duke Energy's projections, all options would have a less than 3% impact (CIP = 2.9%, excavation = 0.01 %, , hybrid = 2.3%) on noise and congestion. I input these percent impacts to the risk-ranking matrix (Table 5-4) along with the total duration of trucking activities (4 years CIP; 7 years excavation; and 5 years hybrid) to evaluate which of the closure options best minimizes human disturbances (Table 9-4).

I evaluated risk from traffic accidents by comparing the average number of annual offsite road miles driven between closure options relative to a baseline estimate of the current road miles driven.[70] I chose a baseline of 33.5 million annual road miles for Person County, North Carolina, based on the reported total vehicle miles traveled in Person County (NCDMV 2017) multiplied by the county average 9.5% contribution of trucks to total AADT (NCDOT 2015). I used the increase in truck miles driven over baseline in the closure options as a surrogate for the potential increase in traffic accidents.

Using the 33.5-million-truck-miles baseline assumption, the CIP option has a 0.13% impact, the excavation option has 0.01% impact, and the hybrid closure option has a 0.09% impact. All closure options have a relative risk rating of <5%. These relative risk ratings appear to be insensitive to lower assumed baseline annual truck miles (see Appendix E for sensitivity analysis); reducing the baseline assumption (e.g., to 6.2 million truck miles, the minimum miles driven in any North Carolina county [Hyde County]) does not appreciably increase the expected percent impact and relative risk rating and, by extension, the risk from traffic accidents. Results are summarized in the NEBA framework (Table 9-4) within the objective of minimizing disturbance to humans during closure.

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and spatial quality assurance. AADT data and a mapping application user interface are available online (http://ncdot.maps.arcgis.com/apps/webappviewer/index.html?id=5f6fe58c1d90482ab9107ccc03026280)

69 A value of 3,300 AADT was chosen as a baseline value for all vehicle traffic by identifying potential transportation routes to and from the Mayo ash basin and selecting the AADT station along the route that currently has the lowest traffic and would experience the greatest proportional increase in trucking traffic from ash basin closure. The baseline AADT value (3,300) was then multiplied by the county average of large truck traffic volume (9.5%) to derive an estimated 314 passes per day along the most sensitive portion of the transportation corridor to and from Mayo (Appendix E).

70 The difference of baseline miles and closure option miles was divided by the baseline miles and multiplied by 100 to get a percent impact.

**Table 9-4. Summary of relative risk ratings for attributes that characterize potential hazards to communities during remediation activities. Darker shading and higher codes indicate greater impact.**

| **Objective** | Minimize Human Disturbance | | |
|---|---|---|---|
| **Hazard** | Noise and Traffic Congestion | Traffic Accidents | Air Pollution |
| **Potentially Affected Populations** | Local Residents/Visitors | Local Residents/Visitors | Reasonable Maximum Exposure |
| **Scenario** | | | |
| Baseline | baseline | baseline | baseline |
| CIP | **2A** | **2A** | **--** |
| Excavation | **3A** | **3A** | **--** |
| Hybrid | **3A** | **3A** | |

"--" indicates "no meaningful risk."

Disturbance and risk created by all closure options are minimal (i.e., risk rating of A).[71] All closure options support safe air quality from diesel truck emissions along the transportation routes and create minimal disturbance to community safety. Thus, all closure options comparably satisfy the third objective of ash basin closure—to minimize risk and disturbance to humans from closure.

71 Sensitivity analyses exploring different assumptions for CIP disturbance and subsequent effects to relative risk ratings are provided in Appendix E.

# 10 Conclusion 4: Most closure options for the Mayo ash basin produce no net environmental disturbance.

Environmental services are derived from ecological processes or functions that have value to individuals or society, with provision of a healthy environment to humans being one of the most essential environmental services. Environmental services that support human health include functions to purify freshwater, provide food, supply recreational opportunities, and contribute to cultural values (MEA 2005). For example, forests provide habitat for deer that are hunted for food; surface water supports fish populations that are food for bald eagles, a previously threatened and endangered species highly valued by our society;[72] and soil and wetlands purify groundwater and surface water, respectively, by adsorbing contaminants. Central to weighing the net environmental benefits of the closure options under consideration here is understanding how they differentially impact the variety of environmental services at the site and in the area.

The Mayo Plant, though an industrial site, supports a diversity of habitats that provide environmental services. Figure 10-1 illustrates the types of habitats at the site. The ash impoundment provides habitat that supports birds and mammals; the open water habitat of the impoundment also removes solids from surface water by providing a low-flow environment in which ash particles and other solids can settle into the sediment before the treated water can enter Mayo Lake. The onsite forest provides biodiversity protection in the form of foraging, shelter, and breeding habitat for birds and mammals, among other types of organisms; watershed protection; landscape beauty; and carbon sequestration (Bishop and Landell-Mills 2012). Beyond the Mayo Plant, Mayo Lake provides aquatic habitat that supports a variety of fish and aquatic life (Duke Energy 2018a), which then provide food for birds and mammals.

72 Bald eagles were taken off the federal list of threatened and endangered species in 2007 (https://www.fws.gov/midwest/eagle/).

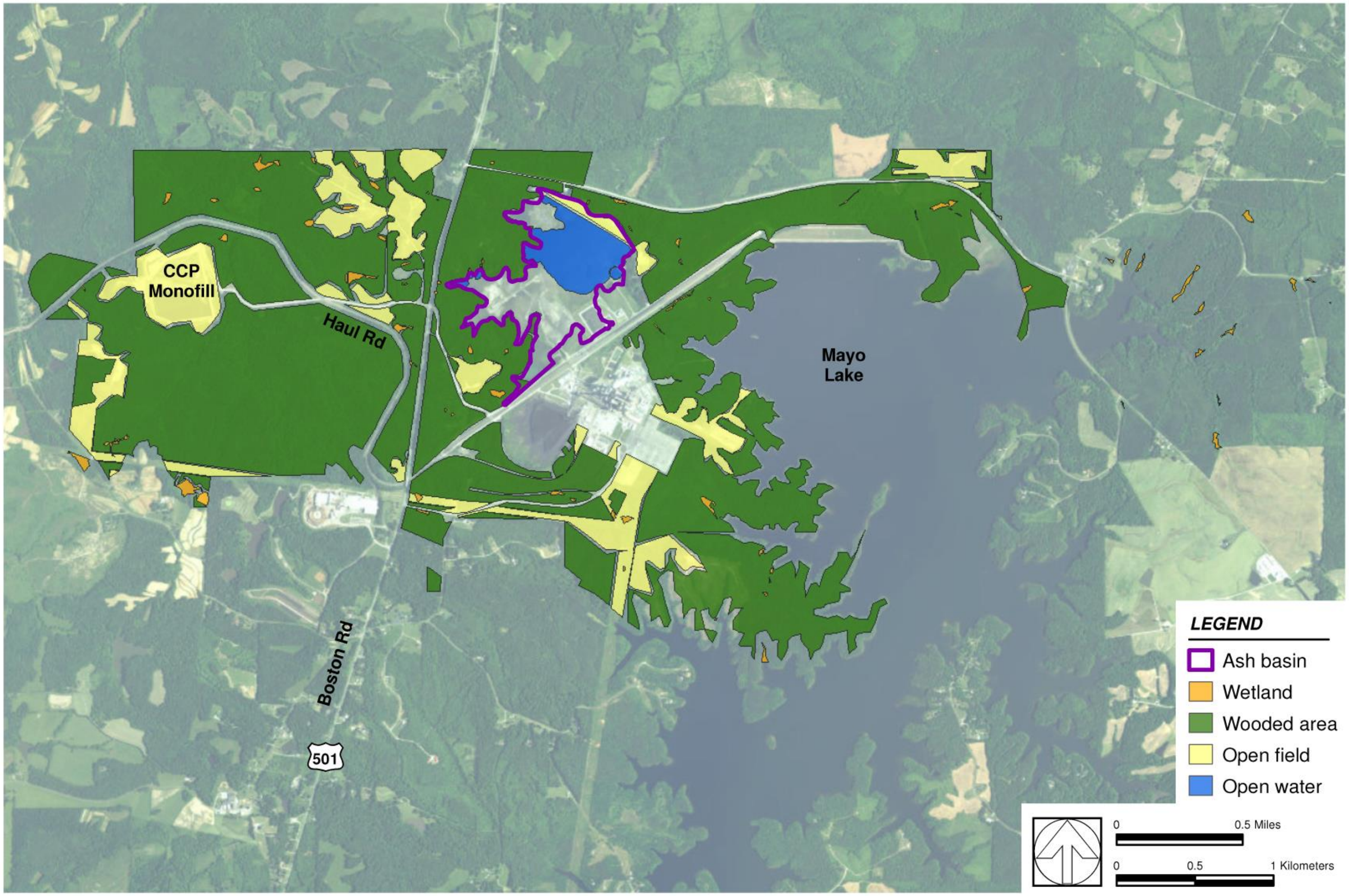


Figure 10-1. Map of habitat types currently present at the Mayo Plant

Plants serve a vital ecosystem role by converting solar energy and carbon dioxide into food (for themselves) and oxygen. Plants then become food for other organisms. As such, "plants provide the energy and air required by most life forms on Earth."[73] NPP represents a measure of the mass of chemically fixed carbon produced by a plant community during a given period and reflects the rate at which different ecosystems are able to sequester carbon. Given the foundational role of primary production in supporting ecological food webs and healthy air, NPP is a good surrogate for environmental services provided by different habitat types (Efroymson et al. 2003). For example, the annual NPP of a temperate forest habitat is approximately 2.5 times higher than for temperate grasslands or freshwater ecosystems (Ricklefs 2008). By multiplying the acres of habitat type by NPP, NPP becomes a single metric by which to compare the different levels of environmental services impacted by ash basin closure.[74]

The fourth objective for ash basin closure, to minimize environmental disturbance, is represented by the environmental services protection of biodiversity and natural beauty. For purposes of the NEBA, these considerations were evaluated based on differences in habitat-derived services estimated from the NPP of impacted habitat acres under the closure options.

## 10.1 Excavation and hybrid closure options result in net gains of habitat-derived environmental services.

Regardless of the closure option, habitat, and habitat-derived environmental services, will be altered. CIP closure requires removing existing habitat within the footprint of the ash basin, possible temporary removal of forest habitat to create a borrow pit to source earthen materials for the cap, and restoring the ash basin with grass cap habitat. Excavation and onsite landfilling require temporary loss and future modification of existing habitats within the footprint of the ash basin and permanent conversion of some forest habitat to grass cap at the landfill site. The hybrid option requires temporary loss and future modification of existing habitats within the

[73] https://earthobservatory.nasa.gov/GlobalMaps/view.php?d1=MOD17A2_M_PSN

[74] I used rates of NPP by stand age from He et al. (2012, Figure 2c.) for mixed forests as the basis for establishing NPP of onsite wooded habitats and used relative rates of NPP from Ricklefs (2008) to scale NPP for other habitat types.

footprint of the ash basin. All closure options include restoration of the ash basin footprint, but the collateral losses of habitat, the differences in service levels of restored habitat, and the timelines for recovery of the habitats vary based on construction schedules and the acreages and types of habitat lost or restored. This makes it challenging to appreciate the net gain or loss of environmental services. To address this challenge, I used a HEA to quantify the differences in environmental services resulting from each closure option.

HEA is an assessment method widely used in NRDA to facilitate restoration scaling for environmental services (Dunford et al. 2004; Desvousges et al. 2018; Penn undated). Numerous damage assessment restoration plans based on the use of HEA can be found on the U.S. Fish and Wildlife Service[75] and NOAA[76] websites and include sites such as the St. Lawrence River near Massena, New York; Onondaga Lake near Syracuse, New York; and LaVaca Bay in Texas. As Desvousges et al. (2018) describe, use of HEA has expanded in recent years beyond original applications for NRDA to address environmental service losses from other causes such as forest fires and climate change. As the authors note, HEA has also been used as an assessment tool in NEBA applications, such as evaluating the effects of transmission line routing on habitats of greater sage-grouse (*Centrocercus urophasianus*), a proposed threatened species.

The objective of HEA is to estimate the amount of compensatory services necessary to equal the value of the services lost because of a specific release or incident. The method calculates debits based on services lost because of resource losses and credits for services gained due to resource gains. The latter are often scaled to compensate for, or offset, the loss in services. A discount rate is used to standardize the different time intervals in which the debits and credits occur, so the services are usually expressed in terms of discounted acre-years of equivalent habitat, or DSAYs (Dunford et al. 2004; Desvousges et al. 2018; Penn undated).

The HEA methodology was used here to estimate changes in environmental service levels that will accrue under closure options. Environmental services currently provided by the site will be eliminated when the ash basin is closed. After closure is complete, there will be a new level of

[75] www.doi.gov/restoration

[76] www.darrp.noaa.gov

environmental services provided as habitat is restored. Since post-closure habitats may differ from those that currently occur onsite, future services could be greater or less than what occurs at present. Similarly, land used as a borrow area or converted to landfill, as per the closure options, will also impact the net level of services, as services currently provided by those habitats may be reduced or eliminated. The environmental service losses and gains from onsite and offsite habitats must be considered together when determining the overall net effect of a closure option.

A common ecological metric is required to make comparisons between service gains and losses from various habitat types. For purposes of this evaluation, I used annual NPP as the metric to standardize across habitat types. In terms of habitats currently occurring on the site, wooded areas have the highest NPP, so that is used as the basis for defining service level, and the service levels for other habitat types (open fields, open water) are expressed as a proportion of that baseline service. Based on He et al. (2012), and assuming a tree stand age of 50 years, NPP would be approximately 6.4 tons of carbon per hectare per year (6.4 t C/ha/yr) in wooded areas onsite. Based on relative rates of NPP from Ricklefs (2008), the NPP for open field and open water habitats would be approximately 40% of the temperate forest rate. To prevent overestimation of NPP in open water areas of the ash basin that may not provide the same level of NPP as natural freshwater habitats (perhaps from limited abundance or diversity of vegetation), I assumed that open water areas of the ash basin produce NPP that is 25% that of natural ecosystems.[77] Therefore, I applied a four-fold habitat quality factor to scale NPP at these open water areas of the ash basin to approximately 10% of the rate for wooded habitats. Deforested land for borrow areas was assumed to be reforested after closure was complete, and landfill areas were assumed to recover to grass cap. The grass cap on landfill was given a service value of 8%,[78] as was done for CIP.

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77 I observed open water areas of the ash basin that supported aquatic vegetation but do not know the extent of vegetation in the open water areas of the ash basin. Thus, I made a conservative assumption (i.e., one that reduces the present value of the habitat) that these areas of the ash basin provide a reduced level of NPP compared to natural open freshwater areas.

78 An open field provides a relatively lower NPP service level than forest habitat (40% of forest NPP; Ricklefs 2008), and since a grass cap requires periodic maintenance mowing, for purposes of the HEA it was assumed never to reach a level of NPP service equivalent to an open field. Grass cap was assumed to have 20% of the NPP service level for open field, which is 8% of forest NPP.

For each closure option, I used the acreage of existing habitat types and the level of service of that habitat type to establish a baseline level of service. Based on the timelines for the various closure options, a HEA was conducted to calculate the net change in service flow of the closure area over the next 150 years at a 3% discount rate.[79] Similarly, a HEA was run to calculate the net change in environmental services deriving from areas used either as borrow or for landfill expansion. Because NPP standardizes service levels across habitat types, the DSAY estimates for all affected habitats can be summed to calculate the net service gain/loss associated with each closure option. In addition to the assumptions identified above, several other assumptions were made to support the HEA, which are described in Appendix D.

Results of the HEA are presented in Table 10-1[80] and indicate that all but one closure option for the ash basin at Mayo result in a net gain in NPP services. Only CIP closure will result in a net loss of environmental services due primarily to the reduced NPP services provided by the grass cap that will replace all the existing habitats in the ash basin, such that environmental services produced after closure will not compensate for the service losses resulting from the closure.[81] Excavation and hybrid closures produce net gains in environmental services because of the amount of forested land that will be restored within the basin and the relatively smaller footprint of the new landfill (excavation) or borrow area (hybrid) compared to the restored ash basin area.

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[79] Environmental services in future years are discounted, which places a lower value on benefits that will take longer to accrue. The basis for this is that humans place greater value on services in the present and less value on services that occur in the future.

[80] A full description of the methods, assumptions, results, and sensitivity analyses for the HEA are provided in Appendix D.

[81] Note, however, that the environmental services lost due to CIP could be offset (see discussion in Section 11) by a suitable reforestation project that would then result in all closure options causing no net loss of habitat-derived environmental services in the HEA model.

**Table 10-1. Summary of NPP DSAYs for closure options**

| | | CIP | Excavation | Hybrid |
|---|---|---|---|---|
| **Ash basin losses** | Open Field | | | |
| | Grass Cap | −27 | −26 | −26 |
| | Open Water | −167 | −162 | −162 |
| | Stream | | | |
| | Wetland | | | |
| | Wooded | −161 | −156 | −156 |
| | **Total losses** | −356 | −344 | −344 |
| **Ash basin post-closure gains** | Open Field | | 127 | 26 |
| | Grass Cap | 295 | | 148 |
| | Open Water | | | |
| | Stream | | 8 | 3 |
| | Wetland | | 16 | 3 |
| | Wooded | | 2,438 | 1,305 |
| | **Total gains** | 295 | 2,589 | 1,486 |
| **Landfill/borrow losses** | Forest | −371 | −590 | |
| | Open field | | −151 | |
| | Grass Cap | | | −9 |
| | Wetland | | | |
| | **Total losses** | −371 | −741 | −9 |
| **Landfill/borrow post-closure gains** | Forest | 265 | | |
| | Grass Cap | | 56 | 9 |
| | **Total gains** | 265 | 56 | 9 |
| **Net Gain/Loss per Option** | | **−166** | **1,559** | **1,142** |

**Note:** DSAYs for specific habitat types are reported here rounded to the nearest whole number. As such, the net gain/loss per option differs slightly from the sum of the individual DSAYs reported in the table.

## 10.2 NEBA – Minimize Environmental Disturbance

The impact of the closure options on environmental services was computed as the percentage difference in DSAYs produced by the closure option and the absolute value of the DSAY losses. The DSAY losses represent the NPP services that would have been produced by the site, borrow areas, and landfills but for the project closure. The DSAY gains represent the NPP services restored after project closure plus any future gains realized from existing habitats before remediation begins. The sum of DSAY losses and gains represents the net change of NPP services for the project resulting from closure. Dividing the net DSAYs by the absolute value of the DSAY losses provides a percentage of the impact. From these calculations, the CIP closure as currently defined will have a 23% impact,[82] while all other closure options will have no net adverse impact on NPP services and will, in fact, increase net NPP services (Table 10-2). These percent impacts were input to the risk-ranking matrix (Table 5-4) along with the duration of the closure activities (4 years CIP, 7 years Excavation, and 5 years hybrid) to evaluate, within the NEBA construct, which of the closure options best minimizes environmental disturbances (Table 10-3).

**Table 10-2. Percent impact of ash basin closure options.**

| | CIP | Excavation | Hybrid |
|---|---|---|---|
| DSAY Losses[a] | −726 | −1,085 | −353 |
| DSAY Gains | 561 | 2,645 | 1,495 |
| Percent Impact (%) | 23% | 0% | 0% |

[a] Absolute value of DSAY losses is equivalent to baseline services of the affected habitat but for the closure.

**Table 10-3. Summary of relative risk ratings for habitat changes that affect provision of environmental services. Darker shading and higher codes indicate greater impact.**

| **Objective** | **Minimize Environmental Disturbance** |
|---|---|
| **Hazard** | Habitat Change |
| Attribute | DSAYs |
| **Scenario** | |
| Baseline | baseline |
| CIP | **2C** |
| Excavation | **--** |
| Hybrid | **--** |

Within the objective of minimizing environmental disturbance from closure, my analyses indicate that excavation and hybrid closure options produce a net benefit in habitat-derived environmental services; CIP closure slightly decreases habitat-derived environmental services. Thus, all closure options except CIP, as currently defined, satisfy the fourth objective of ash basin closure—to minimize risk and disturbance to the local environment from closure.

[82] As discussed below, this habitat impact could be offset with an appropriate reforestation project.

# 11 Conclusion 5: Most closure options for the Mayo ash basin produce comparable environmental services.

Identifying environmental actions that maximize environmental services (the fifth objective for ash basin closure) is a function of NEBA (Efroymson et al. 2003, 2004) and the overarching objective that encompasses each of the other four objectives and all of the environmental services that have been considered to this point. Table 11-1 summarizes the relative risk ratings for all attributes and objectives. Impacts to environmental services considered in this NEBA focused on key community-relevant concerns. Risk to construction workers from construction operations, risks to local and global populations from increased greenhouse gas emissions, and "wear-and-tear" damage to roadways from trucking were not estimated. Each of these risks, however, would scale with the duration, frequency, and intensity of construction operations.

Sensitivity analyses of the specifications of the NEBA framework show that the specific relative risk ratings presented in this NEBA can change depending on how baseline is defined (see Appendix E). The purpose of the risk matrix, and the risk ratings that result from it, is to consolidate the results from a variety of different analyses for a variety of different data types and attributes into a single framework for comparative analysis. It is imperative, however, to consider the underlying information used to develop the risk ratings to interpret the differences between closure options, particularly when percent impacts or durations of closure options are similar but receive different risk ratings.

As noted in Section 5, NEBA analysis provides an opportunity to better understand the net environmental benefits of possible closure options. If Duke Energy's preferred closure option for reasons not considered in the NEBA does not best maximize environmental services to the local community as currently defined, the NEBA results provide insight into how environmental services could be improved for that closure option. For instance, if Duke Energy's preferred closure option for the Mayo Plant is CIP closure but the HEA results for the currently defined CIP closure option estimate a net environmental service loss of an approximate 166 DSAYs, Duke Energy could consider incorporating into an updated CIP closure plan for the Mayo plant a mitigation project that compensates for the net environmental service losses projected from the currently defined CIP closure option. As an example, if Duke Energy started a reforestation project outside of the ash basin in 2021 (when onsite preparation of the ash basin begins), the reforestation project would gain 25.1 DSAYs/acre over the lifetime of the site (150 years in the HEA), requiring an approximate 6.6 acre project to compensate for the 166 DSAY loss projected in the HEA. Re-analysis of the HEA component of the NEBA for the updated possible closure options would then result in no net environmental losses (as NPP services) from habitat alteration of the basin under any closure option.

From the closure options considered and the analyses presented in this report, which are based on a scientific definition of risk acceptability and include no value weighting, all closure options except CIP as currently defined produce comparable environmental benefits because they offer equivalent protection of human and ecological health from CCR exposure, similar levels of disturbance to humans, and net gains in habitat-derived environmental services. Thus, all closure options except CIP provide comparable net environmental services and disturbance to the community, similarly satisfying the fifth objective of ash basin closure—to maximize local environmental services.

**Table 11-1. NEBA for closure of the ash basin at the Mayo Plant. Darker shading and higher alphanumeric codes indicate greater impact.**

| **Objective** | **Protect Human Health from CCR** | | | | **Protect Ecological Health from CCR** | | | | | | | | | | **Minimize Human Disturbance** | | | **Minimize Environmental Disturbance** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hazard** | Exposure to CCR | | | | Exposure to CCR | | | | | | | | | | Noise and Traffic Congestion | Traffic Accidents | Air Pollution | Habitat Change |
| **Potentially Affected Populations** | Local Residents/Visitors | Onsite Trespassers | Onsite Construction Workers | Offsite Recreational Waders | Fish Populations | Aquatic Omnivore Birds (mallard) | Aquatic Piscivore Birds (great blue heron) | Aquatic Carnivore Birds (bald eagle) | Aquatic Herbivore Mammals (muskrat) | Aquatic Piscivore Mammals (river otter) | Terrestrial Omnivore Birds (robin) | Terrestrial Carnivore Birds (red tail hawk) | Terrestrial Herbivore Mammals (meadow vole) | Terrestrial Carnivore Mammals (red fox) | Local Residents/Visitors | Local Residents/Visitors | Reasonable Maximum Exposure | DSAYs |
| **Scenario** | | | | | | | | | | | | | | | | | | |
| Baseline | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | baseline | baseline | baseline | baseline |
| CIP | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **2A** | **2A** | -- | **2C** |
| Excavation | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **3A** | **3A** | -- | **--** |
| Hybrid | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **--** | **3A** | **3A** | -- | -- |

"--" indicates "no meaningful risk."

# 12 References

Bishop, J., and N. Landell-Mills. 2012. Forest Environmental Services: An Overview. In: Selling Forest Environmental Services: Market-Based Mechanisms for Conservation and Development. Eds. S. Pagiola, J. Bishop, and N. Landell-Mills. New York: Earthscan Publications Limited.

Cormier, S., S. Norton, G. Suter, and D. Reed-Judkins. 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Washington, DC, EPA/822/B-00/025, 2000.

Desvousges, W.H., N. Gard, H.J. Michael, and A.D. Chance. 2018. Habitat and Resource Equivalency Analysis: A Critical Assessment. Ecological Economics. 1(143):74–89.

Draovitch, P. 2018. Letter to Sheila Holman, NCDEQ, from Paul Draovitch, Duke Energy. Subject: Mayo Steam Station HB630 Completion. August 30, 2018.

Dunford, R.W., T.C. Ginn, and W.H. Desvousges. 2004. The use of habitat equivalency analysis in natural resource damage assessments. Ecological economics. 48(1):49–70.

Duke Energy. 2018a. Mayo Steam Electric Plant 2017 Environmental Monitoring Report. Water Resources Unit Environmental Sciences Section. Duke Energy Progress. April 2018.

Duke Energy. 2018b. “Copy of DRAFT MAYO alternatives 20181102 (2)_BLB COMMENT 03NOV2018.xlsx”.

Efroymson, R.A., J.P. Nicolette, and G.W. Suter. 2003. A Framework for Net Environmental Benefit Analysis for Remediation or Restoration of Contaminated Sites. U.S. Department of Energy National Petroleum Technology Office. ORNL/TM-2003/17.

Efroymson, R.A., J.P. Nicolette, and G.W. Suter. 2004. A framework for net environmental benefit analysis for remediation or restoration of contaminated sites. Environ Manag. 34(3):315–331.

EPRI. 2009. Coal Ash: Characteristics, Management and Environmental Issues. Electric Power Research Institute, Palo Alto, California, September 2009.

Forkenbrock, D.J., 1999. External costs of intercity truck freight transportation. Transportation Research Part A: Policy and Practice. 33(7):505–526.

Griffith, G., J. Omernik, and J. Comstock. 2002. Ecoregions of North Carolina Regional Descriptions. August 31, 2002.

He, L., J.M. Chen, Y. Pan, R. Birdsey, and J. Kattge. 2012. Relationships between net primary productivity and forest stand age in US forests. Global Biogeochemical Cycles. 26(3): doi:10.1029/2010GB003942.

Holman, S. 2018. Letter to Paul Draovitch, Duke Energy, from Sheila Holman, NCDEQ. Subject: Completion of Permanent Alternate Water Supply Requirements Under General Statute 130A-309.211(cl) Mayo Steam Electric Plant. October 12, 2018.

Hosmer, J. 2017. Expert Report of J. Lawrence Hosmer in the Matter of Roanoke River Basin Association v. Duke Energy Progress, LLC. No. 1:16-cv-607 in the United States District Court for the Middle District of North Carolina. December 1, 2017.

Hunter, P.R., and L. Fewtrell. 2001. Acceptable risk. In: Water Quality: Guidelines, Standards and Health. Edited by Lorna Fewtrell and Jamie Bartram. World Health Organization (WHO). Published by IWA Publishing, London, UK. ISBN: 1 900222 28 0.

MEA. 2005. Ecosystems and human well-being: Synthesis. Millennium Ecosystem Assessment. World Resources Institute. Island Press, Washington, DC.

NCDEQ. 2016. Meeting Officer's Report Coal Ash Impoundment Classifications, Mayo Steam Electric Plant. April 28, 2016.

NHTSA. 2016. 2015 Motor Vehicle Crashes: Overview. Traffic Safety Facts Research Note. U.S. Department of Transportation. National Highway Traffic Safety Administration. DOT HS 812 318. August 2016.

NCDMV. 2017. North Carolina 2016 Traffic Crash Facts: An Illustrated Analysis of North Carolina Traffic Crash Statistics. North Carolina Division of Motor Vehicles.

NCDOT. 2015. NCDOT 2015 vehicle classification station shapefiles and documentation. North Carolina Department of Transportation. Available from: https://connect.ncdot.gov/resources/State-Mapping/Documents/Forms/AllItems.aspx. Accessed: October 26, 2018.

NOAA. 1990. Excavation and rock washing treatment technology: Net environmental benefit analysis. Hazardous Materials Response Branch, National Oceanic and Atmospheric Administration, Seattle, Washington. July 1990.

NOAA. 1996. Guidance Document for Natural Resource Damage Assessment Under the Oil Pollution Act of 1990. Damage Assessment and Restoration Program, National Oceanic and Atmospheric Administration, Silver Spring, MD. August 1996.

OEHHA. 2015. Air Toxics Hot Spots Program. Guidance Manual for Preparation of Health Risk Assessment. Appendix D. Risk Assessment Procedures to Evaluate Particulate Emissions form Diesel-Fueled Engines. Office of Environmental Health Hazard Assessment California EPA.

OSAT. 2011. Summary Report for the Fate and Effects of Remnant Oil in the Beach Environment. Operational Science Advisory Team - 2. Gulf Coast Incident Management. February 10, 2011.

Penn, T. undated. A Summary of the Natural Resource Damage Assessment Regulations under the United States Oil Pollution Act. National Oceanic and Atmospheric Administration. Silver Spring, MD.

Ricklefs, R.E. 2008. The economy of nature. Sixth edition. W.H. Freeman and Company, New York.

Robberson, B. 2006. Net environmental benefit analysis (NEBA) decision-making tool: Developing consensus for environmental decision-making in emergency response [Internet]. U.S. EPA. Region 9 / Regional Response Teams; [cited 2016 Dec 8]. Available from http://slideplayer.com/slide/4830548/.

SynTerra. 2015a. Comprehensive site assessment report - Mayo Steam Electric Plant. September 2, 2015. Roxboro, NC.

SynTerra. 2015b. Corrective action plan - part 1: Mayo Steam Electric Plant. December 1, 2015. Roxboro, NC.

SynTerra. 2016a. Corrective action plan - part 2: Mayo Steam Electric Plant. February 29, 2016. Roxboro, NC.

SynTerra. 2016b. Comprehensive site assessment, supplement 1 - Mayo Steam Electric Plant. July 7, 2016. Roxboro, NC.

SynTerra. 2016c. Baseline Human Health and Ecological Risk Assessment. Appendix E of Corrective action plan - part 2. February 2016.

SynTerra. 2017. 2017 Comprehensive Site Assessment Update. October 31, 2017. Roxboro, NC.

SynTerra. 2018. Human Health and Ecological Risk Assessment Summary Update. November 2018.

TVA. 2016. Final Ash Impoundment Closure Environmental Impact Statement: Part I – Programmatic NEPA Review. Tennessee Valley Authority. Chattanooga, TN. June 2016.

USGS. 2015. Trace Elements in Coal Ash. Fact Sheet 2015–3037. U.S. Geological Survey. May.

U.S. EPA. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. EPA/540/G-89/004. OSWER Directive 9355.3-01. October 1988.

U.S. EPA. 1989. Risk Assessment Guidance for Superfund: Volume 1 Human Health Evaluation Manual (Part A). U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. EPA/540/1-89/002. December.

U.S. EPA. 1994. RCRA Corrective Action Plan (final). U.S. Environmental Protection Agency, Office of Waste Programs Enforcement, Office of Solid Waste. OSWER Directive 9902.3-2A. May 1994.

U.S. EPA. 1997. Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. EPA 540-R-97-006. June.

U.S. EPA. 1998. Guidelines for Ecological Risk Assessment. U.S. Environmental Protection Agency. EPA/630/R-95/002F. April 1998.

U.S. EPA. 2000. Risk Characterization Handbook. U.S. Environmental Protection Agency, Office of Science Policy and Office of Research and Development, Washington, DC. EPA 100-B-00-002. December.

U.S. EPA. 2009. Characterization of Coal Combustion Residues from Electric Utilities – Leaching and Characterization Data. U.S. Environmental Protection Agency. EPA-600/R-09/151. December.

U.S. EPA. 2010. Superfund Green Remediation Strategy. Office of Superfund Remediation and Technology Innovation. U.S. Environmental Protection Agency. September 2010.

U.S. EPA. 2011. Haul Road Workgroup Recommendations. U.S. Environmental Protection Agency. November 2011.

U.S. EPA. 2015. MOVES2014a User Guide. U.S. Environmental Protection Agency, Assessment and Standards Division, Office of Transportation and Air Quality. EPA-420-B-15-095. November 2015.

U.S. EPA. 2016. User's Guide for the AMS/EPA Regulatory Model (AERMOD). U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division, Air Quality Modeling Group. EPA-454/B-16-011. December 2016.

U.S. EPA. 2017a. About Risk Assessment. https://www.epa.gov/risk/about-risk-assessment#whatisrisk. Last updated: May 1, 2017. Accessed: November 8, 2017.

U.S. EPA. 2017b. Water Quality Criteria. https://www.epa.gov/wqc. Last updated: July 5, 2017. Accessed: November 8, 2017.

U.S. EPA. 2017c. Coal ash basics. https://www.epa.gov/coalash/coal-ash-basics. Last updated: April 26, 2017. Accessed: November 9, 2017.

Williams, W.A., and J.A. Tice. 2018. 2018 Annual Coal Combustion Residuals Surface Impoundment Inspection Report – Rogers Energy Complex. May 16, 2018.

# Appendix A

## *Curriculum Vitae* of Dr. Ann Michelle Morrison, Sc.D.

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## Professional Profile

Dr. Morrison has over 20 years of experience evaluating the relationship between anthropogenic contamination and health effects to aquatic life and humans. Dr. Morrison specializes in natural resource damage assessment (NRDA), environmental causal analysis, and assessments of water quality conditions. Dr. Morrison has provided scientific consultation regarding the design of field studies for NRDA, and she has worked closely with legal counsel during scientific assessments and settlement negotiations with state and federal trustees. Dr. Morrison has performed detailed technical assessments of injuries to aquatic resources, including vegetation, benthic infauna, fishes, shellfishes, and corals. She has also developed site-specific sediment toxicity thresholds based on the empirical relationships of chemical concentrations to biological effects. She has provided expert testimony concerning injury to aquatic resources and the net environmental benefits of remediation alternatives.

Projects she has been involved with have concerned oil spills, sewage releases, heavy metal contamination, and various industrial and municipal facilities that have generated complex releases to the environment. Dr. Morrison applies statistical tools and weight-of-evidence approaches to delineate exposure zones, predict the likelihood of contamination events, evaluate net environmental benefits, and assess causation. She uses a broad knowledge of aquatic life and human health to assess risk and injury to these populations.

## Academic Credentials & Professional Honors

Sc.D., Environmental Health, Harvard University, 2004

M.S., Environmental Health, Harvard University, 2001

B.S., Biology, Rhodes College, 1997

## Prior Experience

Senior Scientist, Sole Proprietor, Morrison Environmental Data Services, 2004–2007

Data Analyst, ETI Professionals, 2005

Scientist, NIH Toxicology Training Grant, Harvard School of Public Health, 2000–2004

Guest Student, Woods Hole Oceanographic Institution, Stegeman Lab, 2001–2004

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Society of Environmental Toxicology and Chemistry — SETAC

North Atlantic Chapter of SETAC

## Publications

Mearns AJ, Reish DJ, Bissell M, Morrison AM, Rempel-Hester MA, Arthur C, Rutherford N, Pryor R. Effects of pollution on marine organisms. Water Environment Research 2018; 90(10):1206–1300.

Mearns AJ, Reish DJ, Oshida PS, Morrison AM, Rempel-Hester MA, Arthur C, Rutherford N, Pryor R. Effects of pollution on marine organisms. Water Environment Research 2017; 89(10):1704–1798.

Morrison AM, Edwards M, Buonagurio J, Cook L, Murray K, Boehm P. Assessing the representativeness and sufficiency of water samples collected during an oil spill. Proceedings, 2017 International Oil Spill Conference, Vol 2017, No 1.

Mearns AJ, Reish DJ, Oshida PS, Morrison AM, Rempel-Hester MA, Arthur C, Rutherford N, Pryor R. Effects of pollution on marine organisms. Water Environment Research 2016; 88(10):1693–1807.

Morrison AM, Kashuba R, Menzie CA. Evaluating alternative causes of environmental change. Environmental Perspectives 2016; 1.

Boehm PD, Morrison AM, Semenova S, Kashuba R, Ahnell A, Monti C. Comprehensive oil spill liability estimation. Environmental Perspectives 2016; 1.

Boehm PD, Morrison AM. Oil spill liability modeling: helping to manage existential risks. Oil & Gas Insight, 2016; 4.

Morrison AMS, Goldstone JV, Lamb DC, Kubota A, Lemaire B, Stegeman JJ. Identification, modeling and ligand affinity of early deuterostome CYP51s, and functional characterization of recombinant zebrafish sterol 14α-demethylase. Biochimica et Biophysica Acta, 2014; 1840:1825–1836.

Menzie C, Kane Driscoll SB, Kierski M, Morrison AM. Advances in risk assessment in support of sediment risk management. In: Processes, Assessment and Remediation of Contaminated Sediments. Reible DD (ed), SERDP ESTCP Environmental Remediation Technology, Vol. 6, pp. 107–130, 2014.

Mudge S, Morrison AM. Tracking sources of sewage in the environment. Environmental Forensic Notes, 2010; 9.

Pietari J, Bigham G, Morrison AM. Source tracking for identification of microbial pollution sources. Environmental Forensic Notes, 2009; 6.

Goldstone JV, Goldstone HMH, Morrison AM, Tarrant AM, Kern SE, Woodin BR, Stegeman JJ. Cytochrome P450 1 genes in early deuterostomes (tunicates and sea urchins) and vertebrates (chicken and frog): Origin and diversification of the CYP1 gene family. Molecular Biology and Evolution 24(12):2619–31, 2007.

Morrison AM. Receiver Operating Characteristic (ROC) Curve Analysis of Antecedent Rainfall and the Alewife/Mystic River Receiving Waters. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2005-04, 2005. 26 p.

Morrison AM, Coughlin K. Results of intensive monitoring at Boston Harbor beaches, 1996–2004. Boston, Massachusetts Water Resources Authority, Report ENQUAD 2005-05, 76 pp., 2004.

Morrison AM, Coughlin K, Shine JP, Coull BA, Rex AC. Receiver operating characteristic curve analysis of beach water quality indicator variables. Applied and Environmental Microbiology, 2003; 69:6405–6411.

Coughlin K, Stanley AM. Boston Harbor beach study suggests a change in beach management. Coastlines, 2001; Issue 11.6.

Coughlin K, Stanley AM. Water quality at four Boston Harbor beaches: Results of intensive monitoring 1996–2000. Boston, Massachusetts Water Resources Authority, Report ENQUAD 2001-18, 46 pp., 2001.

**Published Abstracts**

Stegeman J, Handley-Goldstone H, Goldstone J, Tarrant A, Morrison AM, Wilson J, Kern S. Pantomic studies in environmental toxicology answers, questions and extrapolation. Journal of Experimental Zoology Part a-Comparative Experimental Biology, 2006; 305A:181.

Goldstone JV, Goldstone HMH, Morrison AM, Tarrant A, Kern SE, Woodin BR, Stegeman JJ. Functional evolution of the cytochrome P450I gene family: Evidence of a pre-vertebrate origin. Marine Environmental Research, 2006; 62: S47

Handley HH, Goldstone JV, Morrison AM, Tarrant, Wilson JY, Godard CA, Woodin BR, Stegeman JJ. Abstracts from the 12th International Symposium on Pollutant Responses in Marine Organisms (PRIMO 12) — Receptors and Regulation of Cytochrome P450. Marine Environmental Research, 2004; 58:131+.

Morrison AM, Stegeman JJ. Abstracts from the Twelfth International Symposium on Pollutant Responses in Marine Organisms (PRIMO 12) — Cloning, Expression and Characterization of Cytochrome P450 51: An investigation of CYP51 azole sensitivity in aquatic animals. Marine Environmental Research, 2004; 58:131+.

Morrison AM, Stegeman JJ. CYP51 azole sensitivity in lower vertebrates and invertebrate. Drug Metabolism Reviews: Biotransformation and Disposition of Xenobiotics, 2003; 35(2):179.

**Presentations**

Morrison AM, Ma J, Gard N, Palmquist K, Lin C, Deines A. Ecosystem services accounting in support of corporate environmental stewardship in a changing climate. Society of Environmental Toxicology and Chemistry (SETAC) North America 39th Annual Meeting, Sacramento, CA. November 5–8, 2018.

Pietari J, Morrison AM, Kashuba R, Boehm PD. Incorporating a framework for risk assessment, risk management, and risk mitigation of extreme weather events at Superfund sites. Society of Environmental

Toxicology and Chemistry (SETAC) North America 39th Annual Meeting, Sacramento, CA. November 5–8, 2018.

Deines AM, Palmquist K, Morrison AM. Global Status and Risk of Non-Native Fish Aquaculture. 148th Annual Meeting of the American Fisheries Society, Atlantic City, NJ. August 19–23, 2018.

Morrison AM, Palmquist K, Kashuba R. Baseline in the Open-Access and “Big Data” Era. Law Seminars International. Washington, D.C. March 1, 2018.

Palmquist K, Morrison AM, Edwards ME. Addressing white hat bias: Lessons from environmental litigation. Society of Environmental Toxicology and Chemistry (SETAC) North America 38th Annual Meeting, Minneapolis, MN. November 12–16, 2017.

Palmquist KR, Ginn TC, Morrison AM, Boehm PD. 2017. Addressing Spatial Data Gaps in Deep-sea Benthic Sediment Sampling Following a Large-Scale Oil Spill. Battelle Sediment Conference in New Orleans, LA.

Morrison AM. The Science. Natural Resource Damages 101. Law Seminars International. Washington, D.C. March 9, 2016.

Morrison AM, Murray KJ, Cook LC, Boehm PD. Spatial and Temporal Extent of PAHs Associated with Surface Oil Distributions (Anomalies). Gulf of Mexico Research Initiative Conference. Tampa, FL. February 1–4, 2016.

Boehm PD, Morrison AM. The Interplay of Data Needs and Data Analysis Frameworks to Optimize the Collection and Use of Data from Oil Spills. Gulf of Mexico Research Initiative Conference. Tampa, FL. February 1–4, 2016.

Whaley JE, Morrison AM, Savery LC. Using the Causal Analysis Framework to Investigate Marine Mammal Unusual Mortality Events (poster), Society of Marine Mammalogy Biennial Conference, San Francisco, CA. December 2015.

Kashuba R, Morrison AM, Menzie C. The Application and Misapplication of Directed Acyclic Graphs for Causal Inference in Ecology. Society of Environmental Toxicology and Chemistry (SETAC) North America 36th Annual Meeting, Salt Lake City, UT. November 1–5, 2015.

Kierski M, Morrison AM, Kane Driscoll S, Menzie C. A Refined Multi-Site Model to Estimate the Toxicity of PAH-Contaminated Sediments at MGP Sites. Society of Environmental Toxicology and Chemistry (SETAC) North America 36th Annual Meeting, Salt Lake City, UT. November 1–5, 2015.

Morrison AM, McArdle M, Menzie C. A Tiered Approach to Causal Analysis in Natural Resource Damage Assessment. 35th Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Vancouver, BC, Canada. November 9–13, 2014.

Morrison AM, Kane Driscoll S, McArdle M, Menzie C. Integrated environmental benefit analysis of sediment remediation thresholds. 32nd Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Boston, MA. November 14–17, 2011.

Kierski M, Morrison AM, Kane Driscoll S, Menzie C. A multi-site model to estimate the toxicity of PAH contaminated sediments at MGP sites. 32nd Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Boston, MA. November 14–17, 2011.

Kierski M, Morrison AM, Kane Driscoll S, Menzie C. Use of receiver operating characteristic curve analysis to estimate ecological risk zones as part of an ecological risk assessment. 31st Annual Society of Environmental Toxicology and Chemistry (SETAC) Meeting, Portland, OR. November 7–11, 2010.

Morrison AM, Coughlin K, Rex A. Bayesian network predictions of Enterococcus exceedances at four Boston Harbor beaches. Water Resources Conference 2008, Amherst, MA. April 8, 2008.

Stegeman J, Handley-Goldstone H, Goldstone J, Tarrant A, Morrison AM, Wilson J, Kern S. Pantomic studies in environmental toxicology answers, questions and extrapolation. 15th International Congress of Comparative Endocrinology, Boston, MA. 2005.

Goldstone JV, Goldstone HMH, Morrison AM, Tarrant A, Kern SE, Woodin BR, Stegeman JJ. Functional evolution of the cytochrome P450I gene family: Evidence of a pre-vertebrate origin. 13th International Symposium on Pollutant Responses in Marine Organisms (PRIMO 13), Alessandria, Italy, June 2005.

Morrison AM, Stegeman JJ. CYP51 azole sensitivity in lower vertebrates and invertebrate. 12th North American Meeting of the International Society for the Study of Xenobiotics, Providence, RI. October 12–16, 2003.

Morrison AM, Stegeman JJ. Cloning, expression and characterization of Cytochrome P450 51: An investigation of CYP51 azole sensitivity in aquatic animals. 12th International Symposium, Pollutant Responses in Marine Organisms, Tampa, FL. May 2003.

Handley HH, Goldstone JV, Morrison AM, Tarrant AM, Wilson JY, Godard CA, Woodin BR, Stegeman JJ. 12th International Symposium, Pollutant Responses in Marine Organisms, Tampa, FL. May 2003.

Morrison AM, Coughlin KA, Shine JP, Coull BA, Rex AC. Receiver operating characteristic curve analysis of beach water quality indicator variables. Pathogens, Bacterial Indicators, and Watersheds: Treatment, Analysis, Source Tracking, and Phase II Stormwater Issues. New England Watershed Association, Milford, MA. May 14, 2003.

Stanley AM, Coughlin KA, Shine JP, Coull BA, Rex AC. Receiver operating characteristic analysis is a simple and effective tool for using rainfall data to predict bathing beach bacterial water quality. 102nd General Meeting, American Society for Microbiology, Salt Lake City, UT. May 2002.

Coughlin K, Stanley AM. Five years of intensive monitoring at Boston harbor beaches: Overview of beach water quality and use of the Enterococcus standard to predict water quality. Massachusetts Coastal Zone Marine Monitoring Symposium, Boston, MA. May 2001.

Smith SR, Grayston LM, Stanley AM, Webster G, McKenna SA. CARICOMP coral reef monitoring: A comparison of continuous intercept chain and video transect techniques. Scientific Aspects of Coral Reef Assessment, Monitoring and Management, National Coral Reef Institute (NCRI), Nova Southeastern University, Ft. Lauderdale, FL. 1999.

## Project Experience

Dr. Morrison has been involved in numerous complex projects relating to environmental contamination and potential risk to humans and biological resources in the affected environment.

**Risk Assessments and Natural Resource Assessments**

Expert witness concerning net environmental benefits from coal ash closure alternatives at two coal ash plants in North Carolina. *Roanoke River Basin Association v. Duke Energy Progress,* LLC, United States District Court, Middle District of North Carolina, Case No. 1:16-cv-607 and *Roanoke River Basin Association v. Duke Energy Progress,* LLC, United States District Court, Middle District of North Carolina, Case No. No. 1:17-cv-452.

Expert witness concerning potential damages to terrestrial and aquatic resources, including coral reefs, endangered sea turtles, fish and shellfish, and seagrass beds, resulting from a coastal development project on the Caribbean island of Nevis. Anne Hendricks Bass vs. Director of Physical Planning, Development Advisory Committee, and Caribbean Development Consultant Limited. Eastern Caribbean Supreme Court, in the High Court of Justice Saint Christopher and Nevis, Nevis Circuit, Civil Case No. NEVHCV2016/0014.

Expert witness concerning potential impacts to California fishery populations from the Refugio oil spill. Andrews et al. v. Plains All American Pipeline, L.P. et al. United States District Court, Central District of California, Wester Division, Case No. 2:15-cv-04113-PSG-JEM.

Provided analysis and technical support in Florida v. Georgia United States Supreme Court case that considered questions of causation relative to alleged adverse ecological changes in downstream river and bay populations.

Conducted a comprehensive review of an environmental impact assessment of potential impacts to coral reefs from a proposed dairy farm development in Hawaii.

Provided scientific support for the Deepwater Horizon NRDA in the Gulf of Mexico.

Developed a cooperative NRDA field study in the offshore waters of the Gulf of Mexico to collect sediment samples for analysis of chemistry, toxicology, and benthic infauna.

Expert witness concerning alleged injuries to aquatic resources from disposal of bauxite ore processing wastes for the case: Commissioner of the Department of Planning and Natural Resources, Alicia V. Barnes, et al. v. Virgin Islands Alumina Company et al. District Court of the Virgin Islands, Division of St. Croix, Civil Case No. 2005-0062.

Developed decision management products for beach water quality stakeholders using statistical data analysis tools such as receiver operating characteristic (ROC) curves and Bayesian networks to improve public beach advisories related to elevated fecal bacteria.

Developed net environmental benefit analysis (NEBA) for a lead contaminated river. This analysis used site-specific data to evaluate the costs and benefits of two different remediation options that were being considered. The NEBA was successfully used by the client to negotiate a higher remediation goal than original proposed by the state Department of Environmental Protection.

Performed ROC curve analyses of site-specific polycyclic aromatic hydrocarbon (PAH) toxicity data to assess the relationship between PAH concentration and toxicity at three ecological risk assessment projects in Wisconsin. The curves were used to identify site-specific toxicity thresholds for PAH concentration in sediment that were indicative of various zones of toxicity (no toxicity, low toxicity, and high toxicity), with very limited misidentification of sediments.

Provided research support to calculate site-specific no-observed-adverse-effect level (NOAEL) and lowest-observed-adverse-effect level (LOAEL) concentrations for mammals and birds for use in a baseline ecological risk assessment in Wisconsin.

Performed ROC curve analysis of national mercury toxicity data to assess the relationship between mercury concentration and toxicity. The curves were also used to identify a threshold mercury concentration for sediment that indicates likely toxicity, with very limited misidentification of sediments that are not toxic.

Assembled and analyzed data and reviewed remedial investigations to conduct a screening-level ecological risk assessment for sediment, surface water, and groundwater for a site in Connecticut. The chemicals considered were total petroleum hydrocarbons (TPH), metals, and PAHs.

Reviewed species lists and created summary descriptions of organisms that could be potentially impacted by dam construction on a high-altitude river in the Caribbean. This information was important to develop the risk assessment from dam construction.

Researched the toxicity of malathion to fish to support a technical review of the National Marine Fisheries biological opinion for the registration of pesticides containing malathion.

**Ecological and Toxicity Studies**

Conducted surveys to assess the health of coral reefs, seagrass beds, and mangrove swamps in the nearshore environment of Bermuda. Projects included area-wide habitat surveys as well as targeted sites potentially impacted by a heavy metals dump, hot water effluent from an incinerator, sedimentation from cruise ship traffic, and chronic release of raw sewage. In addition to ecological surveys, water quality was assessed through measurements of trace metals in water, sediment, and coral tissue.

Surveyed juvenile coral recruitment in the Florida Keys to evaluate if marine protected areas (MPAs) provide a benefit to coral recruitment.

Studied cytochrome P450 family enzymes, including CYP51 and CYP1, examining their sensitivity to environmental chemicals and their evolution through molecular biology and biochemistry approaches.

**Environmental Forensics Projects**

Performed document review, information management, and technical writing for numerous complex projects that dealt with historical petroleum contamination and multiple site owners in several types of environmental media.

Reviewed documents, assembled data, and researched metal concentrations associated with crude oil and railroads in support of a Superfund project in Oklahoma.

Examined the correlation of multiple contaminants (PAHs, metals) with polychlorinated biphenyl (PCB) congeners at a historically contaminated site in Alabama to identify the likely origins of the PCB contamination.

Performed statistical analysis to determine source contribution in a chemical fingerprinting case at a Superfund site in Washington that involved hydrocarbons in water, sediment, and groundwater.

**Human Health Projects**

Organized, managed, and simplified a complex database of field sampling reports for a litigation case in Louisiana regarding human air exposure to PAHs.

Performed data analysis and document review for a Superfund site in Oklahoma. The analyses used hydrocarbon chromatograms and limited PAH and metal data to identify the likely sources of contamination.

Researched and compiled screening-level human health inhalation toxicity values for refinery-related gases for an overseas project.

Developed a questionnaire and related database for industrial hygiene surveys to support regulatory compliance for a highly specialized industry.

# Appendix B

## Human Health and Ecological Risk Assessment Summary Update for Mayo Steam Electric Plant

# Human Health And Ecological Risk Assessment

## Summary Update

### For

**Mayo Steam Electric Plant**
**10660 Boston Road**
**Roxboro, North Carolina 27574**

**November 2018**

**Prepared For**

**Duke Energy Progress, LLC**
**526 South Church Street**
**Charlotte, North Carolina 28202**


Matt Huddleston, Ph.D.
Senior Scientist

Heather Smith
Environmental Scientist

# 1.0 INTRODUCTION

This update to the Mayo Steam Electric Plant (Mayo or Site) human health and ecological risk assessment incorporates results from sampling events conducted October 2008 through July 2018. The samples were collected from surface water, sediment, and groundwater. This update was performed in support of a Net Environmental Benefits Analysis. As set forth below in detail, this updated risk assessment concludes that: (1) the Mayo ash basin does not cause any material increase in risks to human health for potential human receptors located on-Site or off-Site; and (2) the Mayo ash basin does not cause any material increase in risks to ecological receptors.

The original 2016 risk assessment was a component of the Corrective Action Plan Part 2 pertaining to Mayo (SynTerra, 2016). To assist in corrective action decision making, the risk assessment characterized potential effects on humans and wildlife exposed to naturally occurring elements, often associated with coal ash, present in environmental media. Corrective action is to be implemented with the goal of ensuring future site conditions remain protective of human health and the environment, as required by the 2014 North Carolina General Assembly Session Law 2014-122, Coal Ash Management Act (CAMA). The risk assessment was updated as part of the 2017 Comprehensive Site Assessment (CSA) Update report (SynTerra, 2017). This update follows the methods of the 2016 risk assessment (SynTerra, 2016) and is based on U.S. Environmental Protection Agency (USEPA) risk assessment guidance (USEPA, 1989; 1991; 1998).

Areas of wetness (AOWs), or seeps, are not subject to this risk assessment update. AOWs associated with engineered structures, also referred to as "constructed seeps," have been addressed in a National Pollutant Discharge Elimination System (NPDES) permit. Under the permit, Duke Energy is required to capture the discharge from the constructed seeps and pump it back into the basin. Other AOWs (non-constructed seeps) are now addressed under a Special Order by Consent (SOC) issued by the North Carolina Environmental Management Commission (EMC SOC WQ S18-005). Many AOWs are expected to reduce in flow or be eliminated after decanting (*i.e.*, removal of the free water). The SOC requires that any seeps remaining after decanting must be addressed with a corrective action plan that must "protect public health, safety, and welfare, the environment, and natural resources" (EMC SOC WQ S18-005, 2. d.).

This risk assessment update includes results from samples of surface water, sediment, and groundwater collected since the 2017 CSA update. New information regarding groundwater flow and the treatment of source areas other than the ash basin has resulted in refinement of exposure pathways and exposure areas. The Conceptual Site

Models (CSMs) (**Figures 1 and 2**) reflect potentially complete exposure pathways with potential risks, and exposure areas are depicted in **Figures 3 and 4**. Changes to the CSMs include:

- Exposure to coal combustion residual (CCR) constituents by Site workers is considered incomplete, because Duke Energy maintains strict health and safety requirements and training. The use of personal protective equipment (*e.g.*, boots, gloves, safety glasses) and other safety behaviors exhibited by Site workers limits exposure to CCR constituents. Following conservative risk assessment practices, the initial risk assessment report considered CCR constituent exposure pathways for Site workers to be potentially complete. Further information has revealed that on-Site worker exposure pathways are incomplete, and this risk assessment update has been revised to reflect this change.

- Swimming, boating, and fishing exposures are considered incomplete because updated modeling and data collection demonstrate that groundwater migration from the ash basin does not influence Mayo Lake, and observations of Crutchfield Branch confirms that it is not of sufficient size to support these recreational uses.

- The number of human exposure areas reduced from three to two (**Figure 3**), and the number of ecological exposure areas reduced from four to one (**Figure 4**). Other exposure areas evaluated in the 2016 risk assessment were eliminated because they are not influenced by groundwater flow from the ash basin.

Results from samples of surface water, sediment, and groundwater were compared with human health and ecological screening values (**Attachments 1 and 2**) to identify constituents of potential concern (COPCs) for further review. Exposure point concentrations (EPCs) were calculated for COPCs (**Attachments 3 and 4**) to incorporate into human health and ecological risk models. Results of risk estimates (**Attachments 5 and 6**) are summarized below.

# 2.0 SUMMARY OF RISK FINDINGS

## 2.1 Human Health

There is no exposure to residential receptors at Mayo because no one lives on-Site or near enough to the Site to be affected by groundwater migration from the ash basin. A potential receptor off-Site is a recreational wader in Crutchfield Branch. However, background concentrations of the same elements also present similar risks to the same potential receptors. Those risks are not associated with the ash basin.

- There is no material increase in risks associated with the off-Site wader exposure scenario.
    - There is no material increase in cancer risks attributable to the ash basin for the wader exposure scenario. Incorporating hexavalent chromium concentrations in surface water samples collected since the 2017 CSA update produced modeled potential carcinogenic risks under the wader scenario. However, the modeled risks are not materially greater than the background level of risk. The hexavalent chromium EPC calculated based on sampling data for use in the risk assessment was 1.6 μg/L, compared to the upstream concentration of 0.94 μg/L. Although the EPC was slightly greater than the background, it does not produce a materially greater amount of risk in the model. There is, therefore, no material increase in cancer risks attributable to the ash basin.
    - No evidence of non-carcinogenic risks for the recreational wader was identified.
- There is no increase in risks associated with on-Site exposure scenarios.
    - The updated risk assessment found no evidence of risks associated with exposure to groundwater by Site workers.
    - Trespasser exposure was evaluated based on surface water and sediment samples collected from the shallow on-Site portions of Crutchfield Branch, which identified hexavalent chromium as a constituent of potential concern. The hexavalent chromium EPC calculated based upon sampling data for use in the risk assessment for on-Site surface water was 0.36 μg/L, compared to the upstream concentration of 0.94 μg/L at sampling location SW-REF1. There is, therefore, no increase in risks associated with the trespasser exposure scenario.

In summary, there is no material increase in risks to human health attributable to the Mayo ash basin.

## 2.2 Ecological

There is no evidence of ecological risks associated with the Crutchfield Branch exposure area.

- In practice, ecological risks are quantified by comparing an average daily dose (ADD) of a constituent to a toxicity reference value (TRV) for a given wildlife receptor. The ratio of the ADD and TRV is the hazard quotient (HQ), where an HQ less than unity (1) indicates no evidence of risks. TRVs are generally no-observed-adverse-effects-levels (NOAEL) or a lowest-observed-adverse-effects-levels (LOAEL) from toxicity studies published in scientific literature.
- No HQs based on NOAELS or LOAELs exceeded unity for the wildlife receptors (mallard duck, great blue heron, muskrat, river otter, bald eagle, American robin, meadow vole, red-tailed hawk, red fox) exposed to surface water and sediments.

In summary, the Mayo ash basin does not cause any increase in risks to ecological receptors.

# 3.0 REFERENCES

SynTerra. (2016). Corrective Action Plan Part 2 – Mayo Steam Electric Plant, February 2016.

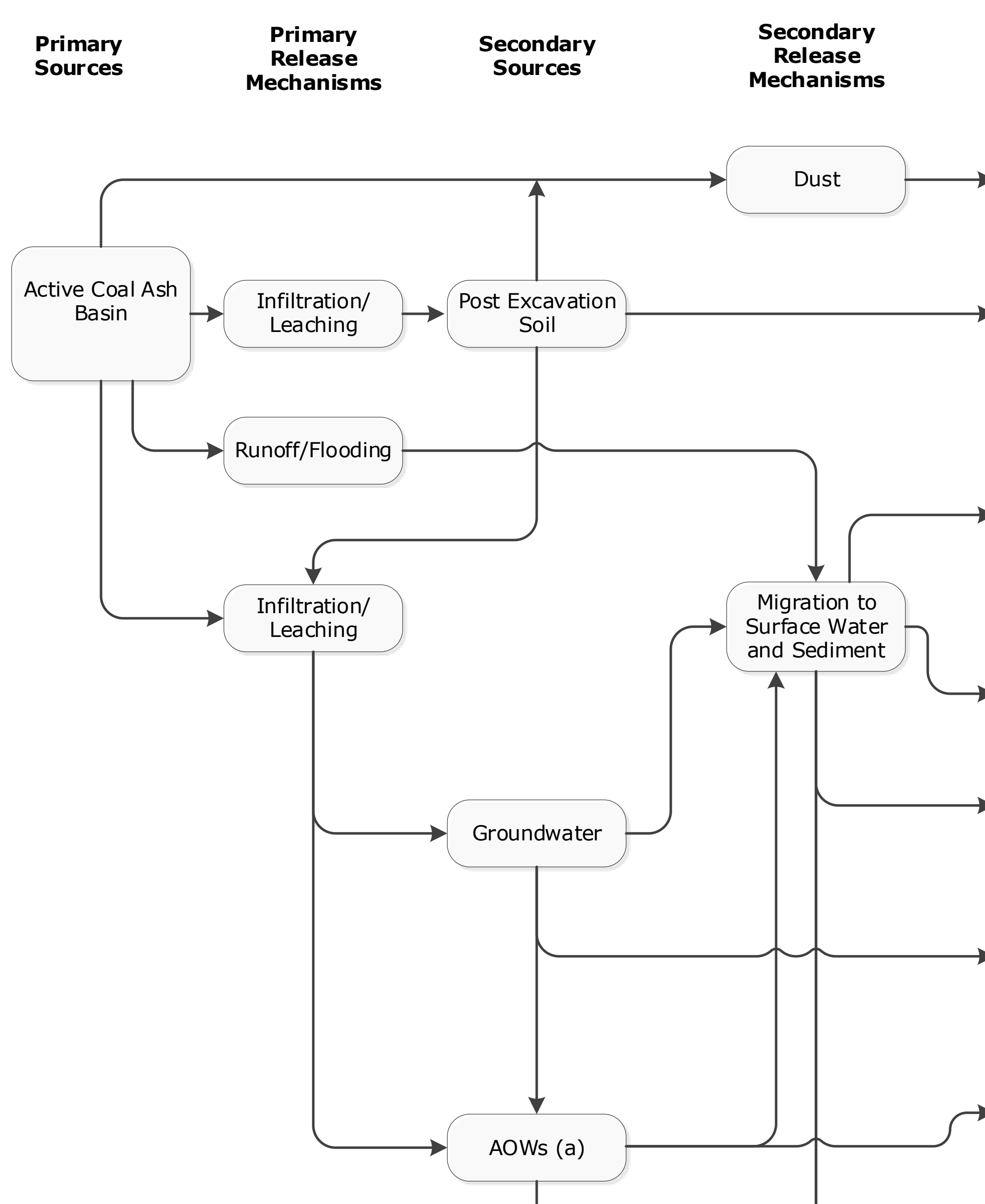
SynTerra. (2017). 2017 Comprehensive Site Assessment Update, October 2017.

United States Environmental Protection Agency. (1989). Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part A). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/1-89/002.

United States Environmental Protection Agency. (1991). Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). Office of Emergency and Remedial Response, Washington, D.C. EPA/540/R-92/003.

United States Environmental Protection Agency. (1998). Guidelines for Ecological Risk Assessment. Washington, D.C. EPA/630/R-95/002F.

# FIGURES




| Potential Exposure Media | Potential Exposure Route | Current/ Future Off-Site Resident Adult/Child | Current/ Future On-Site Recreational Trespasser | Current/ Future Off-Site Recreational Swimmer | Current/ Future Off-Site Recreational Wader | Current/ Future Off-Site Recreational Boater | Current/ Future Off-Site Recreational / Subsistence Fisher | Current/ Future On-site Commercial/ Industrial Worker | Current/ Future On-Site Construction Worker |
|---|---|---|---|---|---|---|---|---|---|
| | | **Human Receptors** | | | | | | | |
| Outdoor Air | Inhalation | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Soil Remaining Post-Excavation (b) | Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Surface Water (Off-site) | Drinking Water Use (e) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Incidental Ingestion | ○ | ● | ○ | ●(d) | ○ | ○ | ○ | ○ |
| | Dermal Contact | ○ | ○ | ○ | ● | ○ | ○ | ○ | ○ |
| Sediment (Off-site) | Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Fish Tissue (c) | Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Groundwater | Drinking Water Use | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○(e) |
| | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○(e) |
| AOW Water (On-site) | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| AOW Soil (On-site) | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Surface Water (On-site) | Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Sediment (On-site) | Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Dermal Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**NOTES**

● Potentially complete exposure pathway based on results of 2018 risk assessment update.

○ Pathway evaluated and found incomplete/insignificant.

(a) Areas of wetness (AOWs) are addressed in the Special Order by Consent (SOC) and not evaluated in the risk assessment update at this time.

(b) Pathway incomplete as long as ash remains in place; re-evaluation upon excavation (if conducted) may be warranted.

(c) Concentration of COPC in fish tissue modeled from surface water concentration.

(d) Incidental surface water ingestion assumed only to occur for receptors for the wading scenario.

(e) Groundwater exposure evaluated in the risk assessment update, although an incomplete exposure pathway for construction worker.

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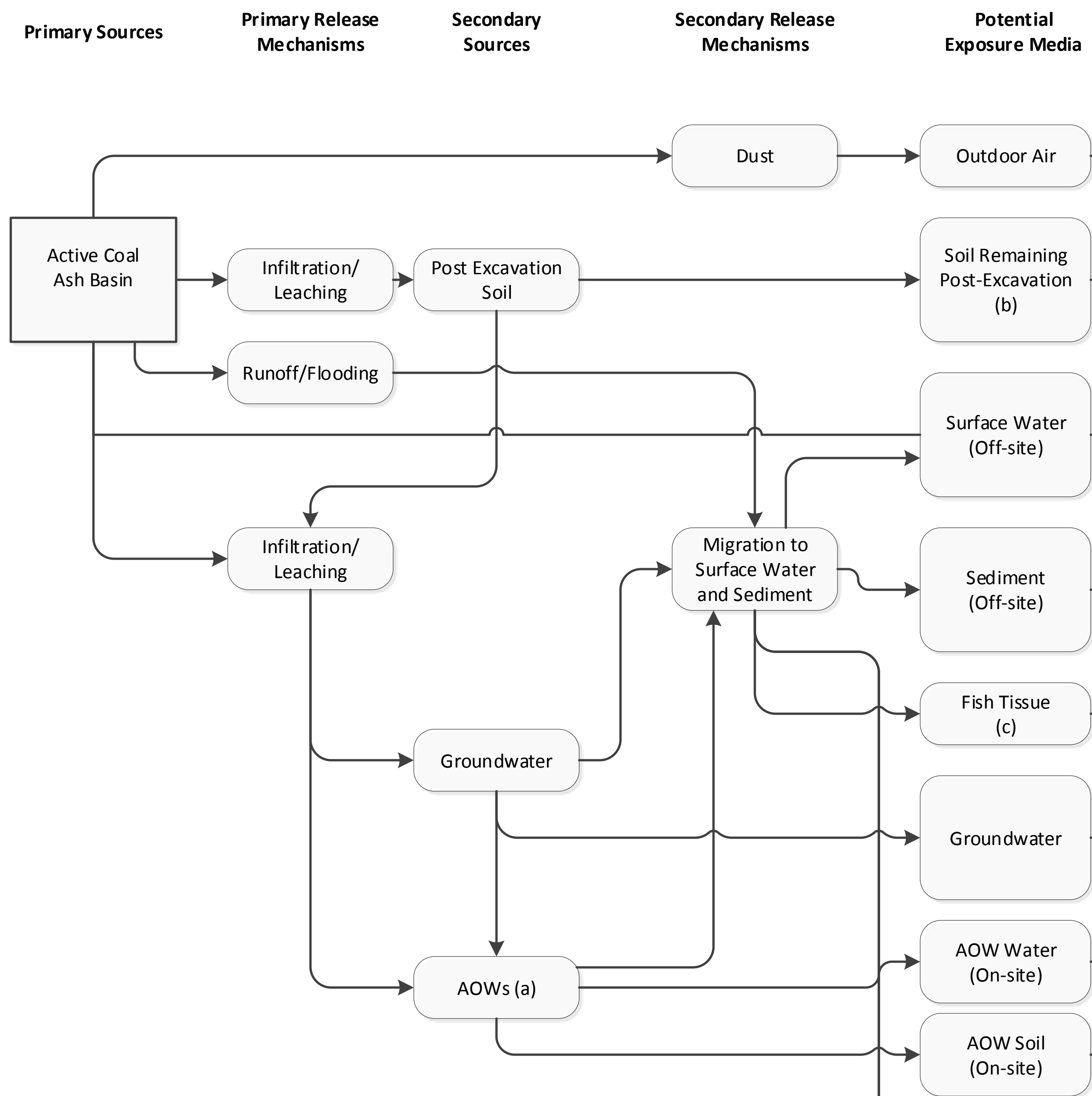
**FIGURE 1**
**HUMAN HEALTH RISK ASSESSMENT**
**CONCEPTUAL SITE MODEL**
**MAYO STEAM ELECTRIC PLANT**
**ROXBORO, NORTH CAROLINA**




| Potential Exposure Media | Potential Exposure Route | AQUATIC RECEPTORS: Fish | AQUATIC RECEPTORS: Benthic Invertebrates | AQUATIC RECEPTORS: Avian (e): Mallard (Omnivore) | AQUATIC RECEPTORS: Avian (e): Great Blue Heron (Piscivore) | AQUATIC RECEPTORS: Mammal: Muskrat (Herbivore) | AQUATIC RECEPTORS: Mammal: River Otter (Piscivore) | TERRESTRIAL RECEPTORS (e): Avian: Robin (Omnivore) | TERRESTRIAL RECEPTORS (e): Avian: Red-Tailed Hawk (Carnivore) | TERRESTRIAL RECEPTORS (e): Mammal: Meadow Vole (Herbivore) | TERRESTRIAL RECEPTORS (e): Mammal: Red Fox (Carnivore) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Outdoor Air | Inhalation | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Soil Remaining Post-Excavation (b) | Plant/Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Surface Water (Off-site) | Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ●(d) | ●(d) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Sediment (Off-site) | Plant/Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ○ | ●(d) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Fish Tissue (c) | Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Groundwater | Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| AOW Water (On-site) | Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| AOW Soil (On-site) | Plant/Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Surface Water (On-site) | Ingestion | ●(d) | ●(d) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| Sediment (On-site) | Plant/Incidental Ingestion | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |
| | Direct Contact | ○ | ●(d) | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

**NOTES**

● Potentially complete exposure pathways based on results o 2018 risk assessment update.

○ Pathway evaluated and found incomplete/insignificant.

(a) Areas of wetness (AOWs) are addressed in the Special Order by Consent (SOC) and not evaluated in the risk assessment update at this time.

(b) Pathway incomplete as long as ash remains in place; re-evaluation upon excavation (if conducted) may be warranted.

(c) Concentration of COPC in fish tissue modeled from surface water concentration.

(d) Based on screening against aquatic life criteria.

(e) Bald eagle (carnivore) included in the ecological risk assessment.

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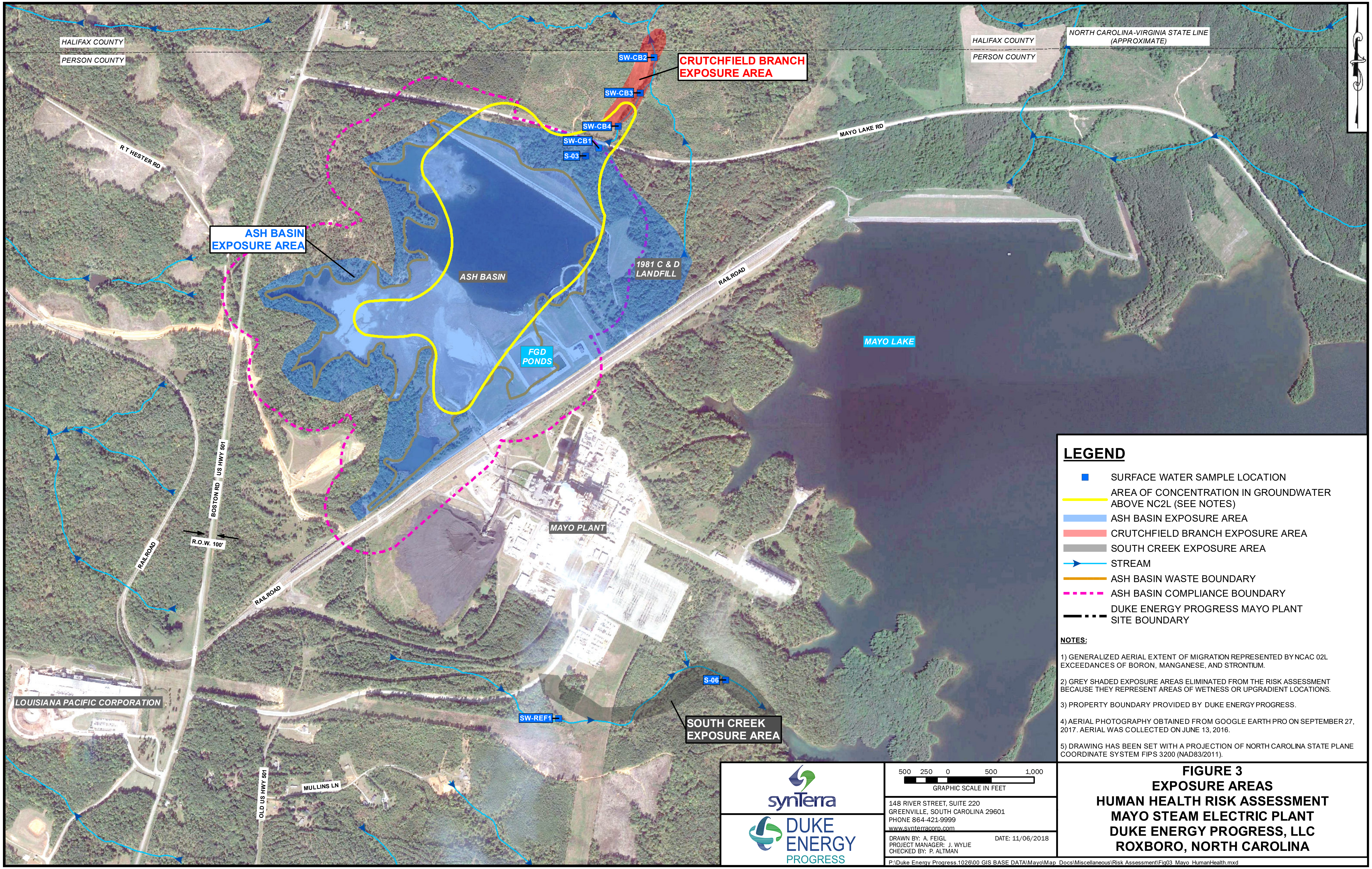
**FIGURE 2**
**ECOLOGICAL RISK ASSESSMENT**
**CONCEPTUAL SITE MODEL**
**MAYO STEAM ELECTRIC PLANT**
**ROXBORO, NORTH CAROLINA**




## LEGEND

- SURFACE WATER SAMPLE LOCATION
- AREA OF CONCENTRATION IN GROUNDWATER ABOVE NC2L (SEE NOTES)
- ASH BASIN EXPOSURE AREA
- CRUTCHFIELD BRANCH EXPOSURE AREA
- SOUTH CREEK EXPOSURE AREA
- STREAM
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- DUKE ENERGY PROGRESS MAYO PLANT SITE BOUNDARY

**NOTES:**

1) GENERALIZED AERIAL EXTENT OF MIGRATION REPRESENTED BY NCAC 02L EXCEEDANCES OF BORON, MANGANESE, AND STRONTIUM.

2) GREY SHADED EXPOSURE AREAS ELIMINATED FROM THE RISK ASSESSMENT BECAUSE THEY REPRESENT AREAS OF WETNESS OR UPGRADIENT LOCATIONS.

3) PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY PROGRESS.

4) AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON SEPTEMBER 27, 2017. AERIAL WAS COLLECTED ON JUNE 13, 2016.

5) DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83/2011).

synTerra

DUKE ENERGY PROGRESS

500 250 0 500 1,000

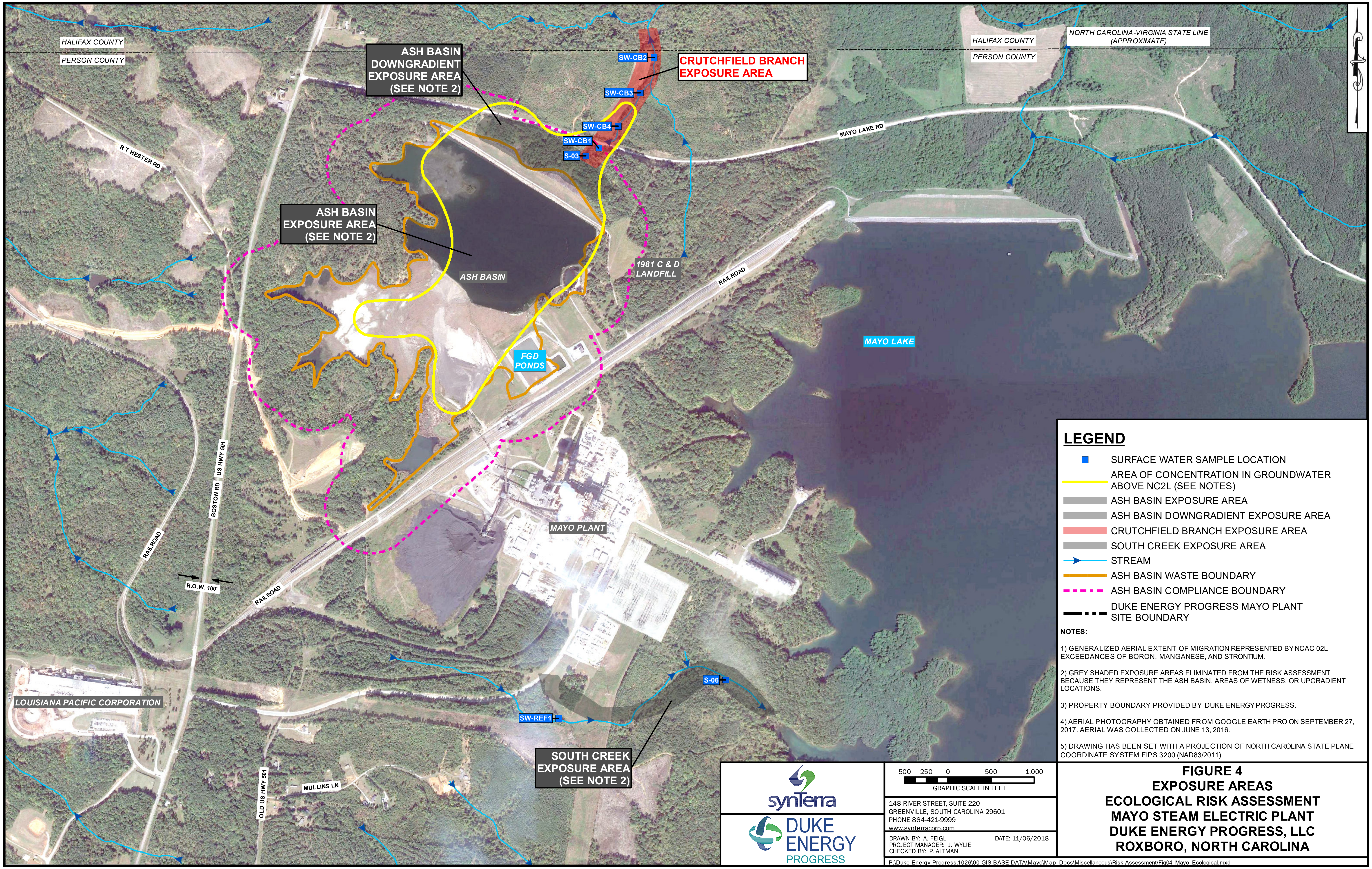
GRAPHIC SCALE IN FEET


148 RIVER STREET, SUITE 220
GREENVILLE, SOUTH CAROLINA 29601
PHONE 864-421-9999
www.synterracorp.com


DRAWN BY: A. FEIGL
DATE: 11/06/2018
PROJECT MANAGER: J. WYLIE
CHECKED BY: P. ALTMAN

# FIGURE 3
# EXPOSURE AREAS
# HUMAN HEALTH RISK ASSESSMENT
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC
# ROXBORO, NORTH CAROLINA

P:\Duke Energy Progress.1026\00 GIS BASE DATA\Mayo\Map_Docs\Miscellaneous\Risk Assessment\Fig03_Mayo_HumanHealth.mxd




## LEGEND

- SURFACE WATER SAMPLE LOCATION
- AREA OF CONCENTRATION IN GROUNDWATER ABOVE NC2L (SEE NOTES)
- ASH BASIN EXPOSURE AREA
- ASH BASIN DOWNGRADIENT EXPOSURE AREA
- CRUTCHFIELD BRANCH EXPOSURE AREA
- SOUTH CREEK EXPOSURE AREA
- STREAM
- ASH BASIN WASTE BOUNDARY
- ASH BASIN COMPLIANCE BOUNDARY
- DUKE ENERGY PROGRESS MAYO PLANT SITE BOUNDARY

NOTES:

1) GENERALIZED AERIAL EXTENT OF MIGRATION REPRESENTED BY NCAC 02L EXCEEDANCES OF BORON, MANGANESE, AND STRONTIUM.

2) GREY SHADED EXPOSURE AREAS ELIMINATED FROM THE RISK ASSESSMENT BECAUSE THEY REPRESENT THE ASH BASIN, AREAS OF WETNESS, OR UPGRADIENT LOCATIONS.

3) PROPERTY BOUNDARY PROVIDED BY DUKE ENERGY PROGRESS.

4) AERIAL PHOTOGRAPHY OBTAINED FROM GOOGLE EARTH PRO ON SEPTEMBER 27, 2017. AERIAL WAS COLLECTED ON JUNE 13, 2016.

5) DRAWING HAS BEEN SET WITH A PROJECTION OF NORTH CAROLINA STATE PLANE COORDINATE SYSTEM FIPS 3200 (NAD83/2011).

synTerra

DUKE ENERGY PROGRESS

500 250 0 500 1,000

GRAPHIC SCALE IN FEET

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DRAWN BY: A. FEIGL DATE: 11/06/2018
PROJECT MANAGER: J. WYLIE
CHECKED BY: P. ALTMAN

# FIGURE 4
# EXPOSURE AREAS
# ECOLOGICAL RISK ASSESSMENT
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC
# ROXBORO, NORTH CAROLINA

P:\Duke Energy Progress.1026\00 GIS BASE DATA\Mayo\Map_Docs\Miscellaneous\Risk Assessment\Fig04_Mayo_Ecological.mxd

# ATTACHMENTS

**TABLE 1-1**
**HUMAN HEALTH SCREENING - GROUNDWATER (SURFICIAL)**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (µg/L) | | Concentration Used for Screening (µg/L) | 15A NCAC 02L .0202 Standard (e) (µg/L) | 15A NCAC 02L .0202 IMAC (e) (µg/L) | DHHS Screening Level (d) (µg/L) | Federal MCL/ SMCL (c) (µg/L) | Tap Water RSL HI = 0.2 (a) (µg/L) | Screening Value Used (µg/L) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | | | | | | | |
| Aluminum | 7429-90-5 | 32 | 28 | 6 | 158 | 158 | NA | NA | 3,500 | 50 to 200 (i) | 4,000 | 3,500 | N |
| Antimony | 7440-36-0 | 72 | 1 | 2 | 2 | 2 | 1 | NA | 1 | 6 | 1.56 (m) | 1 | Y |
| Arsenic | 7440-38-2 | 72 | 11 | 0.4 | 2.44 | 2.44 | 10 | NA | 10 | 10 | 0.052 (h,jj) | 10 | N |
| Barium | 7440-39-3 | 72 | 72 | 20 | 137 | 137 | 700 | NA | 700 | 2,000 | 760 | 700 | N |
| Beryllium | 7440-41-7 | 72 | 1 | 0.502 | 0.502 | 0.502 | NA | 4 | 4 | 4 | 5 | 4 | N |
| Boron | 7440-42-8 | 72 | 68 | 122 | 1,330 | 1,330 | 700 | NA | 700 | NA | 800 | 700 | Y |
| Cadmium | 7440-43-9 | 72 | 1 | 0.092 | 0.092 | 0.092 | 2 | NA | 2 | 5 | 1.84 | 2 | N |
| Chromium (Total) | 7440-47-3 | 72 | 16 | 0.54 | 43 | 43 | 10 | NA | 10 | 100 | 4,400 (n) | 10 | Y |
| Chromium (VI) | 18540-29-9 | 24 | 12 | 0.028 | 0.62 | 0.62 | NA | NA | 0.07 | NA | 0.035 (jj) | 0.07 | Y |
| Cobalt | 7440-48-4 | 68 | 44 | 1.07 | 10.3 | 10.3 | NA | 1 | 1 | NA | 1.2 | 1 | Y |
| Copper | 7440-50-8 | 36 | 5 | 0.338 | 1.32 | 1.32 | 1,000 | NA | 1,000 | 1,300 (k) | 160 | 1,000 | N |
| Lead | 7439-92-1 | 72 | 2 | 0.22 | 1 | 1 | 15 | NA | 15 | 15 (l) | 15 (jj) | 15 | N |
| Lithium | 7439-93-2 | 42 | 0 | ND | ND | ND | NA | NA | NA | NA | 8 | 8 | N |
| Manganese | 7439-96-5 | 36 | 36 | 6 | 1,530 | 1,530 | 50 | NA | 200 | 50 (i) | 86 | 50 | Y |
| Mercury | 7439-97-6 | 72 | 3 | 0.06 | 0.12 | 0.12 | 1 | NA | 1 | 2 | 1.14 (o) | 1 | N |
| Molybdenum | 7439-98-7 | 68 | 23 | 0.108 | 6.12 | 6.12 | NA | NA | 18 | NA | 20 | 18 | N |
| Nickel | 7440-02-0 | 36 | 26 | 0.627 | 4 | 4 | 100 | NA | 100 | NA | 78 (p) | 100 | N |
| Selenium | 7782-49-2 | 72 | 1 | 1.6 | 1.6 | 1.6 | 20 | NA | 20 | 50 | 20 | 20 | N |
| Strontium | 7440-24-6 | 32 | 32 | 55 | 342 | 342 | NA | NA | 2,100 | NA | 2,400 | 2,100 | N |
| Thallium | 7440-28-0 | 72 | 0 | ND | ND | ND | 0.2 | NA | 0.2 | 2 | 0.04 (q) | 0.2 | N |
| Vanadium | 7440-62-2 | 32 | 13 | 0.175 | 0.711 | 0.711 | NA | NA | 0.3 | NA | 17.2 | 0.3 | Y |
| Zinc | 7440-66-6 | 36 | 18 | 2.738 | 39 | 39 | 1 | NA | 1 | 5,000 (i) | 1,200 | 1 | Y |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122,
http://www.ncleg.net/Sessions/2013/Bills
/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitation Limit (PQL) but above Method Detection Limit (MDL) and therefore concentration is estimated

# TABLE 1-1
# HUMAN HEALTH SCREENING - GROUNDWATER (SURFICIAL)
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.
(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf
(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental
Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf
(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.
(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.
(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf
(h) - Value applies to inorganic form of arsenic only.
(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals
(j) - Value for Total Chromium.
(k) - Copper Treatment Technology Action Level is 1.3 mg/L.
(l) - Lead Treatment Technology Action Level is 0.015 mg/L.
(m) - RSL for Antimony (metallic) used for Antimony.
(n) - Value for Chromium (III), Insoluble Salts used for Chromium.
(o) - RSL for Mercuric Chloride used for Mercury.
(p) - RSL for Nickel Soluble Salts used for Nickel.
(q) - RSL for Thallium (Soluble Salts) used for Thallium.
(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(s) - Value for Inorganic Mercury.
(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 μ/gL and 12.82 μ/gL, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.
(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 μ/gL.
(w) - Applicable only to persons with a sodium restrictive diet.
(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php
(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.
(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.
(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.
(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (μg/kg dw)
(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/
(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf
(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents
(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)
(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)
(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361
(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included
as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.
(jj) - Hazard Index = 0.1

## TABLE 1-2
## HUMAN HEALTH SCREENING - GROUNDWATER (TRANSITION/BEDROCK)
## MAYO STEAM STATION
## DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (µg/L) Min. | Range of Detection (µg/L) Max. | Concentration Used for Screening (µg/L) | 15A NCAC 02L .0202 Standard (e) (µg/L) | 15A NCAC 02L .0202 IMAC (e) (µg/L) | DHHS Screening Level (d) (µg/L) | Federal MCL/ SMCL (c) (µg/L) | Tap Water RSL HI = 0.2 (a) (µg/L) | Screening Value Used (µg/L) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 7429-90-5 | 390 | 357 | 4.845 | 2,110 | 2,110 | NA | NA | 3,500 | 50 to 200 (i) | 4,000 | 3,500 | N |
| Antimony | 7440-36-0 | 479 | 8 | 0.13 | 3.68 | 3.68 | 1 | NA | 1 | 6 | 1.56 (m) | 1 | Y |
| Arsenic | 7440-38-2 | 479 | 62 | 0.28 | 143 | 143 | 10 | NA | 10 | 10 | 0.052 (h,jj) | 10 | Y |
| Barium | 7440-39-3 | 479 | 416 | 1.845 | 1,080 | 1,080 | 700 | NA | 700 | 2,000 | 760 | 700 | Y |
| Beryllium | 7440-41-7 | 375 | 0 | ND | ND | ND | NA | 4 | 4 | 4 | 5 | 4 | N |
| Boron | 7440-42-8 | 479 | 127 | 3 | 5,090 | 5,090 | 700 | NA | 700 | NA | 800 | 700 | Y |
| Cadmium | 7440-43-9 | 479 | 20 | 0.037 | 2.19 | 2.19 | 2 | NA | 2 | 5 | 1.84 | 2 | Y |
| Chromium (Total) | 7440-47-3 | 479 | 47 | 0.383 | 53 | 53 | 10 | NA | 10 | 100 | 4,400 (n) | 10 | Y |
| Chromium (VI) | 18540-29-9 | 174 | 89 | 0.025 | 3.7 | 3.7 | NA | NA | 0.07 | NA | 0.035 (jj) | 0.07 | Y |
| Cobalt | 7440-48-4 | 367 | 58 | 0.404 | 6.71 | 6.71 | NA | 1 | 1 | NA | 1.2 | 1 | Y |
| Copper | 7440-50-8 | 398 | 58 | 0.508 | 184 | 184 | 1,000 | NA | 1,000 | 1,300 (k) | 160 | 1,000 | N |
| Lead | 7439-92-1 | 479 | 11 | 0.1 | 11 | 11 | 15 | NA | 15 | 15 (l) | 15 (jj) | 15 | N |
| Lithium | 7439-93-2 | 125 | 45 | 1.672 | 24 | 24 | NA | NA | NA | NA | 8 | 8 | Y |
| Manganese | 7439-96-5 | 398 | 370 | 5 | 6,960 | 6,960 | 50 | NA | 200 | 50 (i) | 86 | 50 | Y |
| Mercury | 7439-97-6 | 479 | 24 | 0.06 | 0.66 | 0.66 | 1 | NA | 1 | 2 | 1.14 (o) | 1 | N |
| Molybdenum | 7439-98-7 | 367 | 223 | 0.358 | 269 | 269 | NA | NA | 18 | NA | 20 | 18 | Y |
| Nickel | 7440-02-0 | 398 | 75 | 0.38 | 56 | 56 | 100 | NA | 100 | NA | 78 (p) | 100 | N |
| Selenium | 7782-49-2 | 479 | 10 | 0.395 | 150 | 150 | 20 | NA | 20 | 50 | 20 | 20 | Y |
| Strontium | 7440-24-6 | 270 | 270 | 57 | 3,070 | 3,070 | NA | NA | 2,100 | NA | 2,400 | 2,100 | Y |
| Thallium | 7440-28-0 | 479 | 7 | 0.012 | 0.361 | 0.361 | 0.2 | NA | 0.2 | 2 | 0.04 (q) | 0.2 | Y |
| Vanadium | 7440-62-2 | 278 | 188 | 0.134 | 23.3 | 23.3 | NA | NA | 0.3 | NA | 17.2 | 0.3 | Y |
| Zinc | 7440-66-6 | 398 | 137 | 1.973 | 110 | 110 | 1 | NA | 1 | 5,000 (i) | 1,200 | 1 | Y |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122,
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/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
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CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitation Limit (PQL) but above Method Detection Limit (MDL) and therefore concentration is estimated

**TABLE 1-2**
**HUMAN HEALTH SCREENING - GROUNDWATER (TRANSITION/BEDROCK)**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
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USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.
(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf
(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental
Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf
(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.
(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.
(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf
(h) - Value applies to inorganic form of arsenic only.
(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals
(j) - Value for Total Chromium.
(k) - Copper Treatment Technology Action Level is 1.3 mg/L.
(l) - Lead Treatment Technology Action Level is 0.015 mg/L.
(m) - RSL for Antimony (metallic) used for Antimony.
(n) - Value for Chromium (III), Insoluble Salts used for Chromium.
(o) - RSL for Mercuric Chloride used for Mercury.
(p) - RSL for Nickel Soluble Salts used for Nickel.
(q) - RSL for Thallium (Soluble Salts) used for Thallium.
(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(s) - Value for Inorganic Mercury.
(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 µ/gL and 12.82 µ/gL, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.
(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µ/gL.
(w) - Applicable only to persons with a sodium restrictive diet.
(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php
(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.
(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.
(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.
(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)
(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/
(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf
(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents
(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)
(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)
(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361
(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included
as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.
(jj) - Hazard Index = 0.1

**TABLE 1-3**
**HUMAN HEALTH SCREENING - OFFSITE SEDIMENT**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (mg/kg) | | Concentration Used for Screening (mg/kg) | NC PSRG Residential Health Screening Level (hh) (mg/kg) | Residential Soil RSL (a) HI = 0.2 (mg/kg) | NC PSRG Industrial Health Screening Level (hh) (mg/kg) | Industrial Soil RSL (a) HI = 0.2 (mg/kg) | Residential Screening Value Used (mg/kg) | Industrial Screening Value Used (mg/kg) | Residential COPC? | Industrial COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | | | | | | | | |
| Aluminum | 7429-90-5 | 3 | 3 | 2,300 | 7,350 | 7,350 | 15,000 | 15,400 | 100,000 | 220,000 | 15,000 | 100,000 | N | N |
| Antimony | 7440-36-0 | 3 | 0 | ND | ND | ND | 6.2 (m) | 6.2 (m) | 94 (m) | 94 (m) | 6.2 | 94 | N | N |
| Arsenic | 7440-38-2 | 3 | 1 | 0.28 | 0.28 | 0.28 | 0.68 (h) | 0.68 (h, jj) | 3 (h) | 3 (h, jj) | 0.68 | 3 | N | N |
| Barium | 7440-39-3 | 3 | 3 | 18 | 98.2 | 98.2 | 3,000 | 3,000 | 44,000 | 44,000 | 3,000 | 44,000 | N | N |
| Beryllium | 7440-41-7 | 3 | 3 | 0.11 | 0.29 | 0.29 | 32 | 32 | 460 | 460 | 32 | 460 | N | N |
| Boron | 7440-42-8 | 3 | 0 | ND | ND | ND | 3,200 | 3,200 | 46,000 | 46,000 | 3,200 | 46,000 | N | N |
| Cadmium | 7440-43-9 | 3 | 0 | ND | ND | ND | 14 | 14.2 | 200 | 196 | 14 | 200 | N | N |
| Chromium (Total) | 7440-47-3 | 3 | 3 | 4.8 | 13.9 | 13.9 | 24,000 (n) | 24,000 (n) | 100,000 (n) | 360,000 (n) | 24,000 | 100,000 | N | N |
| Cobalt | 7440-48-4 | 3 | 3 | 1.5 | 6.1 | 6.1 | 4.6 | 4.6 | 70 | 70 | 4.6 | 70 | Y | N |
| Copper | 7440-50-8 | 3 | 3 | 1.7 | 9.5 | 9.5 | 620 | 620 | 9,400 | 9,400 | 620 | 9,400 | N | N |
| Lead | 7439-92-1 | 3 | 3 | 1.9 | 7.4 | 7.4 | 400 | 400 (jj) | 800 | 800 (jj) | 400 | 800 | N | N |
| Manganese | 7439-96-5 | 3 | 3 | 120 | 480 | 480 | 360 | 360 | 5,200 | 5,200 | 360 | 5,200 | Y | N |
| Mercury | 7439-97-6 | 3 | 1 | 0.027 | 0.027 | 0.027 | 4.6 (o) | 4.6 (o) | 3.1 (o) | 70 (o) | 4.6 | 3.1 | N | N |
| Molybdenum | 7439-98-7 | 3 | 0 | ND | ND | ND | 78 | 78 | 1,200 | 1,160 | 78 | 1,200 | N | N |
| Nickel | 7440-02-0 | 3 | 3 | 1.1 | 5 | 5 | 300 (p) | 300 (p) | 4,400 (p) | 4,400 (p) | 300 | 4,400 | N | N |
| Selenium | 7782-49-2 | 3 | 0 | ND | ND | ND | 78 | 78 | 1,200 | 1,160 | 78 | 1,200 | N | N |
| Strontium | 7440-24-6 | 3 | 3 | 5.3 | 16.3 | 16.3 | 9,400 | 9,400 | 100,000 | 140,000 | 9,400 | 100,000 | N | N |
| Thallium | 7440-28-0 | 3 | 0 | ND | ND | ND | 0.16 (q) | 0.156 (q) | 2.4 (q) | 2.4 (q) | 0.16 | 2.4 | N | N |
| Vanadium | 7440-62-2 | 3 | 3 | 6.2 | 19.2 | 19.2 | 78 | 78 | 1,160 | 1,160 | 78 | 1,160 | N | N |
| Zinc | 7440-66-6 | 3 | 3 | 7.3 | 31.4 | 31.4 | 4,600 | 4,600 | 70,000 | 70,000 | 4,600 | 70,000 | N | N |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122,
http://www.ncleg.net/Sessions/2013/Bills
/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human HealtH
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitation Limit (PQL) but above Method Detection Limit (MDL) and therefore concentration is estimated

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.

(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf

# TABLE 1-3
# HUMAN HEALTH SCREENING - OFFSITE SEDIMENT
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.

(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.

(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf

(h) - Value applies to inorganic form of arsenic only.

(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

(j) - Value for Total Chromium.

(k) - Copper Treatment Technology Action Level is 1.3 mg/L.

(l) - Lead Treatment Technology Action Level is 0.015 mg/L.

(m) - RSL for Antimony (metallic) used for Antimony.

(n) - Value for Chromium (III), Insoluble Salts used for Chromium.

(o) - RSL for Mercuric Chloride used for Mercury.

(p) - RSL for Nickel Soluble Salts used for Nickel.

(q) - RSL for Thallium (Soluble Salts) used for Thallium.

(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(s) - Value for Inorganic Mercury.

(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.

(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.

(w) - Applicable only to persons with a sodium restrictive diet.

(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php

(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.

(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.

(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.

(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)

(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/

(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf

(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included
as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.

(jj) - Hazard Index = 0.1

# TABLE 1-4
# HUMAN HEALTH SCREENING - ONSITE SOIL SEDIMENT
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (mg/kg) | | Concentration Used for Screening (mg/kg) | NC PSRG Residential Health Screening Level (hh) (mg/kg) | Residential Soil RSL (a) HI = 0.2 (mg/kg) | NC PSRG Industrial Health Screening Level (hh) (mg/kg) | Industrial Soil RSL (a) HI = 0.2 (mg/kg) | Residential Screening Value Used (mg/kg) | Industrial Screening Value Used (mg/kg) | Residential COPC? | Industrial COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | | | | | | | | |
| Aluminum | 7429-90-5 | 3 | 3 | 4,800 | 6,760 | 6,760 | 15,000 | 15,400 | 100,000 | 220,000 | 15,000 | 100,000 | N | N |
| Antimony | 7440-36-0 | 3 | 0 | ND | ND | ND | 6.2 (m) | 6.2 (m) | 94 (m) | 94 (m) | 6.2 | 94 | N | N |
| Arsenic | 7440-38-2 | 3 | 1 | 0.44 | 0.44 | 0.44 | 0.68 (h) | 0.68 (h, jj) | 3 (h) | 3 (h, jj) | 0.67 | 3 | N | N |
| Barium | 7440-39-3 | 3 | 3 | 32 | 53.1 | 53.1 | 3,000 | 3,000 | 44,000 | 44,000 | 3,000 | 44,000 | N | N |
| Beryllium | 7440-41-7 | 3 | 3 | 0.29 | 0.44 | 0.44 | 32 | 32 | 460 | 460 | 32 | 460 | N | N |
| Boron | 7440-42-8 | 3 | 0 | ND | ND | ND | 3,200 | 3,200 | 46,000 | 46,000 | 3,200 | 46,000 | N | N |
| Cadmium | 7440-43-9 | 3 | 1 | 0.036 | 0.036 | 0.036 | 14 | 14.2 | 200 | 196 | 14 | 200 | N | N |
| Chromium (Total) | 7440-47-3 | 3 | 3 | 13.1 | 94.4 | 94.4 | 24,000 (n) | 24,000 (n) | 100,000 (n) | 360,000 (n) | 24,000 | 100,000 | N | N |
| Cobalt | 7440-48-4 | 3 | 3 | 3.4 | 7.4 | 7.4 | 4.6 | 4.6 | 70 | 70 | 4.6 | 70 | Y | N |
| Copper | 7440-50-8 | 3 | 3 | 4.5 | 10.4 | 10.4 | 620 | 620 | 9,400 | 9,400 | 620 | 9,400 | N | N |
| Lead | 7439-92-1 | 3 | 3 | 2.5 | 14 | 14 | 400 | 400 (jj) | 800 | 800 (jj) | 400 | 800 | N | N |
| Manganese | 7439-96-5 | 3 | 3 | 186 | 610 | 610 | 360 | 360 | 5,200 | 5,200 | 360 | 5,200 | Y | N |
| Mercury | 7439-97-6 | 3 | 1 | 0.0065 | 0.0065 | 0.0065 | 4.6 (o) | 4.6 (o) | 3.1 (o) | 70 (o) | 4.6 | 3.1 | N | N |
| Molybdenum | 7439-98-7 | 3 | 0 | ND | ND | ND | 78 | 78 | 1,200 | 1,160 | 78 | 1,200 | N | N |
| Nickel | 7440-02-0 | 3 | 3 | 2.8 | 5.2 | 5.2 | 300 (p) | 300 (p) | 4,400 (p) | 4,400 (p) | 300 | 4,400 | N | N |
| Selenium | 7782-49-2 | 3 | 0 | ND | ND | ND | 78 | 78 | 1,200 | 1,160 | 78 | 1,200 | N | N |
| Strontium | 7440-24-6 | 3 | 3 | 8.3 | 10.3 | 10.3 | 9,400 | 9,400 | 100,000 | 140,000 | 9,400 | 100,000 | N | N |
| Thallium | 7440-28-0 | 3 | 0 | ND | ND | ND | 0.16 (q) | 0.156 (q) | 2.4 (q) | 2.4 (q) | 0.16 | 2.4 | N | N |
| Vanadium | 7440-62-2 | 3 | 3 | 10 | 42.5 | 42.5 | 78 | 78 | 1,160 | 1,160 | 78 | 1,160 | N | N |
| Zinc | 7440-66-6 | 3 | 3 | 12.6 | 39.6 | 39.6 | 4,600 | 4,600 | 70,000 | 70,000 | 4,600 | 70,000 | N | N |

* Data evaluation includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: TCP

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122, http://www.ncleg.net/Sessions/2013/Bills /Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resource
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitation Limit (PQL) but above Method Detection Limit (MDL) and therefore concentration is estimated

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018. https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018. https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.

(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018. https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf

# TABLE 1-4
# HUMAN HEALTH SCREENING - ONSITE SOIL SEDIMENT
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.

(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf

WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.

Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.

For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.

For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.

(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf

(h) - Value applies to inorganic form of arsenic only.

(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

(j) - Value for Total Chromium.

(k) - Copper Treatment Technology Action Level is 1.3 mg/L.

(l) - Lead Treatment Technology Action Level is 0.015 mg/L.

(m) - RSL for Antimony (metallic) used for Antimony.

(n) - Value for Chromium (III), Insoluble Salts used for Chromium.

(o) - RSL for Mercuric Chloride used for Mercury.

(p) - RSL for Nickel Soluble Salts used for Nickel.

(q) - RSL for Thallium (Soluble Salts) used for Thallium.

(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(s) - Value for Inorganic Mercury.

(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.

(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.

(w) - Applicable only to persons with a sodium restrictive diet.

(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php

(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.

(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.

(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.

(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)

(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/

(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf

(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included
as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.

(jj) - Hazard Index = 0.1

**TABLE 1-5**
**HUMAN HEALTH SCREENING - OFFSITE SURFACE WATER**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (µg/L) | | Concentration Used for Screening (µg/L) | USEPA AWQC Consumption of Water and Organism (b) (µg/L) | USEPA AWQC Consumption of Organism Only (b) (µg/L) | Federal MCL/ SMCL (c) (µg/L) | Tap Water RSL HI = 0.2 (a) (µg/L) | Screening Value Used (µg/L) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | | | | | | |
| Aluminum | 7429-90-5 | 20 | 20 | 61 | 590 | 590 | NA | NA | 50 to 200 (i) | 4,000 | 50 | Y |
| Antimony | 7440-36-0 | 20 | 0 | ND | ND | ND | 5.6 | 640 | 6 | 1.56 (m) | 1 | N |
| Arsenic | 7440-38-2 | 20 | 2 | 0.76 | 1.06 | 1.06 | 0.018 (h) | 0.14 (h) | 10 | 0.052 (h, jj) | 10 | N |
| Barium | 7440-39-3 | 20 | 20 | 32 | 90 | 90 | 1,000 | NA | 2,000 | 760 | 700 | N |
| Beryllium | 7440-41-7 | 20 | 0 | ND | ND | ND | NA | NA | 4 | 5 | 4 | N |
| Boron | 7440-42-8 | 20 | 20 | 422 | 1,110 | 1,110 | NA | NA | NA | 800 | 700 | Y |
| Cadmium | 7440-43-9 | 20 | 1 | 0.059 | 0.059 | 0.059 | NA | NA | 5 | 1.84 | 2 | N |
| Chromium (Total) | 7440-47-3 | 20 | 2 | 0.34 | 0.492 | 0.492 | NA | NA | 100 | 4,400 (n) | 10 | N |
| Chromium (VI) | 18540-29-9 | 17 | 2 | 0.038 | 1.6 | 1.6 | NA | NA | NA | 0.035 (jj) | 0.035 | Y |
| Cobalt | 7440-48-4 | 20 | 19 | 0.891 | 3.05 | 3.05 | NA | NA | NA | 1.2 | 1 | Y |
| Copper | 7440-50-8 | 20 | 6 | 0.345 | 1.33 | 1.33 | 1,300 | NA | 1,300 (k) | 160 | 1,000 | N |
| Lead | 7439-92-1 | 20 | 0 | ND | ND | ND | NA | NA | 15 (l) | 15 (jj) | 15 | N |
| Lithium | 7439-93-2 | 3 | 1 | 2.585 | 2.585 | 2.585 | NA | NA | NA | 8 | 8 | N |
| Manganese | 7439-96-5 | 20 | 20 | 745 | 8,330 | 8,330 | 50 | 100 | 50 (i) | 86 | 50 | Y |
| Mercury | 7439-97-6 | 20 | 12 | 0.00124 | 0.00332 | 0.00332 | NA | NA | 2 | 1.14 (o) | 1 | N |
| Molybdenum | 7439-98-7 | 20 | 9 | 0.094 | 1.1 | 1.1 | NA | NA | NA | 20 | 20 | N |
| Nickel | 7440-02-0 | 20 | 13 | 0.37 | 1.1 | 1.1 | 610 | 4,600 | NA | 78 (p) | 100 | N |
| Selenium | 7782-49-2 | 20 | 0 | ND | ND | ND | 170 | 4,200 | 50 | 20 | 20 | N |
| Strontium | 7440-24-6 | 20 | 20 | 191 | 338 | 338 | NA | NA | NA | 2,400 | 2,400 | N |
| Thallium | 7440-28-0 | 20 | 3 | 0.092 | 0.119 | 0.119 | 0.24 | 0.47 | 2 | 0.04 (q) | 0.2 | N |
| Vanadium | 7440-62-2 | 20 | 20 | 0.255 | 1.62 | 1.62 | NA | NA | NA | 17.2 | 17 | N |
| Zinc | 7440-66-6 | 20 | 13 | 3.072 | 10 | 10 | 7,400 | 26,000 | 5,000 (i) | 1,200 | 1 | Y |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted.

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122,
http://www.ncleg.net/Sessions/2013/Bills/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human HealtH
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value

# TABLE 1-5
# HUMAN HEALTH SCREENING - OFFSITE SURFACE WATER
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.

(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental
Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf

(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.

(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.

(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf

(h) - Value applies to inorganic form of arsenic only.

(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

(j) - Value for Total Chromium.

(k) - Copper Treatment Technology Action Level is 1.3 mg/L.

(l) - Lead Treatment Technology Action Level is 0.015 mg/L.

(m) - RSL for Antimony (metallic) used for Antimony.

(n) - Value for Chromium (III), Insoluble Salts used for Chromium.

(o) - RSL for Mercuric Chloride used for Mercury.

(p) - RSL for Nickel Soluble Salts used for Nickel.

(q) - RSL for Thallium (Soluble Salts) used for Thallium.

(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(s) - Value for Inorganic Mercury.

(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.

(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.

(w) - Applicable only to persons with a sodium restrictive diet.

(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php

(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.

(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.

(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.

(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)

(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/

**TABLE 1-5**
**HUMAN HEALTH SCREENING - OFFSITE SURFACE WATER**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2. http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf

(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.

(jj) - Hazard Index = 0.1

**TABLE 1-6**
**HUMAN HEALTH SCREENING - ONSITE SURFACE WATER**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (µg/L) Min. | Range of Detection (µg/L) Max. | Concentration Used for Screening (µg/L) | USEPA AWQC Consumption of Organism Only (b) (µg/L) | Federal MCL/ SMCL (c) (µg/L) | Tap Water RSL HI = 0.2 (a) (µg/L) | Screening Value Used (µg/L) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 7429-90-5 | 25 | 25 | 11 | 965 | 965 | NA | 50 to 200 (i) | 4,000 | 50 | Y |
| Antimony | 7440-36-0 | 25 | 0 | ND | ND | ND | 640 | 6 | 1.56 (m) | 1 | N |
| Arsenic | 7440-38-2 | 25 | 1 | 1.7 | 1.7 | 1.7 | 0.14 (h) | 10 | 0.052 (h,jj) | 10 | N |
| Barium | 7440-39-3 | 25 | 25 | 40 | 108 | 108 | NA | 2,000 | 760 | 700 | N |
| Beryllium | 7440-41-7 | 18 | 0 | ND | ND | ND | NA | 4 | 5 | 4 | N |
| Boron | 7440-42-8 | 25 | 25 | 637 | 1,510 | 1,510 | NA | NA | 800 | 700 | Y |
| Cadmium | 7440-43-9 | 25 | 0 | ND | ND | ND | NA | 5 | 1.84 | 2 | N |
| Chromium (Total) | 7440-47-3 | 25 | 1 | 1.25 | 1.25 | 1.25 | NA | 100 | 4,400 (n) | 10 | N |
| Chromium (VI) | 18540-29-9 | 14 | 1 | 0.36 | 0.36 | 0.36 | NA | NA | 0.035 (jj) | 0.035 | Y |
| Cobalt | 7440-48-4 | 18 | 13 | 0.541 | 6.29 | 6.29 | NA | NA | 1.2 | 1 | Y |
| Copper | 7440-50-8 | 25 | 6 | 0.347 | 1.65 | 1.65 | NA | 1,300 (k) | 160 | 1,000 | N |
| Lead | 7439-92-1 | 25 | 0 | ND | ND | ND | NA | 15 (l) | 15 (jj) | 15 | N |
| Lithium | 7439-93-2 | 3 | 2 | 1.67 | 3.106 | 3.106 | NA | NA | 8 | 8 | N |
| Manganese | 7439-96-5 | 25 | 25 | 536 | 4,370 | 4,370 | 100 | 50 (i) | 86 | 50 | Y |
| Mercury | 7439-97-6 | 25 | 16 | 0.00151 | 0.023 | 0.023 | NA | 2 | 1.14 (o) | 1 | N |
| Molybdenum | 7439-98-7 | 25 | 1 | 2.53 | 2.53 | 2.53 | NA | NA | 20 | 20 | N |
| Nickel | 7440-02-0 | 25 | 10 | 0.419 | 1.52 | 1.52 | 4,600 | NA | 78 (p) | 100 | N |
| Selenium | 7782-49-2 | 25 | 0 | ND | ND | ND | 4,200 | 50 | 20 | 20 | N |
| Strontium | 7440-24-6 | 18 | 18 | 231 | 538 | 538 | NA | NA | 2,400 | 2,400 | N |
| Thallium | 7440-28-0 | 25 | 3 | 0.121 | 0.193 | 0.193 | 0.47 | 2 | 0.04 (q) | 0.20 | N |
| Vanadium | 7440-62-2 | 18 | 14 | 0.31 | 1.83 | 1.83 | NA | NA | 17.2 | 17 | N |
| Zinc | 7440-66-6 | 25 | 12 | 2.7 | 19 | 19 | 26,000 | 5,000 (i) | 1,200 | 1 | Y |

* Data evaluation includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: TCP

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122, http://www.ncleg.net/Sessions/2013/Bills/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-human-health-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.
(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf

(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364 Amended April 2013.

(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015. http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf

WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.

Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.

For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.

For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.

(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update. https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf

(h) - Value applies to inorganic form of arsenic only.

(i) - Value is the Secondary Maximum Contaminant Level. https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

(j) - Value for Total Chromium.

(k) - Copper Treatment Technology Action Level is 1.3 mg/L.

(l) - Lead Treatment Technology Action Level is 0.015 mg/L.

(m) - RSL for Antimony (metallic) used for Antimony.

(n) - Value for Chromium (III), Insoluble Salts used for Chromium.

(o) - RSL for Mercuric Chloride used for Mercury.

(p) - RSL for Nickel Soluble Salts used for Nickel.

(q) - RSL for Thallium (Soluble Salts) used for Thallium.

(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(s) - Value for Inorganic Mercury.

(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.

(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.

(w) - Applicable only to persons with a sodium restrictive diet.

(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php

(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.

(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.

(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.

(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)

(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/

(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2. http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf

(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is not typically included as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitoring programs for the site.

(jj) - Hazard Index = 0.1

# TABLE 2-1
# ECOLOGICAL SCREENING - SEDIMENT - CRUTCHFIELD BRANCH
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (mg/kg) | | Concentration Used for Screening (mg/kg) | USEPA Region 4 Sediment Screening Values (g) (mg/kg) | | | | Screening Value Used (mg/kg) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | ESV | | RSV | | | |
| Aluminum | 7429-90-5 | 6 | 6 | 2,300 | 7,350 | 7,350 | 25,000 | (x) | 58,000 | (x) | 25,000 | N |
| Antimony | 7440-36-0 | 6 | 0 | ND | ND | ND | 2 | (y) | 25 | (y) | 2 | N |
| Arsenic | 7440-38-2 | 6 | 2 | 0.28 | 0.44 | 0.44 | 9.8 | (z) | 33 | (z) | 9.8 | N |
| Barium | 7440-39-3 | 6 | 6 | 18 | 98.2 | 98.2 | 20 | (z) | 60 | (z) | 20 | Y |
| Beryllium | 7440-41-7 | 6 | 6 | 0.11 | 0.44 | 0.44 | NA | | NA | | NA | N |
| Boron | 7440-42-8 | 6 | 0 | ND | ND | ND | NA | | NA | | NA | N |
| Cadmium | 7440-43-9 | 6 | 1 | 0.036 | 0.036 | 0.036 | 1 | (z) | 5 | (z) | 1 | N |
| Chromium (Total) | 7440-47-3 | 6 | 6 | 4.8 | 94.4 | 94.4 | 43.4 | (z) | 111 | (z) | 43.4 | Y |
| Cobalt | 7440-48-4 | 6 | 6 | 1.5 | 7.4 | 7.4 | 50 | (aa) | NA | (aa) | 50 | N |
| Copper | 7440-50-8 | 6 | 6 | 1.7 | 10.4 | 10.4 | 31.6 | (z) | 149 | (z) | 31.6 | N |
| Lead | 7439-92-1 | 6 | 6 | 1.9 | 14 | 14 | 35.8 | (z) | 128 | (z) | 35.8 | N |
| Manganese | 7439-96-5 | 6 | 6 | 120 | 610 | 610 | 460 | (bb) | 1,100 | (bb) | 460 | Y |
| Mercury | 7439-97-6 | 6 | 2 | 0.0065 | 0.027 | 0.027 | 0.18 | (z) | 1.1 | (z) | 0.18 | N |
| Molybdenum | 7439-98-7 | 6 | 0 | ND | ND | ND | NA | | NA | | NA | N |
| Nickel | 7440-02-0 | 6 | 6 | 1.1 | 5.2 | 5.2 | 22.7 | (z) | 48.6 | (z) | 22.7 | N |
| Selenium | 7782-49-2 | 6 | 0 | ND | ND | ND | 0.8 | (bb) | 1.2 | (bb) | 0.8 | N |
| Strontium | 7440-24-6 | 6 | 6 | 5.3 | 16.3 | 16.3 | NA | | NA | | NA | N |
| Thallium | 7440-28-0 | 6 | 0 | ND | ND | ND | NA | | NA | | NA | N |
| Vanadium | 7440-62-2 | 6 | 6 | 6.2 | 42.5 | 42.5 | NA | | NA | | NA | N |
| Zinc | 7440-66-6 | 6 | 6 | 7.3 | 39.6 | 39.6 | 121 | (z) | 459 | (z) | 121 | N |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122, http://www.ncleg.net/Sessions/2013/Bills/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
COPC - Constituent of Potential Concern
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NA - Not Available
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
SSL - Soil Screening Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitatio
(PQL) but above Method Detection Limit (MDL) and therefor

# TABLE 2-1
# ECOLOGICAL SCREENING - SEDIMENT - CRUTCHFIELD BRANCH
# MAYO STEAM STATION
# DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables

(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.

(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf

(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf

(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.

(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.

(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf

(h) - Value applies to inorganic form of arsenic only.

(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals

(j) - Value for Total Chromium.

(k) - Copper Treatment Technology Action Level is 1.3 mg/L.

(l) - Lead Treatment Technology Action Level is 0.015 mg/L.

(m) - RSL for Antimony (metallic) used for Antimony.

(n) - Value for Chromium (III), Insoluble Salts used for Chromium.

(o) - RSL for Mercuric Chloride used for Mercury.

(p) - RSL for Nickel Soluble Salts used for Nickel.

(q) - RSL for Thallium (Soluble Salts) used for Thallium.

(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(s) - Value for Inorganic Mercury.

(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.

(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.

(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.

(w) - Applicable only to persons with a sodium restrictive diet.

(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php

(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.

(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.

(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.

(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)

(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/

(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf

(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents

(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)

(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)

(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

(ii) - As part of the water quality evaluation conducted under the CSA, pH was measured and is reported as a metric data set. The pH comparison criteria are included as ranges as opposed to single screening values. pH is as part of a risk assessment based on potential toxic effects, therefore; pH was not investigated further as a category 1 COPC. Water quality relative to pH will be addressed as a component of water quality monitorin

**TABLE 2-2**
**ECOLOGICAL SCREENING - SURFACE WATER - CRUTCHFIELD BRANCH**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Analyte | CAS | Number of Samples | Frequency of Detection | Range of Detection (µg/L) | | Concentration Used for Screening (µg/L) | 15A NCAC 2B Freshwater Aquatic Life Acute (f) (µg/L) | | 15A NCAC 2B Freshwater Aquatic Life Chronic (f) (µg/L) | | USEPA Region 4 Freshwater Acute Screening Values (g) (µg/L) | | USEPA Region 4 Freshwater Chronic Screening Values (g) (µg/L) | | USEPA AWQC (b) CMC (acute) (µg/L) | | USEPA AWQC (b) CCC (chronic) (µg/L) | | Screening Value Used (µg/L) | COPC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Min. | Max. | | Total | Dissolved | Total | Dissolved | Total | Dissolved | Total | Dissolved | Total | Dissolved | Total | Dissolved | | |
| Aluminum | 7429-90-5 | 44 | 44 | 11 | 965 | 965 | NA | NA | NA | NA | 750 (b) | NA | 87 (b) | NA | 750 | NA | 87 | NA | 87 | Y |
| Antimony | 7440-36-0 | 44 | 0 | ND | ND | ND | NA | NA | NA | NA | 900 (cc) | NA | 190 (cc) | NA | NA | NA | NA | NA | 190 | N |
| Arsenic | 7440-38-2 | 44 | 2 | 1.06 | 1.7 | 1.7 | NA | 340 | NA | 150 | 340 (b, h) | NA | 150 (b, h) | NA | 340 (h) | NA | 150 (h) | NA | 150 | N |
| Barium | 7440-39-3 | 44 | 44 | 32 | 108 | 108 | NA | NA | NA | NA | 2000 (cc) | NA | 220 (cc) | NA | NA | NA | NA | NA | 220 | N |
| Beryllium | 7440-41-7 | 37 | 0 | ND | ND | ND | NA | 65 | NA | 6.5 | 31 (r, cc) | NA | 3.6 (r, cc) | NA | NA | NA | NA | NA | 4 | N |
| Boron | 7440-42-8 | 44 | 44 | 422 | 1,510 | 1,510 | NA | NA | NA | NA | 34,000 (cc) | NA | 7,200 (cc) | NA | NA | NA | NA | NA | 7,200 | N |
| Cadmium | 7440-43-9 | 44 | 1 | 0.059 | 0.059 | 0.059 | NA | NA | NA | NA | 1.1 (r) | NA | 0.16 (r) | NA | NA | 1.8 (r) | NA | 0.72 (r) | 0.16 | N |
| Chromium (Total) | 7440-47-3 | 44 | 3 | 0.34 | 1.25 | 1.25 | NA | NA | 50 | NA | 1,022 (n, r) | NA | 48.8 (n, r) | NA | NA | NA | NA | NA | 50 | N |
| Chromium (VI) | 18540-29-9 | 30 | 3 | 0.038 | 1.6 | 1.6 | NA | 16 | NA | 11 | 16 | NA | 11 | NA | NA | 16 | NA | 11 | 11 | N |
| Cobalt | 7440-48-4 | 37 | 31 | 0.541 | 6.29 | 6.29 | NA | NA | NA | NA | 120 (cc) | NA | 19 (cc) | NA | NA | NA | NA | NA | 19 | N |
| Copper | 7440-50-8 | 44 | 12 | 0.345 | 1.65 | 1.65 | NA | NA | NA | NA | 7.3 (r) | NA | 5.16 (r) | NA | NA | NA | NA | NA | 5 | N |
| Lead | 7439-92-1 | 44 | 0 | ND | ND | ND | NA | NA | NA | NA | 33.8 (r) | NA | 1.32 (r) | NA | NA | 65 (r) | NA | 2.5 (r) | 1 | N |
| Manganese | 7439-96-5 | 44 | 44 | 536 | 8,330 | 8,330 | NA | NA | NA | NA | 1,680 (cc) | NA | 93 (cc) | NA | NA | NA | NA | NA | 93 | Y |
| Mercury | 7439-97-6 | 44 | 28 | 0.00124 | 0.023 | 0.023 | NA | NA | 0.012 | NA | 1.4 (b, s) | NA | 0.77 (b, s) | NA | NA | 1.4 (s) | NA | 0.77 (s) | 0.01 | Y |
| Molybdenum | 7439-98-7 | 44 | 9 | 0.094 | 2.53 | 2.53 | NA | NA | NA | NA | 7,200 (cc) | NA | 800 (cc) | NA | NA | NA | NA | NA | 800 | N |
| Nickel | 7440-02-0 | 44 | 22 | 0.37 | 1.52 | 1.52 | NA | NA | NA | NA | 261 (r) | NA | 29 (r) | NA | NA | 470 (r) | NA | 52.0 (r) | 29 | N |
| Selenium | 7782-49-2 | 44 | 0 | ND | ND | ND | NA | NA | 5 | NA | 20 (cc) | NA | 5 (cc) | NA | NA | NA | NA | NA | 5 | N |
| Strontium | 7440-24-6 | 37 | 37 | 191 | 538 | 538 | NA | NA | NA | NA | 48,000 (cc) | NA | 5,300 (cc) | NA | NA | NA | NA | NA | 5,300 | N |
| Thallium | 7440-28-0 | 44 | 6 | 0.092 | 0.193 | 0.193 | NA | NA | NA | NA | 54 (cc) | NA | 6 (cc) | NA | NA | NA | NA | NA | 6 | N |
| Vanadium | 7440-62-2 | 37 | 33 | 0.255 | 1.83 | 1.83 | NA | NA | NA | NA | 79 (cc) | NA | 27 (cc) | NA | NA | NA | NA | NA | 27 | N |
| Zinc | 7440-66-6 | 44 | 25 | 2.7 | 19 | 19 | NA | NA | NA | NA | 67 (r) | NA | 67 (r) | NA | 120 (r) | NA | 120 (r) | NA | 67 | N |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

AWQC - Ambient Water Quality Criteria
CAMA - Coal Ash Management Act
North Carolina Session Law 2014-122, http://www.ncleg.net/Sessions/2013/Bills/Senate/PDF/S729v7.pdf
CAS - Chemical Abstracts Service
CCC - Criterion Continuous Concentration
CMC - Criterion Maximum Concentration
DENR - Department of Environment and Natural Resources
DHHS - Department of Health and Human Services
ESV - Ecological Screening Value
HH - Human Health
HI - Hazard Index
IMAC - Interim Maximum Allowable Concentration
MCL - Maximum Contaminant Level
mg/kg - milligrams/kilogram
NC - North Carolina
NCAC - North Carolina Administrative Code
ORNL - Oak Ridge National Laboratory
PSRG - Preliminary Soil Remediation Goal
Q - Qualifier
RSL - Regional Screening Level
RSV - Refinement Screening Value
SMCL - Secondary Maximum Contaminant Level
su - Standard units
µg/L - micrograms/liter
USEPA - United States Environmental Protection Agency
WS - Water Supply
< - Concentration not detected at or above the reporting limit
j - Indicates concentration reported below Practical Quantitation Limit (PQL) but above Method Detection Limit (MDL) and therefore concentration is estimated

## TABLE 2-2
## ECOLOGICAL SCREENING - SURFACE WATER - CRUTCHFIELD BRANCH
## MAYO STEAM STATION
## DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC

COPC - Constituent of Potential Concern NA - Not Available

(a) - USEPA Regional Screening Levels (May 2018). Values for Residential Soil, Industrial Soil, and Tap Water. HI = 0.2. Accessed October 2018.
https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables
(b) - USEPA National Recommended Water Quality Criteria. USEPA Office of Water and Office of Science and Technology. Accessed October 2018.
https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table
USEPA AWQC Human Health for the Consumption of Organism Only apply to total concentrations.
(c) - USEPA 2018 Edition of the Drinking Water Standards and Health Advisories. March 2018. Accessed October 2018.
https://www.epa.gov/sites/production/files/2018-03/documents/dwtable2018.pdf
(d) - DHHS Screening Levels. Department of Health and Human Services, Division of Public Health, Epidemiology Section, Occupational and Environmental
Epidemiology Branch. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24814087&name=DLFE-112704.pdf
(e) - North Carolina 15A NCAC 02L .0202 Groundwater Standards & IMACs. http://portal.ncdenr.org/c/document_library/get_file?uuid=1aa3fa13-2c0f-45b7-ae96-5427fb1d25b4&groupId=38364
Amended April 2013.
(f) - North Carolina 15A NCAC 02B Surface Water and Wetland Standards. Amended January 1, 2015.
http://reports.oah.state.nc.us/ncac/title%2015a%20-%20environmental%20quality/chapter%2002%20-%20environmental%20management/subchapter%20b/subchapter%20b%20rules.pdf
WS standards are applicable to all Water Supply Classifications. WS standards are based on the consumption of fish and water.
Human Health Standards are based on the consumption of fish only unless dermal contact studies are available.
For Class C, use the most stringent of freshwater (or, if applicable, saltwater) column and the Human Health column.
For a WS water, use the most stringent of Freshwater, WS and Human Health. Likewise, Trout Waters and High Quality Waters must adhere to the most stingent of all applicable standards.
(g) - USEPA Region 4. 2018. Region 4 Ecological Risk Assessment Supplemental Guidance. March 2018 Update.
https://www.epa.gov/sites/production/files/2018-03/documents/era_regional_supplemental_guidance_report-march-2018_update.pdf
(h) - Value applies to inorganic form of arsenic only.
(i) - Value is the Secondary Maximum Contaminant Level.
https://www.epa.gov/dwstandardsregulations/secondary-drinking-water-standards-guidance-nuisance-chemicals
(j) - Value for Total Chromium.
(k) - Copper Treatment Technology Action Level is 1.3 mg/L.
(l) - Lead Treatment Technology Action Level is 0.015 mg/L.
(m) - RSL for Antimony (metallic) used for Antimony.
(n) - Value for Chromium (III), Insoluble Salts used for Chromium.
(o) - RSL for Mercuric Chloride used for Mercury.
(p) - RSL for Nickel Soluble Salts used for Nickel.
(q) - RSL for Thallium (Soluble Salts) used for Thallium.
(r) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(s) - Value for Inorganic Mercury.
(t) - Acute AWQC is equal to 1/[(f1/CMC1) + (f2/CMC2)] where f1 and f2 are the fractions of total selenium that are treated as selenite and selenate, respectively, and
CMC1 and CMC2 are 185.9 µg/L and 12.82 µg/L, respectively. Calculated assuming that all selenium is present as selenate, a likely overly conservative assumption.
(u) - Criterion expressed as a function of total hardness (mg/L). Value displayed is the site-specific total hardness of mg/L.
(v) - Chloride Action Level for Toxic Substances Applicable to NPDES Permits is 230,000 µg/L.
(w) - Applicable only to persons with a sodium restrictive diet.
(x) - Los Alamos National Laboratory ECORISK Database. http://www.lanl.gov/community-environment/environmental-stewardship/protection/eco-risk-assessment.php
(y) - Long, Edward R., and Lee G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program.
NOAA Technical Memorandum NOS OMA 52. Used effects range low (ER-L) for chronic and effects range medium (ER-M) for acute.
(z) - MacDonald, D.D.; Ingersoll, C.G.; Smorong, D.E.; Lindskoog, R.A.; Sloane, G.; and T. Bernacki. 2003. Development and Evaluation of Numerical Sediment Quality Assessment Guidelines for
Florida Inland Waters. Florida Department of Environmental Protection, Tallahassee, FL. Used threshold effect concentration (TEC) for the ESV and probable effect concentration (PEC) for the RSV.
(aa) - Persaud, D., R. Jaagumagi and A. Hayton. 1993. Guidelines for the protection and management of aquatic sediment quality in Ontario. Ontario Ministry of the Environment. Queen's Printer of Ontario.
(bb) - Los Alamos National Laboratory ECORISK Database. September 2017. http://www.lanl.gov/environment/protection/eco-risk-assessment.php (µg/kg dw)
(cc) - Great Lakes Initiative (GLI) Clearinghouse resources Tier II criteria revised 2013. http://www.epa.gov/gliclearinghouse/
(dd) - Suter, G.W., and Tsao, C.L. 1996. Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision. ES/ER/TM-96/R2.
http://www.esd.ornl.gov/programs/ecorisk/documents/tm96r2.pdf
(ee) - USEPA. Interim Ecological Soil Screening Level Documents. Accessed October 2018. http://www2.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents
(ff) - Efroymson, R.A., M.E. Will, and G.W. Suter II, 1997a. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-126/R2. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm126r21.pdf)
(gg) - Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten, 1997b. Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants:
1997 Revision. Oak Ridge National Laboratory, Oak Ridge, TN. ES/ER/TM-85/R3. (Available at http://www.esd.ornl.gov/programs/ecorisk/documents/tm85r3.pdf)
(hh) - North Carolina Preliminary Soil Remediation Goals (PSRG) Table. HI = 0.2. September 2015. http://portal.ncdenr.org/c/document_library/get_file?uuid=0f601ffa-574d-4479-bbb4-253af0665bf5&groupId=38361

**TABLE 3-1**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**HUMAN HEALTH - GROUNDWATER (SURFICIAL)**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean of Detected Concentration | UCL Selected | UCL | Exposure Point Concentration | Exposure Point Concentration (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | µg/L | 72 | 1 | 2 | 2 | 2 | --- | --- | 2 | 0.002 |
| Boron | µg/L | 72 | 68 | 122 | 1,330 | 755.5 | 95% KM (Chebychev) | 914.2 | 914.2 | 0.9142 |
| Chromium (Total) | µg/L | 72 | 16 | 0.54 | 43 | 8.228 | KM H | 1.84 | 1.84 | 0.00184 |
| Chromium (VI) | µg/L | 24 | 12 | 0.028 | 0.62 | 0.2 | 95% KM (Chebychev) | 0.235 | 0.235 | 0.000235 |
| Cobalt | µg/L | 68 | 44 | 1.07 | 10.3 | 3.342 | 95% GROS Approximate Gamma | 3.013 | 3.013 | 0.003013 |
| Manganese | µg/L | 36 | 36 | 6 | 1,530 | 625.1 | 95% Adjusted Gamma | 810.3 | 810.3 | 0.8103 |
| Vanadium | µg/L | 32 | 13 | 0.175 | 0.711 | 0.409 | 95% KM (t) | 0.338 | 0.338 | 0.000338 |
| Zinc | µg/L | 36 | 18 | 2.738 | 39 | 10.21 | 95% GROS Approximate Gamma | 9.683 | 9.683 | 0.009683 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

ND - Not Determined

Mean - Arithmetic mean

UCL - 95% Upper Confidence Limit

mg/L - milligrams per liter

µg/L - micrograms per liter

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).
(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0
(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.
(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 3-2**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**HUMAN HEALTH - GROUNDWATER (TRANSITION/BEDROCK)**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean of Detected Concentration | UCL Selected | UCL | Exposure Point Concentration | Exposure Point Concentration (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | µg/L | 479 | 8 | 0.13 | 3.68 | 1.49 | 95% KM (t) | 0.191 | 0.191 | 0.000191 |
| Arsenic | µg/L | 479 | 62 | 0.28 | 143 | 11.47 | 95% KM (Chebychev) | 4.012 | 4.012 | 0.004012 |
| Barium | µg/L | 479 | 416 | 1.845 | 1,080 | 72.97 | 95% KM (Chebychev) | 90.88 | 90.88 | 0.09088 |
| Boron | µg/L | 479 | 127 | 3 | 5,090 | 1,026 | 95% KM (Chebychev) | 419.2 | 419.2 | 0.4192 |
| Cadmium | µg/L | 479 | 20 | 0.037 | 2.19 | 0.331 | KM H | 0.0802 | 0.0802 | 0.0000802 |
| Chromium (Total) | µg/L | 479 | 47 | 0.383 | 53 | 4.518 | KM H | 0.896 | 0.896 | 0.000896 |
| Chromium (VI) | µg/L | 174 | 89 | 0.025 | 3.7 | 0.292 | KM H | 0.156 | 0.156 | 0.000156 |
| Cobalt | µg/L | 367 | 58 | 0.404 | 6.71 | 2.692 | KM H | 0.898 | 0.898 | 0.000898 |
| Lithium | µg/L | 125 | 45 | 1.672 | 24 | 6.526 | KM H | 4.864 | 4.864 | 0.004864 |
| Manganese | µg/L | 398 | 370 | 5 | 6,960 | 614.8 | 95% KM (Chebychev) | 801.4 | 801.4 | 0.8014 |
| Molybdenum | µg/L | 367 | 223 | 0.358 | 269 | 10.23 | 95% KM (Chebychev) | 10.54 | 10.54 | 0.01054 |
| Selenium | µg/L | 479 | 10 | 0.395 | 150 | 15.84 | 95% KM (Chebychev) | 2.377 | 2.377 | 0.002377 |
| Strontium | µg/L | 270 | 270 | 57 | 3,070 | 498.4 | 95% Chebychev (Mean, Sd) | 667.5 | 667.5 | 0.6675 |
| Thallium | µg/L | 479 | 7 | 0.012 | 0.361 | 0.133 | 95% KM (t) | 0.0889 | 0.0889 | 0.0000889 |
| Vanadium | µg/L | 278 | 188 | 0.134 | 23.3 | 1.553 | 95% KM (Chebychev) | 1.713 | 1.713 | 0.001713 |
| Zinc | µg/L | 398 | 137 | 1.973 | 110 | 14.96 | 95% KM (Chebychev) | 9.762 | 9.762 | 0.009762 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

ND - Not Determined

Mean - Arithmetic mean

UCL - 95% Upper Confidence Limit

mg/L - milligrams per liter

µg/L - micrograms per liter

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).

(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 3-3**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**HUMAN HEALTH - OFFSITE SEDIMENT**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Cobalt | mg/kg | 3 | 3 | 1.5 | 6.1 | 3.7 | --- | --- | 6.1 |
| Manganese | mg/kg | 3 | 3 | 120 | 480 | 327.7 | --- | --- | 480 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

Mean - Arithmetic mean

mg/kg - milligrams per kilogram

ND - Not Determined

UCL - 95% Upper Confidence Limit

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).

(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 3-4**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**HUMAN HEALTH - ONSITE SEDIMENT**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Cobalt | mg/kg | 3 | 3 | 3.4 | 7.4 | 5.1 | --- | --- | 7.4 |
| Manganese | mg/kg | 3 | 3 | 186 | 610 | 452.7 | --- | --- | 610 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: TCP

**Notes:**

---: Calculations were not performed due to lack of samples

ND - Not Determined

Mean - Arithmetic mean

UCL - 95% Upper Confidence Limit

mg/kg - milligrams per kilogram

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).

(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 3-5**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**HUMAN HEALTH - OFFSITE SURFACE WATER**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration | Exposure Point Concentration (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | µg/L | 20 | 20 | 61 | 590 | 160 | 95% Adjusted Gamma | 213.4 | 213.4 | 0.2134 |
| Boron | µg/L | 20 | 20 | 422 | 1,110 | 808.8 | 95% Student's-t | 892.5 | 892.5 | 0.8925 |
| Chromium (VI) | µg/L | 17 | 2 | 0.038 | 1.6 | 0.819 | --- | --- | 1.6 | 0.0016 |
| Cobalt | µg/L | 20 | 19 | 0.891 | 3.05 | 1.516 | 95% KM (BCA) | 1.756 | 1.756 | 0.001756 |
| Manganese | µg/L | 20 | 20 | 745 | 8,330 | 2,174 | 95% H | 2,954 | 2954 | 2.954 |
| Zinc | µg/L | 20 | 13 | 3.072 | 10 | 5.869 | 95% KM (t) | 6.009 | 6.009 | 0.006009 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

ND - Not Determined

Mean - Arithmetic mean

UCL - 95% Upper Confidence Limit

mg/L - milligrams per liter

µg/L - micrograms per liter

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).

(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 3-6**

**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**

**HUMAN HEALTH - ONSITE SURFACE WATER**

**MAYO STEAM STATION**

**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration | Exposure Point Concentration (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | µg/L | 25 | 25 | 11 | 965 | 140.1 | 95% H-UCL | 221 | 221 | 0.2206 |
| Boron | µg/L | 25 | 25 | 637 | 1,510 | 1,183 | 95% Student's-t | 1,247 | 1,247 | 1.247 |
| Chromium (VI) | µg/L | 14 | 1 | 0.36 | 0.36 | 0.36 | --- | --- | 0.36 | 0.00036 |
| Cobalt | µg/L | 18 | 13 | 0.541 | 6.29 | 1.776 | 95% KM (Chebychev) | 3.015 | 3.015 | 0.003015 |
| Manganese | µg/L | 25 | 25 | 536 | 4,370 | 1,071 | 95% Modified-t UCL | 1,358 | 1,358 | 1.358 |
| Zinc | µg/L | 25 | 12 | 2.7 | 19 | 7.009 | 95% GROS Adjusted Gamma UCL | 7.206 | 7.206 | 0.007206 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: TCP

**Notes:**

---: Calculations were not performed due to lack of samples

Mean - Arithmetic mean

mg/L - milligrams per liter

µg/L - micrograms per liter

ND - Not Determined

UCL - 95% Upper Confidence Limit

(a)- Mean calculated by ProUCL using the Kaplan-Meier (KM) estimation method for non-detect values: only given for datasets with FOD less than 100% and that met the minimum sample size and FOD requirements for use with ProUCL; see note (b).

(b)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(c) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(d) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 4-1**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**ECOLOGICAL - SEDIMENT - CRUTCHFIELD BRANCH**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|
| Barium | mg/kg | 6 | 6 | 18 | 98.2 | 45.93 | --- | --- | 98.2 |
| Chromium (Total) | mg/kg | 6 | 6 | 4.8 | 94.4 | 26.38 | --- | --- | 94.4 |
| Manganese | mg/kg | 6 | 6 | 120 | 610 | 390.2 | --- | --- | 610 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

Mean - Arithmetic mean

mg/kg - milligrams per kilogram

µg/L - micrograms per liter

UCL - 95% Upper Confidence Limit

(a)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(b) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(c) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

**TABLE 4-2**
**SUMMARY OF EXPOSURE POINT CONCENTRATIONS**
**ECOLOGICAL - SURFACE WATER - CRUTCHFIELD BRANCH**
**MAYO STEAM STATION**
**DUKE ENERGY CAROLINAS, LLC, ROXBORO, NC**

| Constituent | Reporting Units | Number of Samples | Frequency of Detection | Minimum Detected Concentration | Maximum Detected Concentration | Mean Detected Concentration | UCL Selected | UCL | Exposure Point Concentration | Exposure Point Concentration (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | µg/L | 44 | 44 | 11 | 965 | 149.7 | 95% H-UCL | 198.6 | 198.6 | 0.1986 |
| Manganese | µg/L | 44 | 44 | 536 | 8,330 | 1,561 | 95% Chebyshev (Mean, Sd) UCL | 2,501 | 2,501 | 2.501 |
| Mercury | µg/L | 44 | 28 | 0.00124 | 0.023 | 0.00351 | 95% H-UCL | 0.00389 | 0.00389 | 0.00000389 |

* Data evaluated includes data from 2015 to 2nd quarter 2018, unless otherwise noted

Prepared by: HEG Checked by: HES

**Notes:**

---: Calculations were not performed due to lack of samples

Mean - Arithmetic mean

mg/L - milligrams per liter

µg/L - micrograms per liter

UCL - 95% Upper Confidence Limit

(a)- Sample size was greater than or equal to 10 and the number of detected values was greater than or equal to 6, therefore, a 95% UCL was calculated by ProUCL. The UCL shown is the one recommended by ProUCL. If more than one UCL was recommended, the higher UCL was selected. ProUCL, version 5.0

(b) - 0 is defined as a number of samples analyzed or the frequency of detection among samples.

(c) - The 95% UCL values are calculated using the ProUCL software (V. 5.0; USEPA, 2013a). The ProUCL software performs a goodness-of-fit test that accounts for data sets without any non-detect observations, as well as data sets with non-detect observations. The software then determines the distribution of the data set for which the EPC is being derived (e.g., normal, lognormal, gamma, or non-discernable), and then calculates a conservative and stable 95% UCL value in accordance with the framework described in "Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites" (USEPA, 2002b). The software includes numerous algorithms for calculating 95% UCL values, and provides a recommended UCL value based on the algorithm that is most applicable to the statistical distribution of the data set. ProUCL will calculate a 95% UCL where there are 3 or more total samples with detected concentrations. Where too few samples or detects are available, the maximum detected concentration is used as the EPC.

# TABLE 5-1
# SUMMARY OF ON-SITE SEDIMENT EPC/RBC COMPARISON
# ON-SITE TRESPASSER - ADOLESCENT (AGE 6 to <16)
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC ROXBORO, NC

| COPC | CAS | Risk-Based Concentration | | | | Sediment | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/kg) | Cancer (mg/kg) | Final (mg/kg) | Basis | Exposure Point Concentration (mg/kg) | Non-Cancer | Cancer |
| Cobalt | 7440-48-4 | 1.1E+04 | | 1.1E+04 | nc | 7 | 0.001 | nc |
| Manganese | 7439-96-5 | 5.0E+05 | nc | 5.0E+05 | nc | 610 | 0.001 | nc |
| | | | | | Cumulative Risk | | 0.002 | 0.0E+00 |

Prepared by: HHS Checked by: TCP

**Notes:**

COPC - Chemical of potential concern

c - Remedial goal based on cancer risk

nc - Remedial goal based on non-cancer hazard index

**Exposure Routes Evaluated**

| | |
|---|---|
| Incidental Ingestion | No |
| Dermal Contact | Yes |
| Particulate Inhalation | No |
| Ambient Vapor Inhalation | No |
| **Target Hazard Index (per Chemical)** | **1E+00** |
| **Target Cancer Risk (per Chemical)** | **1E-04** |

# TABLE 5-2
# SUMMARY OF ON-SITE SURFACE WATER EPC/RBC COMPARISON
# ON-SITE TRESPASSER - ADOLESCENT (AGE 6 to <16)
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC ROXBORO, NC

| COPC | CAS | Risk-Based Concentration | | | | Surface Water | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/L) | Cancer (mg/L) | Final (mg/L) | Basis | Exposure Point Concentration (mg/L) | Non-Cancer | Cancer |
| Aluminum | 7429-90-5 | 1.3E+04 | nc | 1.3E+04 | nc | 0.2 | 0.00002 | nc |
| Boron | 7440-42-8 | 2.6E+03 | nc | 2.6E+03 | nc | 1 | 0.0005 | nc |
| Chromium (VI) | 18540-29-9 | 1.7E+00 | 2.6E-01 | 2.6E-01 | c | 0.0004 | 0.001 | 0.0014 |
| Cobalt | 7440-48-4 | 4.6E+00 | nc | 4.6E+00 | nc | 0.003 | 0.001 | nc |
| Manganese | 7439-96-5 | 2.4E+02 | nc | 2.4E+02 | nc | 1 | 0.006 | nc |
| Zinc | 7440-66-6 | 4.4E+03 | nc | 4.4E+03 | nc | 0.01 | 0.000002 | nc |
| | | | | | **Cumulative Risk** | | **0.01** | **1.4E-03** |

Prepared by: HHS Checked by: TCP

**Notes:**

COPC - Chemical of potential concern

c - Remedial goal based on cancer risk

nc - Remedial goal based on non-cancer hazard index

NA - No toxicity value available; remedial goal not calculated

NC - Not Calculated

[a] Final RBC value for lead is 15 ug/L or surface/seep water exposures. Refer to Attachment D, Section 2.5 of the *Mayo Steam Electric Plant CAP* (SynTerra 2015).

[b] Lead was not included in the cumulative risk calculation.

**Exposure Routes Evaluated**

| | |
|---|---|
| Incidental Ingestion | No |
| Dermal Contact | Yes |
| Ambient Vapor Inhalation | No |
| **Target Hazard Index (per Chemical)** | **1E+00** |
| **Target Cancer Risk (per Chemical)** | **1E-04** |

**TABLE 5-3**
**SUMMARY OF ON-SITE GROUNDWATER EPC/RBC COMPARISON**
**CONSTRUCTION - CONSTRUCTION WORKER (ADULT)**
**MAYO STEAM ELECTRIC PLANT**
**DUKE ENERGY PROGRESS, LLC ROXBORO, NC**

| COPC | CAS | Risk-Based Concentration | | | | Ash Basin- Surficial Groundwater | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/L) | Cancer (mg/L) | Final (mg/L) | Basis | Exposure Point Concentration (mg/L) | Non-Cancer | Cancer |
| Antimony | 7440-36-0 | 1.7E+01 | nc | 1.7E+01 | nc | 0.002 | 0.0001 | nc |
| Boron | 7440-42-8 | 1.9E+04 | nc | 1.9E+04 | nc | 0.9 | 0.00005 | nc |
| Chromium, Total | 7440-47-3 | 8.6E+03 | nc | 8.6E+03 | nc | 0.002 | 0.0000002 | nc |
| Chromium (VI) | 18540-29-9 | 2.8E+01 | 7.6E+01 | 2.8E+01 | nc | 0.0002 | 0.00001 | nc |
| Cobalt | 7440-48-4 | 3.3E+02 | nc | 3.3E+02 | nc | 0.003 | 0.00001 | nc |
| Manganese | 7439-96-5 | 2.2E+03 | nc | 2.2E+03 | nc | 0.8 | 0.0004 | nc |
| Vanadium | 7440-62-2 | 9.6E+02 | nc | 9.6E+02 | nc | 0.0003 | 0.0000004 | nc |
| Zinc | 7440-66-6 | 3.1E+04 | nc | 3.1E+04 | nc | 0.01 | 0.0000003 | nc |
| | | | | | **Cumulative Risk** | | **0.001** | **0.00E+00** |

Prepared by: HHS Checked by: TCP

| COPC | CAS | Risk-Based Concentration | | | | Ash Basin Transition/Bedrock Groundwater | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/L) | Cancer (mg/L) | Final (mg/L) | Basis | Exposure Point Concentration (mg/L) | Non-Cancer | Cancer |
| Antimony | 7440-36-0 | 1.7E+01 | nc | 1.7E+01 | nc | 0.0002 | 0.00001 | nc |
| Arsenic | 7440-38-2 | 2.9E+01 | 4.5E+02 | 2.9E+01 | nc | 0.004 | 0.0001 | nc |
| Barium | 7440-39-3 | 5.0E+03 | nc | 5.0E+03 | nc | 0.09 | 0.00002 | nc |
| Boron | 7440-42-8 | 1.9E+04 | nc | 1.9E+04 | nc | 0.4 | 0.00002 | nc |
| Cadmium | 7440-43-9 | 1.0E+01 | nc | 1.0E+01 | nc | 0.0001 | 0.00001 | nc |
| Chromium, Total | 7440-47-3 | 8.6E+03 | nc | 8.6E+03 | nc | 0.001 | 0.0000001 | nc |
| Chromium (VI) | 18540-29-9 | 2.8E+01 | 7.6E+01 | 2.8E+01 | nc | 0.0002 | 0.00001 | nc |
| Cobalt | 7440-48-4 | 3.3E+02 | nc | 3.3E+02 | nc | 0.001 | 0.000003 | nc |
| Lithium | 7439-93-2 | NA | | | | 0.005 | NC | nc |
| Manganese | 7439-96-5 | 2.2E+03 | nc | 2.2E+03 | nc | 0.8 | 0.0004 | nc |
| Molybdenum | 7439-98-7 | 4.8E+02 | nc | 4.8E+02 | nc | 0.01 | 0.00002 | nc |
| Selenium | 7782-49-2 | 4.8E+02 | nc | 4.8E+02 | nc | 0.002 | 0.000005 | nc |
| Strontium | 7440-24-6 | 1.9E+05 | nc | 1.9E+05 | nc | 0.7 | 0.000003 | nc |
| Thallium | 7440-28-0 | NA | | | | 0.0001 | NC | nc |
| Vanadium | 7440-62-2 | 9.6E+02 | nc | 9.6E+02 | nc | 0.002 | 0.000002 | nc |
| Zinc | 7440-66-6 | 3.1E+04 | nc | 3.1E+04 | nc | 0.01 | 0.0000003 | nc |
| | | | | | **Cumulative Risk** | | **0.001** | **0.00E+00** |

Prepared by: HHS Checked by: TCP

**Notes:**
COPC - Chemical of potential concern
c - Remedial goal based on cancer risk
nc - Remedial goal based on non-cancer hazard index
NA - No toxicity value available; remedial goal not calculated
NC - Not Calculated

**Exposure Routes Evaluated**

| | |
|---|---|
| Incidental Ingestion | Yes |
| Dermal Contact | Yes |
| Ambient Vapor Inhalation | No |

| | |
|---|---|
| **Target Hazard Index (per Chemical)** | **1E+00** |
| **Target Cancer Risk (per Chemical)** | **1E-04** |

# TABLE 5-4
# SUMMARY OF OFF-SITE SEDIMENT EPC/RBC COMPARISON
# RECREATIONAL WADER - CHILD, ADOLESCENT, and ADULT
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC ROXBORO, NC

| COPC | CAS | Risk-Based Concentration | | | | Sediment | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/kg) | Cancer (mg/kg) | Final (mg/kg) | Basis | Exposure Point Concentration (mg/kg) | Non-Cancer | Cancer |
| Cobalt | 7440-48-4 | 3.7E+03 | nc | 3.7E+03 | nc | 6 | 0.002 | nc |
| Manganese | 7439-96-5 | 1.7E+06 | | 1.7E+06 | nc | 480 | 0.0003 | nc |
| | | | | | **Cumulative Risk** | | **0.002** | **0.00E+00** |

Prepared by: HHS Checked by: TCP

**Notes:**

COPC - Chemical of potential concern

c - Remedial goal based on cancer risk

nc - Remedial goal based on non-cancer hazard index

| **Exposure Routes Evaluated** | |
|---|---|
| Incidental Ingestion | Yes |
| Dermal Contact | Yes |
| Particulate Inhalation | No |
| Ambient Vapor Inhalation | No |
| **Target Hazard Index (per Chemical)** | **1E+00** |
| **Target Cancer Risk (per Chemical)** | **1E-04** |

# TABLE 5-5
# SUMMARY OF OFF-SITE SURFACE WATER EPC/RBC COMPARISON
# RECREATIONAL WADER - CHILD, ADOLESCENT, and ADULT
# MAYO STEAM ELECTRIC PLANT
# DUKE ENERGY PROGRESS, LLC ROXBORO, NC

| COPC | CAS | Risk-Based Concentration | | | | Surface Water | Risk Ratio | |
|---|---|---|---|---|---|---|---|---|
| | | Non-Cancer (mg/L) | Cancer (mg/L) | Final (mg/L) | Basis | Exposure Point Concentration (mg/L) | Non-Cancer | Cancer |
| Aluminum | 7429-90-5 | 1.2E+03 | nc | 1.2E+03 | nc | 0.2 | 0.000 | nc |
| Boron | 7440-42-8 | 2.4E+02 | nc | 2.4E+02 | nc | 0.9 | 0.004 | nc |
| Chromium (VI) | 18540-29-9 | 9.5E-01 | 8.3E-02 | 8.3E-02 | c | 0.002 | 0.002 | 1.9E-02 |
| Cobalt | 7440-48-4 | 3.6E-01 | nc | 3.6E-01 | nc | 0.002 | 0.005 | nc |
| Manganese | 7439-96-5 | 9.0E+01 | nc | 9.0E+01 | nc | 3 | 0.03 | nc |
| Zinc | 7440-66-6 | 3.6E+02 | nc | 3.6E+02 | nc | 0.006 | 0.00002 | nc |
| | | | | | **Cumulative Risk** | | **0.04** | **1.9E-02** |

Prepared by: HHS Checked by: TCP

**Notes:**

NA - No toxicity value available; remedial goal not calculated

COPC - Chemical of potential concern

NC - Not Calculated

c - Remedial goal based on cancer risk

nc - Remedial goal based on non-cancer hazard index

**Exposure Routes Evaluated**

| | |
|---|---|
| Incidental Ingestion | Yes |
| Dermal Contact | Yes |
| Ambient Vapor Inhalation | No |
| **Target Hazard Index (per Chemical)** | **1E+00** |
| **Target Cancer Risk (per Chemical)** | **1E-04** |

**TABLE 5-6**
**SUMMARY OF RISK ESTIMATES**
**MAYO STEAM ELECTRIC PLANT**
**DUKE ENERGY PROGRESS, LLC ROXBORO, NC**

| Source Table (PRG Tables) | Media | Exposure Pathway | Risk Ratio - Non - cancer | Risk Ratio - Cancer |
|---|---|---|---|---|
| **TABLE 5-1** | Sediment - On-Site | ON-SITE TRESPASSER - ADOLESCENT (AGE 6-<16) | 0.002 | 0.00E+00 |
| **TABLE 5-2** | Surface Water - On-site | ON-SITE TRESPASSER - ADOLESCENT (AGE 6-<16) | 0.008 | 1.36E-03 |
| **TABLE 5-3** | Groundwater-Surficial Aquifer | CONSTRUCTION - CONSTRUCTION WORKER (ADULT) | 0.001 | 0.00E+00 |
| | Groundwater-Transition /Bedrock | CONSTRUCTION - CONSTRUCTION WORKER (ADULT) | 0.001 | 0.00E+00 |
| **TABLE 5-4** | Sediment- Off-Site | OFF-SITE RECREATIONAL WADER - CHILD, ADOLESCENT, and ADULT | 0.002 | 0.00E+00 |
| **TABLE 5-5** | Surface Water- Off-Site | OFF-SITE RECREATIONAL WADER - CHILD, ADOLESCENT, and ADULT | 0.04 | 1.92E-02 |

Prepared by: HHS Checked by: TCP

**Table 1**
**Exposure Parameters for Ecological Receptors**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Parameter | Body Weight | Food Ingestion Rate | Water Ingestion Rate | Dietary Composition | | | | | | Home Range | Seasonal Use Factor[j] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Plants | Mammal/Terr. Vertebrates | Fish | Invertebrates | Birds | Soil | | |
| Algorithm ID | BW | $IR_F$ | $IR_W$ | $P_F$ | $A_M$ | $A_F$ | $A_I$ | $A_B$ | $S_F$ | HR | SUF |
| Units | kg | kg/kg BW/day | L/kg BW/day | % | % | % | % | % | % | hectares | unitless |
| **Ecological Receptors** — HERBIVORE | | | | | | | | | | | |
| Meadow Vole[a] | 0.033 | 0.33 | 0.21 | 97.6% | 0% | 0% | 0% | 0% | 2.4% | 0.027 | 1 |
| Muskrat[b] | 1.17 | 0.3 | 0.97 | 99.3% | 0% | 0% | 0% | 0% | 0.7% | 0.13 | 1 |
| OMNIVORE | | | | | | | | | | | |
| Mallard Duck[c] | 1.134 | 0.068 | 0.057 | 48.3% | 0% | 0% | 48.3% | 0% | 3.3% | 435 | 1 |
| American Robin[d] | 0.08 | 0.129 | 0.14 | 40% | 0% | 0% | 58% | 0% | 2% | 0.42 | 1 |
| CARNIVORE | | | | | | | | | | | |
| Red-Tailed Hawk[e] | 1.06 | 0.18 | 0.058 | 0% | 91.5% | 0% | 0% | 8.5% | 0% | 876 | 1 |
| Bald Eagle[f] | 3.75 | 0.12 | 0.058 | 0% | 28% | 58% | 0% | 13.5% | 0.5% | 2199 | 1 |
| Red Fox[g] | 4.54 | 0.16 | 0.085 | 6% | 89% | 0% | 2% | 0% | 3% | 1226 | 1 |
| PISCIVORE | | | | | | | | | | | |
| River Otter[h] | 6.76 | 0.19 | 0.081 | 0% | 0% | 100% | 0% | 0% | 0% | 348 | 1 |
| Great Blue Heron[i] | 2.229 | 0.18 | 0.045 | 0% | 0% | 90% | 9.5% | 0% | 0.5% | 227 | 1 |

**NOTES:**

BW - Body Weight
kg - Kilograms
IR - Ingestion Rate
HR - Home Range
SUF - Seasonal Use Factor

$P_F$ - Plant Matter Ingestion Percentage
$A_M$ - Mammal/Terrestrial Vertebrate ingestion percentage
$A_F$ - Fish Ingestion Percentage
$A_B$ - Bird Ingestion Percentage
$S_F$ - Soil Ingestion Percentage

kg/kg BW/day - Kilograms Food per Kilograms Body Weight per Day
L/kg BW/day - Liters Water per Kilogram Body Weight per Day

[a] BW, $IR_f$, $IR_w$, $P_F$, HR from USEPA 1993 (sections 2-328 and 2-329); $S_F$ from Sample and Suter 1994
[b] BW, $IR_f$, $IR_w$, $P_F$, HR from USEPA 1993 (sections 2-340 and 2-341); $S_F$ from TechLaw Inc. 2013; $IR_F$ from Nagy 2001
[c] BW, $P_F$, $A_I$, HR from USEPA 1993 (sections 2-43 and 2-45); $S_F$ from Beyer et al. 1994; $IR_F$ from Nagy 2001
[d] BW, $P_F$, $A_I$, HR from USEPA 1993 (sections 2-197 and 2-198); $S_F$ from Sample and Suter 1994; $IR_F$ from Nagy 2001
[e] BW, $P_F$, $A_M$, $A_B$, $IR_F$, HR from USEPA 1993 (sections 2-82 and 2-83)
[f] BW, $P_F$, $A_F$, $A_M$, $A_B$, HR from USEPA 1993 (sections 2-91 and 2-97); $IR_F$ from Nagy 2001
[g] BW, $P_F$, $A_F$, $A_I$, HR from USEPA 1993 (sections 2-224 and 2-225); $S_F$ from Beyer et al. 1994
[h] BW, $IR_w$, $A_F$, HR from USEPA 1993 (sections 2-264 and 2-266); $S_F$ from Sample and Suter 1994; $IR_F$ from Nagy 2001
[i] BW, $P_F$, $A_F$, $A_I$, HR from USEPA 1993 (sections 2-8 and 2-9); $S_F$ from Sample and Suter 1994; $IR_F$ from Nagy 2001
[j] Seasonal Use Factor is set to a default of 1 to be overly conservative and protective of ecological receptors.

**Table 2**
**Toxicity Reference Values for Ecological Receptors**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Analyte | TRVs (NOAEL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Aquatic | | | | | Terrestrial | | | |
| | Mallard Duck (mg/kg/day) | Great Blue Heron (mg/kg/day) | Bald Eagle (mg/kg/day) | Muskrat (mg/kg/day) | River Otter (mg/kg/day) | American Robin (mg/kg/day) | Red-Tailed Hawk (mg/kg/day) | Meadow Vole (mg/kg/day) | Red Fox (mg/kg/day) |
| Aluminum[a] | 110 | 110 | 110 | 1.93 | 1.93 | 110 | 110 | 1.93 | 1.93 |
| Antimony[a] | NA | NA | NA | 0.059 | 0.059 | NA | NA | 0.059 | 0.059 |
| Arsenic[b] | 2.24 | 2.24 | 2.24 | 1.04 | 1.04 | 2.24 | 2.24 | 1.04 | 1.04 |
| Barium[c] | 20.8 | 20.8 | 20.8 | 51.8 | 51.8 | 20.8 | 20.8 | 51.8 | 51.8 |
| Beryllium[a] | NA | NA | NA | 0.532 | 0.532 | NA | NA | 0.532 | 0.532 |
| Boron[a, b] | 28.8 | 28.8 | 28.8 | 28 | 28 | 28.8 | 28.8 | 28 | 28 |
| Cadmium[a] | 1.47 | 1.47 | 1.47 | 0.77 | 0.77 | 1.47 | 1.47 | 0.77 | 0.77 |
| Calcium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Chromium, Total[d] | 1 | 1 | 1 | 2740 | 2740 | 1 | 1 | 2740 | 2740 |
| Chromium VI (hexavalent)[a] | NA | NA | NA | 9.24 | 9.24 | NA | NA | 9.24 | 9.24 |
| Chromium III[a] | 2.66 | 2.66 | 2.66 | 2.4 | 2.4 | 2.66 | 2.66 | 2.4 | 2.4 |
| Cobalt[a] | 7.61 | 7.61 | 7.61 | 7.33 | 7.33 | 7.61 | 7.61 | 7.33 | 7.33 |
| Copper[a] | 4.05 | 4.05 | 4.05 | 5.6 | 5.6 | 4.05 | 4.05 | 5.6 | 5.6 |
| Iron | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Lead[b] | 1.63 | 1.63 | 1.63 | 4.7 | 4.7 | 1.63 | 1.63 | 4.7 | 4.7 |
| Magnesium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Manganese[a] | 179 | 179 | 179 | 51.5 | 51.5 | 179 | 179 | 51.5 | 51.5 |
| Mercury[e] | 3.25 | 3.25 | 3.25 | 1.01 | 1.01 | 3.25 | 3.25 | 1.01 | 1.01 |
| Molybdenum[a, d] | 3.53 | 3.53 | 3.53 | 0.26 | 0.26 | 3.53 | 3.53 | 0.26 | 0.26 |
| Nickel[a] | 6.71 | 6.71 | 6.71 | 1.7 | 1.7 | 6.71 | 6.71 | 1.7 | 1.7 |
| Potassium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Selenium[a] | 0.29 | 0.29 | 0.29 | 0.143 | 0.143 | 0.29 | 0.29 | 0.143 | 0.143 |
| Sodium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Strontium[a, d] | NA | NA | NA | 263 | 263 | NA | NA | 263 | 263 |
| Thallium[a] | NA | NA | NA | 0.015 | 0.015 | NA | NA | 0.015 | 0.015 |
| Titanium | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Vanadium[a] | 0.344 | 0.344 | 0.344 | 4.16 | 4.16 | 0.344 | 0.344 | 4.16 | 4.16 |
| Zinc[a] | 66.1 | 66.1 | 66.1 | 75.4 | 75.4 | 66.1 | 66.1 | 75.4 | 75.4 |
| Nitrate[d] | NA | NA | NA | 507 | 507 | NA | NA | 507 | 507 |

**Table 2 (Cont.)**

| Analyte | TRVs (LOAEL) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Aquatic | | | | | Terrestrial | | | |
| | Mallard Duck (mg/kg/day) | Heron (mg/kg/day) | Bald Eagle (mg/kg/day) | Muskrat (mg/kg/day) | River Otter (mg/kg/day) | Robin (mg/kg/day) | Hawk (mg/kg/day) | Meadow Vole (mg/kg/day) | Red Fox (mg/kg/day) |
| Aluminum[a] | 1100 | 1100 | 1100 | 19.3 | 19.3 | 1100 | 1100 | 19.3 | 19.3 |
| Antimony[a] | NA | NA | NA | 0.59 | 0.59 | NA | NA | 0.59 | 0.59 |
| Arsenic[b] | 40.3 | 40.3 | 40.3 | 1.66 | 1.66 | 40.3 | 40.3 | 1.66 | 1.66 |
| Barium[c] | 41.7 | 41.7 | 41.7 | 75 | 75 | 41.7 | 41.7 | 75 | 75 |
| Beryllium[a] | NA | NA | NA | 6.6 | 6.6 | NA | NA | 6.6 | 6.6 |
| Boron[a, b] | 100 | 100 | 100 | 93.6 | 93.6 | 100 | 100 | 93.6 | 93.6 |
| Cadmium[a] | 2.37 | 2.37 | 2.37 | 10 | 10 | 2.37 | 2.37 | 10 | 10 |
| Calcium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Chromium, Total[d] | 5 | 5 | 5 | 27400 | 27400 | 5 | 5 | 27400 | 27400 |
| Chromium VI (hexavalent)[a] | NA | NA | NA | 40 | 40 | NA | NA | 40 | 40 |
| Chromium III[a] | 2.66 | 2.66 | 2.66 | 9.625 | 9.625 | 2.66 | 2.66 | 9.625 | 9.625 |
| Cobalt[a] | 7.8 | 7.8 | 7.8 | 10.9 | 10.9 | 7.8 | 7.8 | 10.9 | 10.9 |
| Copper[a] | 12.1 | 12.1 | 12.1 | 9.34 | 9.34 | 12.1 | 12.1 | 9.34 | 9.34 |
| Iron | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Lead[b] | 3.26 | 3.26 | 3.26 | 8.9 | 8.9 | 3.26 | 3.26 | 8.9 | 8.9 |
| Magnesium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Manganese[a] | 348 | 348 | 348 | 71 | 71 | 348 | 348 | 71 | 71 |
| Mercury[e] | 0.37 | 0.37 | 0.37 | 0.16 | 0.16 | 0.37 | 0.37 | 0.16 | 0.16 |
| Molybdenum[a, d] | 35.3 | 35.3 | 35.3 | 2.6 | 2.6 | 35.3 | 35.3 | 2.6 | 2.6 |
| Nickel[a] | 11.5 | 11.5 | 11.5 | 3.4 | 3.4 | 11.5 | 11.5 | 3.4 | 3.4 |
| Potassium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Selenium[a] | 0.579 | 0.579 | 0.579 | 0.215 | 0.215 | 0.579 | 0.579 | 0.215 | 0.215 |
| Sodium | EN | EN | EN | EN | EN | EN | EN | EN | EN |
| Strontium[a, d] | NA | NA | NA | 2630 | 2630 | NA | NA | 2630 | 2630 |
| Thallium[a] | NA | NA | NA | 0.075 | 0.075 | NA | NA | 0.075 | 0.075 |
| Vanadium[a] | 0.688 | 0.688 | 0.688 | 8.31 | 8.31 | 0.688 | 0.688 | 8.31 | 8.31 |
| Zinc[a] | 66.5 | 66.5 | 66.5 | 75.9 | 75.9 | 66.5 | 66.5 | 75.9 | 75.9 |
| Nitrate[d] | NA | NA | NA | 1130 | 1130 | NA | NA | 1130 | 1130 |

**NOTES:**

NOAEL - No Observed Adverse Effects Level

LOAEL - Lowest Observed Effects Level

EN - Essential nutrient

NA - Not available

TRV - Toxicity Reference Value

[a] CH2M Hill. 2014. Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site. CHPRC-01311. Revision 2. July. Http://pdw.hanford.gov/arpir/pdf.cfm?accession=0088115

[b] USEPA 2005 EcoSSL

[c] Only a single paper (Johnson et al., 1960) with data on the toxicity of barium hydroxide to one avian species (chicken) was identified by USEPA (2005); therefore, an avian TRV could not be derived and an Eco-SSL could not be calculated for avian wildlife (calculation requires a minimum of three results for two test species). Johnson et al. (1960) reports a subchronic NOAEL of 208.26 mg/kg/d. The NOAEL was multiplied by an uncertainty factor of 0.1 to derive a very conservative TRV of 20.8 mg/kg/d.

[d] Sample et al. 1996

**Table 3**
**Exposure Area and Area Use Factors for Ecological Receptors**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Exposure Point | Exposure Area[a] (hectares) | Area Use Factor (AUF) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Mallard Duck | Great Blue Heron | Muskrat | River Otter | Bald Eagle | American Robin | Red-Tailed Hawk | Meadow Vole | Red Fox |
| Crutchfield Branch | 4.3 | 0.99% | 1.89% | 100% | 1.24% | 0.20% | 100% | 0.491% | 100% | 0.35% |

**NOTES:**
[a] Crutchfield Branch flow northeast from the northeast side of the ash basin. The exposure area includes some on site and off site sample locations.

**Table 4**
**EPCs for Use in the Risk Assessment**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | Terrestrial EPCs[a] | | Aquatic EPCs[a, b] | |
|---|---|---|---|---|---|
| **COPC** | **CASRN** | **Soil EPC Used in Risk Assessment[c] (mg/kg)** | **Seep Water EPC Used in Risk Assessment (mg/L)** | **Sediment EPC Used in Risk Assessment[c] (mg/kg)** | **Surface Water EPC Used in Risk Assessment (mg/L)** |
| Aluminum | 7429-90-5 | | 0.1986 | | 0.1986 |
| Barium | 7440-39-3 | 98.2 | | 98.2 | |
| Chromium, Total | 7440-47-3 | 94.4 | | 94.4 | |
| Manganese | 7439-96-5 | 610 | 2.501 | 610 | 2.501 |
| Mercury | 7439-97-6 | | 0.00000389 | | 0.00000389 |

Created By: TCP Checked By: HES

**NOTES:**
COPC - Constituent of Potential Concern
CASRN - Chemical Abstracts Service Registration Number
EPC - Exposure Point Concentration

[a] EPCs for surface water are based on 95% UCLs. EPCs for sediment are based on maximum detected values.

[b] Terrestrial EPCs listed are values from the Aquatic EPCs list and are used to evaluate exposure to terrestrial receptor groups in this model.

[c] Analysis of solids (i.e., soil and sediment) was reported as dry weight.

**Table 5**
**Calculation of Average Daily Doses for American Robin**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | | | | AVERAGE DAILY DOSE VIA: WATER | | PLANTS/VEGETATION | | | | INVERTEBRATES | | | SOIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $EPC_w$ | $EPC_s$ | | | $EPC_p$ | | | $EPC_{inv}$ | $NIR_w$ | $ADD_w$ | $P_f$ | $NIR_f$ | $NIR_p$ | $ADD_p$ | $A_f$ | $NIR_a$ | $ADD_a$ | $S_f$ | $NIR_s$ | $ADD_s$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Slope, or Plant Uptake (BAF) | Intercept | Estimated[1] Concentration in Vegetation (mg/kg dry) | Slope, or Invertebrate Uptake (BAF) | Intercept | Estimated[2] Concentration in Invertebrates (mg/kg dry) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Plant Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Plant Ingestion Rate, Dry (kg/kg BW/day) | Unadjusted Average Daily Dose Plant (mg/kg/day) | Fraction Diet Invertebrates (percent) | Invertebrates Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Invertebrates (mg/kg/day) | Fraction Diet Soil (percent) | Soil Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Soil (mg/kg/day) | Bioavailability[3] (percent) | Omnivore Intake (mg/kg/day) | Seasonal Use Factor | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Omnivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.0008 | | 0 | 0.22 | | 0 | 0.14 | 0.0278 | 40% | 0.129 | 0.01 | 0 | 58% | 0.0097 | 0 | 2% | 0.00034 | 0 | 100% | 0.0278 | 1 | 1 | 0.03 |
| Barium | | 98.2 | 0.03 | | 2.946 | 0.22 | | 21.6 | 0.14 | 0 | 40% | 0.129 | 0.01 | 0.022802 | 58% | 0.0097 | 0.21013347 | 2% | 0.00034 | 0.03294 | 100% | 0.2659 | 1 | 1 | 0.2659 |
| Chromium, Total | | 94.4 | 0.0015 | | 0.1416 | -0.067 | 2.481 | 8.81 | 0.14 | 0 | 40% | 0.129 | 0.01 | 0.001096 | 58% | 0.0097 | 0.08572797 | 2% | 0.00034 | 0.03166 | 100% | 0.11849 | 1 | 1 | 0.11849 |
| Manganese | 2.501 | 610 | 0.05 | | 30.5 | 0.682 | -0.809 | 35.34 | 0.14 | 0.3501 | 40% | 0.129 | 0.01 | 0.23607 | 58% | 0.0097 | 0.34372551 | 2% | 0.00034 | 0.20459 | 100% | 1.13 | 1 | 1 | 1.13 |
| Mercury | 0.00000389 | | | | | | | | 0.14 | 0.0000005 | 40% | 0.129 | 0.01 | 0 | 58% | 0.0097 | 0 | 2% | 0.00034 | 0 | 100% | 0.000001 | 1 | 1 | 0.000001 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Bechtel Jacobs Company 1998a; Baes et al. 1984 (Mo); Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.

[2] Sample et al. 1998b; EPA 1999 (Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities); Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.

[3] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 6**
**Calculation of Average Daily Doses for Red-Tailed Hawk**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | AVERAGE DAILY DOSE VIA: | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | WATER | | VERTEBRATE PREY | | | | | | | | | | |
| | $EPC_w$ | $EPC_s$ | | | $EPC_{mb}$ | $NIR_w$ | $ADD_w$ | $P_T$ | $P_A$ | $NIR_f$ | $NIR_a$ | $ADD_a$ | BF | $ADD_t$ | SUF | AUF | $ADD_{TOT}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Slope, or Vertebrate Uptake (BAF)[1] | Intercept | Estimated Concentration in Mammals and Birds (mg/kg) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Terrestrial Vertebrates (percent) | Fraction Diet Avian Vertebrates (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Vertebrate Ingestion Rate (kg/kg BW/day) | Unadjusted Average Daily Dose (mg/kg/day) | Bioavailability[2] (percent) | Carnivore Intake (mg/kg/day) | Seasonal Use Factor (unitless) | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Carnivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 1 | | 0 | 0.058 | 0.01 | 91.5% | 8.5% | 0.18 | 0.18 | 0 | 100% | 0.01 | 1 | 0.0049 | 0.00006 |
| Barium | | 98.2 | 0.7 | -1.412 | 6.04 | 0.058 | 0 | 91.5% | 8.5% | 0.18 | 0.18 | 1.0877441 | 100% | 1.088 | 1 | 0.0049 | 0.005339 |
| Chromium, Total | | 94.4 | 0.1444 | -1.4599 | 0.45 | 0.058 | 0 | 91.5% | 8.5% | 0.18 | 0.18 | 0.0806180 | 100% | 0.0806 | 1 | 0.0049 | 0.0003957 |
| Manganese | 2.501 | 610 | 0.004 | | 2.44 | 0.058 | 0.15 | 91.5% | 8.5% | 0.18 | 0.18 | 0.4392000 | 100% | 0.58 | 1 | 0.0049 | 0.0029 |
| Mercury | 0.00000389 | | | | | 0.058 | 0.0000002 | 91.5% | 8.5% | 0.18 | 0.18 | 0 | 100% | 0.0000002 | 1 | 0.0049 | 0.000000001 |

**NOTES:**
EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Sample et al. 1998a; EPA 2007 EcoSSLs, Att 4-1, Table 4a
[2] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 7**
**Calculation of Average Daily Doses for Meadow Vole**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | AVERAGE DAILY DOSE VIA: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | WATER | | PLANTS / VEGETATION | | | | SOIL | | | | | | | |
| | $EPC_w$ | $EPC_s$ | | | $EPC_p$ | $NIR_W$ | $ADD_W$ | $P_f$ | $NIR_f$ | $NIR_p$ | $ADD_p$ | $S_f$ | $NIR_S$ | $ADD_S$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Slope, or Plant Uptake (BAF) | Intercept | Estimated[1] Concentration in Vegetation (mg/kg dry) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Plant Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Plant Ingestion Rate, Dry (kg/kg/day) | Unadjusted Average Daily Dose Plant (mg/kg/day) | Fraction Diet Soil (percent) | Soil Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Soil (mg/kg/day) | Bioavailability[2] (percent) | Herbivore Intake (mg/kg/day) | Seasonal Use Factor | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Herbivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.0008 | | 0 | 0.21 | 0.04 | 97.6% | 0.33 | 0.048 | 0 | 2.4% | 0.001 | 0 | 100% | 0.042 | 1 | 1 | 0.04 |
| Barium | | 98.2 | 0.03 | | 2.946 | 0.21 | 0 | 97.6% | 0.33 | 0.048 | 0.142327 | 2.4% | 0.001 | 0.10111 | 100% | 0.243 | 1 | 1 | 0.2434 |
| Chromium, Total | | 94.4 | 0.0015 | | 0.1416 | 0.21 | 0 | 97.6% | 0.33 | 0.048 | 0.006841 | 2.4% | 0.001 | 0.09719 | 100% | 0.104 | 1 | 1 | 0.104035 |
| Manganese | 2.501 | 610 | 0.05 | | 30.5 | 0.21 | 0.53 | 97.6% | 0.33 | 0.048 | 1.473516 | 2.4% | 0.001 | 0.62806 | 100% | 2.627 | 1 | 1 | 2.63 |
| Mercury | 0.00000389 | | | | | 0.21 | 0.000001 | 97.6% | 0.33 | 0.048 | 0 | 2.4% | 0.001 | 0 | 100% | 0.000 | 1 | 1 | 0.000001 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Bechtel Jacobs Company 1998a; Baes et al. 1984 (Mo); Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.

[2] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 8**
**Calculation of Average Daily Doses for Red Fox**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Analyte | $EPC_w$ COPEC in Water (mg/L) | $EPC_s$ COPEC in Solid (mg/kg) | Slope, or Mammal Uptake (BAF) | Intercept | $epc_m$ Estimated[1] Concentration in Mammals (mg/kg) | Slope, or Plant Uptake (BAF) | Intercept | $epc_p$ Estimated[2] Concentration in Vegetation (mg/kg dry) | Slope, or Invertebrate Uptake (BAF) | Intercept | $epc_{inv}$ Estimated[3] Concentration in Invertebrates (mg/kg dry) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 0.1986 | | 1 | | 0 | 0.0008 | | 0 | 0.22 | | 0 |
| Barium | | 98.2 | 0.7 | -1.412 | 6.04302 | 0.03 | | 2.946 | 0.22 | | 21.604 |
| Chromium, Total | | 94.4 | 0.1444 | -1.4599 | 0.44788 | 0.0015 | | 0.1416 | -0.067 | 2.481 | 8.81377 |
| Manganese | 2.501 | 610 | 0.004 | | 2.44 | 0.05 | | 30.5 | 0.682 | -0.809 | 35.33871 |
| Mercury | 0.00000389 | | | | | | | | | | |

AVERAGE DAILY DOSE VIA:

| Analyte | WATER: $NIR_w$ Water Ingestion Rate (L/kg BW/day) | WATER: $ADD_w$ Average Daily Dose Water (mg/kg/day) | PLANTS/VEGETATION: $P_f$ Fraction Diet Plant Matter (percent) | PLANTS/VEGETATION: $NIR_f$ Food Ingestion Rate, Wet (kg/kg BW/day) | PLANTS/VEGETATION: $NIR_p$ Plant Ingestion Rate, Dry (kg/kg BW/day) | PLANTS/VEGETATION: $ADD_p$ Average Daily Dose Plant (mg/kg/day) | INVERTEBRATE PREY: $A_i$ Fraction Diet Invertebrates (percent) | INVERTEBRATE PREY: $NIR_i$ Invertebrates Ingestion Rate (kg dry/kg BW/day) | INVERTEBRATE PREY: $ADD_i$ Average Daily Dose Invertebrates (mg/kg/day) |
|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 0.085 | 0.017 | 6% | 0.16 | 0.0014 | 0 | 2% | 0.0004 | 0 |
| Barium | 0.085 | 0 | 6% | 0.16 | 0.0014 | 0.00424224 | 2% | 0.0004 | 0.00898726 |
| Chromium, Total | 0.085 | 0 | 6% | 0.16 | 0.0014 | 0.000203904 | 2% | 0.0004 | 0.00366653 |
| Manganese | 0.085 | 0.213 | 6% | 0.16 | 0.0014 | 0.04392 | 2% | 0.0004 | 0.0147009 |
| Mercury | 0.085 | 0.0000003 | 6% | 0.16 | 0.0014 | 0 | 2% | 0.0004 | 0 |

| Analyte | MAMMAL PREY: $A_m$ Fraction Diet Animal Matter (percent) | MAMMAL PREY: $NIR_m$ Food Ingestion Rate, Wet (kg/kg BW/day) | MAMMAL PREY: $NIR_m$ Mammal Ingestion Rate (kg/kg BW/day) | MAMMAL PREY: $ADD_m$ Unadjusted Average Daily Dose (mg/kg/day) | SOIL: $S_f$ Fraction Diet Soil (percent) | SOIL: $NIR_s$ Soil Ingestion Rate (kg dry/kg BW/day) | SOIL: $ADD_s$ Average Daily Dose Soil (mg/kg/day) | BF Bioavailability[4] (percent) | $ADD_t$ Carnivore Intake (mg/kg/day) | SUF Seasonal Use Factor | AUF Area Use Factor (Exposure Area/Home Range) | $ADD_{tot}$ Adjusted Total Carnivore ADD (mg/kg/day) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 89% | 0.16 | 0.14 | 0 | 3.0% | 0.00062 | 0 | 100% | 0.017 | 1 | 0.0035 | 0.00006 |
| Barium | 89% | 0.16 | 0.14 | 0.8605264 | 3.0% | 0.00062 | 0.06128 | 100% | 0.935 | 1 | 0.0035 | 0.003279 |
| Chromium, Total | 89% | 0.16 | 0.14 | 0.0637778 | 3.0% | 0.00062 | 0.05891 | 100% | 0.127 | 1 | 0.0035 | 0.0004439 |
| Manganese | 89% | 0.16 | 0.14 | 0.347456 | 3.0% | 0.00062 | 0.38064 | 100% | 0.999 | 1 | 0.0035 | 0.0035 |
| Mercury | 89% | 0.16 | 0.14 | 0 | 3.0% | 0.00062 | 0 | 100% | 0.0000003 | 1 | 0.0035 | 0.000000001 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Sample et al. 1998a; EPA 2007 EcoSSLs, Att 4-1, Table 4a; default value of 1 is used for constituents for which a BAF could not be found.

[2] Bechtel Jacobs Company 1998a; Environmental Restoration Division - Manual ERD-AG-003 1999 for non-reproductive tissues; default value of 1 is used for constituents for which a BAF could not be found.

[3] Sample et al. 1998b; Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.

[4] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 9**
**Calculation of Average Daily Doses for Mallard Duck**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | | | | AVERAGE DAILY DOSE VIA: WATER | | PLANTS/VEGETATION | | | | INVERTEBRATES | | | SOIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $EPC_w$ | $EPC_s$ | | | $EPC_p$ | | | $EPC_i$ | $NIR_w$ | $ADD_W$ | $P_f$ | $NIR_f$ | $NIR_p$ | $ADD_p$ | $A_f$ | $NIR_a$ | $ADD_a$ | $S_f$ | $NIR_s$ | $ADD_s$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Slope, or Plant Uptake (BAF) | Intercept | Estimated[1] Concentration in Vegetation (mg/kg dry) | Slope, or Invertebrate Uptake (BAF) | Intercept | Estimated[2] Concentration in Invertebrates (mg/kg dry) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Plant Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Plant Ingestion Rate, Dry (kg/kg BW/day) | Unadjusted Average Daily Dose Plant (mg/kg/day) | Fraction Diet Invertebrates (percent) | Invertebrates Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Invertebrates (mg/kg/day) | Fraction Diet Soil (percent) | Soil Ingestion3 Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Soil (mg/kg/day) | Bioavailability[3] (percent) | Omnivore Intake (mg/kg/day) | Seasonal Use Factor (unitless) | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Omnivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.0008 | | 0 | 1 | | 0 | 0.057 | 0.011 | 48% | 0.068 | 0.0049 | 0 | 48% | 0.007 | 0 | 3.3% | 0.00029 | 0 | 100% | 0.01 | 1 | 0.0099 | 0.000112 |
| Barium | | 98.2 | 0.03 | | 2.946 | 1 | | 98.2 | 0.057 | 0 | 48% | 0.068 | 0.0049 | 0.014514 | 48% | 0.007 | 0.7096 | 3.3% | 0.00029 | 0.02865 | 100% | 0.7527 | 1 | 0.0099 | 0.007441 |
| Chromium, Total | | 94.4 | 0.0015 | | 0.1416 | 0.1 | | 9.44 | 0.057 | 0 | 48% | 0.068 | 0.0049 | 0.000698 | 48% | 0.007 | 0.0682 | 3.3% | 0.00029 | 0.02754 | 100% | 0.09645 | 1 | 0.0099 | 0.000953 |
| Manganese | 2.501 | 610 | 0.05 | | 30.5 | 0.682 | -0.809 | 35.34 | 0.057 | 0.143 | 48% | 0.068 | 0.0049 | 0.150261 | 48% | 0.007 | 0.2553 | 3.3% | 0.00029 | 0.17795 | 100% | 0.73 | 1 | 0.0099 | 0.007178 |
| Mercury | 0.000004 | | | | | | | | 0.057 | 0.0000002 | 48% | 0.068 | 0.0049 | 0 | 48% | 0.007 | 0 | 3.3% | 0.00029 | 0 | 100% | 0.0000002 | 1 | 0.0099 | 0.000000002 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Bechtel Jacobs Company 1998a; Baes et al. 1984 (Mo); Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.

[2] Bechtel Jacobs Company 1998b, Table 2, median BAFs for sediment to benthic invertebrates for As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn; Sample et al. 1998b (earthworms) for Mn; default value of 1 is used for constituents for which a BAF could not be found.

[3] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 10**
**Calculation of Average Daily Doses for Great Blue Heron**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | | | AVERAGE DAILY DOSE VIA: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | WATER | | FISH | | | | INVERTEBRATES | | | | | | | |
| | $EPC_w$ | $EPC_s$ | | $EPC_{fish}$ | | | $EPC_i$ | $NIR_w$ | $ADD_w$ | $A_f$ | $NIR_f$ | $NIR_a$ | $ADD_a$ | $A_f$ | $NIR_a$ | $ADD_a$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Fish Uptake (BCF) | Estimated[1] Concentration in Fish (mg/kg) | Slope, or Invertebrate Uptake (BAF) | Intercept | Estimated[2] Concentration in Invertebrates (mg/kg dry) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Animal Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Fish Ingestion Rate (kg/kg BW/day) | Unadjusted Average Daily Dose (mg/kg/day) | Fraction Diet Invertebrates (percent) | Invertebrates Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Invertebrates (mg/kg/day) | Bioavailability[3] (percent) | Piscivore Intake (mg/kg/day) | Seasonal Use Factor (unitless) | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Piscivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.1 | 0.02 | 1 | | 0.199 | 0.045 | 0.009 | 90% | 0.18 | 0.162 | 0.003 | 10% | 0.004 | 0.0007 | 100% | 0.01 | 1 | 0.019 | 0.0002 |
| Barium | | 98.2 | 4 | 0 | 1 | | 0 | 0.045 | 0 | 90% | 0.18 | 0.162 | 0 | 10% | 0.004 | 0 | 100% | 0 | 1 | 0.019 | 0 |
| Chromium, Total | | 94.4 | 200 | 0 | 0.1 | | 0 | 0.045 | 0 | 90% | 0.18 | 0.162 | 0 | 10% | 0.004 | 0 | 100% | 0 | 1 | 0.019 | 0 |
| Manganese | 2.501 | 610 | 400 | 1,000.4 | 0.682 | -0.809 | 0.83 | 0.045 | 0.113 | 90% | 0.18 | 0.162 | 162.065 | 10% | 0.004 | 0.0031 | 100% | 162.18 | 1 | 0.019 | 3.072 |
| Mercury | 0.00000389 | | 63,000 | 0.25 | 1.136 | | 0.000004 | 0.045 | 0.0000002 | 90% | 0.18 | 0.0405 | 0.0099 | 10% | 0.004 | 0.00000002 | 100% | 0.0099 | 1 | 0.019 | 0.0002 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Al (Voigt et al. 2015), mean of fish tissue BAFs; Cu (USEPA 1980); Environmental Restoration Division - Manual ERD-AG-003 1999.

[2] Bechtel Jacobs Company 1998b, Table 2, median BAFs for sediment to benthic invertebrates for As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn; Sample et al. 1998b (earthworms) for Mn; default value of 1 is used for constituents for which a BAF could not be found.

[3] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 11**
**Calculation of Average Daily Doses for Bald Eagle**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | | | AVERAGE DAILY DOSE VIA: WATER | | VERTEBRATE PREY | | | | | | SOIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $EPC_w$ | $EPC_s$ | | | $EPC_{mb}$ | | $EPC_{fish}$ | $NIR_w$ | $ADD_w$ | $P_{fish}$ | $P_{mb}$ | $NIR_f$ | $NIR_{fish}$ | $NIR_{mb}$ | $ADD_a$ | $S_f$ | $NIR_s$ | $ADD_s$ | BF | $ADD_t$ | SUF | AUF | $ADD_{TOT}$ |
| **Analyte** | **COPEC in Water (mg/L)** | **COPEC in Solid (mg/kg)** | **Slope, or Vertebrate Uptake (BAF)** | **Intercept** | **Estimated[1] Concentration in Mammals and Birds (mg/kg)** | **Fish Uptake (BCF)** | **Estimated[2] Concentration in Fish (mg/kg)** | **Water Ingestion Rate (L/kg BW/day)** | **Unadjusted Average Daily Dose Water (mg/kg/day)** | **Fraction of Diet Fish (percent)** | **Fraction of Diet Mammal + Birds (percent)** | **Food Ingestion Rate, Wet (kg/kg BW/day)** | **Fish Ingestion Rate (kg/kg BW/Day** | **Mammal/Bird Ingestion Rate (kg/kg BW/day)** | **Unadjusted Average Daily Dose (mg/kg/day)** | **Fraction Diet Soil (percent)** | **Soil Ingestion Rate (kg dry/kg BW/day)** | **Unadjusted Average Daily Dose Soil (mg/kg/day)** | **Bioavailability[3] (percent)** | **Carnivore Intake (mg/kg/day)** | **Seasonal Use Factor** | **Area Use Factor (Exposure Area/Home Range)** | **Adjusted Total Carnivore Average Daily Dose (mg/kg/day)** |
| Aluminum | 0.1986 | | 1 | | 0 | 0.1 | 0.01986 | 0.058 | 0.01 | 58% | 42% | 0.12 | 0.0696 | 0.0498 | 0.001 | 0.5% | 0.0006 | 0 | 100% | 0.01 | 1 | 0.00196 | 0.0000 |
| Barium | | 98.2 | 0.7 | -1.412 | 6.04 | 4 | 0 | 0.058 | 0 | 58% | 42% | 0.12 | 0.0696 | 0.0498 | 0.301 | 0.5% | 0.0006 | 0.00766 | 100% | 0.3086 | 1 | 0.00196 | 0.000603 |
| Chromium, Total | | 94.4 | 0.1444 | -1.4599 | 0.45 | 200 | 0 | 0.058 | 0 | 58% | 42% | 0.12 | 0.0696 | 0.0498 | 0.02 | 0.5% | 0.0006 | 0.00736 | 100% | 0.02967 | 1 | 0.00196 | 0.00005801 |
| Manganese | 2.501 | 610 | 0.004 | | 2.44 | 400 | 1,000.4 | 0.058 | 0.15 | 58% | 42% | 0.12 | 0.0696 | 0.0498 | 69.75 | 0.5% | 0.0006 | 0.04758 | 100% | 69.94 | 1 | 0.00196 | 0.137 |
| Mercury | 0.000004 | | | | | 63,000 | 0.24507 | 0.058 | 0.0000002 | 58% | 42% | 0.12 | 0.0696 | 0.0498 | 0.02 | 0.5% | 0.0006 | 0 | 100% | 0.017057 | 1 | 0.00196 | 0.0000334 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Sample et al. 1998a; EPA 2007 EcoSSLs, Att 4-1, Table 4a
[2] Al (Voigt et al. 2015), mean of fish tissue BAFs; Cu (USEPA 1980); Environmental Restoration Division - Manual ERD-AG-003 1999.
[3] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 12**
**Calculation of Average Daily Doses for Muskrat**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | | AVERAGE DAILY DOSE VIA: | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | WATER | | PLANTS / VEGETATION | | | | SOIL | | | | | | | |
| | $EPC_w$ | $EPC_s$ | | | $EPC_p$ | $NIR_W$ | $ADD_w$ | $P_f$ | $NIR_f$ | $NIR_p$ | $ADD_p$ | $S_f$ | $NIR_s$ | $ADD_s$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Slope, or Plant Uptake (BAF) | Intercept | Estimated[1] Concentration in Vegetation (mg/kg dry) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Plant Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Plant Ingestion Rate, Dry (kg/kg/day) | Unadjusted Average Daily Dose Plant (mg/kg/day) | Fraction Diet Soil (percent) | Soil Ingestion Rate (kg dry/kg BW/day) | Unadjusted Average Daily Dose Soil (mg/kg/day) | Bioavailability[2] (percent) | Herbivore Intake (mg/kg/day) | Seasonal Use Factor (unitless) | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Herbivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.0008 | | 0 | 0.97 | 0.19 | 99% | 0.3 | 0.045 | 0 | 1% | 0.000273 | 0 | 100% | 0.19 | 1 | 1 | 0.19 |
| Barium | | 98.2 | 0.03 | | 2.946 | 0.97 | 0 | 99% | 0.3 | 0.045 | 0.13164 | 1% | 0.000273 | 0.00349 | 100% | 0.14 | 1 | 1 | 0.14 |
| Chromium, Total | | 94.4 | 0.0015 | | 0.1416 | 0.97 | 0 | 99% | 0.3 | 0.045 | 0.00633 | 1% | 0.000273 | 0.00335 | 100% | 0.01 | 1 | 1 | 0.01 |
| Manganese | 2.501 | 610 | 0.05 | | 30.5 | 0.97 | 2.43 | 99% | 0.3 | 0.045 | 1.36289 | 1% | 0.000273 | 0.02165 | 100% | 3.81 | 1 | 1 | 3.81 |
| Mercury | 0.000004 | | | | | 0.97 | 0.000004 | 99% | 0.3 | 0.045 | 0 | 1% | 0.000273 | 0 | 100% | 0.000004 | 1 | 1 | 0.000004 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Bechtel Jacobs Company 1998a; Baes et al. 1984 (Mo); Environmental Restoration Division - Manual ERD-AG-003 1999; default value of 1 is used for constituents for which a BAF could not be found.
[2] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 13**
**Calculation of Average Daily Doses for River Otter**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| | | | | | AVERAGE DAILY DOSE VIA: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | DRINKING WATER | | FISH | | | | | | | | |
| | $EPC_w$ | $EPC_s$ | | $EPC_{PREY}$ | $NIR_w$ | $ADD_w$ | $P_f$ | $NIR_f$ | $NIR_a$ | $ADD_a$ | BF | $ADD_t$ | SUF | AUF | $ADD_{tot}$ |
| Analyte | COPEC in Water (mg/L) | COPEC in Solid (mg/kg) | Fish Uptake (BCF) | Estimated[1] Concentration in Fish (mg/kg) | Water Ingestion Rate (L/kg BW/day) | Unadjusted Average Daily Dose Water (mg/kg/day) | Fraction Diet Animal Matter (percent) | Food Ingestion Rate, Wet (kg/kg BW/day) | Fish Ingestion Rate (kg/kg BW/day) | Unadjusted Average Daily Dose (mg/kg/day) | Bioavailability[2] (percent) | Piscivore Intake (mg/kg/day) | Seasonal Use Factor (unitless) | Area Use Factor (Exposure Area/Home Range) | Adjusted Total Piscivore Average Daily Dose (mg/kg/day) |
| Aluminum | 0.1986 | | 0.1 | 0.02 | 0.081 | 0.016 | 100% | 0.19 | 0.19 | 0.0038 | 100% | 0.0199 | 1 | 0.012 | 0.000245 |
| Barium | | 98.2 | 4 | 0 | 0.081 | 0 | 100% | 0.19 | 0.19 | 0 | 100% | 0 | 1 | 0.012 | 0 |
| Chromium, Total | | 94.4 | 200 | 0 | 0.081 | 0 | 100% | 0.19 | 0.19 | 0 | 100% | 0 | 1 | 0.012 | 0 |
| Manganese | 2.501 | 610 | 400 | 1,000.4 | 0.081 | 0.203 | 100% | 0.19 | 0.19 | 190.08 | 100% | 190.279 | 1 | 0.012 | 2.351143 |
| Mercury | 0.000004 | | 63,000 | 0.25 | 0.081 | 0.0000003 | 100% | 0.19 | 0.19 | 0.047 | 100% | 0.047 | 1 | 0.012 | 0.000575 |

**NOTES:**

EPC - Exposure Point Concentration
NIR - Normalized Ingestion Rate
ADD - Average Daily Dose
BF - Bioavailability Factor
BAF - Bioaccumulation Factor
BCF - Bioconcentration Factor
SUF - Seasonal Use Factor
AUF - Area Use Factor

[1] Al (Voigt et al. 2015), mean of fish tissue BAFs; Cu (USEPA 1980); Environmental Restoration Division - Manual ERD-AG-003 1999.

[2] Bioavailability is set to a default of 100% to be conservative and protective of ecological receptors.

**Table 14**
**Hazard Quotients for COPCs - Terrestrial Receptors**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Analyte | Wildlife Receptor Hazard Quotient Estimated using the 'No Observed Adverse Effects Level' | | | |
|---|---|---|---|---|
| | Terrestrial | | | |
| | American Robin | Red-Tailed Hawk | Meadow Vole | Red Fox |
| Aluminum | 2.53E-04 | 5.14E-07 | 2.16E-02 | 3.07E-05 |
| Barium | 1.28E-02 | 2.57E-04 | 4.70E-03 | 6.33E-05 |
| Chromium, Total | 1.18E-01 | 3.96E-04 | 3.80E-05 | 1.62E-07 |
| Manganese | 6.34E-03 | 1.60E-05 | 5.10E-02 | 6.81E-05 |
| Mercury | 1.68E-07 | 3.41E-10 | 8.09E-07 | 1.15E-09 |

| Analyte | Wildlife Receptor Hazard Quotient Estimated using the 'Lowest Observed Adverse Effects Level' | | | |
|---|---|---|---|---|
| | Terrestrial | | | |
| | American Robin | Red-Tailed Hawk | Meadow Vole | Red Fox |
| Aluminum | 2.53E-05 | 5.14E-08 | 2.16E-03 | 3.07E-06 |
| Barium | 6.38E-03 | 1.28E-04 | 3.25E-03 | 4.37E-05 |
| Chromium, Total | 2.37E-02 | 7.91E-05 | 3.80E-06 | 1.62E-08 |
| Manganese | 3.26E-03 | 8.24E-06 | 3.70E-02 | 4.94E-05 |
| Mercury | 1.47E-06 | 2.99E-09 | 5.11E-06 | 7.25E-09 |

**NOTES:**
Hazard Quotients greater than or equal to 1 are highlighted in gray and in boldface.
NC - Not calculated due to lack of a Toxicity Reference Value

**Table 15**
**Hazard Quotients for COPCs - Aquatic Receptors**
**Crutchfield Branch**
**Baseline Ecological Risk Assessment**
**Duke Energy**
**Mayo Steam Electric Plant, Roxboro, NC**

| Analyte | Wildlife Receptor Hazard Quotient Estimated using the 'No Observed Adverse Effects Level' | | | | |
|---|---|---|---|---|---|
| | Aquatic | | | | |
| | Mallard Duck | Great Blue Heron | Bald Eagle[1] | Muskrat | River Otter |
| Aluminum | 1.02E-06 | 2.22E-06 | 1.78E-05 | 9.98E-02 | 1.27E-04 |
| Barium | 3.58E-04 | | 9.40E-05 | 2.61E-03 | |
| Chromium, Total | 9.53E-04 | | 1.96E-03 | 3.53E-06 | |
| Manganese | 4.01E-05 | 1.72E-02 | 1.09E-05 | 7.40E-02 | 4.57E-02 |
| Mercury | 6.74E-10 | 5.79E-05 | 6.02E-04 | 3.74E-06 | 5.70E-04 |

| Analyte | Wildlife Receptor Hazard Quotient Estimated using the 'Lowest Observed Adverse Effects Level' | | | | |
|---|---|---|---|---|---|
| | Aquatic | | | | |
| | Mallard Duck | Great Blue Heron | Bald Eagle[1] | Muskrat | River Otter |
| Aluminum | 1.02E-07 | 2.22E-07 | 1.78E-06 | 9.98E-03 | 1.27E-05 |
| Barium | 1.78E-04 | | 4.69E-05 | 1.80E-03 | |
| Chromium, Total | 1.91E-04 | | 3.91E-04 | 3.53E-07 | |
| Manganese | 2.06E-05 | 8.83E-03 | 5.62E-06 | 5.37E-02 | 3.31E-02 |
| Mercury | 5.92E-09 | 5.08E-04 | 5.28E-03 | 2.36E-05 | 3.60E-03 |

**NOTES:**
Hazard Quotients greater than or equal to 1 are highlighted in gray and in boldface.
NM - Not measured due to lack of a Toxicity Reference Value
[1] The bald eagle was added to this risk assessment model because the species is federally protected and represents a raptor that preys upon fish, primarily, while the Red-Tailed Hawk primarily preys upon small terrestrial vertebrates (e.g., rodents, snakes, etc.). Hazard quotient calculations for the Bald Eagle include hypothetical consumption of fish that inhabit adjacent surface water areas in addition to terrestrial vertebrates that inhabit adjacent areas.

# Appendix C

# Exposure Modeling and Human Health Risk Assessment for Diesel Emissions

# Air Dispersion Modeling for Mayo Ash Basin Closure

I used screening models to evaluate the potential for both cancer and non-cancer risks from diesel exhaust emissions due to increased trucking operations related to the closure of the coal ash basin at the Duke Energy Mayo Plant. The calculated cancer and non-cancer risks are associated with increased diesel trucking activity near residential properties that lie along transportation corridors near the Mayo Plant. Modelling was conducted for cap-in-place (CIP), excavation to an expanded onsite landfill, and hybrid closure options. Details of these closure options are provided in the main body of the report.

Emission rates for the fleet of diesel trucks operating as part of closure activities were calculated based on truck activity and emission factors representative of the region from the U.S. Environmental Protection Agency (EPA) Mobile Vehicle Emissions Simulator (MOVES). I estimated airborne concentrations of emitted pollutants using the EPA model AERMOD for atmospheric dispersion and transport. AERMOD is a Gaussian plume model that accounts for the impacts of meteorology and land characteristics on airborne pollutants. Together these tools allowed for the estimation of airborne concentrations of diesel particulate matter (DPM) emitted from passing trucks and subsequent calculation of potential non-cancer health impacts (hazard index [HI]) and cancer risk estimates (excess lifetime cancer risk [ELCR]).

The following sections detail the data and models used in this evaluation, including the meteorological data, trucking operations, emissions calculations, and dispersion modeling. I also include additional discussion of the results and associated uncertainties.

# Methodology

## Meteorological Data

AERMOD-ready five-year[1] meteorological data sets of hourly surface meteorological data for the years 2012–2016 were generated from the National Weather Service (NWS) Automated Surface Observing System (ASOS) station at the Danville Regional Airport (KDAN) in Danville, Virginia.[2] The Danville Regional Airport is located approximately 35 km from Duke Energy's Mayo Plant. I judged this station to be representative of the meteorology in the region of the Mayo Plant. Surface parameters applied to the modeling study included wind speed and direction, temperature, pressure, relative humidity, and cloud cover. Twice daily rawinsonde[3] observations of upper air winds and temperatures were taken from Greensboro, North Carolina (KGSO), which, at 105 km from Mayo Plant, is the closest upper air sounding site.[4]

The meteorological data were processed using AERMET (v16216) with default options.[5] To better resolve lower wind speeds and avoid over-estimating calm conditions, AERMINUTE was also applied.[6] AERSURFACE[7] was used to define the land-use characteristics in the region around the surface observational site (i.e., Danville Regional Airport). The surface

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1 Use of five years of meteorological data is standard in regulatory application of AERMOD (EPA Guideline on Air Quality Models, Section 8.3.1, 2005).

2 Integrated surface hourly weather observations are available at ftp://ftp.ncdc.noaa.gov/pub/data/noaa/. 2-minute average ASOS wind data are available at ftp://ftp.ncdc.noaa.gov/pub/data/asos-onemin/.

3 A rawinsonde is a device typically carried by weather balloons that collects meteorological and atmospheric data, especially regarding winds.

4 Not all meteorological stations will record upper air data (soundings); however, the difference in locations does not substantively affect the model because the atmosphere at higher levels has less spatial variability. Thus, upper atmospheric conditions at Greensboro, North Carolina, are likely to be similar to those at Danville, Virginia, and, by extension, at the Mayo Plant.

5 AERMET is an EPA program that will read standard recorded meteorological observations, calculate boundary layer meteorological parameters, and output the data in a format readable by the AERMOD model (U.S. EPA 2016).

6 Because the Danville Regional Airport has an ASOS where 2-minute average wind direction and wind speed data are recorded every minute, it was possible to use AERMINUTE with AERMOD. More frequent measurements of wind data allow for better resolution of wind characteristics.

7 AERSURFACE is the EPA model used to calculate average land-use characteristics. It can read standard databases and calculate the average values of surface roughness, albedo, and Bowen ratios, consistent with EPA recommended methods.

characteristics, which are important when calculating the level of atmospheric dispersion in meteorological modeling, include surface roughness, albedo,[8] and Bowen ratio.[9]

## Trucking Operations

Diesel emissions estimates from trucking are based on the number of trucks passing a given receptor location along transportation corridors used during ash basin closure. The total number of truckloads required for transporting ash, earthen fill, and geosynthetic materials under the Mayo closure scenarios were projected by Duke Energy (2018b). These truckloads equate to 11,481 total truck passes for CIP closure; 100 truck passes for excavation to an expanded onsite landfill; and 11,418 truck passes for the hybrid option. I included only loads hauling earthen fill, geosynthetic materials, and other materials in transportation emissions estimates for all options because trucks hauling ash in the excavation option do not leave the Mayo Plant except for crossing U.S. Highway 501, and no residences are present within 150 m of the road along the onsite hauling route. Trucks hauling earthen fill are assumed to travel 11 miles one way from the site, and trucks hauling geosynthetic material are assumed to travel 275 miles one way from Georgetown, South Carolina. Air modeling is conducted for a receptor along the transportation route within the 11-mile radius traveled both by trucks hauling earthen fill and trucks hauling geosynthetic material. Trucks are assumed to travel in round trips, so the number of material loads was doubled to represent the number of truck passes.

## AERMOD

The AERMOD modeling system (U.S. EPA 2016) is a steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of surface and elevated sources. EPA's "Guideline on Air Quality Models" (U.S. EPA 2016) identifies AERMOD as the preferred refined dispersion modeling technique for receptors within 50 km of a modeled source.

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8 Albedo is the ratio of reflected flux density to incident flux density. It indicates how much incoming energy is absorbed by the land surface. Light surfaces (such as snow) will reflect higher levels of incoming energy.

9 Bowen ratio is the ratio of sensible to latent heat fluxes from the earth's surface up into the air. Lower Bowen ratio is indicative of greater water content in the land surface.

The latest version of AERMOD (v16216r) was used with default options to conduct the modeling.

## Modeled Source and Receptors

AERMOD was configured to simulate an approximately 1-km stretch of road. This road segment was assumed representative of any segment along the proposed transportation corridors. The road emission source was modeled as a continuous distribution of emission along the road due to the passage of multiple trucks. In the cross-road direction, the emissions drop off based on a normal (or Gaussian) distribution. The road emissions were represented using a line of closely spaced volume sources running down the center of the road. Volume sources define the initial pollutant distribution based on an initial release height and the standard deviation of the normal distribution in both the vertical and horizontal directions (sigma-y and sigma-z). The appropriate values for the release height and standard deviations were calculated based on guidance in EPA's Haul Road Working Group Final Report (U.S. EPA 2010).

Transport and dispersion of pollutants away from the road segment may be sensitive to the predominant wind directions at the site and the orientation of the road compared to those predominant wind directions. To fully evaluate the impacts of any road segment, four orientations of the road were considered. Modeled orientations included roads running north/south, east/west, northeast/southwest, and northwest/southeast. For each modeled road orientation, receptors were included on both sides of the road to represent impacts at distances between 10 and 150 m from the edge of the road. The representative road segments and sampling receptor locations are shown in Figure C-1.

AERMOD was run for the five-year period (2012–2016) defined by the meteorological data. The resulting five-year average dispersion factors were assumed representative of long-term average dispersion of truck roadway emissions along roads in this region.

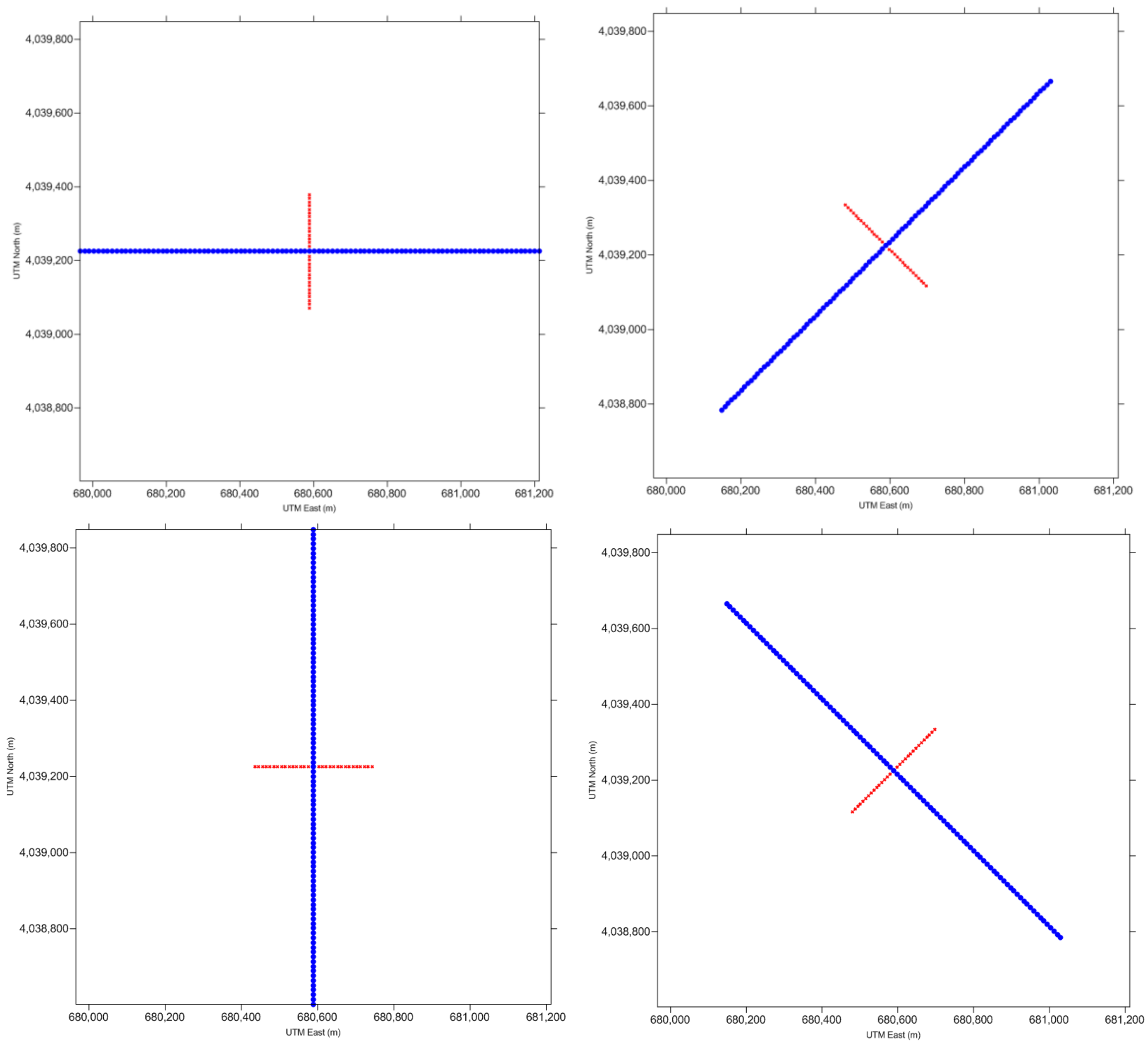


Figure C-1. Location of road sources (blue) and sampling receptors (red) for each of 4 road orientations

## Source Emission Rates

Emission rates for mobile sources are typically calculated based on a combination of emission factors and activity rates. The emission factors define the amount of pollutant emitted per unit distance traveled (grams of pollutant per kilometer traveled), and the activity rates define how much activity occurs (i.e., the number of kilometers driven by the vehicles). Emission factors will be specific to the type of vehicle being considered, the model year, the age of the vehicle, and the local climate. For this evaluation, EPA's MOVES model was used to define fleet average emission factors for various years between 2018 and 2050 (2050 is the last year simulated by MOVES) (U.S. EPA 2015). The 2050 emission factors were retained for all years after 2050. These emission factors are specific to North Carolina and have been selected to represent large, single-unit diesel trucks.

Tailpipe emissions from diesel trucks (DPM) are the subset of $PM_{10}$ of particular interest when evaluating the cancer and non-cancer risk estimates in this analysis. The DPM emission factors generated by MOVES were multiplied by the expected number of trucks under each of the considered scenarios to calculate emission rates for each scenario.

For the cancer risk analysis, emissions were calculated as an average over the regulatory default 70-year residential exposure duration. If the truck activity for a scenario occurs over a shorter period, the duration of the truck activity exposure is factored into the 70-year averaging time (OEHHA 2015). These average emission rates were multiplied by the dispersion factors calculated by AERMOD to predict airborne concentrations. The resulting values were then multiplied by the cancer unit risk factor[10] to quantify cancer risk.

For the non-cancer analysis, airborne concentrations of DPM were calculated and compared to the non-cancer risk threshold of 5 $\mu g/m^3$.[11] In this case, the average concentrations are not tied to a 70-year period and are calculated over the period of operation for each closure option.

10 A "reasonable estimate" for the inhalation unit risk of $3.0 \times 10^{-4}$ $(\mu g/m^3)^{-1}$ was applied based on California guidelines (OEHHA 2015).

11 North Carolina defers to the EPA's chronic non-cancer reference concentration (RfC) for DPM of 5 $\mu g/m^3$ based on diesel engine exhaust to estimate risk from diesel emissions (Integrated Risk Information System [IRIS]. U.S. EPA. Diesel engine exhaust).

# Uncertainties

A number of uncertainties should be considered when evaluating the modeled results. First, air dispersion modeling is a mathematical calculation of pollutant transport and dispersion and may differ from real world conditions. Typically, for regulatory applications, air dispersion models are expected to predict concentrations within a factor of two. Longer averaging periods, such as those used in this study, would often have lower uncertainties as compared with shorter average periods such as 1-hour or 24-hour averages.

The calculation of emission factors is meant to represent fleet average characteristics. The fleet of trucks used at this specific site may differ from the average values included in MOVES. This may result in higher or lower actual emission rates. Additionally, MOVES includes predictions of future year emission factors based on typical patterns of vehicle turnover and any regulations scheduled to be implemented in future years. Not all future regulations are presently known and future conditions may vary from these estimates.

For the non-cancer risk, an evaluation of the average concentrations was calculated over the actual period of activity, which varies between closure options. For this portion of the evaluation, there was no accounting for how long the emissions were present. The non-cancer risk value is generally considered applicable over a period of approximately eight years. For activities that occur for less than eight years, comparison with this risk value may overstate the actual risk. Correspondingly, for activities that run significantly longer than eight years, there may be sub-periods with higher average concentrations and higher associated non-cancer risk.

# Results

Worst-case impacts were calculated for each distance from the modeled road. The worst-case result represents the highest value calculated over the four road orientations. This may not be the same orientation for all distances. For example, a road that runs northeast/southwest aligns with the predominant wind direction. This results in higher concentrations for receptors close to the road. For receptors farther away from the edge of the road, the worst case occurs for a northwest/southeast road where winds are perpendicular to the road. Worst-case results are reported in Table 9-2 of the main report. The following sections include results for all road orientations and distances from both sides of the road.

## Model-estimated cancer risk

ELCR results for the four road orientations and both sides of the road are provided in Table C-1.

**Table C-1. ELCR estimates from DPM exposure due to trucking operations associated with closure of the Mayo Plant under CIP closure, excavation closure, and hybrid closure. Results are for each road orientation and distances from both sides of the road (ELCR columns per orientation).**

| | E-W Run | | NE-SW Run | | N-S Run | | NW-SE Run | |
|---|---|---|---|---|---|---|---|---|
| **CIP** | | | | | | | | |
| 10 m | 2.1E-09 | 2.0E-09 | 2.5E-09 | 2.8E-09 | 2.2E-09 | 1.7E-09 | 1.6E-09 | 1.6E-09 |
| 20 m | 2.0E-09 | 1.8E-09 | 2.0E-09 | 2.2E-09 | 2.1E-09 | 1.6E-09 | 1.6E-09 | 1.8E-09 |
| 30 m | 1.6E-09 | 1.4E-09 | 1.6E-09 | 1.8E-09 | 1.7E-09 | 1.3E-09 | 1.3E-09 | 1.5E-09 |
| 40 m | 1.3E-09 | 1.2E-09 | 1.3E-09 | 1.5E-09 | 1.4E-09 | 1.1E-09 | 1.1E-09 | 1.2E-09 |
| 50 m | 1.1E-09 | 1.0E-09 | 1.0E-09 | 1.2E-09 | 1.2E-09 | 9.4E-10 | 9.7E-10 | 1.1E-09 |
| 60 m | 1.0E-09 | 8.8E-10 | 8.9E-10 | 1.1E-09 | 1.1E-09 | 8.3E-10 | 8.6E-10 | 9.6E-10 |
| 70 m | 9.0E-10 | 7.8E-10 | 7.7E-10 | 9.4E-10 | 9.6E-10 | 7.4E-10 | 7.7E-10 | 8.6E-10 |
| 80 m | 8.2E-10 | 7.0E-10 | 6.8E-10 | 8.4E-10 | 8.6E-10 | 6.7E-10 | 7.0E-10 | 7.8E-10 |
| 90 m | 7.4E-10 | 6.3E-10 | 6.1E-10 | 7.5E-10 | 7.9E-10 | 6.1E-10 | 6.4E-10 | 7.1E-10 |
| 100 m | 6.9E-10 | 5.8E-10 | 5.5E-10 | 6.8E-10 | 7.2E-10 | 5.6E-10 | 5.9E-10 | 6.6E-10 |
| 110 m | 6.3E-10 | 5.3E-10 | 4.9E-10 | 6.2E-10 | 6.6E-10 | 5.2E-10 | 5.5E-10 | 6.1E-10 |
| 120 m | 5.9E-10 | 4.9E-10 | 4.5E-10 | 5.7E-10 | 6.1E-10 | 4.9E-10 | 5.1E-10 | 5.7E-10 |
| 130 m | 5.5E-10 | 4.6E-10 | 4.1E-10 | 5.2E-10 | 5.7E-10 | 4.6E-10 | 4.8E-10 | 5.3E-10 |
| 140 m | 5.2E-10 | 4.3E-10 | 3.8E-10 | 4.8E-10 | 5.3E-10 | 4.3E-10 | 4.5E-10 | 5.0E-10 |
| 150 m | 4.9E-10 | 4.0E-10 | 3.5E-10 | 4.5E-10 | 5.0E-10 | 4.1E-10 | 4.3E-10 | 4.7E-10 |
| **Excavation** | | | | | | | | |
| 10 m | 1.1E-11 | 1.1E-11 | 1.4E-11 | 1.5E-11 | 1.2E-11 | 9.3E-12 | 8.8E-12 | 8.9E-12 |
| 20 m | 1.1E-11 | 9.8E-12 | 1.1E-11 | 1.2E-11 | 1.1E-11 | 8.8E-12 | 8.9E-12 | 9.7E-12 |
| 30 m | 8.6E-12 | 7.8E-12 | 8.5E-12 | 9.6E-12 | 9.2E-12 | 7.1E-12 | 7.2E-12 | 8.0E-12 |
| 40 m | 7.2E-12 | 6.5E-12 | 6.8E-12 | 7.9E-12 | 7.8E-12 | 5.9E-12 | 6.1E-12 | 6.8E-12 |
| 50 m | 6.2E-12 | 5.5E-12 | 5.7E-12 | 6.7E-12 | 6.7E-12 | 5.1E-12 | 5.3E-12 | 5.9E-12 |
| 60 m | 5.5E-12 | 4.8E-12 | 4.8E-12 | 5.8E-12 | 5.9E-12 | 4.5E-12 | 4.7E-12 | 5.2E-12 |
| 70 m | 4.9E-12 | 4.2E-12 | 4.2E-12 | 5.1E-12 | 5.2E-12 | 4.0E-12 | 4.2E-12 | 4.7E-12 |
| 80 m | 4.4E-12 | 3.8E-12 | 3.7E-12 | 4.5E-12 | 4.7E-12 | 3.6E-12 | 3.8E-12 | 4.2E-12 |
| 90 m | 4.0E-12 | 3.4E-12 | 3.3E-12 | 4.1E-12 | 4.3E-12 | 3.3E-12 | 3.5E-12 | 3.9E-12 |
| 100 m | 3.7E-12 | 3.1E-12 | 3.0E-12 | 3.7E-12 | 3.9E-12 | 3.1E-12 | 3.2E-12 | 3.6E-12 |
| 110 m | 3.4E-12 | 2.9E-12 | 2.7E-12 | 3.4E-12 | 3.6E-12 | 2.8E-12 | 3.0E-12 | 3.3E-12 |
| 120 m | 3.2E-12 | 2.7E-12 | 2.4E-12 | 3.1E-12 | 3.3E-12 | 2.6E-12 | 2.8E-12 | 3.1E-12 |
| 130 m | 3.0E-12 | 2.5E-12 | 2.2E-12 | 2.8E-12 | 3.1E-12 | 2.5E-12 | 2.6E-12 | 2.9E-12 |
| 140 m | 2.8E-12 | 2.3E-12 | 2.1E-12 | 2.6E-12 | 2.9E-12 | 2.3E-12 | 2.4E-12 | 2.7E-12 |
| 150 m | 2.7E-12 | 2.2E-12 | 1.9E-12 | 2.4E-12 | 2.7E-12 | 2.2E-12 | 2.3E-12 | 2.6E-12 |

**Table C-1. (cont). ELCR estimates from DPM exposure due to trucking operations associated with closure of the Mayo Plant under CIP closure, excavation closure, and hybrid closure. Results are for each road orientation and distances from both sides of the road (ELCR columns per orientation).**

| | E-W Run | | | NE-SW Run | | | N-S Run | | | NW-SE Run | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hybrid** | | | | | | | | | | | |
| 10 m | 1.5E-09 | 1.4E-09 | | 1.8E-09 | 2.0E-09 | | 1.6E-09 | 1.2E-09 | | 1.1E-09 | 1.2E-09 |
| 20 m | 1.4E-09 | 1.3E-09 | | 1.4E-09 | 1.6E-09 | | 1.5E-09 | 1.1E-09 | | 1.2E-09 | 1.3E-09 |
| 30 m | 1.1E-09 | 1.0E-09 | | 1.1E-09 | 1.2E-09 | | 1.2E-09 | 9.2E-10 | | 9.4E-10 | 1.0E-09 |
| 40 m | 9.4E-10 | 8.4E-10 | | 8.9E-10 | 1.0E-09 | | 1.0E-09 | 7.7E-10 | | 7.9E-10 | 8.8E-10 |
| 50 m | 8.1E-10 | 7.2E-10 | | 7.4E-10 | 8.7E-10 | | 8.7E-10 | 6.6E-10 | | 6.9E-10 | 7.6E-10 |
| 60 m | 7.1E-10 | 6.2E-10 | | 6.3E-10 | 7.5E-10 | | 7.6E-10 | 5.8E-10 | | 6.1E-10 | 6.8E-10 |
| 70 m | 6.4E-10 | 5.5E-10 | | 5.5E-10 | 6.6E-10 | | 6.8E-10 | 5.2E-10 | | 5.4E-10 | 6.0E-10 |
| 80 m | 5.8E-10 | 4.9E-10 | | 4.8E-10 | 5.9E-10 | | 6.1E-10 | 4.7E-10 | | 4.9E-10 | 5.5E-10 |
| 90 m | 5.3E-10 | 4.5E-10 | | 4.3E-10 | 5.3E-10 | | 5.5E-10 | 4.3E-10 | | 4.5E-10 | 5.0E-10 |
| 100 m | 4.8E-10 | 4.1E-10 | | 3.8E-10 | 4.8E-10 | | 5.1E-10 | 4.0E-10 | | 4.1E-10 | 4.6E-10 |
| 110 m | 4.5E-10 | 3.8E-10 | | 3.5E-10 | 4.4E-10 | | 4.7E-10 | 3.7E-10 | | 3.8E-10 | 4.3E-10 |
| 120 m | 4.2E-10 | 3.5E-10 | | 3.2E-10 | 4.0E-10 | | 4.3E-10 | 3.4E-10 | | 3.6E-10 | 4.0E-10 |
| 130 m | 3.9E-10 | 3.2E-10 | | 2.9E-10 | 3.7E-10 | | 4.0E-10 | 3.2E-10 | | 3.4E-10 | 3.8E-10 |
| 140 m | 3.7E-10 | 3.0E-10 | | 2.7E-10 | 3.4E-10 | | 3.8E-10 | 3.0E-10 | | 3.2E-10 | 3.5E-10 |
| 150 m | 3.4E-10 | 2.8E-10 | | 2.5E-10 | 3.2E-10 | | 3.5E-10 | 2.9E-10 | | 3.0E-10 | 3.3E-10 |

## Model-estimated non-cancer risk

HI results for the four road orientations and both sides of the road are provided in Table C-2.

**Table C-2. HI estimates from DPM exposure due to trucking operations associated with closure of the Mayo Plant under CIP closure, excavation closures, and hybrid closure. Results are for each road orientation and distances from both sides of the road (HI columns per orientation).**

| | E-W Run | | NE-SW Run | | N-S Run | | NW-SE Run | |
|---|---|---|---|---|---|---|---|---|
| **CIP** | | | | | | | | |
| 10 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 40 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 60 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 70 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 80 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 90 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 100 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 110 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 120 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 130 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 140 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 150 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Excavation** | | | | | | | | |
| 10 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 40 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 50 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 60 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 70 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 80 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 90 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 100 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 110 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 120 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 130 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 140 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 150 m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table C-2. (cont). HI estimates from DPM exposure due to trucking operations associated with closure of the Mayo Plant under CIP closure, excavation closure, and hybrid closure. Results are for each road orientation and distances from both sides of the road (HI columns per orientation).**

| | E-W Run | | | NE-SW Run | | | N-S Run | | | NW-SE Run | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Hybrid** | | | | | | | | | | | |
| 10 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 20 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 30 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 40 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 50 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 60 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 70 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 80 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 90 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 100 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 110 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 120 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 130 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 140 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |
| 150 m | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 | | 0.000 | 0.000 |

# Appendix D

## Habitat Equivalency Analysis

# Habitat Equivalency Analysis

Habitat equivalency analysis (HEA) was used to estimate changes in ecological service levels under different closure options for the Mayo Plant ash basin. The extent of ecological service flows currently provided by ash basin habitats (wooded areas, open field, open water, etc.) and associated sites (borrow/landfill areas) was calculated and compared to service flows provided by post-closure habitats in these areas.

The HEA proceeded in four steps:

1. **Estimate habitat areas:** The acres of different habitat types (e.g., forest, open field, open water, wetland) that would be affected by closure under each closure option (i.e., cap in place [CIP], excavation, and hybrid closures) were estimated from aerial imagery.
2. **Evaluate ecological service levels:** The relative level of ecological services provided by these habitats was estimated in terms of net primary productivity (NPP).
3. **Apply discounting for future services:** The relative levels of ecological services were calculated over time according to the construction implementation schedule developed by Duke Energy (2018b) and expressed in units of discounted service acre-years (DSAYs).
4. **Calculate discounted ecological services:** DSAYs were summed across the gains and losses of each habitat type to produce a net gain or loss in ecological service levels for each closure option.

## Estimate Habitat Areas

Acreages of current habitat types were calculated from geographic information system (GIS) files provided by Duke Energy that included spatial representations of the current acreage of open field, wetland, wooded area, and open water habitats surrounding the ash basin. The acreages of ash basin to be closed and land converted to landfill or borrow were based on information provided by Duke Energy (2018b) according to the assumptions below. For the excavation and hybrid options, the closure-by-removal portions of the ash basin were assumed to be restored to historical, pre-basin conditions. Historical acreage of forested, open field, and stream habitat types were estimated by measuring pre-basin aerial photographs provided in the comprehensive site assessment (CSA; SynTerra 2015a) using GIS. Unclassified current habitat areas in the ash basin footprint were assumed to be bare ground and to have a 0% service value. Historical habitat types were broadly classified into forest, open water, and unclassified open areas since not all currently measured habitat types (e.g., wetland) could be resolved from historical images. Historical open unclassified areas (i.e., not forest or open water habitat types) were estimated by assuming the current site-wide percentages of wetland (9.6%) and open field (90.4%) applied to these areas within the historical ash basin footprint. It is important to note that not all closure options impacted all basin habitat areas, thus different closure options may be modeled in the HEA using different total areas.

Additional assumptions used to calculate habitat areas included:

- The historical stream habitat area of the Crutchfield Branch was available only as linear spatial feature. To calculate the area of restored stream features as open water, I assumed a restored stream would have a width of 6 ft.
- Fill material for closure was assumed to be derived from excavation of basin dam features and new, onsite borrow pits. The areal extent of these borrow pits was calculated from the volume (cubic yards) of required earthen fill material, assuming borrow pits would be dug to 15 ft.
- Area lost to borrow pit excavation was assumed to contain forest habitat, which is the predominant non-basin habitat type on the Mayo property.

## Evaluate Ecological Services

NPP was used to standardize ecological services across habitat types. NPP is a measure of how much photosynthesis occurs in an area greater than the amount required by the plants for immediate respiration needs. Fundamentally, NPP is a measure of the energy available to perform ecological services and is a useful currency for comparing habitats (Efroymson et al.

2003). NPP is often referred to in terms of carbon fixation or carbon storage, as the removal of carbon from the atmosphere is a primary reaction of photosynthesis.

Of the habitats currently occurring on the site, mixed forested areas have the highest NPP; that is, per acre of forest, photosynthesis fixes more carbon/produces more energy for ecological services (Ricklefs 2008). As such, NPP service levels for all habitat types were normalized to the NPP service level of forested habitat. Specifically, the service levels for all habitat types were expressed as a proportion of the maximum wooded area service level (He et al. 2012).

To compare results between the different closure options, a set of assumptions was used for all options evaluated.

- Figure 22.12 from Ricklefs (2008) was used as the basis for determining relative rates of NPP for different ecosystem types. For this evaluation, temperate forest (woodland) was considered the base habitat with a relative NPP of 100%. Other habitat types were normalized as a proportion of that value based on the relative levels of NPP shown in Ricklefs' Figure 22.12 (2008), using temperate grassland as representative of open fields and freshwater environments as representative of open water.
  - Based on Ricklefs' Figure 22.12 (2008), NPP values for open field and open water habitats were assumed to be 40% of the forest value. However, because aquatic habitats of the ash basin may not be functionally equivalent to naturally occurring freshwater ecosystems (e.g., less abundant or diverse vegetation), a habitat quality adjustment factor of 4 was applied, lowering the relative NPP value for ash basin open water habitat to 10% of temperate forest NPP.
- Figure 2c from He et al. (2012) was used to estimate NPP of woodland areas based on stand age.
  - The NPP functions for the three forest types (broadleaf, needleleaf, mixed) from Figure 2c of He et al. (2012) were digitized to allow calculation of NPP by stand age. For example, for mixed forests this

function shows rapidly increasing NPP up to a maximum at 45 years, after which the NPP declines slightly to level off at approximately 85% of the maximum.

  - All wooded areas currently occurring in the ash basin or on borrow or landfill areas were assumed to be 50 years old, which, based on He et al. (2012), provide approximately 97% of maximum NPP function in the case of broadleaf and mixed forests and 84% for needleleaf forests. Other habitats were normalized from the higher value using the relative rates of NPP described above.

- Baseline levels of service (NPP) in the absence of closure activities were assumed to continue at the current rate for 150 years, accounting for slight changes in wooded area NPP by age as calculated from the NPP function of He et al. (2012).

## Apply Discounting for Future Services

HEA applies a discounting function when calculating the amount of ecological services derived from an acre over a year and uses as its metric a discounted service acre-year, or DSAY. Discounting is necessary because ecological services occurring in the future are assumed to be less valuable to people than the same services performed now (Dunford et al. 2004; Desvousges et al. 2018; Penn undated). This allows the ecological services occurring far in the future to be considered on par with contemporary services. Thus, factors determining when closure and remediation begin and the duration of these processes are important parameters of the final DSAY estimate.

I used the closure schedule provided by Duke Energy (2018b) to develop timelines for habitat loss and gain under each closure option. For purposes of the HEA, only site preparation, construction, and site restoration times were included. Pre-design and design permitting periods were assumed to have no effect on ecological services. The closure schedule estimated duration of each activity in months; however, since the HEA model calculates DSAYs on an annual basis, the activity durations were rounded up the nearest full year. This has a negligible impact on DSAY estimates.

The following assumptions were then used to standardize timing of activities among the closure options:

- For all options, removal of existing onsite habitats was assumed to occur in the year that construction begins and was assumed to be completed the same year such that no ecological service is provided by the end of the first construction year.
- Ecological services of areas used for borrow or as landfill were assumed to be lost in the year construction starts, and borrow/landfill site preparation was assumed to be complete the same year such that no ecological service is provided by the end of the first construction year.
- Ecological service gains from restoration (ash basin and borrow area) were assumed to begin in the year following completion of construction activities.
- Post-closure habitats were presumed eventually to provide the same level of service as equivalent pre-closure habitats with the following conditions:
  - Forests would be age 0 in the year when restoration was completed and would generate an increasing level of NPP as they grow, following the rates calculated from the NPP curves of He et al. (2012).
  - Restored open field habitat would take five years (based on professional judgement) to reach the baseline relative to forest NPP of 40%, with service levels increasing linearly over that time.
  - Restored wetland and stream habitat would be functionally equivalent to natural freshwater ecosystems and would provide an NPP relative to forests of 40% after five years (based on professional judgement), increasing linearly over that time.

  - Periodic mowing is required to maintain a grass cap, so grass cap was assumed never to reach a level of service equivalent to an open field. Grass cap was assumed to have 20% of the NPP service level for open field, which is 8% of forest NPP. Grass cap was assigned a post-closure service level of 8%, with full service attained in 2 years.
  - Bare ground was assumed to provide no ecological service.
- The base year for discounting is 2019 in all scenarios.
- A discount rate of 3% is applied in all scenarios.
- The HEA is run for 150 years for all closure options.

## Calculate Discounted Ecological Services

Calculation of DSAYs is a summation of the discounted losses and gains in service values across habitat types. The net DSAYs calculated for each closure option are reported in Table 10-1 of the main body of this report.

A sensitivity analysis of key parameters (based on professional experience) and assumptions used in the HEA was conducted to evaluate how sensitive the HEA results are to changes in (1) the duration over which the services were evaluated (i.e., 150 years), (2) the assumed relative NPP of ash basin open water and open fields, and (3) habitat created by restoration of borrow areas. The results are discussed in the context of uncertainty in the net environmental benefit analysis (NEBA) in Appendix E.

# Appendix E

# Net Environmental Benefit Analysis

# Net Environmental Benefit Analysis

Net environmental benefit analysis (NEBA) is a structured framework for comparing impacts and benefits to environmental services to support decision-making (Efroymson et al. 2003, 2004). In the NEBA application for Mayo ash basin closure, a risk-ranking approach, based on that described by Robberson (2006), was applied. The risk-ranking approach develops alphanumerical estimates of relative risk by closure option and by attribute (e.g., risk to a receptor, change in ecological services), which allows comparison of the relative differences in impact between closure options to a variety of attributes. In this way, tradeoffs can be visualized to inform decision-making.

## Risk-Ranking Matrix

The risk-ranking matrix includes two axes that characterize risk. The y-axis shows the level of impact, or risk, to an attribute, and the x-axis shows the duration of the impact (which is directly related to the time to recovery). Both are important to evaluate the relative differences in risk posed by closure options. A moderate level of impact over a long duration can potentially have an overall greater negative impact on the environment than a higher impact over a very short period (Robberson 2006). The pattern of shading of the risk matrix conveys this general principle, though the exact shading of the cells is based on best professional judgement. Robberson (2006) describes darker shading as indicating a higher level of concern over the level of impact to a resource or environmental service. The NEBA matrix developed by the Operational Science Advisory Team-2 (OSAT 2011) used a similar color coding approach to compare risk from further cleanup of oil on beaches of the Gulf of Mexico following the Deepwater Horizon oil spill. The risk-ranking matrix used in the NEBA of closure options for the Mayo ash basin is shown in Table E-1.

**Table E-1. Risk-ranking matrix for impacts and risk from closure activities. Darker shading and higher codes indicate greater impact.**

| | | Duration of Impact (years) | | | |
|---|---|---|---|---|---|
| | | 10–15 **(4)** | 5–9 **(3)** | 1–4 **(2)** | <1 **(1)** |
| **% Impact** | No meaningful risk | -- | -- | -- | -- |
| | <5% **(A)** | **4A** | **3A** | **2A** | **1A** |
| | 5–19% **(B)** | **4B** | **3B** | **2B** | **1B** |
| | 20–39% **(C)** | **4C** | **3C** | **2C** | **1C** |
| | 40–59% **(D)** | **4D** | **3D** | **2D** | **1D** |
| | 60–79% **(E)** | **4E** | **3E** | **2E** | **1E** |
| | >80% **(F)** | **4F** | **3F** | **2F** | **1F** |

The percent impact levels (e.g., <5%, 5–19%) were defined based on best professional judgement and regulatory precedent. A <5% impact characterizes a very minor potential or expected impact that may be functionally indistinct from baseline conditions due to uncertainty in metrics or the estimated effects. As such, this level of impact was given no shading, regardless of the duration of impact. Impacts between 5–19% are considered low in the NEBA framework (Efroymson et al. 2003). This impact level was shaded to reflect this low risk. Levels of impact >20% were separated at intervals of 20% based on best professional judgement and consistent with the risk-ranking approach used by Robberson (2006).

Similarly, the categories used to define duration of impact were based on best professional judgment and regulatory precedent. Robberson (2006) defines recovery in <1 year as “rapid,” with shading that indicates a generally low level of concern across the levels of impact. The remaining categories of time in the risk-ranking matrix were divided at roughly 5-year intervals. As Robberson (2006) notes, the exact size of the risk matrix is a function of decisions made about scaling the matrix, which is a function of the closure and remediation being considered and the attributes included in the NEBA. The risk-ranking matrix applied here could have been defined differently. For example, the duration of impact categories could have been expanded to six (e.g., <1 year, 1–3 years, 3–6 years, 6–10 years, 10–15 years, >15 years), which would have changed the alphanumeric risk ratings and perhaps some of the shading of attributes evaluated in the NEBA. The purpose of the risk matrix, and the risk ratings that result from it, is to consolidate the results from a variety of different analyses for a variety of different data types and attributes into a single framework for comparative analysis. It is imperative, however, to consider the underlying information used to develop the risk ratings to interpret the differences between closure options, particularly when percent impacts or durations of closure options are similar but receive different risk ratings. It is inappropriate to assume a risk rating for one attribute is scientifically equivalent to the risk rating of another attribute because the comparative metrics that form the foundation of the risk ratings can be fundamentally different (e.g., a hazard quotient for risk to a bird species is different from discounted service acre-years [DSAYs] for environmental services from a habitat). Thus, the risk ratings in the NEBA matrix permit a relative comparison of impacts between closure options within attributes. Decision-makers can use the NEBA framework to identify the relative impacts of closure options across many different attributes, but the NEBA matrix does not, by design, elevate, or increase the value of, any specific risk or benefit in the framework.

## Risk Rating Sensitivity

Uncertainty in a NEBA can be evaluated by examining the uncertainty in the assumptions and analyses used as inputs to the risk-ranking matrix. The following sections examine how differences in assumptions could affect relative risk ratings in the NEBA framework for attributes found to have levels of impact. Attributes for which no meaningful risk was found (e.g., human health risk assessments, ecological health risk assessments) are not included in the following discussion.

### Noise and congestion from trucking traffic

I used the number of trucks per day passing[1] a receptor along a near-site transportation corridor as a metric to examine the differences in noise and traffic congestion under the closure options. I compared the increase in truck passes due to hauling earthen fill, geosynthetic material, and

[1] Truck passes per day resulting from trucking activities is calculated as the total number of loads required to transport earthen fill, geosynthetic materials, and other materials multiplied by two to account for return trips. The resulting total number of passes is then divided evenly among the total number of months of trucking time multiplied by 26 working days per month.

other materials under the closure options[2] to the current number of truck passes for the same receptor.

The current (or baseline) number of truck passes was estimated from North Carolina Department of Transportation (NCDOT) annual average daily traffic (AADT) data collected at thousands of locations across the state and the proportion of road miles driven by large trucks in North Carolina. AADT is an estimated daily traffic volume at a specific location, which captures traffic in all lanes traveling in both directions and is assumed to represent typical traffic volume for a year.[3] Not all AADT data, however, differentiate between large trucks such as those to be used in ash basin closure and other traffic such as cars, which is a relevant distinction when considering impacts to communities from increased noise. NCDOT performs vehicle classification[4] on trucking routes to estimate annualized truck percentage to apply to AADT to determine truck AADT (NCDOT 2015). The average annualized truck percentage for Person County is 9.5%.

The precise transportation corridor for all trucks travelling to and from the Mayo ash basin and landfill sites during ash basin closure is unknown; however, likely corridors in the communities local to Mayo can be identified by examining road maps and AADT statistics. The Mayo Plant is situated along US 501 (Boston Rd) (Figure E-1). The excavation closure option involves a single crossing of US 501 immediately west of the ash basin, and the US 501 corridor is assumed to be the primary transportation route for offsite hauling for cover materials including topsoil and geosynthetic materials. The nearest traffic measuring station to Mayo is immediately north of the Mayo Plant where US 501 crosses into Virginia with Station ID 7200001 reporting 3,300 AADT in 2017. South of the Mayo Plant on US 501 is Station ID 7200002, which reports 3,800 AADT in 2017. To best capture trucking related impacts to sensitive communities along

[2] Truck trips to haul ash were not included in the estimate for Mayo ash basin closure because trucks hauling ash would not leave the Mayo property (with the exception of crossing U.S. Route 501) and would not affect community receptors along the transportation corridors.

[3] AADT is calculated from two days of traffic counts at each station during weekdays, excluding holidays. Raw monitoring data consists of counts of axle pairs made by pneumatic tube counters that are converted to traffic volume by applying axle correction factors, and expanded to annual estimates by seasonal correction factors. Derived AADT values are checked for quality against nearby stations and historical station-specific values (NCDOT 2015).

[4] Vehicle classification is assigned based on number of axles, space between axles, weight of the first axle, and total weight of the vehicle.

the transportation corridor, I assumed a baseline truck passes per day of 314, which was computed by multiplying 3,300 AADT (2017 estimate from US 501 Station ID 7200001 in 2017) by the Person County average percent of truck AADT (9.5%; NCDOT 2015).[5]

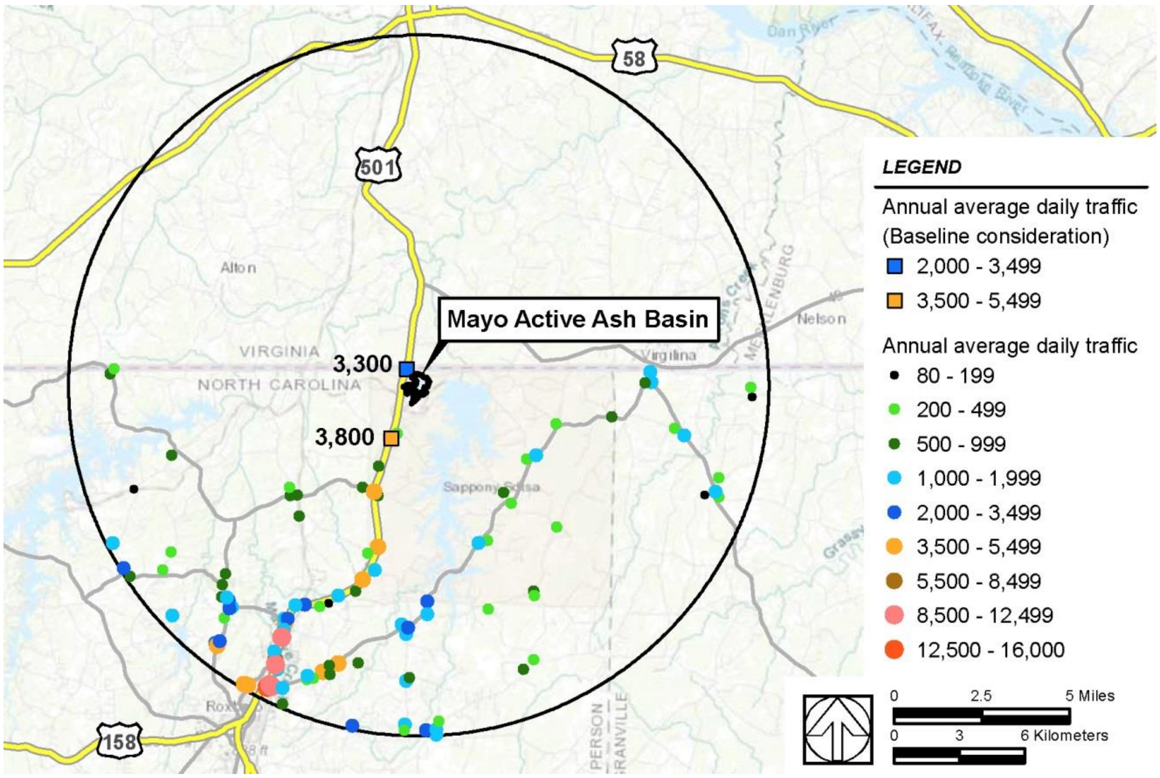


Figure E-1. NCDOT annual average daily traffic (AADT) measurement stations near Mayo. Traffic stations and AADT values considered when determining the baseline number of truck passes are indicated as squares.

The sensitivity of the NEBA relative risk ratings to the baseline assumption of 314 trucks per day was evaluated by calculating relative risk ratings for a range of baseline truck traffic levels, based on the minimum and maximum AADT values for any NCDOT station within a 50-mile radius of the Mayo ash basin, using AADT from the most recent year that data are available for a particular station and assuming 9.5% truck traffic as previously described. Figure E-2 plots the

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[5] AADT data are not available for every road or every location along a road. It is possible during closure of the Mayo ash basin that trucks will utilize less traveled roads (i.e., with lower AADT), which would have a lower baseline truck passes per day estimate and result in a higher percent impact from ash basin closure for these sensitive communities; however, by choosing the lowest available AADT estimate from roads within 10 miles of Mayo along the most likely transportation corridors to and from Mayo to a major road (e.g., highway), my analyses have considered sensitive communities that would be more affected by traffic noise and congestion from ash basin closure trucking.

resulting percent impact for closure options along with the resulting relative risk rating across the range of 2 to 18,541 truck passes per day.

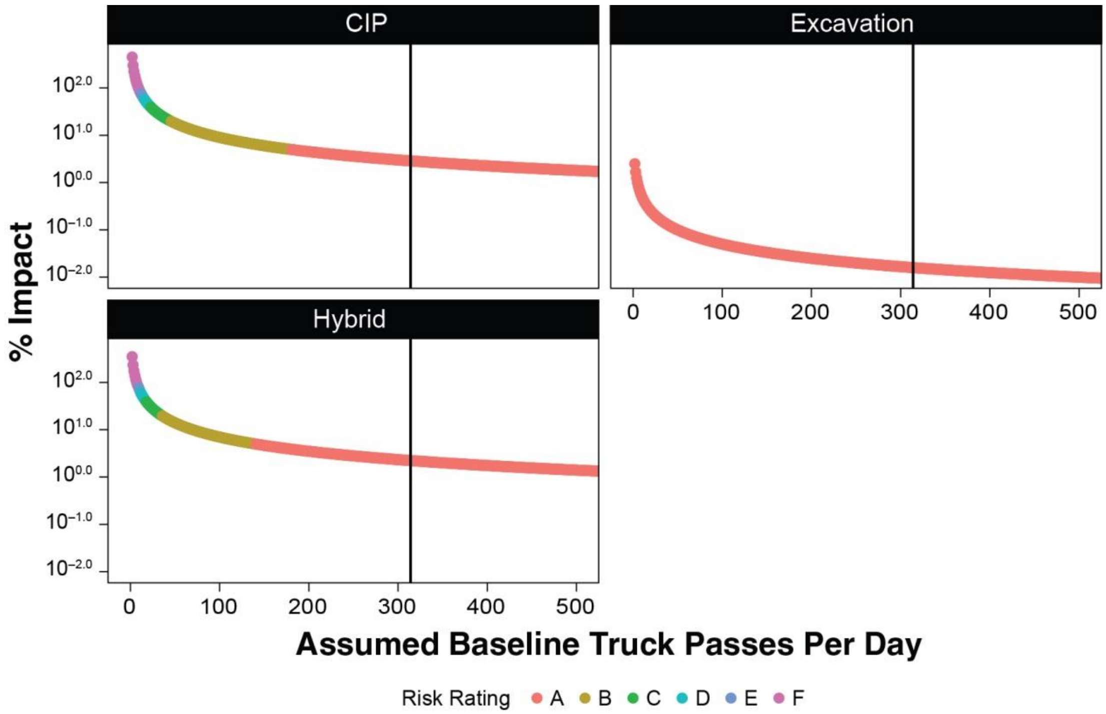


Figure E-2. Sensitivity of NEBA relative risk rating for noise and congestion impacts from trucking operations. The vertical line indicates the assumed baseline 314 truck passes per day. The y-axis is plotted on a log10 scale and the X axis is truncated at 500 to improve visualization.

Using a baseline truck passes per day of 314, all closure options (CIP, excavation, and hybrid) fall into the lowest relative risk rating (A, <5%) for traffic-induced noise and congestion during closure of the Mayo ash basin (Figure E-2). Higher risk ratings would result from a lower baseline truck traffic assumption; decreasing the baseline truck traffic assumption to 180 in the CIP option or 140 in the hybrid option would increase risk to the B (5-19%) risk rating. The average daily truck passes in the excavation option would need to be between 1 and 2 trucks per day to increase to a B risk rating.

## Traffic accidents

I evaluated risk of traffic accidents by comparing the average number of annual offsite road miles driven between closure options relative to a baseline estimate of the current annual road miles driven.[6] I chose a baseline of 33.5 million annual truck road miles based on the reported total vehicle miles traveled in Person County, North Carolina (NCDOT 2017) multiplied by the county average 9.5% contribution of trucks to total AADT (NCDOT 2015).

The sensitivity of the NEBA relative risk ratings to the baseline assumption of 33.5 million truck miles per year was evaluated by calculating relative risk ratings for alternative baseline truck mile assumptions derived from the counties in NC with the minimum (Hyde County) and maximum (Mecklenburg County) reported vehicle miles driven, resulting in a sensitivity range estimated from 6.2 million to 641 million truck miles per year. Figure E-3 plots the resulting percent impact for the CIP, excavation, and hybrid closure options, along with the resulting relative risk ratings across the range of truck miles per year.

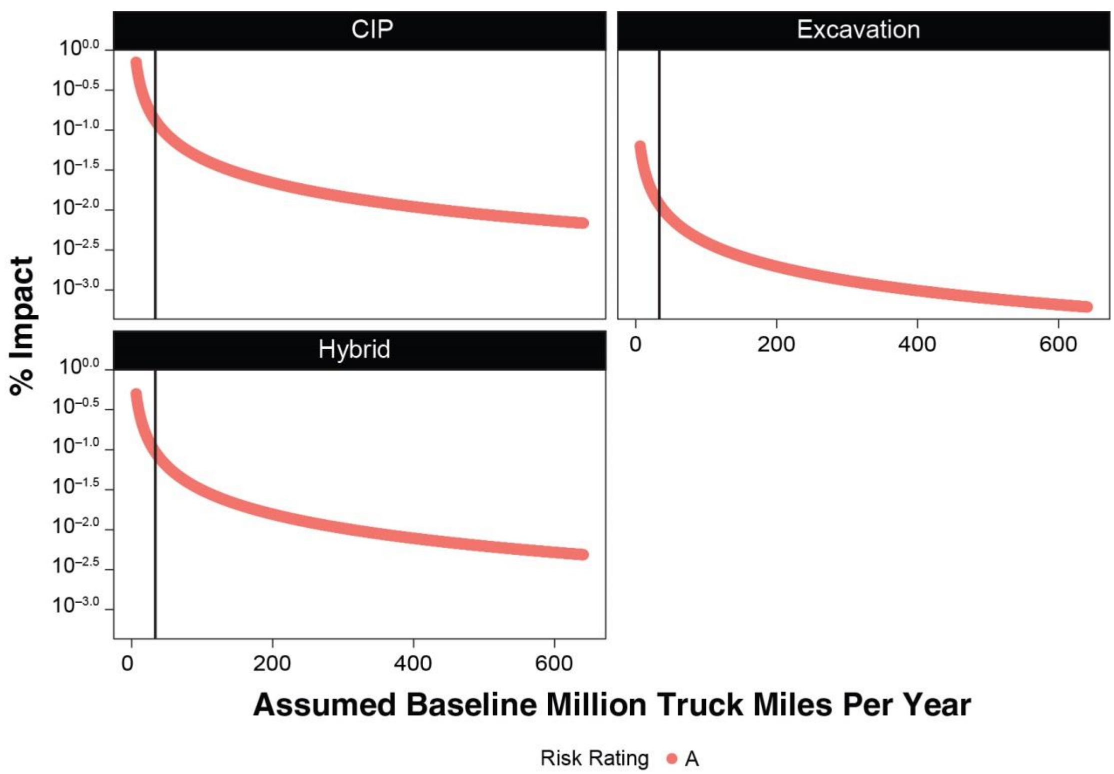


Figure E-3. Sensitivity of NEBA relative risk rating for traffic accidents due to trucking activities. The vertical line indicates the assumed baseline 33.5 million truck miles per year. The y-axis is plotted on a log10 scale to improve visualization.

6 The difference between the baseline miles assumption and the closure assumption was divided by the baseline miles assumption and multiplied by 100 to get a percent impact.

Using the 33.5 million truck miles baseline assumption, the CIP option has a 0.13% impact; excavation has a 0.01% impact; and the hybrid closure option has a 0.09% impact. All closure options have a relative risk rating of A (<5%). These relative risk ratings do not appear to be sensitive to lower assumed baseline annual truck miles. The vertical lines in Figure E-3 indicate the location of the baseline assumption. Reducing the baseline assumption to the 6.2 million truck miles minimum increases percent impact to 0.7, 0.06, and 0.5% for CIP, excavation, and hybrid closure options, respectively; the risk ratings are unchanged.

## Habitat Equivalency Analysis

Uncertainty in the habitat equivalency analysis (HEA) that examined disruption of ecological services from ash basin closure was explored through sensitivity analyses of key assumptions in the HEA. To test sensitivity, I re-ran HEA models with the following changes:

1. Running the HEA for 100 years instead of 150 years.
2. Assuming the open water habitats of the ash ponds provide ecological services at 40% of wooded areas instead of 10%.
3. Assuming open field habitats provide ecological services at 20% of wooded areas instead of 40%.
4. Assuming borrow areas under the CIP option are restored to open fields, not reforested.

For each sensitivity analysis, all parameters in the base model were held constant except the one parameter varied to understand the sensitivity of the model to each assumption (Table E-2).

**Table E-2. Change in DSAYs from base model[a] for key HEA assumptions**

| Closure Option | 100-year model[b] | Ash basin water 40%[c] | Borrow becomes field[d] | Open Field 20%[e] |
|---|---|---|---|---|
| CIP | 2 | −501 | −240 | 0 |
| Excavation | −107 | −486 | 0 | -60 |
| Hybrid | −66 | −486 | 0 | -12 |

[a] Base models were run for 150 years with ash basin open water NPP services at 10%, borrow fields were assumed to become forest (CIP closure) or grass cap (hybrid and excavation closure), and open field NPP services at 40%.
[b] Base models except the HEA was run for 100 years.
[c] Base models except ash basin open water NPP service at 40%.
[d] Base models except borrow pits were assumed to become open field for CIP option.
[e] Base models except open field NPP services decreased to 20%.

Running HEAs for 100 years increased net DSAYs slightly for the CIP closure option and decreased net DSAYs for excavation and hybrid closure options. Increasing the ash basin open water service level to 40% resulted in net decreases in DSAYs for all options. Assuming borrow areas would be returned to open field resulted in a decrease in net DSAYs for CIP; there are no borrow areas in the excavation or hybrid closures, so there is no net change in DSAYs for that option. Decreasing open field services to 20% slightly reduced net DSAYs in all options except for CIP closure.

Looking at the change in net DSAYs between the sensitivity models and their base models, the changes in assumptions have relatively consistent effects on net DSAYs. For example, changing ash basin open water services from 10 to 40% affects all closure options similarly, since the same level of service change is applied over the same areal extent (54 acres of open water) in all closure options. The slight difference in DSAY losses between options is due to differences in the year construction starts and hence existing services are lost. Assuming open field services at 20% has a larger effect on the excavation option since this option restores greater open field acreage than the hybrid option. Changing the service level of borrow acreage habitat after borrow is complete only affects options that have borrow areas (CIP). However, since the directionality of net NPP services provided by the closure options does not change under this sensitivity analysis (i.e., hybrid closure and excavation closure have net NPP service gains, while CIP closure results in net NPP service losses), this demonstrates that the model can differentiate between relative differences in NPP service level changes with consistency.

Changes in net DSAYs with changing assumptions may change the relative risk rating applied to a closure option in the NEBA. However, the relative similarity in the how DSAYs change with assumptions between the various closure options and the result that the excavation or hybrid closure options always result in substantially greater net DSAYs than CIP under any sensitivity analysis supports the relative risk ratings for decision support in the NEBA.

## Closure Option Assumptions

The following assumptions were used to calculate NEBA input values related to trucking activities and habitat acreages, unless otherwise specified by Duke Energy (2018).

- The density of ash was assumed to be 1.2 ash tons/CY.
- Borrow pit acreage required to supply earthen fill and cover material was assumed to be dug to a depth of 15 ft to meet volume requirements. Borrow pits not specifically identified were assumed to contain a mixed forest habitat that would be restored upon closure completion.
- Excavation was assumed to proceed at a rate of 1,000,000 CY/year for all types of excavation material combined including ash, underlying over-excavated or residual soil, and dam and embankment material.
- CIP cover systems were assumed to require two layers of geosynthetic material. New landfill areas were assumed to require five layers of geosynthetic material. Geosynthetic material was assumed to be transported from Georgetown, South Carolina, at a rate of six loads per day, and 3 acres per load.
- Covers/caps for both CIP and landfills were assumed to receive 18 in. of cover soil plus 6 in. of topsoil. New landfills also were assumed to receive 2 ft of liner soil. Topsoil was assumed to come from an offsite commercial facility requiring no additional borrow area.
- Unless otherwise specified, offsite borrow material and topsoil were assumed to be from sources 11 miles away (one way).

- Offsite truck capacity was assumed to be 20 CY of ash or earthen material.
- Working hours were assumed to be 10 hr/days, 6 days/week, and 26 days/month.
- Earthen fill material was assumed to be hauled in at a rate based on 1,000,000 CY/year.
- In excavated areas, 1 ft of over-excavation of residual soil was assumed. When restoring these areas, 2 ft of additional soil material plus 6 in. of top soil was assumed necessary to establish vegetative stabilization over the total area.