Species Status Assessment (SSA) Report

For the

Seaside Alder (*Alnus maritima*)

Version 1.2

May 31, 2018

Photo credit: Bill Hubick, Maryland Biodiversity Project

May 2018
U.S. Fish and Wildlife Service
Northeast, Southeast, and Southwest Regions

ACKNOWLEDGEMENTS

The research for this document was prepared by Cherry Keller (U.S. Fish and Wildlife Service (USFWS—Chesapeake Bay Field Office), Michele Elmore (USFWS—Georgia Ecological Services Field Office), Alisha Autio (USFWS—Tulsa Field Office), and Hayley Dikeman (USFWS—Southwest Regional Office), with technical assistance from Krishna Gifford (USFWS—Northeast Regional Office).

We greatly appreciate the assistance of Chris Frye (Maryland Department of Natural Resources (MDDNR)), William McAvoy (Delaware Department of Natural Resources and Environmental Control), Dr. Mincy Moffett and Tom Patrick (Georgia Department of Natural Resources), Mark Howery (Oklahoma Department of Wildlife Conservation), Amy Buthod (Oklahoma Biological Survey/Natural Heritage Inventory), Jennifer Ceska (Georgia Plant Conservation Alliance), Jim Ozier (Georgia Power Company), Jona Tucker (The Nature Conservancy), Al Rizzo (USFWS—Prime Hook National Wildlife Refuge), Matt Wittbeck (USFWS—Blackwater National Wildlife Refuge), Kerry Graves (USFWS—Tishomingo National Fish Hatchery), Nicole Rankin (USFWS—Southeast Regional Office), Pete Pattavina (USFWS—Southeast Regional), and Martin Miller (USFWS—Northeast Regional Office) who provided helpful information and review of the draft document.

We also thank Dr. Jim Schrader (Iowa State University), Dr. J. Phil Gibson (Oklahoma University), Dr. Catherine Borer (Berry College), and Dr. Michael Kearney (University of Maryland), who conducted peer review and provided helpful comments.

Suggested Reference:
U.S. Fish and Wildlife Service (Service). 2018. Species Status Assessment for the Seaside Alder (Alnus maritima), Version 1.2. May 2018. Hadley, MA.

Table of Contents

EXECUTIVE SUMMARY

This report summarizes the results of a species status assessment (SSA) conducted for *Alnus maritima* (seaside alder) and its three subspecies (*Alnus maritima* spp. *maritima* (Delmarva alder), *Alnus maritima* spp. *georgiensis* (Georgia alder), and *Alnus maritima* spp. *oklahomensis* (Oklahoma alder) to assess the species' and subspecies' overall viability. The seaside alder is a large, deciduous shrub or small tree, 16 to 23 feet (ft) (5 to 7 meters (m)) tall that grows in multi-stemmed clumps, instead of individual trees, in the wet soils of river, stream or pond edges. Despite its name, it is known to only occur in freshwater habitats and prefers areas with full sun and soils that are at least periodically saturated or inundated. The seaside alder occurs in three disjunct geographic areas that represent the subspecies designations: Maryland/Delaware (Delmarva alder), Georgia (Georgia alder), and Oklahoma (Oklahoma alder).

To assess the biological status of the seaside alder across the species and each of the subspecies' range(s), we used the best available information, including peer reviewed scientific literature, academic reports, the best professional judgement of experts, and survey data provided by state agencies, the U.S. Fish and Wildlife Service (Service), and academic institutions to inform our analyses.

The seaside alder inhabits the riparian areas of multiple freshwater tidal rivers and ponds/marshes in Maryland and Delaware, a single spring-fed marsh/pond/stream system in Georgia, and several spring-fed creeks/streams in Oklahoma. While each subspecies is represented by slightly different freshwater habitat types all of these habitats contain the components of sunlight, water quality, and periodically inundated (hydric) soils needed by the individual plants. The seaside alder is capable of sexual and asexual reproduction, but evidence of new plants from seedlings is rare and, like many other riparian shrubs, seaside alder primarily reproduces asexually through clones and runners. Vegetative growth enables it to persist in many areas despite some shading, or regenerate from broken stems after floods.

The primary stressors to the seaside alder include natural processes (e.g., changes to drought cycles, air temperature, precipitation patterns, flooding regimes, and sea level rise) or human-mediated actions (e.g., human population growth, development, and mining), that cause decreased ground and aquifer water quantity, and water quality degradation. Other stressors having direct or indirect effects to some individuals or some smaller subpopulations include herbivory, forest pests such as the emerald ash borer, nonnative invasive species, and nutrient runoff. There are some ongoing and potential future conservation actions (e.g., maintenance of riparian buffers, establishing safeguarding sites or population augmentation, land protection, and limits on groundwater pumping) that are or may ameliorate the stressors. The specific activities, natural processes, and conservation actions involved vary depending upon the subspecies. For example, while the spread of the emerald ash borer is occurring in all three geographically occupied areas and droughts occur in Georgia and Oklahoma, saline storm surges and rising sea levels affect only the Delmarva alder, nonnative invasive species affects only the Georgia alder, and water withdrawals associated with mining affects only the Oklahoma alder. Ongoing or prior conservation actions include maintaining general riparian buffers that improve water quality for the Delmarva alder, population augmentation of and land protection in the vicinity of the Georgia alder, and limits on ground water pumping that benefits the Oklahoma alder.

Ongoing actions yet to show results or future actions include safeguarding sites for the Georgia alder in three locations outside of the species' historical and current range.

The SSA analyzes what the seaside alder and its three subspecies need to ensure viability, defined as the ability to persist over the next 30 to 80 years, based on population resiliency and species and subspecies representation and redundancy, respectively. Resiliency describes the ability of populations to withstand stochastic events. Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events. Representation describes the ability of a species to adapt to changing environmental condition, measured by the breadth of genetic or environmental diversity within and among populations.

Throughout the SSA Report, we use the term "analysis units" rather than population because it is difficult to delineate biological populations of the seaside alder in each region due to the plant's clonal behavior and other challenges associated with identifying population boundaries. To analyze the viability of the species (seaside alder) as a whole, our larger analytical units are the three subspecies (Delmarva, Georgia, and Oklahoma alders) as a surrogate for "populations," and we refer to them as species analysis units. To analyze the viability of each subspecies, our analysis units are the U.S. Geological Survey (USGS) HUC 12 watersheds as a surrogate for "populations," and we refer to them as subspecies analysis units. The HUC 12 watershed includes the stretch of stream where seaside alder records occur and the adjacent uplands that may drain into the stream or pond, which may affect the watershed's water quality and quantity—two factors that influence seaside alder. The HUC 12s often include multiple sites and the relative number of sites reflects the overall abundance of seaside alder in the analysis unit. The analysis of the species as a whole is based on the resiliency of the smaller analytical units (i.e., the HUC 12 watersheds). Therefore, when we discuss the species' resiliency, we are including all of the subspecies and their analysis units. We assigned an equal weight to each subspecies to derive the seaside alder's current resiliency of the analysis units, and redundancy and representation of the species (conservation biology principles, together known as the 3Rs).

For the seaside alder (or its subspecies) to maintain viability, its analysis units (i.e., subspecies or HUCs, depending on the scale) must be sufficiently resilient to withstand stochastic events arising from spatially and temporally random factors, must have sufficient redundancy to withstand catastrophic events, and maintain representation to adapt to changing environmental conditions. The resiliency of a HUC watershed population was described as low, moderate or high based on similar definitions for each geographic area with some differences based on that geographic region.

A resilient analysis unit in all areas is defined by multiple subpopulations (i.e., sites), with a large number of individuals (i.e., abundance) in each subpopulation, and where recruitment exceeds mortality. Recruitment may be happening through asexual or sexual reproduction. In addition, resilient analysis units contain sites that provide sun, periodically inundated soils and freshwater and places secure from applicable primary stressors.

Maintaining representation in the form of genetic or ecological diversity is important to maintain the capacity of the seaside alder to adapt to future environmental changes. The level of genetic or ecological diversity needed to maintain adaptability for the seaside alder species as a whole, or any of the subspecies, is unknown. We assume that the current level of genetic diversity needs to be maintained. Studies of population genetics have evaluated inbreeding in the Georgia and Oklahoma alder, although it was not found at significant levels.

The seaside alder needs to have multiple resilient analysis units distributed throughout its range to provide for redundancy. The more analysis units, and the wider the distribution of those analysis units, the more redundancy the species will exhibit. Redundancy reduces the risk that a large portion of the species' range will be negatively affected by a catastrophic natural or anthropogenic event at a given point in time. Species that are well-distributed across their historical ranges are considered less susceptible to extinction and more likely to be viable than species confined to small portions of their ranges. The level of redundancy needed to maintain the seaside alder is unknown. However, it is likely that the currently occupied analysis units and subpopulations remaining need to be maintained.

For the seaside alder as a whole, its current condition can be summarized as having analysis units with mostly high resiliency, redundancy of extant 35 analysis units (as of April 17, 2018), and representation in terms of genetic and ecological diversity. The condition of these analysis units are: 20 in high condition, 12 in moderate condition, and 3 in low condition; thus ensuring the species' ability to withstand stochastic events. These 35 analysis units are distributed across 3 areas (i.e., corresponds to the subspecies) of the country—27 in Maryland/Delaware (with a range of high (19), moderate (10), and low (3) resiliency categories), 1 in Georgia (with a high resiliency category), and 7 in Oklahoma (with a range of high (4) and moderate (3) resiliency categories)—thus ensuring the species' ability to withstand catastrophic events. Across the range, the species occurs in a wide range of freshwater habitat types (tidal rivers, marsh and ponds, and spring-fed streams and rivers) and is adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment. Genetic diversity was sufficiently varied across the range to indicate subspecies.

To assess the future resiliency of analysis units and the redundancy and representation for the subspecies as a whole and each subspecies, we used the demographic and habitat information to predict how the 35 HUC watershed analysis units currently occupied by the Delmarva/Georgia/Oklahoma alder will respond to the primary factors likely to influence the species' condition in the future. These influence factors varied by geographic area and included: changing climate conditions (increases in saline storm surges, drought, flooding, and temperature), decreased water availability, urbanization, human population growth, and conservation management, where applicable. Our analysis is limited to three future scenarios, which are representative examples from the potential range of plausible scenarios, and that describe how these stressors to the species may drive changes from current conditions. Because the stressors vary by geographic region (or subspecies) we describe these stressors and future scenarios for each region below.

Projections of seaside alder resiliency, redundancy and representation were forecasted using two time steps, 30 and 80 years out (2050 and 2100) for most scenarios (see the Delmarva alder section summarized below and in more detail in Chapter 5 for 2100 time step surrogate information). These time steps were chosen to correspond to the range of available sea level rise, groundwater, and climate model forecasts, depending on the relevant data for each subspecies. In addition, the 2050 time step represents a time frame during which the effects of any applicable conservation management can be implemented and realized, and is a reasonable timeframe for the species to respond to potential changes on the landscape. The 2100 time step represents a potential longer-term trajectory for the species, but with a lower confidence in the outcome than in the 2050 projection. Results of these projections are described for each geographic region (or subspecies) below.

For the Delmarva alder, vulnerability to saline storm surge is so important to its survival and resiliency that it is used as the major parameter describing the environmental condition of the 27 analysis units currently occupied and projected in the future. We modelled three scenarios (*Continuation or Minor Impacts*, *Moderate Impacts*, and *Major Impacts*) for future sea level rise using the Sea Level Affecting Marshes Model (SLAMM) out to the year 2050 because: (1) the SLAMM model's 2025 output is only 8 years away from the current condition and did not appreciably differ from our Continuation and Moderate Impacts Scenarios' projection at year 2050, and (2) the Continuation or Minor Impacts projection to 2075 and 2100 outputs do not change appreciably from our Major Impacts Scenario's projection at year 2050. We recognize that sun/shade and periodically inundated soil condition also contribute to Delmarva alder's resiliency, however, we are unable to quantify changes in those values across time at the analysis unit level and available information suggests there has been little change in those parameters within the last 30 years. Therefore, our future scenarios focus solely on changes in sea level rise which would cause shifts in salinity values in the analysis units.

The total number of Delmarva alder analysis units occupied by 2050 is expected to range between 24 and 27 depending on whether the Major Impacts Scenario or Continuation/Minor Impacts Scenario of sea level rise occur. The losses are on the periphery of the range and the 24 analysis units remaining under the Major Impacts Scenario are all adjacent to at least one other analysis unit in high or medium condition. Thus, under the Major Impacts Scenario for 2050 (or the Continuation/Minor Impacts Scenario for 2100) there would be 11 highly resilient analysis units, 12 of moderate resiliency, and 1 of low resiliency. Overall, we consider the Delmarva alder to retain high redundancy in the future. By 2050, even under the Major Impacts Scenario, the remaining analysis units would span the range of habitats available on the Delmarva and would include all currently occupied types of wetland habitats. Thus, representation is expected to be high under the Major Impacts 2050 Scenario (or the Continuation 2100 Scenario). By 2050, under the Major Impacts Scenario, there would be 11 highly resilient analysis units, 12 moderately resilient analysis units, and 1 analysis unit with low resiliency. While this is a decrease from current conditions, we consider the overall resiliency of Delmarva alder to remain high.

The Georgia alder is known from only one site (Drummond Swamp) but has remained relatively stable over potentially a very long time. However changing climate conditions and the effects of urbanization may have significant influences on this analysis unit in the future. Therefore, three scenarios were used to characterize plausible futures for the Georgia alder. Resiliency, representation and redundancy were forecasted for each scenario under the 8.5 RCP climate predictions with variable levels of urbanization (based on the SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model) and conservation management. In general, these scenarios are (1) *Continuation*: where current conservation management is coupled with potential effects of changing climate condition and urbanization; (2) *Increased Impact*: where conservation management regresses and synergistic impacts of changing climate and urbanization increase; and (3) *Conservation Focused*: where conservation management increases and strategically targets actions to abate impacts of changing climate and urbanization.

In the *Continuation Scenario* the resiliency of the Georgia alder is predicted to decline but overall future condition remains moderate. In the *Increased Impact Scenario* all 3Rs are expected to decline and overall condition in the future is low. In the *Conservation Focused* scenario it is plausible that conservation efforts (water conservation, land protection and management, safeguarding, etc.) could maintain the resiliency (high), representation (low to moderate) and redundancy (low) of the Georgia alder at current conditions at least through 2050. While all scenarios present some risk of extirpation of the sole Georgia alder analysis unit due to stochastic events, risk of extirpation is greatest with the Increased Impact scenario. Since Georgia alder is only known from the Drummond Swamp location, extirpation of this analysis unit would result in the extirpation of the Georgia alder subspecies.

There are three main drivers affecting the future condition of the Oklahoma alder: changing climate conditions, decreased water availability, and conservation management. We have forecast what Oklahoma alder may have in terms of resiliency, redundancy, and representation under two plausible future scenarios in two time steps, 2050 and 2100. Each scenario uses the climate projections under the 8.5 RCP emissions scenario. In general these scenarios are: (1) *Continuation*: where current groundwater withdrawal continue as in the recent past and continuing climate changes as projected into the future; and (2) *Conservation Focused*: where current groundwater withdrawal continue as in the recent past and continuing climate changes as projected into the future with conservation management and augmentation to analysis units.

Under all scenarios the Oklahoma alder's overall average score is a Moderate condition for 2050 and a Moderate condition for 2100. However, resiliency will change within the individual analysis units over time. For instance, in the 2050 Continuation Scenario there will be three analysis units with a resiliency score of High, and in the 2100 Continuation Scenario there are zero analysis units with a resiliency score of High. In general, the resiliency scores of the Oklahoma alder decrease as time goes on (from 2050 to 2100) regardless of the scenario. Notably, the 2050 Continuation Scenario does not differ from the current condition, though it is 30 years in the future. All of the analysis units will be impacted by changing climate conditions and decreased water availability. However, looking at "overall data" can be misleading because overall, the Oklahoma alder is scored as moderate for all future scenarios. Many of the analysis units had a habitat score move from a High to a Low score, which averages to a Medium. Analysis units with both a low demographic score and habitat score are most vulnerable: Bois d' Arc and Sandy Creek. In addition, our analysis underestimates the current population of Oklahoma alder due to a reported location that became known to us subsequent to the completion of the analysis.

For the species as a whole, the seaside alder's future viability can be summarized as having moderate to high resiliency, redundancy, and representation. The species is projected to be extant in a total of the 35 analysis units (i.e., HUCs) known as of April 17, 2018, under the most favorable suite of scenarios and in 32 analysis units under the least favorable suite of scenarios. Although there are other suites of scenarios we analyzed at the subspecies scale (e.g., Moderate Impacts 2050 for Delmarva alder and Continuation for Georgia alder), we do not summarize them here at the species scale because their results are contained within and bracketed by the results in the most favorable and least favorable suite of scenarios discussed below. However, we do note that all of the potential scenarios are considered plausible, and that there likely are additional locations of seaside alder in Delaware and Oklahoma that are not incorporated into our analysis due to insufficient data. Therefore, the summary below likely underestimates the species' future condition.

By 2050:

- Under the most favorable suite of scenarios (Continuation 2050 for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders):
    - 35 analysis units are anticipated to be categorized as: 14 in high condition, 17 in moderate condition, and 4 in low condition; thus ensuring the species' ability to withstand stochastic events (resiliency).
    - These 35 analysis units are distributed across 3 disjunct areas of the country (27 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma), thus ensuring the species' ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
    - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment (representation).

- Under the least favorable suite of scenarios (Major Impacts 2050 for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder):
    - 35 analysis units are anticipated to be categorized as: 14 in high condition, 16 in moderate condition, 2 in low condition, and 3 extirpated. Thus, despite some losses in the Delmarva region, the species retains the species' ability to withstand stochastic events (resiliency).
    - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
    - Within these geographic areas, the species retains representation by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the

plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

By 2100:

- Under the most favorable suite of scenarios (Major Impacts 2050 (as proxy since the effect to the subspecies is the same in 2100) for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders):
  - 35 analysis units are anticipated to be categorized as: 11 in high condition, 18 in moderate condition, 3 in low condition, and 3 are extirpated; thus ensuring the species' ability to withstand stochastic events. Thus, despite some losses in the Delmarva region, the species retains the ability to withstand stochastic events (resiliency).
  - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
  - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in three separate freshwater habitat types (tidal rivers, marsh, and spring-fed rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

- Under the least favorable suite of scenarios (Major Impacts 2050 (as proxy since there is only one 2100 scenario available) for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder):
  - 35 analysis units are anticipated to be categorized as: 11 in high condition, 16 in moderate condition, 5 in low condition, and 3 are extirpated; thus ensuring the species' ability to withstand stochastic events (resiliency).
  - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
  - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh, and spring-fed rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

The seaside alder's (rangewide) future viability can be summarized as having moderate to high resiliency, redundancy, and representation depending upon the timeframe (2050 vs. 2100) and scenarios. By 2050, the species is projected to be extant in a total of 35 analysis units (i.e., HUCs) under the most favorable suite of scenarios (Continuation 2050 for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders) and in 32 analysis units under the least favorable suite of scenarios (Major Impacts 2050 for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder). Under the most favorable suite of scenarios, the 35 analysis units include 40 percent (n=14) in high condition, 49 percent (n=17) in moderate condition, and 11 percent (n=4) in low condition (note: totals may not sum to 100 due to rounding). Under the least favorable suite of scenarios, the 35 analysis units include 40 percent (n=14) in high condition, 46 percent (n=16) in moderate condition, and 5 percent (n=2) in low condition, and 8 percent extirpated (n=3) (note: totals may not sum to 100 due to rounding). In each of these cases, while the resiliency has some minor fluctuations, the species' retains the ability to withstand stochastic events, despite some losses in the Delmarva region. Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs (with the exception of Georgia). Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment.

By 2100, the species is projected to be extant in a total of 32 out of 35 analysis units (i.e., HUCs) under the most favorable suite of scenarios (Major Impacts 2050 (as proxy since the effect to the subspecies is the same in 2100) for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders) and in 32 out of 35 analysis units under the least favorable suite of scenarios (Major Impacts 2050 (as proxy since there is only one 2100 scenario available) for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder). Under the most favorable suite of scenarios, the 35 analysis units include 31 percent (n=11) in high condition, 51 percent (n=18) in moderate condition, 9 percent (n=3) in low condition, and 9 percent (n=3) extirpated (note: totals may not sum to 100 due to rounding). Under the least favorable suite of scenarios, the 35 analysis units include 31 percent (n=11) in high condition, 46 percent (n=16) in moderate condition, and 14 percent (n=5) in low condition, and 9 percent extirpated (n=3) (note: totals may not sum to 100 due to rounding). In each of these cases, while the resiliency has some minor fluctuations, the species' retains the ability to withstand stochastic events, despite some losses in the Delmarva region. Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs (with the exception of Georgia). Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment.

At the subspecies level, the total number of Delmarva alder analysis units occupied is expected to range between 24 and 27 depending on whether the Major Impacts Scenario or Continuation/Minor Impacts Scenario of sea level rise occur. The losses are on the periphery of the range and the 24 analysis units remaining under the Major Impacts Scenario are all adjacent to at least one other analysis unit in high or medium condition. Thus, under the Major Impacts Scenario for 2050 (or the Continuation Scenario for 2100) there would be 11 highly resilient analysis units, 12 of moderate resiliency, and 1 of low resiliency. Overall, we consider the Delmarva alder to retain high redundancy in the future. By 2050, even under the Major Impacts Scenario, the remaining analysis units would span the range of habitats available on the Delmarva and would include all currently occupied types of wetland habitats. Thus, representation is expected to be high under the Major Impacts 2050 Scenario (or the Continuation 2100 Scenario). By 2050, under the Major Impacts Scenario, there would be 11 highly resilient analysis units, 12 moderately resilient analysis units, and 1 analysis unit with low resiliency. While this is a decrease from current conditions, we consider the overall resiliency of Delmarva alder to remain high.

In the *Continuation Scenario* the resiliency of the Georgia alder is predicted to decline but overall future condition remains moderate. In the *Increased Impact Scenario* all 3Rs are expected to decline and overall condition in the future is low. In the *Conservation Focused* scenario it is plausible that conservation efforts (water conservation, land protection and management, safeguarding, etc.) could maintain the resiliency (high), representation (low to moderate) and redundancy (low) of the Georgia alder at current conditions at least through 2050. While all scenarios present some risk of extirpation of the sole Georgia alder analysis unit due to stochastic events, risk of extirpation is greatest with the Increased Impact scenario. Since Georgia alder is only known from the Drummond Swamp location, extirpation of this analysis unit would result in the extirpation of the Georgia alder subspecies.

Under all scenarios the Oklahoma alder's overall average score is a Moderate condition for 2050 and a Moderate condition for 2100. However, resiliency will change within the individual analysis units over time. For instance, in the 2050 Continuation Scenario there will be three analysis units with a resiliency score of High, and in the 2100 Continuation Scenario there are zero analysis units with a resiliency score of High. In general, the resiliency scores of the Oklahoma alder decrease as time goes on (from 2050 to 2100) regardless of the scenario. Notably, the 2050 Continuation Scenario does not differ from the current condition, though it is 30 years in the future. All of the analysis units will be impacted by changing climate conditions and decreased water availability. However, looking at "overall data" can be misleading because overall, the Oklahoma alder is scored as moderate for all future scenarios. Many of the analysis units had a habitat score move from a High to a Low score, which averages to a Medium. Analysis units with both a low demographic score and habitat score are most vulnerable: Bois d' Arc and Sandy Creek. In addition, our analysis underestimates the current population of Oklahoma alder due to a reported location that became known to us subsequent to the completion of the analysis.

Chapter 1. INTRODUCTION

1.1 Background

This report summarizes the results of a species status assessment (SSA) conducted for *Alnus maritima sensu lato* (henceforth referred to as the seaside alder). In 2010, we, the U.S Fish and Wildlife Service (Service) received a petition to list 404 aquatic, riparian and wetland species, including the seaside alder, as endangered or threatened under the Endangered Species Act of 1973, as amended (Act) (Center for Biological Diversity (CBD) 2010, pp. 1–66, 86). In 2011, the Service made a substantial 90-day petition finding for 371 species, including the seaside alder, indicating that listing may be warranted (76 FR 59836; September 27, 2011) and initiated a status review. Thus, we conducted a SSA to compile the best scientific and commercial information available regarding the species' biology and factors that influence the species' viability.

While the petition did not discuss the plant's taxonomy beyond the species' level, we know that the seaside alder comprises three subspecies (see Chapter 2—***Taxonomy***, below): *Alnus maritima* spp. *maritima* (henceforth referred to as the Delmarva alder), *Alnus maritima* spp. *georgiensis* (henceforth referred to as the Georgia alder), and *Alnus maritima* spp. *oklahomensis* (henceforth referred to as the Oklahoma alder). Although the petitioned entity is a valid species, we chose to conduct a status review at both the species and subspecies level. Thus, this SSA report includes information for the species (seaside alder) and each of the three subspecies (Delmarva alder, Georgia alder, and Oklahoma alder).

1.2 Analytical Framework

This SSA report for the seaside alder is intended to provide the biological support for the decision on whether or not to propose listing the species or its component subspecies as threatened or endangered and if so, whether or not to propose designating critical habitat. The process and this SSA report do not represent a listing decision by the Service. Instead, this SSA report provides a review of the best available information strictly related to the biological status of the seaside alder. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and a decision will be announced in the Federal Register.

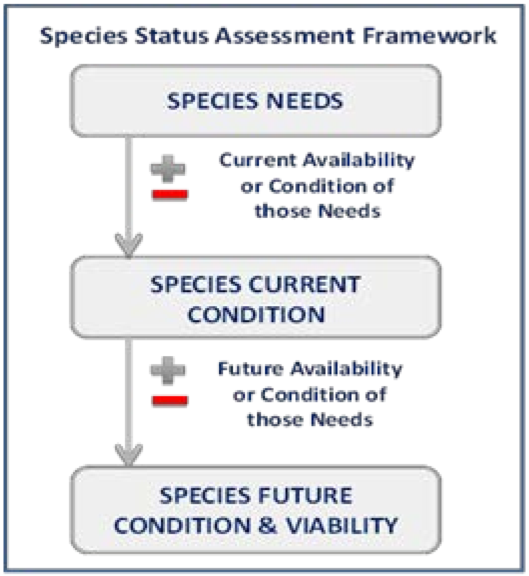


Figure 1. Species Status Assessment Framework

Using the SSA framework (figure 1), we consider what a species needs to maintain viability by characterizing the biological status of the species in terms of its resiliency, redundancy, and representation (Smith *et al*. 2018, entire). For the purpose of this assessment, we generally define viability as the ability of the species to sustain "populations" in natural ecosystems within a biologically meaningful timeframe: in this case, approximately 30 to 80 years. We chose 30 to 80 years because the best available data allow us to reasonably predict the potential significant effects of stressors within the range of the seaside alder within this timeframe.

Throughout the SSA Report, we use the term "analysis units" rather than population because it is difficult to delineate biological populations of the seaside alder in each region due to the plant's clonal behavior and other challenges associated with identifying population boundaries. To analyze the viability of the species (seaside alder) as a whole, our larger analytical units are the three subspecies (Delmarva, Georgia, and Oklahoma alders) as a surrogate for "populations," and we refer to them as species analysis units. To analyze the viability of each subspecies, our analysis units are the U.S. Geological Survey (USGS) Hydrologic Unit Code (HUC) 12 watersheds as a surrogate for "populations," and we refer to them as subspecies analysis units. The HUC 12 watershed includes the stretch of stream where seaside alder records occur and the adjacent uplands that may drain into the stream or pond, which may affect the watershed's water quality and quantity—two factors that influence seaside alder. The HUC 12s often include multiple sites and the relative number of sites reflects the overall abundance of seaside alder in the analysis unit. The analysis of the species as a whole is based on the resiliency of the smaller analytical units (i.e., the HUC 12 watersheds). Therefore, when we discuss the species' resiliency, we are including all of the subspecies and their analysis units. We assigned an equal weight to each subspecies to derive the seaside alder's current resiliency of the analysis units, and redundancy and representation of the species (conservation biology principles, together known as the 3Rs).

Resiliency, redundancy, and representation are defined as follows:

- *Resiliency* describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, germination versus death rates and population size (or persistence, if other data are lacking). Highly resilient populations are better able to withstand disturbances such as random fluctuations in germination rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the impacts of anthropogenic activities.
- *Redundancy* describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations; for example, wildfire or flooding).
- *Representation* describes the ability of a species to adapt to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and gauges the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range.

The decision whether to list a species is based on an assessment of the species' risk of extinction currently or in the foreseeable future. Therefore, to inform this assessment of extinction risk, we describe the species' current biological status and assess how this status may change in the future under a range of scenarios to account for the uncertainty of the species' future. We evaluate the current biological status of the seaside alder by assessing the primary factors negatively and positively affecting the species to describe its current condition in terms of resiliency, redundancy, and representation. We then evaluate the future biological status of the seaside alder by describing a range of plausible future scenarios based on projected stressors at 30 and 80 year time steps. These scenarios do not include all possible futures, but rather include specific plausible scenarios that focus on the most influential factors that affect its future viability.

Chapter 2. SPECIES INFORMATION

2.1 Taxonomy and Genetics

The seaside alder is one of eight species of North American alders. It is the only North American member of subgenus *Clethropsis* (Furlow 1979, entire); all other members of this subgenus occur in southern Asia. Subgenera *Clethropsis* is distinguished from other alders by its autumn flowering whereas all other alders flower in spring. This autumn flowering prevents seaside alder from hybridizing naturally with other alder species and aids in identifying this species in the wild (Schrader and Graves 2000a, p. 74).

The species occurs in three regional populations in Maryland and Delaware on the Delmarva Peninsula, Oklahoma, and Georgia (figure 2) and these have been formally described as three subspecies based on detailed analysis of morphology and growth habits of specimens (Schrader and Graves 2002, pp. 397–400). The Oklahoma alder (*Alnus maritima* spp. *oklahomensis*) and Georgia alder (*A. maritima* spp. *georgiensis*) were described as distinct from the Delmarva alder (*A. maritima* spp. *maritima*) due to the notable range disjunctions, distinctive traits associated with strobili (female cones) length/width ratio, leaf size and shape, and size and shape of the plant, thus meriting subspecies rank (Schrader and Graves 2002, pp. 397–400; Schrader and Graves 2003, pp. 390–392). Subsequent genetics studies using the genome fingerprinting method of inter–simple sequence repeats–polymerase chain reaction (ISSR–PCR) polymorphisms and microsatellite data also support recognition of the three subspecies (Schrader and Graves 2004, entire; Jones and Gibson 2011, entire). All evidence supports recognition of three subspecies of seaside alder. No evidence based claim has been published refuting recognition of seaside alder as comprising three distinct infraspecific taxa. Therefore, based on the best available scientific information, the Service accepts the taxonomic treatment of the three subspecies.

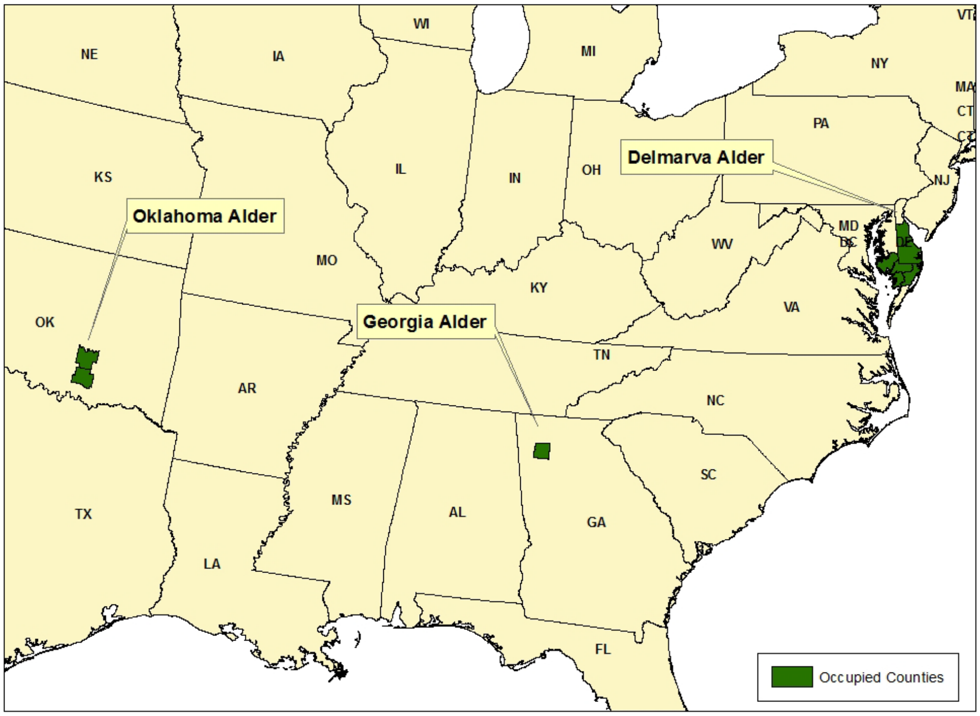


Figure 2. Distribution of seaside alder showing the currently occupied States and Counties by the three subspecies: the Delmarva alder (*Alnus maritima* spp. *maritima*), Oklahoma alder (*Alnus maritima* spp. *oklahomensis*) and Georgia alder (*Alnus maritima* spp. *georgiensis*).

For clarity throughout the SSA report, we will use the name seaside alder to refer to the species generally, and use the names Delmarva alder, Georgia alder, and Oklahoma alder to refer to the subspecies specifically.

Genetic Diversity

Microsatellite data suggest that the differences in genotypes are greatest between the three subspecies (referred to in Jones and Gibson (2011) as regional populations), "Although gene flow is clearly impossible, and therefore non-existent among regional populations (subspecies), *A. maritima* appears to have maintained adequate levels of gene flow within regions through networks of subpopulations" (Jones and Gibson 2011, p. 1011). The Oklahoma alder is more closely related to the Georgia alder (figure 3) than to the Delmarva alder. While both the Oklahoma and Georgia populations have similar outcrossing rates, a slightly higher degree of inbreeding was detected in the Oklahoma population. Still, there was not a significant level of inbreeding detected in either population (Jones and Gibson 2012, p. 6).

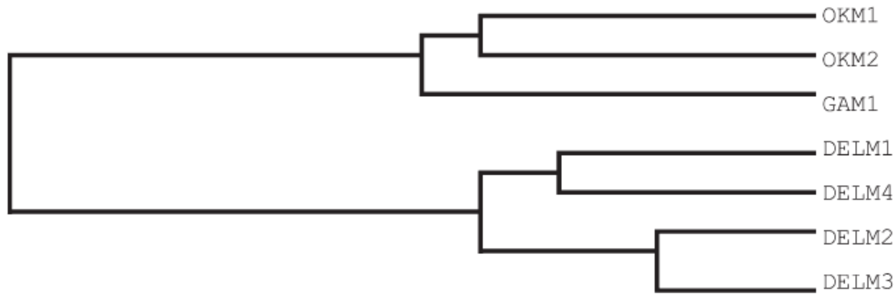


Figure 3. Phylogenetic tree of *Alnus maritima* derived from Jones and Gibson 2012.

2.2 Species Description

The seaside alder is a large, deciduous shrub or small tree, 16 to 23 feet (ft) (5 to 7 meters (m)) tall (Jones 2013, p.3) that grows in multi-stemmed clumps, instead of individual trees, in the wet soils of river, stream or pond edges (see section 2.5.1 below for pictures). Despite its name, it only occurs in freshwater habitats and prefers areas with full sun and soils that are at least periodically saturated or inundated. This shrub has glossy, dark green leaves that turn reddish-brown in the fall.

The plant is monecious meaning that male and female gametes are produced in separate flower clusters which occur on the same plant. It also reproduces asexually through cloning. The flowers are produced in the late summer/early fall prior to leaf detachment; pistillate or female flowers are borne in woody cones at leaf axils, while the staminate or male flowers are borne in bright yellow catkins that hang loosely at the tips of branches, typical of trees that disperse pollen by wind (Jones 2013, pp. 2–4). This species can be distinguished from other alders by the large size of the pistillate cones (0.5 to 1.0 inch (in)) (1 to 3 centimeters (cm)), leaf venation, and its late summer flowering habit (Brown and Brown 1972, entire; Furlow 1979, entire). Its attractive and colorful fall foliage created interest in developing horticultural varieties and plants have been successfully cultivated in university settings and arboretums (Schrader and Graves 2000a, p.77; Graves and Schrader 2004, entire; Kratsch 2008, entire).

2.3 Historical and Current Range and Distribution

2.3.1 Seaside Alder

As discussed above under Taxonomy, the seaside alder historically and currently has a disjunct distribution in Delaware, Maryland, Georgia, and Oklahoma (see figure 2, above). Because this is the only North American alder that flowers in the fall and all other fall flowering alders occur in Asia, researchers hypothesize that the seaside alder originated in Asia, moved into North America across the Bering land bridge and may have been a widely distributed pioneer species under particularly wet conditions after glacial recession during the late Pleistocene. Later, the progression of late-successional tree species may have gradually forced seaside alder into its current range (Schrader and Graves 2004, pp. 234–235). This theory is also supported by microsatellite data as the Oklahoma alder appears to be the oldest of the three subspecies (Schrader and Graves 2004, p. 233).

Some botanists consider seaside alder to be the most specialized of the alder species because it is the most hydrophilic of all American alders. This may have given this species a strong advantage over other pioneer species under particularly wet conditions in the past (Schrader and Graves 2002, p. 394).

2.3.2 Delmarva Alder

The Delmarva Peninsula, or simply called the Delmarva, is a large peninsula of land between the Chesapeake Bay and Atlantic Ocean that comprises Delaware, the Eastern Shore of Maryland, and the Eastern Shore of Virginia. The name ***Delmarva*** is a combination of the three State names **Del**aware, **Mar**yland and **V**irgini**a** (abbreviated VA). The Delmarva alder occurs along the edges of many of the Delmarva's major rivers. It was first described here in 1785 (Marshall 1785, as described in Stibolt *et al*. 1977).

Historical Distribution: Delmarva alder was first discovered in 1785 (Stibolt 1977, p. 373) and has been described in various reports and regional floras since that time. Shreve *et al*. (1910, p. 128) described Delmarva alder associated with the Nanticoke River drainage and white cedar swamps of the Nanticoke and Marshyhope Rivers, extending into Delaware, which continues to be the heart of the range today, but no maps or distribution by counties was provided. Comparison of occupied counties in older floras indicates some differences in different floras (table 1). In 1946, it was described as "frequent" on the borders of streams and ponds in four counties (Tatnall 1946, p. 99). Stibolt (1981, p.197) reported its presence in five counties and is the first and only study to report its presence in Caroline County, Maryland, with one record in the Choptank River. Current surveys have not found it there despite surveys for other species by State botanists. Our understanding of the Delmarva alder's current distribution includes two additional counties since Stibolt's (1981, p. 197) report (table 1). We interpret this increase in the number of counties occupied to be more likely a result of increased survey effort over time than an increase in the true distribution.

Table 1. Maryland (MD) and Delaware (DE) Counties occupied by Delmarva alder from three time periods and sources.

Counties Occupied (Tatnall 1946)	Counties Occupied (Stibolt 1981)	Counties Currently Occupied (State Records 1987–2017)
		Kent, DE
Sussex, DE	Sussex, DE	Sussex, DE
Dorchester, MD	Dorchester, MD	Dorchester, MD
Wicomico, MD	Wicomico, MD	Wicomico, MD
Worcester, MD	Worcester, MD	Worcester, MD
-	Caroline, MD	-
		Somerset, MD

Current Distribution: Our current understanding of the distribution is based on geographic information system (GIS) data provided by the States which map records of occurrence primarily as point locations; these indicate the location of a patch of Delmarva alder that may range from a small patch to an area greater than 10 hectares (ha) (25 acres (ac)). In addition, field visits were conducted as part of this status assessment to update the occurrence information as time allowed. Thus the data are broad records of occurrence, not precise mapping of the extent of each patch. And according to the State botanists collecting this data, it should be assumed that individual plants occur in between locations (Frye and McAvoy 2017). In addition, these data represent the minimum distribution as we are aware of additional records but the supporting information on those records are not available to us. Given this situation and the difficulty of surveying all potential habitat on the Delmarva, we consider this distribution to be based on the best available information but likely underestimates the overall abundance of the subspecies. The Delmarva alder's current distribution includes six counties (table 1).

We also overlaid the first map of the Delmarva alder distribution (Stibolt 1981, p. 197) onto the distribution of current GIS records and compared the number of U.S. Geological Survey (USGS) Hydrologic Unit Codes (HUCs) that were occupied (figure 4). The Stibolt distribution included 32 HUCs; the current distribution includes 27 HUCs, most of which overlap the Stibolt distribution. While there are some watersheds currently occupied that were not part of the Stibolt map and some identified on the Stibolt map that do not have current State records, there has not been any deliberate effort to survey the Stibolt mapped areas. It is possible that the true distribution is more similar to the combined records from the Stibolt map and the current State records, but additional surveys would be needed to confirm that hypothesis. Despite these differences, we consider these two distributions to be generally similar and most likely a result of different levels of survey effort. The heart of the range where Delmarva alder is most abundant continues to be the Nanticoke, Wicomico, and Pocomoke River drainages in Sussex County, DE and Dorchester and Wicomico Counties, MD where it was historically described (Shreve *et al.* 1910, p. 128). Although we do not have population count data from which to derive a true population trend, the best available information suggests a relatively stable trend in distribution.

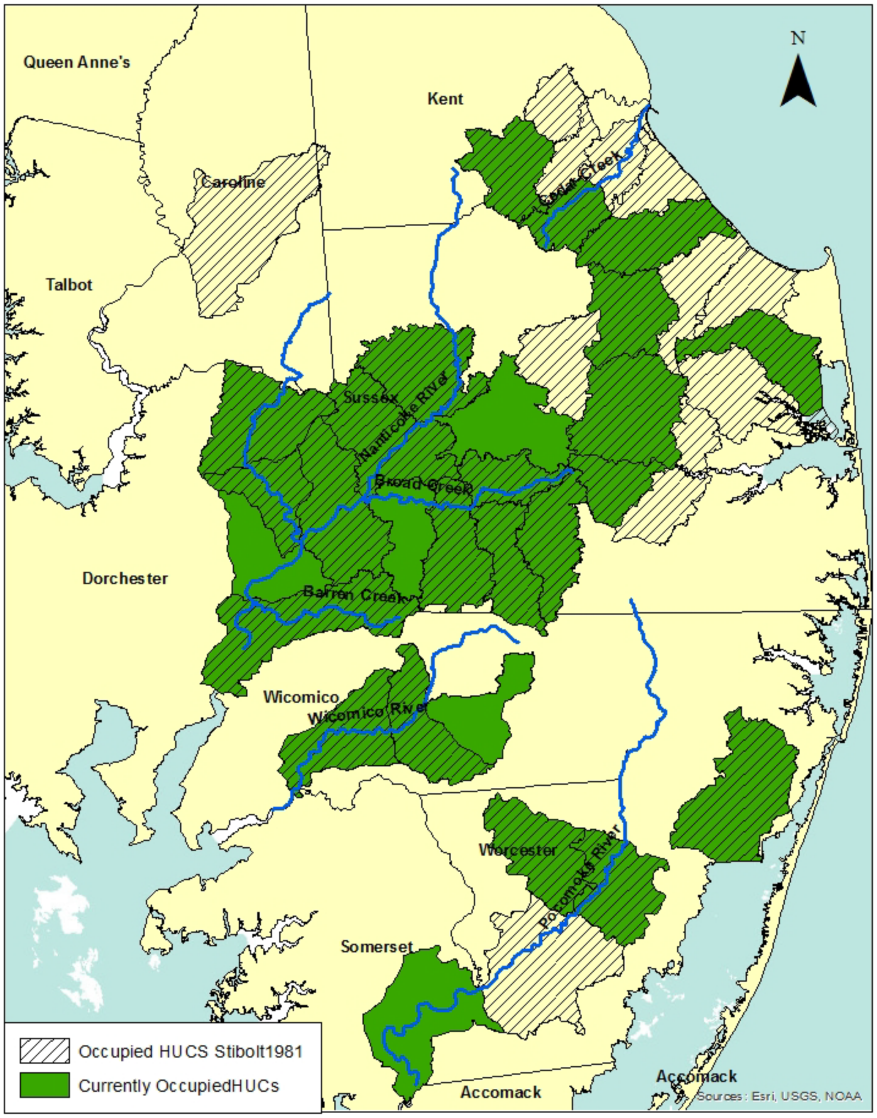


Figure 4. Distribution of HUCS considered occupied by the best available current State and Service data, including from an older survey (Stibolt 1981, entire).

2.3.3 Georgia Alder

Georgia alder, located in Bartow County, Georgia (GA), was discovered in 1997 at Drummond Swamp, though understood to be present for at least 100 years (Ranger 1997, p. 1) and probably since the late Pleistocene (Jones 2013, p. 8; figure 5).

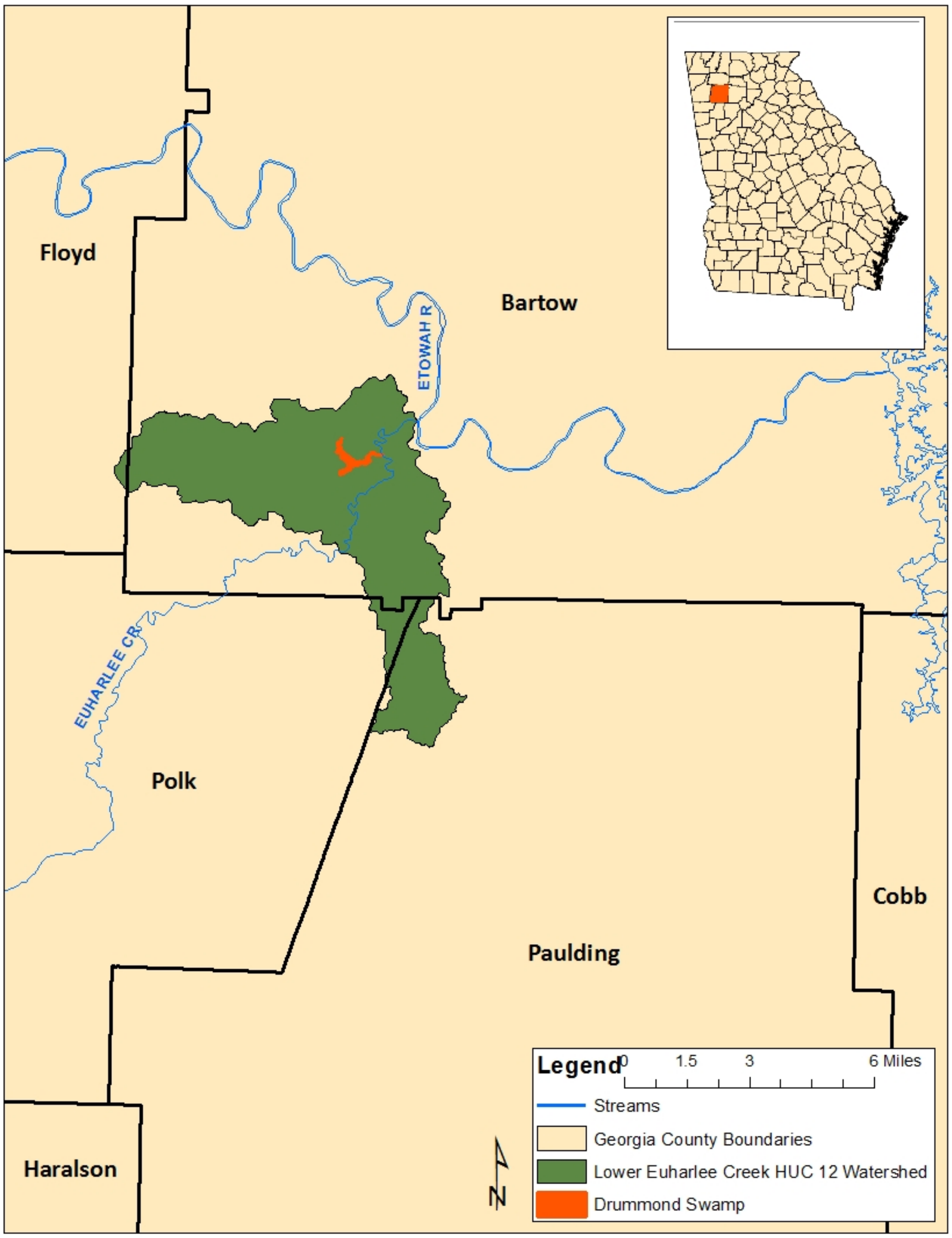


Figure 5. Lower Euharlee Creek HUC currently occupied by Georgia alder in Bartow County, Georgia.

Georgia alder occurs within Drummond Swamp, which likely contains the largest stand of seaside alder in the world (Schrader and Graves 2002, p. 393); the shrub occupies over 35 ac (14 ha) of the 200-ac (80-ac) site (Chafin 2017, p. 4). In 1997, surveys concluded there were about 200 clumps of Georgia alder in 2 main areas. However, a 2014 aerial survey produced estimates of approximately 3,000 clumps in about 6 main areas in the 200-ac (80-ha) site (Georgia Department of Natural Resources (GA DNR) 2017, pp 3–4; GA DNR 2014, entire). This increase in abundance is most likely a result of survey approach and effort rather than a true increase in abundance. However, according to 2014 survey data, the Georgia alder appears to be spreading into new areas around Drummond Swamp that have recently been converted from pasture to wetland by beaver damming (Chafin 2017, p. 5).

2.3.4 Oklahoma Alder

The Oklahoma alder was historically found on Mill Creek (tributary to Bois d' Arc Creek), Sheep Creek, Canyon Creek, Little Blue Creek, Blue River, Pennington Creek, Reagan Branch, and Sandy Creek, within Pontotoc and Johnston Counties of south central Oklahoma (figure 6). Data sets are primarily point locations that indicate the location of a patch of Oklahoma alder that may range from a small patch to an area of multiple acres and individual plants may occur in between locations.

Currently, the range of the subspecies has been reduced, though additional populations may still be on the landscape (Howery 2018; Ehardt 2016, entire). The population in the southern portion, the Lower Desperado site, of the Desperado Spring Falls watershed along the Blue River, has been extirpated (Oklahoma Natural Heritage Inventory 2018, entire). The cause of extirpation is unclear.

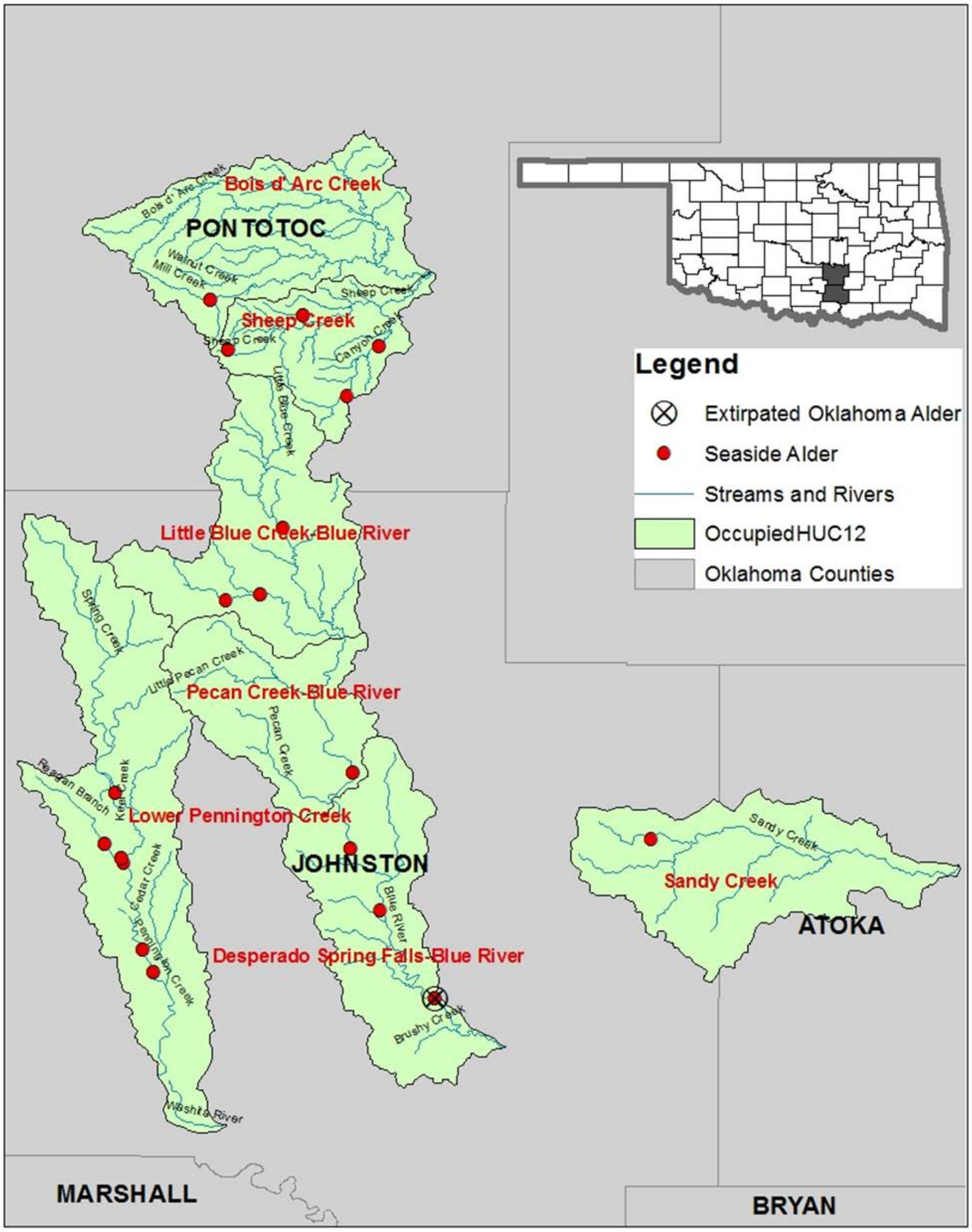


Figure 6. Known records of the Oklahoma alder from the Oklahoma Natural Heritage Inventory (2018, entire).

2.4 Life History[1]

2.4.1 Annual Cycle

The seaside alder initiates floral development in spring, the catkins (drooping cluster of unisexual flowers) open for pollination in late summer to early autumn, and the fertilized catkins undergo dormancy through the first winter. Seeds mature the following year. Most seeds are dispersed in late fall and early winter of the second year, and some are dispersed in the spring (figure 7, table 2). About two-thirds of the seeds are dispersed in the fall and one-third are released in the early spring. The viability of seeds released in the spring was lower (40 percent germination for seeds released in spring compared to 58 percent in the fall) (Schrader and Graves 2000b, p. 73–76). Seeds can float downstream and germinate.

Figure 7. Development of pistillate cone or strobili over 2 years from left to right: pollination, to green strobili, to mature woody cone containing mature seeds.

[1] Life history refers to a series of changes undergone by an organism during its lifetime.

Table 2. Phenology of seed development in seaside alder.

Year 1	Year 1	Year 1	Year 1	Year 2	Year 2	Year 2	Year 2	Year 3
March April May	June July Aug	Sept Oct Nov	Dec Jan Feb	March April May	June July Aug	Sept Oct Nov	Dec Jan Feb	March April May
Spring	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**
Flower development starts								
	wind pollination late summer (Aug and Sept)							
		Fertilized catkins go into dormancy						
				Green strobili and seeds begin to develop				
					Strobili enlarge and begin to mature	Strobili turn woody and brown		
						Seeds begin to drop out of woody strobili		
						About 2/3 of seeds drop in fall		About 1/3 of seeds still present in March
						Empty strobili persist at least one year, some can persist an additional year		

2.4.2 Reproduction:

The plant is monecious meaning that male and female gametes are produced in separate flower clusters which occur on the same plant. It also reproduces asexually through cloning. The flowers are produced in the late summer/early fall; pistillate or female flowers are borne in woody cones at leaf axils, while the staminate or male flowers are borne in bright yellow catkins that hang loosely at the tips of branches, typical of trees that disperse pollen by wind (Jones 2013, pp. 2–4).

2.4.3 Reproductive Strategy:

The seaside alder exhibits both sexual and asexual reproduction and the relative advantages of these two strategies are discussed in the literature (Williams 1975, entire; Otto and Lenormand 2002, entire; Rice 2002, entire; Silverton 2008, entire). Sexual reproduction increases genetic diversity, reduces the effects of deleterious recessive mutations, and provides the genetic diversity that is the basis for selection and adaption in the face of environmental variation. However, sexual reproduction can result in a loss of adaptive combinations of genes and reduces the contribution of an individual's genes to the next generation. Asexual reproduction, such as cloning, can perpetuate favorable adaptations of individuals. A species that is capable of both sexual and asexual reproduction, like the seaside alder, may be more resilient than another species that reproduces only through one of these strategies.

With many woody plants, colonies arise by wide-ranging roots that send up new shoots or suckers. Trees and shrubs with branches that touch the ground, like the seaside alder, can also form colonies via layering. For example, the Oklahoma alder has been documented to quickly produce new shoots from flood-induced broken stems (Rice and Gibson 2009, p. 63; see figure 8 below).

Genetic diversity provides needed variation for adaptation to changing conditions. Woody plants that frequently reproduce asexually through suckers or layering and producing clones could be at greater risk of losing genetic diversity. However, the tendency for a plant species to clone does not generally result in a monotypic stand of one genotype; in fact, hundreds of studied species were found to have multiple clones of different genotypes (Ellstrand and Roose 1987, p. 127; Silverton 2008, entire).

In general, clonal growth is an important component of the life history of riparian woody shrubs and may be related to the relative disturbance levels (e.g., flow regimes) along rivers. Douhovnikoff *et al*. (2005, entire) compared the extent of willow (*Salicaceae*) clones in rivers with high disturbance versus low disturbance flows and found that the low disturbance regime was associated with greater clonal growth and reduced genotypic variation. As disturbance is reduced, clones expand, stems are larger, the canopy closes, and there is little space or light available for seedling development. The life history of willows on active floodplains often had the following life history traits: high juvenile mortality (seedling survival is difficult on exposed soils that might dry out); wind dispersal; vegetative reproduction and dispersal; and stochastic seed recruitment (Karrenberg *et al*. 2002, p. 743). High seedling mortality (exceeding 90 percent) has also been documented in Wisconsin willows, (*Salix spp.*), and river birch (*Betula nigra*) (Dixon 2003, p. 131–133).

Overall, the ability to reproduce both sexually and asexually is likely an advantage to seaside alder. Vegetative growth enables it to persist in many areas despite some shading, or regenerate from broken stems after floods. Sexual reproduction occurs or there would not be the genetic diversity that is present, however, sexual reproduction appears to be occurring less frequently. It is possible that sexual reproduction occurs more frequently in areas with newly scoured sediments from more catastrophic flooding (Douhovnikoff *et al*. 2005, entire). The conditions needed for seedling establishment in the wild are still unknown.

Figure 8. New green stems of Delmarva alder growing up through broken branches of a mature Delmarva shrub (photo credit USFWS). (See figure 1 in Rice and Gibson 2009 for additional example in Oklahoma).

2.5 Individual Requirements (Ecological Setting and Habitat Needs)

2.5.1 Seaside alder

As discussed above under section 2.3 Historical and Current Range and Distribution, the seaside alder occurs in three disjunct subspecies and these occur along the edges, or in the shallow water, of different wetland types. For example, on the Delmarva Peninsula, it is found on the edges of freshwater tidal rivers as well as the shallow areas of ponds and marshes; in Oklahoma, it is found on the edges and sandbars of freshwater streams and rivers; and in Georgia, it is found on the edge of a large swamp and associated stream (Jones 2013, p. 3). While each subspecies is represented by slightly different freshwater habitat types, all of these habitats contain the components of sunlight, water quality, and periodically inundated (hydric) soils needed by the individual plants. Specifics of each habitat type are described below.

The model below (figure 9) illustrates these relationships and these help to identify both the range of habitat in which it occurs and potential stressors (Chapter 3—Factors Influencing Viability) in the subsequent sections.

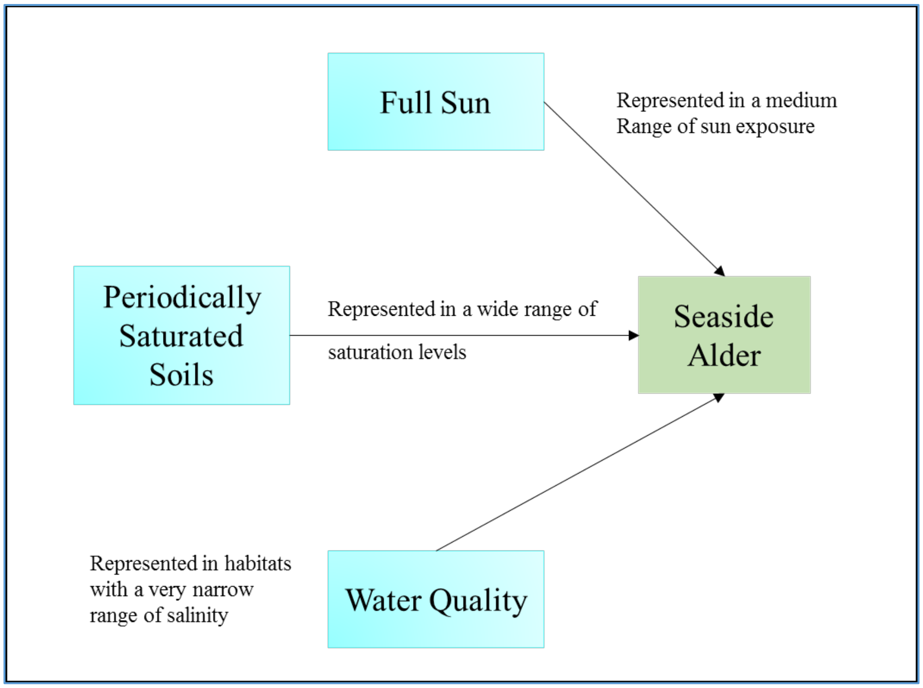


Figure 9. Basic ecological requirements for seaside alder.

Like many wetland shrubs, seaside alder has many features that enable it to survive in an environment where water levels can change dramatically and conditions can be highly variable. These life history features reflect its adaptability to different conditions and contribute to the health of populations on the landscape. Table 3 summarizes previous research on the seaside alder's life history traits.

Table 3. Summary of seaside alder life history research.

Research on ecological requirement for freshwater wetlands with periodic soil saturation
Survives wide range of water depths and quantities: In the wild seaside alder occurs only where soils are at least frequently inundated (Schrader and Graves 2000a, p.77). However, in the lab, young plants survived a wide range of moisture conditions from total flooding to severe drought (Schrader *et al*. 2005, entire). Field trials with 1-year old seedlings installed on well-drained soils in Iowa indicated that with only rain for water and no irrigation, plants appeared healthy and showed abundant growth. Attempts to grow the Oklahoma alder in the arid climate of northern Utah found that they would not survive without water—but if irrigated and in partial shade, they survived with no signs of stress (Kratsch 2008, entire). In Georgia, seedlings outplanted as part of a "safeguarding" program (see section 3.3.4) into three different sites with varying water availability have shown some mixed results. One site was flooded due to beaver activity and all seedlings were lost. At other sites seedlings are surviving with varying results mostly from competition from other species (Byrd 2018; Richards 2017).
Roots can fix nitrogen with symbiotic bacteria: Roots of this plant have nitrogen fixing nodules that result from a symbiotic relationship with the actinobacteria *Frankia*; this enables the plant to live in nitrogen poor soils and survive periodic inundation when oxygen levels in the soils become low. Experiments in the lab indicate seaside alder has the highest levels of *Frankia* nodules when grown in lower nitrogen soils, and nodule growth will adjust to changing levels of nitrogen added to the soil (Law and Graves 2005 entire). *Frankia* nodules are also able to occur and persist even when seedlings are grown on flooded sites where soil oxygen levels are low, though nodules grow differently to increase access to oxygen (Kratsch and Graves 2004, entire). There is no suggestion from the current literature that the presence of *Frankia* bacteria in the soils is limiting, and the bacteria have been observed to be transported by birds (Pashke and Dawson 1993, entire). There is ongoing research into the relationship between *Frankia* and seedling growth (Gibson 2018a), but at this time, no data are available to suggest that the relative abundance of *Frankia* in the soil is a limiting factor or a stressor.
Roots do well in relatively low oxygen soils: A laboratory study of plant growth of Delmarva alder seedlings found that plants could tolerate a wide range of oxygen levels in the soil. However, photosynthetic rate, plant dry mass, leaf nitrogen, and nodule total weight were maximum when soil oxygen levels were between 15 and 25 percent (Kratsch and Graves 2005, entire).
Does not tolerate saltwater: Both lab studies and field studies indicate this species is injured from salt in the root zones. Injury from low salinities is visually evident as browning of the leaf margins beginning with the lower leaves, but diminished photosynthesis is occurring even before changes are visually evident from the plant. Individual plants grown in the lab were planted along a salinity gradient in the field; after 5 months, no survival occurred in areas with salinity of 5 parts per thousand (ppt) and damage was evident in areas with salinity of 2 ppt. Only where salinity was less than 1 ppt and generally less than 0.5 ppt was salt stress not evident. Inundation of the root zone had a greater effect than simply applying the saline water from the surface (Graves and Gallagher 2003, entire).

Table 3, continued. Summary of seaside alder life history research.

Research on the ecological requirement of open sun
Does well in open sun—Out-competes *A. serrulata* in open sun: Seaside alder occurs with smooth alder (*Alnus serrulata*) in the Delmarva Peninsula and in Georgia, though these two species are not sympatric in Oklahoma. Where they co-occur, the seaside alder inhabits the more open and sunny areas, extending out into the water to a greater degree and appears to out-compete the smooth alder in this open sun setting. Experiments to evaluate shade tolerance in these two species revealed that seaside alder seedlings had greater photosynthetic capacity and grew more quickly than smooth alder seedlings in full sunlight but the reverse was true in shade (Schrader *et al*. 2006, entire).
Research and Life History Features related to Reproduction
Wind Pollinated—Pollen flow is good: The seaside alder is wind pollinated with no chance for hybridization because it is the only Alder that flowers in late summer/early fall. Comparison of the genetics of seeds and their maternal plants indicate a highly outcrossed population with 94 percent of offspring (seeds) from two parent individuals and only 6 percent from self-fertilization in the Oklahoma and Georgia populations (Jones and Gibson 2012, p. 15). "In Oklahoma, some offspring (seeds) collected from the main Blue River population were potentially sired by pollen parent trees located 5 to 7 kilometers (3 to 4 miles) away in nearby creeks." (Jones 2013, p. 9). However, the presence of seedlings is still rare and most seaside alder plants appear to sustain themselves from asexual reproduction
Seed viability in the lab is good but depends on when they are dispersed: Seed viability in the lab is good or better for the seaside alder than for other alder species. About two-thirds of the seeds are dispersed in the fall and one-third are released in the early spring and viability of seeds released in the spring was lower (40 percent germination for seeds released in spring compared to 58 percent in the fall) (Schrader and Graves 2000b, p. 73–76). Seeds can float downstream but new plants from seeds are rare.
Asexual reproduction aids in resprouting rapidly from large, scouring floods. Flooding can break stems plants, and roots but these shrubs appear to re-sprout rapidly from broken roots. A study in Oklahoma found that major floods that occurred in the summer of 2007 tore away aboveground stems of many of the plants, but new branches began to grow from the root clumps later that summer (Rice and Gibson 2009, p. 59).
Most plants are reproducing asexually and seedlings seem to be rare in the wild. In Oklahoma, a search of 1,848 1 square meter plots, discovered only 20 seedling plants (Rice and Gibson 2009).
Microsatellite data indicate genetic diversity is reasonably good overall; "Although gene flow is clearly impossible, and therefore non-existent among regional populations (subspecies), *A. maritima* appears to have maintained adequate levels of gene flow within regions through networks of subpopulations." (Jones and Gibson 2011, p. 1011). Microsatellite genotyping found high multi-locus out-crossing rates in both the Oklahoma and Georgia populations and no significant inbreeding in either population (Jones and Gibson 2012, entire; Jones 2013, p. 8–9).

Table 3, continued. Summary of seaside alder life history research

Additional Life History Features
Cold hardiness - Can tolerate cold temperatures: Plants can be grown in the lab and raised to mature shrubs for all three subspecies and 2-year old shrubs showed remarkable cold hardiness; all 2-year old trees survived winter in Iowa and Minnesota field plots, and lab results indicate some plants from all three subspecies could survive mid-winter extremes as low as -76 degrees Fahrenheit (°F) (-60 degrees Celsius (°C) (Schrader and Graves 2003, entire).

Summary of individual requirements

<u>Tolerance to sun and shade</u>: Seaside alder prefers full sun but there is some variation in tolerable sun exposure as it can be found in open marsh and on the edge of forests and ponds. Seaside alder occurs with smooth alder (*Alnus serrulata*) in the Delmarva Peninsula and in Georgia, though these two species are not sympatric in Oklahoma. Where they co-occur, seaside alder inhabits the more open and sunny areas, extending out into the water to a greater degree and appears to out-compete smooth alder in this open sun setting. Experiments to evaluate shade tolerance in these two species revealed that seedlings of seaside alder had greater photosynthetic capacity and grew more quickly than smooth alder in full sunlight but the reverse was true in shade (Schrader *et al*. 2006, entire).

<u>Tolerance to periodic soil saturation</u>: In the wild, seaside alder only occurs where soils are at least frequently inundated (Schrader and Graves 2000a, p.77). However, in the lab, young plants survived a wide range of moisture conditions from total flooding to severe drought (Schrader *et al*. 2005, entire). Field trials with 1-year old seedlings installed on well-drained soils in Iowa indicated that with only rain for water and no irrigation, plants appeared healthy and showed abundant growth. Attempts to grow Oklahoma alder in the arid climate of northern Utah found they would not survive without water; but if irrigated and in partial shade, they survived with no signs of stress (Kratsch 2008, entire).

Alders are among the plants that form a symbiotic relationship with a nitrogen fixing actinobacteria (*Frankia* sp.) to overcome nitrogen limiting environments (Jones 2013 p. 3) and survive periodic inundation when oxygen levels in the soil are low. This is achieved through the development of root nodules, an anatomical adjustment on the roots of seaside alder, allowing nitrogen to be absorbed through the air to ensure plant survival. In general, actinorhizal plants are sun loving pioneers in early successional stages of revegetation (Del Tredici 1995, entire). They do best on sandy or swampy soils where nitrogen is scarce and their ability to extract it from the air is a distinct advantage (Del Tredici 1995, entire). Seaside alder and Frankia have evolved to survive these harsh conditions, whereas other plants, shrubs, and trees cannot survive the same anaerobic environment. A laboratory study of plant growth of Delmarva alder seedlings found that plants could tolerate a wide range of oxygen levels in the soil. However, photosynthetic rate, plant dry mass, leaf nitrogen, and nodule total weight were highest when soil oxygen levels ranged between 15 and 25 percent (Kratsch and Graves 2005, entire). Studies show that compared to other species, even other wetland species, symptoms of stress on seaside alder were delayed relative to other species, and only occurred under severely flooded conditions, as a result of the root nodules (Kratsch and Graves 2004, p. 1).

Native soil has specific strains of *Frankia* bacteria that form symbiosis with seaside alder. For the purposes of this SSA, native soil is defined as the soil in which seaside alder naturally occurs. Although *Frankia* is widely distributed throughout most soils, symbiotic efficiency varies among strains inhabiting soils from different geographic regions (Schrader and Graves 2008, p. 33). Seaside alder will thrive in areas of native, inundated soils, but will survive in areas where *Frankia* does not exist, as long as the tree is watered and provided with fertilizer (Schrader and Graves 2008, pp. 33–34).

2.5.2 Delmarva Alder

The Delmarva alder occurs along the edges of fresh tidal rivers including the Nanticoke, Pocomoke and Wicomico Rivers in Maryland, as well as along rivers, creeks and impounded streams in Delaware. In the tidal freshwater rivers of both Maryland and Delaware, the Delmarva alder generally occur in clumps at the edge of the rivers (figure 10) or forms banks of shrubs at the edge of freshwater emergent marshes that occur on the edge or fringe of the rivers (figure 11) (Stibolt 1981, entire; Harrison and Stango 2003, p. 19). Its distribution along these rivers appears to stop at the downstream areas where salinity becomes too high, and does not go further upstream because of shading from adjacent upland forest and lack of open marsh areas (Frye 2016).

This plant occurs in tidal freshwater marshes with very low salinity "Salinity typically ranges from 0 to 0.5 parts per thousand (ppt) due to the dilution of tidal inflow from sufficient upstream freshwater sources, however, spring high tides or low river discharge may result in pulses of higher salinity." Both lab studies and field studies conducted by Graves and Gallagher (2003; entire) indicate this species is injured from salt in the root zones. Injury from even low salinities is visually evident as browning of the leaf margins beginning with the lower leaves, but diminished photosynthesis is occurring even before changes are visually evident from the plant.

Figure 10. The Delmarva alder along the edge of Broad Creek at high tide, Sussex County, DE. (Photo credit C. Keller, USFWS, 2017.)

Figure 11. Large bank of the Delmarva alder (highlighted in blue) between the emergent marsh and wetland forest of a freshwater tidal river, Barren Creek, Wicomico County, MD. Picture taken at low tide thus mud flats between water and emergent marsh are visible. (Photo credit C. Keller, USFWS, 2017).

In parts of Delaware, the seaside alder is often found in slow moving mill ponds which are impoundments created in the 1700s and 1800s to operate sawmills and gristmills. Creation of mill ponds likely flooded some adjacent forest, killing trees and creating the more open sunny habitat where the Delmarva alder does well (figure 12). The fringe of emergent marsh may not be present in the ponds, and the Delmarva alder can grow right along the edge of the adjacent forest. Approximately 85 percent of the Delmarva alder records are associated with rivers and streams and 15 percent are associated with ponds. In these areas, the tidal fresh river water levels change by 3 to 4 ft (0.9 to 1.2 m) twice daily and impoundment water levels change seasonally.

Figure 12. The Delmarva alder (outlined in blue) growing on edge of pond, Sussex County, DE. (Photo credit C. Keller).

A 2003 study that classified Maryland freshwater shrub communities, listed Delmarva alder as the dominant species of one tidal shrubland community (Harrison and Stango 2003, p. 19–21). Salinity typically ranges from 0 to 0.5 ppt due to the dilution of tidal inflow from sufficient upstream freshwater sources, however, spring high tides or low river discharge may result in pulses of higher salinity. Salinity data collected at the time of study indicates a range of 0 to 1.0 ppt (mean ppt = 0.38).

In the Nanticoke and Marshyhope Rivers, the largest patches of tidal fresh emergent marshes along the river provide habitat for the largest banks of Delmarva alder—presumably because they provide large areas of open sun at a shallow water depth that has periodic flooding and seems appropriate for this species. The largest stands of Delmarva alder are where large areas of emergent marsh form at the "slow side" of bends in the river where sediment is deposited and emergent marshes form. Narrow bands of emergent marsh can still provide habitat but the stands of Delmarva alder are smaller. Without any emergent marsh the riverine or impoundment shoreline may still have some Delmarva alder but generally these are individual plants scattered along the shoreline. This is likely a result of both availability of sun and a water depth that is appropriate to provide the periodic saturated soils. Note that this does not mean the very largest marsh is best for the Delmarva alder as this does not seem to be the case (e.g. confluence of the Marshyhope and Nanticoke). However, the largest patches of the Delmarva alder are located in these areas of wider emergent marsh—and they might be stressed or threatened by diminishment of that same marsh through erosion or flooding.

2.5.3 Georgia Alder

The Georgia alder grows in a forested-shrub, spring-fed marsh or swamp located in the Ridge and Valley ecoregion of Georgia. The wetland is known as Drummond Swamp and the upwelling of groundwater is from Blue Hole Spring. The Georgia alder occurs in two habitat conditions within the swamp: a shallow, sunny sagpond and in a spring-run that flows out of the sagpond (figures 13, 14 and 15). Sagponds in this ecoregion are unique depressional wetlands that are formed when dolomite or limestone substrate collapses beneath thick layers of overlying bedrock. These sagponds often harbor many relict Coastal Plain species that migrated northward through the Coosa River valley. Sagponds typically have a gentle gradient, and often exhibit irregular, somewhat concentric zones of vegetation determined by hydroperiod and topography (Edwards *et al.* 2013, pp. 243–245). The Georgia alder in the pond habitat is in open sun, growing either on tussocks of vegetation in the open water or along the edge of the sagpond, while the alder along the spring-run may be partially shaded in some areas. In general, plants from Georgia are in less shade than the plants of the other two subspecies (Schrader and Graves 2002, p. 390). Drummond Swamp contains slightly to moderately acidic soils that are low in phosphorus and very low in potassium (Schrader and Graves 2002, p. 392). The low concentration of potassium in soils of Drummond Swamp may be linked to poor health condition of some of the alders causing chlorosis and scorching of older leaves (Schrader and Graves 2002, p. 392). The hydrology of this site is not entirely known but is manifested as a spring-fed open wetland that appears to be very old. It is theorized that persistence of this forested-shrub marsh, or swamp, through long geologic time periods is related to the upwelling of groundwater from an aquifer in karst geology leading to a very wet and open marshland which is normally too wet to be suitable for other wetland tree species. Beaver activity has also been suggested as an agent in the creation and maintenance of this wetland (NatureServe 2017, entire).

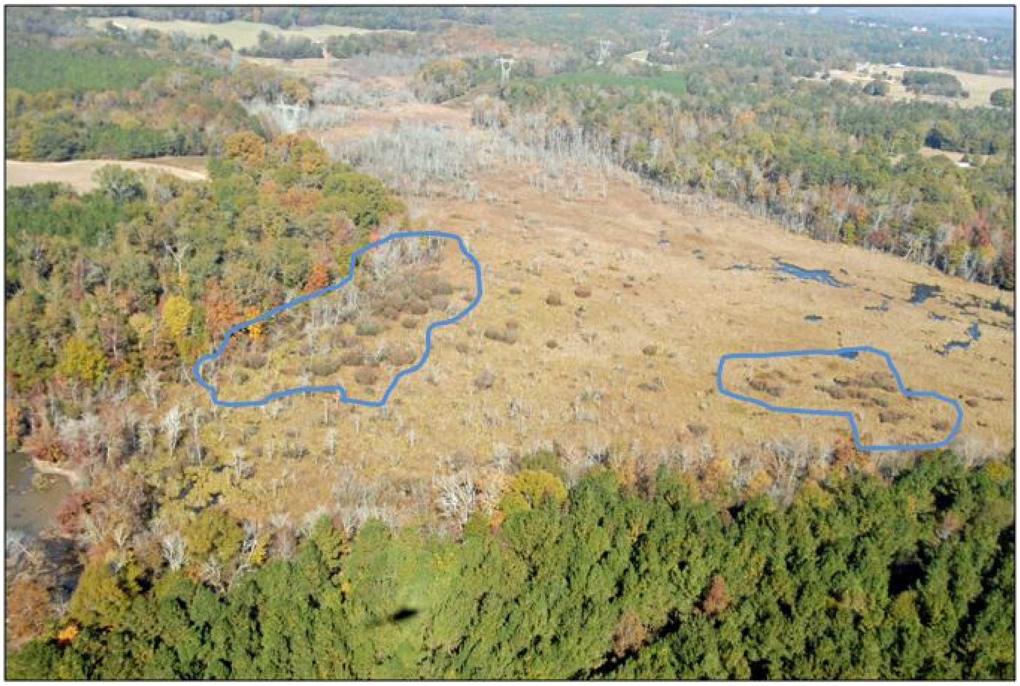


Figure 13. A 2014 aerial photo of Drummond Swamp. Large clusters of the Georgia alder (highlighted in blue) along the edges of the swamp. (Photo credit USFWS).

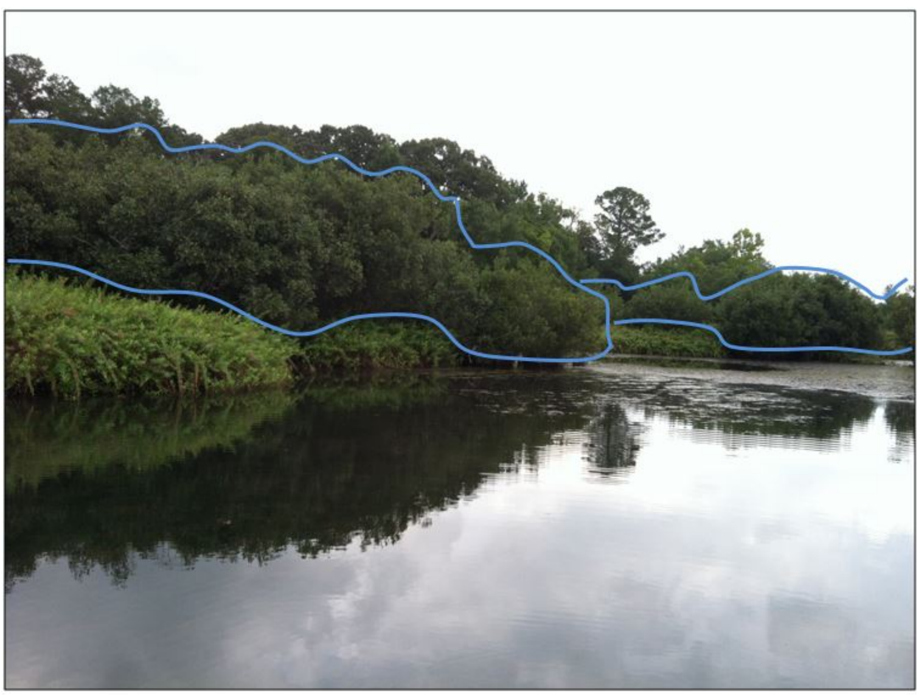


Figure 14. Photo of Blue Hole Spring at Drummond Swamp. Habitat is an open "sag pond" lake formed by slumping of limestone bedrock. Georgia alder (highlighted in blue) along bank between the swamp loosestrife (*Decodon verticillatus)* along the water's edge and riparian forest in back. (Photo credit USFWS).

Figure 15. (a) Photo of "spring-run" habitat downstream from Blue Hole Spring at Drummond Swamp. The Georgia alder occurs in dense patches along the bank of the stream. (Photo credit USFWS). (b) Photo of "swamp" habitat. The Georgia alder occurs in patches in open water. (Photo credit Michelle Carver and Catherine Borer).

Drummond Swamp is situated within the Ridge and Valley Paleozoic-Rock Aquifer, (figure 16), which wells typically yield 1 to 50 gallons per minute (gal/min) but may exceed 3,500 gal/min (Peck and Painter 2016, p. 8). Cressler *et. al*. (1979, p. 9) measured the flow of Blue Hole Spring at Drummond Swamp in 1950 as 3,200 gal/min. A second attempt to measure the flow in 1974 failed due to flooding caused by beaver.

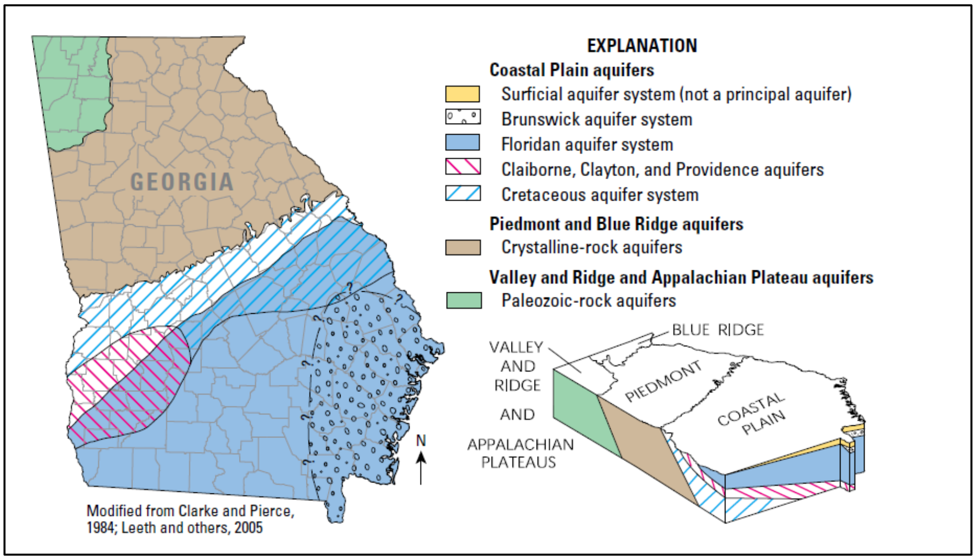


Figure 16. Principle aquifers of Georgia (USGS 2006)

The major water-bearing units in Bartow County consist of carbonate rocks that are deeply weathered and blanketed by a thick layer of residual soil. There are cavities in the carbonate rocks that may extend below the water table. This geologic structure, often referred to as karst geology, has moderately high susceptibility to ground collapse and sinkholes (Cressler *et al.* 1979, p. 17).

Schrader and Graves (2002, pp. 392–393) described the Georgia alder site at Drummond Swamp as receiving more annual rainfall than the Delmarva and Oklahoma regions and may be one reason why Georgia alder can grow further above the water table than do alders of the other two subspecies. The greater soil moisture provided by precipitation may help offset the need for Georgia alder to be as closely associated with saturated soils as are the other two subspecies. Although the Georgia population covers a much smaller area than do the other two subspecies, it supports what is possibly the largest natural monotypic stand of seaside alder in the world, possibly linked to grazing by cattle and herbivory from beaver. Where it is found growing with other bottomland species, the overall large size and rapid growth of Georgia alder make it very competitive with other tree species in Drummond Swamp.

> "In the deepest portions of this habitat, the local endemic *Alnus maritima ssp. georgiensis* may occur as a monotypic species and attain the stature of a small tree. In shallower areas, and along the edges of the wetland, an herbaceous zone occurs in patches, often dominated by *Sparganium americanum, Sagittaria latifolia, Peltandra virginica, Leersia oryzoides, Carex lurida, Boehmeria cylindrica, Juncus effusus*, and *Saururus cernuus*. Other woody shrubs that can occur include *Decodon verticillatus, Acer rubrum var.*

trilobum, Fraxinus pennsylvanica, Itea virginica, Cornus amomum, and *Cornus foemina*. Additional herbaceous species observed within this association are *Hibiscus moscheutos, Polygonum setaceum, Polygonum hydropiperoides, Panicum rigidulum var. elongatum, Carex crinita, Apios americana, Typha latifolia,* and *Impatiens capensis*" (NatureServe 2017).

2.5.4 Oklahoma Alder

The Oklahoma populations occur in riparian areas of the Cross Timbers Ecoregion. The Cross Timbers consist of oak-hickory woodland savanna and native tallgrass prairie. Cross Timbers forests and savannas occur on deep, coarse-textured soils derived from sandstone, whereas fine-textured soils derived from shale and limestone support woodland and grassland vegetation. As stated above the seaside alder needs sunlight, inundated soils and good water quality. The Oklahoma alder's natural occurrence is almost exclusively inundated soils (Kratsch and Graves 2005, p. 775). Oklahoma alders grow in inundated soils on stable portions of the floodplains between bank-full and flood-prone elevations along the edge of, and on islands within, rivers and streams where sunlight is readily available (figure 17; Gibson *et al*. 2008, p. 589; Gibson and Jones 2012, p. 6). Due to less nutrient-enrichment, much of the watershed supports plants that have low nutrient requirements or have adaptations to gain access to nutrients *(i.e.* nodules).

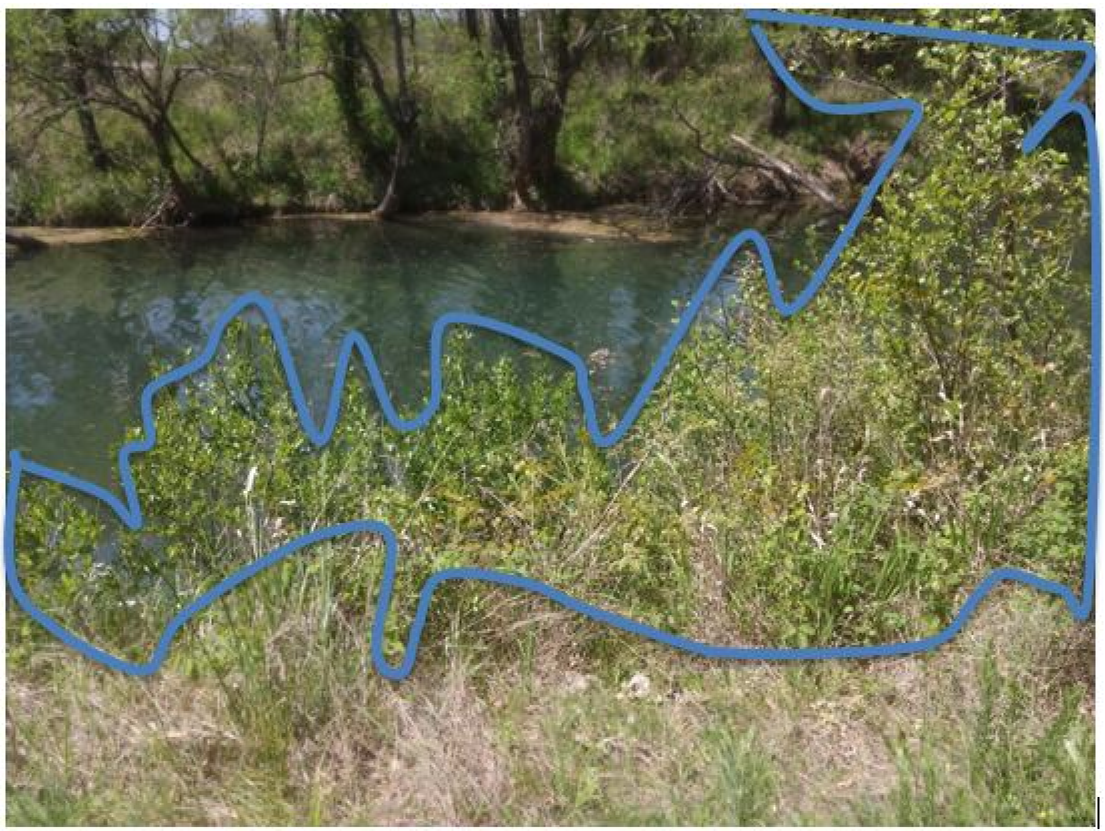


Figure 17. Oklahoma alder (outlined in blue) found along the Blue River in Oklahoma.

The majority of the streams are steep with bedrock substrates because the topography of the area is steep and the soils are shallow. The streams alternate as a gravel/cobble/bedrock/sand system as it passes through the Arbuckle Uplift, but the lower reaches of the watershed become influenced by silt. The streams and rivers where the Oklahoma alder occurs are spring-fed from the Arbuckle-Simpson Aquifer (see below). The water is a calcium bicarbonate type and commonly is hard (Ryder 1996, p. 26). Water clarity is typically good to excellent throughout the watershed (Oklahoma Water Resources Board (OWRB) 2012, p. 40).

Though some studies show that the seaside alder does not need inundated soils to survive, the Oklahoma alder naturally occurs in hydric soils on river and stream banks above the Arbuckle-Simpson Aquifer. The main driving factor for stream flow creating hydric soils is the spring flow from the Arbuckle-Simpson Aquifer. This area is unique because the base flow of these rivers and streams are primarily spring fed. Spring water is available during drought eras, keeping the soils wet for the Oklahoma alder (Tejan and Haase 2008, p. 54).

Arbuckle-Simpson Aquifer

As stated above, the Oklahoma alder occurs along streams and rivers. These streams and rivers along which the Oklahoma alder are found are dependent on spring discharge from the Arbuckle-Simpson aquifer (figure 18). The Arbuckle-Simpson aquifer is up to approximately 9,000 ft (2,743 m) thick and consists of limestone, dolomite, and sandstone. Its high permeability is the result of the enlargement of fractures, joints, and solution channels by partial separation of the rocks. Freshwater may extend to depths of greater than 3,000 ft (914 m).

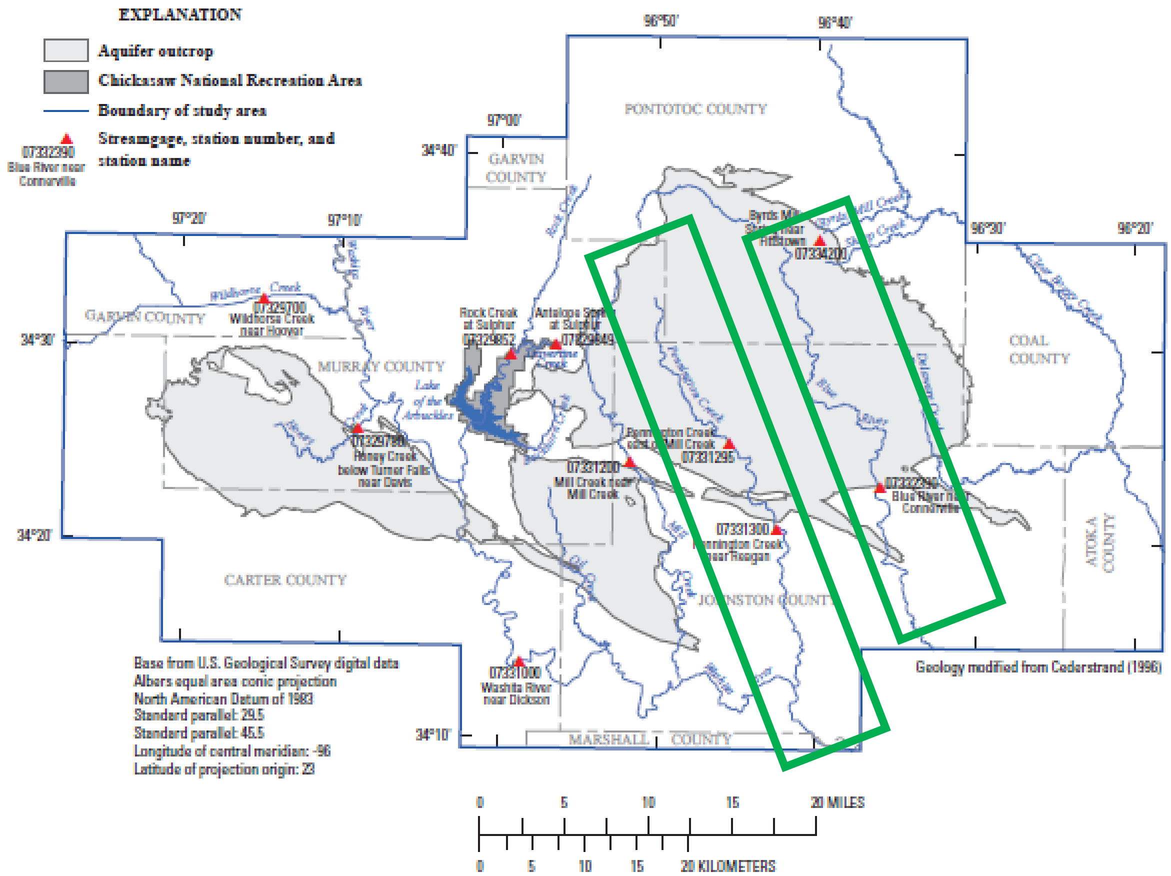


Figure 18. Arbuckle-Simpson aquifer boundary (light blue), streams (dark blue), and stream gages (red triangles). The primary streams are Pennington Creek and Blue River (green boxes). (Christenson *et al.* 2011, p. 31).

Although recharge can be the result of many different processes, the dominant recharge process for the Arbuckle-Simpson aquifer is through precipitation (Christenson *et al.* 2011, p. 32). Precipitation falling on the land surface infiltrates through soil. Some of the soil moisture is evaporated or transpired by plants back to the atmosphere and some continues moving downward through the unsaturated soil zone to recharge groundwater in the aquifer. Studies indicate that streams rely on discharge from the Arbuckle-Simpson aquifer has small ranges of variability during low flow events year round. Stream gauge data from 2003−2008 indicate that streams never went dry, even in the most extreme droughts. Base flows were highest in the winter (January through June) and lowest in the summer (August through October) (Tejan and Haase 2008, p. 75). Streamflow influences sunlight availability (by removing competing vegetation along stream banks) and soil moisture (a wide, slow streamflow will have more areas of saturated soils than do fast, deep streamflows), thus has an influence on the areas in which Oklahoma alder will establish, grow, survive droughts, and persist (Schrader and Graves 2000, p. 77; Kratsch and Graves 2005 p.688; Tejan and Haas 2008, p. 54).

The amount of precipitation that recharges the Arbuckle-Simpson aquifer depends on many factors, such as the amount of water stored in the unsaturated soil zone, the slope of the land surface, the type of rocks and soils that form an aquifer, the type of vegetation and land use overlying the aquifer, and the intensity, season, and duration of precipitation (Christenson *et al.* 2011, p. 40). The estimated recharge rate of the Arbuckle-Simpson Aquifer is 4.7 inches (in) (0.39 ac ft (481 cubic meter (m^3)) per year.

Water in the aquifer is discharged naturally from numerous freshwater and mineral springs that occur on the streams and rivers in which Oklahoma alder inhabit. Flow in these streams and rivers are dependent primarily on groundwater from the aquifer. There are 140 small springs that feed rivers from the Arbuckle-Simpson Aquifer. Much of this discharge becomes the base flow of streams (Ryder 1996, p. 5). Springs that issue from the aquifer discharge from 50 to 18,000 gal/min (0.11 to 40.1 cubic feet per second (CFS)) (Ryder 1996, p. 5).

2.6 "Population" Needs

Resiliency

For "populations" (i.e., analysis units) of seaside alder to be resilient, abundance should be large enough, with multiple groupings distributed throughout each population so that local stochastic events do not eliminate all individuals, allowing the overall population to recover from any one event. A larger number of individuals provides a greater chance that a portion of the population will survive. The health of "populations" is generally contingent upon recruitment (an increase in a natural population as progeny grow and immigrants arrive). Resilient seaside alder populations must produce and disperse seeds, establish seedlings that survive, and maintain mature reproductive individuals in the population. The seaside alder exhibits both sexual and asexual reproduction, but seedlings are rare.

Sexual reproduction increases genetic diversity, reduces the effects of deleterious recessive mutations, and provides the genetic diversity that is the primary basis for selection and adaptation in the face of environmental variation or uncertainty. However, sexual reproduction can result in a loss of adaptive combinations of genes, reducing the contribution of an individual's genes to the next generation. Asexual reproduction occurs in the form of resprouting from stumps, suckers, and possibly layering.

2.7 Species Needs

Representation

Genetic diversity provides needed variation for adaptation to changing conditions. Woody plants that frequently reproduce asexually through suckers or layering and producing clones could be at greater risk of losing genetic diversity. However, the tendency for a plant species to clone does not generally result in a monotypic stand of one genotype; in fact, hundreds of studied species were found to have multiple clones of different genotypes (Ellstrand and Roose 1987, p. 127; Silverton 2008, entire).

Redundancy

Multiple occurrences of the seaside alder reduces the risk that all occurrences will be affected by catastrophic events. The number, distribution, and resiliency of the subspecies and their subpopulations increases the probability that the species has a margin of safety to withstand or bounce back from catastrophic events (e.g., fire).

Chapter 3. FACTORS INFLUENCING VIABILITY

3.1 Seaside Alder

Based on the seaside alder's life history and habitat and ecological needs (sections 2.5, 2.6, and 2.7 above), we identified the potential negative and positive influences and the contributing sources of those influences that are likely to affect the species' viability. We start with an influence diagram (figure 19) for the species' as a whole and then discuss the specific issues most affecting each of the subspecies.

As stated above, sufficient quantities of full sun, good water quality, and hydric soils are important to support the seaside alder's resiliency, redundancy, and representation.

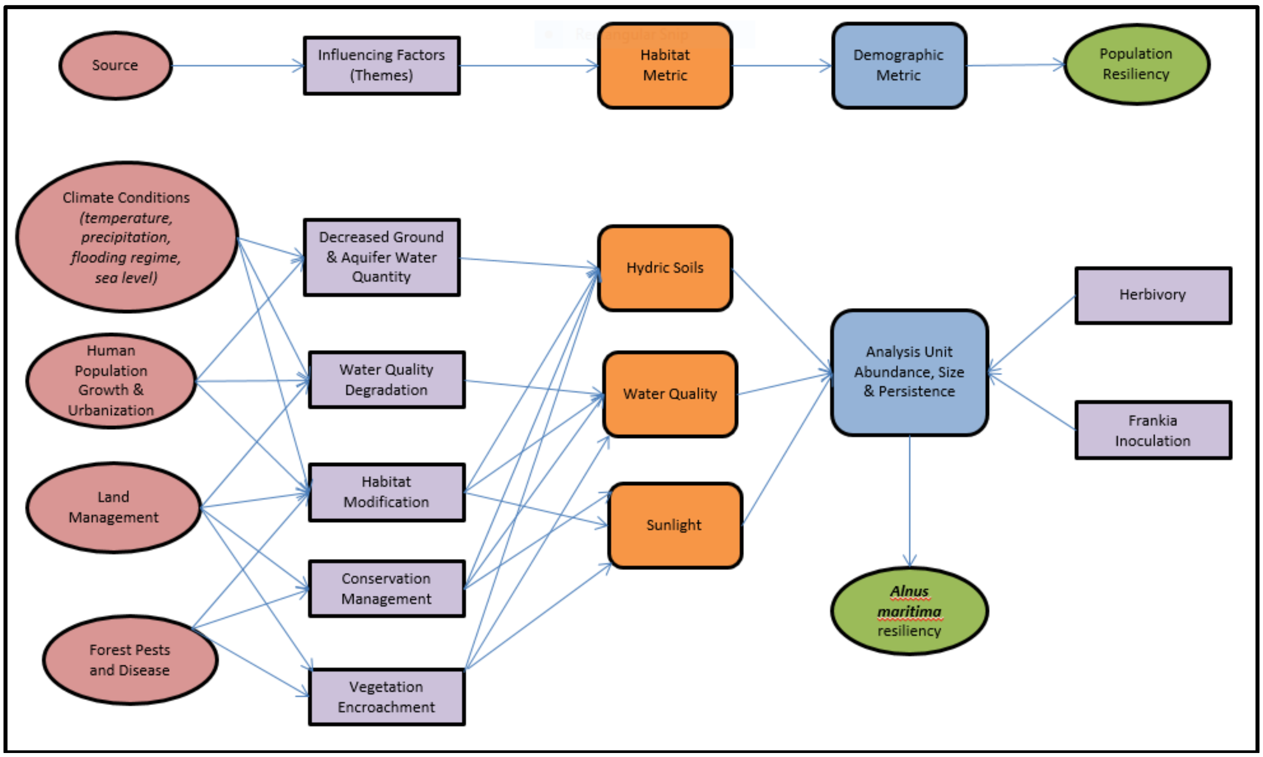


Figure 19. Influence diagram for the seaside alder.

There are two influences that equally affect all three of the subspecies: *Frankia* and the sexual and asexual reproductive strategies. See section **2.4—Life History** for the discussion on Reproductive Strategies.

3.1.2 Frankia Inoculation:

Experiments in the lab indicate seaside alder has the highest levels of Frankia nodules when grown in low nitrogen soils, and nodule growth will adjust to changing levels of nitrogen in the soil (Law and Graves 2005 entire). Frankia nodules are also able to occur and persist even when seedlings are grown in flooded soils where oxygen is low, though nodules grow differently to increase access to oxygen (Kratsch and Graves 2004, entire).

There is no suggestion from the current literature that the presence of Frankia bacteria in the soils is limiting, and it has been observed to be transported by birds (Pashke and Dawson 1993, entire). There is ongoing research into the relationship between Frankia and seedling growth (Gibson 2018a), but at this time, there is no data to suggest that the relative abundance or lack of Frankia in the soil is or will become a stressor to seaside alder.

3.2 Delmarva Alder

The influence diagram below (figure 20) illustrates the environmental factors that can improve or diminish the resiliency of Delmarva alder. These influences primarily work on the plant or its habitat (marsh habitat along the edge or fringes of tidal rivers) through the key environmental requirements of water quality (i.e., for this subspecies, freshwater), periodically saturated soils and full sun. The influence is mediated by the seaside alder's life history and adaptability to the range of habitat conditions. The three influences that have the largest effect are discussed below.

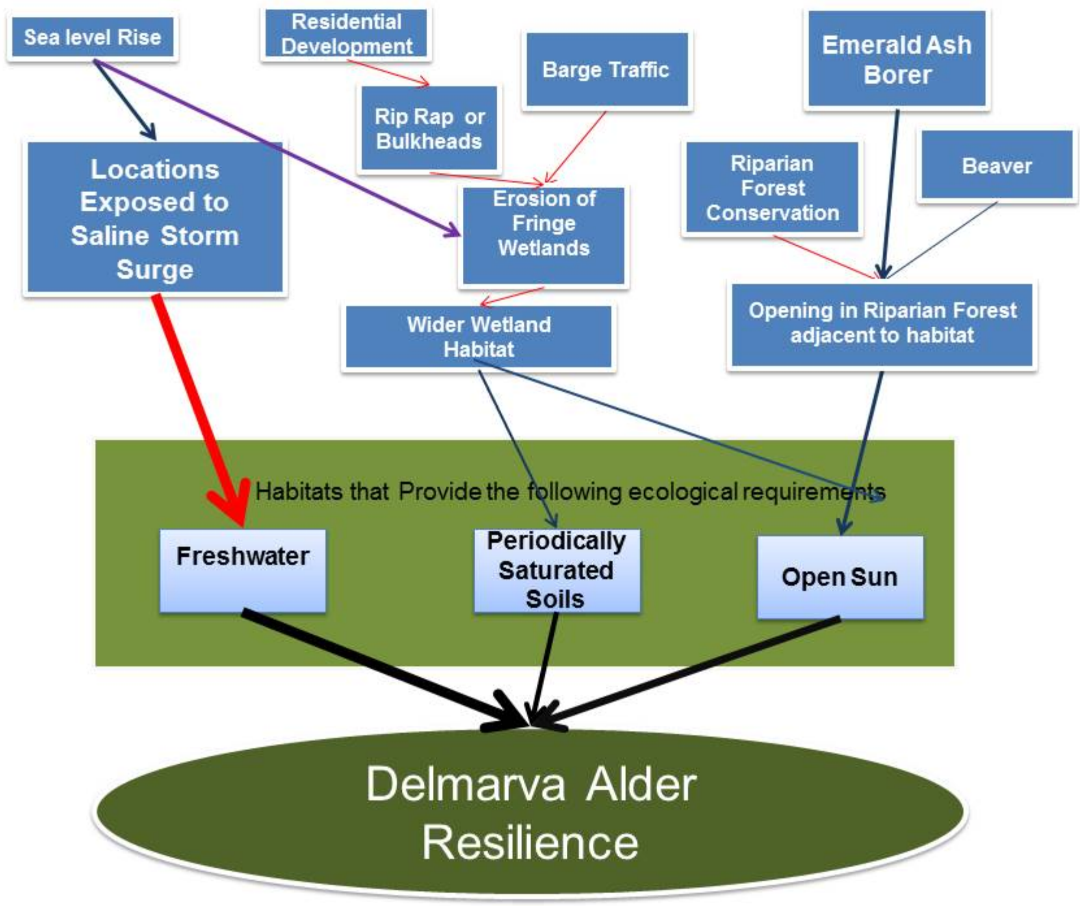


Figure 20. Environmental factors that influence the resiliency of Delmarva alder. Red arrows indicate negative influence, blue arrows indicate positive influence, and purple arrows indicate influences that could be positive or negative. Wider arrows reflect larger relative influence; narrow arrows reflect smaller relative influence.

3.2.1 Sea level rise and exposure to saline storm surges

The largest influence on the Delmarva alder is the presence of salinity, which affects the plant's need for good water quality (i.e., freshwater). The current distribution of this plant is a product of past hurricanes and associated storm surges of saline water that have occurred over the past several hundred years. This factor has had visible influences on its distribution in the past and its effect on individual plants is well documented (Graves and Gallagher 2003, entire). The distribution of Delmarva alder on the Delmarva Peninsula is primarily along rivers in the inland portions of the Peninsula and is often limited along the Atlantic coast to areas behind dams (or roads acting like dams) that both create some open habitat through flooding but also protects the site from the upstream pulse of saltwater that would occur during storm surges from the Atlantic. In fact, Stibolt (1981) noted that the Delmarva alder is more prevalent in ponds in Delaware. Distance to the Atlantic coast can often be misleading if an occupied site is protected by dams or roads.

The Delmarva Peninsula is a low lying landform, and increases in the relative sea levels of the Chesapeake Bay and Atlantic Ocean can potentially increase the "reach" of storm surge because sea water is more proximate. However, wind, rain, bathymetry (the depths and shapes of underwater terrain (NOAA 2018)) and other factors can still have a very strong influence on the reach of saline storm waters. Sites along the Atlantic and Delaware Bay coasts are most vulnerable because the Atlantic coast water has higher salinity than the Chesapeake Bay, an estuary highly influenced by the freshwater inputs of rivers (Chesapeake Bay Program 2017).

Rates of sea level rise in the past have included the combined forces of land subsidence and sea level rise and this has been evident on the Delmarva Peninsula for the past 100 years, especially in the lower portions of the Delmarva Peninsula where elevations are low (Kearney *et al*. 1988, p. 205; Glick *et al*. 2008, pp. 2–18). Historically, these forces combined to produce a relative sea level rise in the Chesapeake Bay region of 3.21 to 3.52 millimeter (mm)/year (yr) (average of 3.4 mm/yr) or approximately 1 ft/100 yrs in the Chesapeake Bay region (NOAA 2006). Rates of sea level rise are anticipated to increase in the future.

A clear example of this influence on Delmarva alder became very apparent in October of 2012 when storm surge from Hurricane Sandy came onshore. Saline waters from the storm surge caused extirpation of the Delmarva alder from one marsh pond, Turkle Pond, at Prime Hook National Wildlife Refuge (NWR) and caused some stress to plants in Fleetwood Pond that was better protected from the surge. These are true ponds or depressions in marshy areas, not located behind impounding dams. There were other areas where the storm surge could have reached Delmarva alder populations, but the dams, or roads that were acting like dams, prevented the saline waters from entering the pond (e.g., Millsboro Pond, Delaware). These impoundments benefit this plant by providing a barrier to saline storm surges and may be why the subspecies' distribution closer to the coast in Delaware is in impounded areas.

The frequency of flooding from saline storm surge is likely to increase in the future because as sea levels rise, saline storm surges will reach further inland. Ezer and Atkinson (2014; entire) document that the hours of flooding above mean high tide in Norfolk (mouth of the Chesapeake Bay) and Lewes Delaware have increased between 1940 and 2010 and this flooding is most often a result of smaller storms rather than hurricanes. Tebaldi *et al.* (2012; p. 6) find that flooding from extreme water levels is likely to be increased by sea level rise but the salinity of this water depends on the influence of river flows down the estuary as well.

Vulnerability to saline storm surge is important to individual survival and population resiliency of Delmarva alder. Consequently, we analyzed this stressor in our assessment.

3.2.2 Riparian Forest Conservation

Other influences that can also affect this plant, but to a much smaller extent include factors that affect the amount of forest canopy and, thus, the amount of sun near Delmarva alder. In general, the streams and rivers where Delmarva alder occur are forested in the upland edges. This is from natural succession and specific efforts to maintain forested buffers along streams to protect water quality; including laws that require maintenance of forest buffers like the Maryland Critical Area law (MDDNR 1984). Some changes in the past extent of forest riparian buffers included historical logging for Atlantic white cedar (*Chamaecyparis thyoides*) or bald cypress (*Taxodium distichum*) in the areas where streams were impounded for hydro-power to run sawmills (e.g., Trap Pond, DE). Both the logging and the impoundment likely created more open sun for the Delmarva alder. However, timber harvest is currently limited in the riparian forest because it is generally too wet for equipment and harvests are not permitted within 50 ft (15 m) of streams (MD Sediment and Erosion Control Program). While individual Delmarva alders may be affected, this is not an influence that is affecting the subspecies as a whole. Therefore, we did not analyze this in our assessment.

3.2.3 Emerald Ash Borer

In 2002, the Asian emerald ash borer (*Agrilus planipennis*) was discovered in Michigan attacking ash trees. This invasive beetle is about 10 mm (0.4 in) long; and adult females lay their eggs in the crevices of bark and the larva feed on the phloem of the tree (Poland and McCullough 2006, entire). The emerald ash borer affects ash trees and symptoms include canopy dieback, beginning in top one-third of canopy, and progressing until the tree is bare. All species of North American ash trees appear to be susceptible to this insect pest (Herms and McCullough 2014, entire). Ash trees are common in the riparian forests of the Delmarva Peninsula. Loss of ash trees in areas where the Delmarva alder occurs will open up more light to adjacent marshes. This pest has already arrived in the counties occupied by Delmarva alder and we anticipate some affects in some areas. However, there is uncertainty in how long the beneficial effect may last as other species of trees may fill in the openings left by ash trees. Maryland foresters are currently attempting control of this pest using the introduction of parasitoid wasps (Maryland Department of Agriculture 2017). While locations of some individual Delmarva alders may be affected, this is not an influence that is affecting the subspecies as a whole. Therefore, we did not analyze this in our assessment.

3.2.4 Erosion of Fringe Wetlands

Many of the locations where Delmarva alder is most abundant are emergent marshes along the edges of large tidal rivers such as the Nanticoke River and its tributaries (i.e., wide fringe wetlands). Large banks of Delmarva alder form on the “slow” side of the bends in the river where sediment is deposited. These areas support large populations of Delmarva alder in a setting where saline waters are not likely to occur. Consequently, erosion of these areas impacts the Delmarva alder. We considered two factors that might influence these areas through erosion of sediments; boat traffic, both commercial barges and recreational boats, and hardening (i.e., rip rap) of the shoreline by residents protecting shoreline from erosion.

Natural erosion can be exacerbated by the wakes of commercial barge and recreational boat traffic (Bauer *et al*. 2002, entire) because the waves created by the wakes pound against riverbanks, thus potentially accelerating both the volume of soil removed and the amount of time it would naturally take for the soil to be moved. Conversely, erosion or sediment loads from upstream areas can deposit silts in downstream areas that increase the width of the emergent marsh occupied by Delmarva alder.

Barge traffic can be documented as occurring in 1909, 1949, 1999, and is currently ongoing (U.S. Army Corps of Engineers (USCOE) 1950; Fauk *et al*. 1997; Keller 2017). The Nanticoke has been periodically dredged to maintain the channel for commercial vessels. Trends are not clear on whether barge traffic is increasing or decreasing but in 1996 there were 50 round trips between May and September (Faulk *et al*. 1997, p. 41). It is possible that the size and speed of barges has increased over time and thus the size of wakes, number of groundings, and potential for erosion of riverine banks and marshes may have increased. However, comparisons of aerial imagery between 1999 and 2017 showed very little change in the widths of the marsh, river or creeks. It is possible that the location of Delmarva alder on the inside or "slow" side of the curves of the river make it less susceptible to these wakes and it is also possible that erosion from other areas upstream are deposited in Delmarva alder habitat downstream. Currently, we do not consider boat traffic to have a clear influence on Delmarva alder nor does it appear that this will influence it in the future.

Residential development along rivers often leads to bank stabilization or hardening of the shoreline through rip rap (large rock) or bulkheads (wooden walls). These "hard stabilizations" cause increased erosion in adjacent portions of the shoreline and eliminate the potential for seaside alder wetlands. However, riverine fringe wetlands general occur where erosion is negligible and where sediment is being deposited, and thus the risk of erosion is low. The main stem of the Nanticoke and Marshyhope Rivers where Delmarva alder is most abundant has very little hard shoreline, very little residential development, and the opportunities for future development are not likely as much of these areas are federally or State owned or owned by conservation organizations such as The Nature Conservancy (TNC). For example, the Marshyhope HUC has 43 percent of the 0.5 mi (0.8 km) buffer surrounding the river protected from development through ownership by public entities or conservation organizations. Shoreline erosion or hardening is not currently or in the future viewed as a strong influence on Delmarva Alder populations, though a few individuals may be impacted in some areas (e.g., Broad Creek). Consequently, we are not considering this in our analysis.

Summary of factors influencing the Delmarva alder: The best available information suggests that the influence of saline storm surges nearer the coast is considered to have had the largest influence on the Delmarva alder in the past, and is likely to have additional influence in the future. The other influences discussed above (riparian forest conservation, emerald ash borer, and erosion of fringe wetlands) do not appear to significantly influence the Delmarva alder at the subspecies level, currently, or likely in the future.

3.3 Georgia Alder

Based on the Georgia alder's life history and habitat needs discussed previously and after consultation with the species experts (Moffett and Pattavina 2017), we identified the potential stressors (negative influences) and the contributing sources of those stressors, as well as conservation actions, that are likely to affect the subspecies' current condition and viability (figure 21).

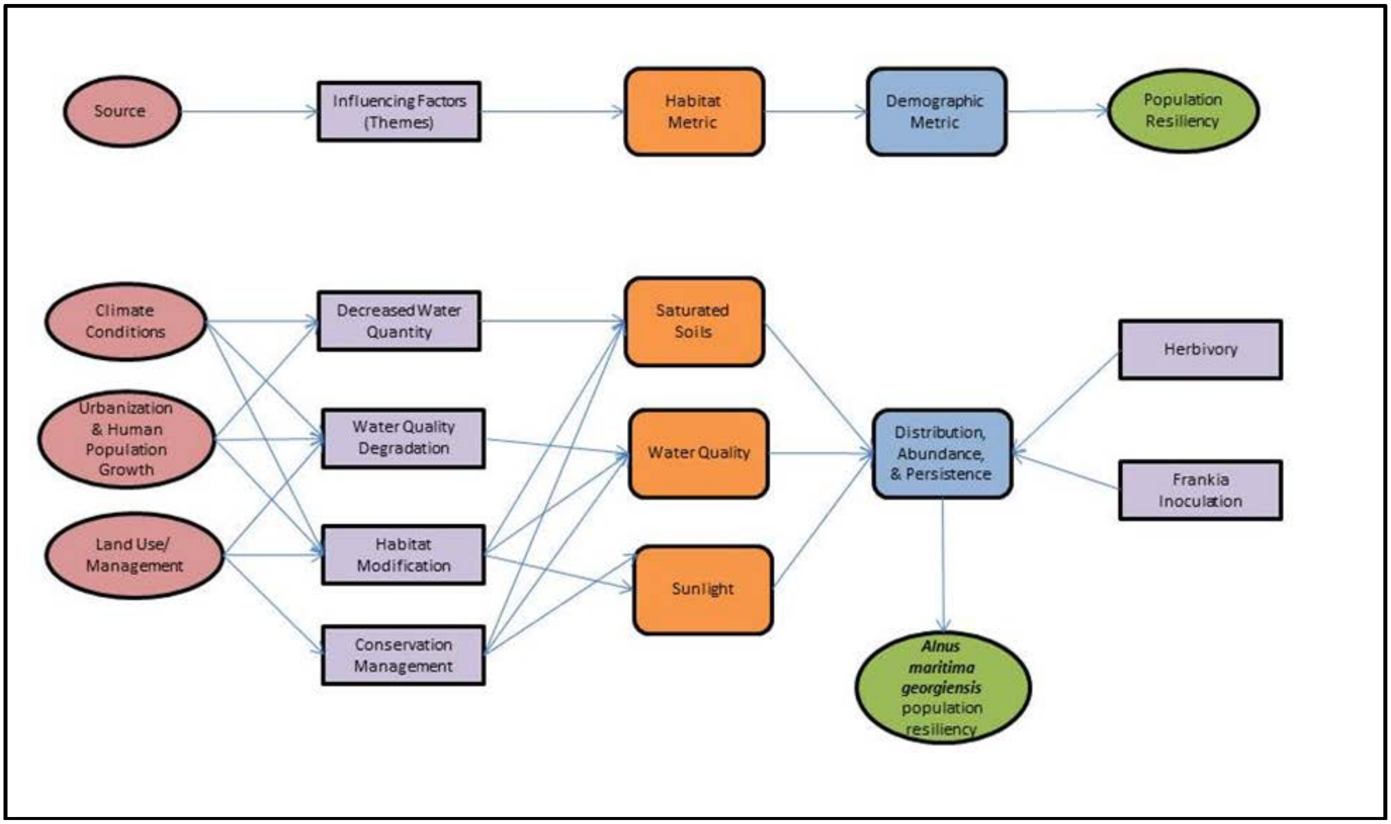


Figure 21. Georgia alder influence diagram.

3.3.1 Urbanization and Human Population Growth

Urbanization refers to a change in land cover and land use from forests or agriculture to increased density of residential and commercial infrastructure. In the Southeast United States, the amount of urban land is projected to increase by 101 percent to 192 percent, with the largest change in the Piedmont ecoregion which includes Atlanta, Georgia (Teranado *et al.* 2014, p. 5). Atlanta is the largest and fastest growing southeastern city with a population of more than a million people (Kundell and Myszewkis 2017). The Georgia alder population is located about 40 mi (64 km) northeast of Atlanta in Bartow County, which is part of the 15-county metro Atlanta area. Due to the close proximity to Atlanta, we consider the potential effects urbanization may have on the Georgia alder. A major feature of urbanized areas is an overall increase in impervious surfaces. Impervious surfaces can be defined as hard surfaces that preclude water infiltration such as paved roads, parking lots, roofs, and highly compacted soils

(O'Driscoll *et al*. 2010, p. 606). Consequently water quantity and quality are impacted as described below (Sun and Lockaby 2012, entire).

Water Quantity (Groundwater Availability)

The Georgia alder population is supported by a spring-fed freshwater wetland where there is an upwelling of groundwater from the Ridge and Valley Paleozoic-Rock Aquifer. Therefore, high spring-flow that provides hydric conditions is an essential habitat need for this population to remain resilient. The karst geology of this region (see section 2.5.3) creates a complex hydrologic environment and the impacts of urbanization on hydrology are not well understood. Generally, urbanization can impact groundwater quantity by changing recharge and discharge dynamics and can lead to overexploitation (direct groundwater withdrawal or pumping) (O'Driscoll *et al*. 2010, p. 617). All of these have been documented in southern U.S., and may have some direct (lowering water table or decreasing spring-flow) or indirect effect on the Georgia alder. Although not documented for the Drummond Swamp watershed, relationships between impervious surface cover and changes in plant density and reduced native plant species richness as a result in changes in water levels, have been documented in some watersheds (Center for Watershed Protection (CWP) 2003, p. 114). Shifts in water level could influence plant species competition and composition such that Georgia alder is negatively impacted.

<u>Impervious Surfaces</u>: Decreased groundwater recharge is the most commonly cited cause for lowered stream base flow in urban streams, especially during dry periods, as a result of increased impervious surfaces (CWP 2003, entire; O'Driscoll *et al*. 2010, p. 615). However, recharge from impervious surfaces may contribute to localized groundwater recharge through the routing of water toward pervious areas or fractures (O'Driscoll *et al*. 2010, p. 615). Natural vegetation within watersheds, especially forests, can be removed and fragmented and replaced by impervious surfaces which alter evapotranspiration and infiltration of water into the ground. Direct destruction or alteration of streams and wetlands, including alteration of spring heads, can further alter recharge and discharge dynamics. As urbanization continues to expand around Atlanta and other nearby cities and towns, impervious surfaces are likely to increase in the region with potential effects on the recharge and discharge dynamics of the Ridge and Valley Paleozoic-Rock Aquifer and the groundwater availability or spring-flow at Drummond Swamp.

<u>Overexploitation</u>: The increasing urbanization rate is a result of increasing human population growth, which results in both residential and commercial development. Bartow County is one of 15 counties within the Atlanta Metropolitan North Georgia Water Planning District (District) (figure 22, below). The 15 counties within the District have experienced continued growth with a current population of over 5 million people and a projected population growth between 7.8 and 8.3 million by 2050 (Georgia Office of Planning and Budget (GOPB) 2015, entire, Water Resources Management Plan (WRMP) 2017, pp. 35, 67). The District relies primarily on surface water from rivers and storage reservoirs as its main source of permitted water supply. Groundwater sources, used by small towns and as a supplemental water sources, account for less than 1 percent of the total permitted public water supply in the District. Self-supplied wells, including residential and commercial such as sod farms (Sills and Phillips 2018), are also used in the region but are not required to obtain a permit if their usage is below 100,000 gallons per day (378,541 liters/day).

The primary source (90 percent) of potable water for Bartow County is surface water from Lake Allatoona (Sills and Phillips 2018) located in southeastern Bartow County within the Etowah River Basin and overlies, in part, the Ridge and Valley Paleozoic Rock Aquifer. Industrial development in the city of Cartersville is one of the largest users of this surface water in Bartow County (WRMP) 2017, p. 76). Currently, there are three permitted groundwater withdrawals for public water supply in Bartow County (Cities of Emerson, Kingston and White, see figure 22, below) (WRMP 2017, p. 40). In 2010, an assessment of the availability of groundwater resources was completed as part of Georgia's Comprehensive Statewide Water Management Plan. Portions of Bartow County were included in this study and it was found that the Ridge and Valley Paleozoic Rock Aquifer could provide a potential sustainable yield ranging from 27 to 70 million gallons per day (102 to 265 million liters/day) (Etowah River Basin Profile (ERBP) 2017, p. 4). Ground-water pumping is the most significant human activity that affects the amount of groundwater in storage and the rate of discharge from an aquifer (USGS 2006, p. 2). However, withdrawal of water from streams (or surface water withdrawals) can also deplete groundwater (Winter *et al*. 1998, p. 3). As human population and urbanization increases, groundwater and surface water withdrawals are expected to increase to meet water needs in the future. Water conservation measures, such as enhanced efficiency standards (WRMP 2017, p. 133), may help mitigate increasing withdrawals to some degree but may not offset water demand during droughts and low flow periods. The water use in the Etowah River Basin (as part of the Alabama-Coosa-Tallapoosa (ACT) River Basin) has been one of the subjects of a decades-long water use dispute between Alabama and Georgia that was spurred by droughts and low flows, but agreements or settlements are still pending regarding any limits on amount of water communities in Georgia can consume from the Coosa Basin (SELC 2018). Increasing water withdrawals to support a growing population, including new self-supplied wells that do not require a permit, will likely influence water availability throughout the region.

The geohydrology of the Ridge and Valley Paleozoic Rock Aquifer, especially near Drummond Swamp (see section 2.6.2), creates the possibility of conditions that could lead to land subsidence and sinkhole formation. In 2002, a 4-ac (1.6 ha) sinkhole formed just downstream from Drummond Swamp (Lesley 2002, p. 103). The cavities formed in the carbonate rocks may have "thin soil roofs" and extend below the water table. Any lowering of the water table can create rock openings from the loss of soil and result in the eventual collapse of the surface and formation of a sinkhole. Land subsidence and sinkhole formation may also occur where large quantities of sediment or rock fragments are removed from water-yielding formations during drilling, well development, and production pumping (summarized from Cressler *et. al.* 1979, p. 17–18).

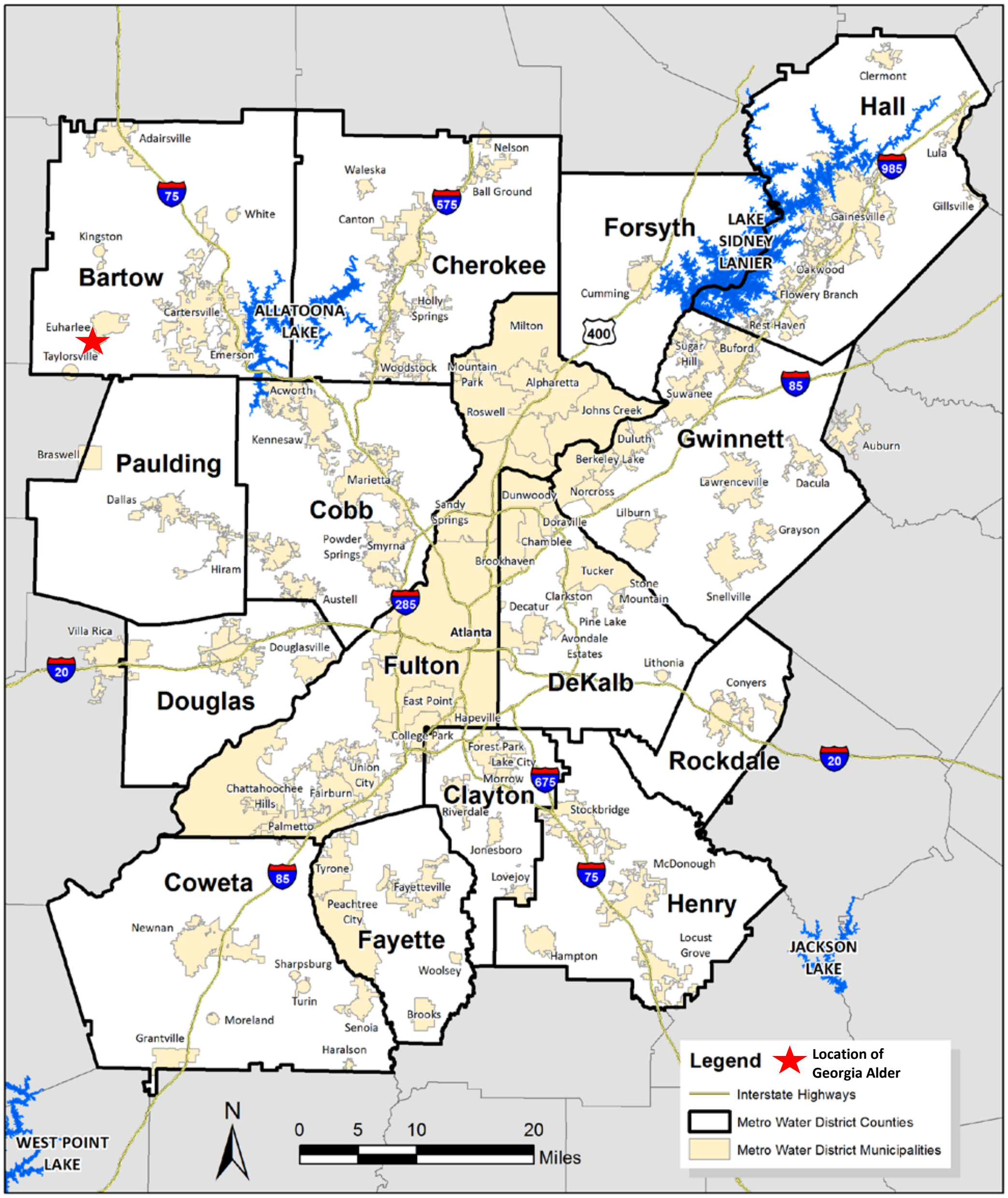


Figure 22. Metropolitan North Georgia Water Planning District with location of Georgia alder (Adapted from WRMP 2017, p. 14).

Water Quality

Urbanization can also have profound effects on water quality such as contamination (pollutants such as trace metals, hydrocarbons and pesticides), nutrient runoff and sedimentation. While rapid transport of contaminants within karst aquifers and to springs has been documented with localized to regional water quality problems (Winter *et al*. 1998, p. 51) impacts to water quality from urbanization are mostly likely to occur at the watershed level or immediately adjacent to the wetland. Most water quality indicators decline when watershed impervious cover exceeds 10 percent, with severe degradation expected beyond 25 percent (CWP 2003, p. 1). In general, while direct impacts of declining water quality on the seaside alder, other than salinity (see the Delmarva alder section above), and the Georgia alder specifically, are unknown, overall degradation of water quality conditions could affect the ecological balance of the wetland plant community. For example, pollutants could affect pH levels causing plant mortality, nutrient inputs can cause eutrophication (algal blooms) and impact plant growth and sedimentation could affect water levels.

Habitat Modification

Urbanization can change landscape conditions adversely modifying habitat conditions. Often development can cause habitat fragmentation which can disrupt gene flow (pollen dispersal) and create "edge effects." Fragmentation can increase potential for invasive plant species to disperse into native habitats. Chinese privet (*Ligustrum sinensis*), which has been observed at Drummond Swamp, is a nonnative, invasive shrub that has an extensive naturalized distribution in the southeastern United States, especially in riparian zones (Hanula *et al*. 2009, p. 292). Chinese privet can form monotypic stands that out compete native plants and require management to restore desired plant and animal communities (Hanula *et al.* 2009, p. 299). Chinese privet has been associated with urbanized and developing landscapes with negative effects on native species richness and diversity in riparian areas (Burton *et al.* 2008, p.107). While Chinese privet grows in a wide range of environmental conditions, inundated soils (or flooding) may reduce its competitive advantage (Brown and Pezeshki 2000, p. 429). Georgia alder occurs in highly saturated soils; however, if water availability decreases at Drummond Swamp Chinese privet may out-compete the Georgia alder.

Forest pests may also become more easily dispersed as development and human population increase. For example, the emerald ash borer (see the emerald ash borer discussion above under the Delmarva alder section for more details) was first documented in Georgia in 2013 and is spreading into northern parts of Georgia, often via movement of contaminated firewood or other contaminated commercial forest products. The emerald ash borer can now be found in 23 counties in Georgia, including in Bartow County (GFC 2016, entire). Green ash (*Fraxinus pennslyvanica*), a somewhat common tree species in the riparian forest adjacent to Drummond Swamp, will likely be affected by emerald ash borer. Increased occurrence of emerald ash borer could alter species composition and structure; however, it is unknown how this could impact the Georgia alder.

Another potential influence is the development of water impoundments such as those associated with road crossings and water regulation (to control flooding or provide a water source). There is currently one road crossing (Hardin Bridge Road) that has impounded Drummond Swamp. This impoundment has been present since at least 1955 (see Appendix A, figure A-1) and is believed to be mostly a positive influence similar to effects from beaver damming (see below). No new roads are planned in the immediate vicinity of Drummond Swamp (Sills and Phillips 2018). Given the close proximity of Drummond Swamp to its outflow into Euharlee Creek and the confluence with the Etowah River (figure 5, above) it is unlikely any new road crossing will be constructed that will impact Drummond Swamp. There is one new reservoir under construction in Paulding County (south of Bartow County) which will draw water from the

Etowah River and the Coosa River Basin (WRMP 2017, p. 138); however this reservoir does not overlie the Ridge and Valley Paleozoic Rock Aquifer.

Herbivory: Although not necessarily a result of urbanization, herbivory can also modify habitat conditions, herbivory of the Georgia alder from both beaver and cattle have been documented at Drummond Swamp. Cattle grazing around Drummond Swamp has been occurring since the early 1940's and Schrader and Graves (2002, p. 393) suggest that extreme herbivory may have provided a competitive advantage to Georgia alder to establish and persist in large stands. However, in recent years the wetland buffers have been allowed to regrow naturally on the properties owned by the Georgia Power Company (GPC) and cattle have been removed from these properties reducing herbivory and trampling along the wetland edges. Beaver appeared at the site sometime after the 1950's and can cut down Georgia alder and other woody species to build dams. Browsing is considered so far to be a positive influence as it increases habitat for Georgia alder and encourages re-sprouting and vegetative reproduction. There are no plans to protect plants from beaver. Georgia alder also appears to be spreading (whether sexually or vegetatively is not known) into new areas around Drummond Swamp that have recently been converted from pasture to wetland by beaver damming (Chafin 2017, p. 5). Deer have been documented to browse the Oklahoma alder (Rice 2017; Tucker 2017) and may also browse Georgia alder.

3.3.2 Land Use/Land Management

Water Quality

Agricultural practices: Nutrient runoff from adjacent cattle farms into wetlands can negatively impact water quality and may be a stressor to the Georgia alder if there is a nutrient imbalance. Eutrophication and algal blooms in Drummond Swamp have been previously observed at the Georgia alder site (Stritch 2014, p. 18; Moffett and Pattavina 2017). Schrader and Graves (2002, p. 389) reported soil nitrate concentrations at the Georgia alder site as two times higher than the alder populations in Oklahoma and Delmarva, possibly as a result of runoff from cattle pastures surrounding the site. Sedimentation from runoff can also influence habitat condition by "filling in" the wetland potentially causing an increase or decrease in available habitat. Cattle grazing and hay fields are common agricultural practices around Drummond Swamp. Reduced or negligible riparian buffers along wetland edges where agriculture occurs may contribute to increased nutrient runoff and sedimentation of the wetland (U.S. Environmental Protection Agency (EPA) 2005, entire). However, the current frequency of algal blooms related to agricultural practices adjacent to Drummond Swamp have not been documented to have a population level effect on the Georgia alder.

Coal ash deposition: Georgia Power Company's (GPC) Plant Bowen is a coal-fired power plant located east of Euharlee Creek and immediately upstream of the confluence with the Etowah River. The Plant is downstream from Drummond Swamp. Operations at Plant Bowen include burning coal, the byproducts of which principally include bottom ash, fly ash and gypsum that are sold for beneficial re-use or managed on-site (GPC 2018b). Metalloids are generally enriched in coals and can become toxic to organisms when ash from the burning of coal containing these metalloids is released into environment (Froelich and Lesley 2001, p. 1). Some plant organisms may experience negative effects on overall growth and metabolism from uptake of heavy metals (Juwarkar and Yadav 2010, p. 266). The ash and gypsum are stored on site at Plant Bowen in an ash pond and in a lined landfill. The plant is converting to dry handling of ash and constructing alternative water treatment options such that the ash pond will be closing (GPC 2018b). As part of the conversion/ash pond closure process, Plant Bowen actively monitors groundwater and ash pond dewatering to ensure procedures, safeguards and wastewater treatment measures are implemented to ensure effluent from Plant Bowen are protective of receiving waterbodies (e.g., Euharlee Creek) (Bowen 2017, p. 2). Monitoring results can be found online (Georgia Power 2018). Since the plant operations are downstream of the swamp and winds are primarily west to east, Plant Bowen presents no appreciable risk to Drummond Swamp.

3.3.3 Climate Conditions

Precipitation, Temperature, and Drought

The average annual precipitation for Bartow County is 4.4 in (11 cm) per month. Average annual temperatures range from a maximum of 71 to 73°F (21.6°C to 22.7°C) and a minimum of 47 to 49°F (8.3°C to 9.4°C). Long term droughts (3 years or more) have occurred on average once about every 40 years.

Drought is a normal component of the southeastern United States and many of Georgia's native ecosystems depend on drought for health and survival. A summary of historical drought in Georgia (Stooksbury 2003, pp. 1-2) reveals that Georgia has experienced major long-term droughts (3 or more years) eight times since 1680 and these droughts occurred about once every 40 years and droughts of two or more years occurred on average about every 25 years. However, post 2002 data show drought frequency may be increasing. Georgia and the Etowah River Basin have experienced more frequent (much less than 40 years) long-term droughts (3 or more years). After the 1998-2002 drought, another long-term drought occurred four years later in 2006-2009 and then again two years later in 2011-2013 (figure 23). The potential for wildfires increase during periods of drought. Wildfire has not been documented at Drummond Swamp, although prescribed fire has been applied to control Chinese privet. Little is known regarding the effects of fire on Georgia alder, however, catastrophic wildfire could negatively impact the Georgia alder population.

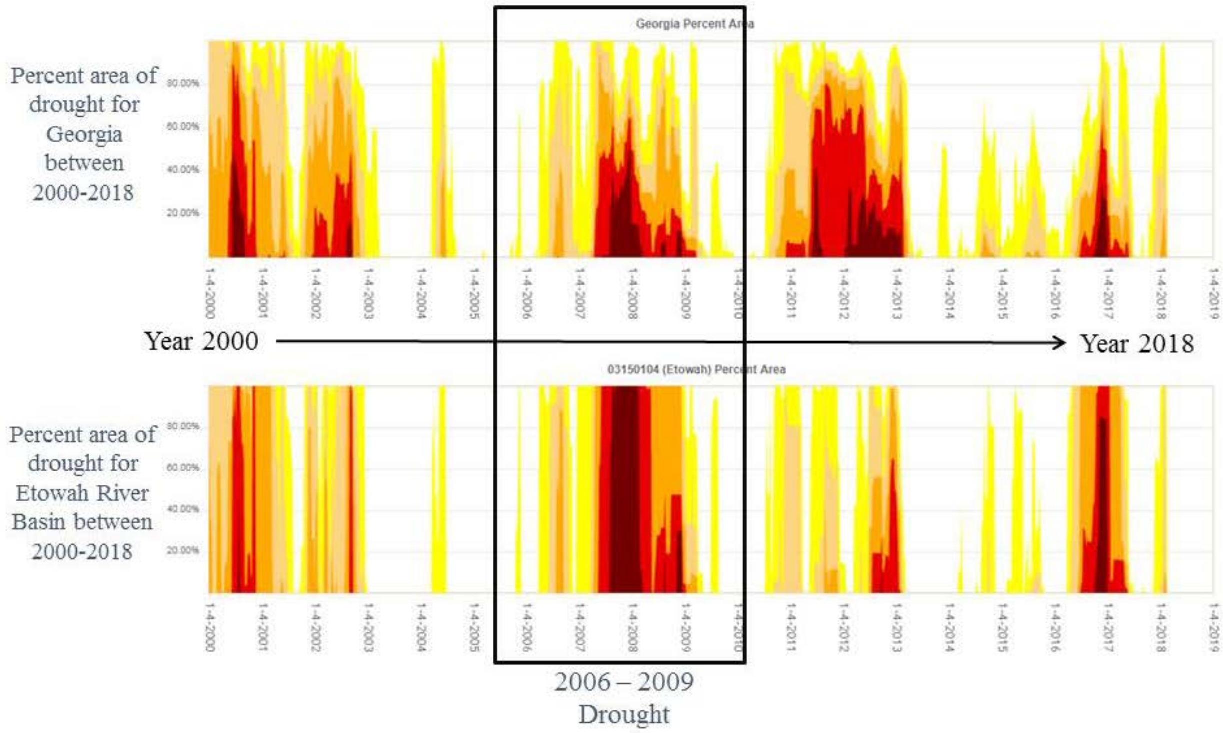
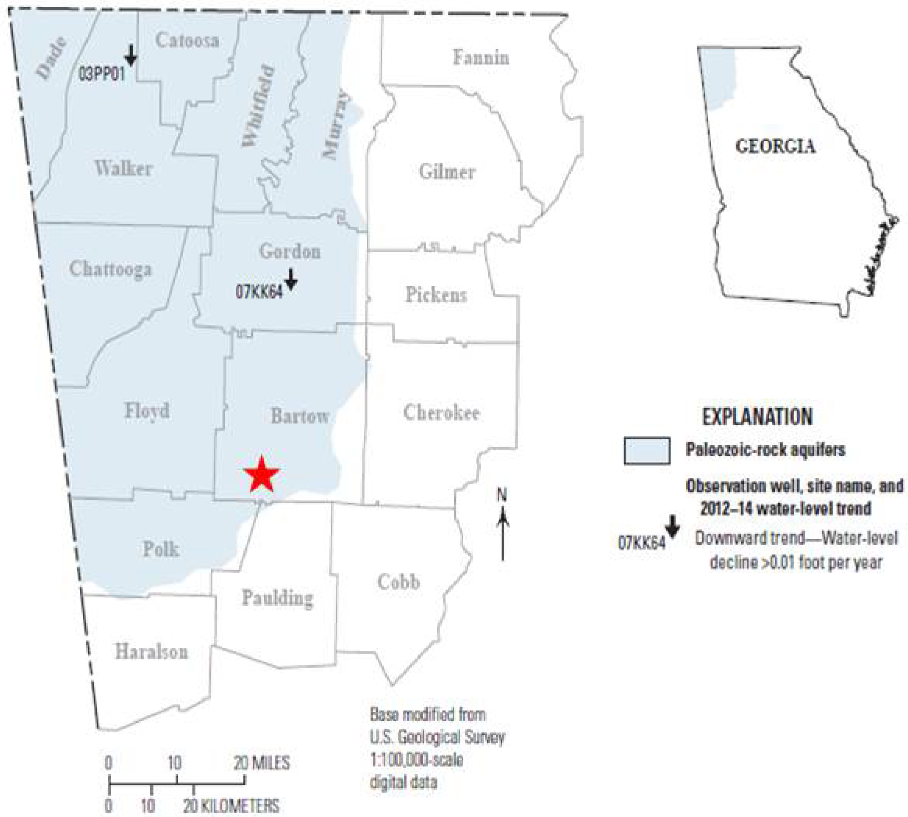


Figure 23. Percent area of historical drought in Georgia (top) and within the Etowah River Basin (bottom) from the years 2000 to 2018. Figure adapted from the United States Drought Monitor (NDMC 2018).

The U.S. Geological Survey collects groundwater data and conducts studies to monitor hydrologic conditions, better define groundwater resources, and address problems related to water supply, water use, and water quality. In Georgia, water levels were monitored continuously in over 170 wells during 2012-2014 (Peck and Painter 2016, p. 1). Monitoring included two wells in the Ridge and Valley Paleozoic Rock Aquifer, the source of ground water at Drummond Swamp (figure 24). In this area, the Ridge and Valley Paleozoic Rock Aquifer is unconfined and shows a pronounced response to precipitation. Hydrographs for the two wells illustrate monthly mean water levels for the monitoring period of record showing periodic upward or downward trends that reflect changes in precipitation and pumping (figure 25). The drought during 2006-2009 is particularly apparent in the Gordon County well (07KK64) hydrograph which is nearest Drummond Swamp. During the monitoring period of record, the water level in the well in Gordon County (07KK64) declined 0.02 ft per year (ft/yr) (0.6 centimeter (cm)/yr) because of pumping from a nearby public-supply well. Conversely, the water level in the well in Walker County (03PP01) increased during the monitoring period of record rising 0.03 ft/yr (0.9 cm/yr). During 2012–2014, water levels in both wells declined at rates of 0.32 to 0.35 ft/yr (9.6 cm/yr to 10.7 cm) (figure 24). These differences relate to variations in local pumping and climatic conditions.



Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2012 to 2014
07KK64	Gordon	1997	–0.02	–0.35
03PP01	Walker	1977	0.03	–0.32

Figure 24. Adapted from USGS Ground Water Conditions in Georgia, 2012-2014 (Peck and Painter 2016). Star represents approximate location of Drummond Swamp.

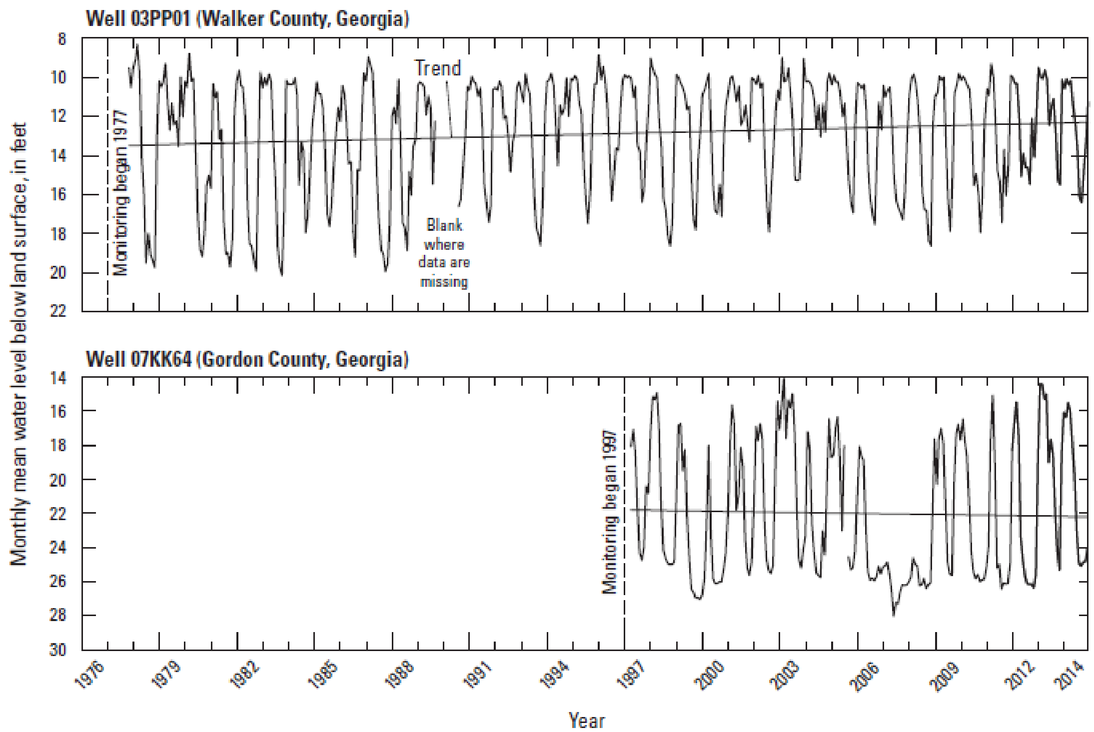


Figure 25. Hydrographs of the Gordon County and Walker County wells adapted from USGS Ground Water Conditions in Georgia, 2012-2014 (Peck and Painter 2016).

Hydric or saturated soils is an important habitat need for all the subspecies of seaside alder to be resilient. The Drummond Swamp site is a very wet forested-shrub marsh, or swamp, and has persisted through long geologic time periods due to the upwelling of groundwater from the aquifer. However, when compared to the other two subspecies, some Georgia alder were growing further above the water table, and were in less shade. The Georgia alder also received a greater amount of annual precipitation than did the other two areas. The greater annual precipitation in the Georgia provenance may be one reason why trees of Georgia alder grow further above the water table than do trees from the other two subspecies. The greater soil moisture provided by precipitation may help offset the need for trees in Georgia to be as closely associated with saturated soils as are the other two subspecies (Schrader and Graves 2002, p. 393). Therefore, shifts in precipitation patterns, increased drought and temperature exposure may reduce the ability for the species to compete with other species. Georgia alder is drought-intolerant and would likely suffer population losses due to both increased frequency of drought and increased groundwater withdrawal by agricultural, municipal, and other users during long-term drought conditions (Stritch 2014, p. 17). In 2009, Gibson (2018b) observed numerous dead clumps of Georgia alder in Drummond Swamp, possibly related to the 2006-2009 drought. However due to lack of monitoring data, it is unknown if any mortality had population effects.

Annual average temperature, precipitation and evapotranspiration are expected to increase for Bartow County, however patterns of precipitation are projected to shift with increasing flooding and droughts in Georgia (EPA 2016a, entire).

3.3.4 Conservation Management

Land Protection

Several land protection efforts within the last 15 years have made considerable progress in conserving Drummond Swamp. The Georgia Power Company (GPC) owns approximately 70 percent of Drummond Swamp, including 24 ac (10 ha) that are under a permanent conservation easement, which protects the acreage from development, held by the Chattowah Open Land Trust (Chafin 2017, p. 1). The GPC made a focused effort to purchase the Drummond Swamp properties from various landowners to buffer Plant Bowen (located downstream) from incompatible development and to protect the wetland due to the presence of the globally rare Georgia alder and its unique plant community (GPC 2018a). The GPC is considering additional permanent conservation easements on portions of these properties (GPC 2018b). For well over a decade, GPC has been an active conservation partner with the Georgia Department of Natural Resources, the Georgia Plant Conservation Alliance (see Conservation Horticulture section below) and others to protect and manage the Georgia alder at Drummond Swamp (see Wetland Buffers, Land Management, and Reforestation section below).

The Service is also actively involved in protection of the site and was successful in advising a gas line company to re-locate a 400-ft (122-m) wide right-of-way alignment originally proposed in 2015 to run through Drummond Swamp (Chafin 2017, p. 8). Other portions of the swamp that harbors the Georgia alder, including the Blue Hole Spring, are owned by other private landowners.

All of Drummond Swamp and the adjacent uplands are within the boundaries of the Etowah Valley Historic District (figure 26). This district is afforded special regulations to provide for the identification of and protection of historical and cultural artifacts and sacred locations of the Muscogee (Creek) Nation and the Eastern Band of the Cherokee Nation, which are two Native American Nations that are historically connected to the Etowah River Valley (referred to collectively as “Native American Nations”). The identification and protection of such artifacts and locations is of great benefit to the public welfare, in that it preserves and promotes understanding of the county’s and the nation’s history, enhances the aesthetic environment, encourages proper economic development, provides tourism opportunities, and benefits all citizens. This ordinance further honors the agreement made with the Nations by Bartow County. Property in the Etowah Valley Historic District is subject to additional procedures prior to rezoning or development, in order to achieve these purposes (Bartow County Code § 7.17). Any development or land disturbance, other than one seeking to erect a single-family residence on a single lot, must seek a permit from the county and an archaeological survey must be conducted. While this ordinance does not necessarily preclude development, it may steer development away from archeological sensitive areas, including the Drummond Swamp area. The Bartow County Government has been engaged in conservation of Drummond Swamp for the past 10 years, and continues to collaborate with partners such as GPC, GA DNR, the Service, Atlanta Botanical Gardens, Universities (e.g., Berry College) and others to help educate and protect the site (Sills and Phillips 2018).

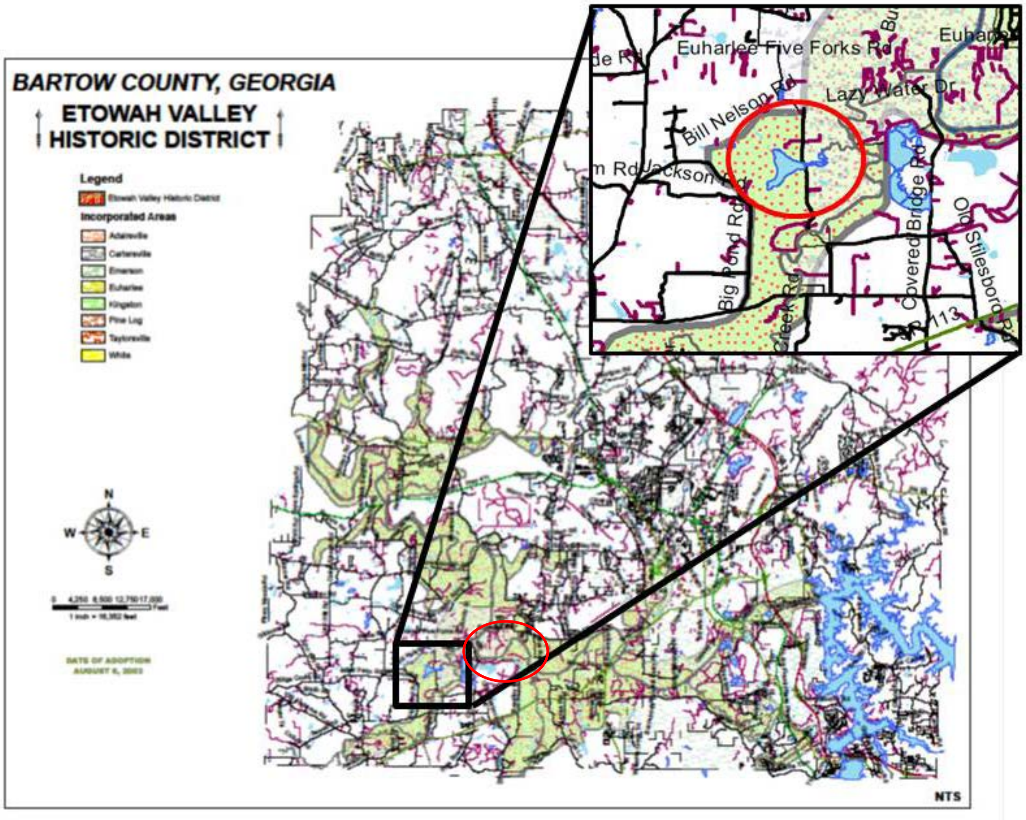


Figure 26. Bartow County, Georgia Etowah Valley Historic District. Drummond Swamp area marked by red circle.

Wetland Buffers, Land Management and Reforestation

Drummond Swamp is considered one of GPC's special management areas and is managed in coordination with the Georgia Department of Natural Resources (Wills 2015, entire) and other conservation partners. GPC's special management areas are designated by GPC on Right-of-Ways (ROWs) managed by GPC and on properties owned and managed by GPC that harbor rare plants and are identified as needing special management considerations. The buffer lands around Plant Bowen (includes Drummond Swamp see land protection section above) owned by GPC have had varying land use in the past and therefore are in different stages of condition and management. The Georgia Soil and Water Conservation Commission and the Georgia Department of Forestry Commission (GFC) recommend best management practices (BMPs) that include vegetative buffers along wetlands to reduce nutrient runoff and sedimentation from adjacent agricultural and forestry practices (GSWC 2007, entire; GFC 2009, entire). The GPC meets or exceeds all recommend BMPs and the wetland buffers have been allowed to regrow naturally on the properties owned by GPC. Cattle have been removed from the tracts of land that GPC acquired as part of their land protection efforts reducing herbivory and trampling along the wetland edges. Some properties previously maintained as hay fields, are in transition with long-term land management goals under discussion. In general, the land is being reforested into loblolly pine plantations but GPC is working with conservation-focused partners (including universities and local government) to determine best land management and conservation strategy. These efforts include enabling important research and monitoring to inform conservation and adaptive management, and outreach and education to bring awareness to the significance of the Georgia alder and the unique ecology of Drummond Swamp (GPC 2018a; GPC 2018b).

Conservation Horticulture (or Safeguarding)

Although rare plants and endangered plant communities almost always receive less publicity, less protection, and lower levels of funding than do animals, the threat to their survival may be greater. The Georgia Plant Conservation Alliance (GPCA), a statewide network of public and private conservation organizations and agencies formed in 1995 The mission of the GPCA is to "study and conserve Georgia's flora through multidisciplinary research, education, and advocacy; facilitate the recovery of rare, threatened, and endangered plants of Georgia and the southeast US through collaborative efforts in our state; support the development and implementation of the Georgia State Wildlife Action Plan, as well as other plant, wildlife, and habitat conservation plans by member agencies and organizations; and communicate the importance of preserving biodiversity worldwide" (GPCA 2008, entire; Ceska 2018). The GPCA has developed a prioritized list of critically endangered plant species coordinated by the GA DNR as part of the State Wildlife Action Plan (SWAP). The Georgia alder is a priority SWAP species and was selected by the GPCA as a top priority species for its conservation activities. In order to "safeguard" this subspecies from any catastrophic event that may extirpate Georgia alder from the only known natural site in Georgia, the GPCA have introduced Georgia alder sourced from Drummond Swamp into three protected "safeguarding" sites in Northwest Georgia (ABG 2012; Richards 2017, Byrd 2018). In 2010, the Atlanta Botanical Garden (ABG), in partnership with GPC via the GPCA, received a grant from the National Fish and Wildlife Foundation's Five Star Restoration Program (funded in part by GPC's parent company, Southern Company, and other private and public organizations) to conduct wetland surveys in northwest Georgia, propagate Georgia alder from Drummond Swamp and to identify potential sites for "safeguarding" Georgia alder (ABG 2012, p.62; Chafin 2017, p.8). Safeguarding refers to all types of propagation and/or outplanting activities that constitute a conservation strategy of last resort. Specifically, safeguarding refers to various propagation and outplanting activities as they relate to *ex situ* or *in situ* efforts, including re-introductions, augmentations/enhancements, and introductions. The GPCA follows strict technical and ethical guidelines for conservation horticulture (GPCA 2008, pp. 4–6). Currently there are three Georgia alder safeguarding sites in other Georgia counties (figure 27) and one augmentation site at Drummond Swamp, summarized below from ABG (2012, entire; Byrd 2017; Richards 2017). *Ex situ* collections of Georgia alder are also held at GPCA propagation partner facilities.

- In 2011, 90 Georgia alders, propagated from plants at Drummond Swamp, were planted on federal land at the Armuchee District/Pocket Recreation Area in the Chattahoochee National Forest (Walker County, Pocket Creek-Johns Creek HUC 12 watershed). Alders had about a 75 percent survival rate in 2012. However in 2015, flooding from increased rainfall and beaver damming caused this planting to fail. In 2016, 11 Georgia alder were re-planted at this site but in a higher (drier) ecotone. This second outplanting needs follow up monitoring to determine status.

- In 2011, about 15 Georgia alder, propagated from plants at Drummond Swamp, were planted at an additional site on federal land in the Armuchee Pocket Recreation Area (Floyd County, Pocket Creek-Johns Creek HUC 12 watershed). In 2016 about six trees were reported to be surviving. Mortality may be related to removal of an impoundment where water tables dropped dramatically.
- In 2012, nine Georgia alder, propagated from plants at Drummond Swamp, were outplanted at the State-owned Conasauga River Natural Area (Murray County, Hampton Island-Conasauga River HUC 12 watershed) into an area that was subsequently hand-cleared of woody competitors. Last monitored in 2016, four trees are doing well and the site is managed by GA DNR.
- In 2010-2012, about 30 alder were outplanted at Drummond Swamp. Prior to planting the site was prepared by removing Chinese privet and, with assistance from GPC, burned using prescribed fire to enhance site conditions for the alder.

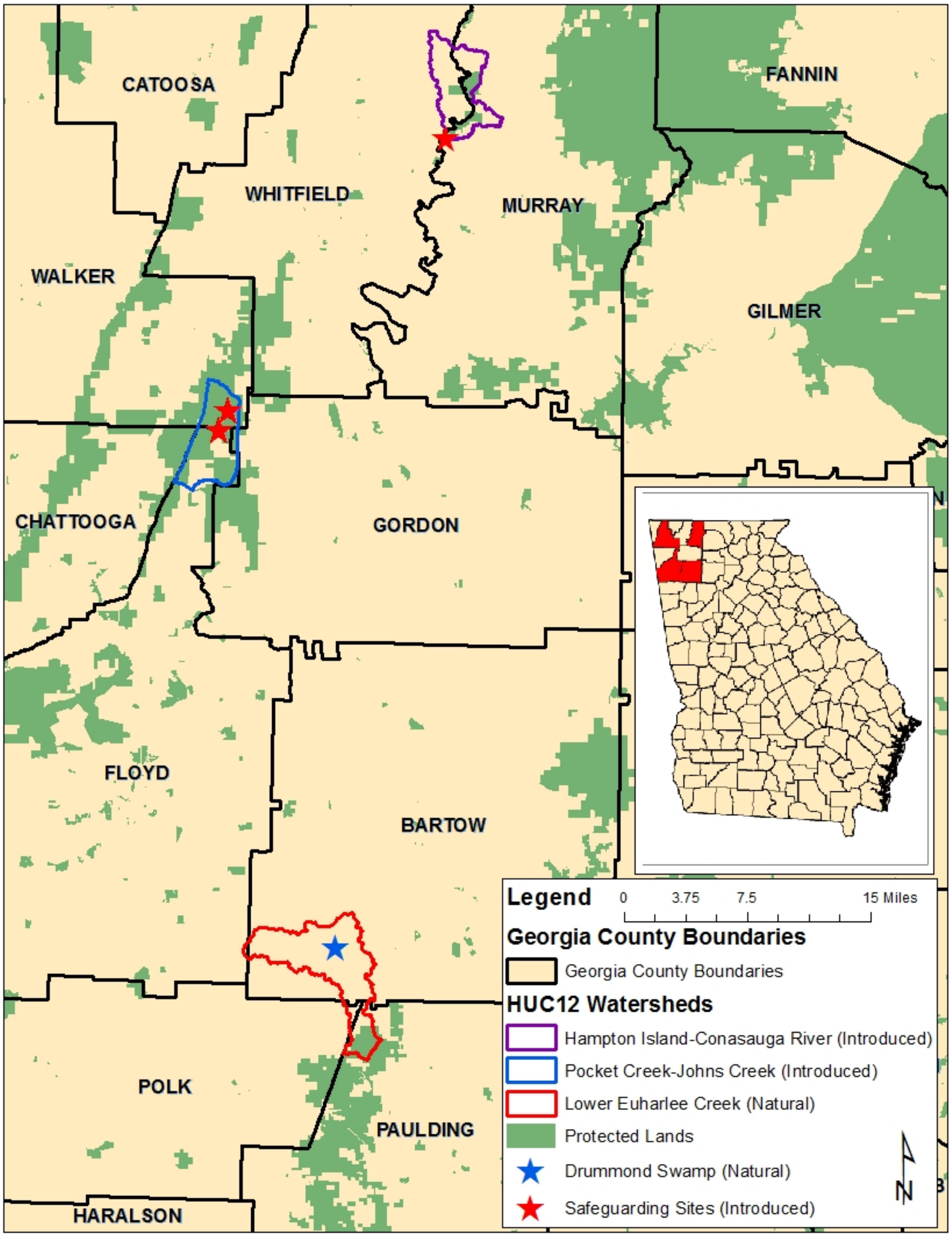


Figure 27. Location of three safeguarding sites and the one known natural site for Georgia alder.

<u>*Summary of factors influencing the Georgia alder*</u>: The best available information suggests that of the past, current and future influences on what the Georgia alder needs for long term viability, (freshwater, hydric soils and sunlight), the largest stressors to viability of the subspecies relate to impacts to water quantity, water quality and habitat due to urbanization (including human

population growth) and changing climate conditions. Water quantity is expected to be impacted by increasing impervious surfaces and overexploitation from urbanization and increasing human water use. Changing climate conditions such as increased frequency of long-term drought, changes in precipitation patterns and evapotranspiration are also important factors affecting water quantity. Water quality is expected to be impacted from runoff and sedimentation due to urbanization. Invasive plant species, especially as Chinese privet, are expected to further modify habitat conditions if water quantity decreases or soils become less saturated. Therefore, we analyze urbanization and future climate conditions as two most significant drivers of change in our assessment. Conservation management, such as land protection, wetland buffers, land management and restoration may have some ameliorating effects on impacts to viability and are also considered in our analysis.

The following factors were not considered to be significant factors affecting water quantity, water quality and habitat at Drummond Swamp that would cause a population effect on the Georgia alder and therefore are not carried forward in our assessment: the effects of future impoundments, the emerald ash borer, herbivory, and coal ash deposition

3.4 Oklahoma Alder

Based on the habitat and demographic needs of Oklahoma alder populations we identified stressors or factors that influence population resiliency (figure 28). Sources are the causes of change in the influences in Oklahoma. Many influences were considered, but only those influences that would impact the Oklahoma alder at a population level are discussed below. Those influences that were considered, but that only affected individuals include herbivory of seedlings, Frankia inoculation, and surface water diversions.

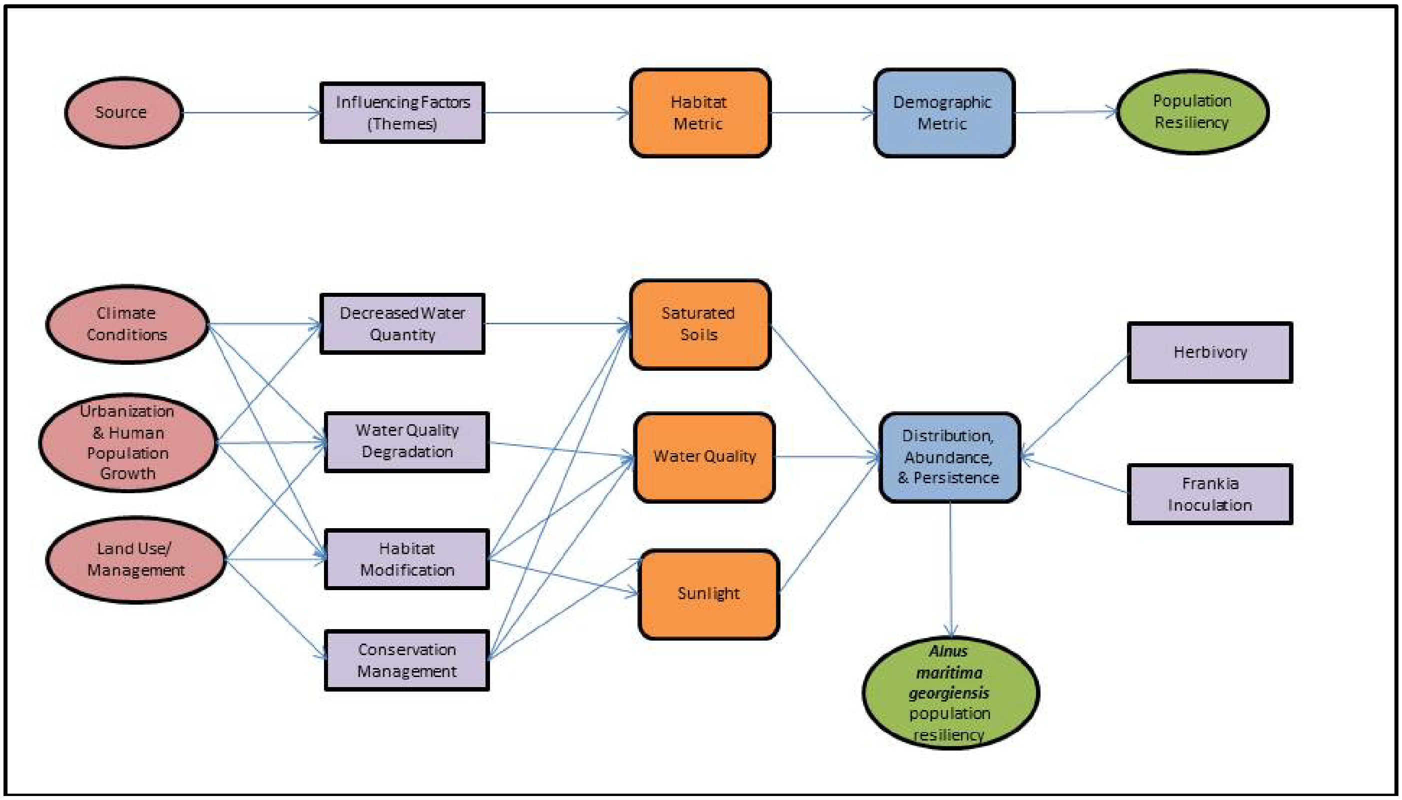


Figure 28. Diagram of influences on the Oklahoma alder.

Since the streams on which Oklahoma alder depend on are connected to the Arbuckle Simpson Aquifer (figure 29), changes to the aquifer level will impact the spring discharge that feeds the streams and therefore stream flow. Discharge into rivers and streams from the Arbuckle-Simpson aquifer provides both water quality and saturated soils. Reduced streamflow will result in a reduction in the saturated soils needed by the subspecies. Aquifer levels are influenced by precipitation, flood events, drought, temperature, and groundwater pumping, these are addressed below.

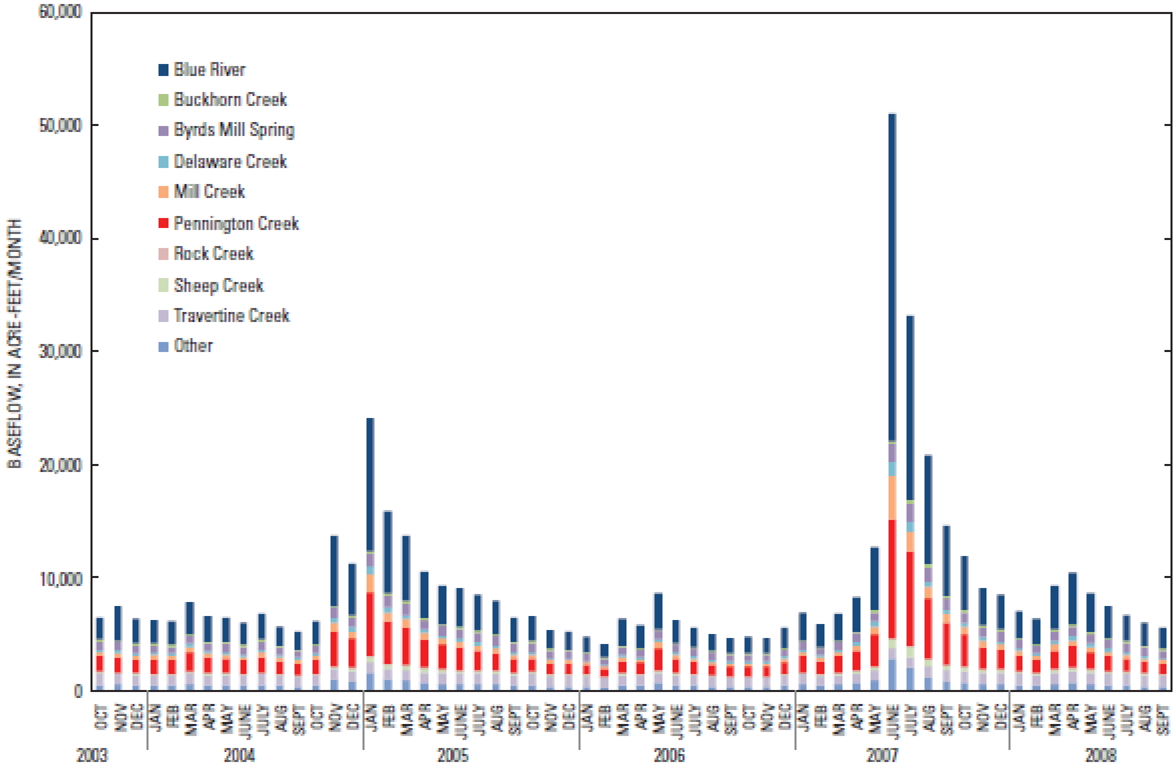


Figure 29. Monthly base flow to streams for the eastern Arbuckle-Simpson aquifer, south-central Oklahoma.

3.4.1 Precipitation

Precipitation is the primary recharge mechanism for the Arbuckle-Simpson aquifer. Figure 30 demonstrates the connection between precipitation and aquifer levels. Consequently, precipitation is needed to maintain the aquifer which in turn provides the base flow for stream occupied by Oklahoma alder.

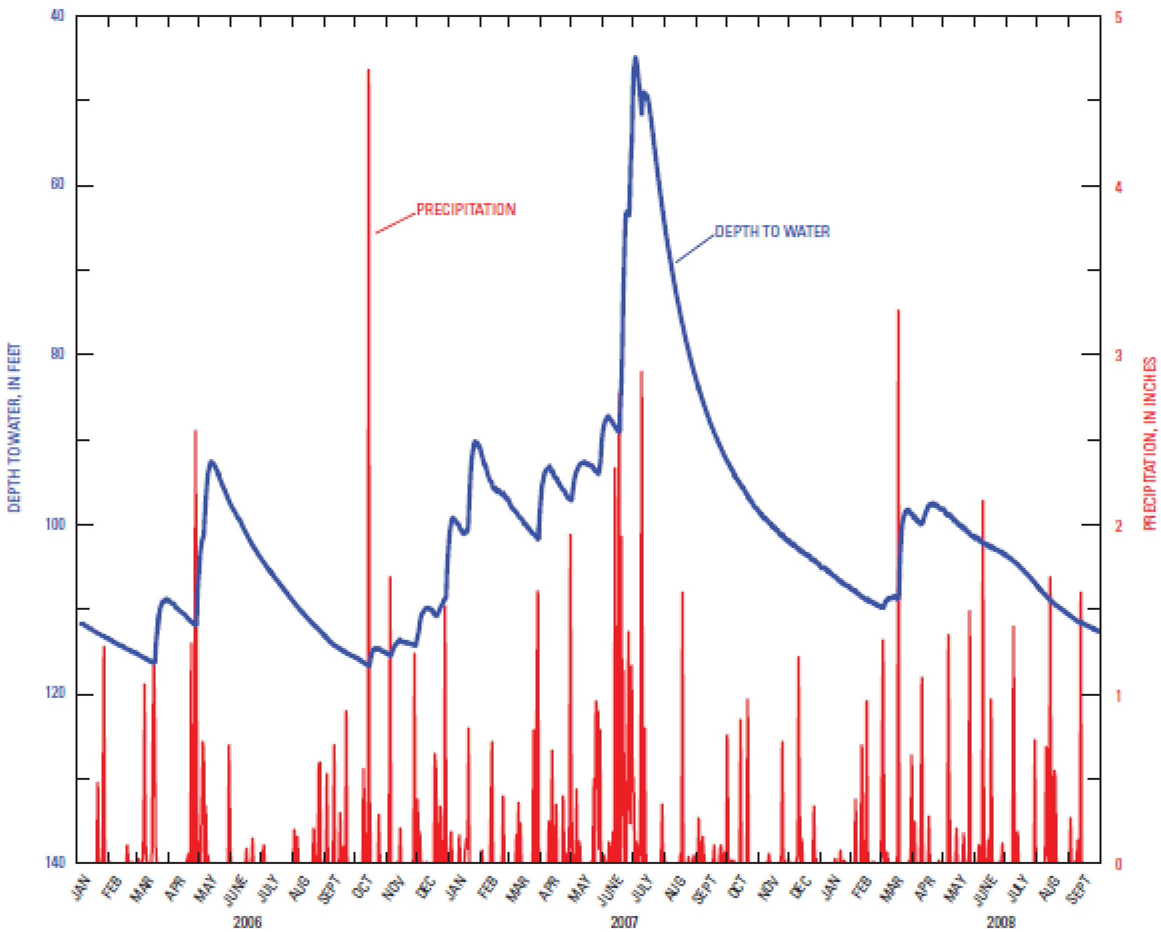


Figure 30. Monthly precipitation and depth to Arbuckle-Simpson Aquifer over a 3 year period (Christenson *et al.* 2011, p. 34).

The annual precipitation for south-central Oklahoma averages between 37.4 and 41.54 in (95 and 105.5 cm) depending on the length of time analyzed (table 3 and figure 31). Monthly average precipitation varies, with low precipitation typically occurring in July and August (table 4 and figure 31) when temperatures are the highest.

Projected future annual average precipitation for this area is within the range of past averages but the timing and duration of rain events is projected to change, with more intense storms of longer duration, which is already occurring (The Southern Climate Impacts Planning Program (SCIPP) 2018, entire). Average rainfall is likely to decrease during spring and summer. Seventy years from now, the longest period without rain each year is likely to be at least 3 days longer than it is today (IPCC 2014, entire). Overall, precipitation is expected to decrease 6 to 10 percent by 2100, with the southwest parts of the State experiencing greater rain loss than the northeast (National Climate Assessment, pp. 65–241).

Table 4. Average monthly and average annual precipitation at Ada, Oklahoma (1971–2000, Christenson *et al.* 2011, p. 25).

Month	**Precipitation (inches)**
January	1.84
February	2.22
March	3.67
April	3.83
May	5.71
June	4.52
July	2.72
August	3.10
September	4.57
October	3.89
November	3.10
December	2.39
Annual	41.54

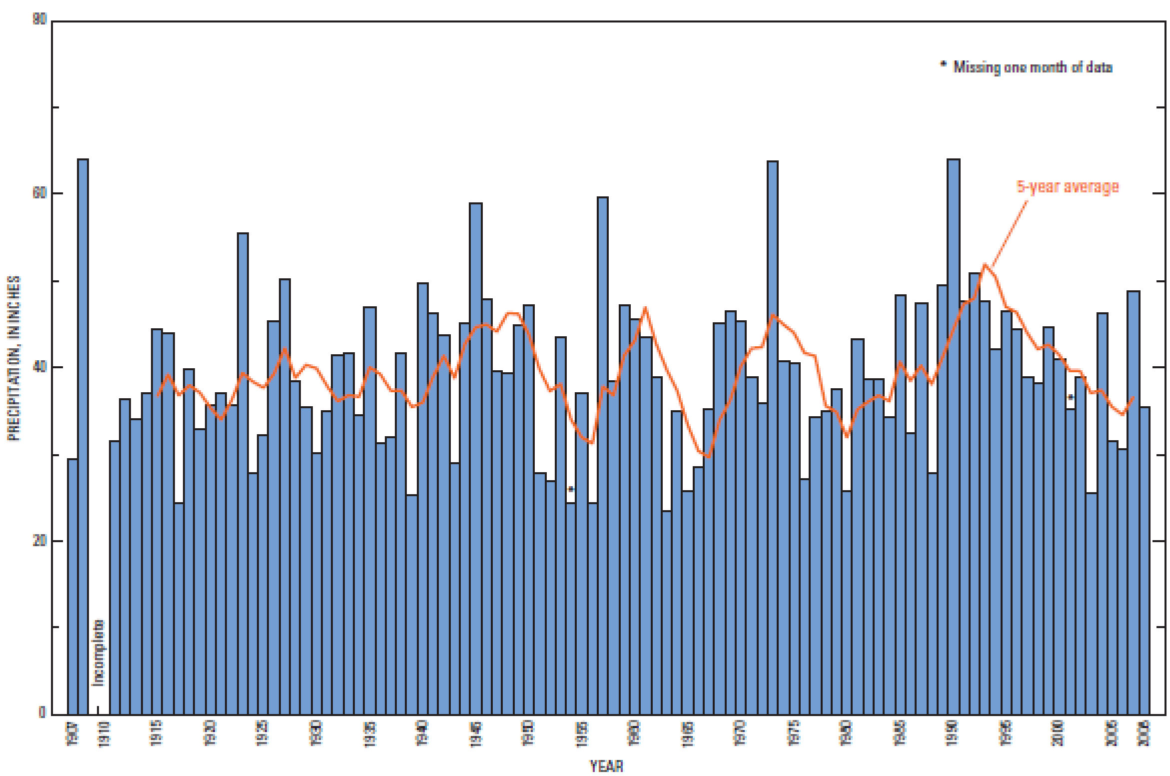


Figure 31. Average monthly and 5 year average annual precipitation at Ada, Oklahoma (1907 to 2008).

Flooding Regime

Oklahoma alder requires an open canopy for full sunlight. In Oklahoma, it is likely that large flood events manage the vegetation riparian area. Water sweeps through rivers removing riparian vegetation and opening the canopy for new establishment of the Oklahoma alder. Large flood events happen in Oklahoma about every 10 to 20 years up until the 1990s (figure 32; Oklahoma Climatological Survey 2018). After the 1990s it appears that floods were less frequent and climate projections indicate that storm events will change in timing and severity. Consequently, future storm events will be more intense and happen at different times (i.e., later or earlier in a season).

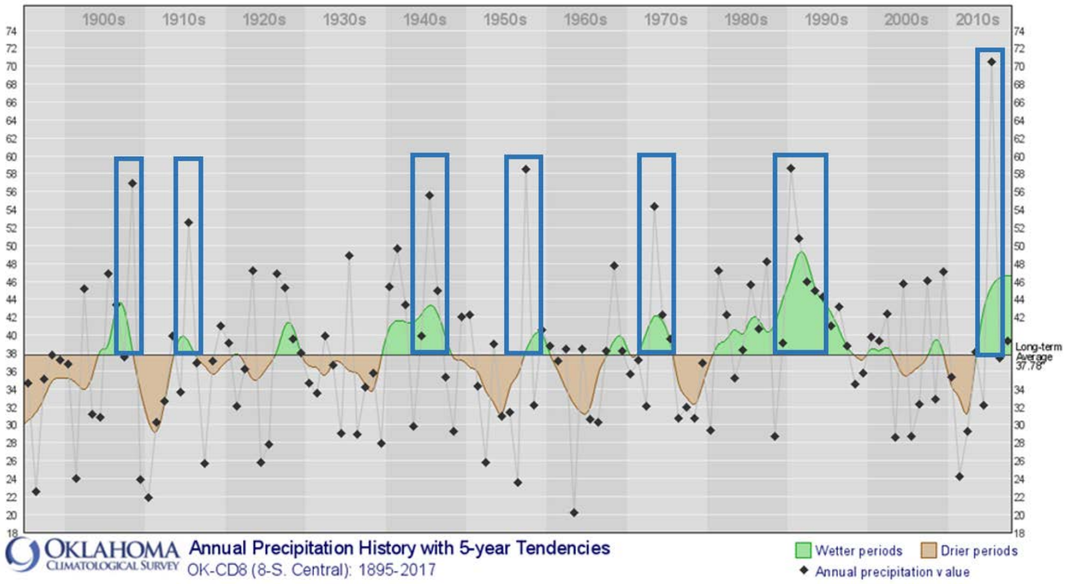


Figure 32. Flood regime from South-Central Oklahoma from 1895 to 2017.

Flood events flush individual Oklahoma alder seedlings, adults, and even populations downstream (Rice and Gibson 2009, p.59). While increased flood events do wash away Oklahoma alders, these scouring events can also break apart roots that can and do establish new individuals downstream. In addition, flooding can break stems from individual plants but the remaining rootstock appear to re-sprout rapidly. A study in Oklahoma found that major floods that occurred in the summer of 2007 tore away above ground stems of many of the plants, but new branches began to re-sprout from rootstock later that summer (Rice and Gibson 2009, p. 59). From anecdotal evidence, floods in 2015 had washed Oklahoma alder downstream from its site near Tishomingo, but in 2017, the populations appear abundant at the same site (Autio 2017). The Oklahoma alder is found growing in clumps instead of individual trees, which may be an adaptive advantage to surviving flood events or be the result of past flood events (Rice and Gibson 2009, p. 59).

Flooding in Oklahoma occurs most often in the spring and fall. Intense downpours have become more common in Oklahoma, with total annual rainfall on very wet days increasing more per year since 1948 than other states in the southern Great Plains. As stated above, the average annual precipitation is projected to remain stable or decrease, the intensity and duration of storm events is projected to increase. Although summer droughts are likely to become more severe, floods may also intensify. During the last 50 years, the amount of rain falling during the wettest four days of the year has increased about 15 percent in the Great Plains. Over the next several decades, the amount of rainfall during the wettest days of the year is likely to continue to increase, which would increase flooding (EPA 2016b, pp. 147–148). Rains following droughts will often be quick and heavy, causing flash-flooding (National Climate Assessment, pp. 65–137).

Precipitation is the primary recharge mechanism for the aquifer. Since the landscape above the Arbuckle-Simpson aquifer is steep, overland flash floods are already intense. Unusually high precipitation over a short time period causes flooding and increases overland flow, which means that precipitation is flowing over the land instead of filtering down through soil and recharging groundwater and the aquifer. Consequently, the increased storm events will result in more runoff, less infiltration to the aquifer, and more intense flood events.

While flood events are needed for maintaining the open canopy allowing full sun to the Oklahoma alder, such flood events could also uproot and kill them. In addition, increased flood events result in less water recharging the aquifer, which results in the amount of spring discharge that maintains the stream in which the Oklahoma alder depends.

3.4.2 Drought Regime

As stated above the Oklahoma alder needs inundated soils and although drought is a recurring part of Oklahoma's climate cycle, prolonged drought would impact soil moisture and therefore the Oklahoma alder.

Drought is driven by the amount of precipitation, which in turn impacts aquifer recharge and spring flow discharge. The first evidence of drought usually is seen in records of rainfall. Within a short period of time, the amount of moisture in soils can begin to decrease. The effects of a drought on flow in streams and reservoirs may not be noticed for several weeks or months. Water levels in wells may not reflect a shortage of rainfall for a year or more after a drought begins (USGS 2017d, entire). In addition, drought is impacted by evapotranspiration, which is tied to temperature. While droughts are part of the ecology in Oklahoma, prolonged droughts that could affect aquifer level and thereby spring flow would likely impact the Oklahoma alder.

In Oklahoma, rainfall has become more unpredictable, swinging back and forth between extreme drought and intense downpours. Climate records show trends of long droughts, some lasting decades, followed by intense flooding. For example, Oklahoma has experienced six multi-year or decade-long drought events since 1920 (Oklahoma Water Resources Board, p. 40). Significant periods of drier than average conditions include the 1910s, 1930s, mid-1950s, mid-1960s, and late 1970s (South Central Climate Science Center 2013). Since modern climatological record-keeping began in the 1890s, Oklahoma has experienced five major multi-year, regional drought events. While overall precipitation was above normal for Oklahoma from 1980 to 2010, the state has experienced record drought during the last 3 years. For the entire month of June in 2011, all of Oklahoma received about 1.1 in (2.8 cm) of rainfall, down from its average monthly rainfall of 4 in (10.1 cm) (SCIPP, 2018). Droughts will become more frequent, last longer and be more intense (National Climate Assessment, entire).

Changes in drought frequency and severity will influence spring discharges from the Arbuckle-Simpson aquifer (Niraula *et al.* 2017, p. 10407; Liuzzo *et al.* 2010, p. 110). Streams above the

Arbuckle-Simpson aquifer experience less severe droughts than other streams in the area because they are primarily spring fed; however, the primary recharge mechanism of the aquifer is precipitation (Tejan and Haas 2008, p. 65; Fairchild *et al.* 1990, p. 11). It is likely that streams continued flowing, but at lower rates. Consequently, we consider drought a factor influencing the Oklahoma alder.

3.4.3 Temperature, Evaporation, and Evapotranspiration

A portion of the rainwater that is initially absorbed into the vegetation and soil returns to the atmosphere through evaporation directly from the soil, or is absorbed into the roots of living plants and transpired through their leaves; collectively, these losses of water vapor are called evapotranspiration. Hence, the amount of recharge to an aquifer is rainfall minus the sum of runoff plus evapotranspiration.

Apart from precipitation, the most significant component of the hydrologic budget is evapotranspiration. Evapotranspiration is the water lost to the atmosphere by two processes-evaporation and transpiration (USGS 2017c, entire). Evaporation is the loss from open bodies of water, such as lakes and reservoirs, wetlands, bare soil, and snow cover; transpiration is the loss from living-plant surfaces. Several factors other than the physical characteristics of the water, soil, snow, and plant surface also affect the evapotranspiration process (USGS 2017c, entire). The more important factors include net solar radiation, surface area of open bodies of water, wind speed, density and type of vegetative cover, availability of soil moisture, root depth, reflective land-surface characteristics, and season of year (USGS 2017c, entire).

"Transpiration rates go up as the temperature goes up, especially during the growing season, when the air is warmer due to stronger sunlight and warmer air masses. Higher temperatures cause the plant cells which control the openings (stoma) where water is released to the atmosphere to open, whereas colder temperatures cause the openings to close. As the relative humidity of the air surrounding the plant rises the transpiration rate falls. It is easier for water to evaporate into dryer air than into more saturated air" (USGS 2017c, entire). As rising temperatures increase, evaporation and water use by plants also increase, causing soils to likely become even drier (EPA 2016b, entire).

Increased movement of the air around a plant will result in a higher transpiration rate. Wind will move the air around, with the result that the more saturated air close to the leaf is replaced by drier air. When moisture is lacking, plants can begin to senesce (premature ageing, which can result in leaf loss) and transpire less water. Plants transpire water at different rates. Some plants which grow in arid regions, such as cacti and succulents, conserve precious water by transpiring less water than other plants" (USGS 2017c, entire). Temperatures are highest in the area occupied by the Oklahoma alder in July and August (table 5), when precipitation is typically lowest.

Table 5. Temperature data for Ada, Oklahoma (1971–2000).

	Mean temperature (degrees Celsius)		
	Daily maximum	Daily minimum	Average
January	9.9	-2.4	3.8
February	13.4	0.2	6.8
March	18.3	4.7	11.5
April	23.0	9.1	16.1
May	26.8	14.3	20.6
June	30.8	18.9	24.8
July	33.8	21.5	27.7
August	33.6	20.8	27.2
September	29.4	16.5	22.9
October	23.9	10.4	17.2
November	16.6	4.1	10.4
December	11.4	-0.8	5.3
Annual	22.1	9.8	16.2

During a drought, the significance of evapotranspiration is magnified, because evapotranspiration continues to deplete the limited remaining water supplies in lakes and streams and the soil. This in turn affects the amount of water the percolates into the aquifer and spring discharge. Changes in evaporation and transpiration during a drought depend on the availability of moisture at the onset of a drought and the severity and duration of a drought. Also, weather conditions during a drought commonly include below-normal cloud cover and humidity and above-normal wind speed. These factors will increase the rate of evaporation from open bodies of water and from the soil surface, if soil moisture is available. See table 6 below for annual evapotranspiration rates calculated for two locations in Oklahoma.

Oklahoma has recently experienced record-breaking heat (figure 33).

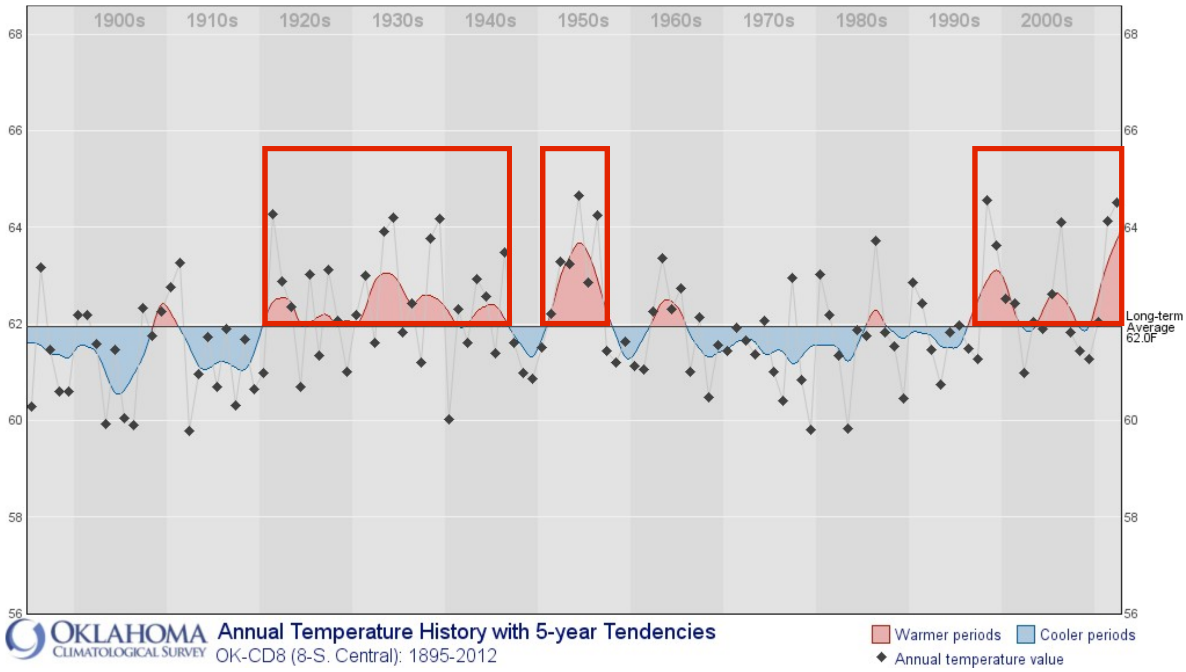


Figure 33. Annual temperature in south-central Oklahoma since 1895. The annual temperature for south central Oklahoma averages 61.9 °F (16.6 °C) from 1895 to 2010. Warmer than average periods have spanned the 1920s through the mid-1940s, the mid-1950s, and the late 1990s through the 2000s.

As temperature increases, droughts become more extreme and any water in the soils evaporates or is quickly used by plants and evapotransported back into the air (Schwinning and Ehleringer 2001, p 464).

Table 6. Annual evapotranspiration calculated for Blue River near Connerville, Oklahoma (07332390), and Pennington Creek near Reagan, Oklahoma (07331300), for water years 2004–8.

Station name	Station number	Water year	Annual precipitation* (inches)	Annual runoff (inches)	Annual evapotranspiration (inches)	Evapotranspiration as percent of precipitation
Blue River near	07332390	2004	32.45	4.13	28.32	87.27
Connerville		2005	42.49	9.43	33.06	77.81
		2006	24.63	3.93	20.70	84.04
		2007	49.68	15.83	33.85	68.14
		2008	32.59	5.56	27.03	82.94
		Average	36.37	7.78	28.59	80.04
Pennington Creek	07331300	2004	32.80	5.02	27.78	84.70
near Reagan		2005	40.15	10.71	29.44	73.33
		2006	22.79	4.78	18.01	79.03
		2007	47.02	18.56	28.46	60.53
		2008	32.01	5.04	26.97	84.25
		Average	34.95	8.82	26.13	76.37

3.4.4 Decreased Water Availability and Aquifer Use

Groundwater pumping

The Arbuckle-Simpson aquifer is an EPA designated sole source aquifer, meaning it supplies at more than 50 percent of the drinking water to nearby areas and there are no reasonably available alternative drinking water sources if the aquifer becomes contaminated. Water from the aquifer is critical and the water is usually a calcium-magnesium bicarbonate type that is suitable for most uses. As discussed, the Oklahoma alder are also dependent on the Arbuckle-Simpson Aquifer because spring discharged streams provide habitat and keep soils hydric even in drought years. So, a reduction in the amount of surface flow from spring discharges is a potential stressor to the species. One of the factors that influence spring discharge into rivers is groundwater pumping.

In the last 44 years, the majority of water used from the Arbuckle-Simpson aquifer served as public water supply for the cities of Ada and Sulphur, Oklahoma, with an average annual use of 2,697 ac-ft (or 63 percent of the total groundwater use), followed by mining (15 percent or an annual average of 648 ac-ft), and irrigation (7 percent or an annual average of 301 ac-ft). Power generation accounted for an annual average of 586 ac-ft (14 percent of the total groundwater used); however, groundwater use for power generation from the aquifer ceased by 1988 when the Oklahoma Gas and Electric Company discontinued operating a power plant north of Sulphur, Oklahoma. Other uses (including recreation and non-irrigation agricultural use) accounted for about 1 percent of groundwater use (Christenson *et al.* 2011, pp. 50–51) (figure 34). As groundwater is taken for municipal use, Pennington Creek and Blue River flows decrease (figure 35).

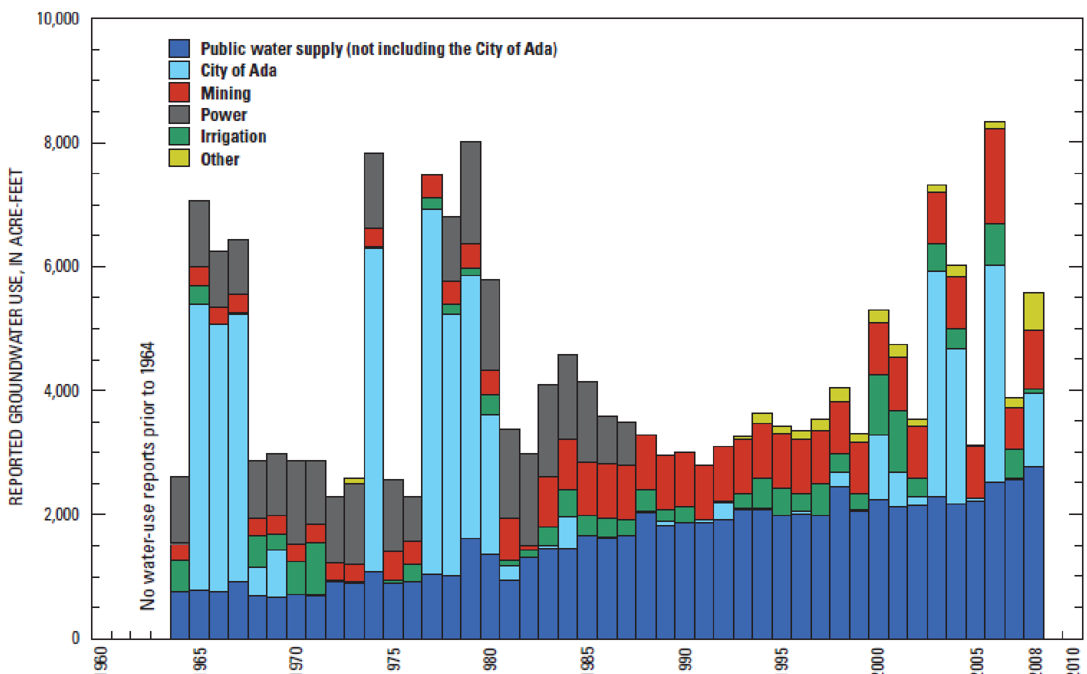


Figure 26. Reported groundwater use from the eastern Arbuckle-Simpson aquifer, south-central Oklahoma, 1964–2008.

Figure 34. Average annual reported groundwater use by type for the eastern Arbuckle-Simpson aquifer, south-central Oklahoma, 1964 to 2008. Adapted from Christenson *et al.* 2011, pp. 50–51.

The average annual recharge of the Arbuckle-Simpson aquifer is 4.7in (0.39 ac ft (481 cubic meter (m^3)) per year, whereas the average aquifer discharge via manmade pumping is 24.4 cubic feet per second (ft^3/s). Wells completed in the Arbuckle-Simpson aquifer commonly yield from

100 to 500 gallons per minute and locally yield as much as 2,500 gallons per minute (Christenson *et al.* 2011, pp. 52). With this in mind, streams that are fed from the aquifer show a decrease in flow over time, too (figure 35).

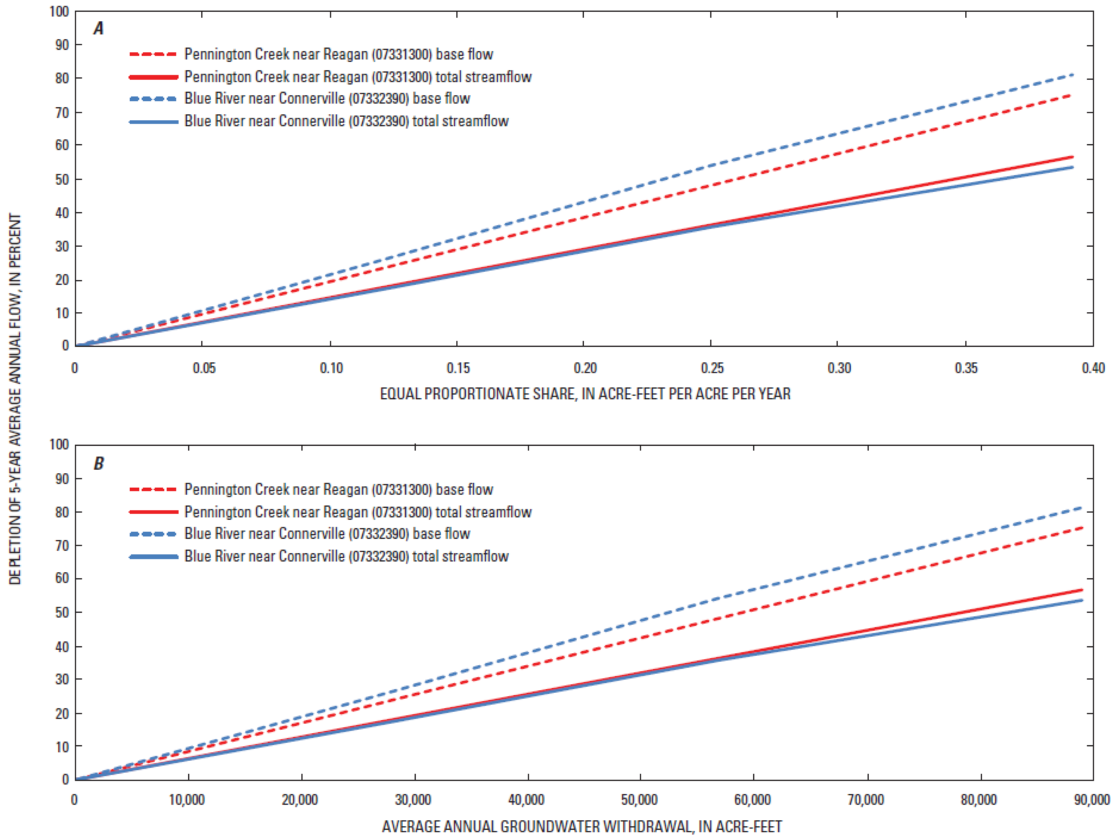


Figure 35. Depletion of 5-year average flow of Blue River, Oklahoma and Pennington Creek, Oklahoma based on average groundwater withdraw.

In summary, groundwater pumping is a major influence on streamflow, and will continue over time. Groundwater pumping is projected to increase in the future. Consequently, we are incorporating this stressor into our analysis.

Precipitation, Drought, and Temperature Patterns

While the effects of changing climate conditions is often talked about in the future tense, our climate is already changing in both averages, and the number and intensity of extremes. Oklahoma has recently experienced record-breaking heat, increased drought, and a slight increase in extreme weather events. As global temperatures continue to rise, Oklahoma is expected to experience more heat waves, drought, and flooding. (The Southern Climate Impacts Planning Program (SCIPP) 2018, entire). The Oklahoma Climatological Service (OCS, 2018, entire) projects the following climate change scenarios, and the associated impacts, to be realistic should the projected range of atmospheric warming materialize for the remainder of the 21st century: (1) the warm season becomes longer and arrives earlier; (2) the cool season warms and shortens which leads to a longer frost-free period and growing season;.(3) increased year-round evaporation from the ground and transpiration from green vegetation; (4) drought frequency and severity increases, especially during summer; (5) drier and warmer conditions will increase the risk of wildfires; (6) rain free periods will lengthen, but individual rainfall events will become more intense; and, (7) more runoff and flash flooding will occur.

The effects of increasing temperatures and drought is likely to increase society's demand for water, while also making it less available.

A change in flooding patterns will influence the amount of hydric soils available for the Oklahoma alder to grow on. Flooding is a normal part of climate in Oklahoma.

3.4.5 Vegetation encroachment

Riparian Buffer Area

The rivers in which the Oklahoma alder occupies usually have untouched riparian areas surrounding them. While riparian buffers are widely considered good for many ecological reasons, riparian plants compete with Oklahoma alder for sunlight. Vegetation encroachment is an important influence on the Oklahoma alder, especially seedlings, but is difficult to quantify. Flooding naturally flushes down vegetation and re-sets the habitat for Oklahoma alder establishment. Thus, flooding is a proxy for sunlight and is considered and influence on the Oklahoma alder (Schrader *et. al*. 2006, p. 987; Graves and Gallagher 2003, entire).

3.4.6 Seedling Niche

A critical concern for this species is its current failure to recruit individuals into existing populations from seed. Seed germination is rare and successful seedling establishment has not been observed in Oklahoma (Jones and Gibson 2012, p. 7).

Seedling ability to germinate may be due to competition with other vegetation for sunlight. One study noted that seedling survival decreased in burned plots due to the release of an aggressively growing competitor (Ehardt 2016, p. 53). In addition, young seedlings require higher levels of nitrogen from the time of germination, to the formulation of true leaves. Waterlogged soils in which Oklahoma alder are found to have lower levels of nitrogen and oxygen. This may be a limiting factor of why seedling establishment is low: one study showed a decline in seedling survival (from 87 percent to 72 percent) when soil nitrogen was lower (4.9 percent to 0.63 percent, respectively) (Schrader 1999, entire). Consequently, recruitment is considered in our analysis. It should be noted that these seedling studies represent the only three attempts to find seedlings to date; one informal survey in 2001, one systematic survey in 2008, and another experimental germination study. Given the longevity of the seaside alder, it is likely that recruitment in this species is episodic rather than annual, so the apparent rarity of seedling recruitment may not be a substantial concern and warrants additional study (Ehardt 2016, entire; Rice and Gibson 2009, entire; Schrader 1999, entire).

3.4.7 Herbivory

Deer, beavers and small mice have impacts on Oklahoma alder. Beavers chew stems of the tree, which kills the tree, but also opens the canopy for new vegetation to grow. This may be beneficial to small alder because sunlight becomes more available, or it may not be beneficial because the Oklahoma alder shrub dies from herbivory. Small mice and deer chew on young Oklahoma alder as a food source, and inhibit the growth of seedlings (Rice 2017; Tucker 2017). It is likely that this is only impacting a few individual and not resulting in population level impacts. Consequently, we are not analyzing this in our assessment.

3.4.8 Mining

There are rock (limestone) and fracking sand mining operations within the Arbuckle-Simpson Aquifer area. Some mines use groundwater, which directly influences the aquifer. Other mines are deep, and must pump water out of the aquifer. The displaced water is discharged into nearby streams. Consequently, this water is lost from the aquifer (Christiansen *et al.* 2011, p. 50; Bentley 2002, entire; Knight 2018, entire; Layden 2017, entire). Due to the potential reduction in the aquifer, mining activities are analyzed in our assessment.

3.4.9 Conservation Management

Protected lands

Portions of Oklahoma alder populations are found on protected lands (table 7) that belong to the Nature Conservancy, the Oklahoma Department of Wildlife Conservation (Blue River Public Fishing and Hunting Area), and the Service (Tishomingo National Fish Hatchery. The Blue River Public Fishing and Hunting Area encompasses approximately 6 miles of the Blue River upstream and downstream from the location at which State Highway 7 crosses the Blue River. On the Blue River Public Fishing and Hunting Area, Oklahoma alders grow along east and west banks and on shallow islands north and south of the highway crossing. Alders are abundant along the banks and on shallow islands along Pennington Creek and Blue River (Rice and Gibson 2009, p. 60).

Subsequent to our analysis, we become aware through the peer and partner review process that there is another Oklahoma alder population on the landscape, specifically, the confirmed population on State Wildlife Management Lands (Howery 2018). Therefore, our analysis is likely an under-estimation of Oklahoma alder populations.

Table 7. Records of Oklahoma alder found on private, Service, and State Wildlife Management Area lands.

Analysis Unit (HUC12)	Records on Private Land	Records on Service Land	Records on State Wildlife Management Area Lands
Lower Pennington Creek	5	1	0
Sheep Creek	4	0	0
Desperado Spring Falls-Blue River	2	0	1
Little Blue Creek-Blue River	2	0	0
Bois d' Arc Creek (Mill Cr.)	1	0	0
Pecan Creek-Blue River	0	1	0
Sandy Creek	1	0	0

Policy/Senate Bill 288

In 2003, the Oklahoma Legislature enacted Senate Bill 288 to amend the Oklahoma Groundwater Law in two significant ways. First, a moratorium for any "sensitive sole source groundwater basin" was imposed on use of groundwater away from the basin. The moratorium is in effect until the OWRB ensures that permits issued to pump water from such a basin "will not reduce the natural flow of water" from basin area streams or springs. Senate Bill 288 also added a new requirement before the OWRB could issue a permit to pump groundwater from such a basin (i.e., whether "the proposed use is not likely to degrade or interfere" with the flow of water from basin area streams and springs). In an Order dated October 23, 2013, the Oklahoma Water Resources Board clarifying the language "will not reduce the natural flow of water" such that groundwater withdrawals are allowable, as long as there is at least 75 percent of river base flow in spring-fed stream above the Arbuckle-Simpson aquifer (Oklahoma Water Resource Board 2013, entire). The OWRB maximum annual yield order limits the amount of groundwater that can be pumped from within the Arbuckle Simpson Aquifer to 0.2 acre-feet per year per acre of land. This is intended to be protective of springs and spring-fed streams within the aquifer. Over the long run, the order likely will not be protective of stream flows outside the boundaries of the Arbuckle-Simpson Aquifer (this applies at least to the lower sections of Pennington Creek where the creek is over the Antlers Aquifer). Groundwater pumping in the Antlers Aquifer is allowed at a rate of 2.0 acre-feet per year per acre of land.

Augmentation

The Nature Conservancy has proposed to plant about 700 Oklahoma alder saplings on the Oka' Yanahli Preserve, near the Blue River (Levesque 2018). The expected survival rate is about 50 percent. Plantings are planned for the Fall of 2018. The likelihood of this being implemented is high and, therefore, we consider this in our assessment.

Seed Conservation

Reestablishment of populations by conservation agencies may become a viable conservation strategy. As such, Oklahoma alder seeds are being sourced from local populations to preserve potential local adaptability and overall genetic diversity (Jones 2013, p. 9; Ehardt 2016, p. 91). There are no definitive plans for the implementation of such re-establishment of populations; consequently we are not considering this in our assessment.

Summary of factors influencing the Oklahoma alder

The primary factor influencing the Oklahoma alder is stream flow, which is dependent upon spring flow from the Arbuckle-Simpson aquifer. The factors that influence this system are precipitation, drought, temperature, flooding, groundwater pumping and mining. Conservation policy will have a beneficial influence on the Oklahoma alder. Overall, the largest influencers on the Oklahoma alder are changing climate conditions, aquifer pumping, flood regimes and conservation policy/augmentation.

Chapter 4. CURRENT CONDITIONS

4.1 Methodology—Analytical Units

To assess the biological status of the seaside alder across the species and each of the subspecies' range(s), we used the best available information, including peer reviewed scientific literature, academic reports, the best professional judgement of experts, and survey data provided by state agencies, the Service, and academic institutions to inform our analyses. Survey methods differ from survey to survey, but they provide information that allows assessment of the population factors.

As stated in the **Introduction**, we use the term analysis units rather than population because it is difficult to delineate biological populations of the seaside alder in each region due to the plant's clonal behavior and other challenges associated with identifying population boundaries.

To analyze the viability of the species (seaside alder) as a whole, our analytical units are the three subspecies (Delmarva, Georgia, and Oklahoma alders). Therefore, when we discuss the species' resiliency, we are using each of the subspecies as a surrogate for the "populations" and we refer to them as species analysis units. We assigned an equal weight to each subspecies to derive the seaside alder's current resiliency, redundancy, and representation.

We also analyzed the viability of each subspecies. We used U.S. Geological Survey (USGS) HUC 12 watersheds as a surrogate for each subspecies rather than "populations." The HUC 12 includes the stretch of stream where seaside alder records occur and the adjacent uplands that may drain into the stream or pond, which may affect the watershed's water quality and quantity—two factors that influence seaside alder. The HUC 12s often include multiple records and the relative number of records reflects the overall abundance of seaside alder in the watershed due to sexual or asexual reproduction, as well as allowing for gene flow and movement through cross-pollination and/or through the movement of seeds in water. These areas are the drainage basins or watersheds that are occupied by this shrub and are reasonable geographic analysis units for consistently analyzing the species' and subspecies' resiliency.

4.2 Current Condition—(Representation, Redundancy and Representation)

For the seaside alder to maintain viability, its analysis units (i.e., subspecies or HUCs, depending on the scale) or some representative portion thereof must be resilient (i.e., withstand stochastic events arising from spatially and temporally random factors). A resilient analysis unit must be large enough that stochastic events do not eliminate all analysis units (i.e., subspecies or HUCs, respectively).

A resilient analysis unit of Delmarva/Georgia/Oklahoma alder consists of multiple subpopulations (i.e., records), with a large number of individuals in each subpopulation, and persistence within each subpopulation because recruitment exceeds mortality. This may include continued resprouting from the root base or pollination and seed dispersal between subpopulations within the analysis unit, which can allow the analysis unit to recover from disturbance events and maintain or increase genetic diversity. In addition, resiliency requires that sites that provide sun, periodically inundated soils and freshwater be present and secure from applicable primary stressors.

4.2.1 Models

Tables 8 and 9 below provide the general definitions we used to define a high, moderate, and low resilient analytical unit (HUC 12 watershed). Specific data used to measure these metrics are defined in each of the subspecies sections below.

Table 8. Analysis unit (HUC 12 watershed) resiliency condition categories for the seaside alder.

High (Good)	Moderate	Low	Extirpated
An analysis unit with high resilience is where abundance is high, the number of subpopulations (i.e., records) is high and spatially dispersed with multiple groupings; seed production is high, recruitment is such that the analysis unit remains stable or increases; and able to withstand stochastic events or recover to current or better condition from stochastic events from seedbank or resprouting; with abundant suitable habitat.	An analysis unit with moderate resilience is where abundance is moderate, the number of subpopulations (i.e., records) is moderate and spatial distribution is limited with few groupings; seed production is moderate, recruitment and mortality are equal such that the analysis unit does not grow; ability to withstand stochastic events or recover from stochastic events is limited due to low abundance and recruitment and reduced seedbank or resprouting; with some suitable habitat.	An analysis unit with low resilience is where abundance is low, the number of subpopulations (i.e., records) is limited to one and spatial distribution is limited; seed production is low, mortality exceeds recruitment such that the analysis unit is declining; ability to withstand stochastic events or recover from stochastic events is unlikely due to low abundance and recruitment and limited seedbank or resprouting; with limited suitable habitat.	An analysis unit with no resiliency is one that might be extirpated completely, either physically or functionally because so few individuals are present that reproduction is unlikely (e.g. little to no cross pollination, flowering, seed production, or genetic exchange), or stressors have killed all plants.

Table 9. Resiliency definitions used for the seaside alder and Delmarva/Georgia/Oklahoma alder analyses.

	High Resiliency	Moderate Resiliency	Low Resiliency
Demographic Factors:	**Abundance** – High number of sub-analysis units in the watershed (*measured as high number of records);* and high abundance in at least one location. **Persistence –** Multiple records within an analysis unit over time and some recent records in the watershed (*repeated records over time at the same location or recent records (i.e., 2000)*).	**Abundance** – Moderate number of sub-analysis units in the watershed (*measured as medium number of records*); and at least one site considered to be medium in abundance. **Persistence –** Moderate number of records within an analysis unit (*repeated records or recent records (i.e., 2000)*).	**Abundance** – Low number of sub-analysis units in the watershed (measured as low number of records). **Persistence -** Low number of records within an analysis unit, or none, (*repeated records or recent records (i.e., 2000)).*
Habitat and Landscape Factors:	**Sites that provide** sun, periodically inundated soils, and freshwater are present in the HUC and the *entire* HUC is **secure from primary stressors.**	**Sites that provide** sun, periodically inundated soils, and freshwater are present in the HUC and *most of* HUC is **secure from primary stressors.**	**Sites that provide** sun, periodically inundated soils, and freshwater are present in the HUC and *very little* of the HUC is **secure from primary stressors.**

Demographic Resiliency Factors: While there are multiple demographic factors that can affect resiliency, we focused on those factors that influence the analysis unit and for which we have sufficient data. The demographic resiliency factors listed below are the analysis unit-level influences we use in our assessment of the current and future condition of the analysis units.

Abundance—The necessary abundance or minimum viable population size and the number of subpopulations are unknown; however, estimations can be attained from available data. The number of occupied sites, indicated by record data, in a watershed indicates the number of subpopulations where seaside alder occurs; though the size of each patch of shrubs indicated by a record is somewhat different, the number of records reflects its relative abundance.

Persistence—Evidence of persistence includes multiple sightings or recent records (since 2000) indicating they have survived and likely reproduced despite events of the past. Persistence is evidence of growth and reproduction either through asexual reproduction from runners or re-sprouting, and/or sexual reproduction from seedlings. Uncertainty exists as to whether existing individual plants arose from sexual or asexual reproduction (seeds or underground runners). In addition, precise information on the size of shrub areas is generally not available in most of the analysis units, therefore it is not possible to track increases in the size of the subpopulation or area occupied over time through either seeds or runners. However, we do assume that if the subpopulation persists over long periods of time, there is some reproduction occurring.

> *Recruitment*—The necessary recruitment needed for a self-sustaining analysis unit is unknown. However, we assume that an analysis unit with more young plants than dead individuals demonstrates high recruitment. We focus on recruitment rather than reproduction because the species reproduces both sexual and asexually, primarily asexually. For a highly resilient population, we assume that new individuals are needed. However, we are unable to directly measure recruitment and reproduction. Therefore, we are using persistence as a surrogate.

Habitat Resiliency Factors: Habitat parameters needed for resilient analysis units of seaside alder include sunlight, inundated soils along streams, rivers, or ponds, and high water quality. Wind pollination is needed for cross pollination and maintaining genetic diversity. Further, nitrogen fixing *Frankia* bacteria within the soil is likely needed to aid in nodule development in the plant. Habitats with appropriate levels of these parameters are considered to contribute to resiliency, while those habitats with levels outside of the appropriate ranges are considered to provide less resiliency. Habitat in Low condition is more susceptible to loss from a single stochastic event such as drought. Although adequate pollination is important, this is not thought to be a limiting factor and was therefore not rated in overall analysis unit resiliency, though is somewhat captured in the reproduction category. In regards to *Frankia*, data is lacking to analyze this factor. Therefore, we are not considering this factor in our analysis.

Representation

Maintaining representation in the form of genetic or ecological diversity is important to maintain the capacity of the seaside alder to adapt to future environmental changes. The level of genetic or ecological diversity needed to maintain adaptability for the seaside alder is unknown. However, it is likely that the current level of genetic diversity needs to be maintained as inbreeding has already been detected in the Georgia and Oklahoma alder, although not at significant levels (Jones and Gibson 2012, p. 6).

Redundancy

The seaside alder needs to have multiple resilient analysis units distributed throughout its range to provide for redundancy. The more analysis units, and the wider the distribution of those analysis units, the more redundancy the species will exhibit. Redundancy reduces the risk that a large portion of the species' range will be negatively affected by a catastrophic natural or anthropogenic event at a given point in time. Species that are well-distributed across their historical ranges are considered less susceptible to extinction and more likely to be viable than species confined to small portions of their ranges (Carroll *et al.* 2010, entire). The level of redundancy needed to maintain the seaside alder is unknown. However, it is likely that the current analysis units and subpopulations remaining need to be maintained.

4.2.1.1 Seaside alder

Despite the ongoing stressors discussed in Chapter 3, the seaside alder remains extant in a total of 35 analysis units distributed across its subspecies in 3 disjunct areas of the country (27 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). The specific condition of these analysis units is summarized in table 10 and described in detail in each of the subspecies' sections below.

Table 10. Summary of the current condition of seaside alder analysis units.

	# of Analysis Units in Each Resiliency Condition Category		
Subspecies	**High**	**Moderate**	**Low**
Delmarva alder	15	9	3
Georgia alder	1	0	0
Oklahoma alder	4	3	0
Total	20	12	3

4.2.1.2 Delmarva alder

We classified the current condition of the analysis units as high, moderate or low based on the number of occupied sites and persistence, as provided below.

> **High resiliency—**Delmarva alder occupies three or more sites; at least one site is considered large; evidence of persistence (recent records since 2000).
> **Moderate Resiliency—**Occupies one or two sites; at least one considered good or medium in size; evidence of persistence (recent records since 2000) at one or both sites.
> **Low Resiliency—**Occupies one site; not considered large or no data on size; low or no evidence of persistence, no recent records (since 2000). Provides no redundancy within the HUC.

In addition to the demographic metrics discussed above, we assessed habitat features of water quality, water quantity, and sunlight availability to characterize the Delmarva alder's resiliency. The presence of suitable wetlands based on the National Wetland Inventory (NWI) habitat data was used as an indicator that there were sufficient saturated wetland soils, open sun and water quality to provide habitat for Delmarva alder. Every HUC (e.g., analysis unit) occupied by the Delmarva alder currently contains wetland habitats used by the Delmarva alder (Freshwater Emergent Wetlands, Freshwater Forested/Shrub Wetlands, Freshwater Ponds or Riverine Wetlands). However, if the HUC contained Estuarine Wetlands, indicating brackish waters in the HUC, it was considered vulnerable to saline storm surge in the future and the occupied sites were evaluated for the potential loss in the future (see Appendix A for more detailed information).

Of the Delmarva alder's 27 HUCs, 15 are classified as having high resiliency, 9 have moderate resiliency, and 3 have low resiliency (table 11). There is a large block of HUCs in high and medium condition located in the central portion of the range and the low condition HUCs are mostly on the periphery (figure 36). See Appendix A for the Delmarva alder detailed metrics supporting the summary table and figure below.

Table 11. Summary of Delmarva alder current condition.

State	Percent Federal and State ownership	ID #	HUC 12 (e.g., Analysis Unit) Name	Year of Earliest Record	Year of most Recent Record	Number of Records	Population Condition
MD	43	27	Stony Bar Creek-Marshyhope Creek	1967	2017	19	High
MD	29	5	Chicone Creek-Nanticoke River	1976	2017	15	High
MD	0	2	Barren Creek-Nanticoke River	1976	2017	13	High
DE	10	30	Tussocky Branch-Broad Creek	1994	2017	11	High
MD	0	25	Shiles Creek-Wicomico River	1940	2002	10	High
DE	3	31	Upper Cedar Creek	1989	2017	9	High
MD	11	4	Butler Mill Branch-Nanticoke River	1989	2017	8	High
MD	20	10	Gales Creek-Nanticoke River	1967	2015	5	High
MD	36	19	Lower Nassawango Creek	1976	2017	5	High
MD	26	22	Puckum Branch-Marshyhope Creek	1967	2017	5	High
MD	1	29	Tonytank Creek-Wicomico River	1940	2016	5	High
DE	3	7	Cow Bridge Branch-Indian River	1993	2017	4	High
DE	16	18	Lower Deep Creek	1994	2017	4	High
DE	41	21	Primehook Creek	1993	2017	4	High
DE	27	13	James Branch	1989	2017	3	High
DE	5	6	Clear Brook-Nanticoke River	2017	2017	2	Moderate
DE	8	32	Upper Mispillion River	1990	1990	2	Moderate
DE	8	15	Long Drain Ditch-Betts Pond	1989	2017	2	Moderate
MD	0	26	South Prong Wicomico River	1987	2017	2	Moderate
DE	2	9	Elliott Pond Branch*	2017	2017	1	Moderate
DE	0	11	Herring Creek-Rehoboth Bay	2001	2016	1	Moderate
DE	31	12	Hitch Pond*	2017	2017	1	Moderate
DE	5	14	Little Creek Broad Creek*	2017	2017	1	Moderate
MD	14	23	Purnell Branch-Pocomoke River	1992	1992	1	Moderate**
DE	3	24	Round Pole Branch-Broadkill River	1989	1989	1	Low
MD	14	8	Cypress Swamp-Pocomoke River	1998	1998	1	Low
MD	0	20	Newport Bay	1977	1977	1	Low
* No records from MD or DE State data but discovered in 2017 work.							
** Condition based on records and additional information.							

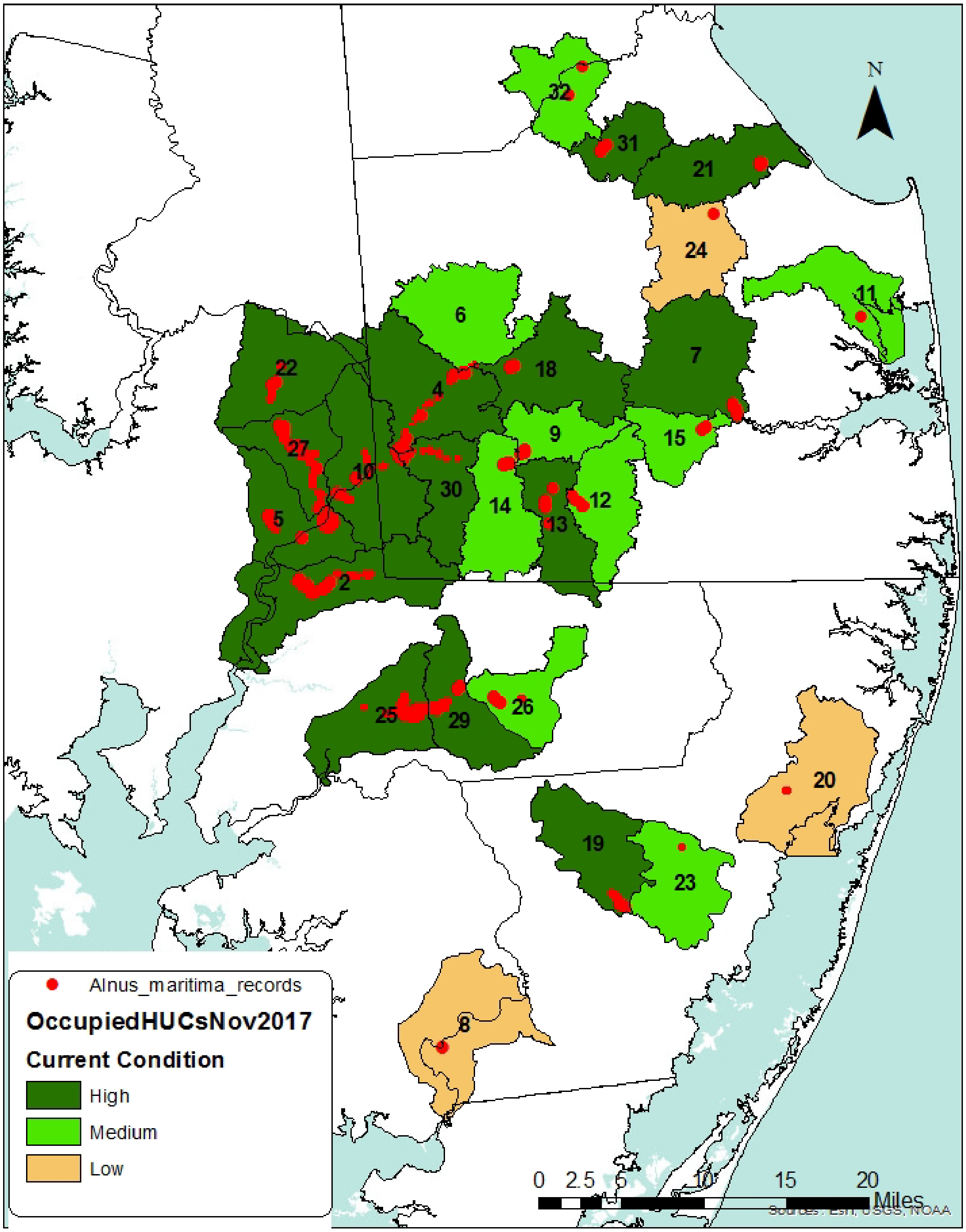


Figure 36. Current condition of Delmarva alder. HUC 12 watershed numbers correspond to names in table 11.

Summary of Delmarva representation and redundancy. Delmarva alder currently occurs in the full range of wetland habitats that it is originally known from; including tidal river marsh and shrub wetlands, to the edges of freshwater ponds and wetland forests. Its genetic diversity is high with low levels of inbreeding (Jones and Gibson 2011, p.1003). Thus we conclude that its *representation is high*.

The *redundancy* of the current Delmarva alder *is also high*. There are 27 HUC watersheds currently occupied by the Delmarva alder; 15 are in high condition, 9 are in moderate condition, and 3 are in low condition; and the connectivity between these is good. All high condition HUC watersheds are adjacent to another high or medium condition HUC, and one medium condition HUC is isolated by a very short distance. The most isolated HUCs are two low condition HUCs and, if lost, would not affect the overall redundancy of the subspecies.

4.2.1.3 Georgia alder

In addition to the analysis units metrics discussed above, we used water quality, water quantity, and sunlight availability as habitat metrics to characterize the Georgia alder's resiliency. Water quality was assessed using a combination of wetland buffer and HUC 12 land cover and impervious surface data; water quantity was assessed using a combination of average precipitation, drought, and temperature conditions, and aquifer condition data; and sunlight availability was assessed using Google Earth imagery (see Appendix A for more detailed information.

Table 12. Summary table of current analysis unit and habitat condition of the Georgia alder

CURRENT CONDITION RESILENCY SUMMARY	Demographic Factors				Habitat Factors				Overall resiliency Score
HUC 12 (analysis unit) Name	**Persistence**	**Abundance**	**Recruitment**	**Demographic Resiliency Score**	**Water Quality**	**Water Quantity**	**Sunlight Availability**	**Habitat Resiliency Score**	
Lower Euharlee Creek	High	Moderate	Moderate	Moderate	High	High	High	High	High

In summary, the overall *resiliency* of the Georgia alder analysis unit at Drummond Swamp is *high*.

As for *representation*, the Drummond Swamp site is the only known naturally occurring location for Georgia alder. In an examination of morphology, growth habitat, distribution, and habitat of Georgia alder conducted by Schrader and Graves (2002, p. 382), the Drummond Swamp analysis unit was described as having two “sub-populations,” Drummond West and Drummond East, that are separated by about 0.5 mi (0.8 km). These “sub-populations” were documented to have more diversity in morphology and habit than those “sub-populations” in the Delmarva, even though the geographical distribution and separation was much less for the Georgia alder subspecies. More recent aerial surveys of the Drummond Swamp site revealed that the Georgia alder are not separated but are distributed throughout the swamp, mostly along the swamp edges and in at least 6 main patches (figure 37) of varying sizes and densities (GDNR 2017, pp. 3–4; Moffett and Pattavina 2017). The Georgia alder occurs in two habitat conditions, in a shallow, sunny, sagpond lake formed by slumping of limestone bedrock and in a spring run that flows into and out of the sagpond. Furthermore, Jones (2013, p. 6) concluded that genetic diversity for the lone Georgia alder analysis unit was comparable to the other subspecies of seaside alder and appears to represent the genetic and ecological diversity known for the subspecies; however, it is limited to one naturally occurring site.

Figure 37. Distribution of Georgia alder (outlined in blue) throughout Drummond Swamp.

Redundancy for the Georgia alder is essentially zero (or very low), since there are no other known naturally occurring Georgia alder subpopulations known within the Lower Euharlee Creek Watershed, other watersheds in Georgia, or in the southeast region. Searches for additional subpopulations have been conducted with no new discoveries. As previously mentioned, there are conservation efforts underway using safeguarding sites to improve the Georgia alder's redundancy.

Summary of the Georgia alder current condition:

The Georgia alder's single analysis unit represents the genetic diversity of the subspecies and is currently considered to have overall high resiliency due to the high level of persistence, moderate levels of abundance and recruitment, and high levels of water quality and quantity and sunlight availability.

4.2.1.4 Oklahoma alder

In addition to the general analysis unit metrics previously discussed, we used sunlight, soil, water withdrawals, river base flow, and aquifer recharge as habitat metrics to characterize the Oklahoma alder's resiliency. Water quantity was assessed using a combination of average annual precipitation, drought regime, stream base flow, and aquifer recharge and discharge. For sunlight availability, we assessed flood regime. See Appendix A for additional information supporting the summary information below.

For some analysis units the specific information was not available; however, using our best professional judgement we made assumptions to complete our analysis based on what we do know about this species, habitat conditions, and the data reported. Demographic factors were assessed with survey data from the Oklahoma Natural Heritage Inventory. These surveys include data from 1946 to 2016 in which notes from each record were infrequently available. Survey data was collected as records. Each record could be a single plant, many individual plants, clumps, or multiple clumps. The information associated with each record varies. Systematic, regular surveys have not been conducted throughout the full range of this species; however, many surveys were conducted between 1946 and 2016 which covered areas within our seven analysis units. It is unclear as to why Desperado Spring Falls-Blue River site was extirpated, but the other two sites of the Oklahoma alder persist within the analysis unit. Survey information within and among analysis units varies in timing, data collected, and surveyor. To assess abundance for each analysis unit we used all survey data available.

Water Quantity –Resilient analysis units need inundated soils. The Oklahoma alder has adapted physiological structures to compete and persist and even thrive in hydric soils. Though some studies show that the seaside alder does not need inundated soils to survive, the Oklahoma alder naturally occurs in hydric soils on river and stream banks above the Arbuckle-Simpson Aquifer. The main driving factor for stream flow creating hydric soils is the spring flow from the Arbuckle-Simpson Aquifer. This area is unique because the base flow of these rivers and streams are primarily spring fed. Spring water is available during drought eras, keeping the soils wet for the Oklahoma alder (Tejan and Haase 2008, p. 54). Drought is typical in Oklahoma, but 3 to 4 years of drought or restricted streams are considered to result in a "moderate" habitat condition score for the Oklahoma alder. Any drought or water restrictions beyond 4 years are considered to result in a "low" habitat condition score for the Oklahoma alder.

Sunlight – Resilient analysis units of the Oklahoma alder need full sunlight and becomes stressed when other riparian vegetation compete for sunlight. Once the Oklahoma alder is shaded, it tends to die off. Flood events flush riparian vegetation from stream/river banks to open up the site for new riparian species, such as the Oklahoma alder.

Table 13. Analysis units for the Oklahoma alder.

Analysis Unit*	Subpopulations (records)	Status
Lower Pennington Creek		Extant
	Upper Pennington Creek	Extant
	Middle Pennington Creek A	Extant
	Middle Pennington Creek B	Extant
	Lower-Lower Pennington Creek A	Extant
	Lower-Lower Pennington Creek B	Extant
Pecan Creek-Blue River		Extant
Desperado Spring Falls-Blue River		Extant
	Upper Desperado	Extant
	Middle Desperado	Extant
	Lower Desperado	Extirpated
Little Blue Creek-Blue River		
	Upper Little Blue	Extant
	Lower Little Blue	Extant
	Stand-alone Sheep Creek	Extant
Bois d'Arc Creek		Extant
Sheep Creek		Extant
	West Sheep Creek	Extant
	Middle Sheep Creek	Extant
	East Sheep Creek	Extant
	Stand-alone Sheep Creek	Extant
Sandy Creek		Extant

* Note: This table underestimates the number of potential analytical units and subpopulations (as of April 17, 2018) because we became aware of an additional record subsequent to the completion of our analysis. While the location became known, the underlying demographic information was not readily available.

Scoring

We averaged all the seven condition category scores for each analysis unit to determine the overall resiliency score. To provide context for this score we established an overall resiliency scale from 0 to 3 to communicate our understanding of the overall condition of each analysis unit (table 14). To determine the overall resiliency scale we first determined the highest score attainable (3) and the lowest score attainable (0). Within this range, we established four overall resiliency levels based on the number of analysis units and habitat factors in the condition categories as shown in Table 15. Appendix A provides the ranking of each analysis unit and habitat factor for current condition.

Table 14. Overall resiliency scale with scoring.

Overall Resiliency	
Extirpated	0–0.49
Low	0.5–1.3
Moderate	1.4–2.1
High	2.2–3.0

For each of the seven analysis unit and habitat factors described in Section 5.2 we developed condition categories (High, Moderate, Low, and Extirpated) to assess the condition of each factor for each analysis unit (table 15) in order to determine the overall analysis unit resiliency. Some factors rely on qualitative metrics while with others, where more data is available, we were able to develop quantitative metrics. We assigned a numerical value to the condition categories, High=3, Moderate=2, Low=1, and Extirpated =0, so we could calculate an overall Score.

Table 15. Oklahoma alder current condition resiliency.

Main River	Analysis Unit*	Abundance Score	Distribution Score	Soil Score	Sunlight Score	Withdrawal Score	Base flow Score	Recharge Score	Analysis Unit Resiliency
Pennington	Lower Pennington Creek	2	3	2	3	3	3	3	High
Blue	Desperado Spring Falls-Blue River	2	2	2	3	3	3	3	High
Blue	Pecan Creek-Blue River	2	1	2	3	3	3	3	Moderate
Blue	Little Blue Creek-Blue River	3	3	2	3	3	3	3	High
Clear Boggy	Sandy Creek	1	1	2	3	3	3	3	Moderate
Clear Boggy	Sheep Creek	2	3	2	3	3	3	3	High
Clear Boggy	Bois d' Arc Creek (Mill Cr)	1	1	3	3	3	3	3	Moderate

* As of April 17, 2018.

Representation

A slightly higher degree of inbreeding was detected in the Oklahoma (as well as the Georgia) subspecies than the Delmarva subspecies. These data suggest that maternal trees in the Blue River analysis unit are potentially mating with related individuals to a greater extent than trees in the Drummond Swamp subspecies. Still, there was not a significant level of inbreeding detected in either analysis unit (Jones and Gibson 2012, p. 6).

Redundancy

Oklahoma alder is restricted to spring-fed streams and rivers above the Arbuckle-Simpson aquifer. More specifically, it is restricted to Mill Creek, Sheep Creek, Sandy Creek, Pennington Creek, Blue River, and their tributaries. Records from Oklahoma Natural Heritage Inventory indicate that Oklahoma alder has been extirpated from one site in the southern portions of the Desperado analysis unit. We are aware of seven analysis units with the number of subpopulations ranging from one to five per analysis unit. Four analysis units have multiple subpopulations and three have only one subpopulation. There is little connectivity potential between analysis units. Consequently, if one analysis unit is lost it is unlikely that another analysis unit will be able to reestablish the lost analysis unit.

Summary of Oklahoma alder current condition:
In summary, there are four analysis units in high and three in moderate condition. There are seven analysis units with multiple subpopulations in four of them, providing redundancy for the Oklahoma alder. The Oklahoma alder is restricted to specific rivers dependent on the Arbuckle-Simpson Aquifer; however, genetic diversity is high, providing representation for the subspecies.

4.2.2 Seaside Alder Current Condition Summary

For the seaside alder as a whole, its current condition can be summarized as having analysis units with mostly high resiliency, redundancy of 35 extant analysis units, and representation in terms of genetic and ecological diversity. The condition of these analysis units are: 20 in high condition, 12 in moderate condition, and 3 in low condition (see table 10); thus ensuring the species' ability to withstand stochastic events (resiliency). These 35 analysis units are distributed across 3 areas (i.e., corresponds to the subspecies) of the country—27 in Maryland/Delaware (with a range of high (19), moderate (10), and low (3) resiliency categories), 1 in Georgia (with a high resiliency category), and 7 in Oklahoma (with a range of high (4) and moderate (3) resiliency categories)—thus ensuring the species' ability to withstand catastrophic events (redundancy). Across the range, the species occurs in a wide range of freshwater habitat types (tidal rivers, marsh and ponds, and spring-fed streams and rivers) and is adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment (representation). Genetic diversity was sufficiently varied across the range to indicate subspecies.

Chapter 5. SPECIES VIABILITY

As discussed in Chapter 1, for the purpose of this assessment, we define **viability** as the ability of the species to sustain analysis units in the wild over time (in this case, 30 to 80 years, based on the range of best available sea level rise, urbanization, groundwater, and climate model forecasts, depending on the relevant data for each subspecies, as well as the effects of conservation management). Using the SSA framework, we describe the species' viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation.

We have considered seaside alder's life history characteristics, identified the habitat and analysis unit requisites needed for viability (Chapter 2), reviewed the factors that may be driving the historical, current, and future conditions of the species and its subspecies (Chapter 3), and estimated the current condition of those needs through the lens of the 3Rs (Chapter 4). Next, we predict the seaside alder's future conditions to inform us of the viability of the species. We used the demographic and habitat information to predict how the 35 HUC watershed analysis units currently occupied by the Delmarva/Georgia/Oklahoma alder will respond to the primary factors likely to influence the species' condition in the future. These influence factors varied by geographic area and included: changing climate conditions (increases in saline storm surges, drought, flooding, and temperature), decreased water availability, urbanization, human population growth, and conservation management, where applicable. Our analysis is limited to three future scenarios, which are representative examples from the potential range of plausible scenarios, and that describe how these stressors to the species may drive changes from current conditions. Because the stressors vary by geographic region (or subspecies), we describe these stressors and future scenarios for each region below.

5.1 Future Scenarios

Projections of seaside alder resiliency, redundancy and representation were forecasted using two time steps, 30 and 80 years out (2050 and 2100) for most scenarios (see the Delmarva alder section below for 2100 time step surrogate information). These time steps were chosen to correspond to the range of available sea level rise, development, groundwater, and climate model forecasts, depending on the relevant data for each subspecies. In addition, the 2050 time step represents a time frame during which the effects of any applicable conservation management can be implemented and realized, and is a reasonable timeframe for the species to respond to potential changes on the landscape. The 2100 time step represents a potential longer-term trajectory for the species, but with a lower confidence in the outcome than in the 2050 projection.

5.1.1 Delmarva alder

The main driver likely to affect the future of the Delmarva alder is the potentially greater area influenced by saline storm surges as sea levels rise (table 16). The magnitude of this stressor is high as Delmarva alder is not tolerant of saltwater and we have seen extirpations of some specific ponds in the past (Hurricane Sandy and Turkle pond at Prime Hook NWR).

Table 16. Summary of past and future changes in influence factors.

Stressor	Magnitude	Trends in the past 30 years	Trends in the next 30 years	Change in Delmarva alder condition in the future
Saline Storm Surges	Large	Frequency of flooding has increased over the past 30 years (Ezer and Atkinson 2014, entire).	Likely to continue to increase in frequency. Analysis units (i.e., HUCs) that are closest to the coast and estuarine areas are likely to be the first ones affected. Inland HUCs are not likely to be affected.	Extirpation is expected in some HUCs but at least 20 HUCs are secure from saline storm surge, including the HUC's with the largest populations
Erosion of Wide Marsh Habitat Bordering Large Tidal Rivers	Medium/ small	No obvious change in the marsh and shoreline of the Nanticoke River is evident or visible in imagery between 1999 and 2017. There are a few areas where deposition is suggested, but overall no major changes despite some commercial and sport boat traffic.	Possibly some increases from faster and larger barges, but the lack of development opportunities along many areas of shoreline (Table current condition) reduces risks of shoreline hardening and loss of habitat. Protected status of most of the pond habitat makes losses in these settings unlikely.	Some reduction may occur but deposition is also likely that may balance this out. No large changes anticipated.
Increased Shade	Medium/ small	In the past 30 years, the amount of shade from riparian forests may have minimally increased as riparian forests mature and conservation laws have emphasized protection of mature forests.	The emerald ash borer will provide some openings in the canopy and provide more sun to Delmarva alder in some locations. Increasing beaver populations may also open a few areas. Sea level rise may also kill some trees in adjacent areas, thus increasing sunlight. But the extent of these influences is likely to be limited. We anticipate the same conservation laws and emphasis on maintaining mature forest in the riparian areas to continue.	Little long term change, with possible short term improvements.

The frequency of flooding from saline storm surge is likely to increase in the future as it has in the past. Ezer and Atkinson (2014; entire) document that the hours of flooding above mean high tide in Norfolk (mouth of the Chesapeake Bay) and Lewes Delaware have increased between 1940 and 2010 and this flooding is most often a result of smaller storms rather than hurricanes. Tebaldi *et al.* (2012, p.6) find that flooding from extreme water levels is likely to be increased by sea level rise but the salinity of this water depends on the influence of freshwater river flows down the estuary as well. The extent of tidal surge is highly dependent on wind direction, location, salinity of adjacent waters and the extent of the rainfall.

While changing climate conditions may increase the frequency of hurricanes or other storms, these do not always produce a storm surge of saline water. For example, the remnants of Hurricane Agnes in 1972 went directly north through the Chesapeake Bay. While Agnes caused major flooding in the Washington, D.C. area, the northern portion of the Bay was more affected by the mass influx of freshwater from 11 in (28 cm) of rain that caused major population effects to oysters and other marine life in the Bay (Chesapeake Research Consortium 1976, pp. 1–29). High levels of flooding can also occur without any associated storms but from the combination of wind direction, spring tides, and ocean currents, as occurred in the summer of 2009 (Sweet *et al*. 2009, entire). We do not have an estimate of how frequently the right conditions occur to produce a saline storm surge, but we assume that sea level rise will result in a “greater reach” of the saltwater further inland when those conditions do occur, including to some analysis units currently occupied by Delmarva alder.

We classified each HUC into High, Moderate, and Low condition based on the following: 1) the proportion of a watershed that has estuarine marsh as evidence of proximity to brackish or saline waters; 2) whether adjunct waters were from the fresher Chesapeake Bay estuary or the more saline waters of the Delaware or Atlantic drainages, 3) whether storm surge from Sandy had occurred in the HUC indicating current exposure to storm surge, and the potential for future exposure; and 4) whether occupied sites were behind dams or roads to determine the relative vulnerability of the current populations to future storm surge.

We have provided three scenarios for future sea level rise relying on the data summarized by Glick *et al*. 2008 (entire) using the Sea Level Affecting Marshes Model (SLAMM) model. This model incorporates inundation, erosion, over-wash, saturation, and salinity as part of the influential parameters, and starts with a base line year of 1996 and projects into the future using various IPCC (2001) scenarios (Glick *et al*. 2008, p.16). Although the IPCC climate models were updated in 2014, the SLAMM model using the older IPCC climate models is the best available information for sea level rise in the Delmarva Peninsula because it is site specific for this area and incorporates the other important influential factors of inundation, erosion, over-wash, saturation, and salinity.

We chose to project three future scenarios out to the year 2050 because: (1) the SLAMM model’s 2025 output is only 8 years away from the current condition and did not appreciably differ from our Continuation and Moderate Impacts scenarios’ projection at year 2050, and (2) given the complexities of sea level rise, increasing storm surges and increasing variability in climate that is expected, the uncertainties in projecting beyond 2050 were too great (Kearny 2013, entire). See table 17 below.

The three future scenarios modelled for sea level rise are:

1) **Continuation:** assumes no increase in the rate of sea level rise in the future and uses the simple extrapolation of the historical rate of change (0.34 m/100 yrs (1.1 ft/100 yrs)) into the future. This is optimistic because the future rate is expected to increase.

2) **Moderate Impacts:** using the **A1BMean** model with a rate of change 0.39 m/100 yrs (1.3 ft/100 yrs), and a value of 17 cm (6.7 in) by 2050.

3) **Major Impacts:** the **A1BMax** scenario with a rate of change of 0.69 m/100 yrs (2.3 ft/100 yrs), and a value of 30 cm (11.8 in) by 2050.

The A1 scenario describes a future world of very rapid economic growth, and global population that peaks in mid-century and declines thereafter; the A1B group is considered balanced between fossil and non-fossil sources of energy. The mean and maximum model results are the average and maximum of model runs (IPCC 2018). The scenarios vary primarily in how fast sea level rises, with the Major Impacts scenario assuming the fastest rate and the highest levels by 2050. Note that the 2050 value under the Major Impact scenario (sea level rise of 30 cm (11.8 in)) is very similar to the 2100 value for the Continuation or Minor Impact scenario (sea level rise of 28 cm (11.0 in)). Thus, consideration of effects out to 2100 could be made using the Continuation or Minor Impact scenario. However, we recognize that the variability in climate is also anticipated to increase with more extremes in temperature and precipitation, and thus predictions of sea level rise are also more difficult to make further into the future (Kearney 2013, entire). Therefore, we have focused on 2050 as the target date for future analysis but have included information for 2100 for comparative purposes.

Table 17. Sea level rise (in centimeters) predicted by three scenarios. The A1BMean and A1BMax values were estimated by the SLAM model; the Continuation scenario is based on the average historical rate of 3.4 mm/year or 0.34 m/100 year extrapolated to the same time frames as the SLAM model.

Scenario	**Centimeters of Sea Level Rise By Year**			
	2025	**2050**	**2075**	**2100**
Continuation or Minor Impact 2050 (Historical Rate at 0.34 m/100 yr (1.1 ft/100 yrs))	3	**11**	19	28
Moderate Impacts 2050 (A1BMean at 0.39 m/100 yr (1.3 ft/100 yrs))	**8**	**17**	**28**	39
Major Impacts 2050 (A1BMax at 0.69 m/100 yr (2.3 ft/100 yrs))	14	**30**	49	69

We recognize that sun/shade and periodically inundated soil condition also contribute to Delmarva alder's resiliency. However, we are unable to quantify changes in those values across time at the analysis unit level and available information suggests these are not likely to be limiting. Therefore, our future scenarios focus solely on changes in sea level rise which would cause shifts in salinity values in the analysis units (see table 18, figure 38). A summary of the expected analysis units and their condition in the future is provided in the table and figure below.

Table 18. The current condition of the analysis unit in each HUC and estimated future condition in 2050 using a Continuation (or Minor Impacts), Moderate Impacts, and Major Impacts scenario for sea level rise.

ID	HUC 12 Name	CURRENT CONDITION	CONTINUATION OR MINOR IMPACTS 2050	MODERATE IMPACTS 2050	MAJOR IMPACTS 2050
	HUCs That Are Not Expected to Change in the Future				
27	Stony Bar Creek-Marshyhope Creek	High	High	High	High
30	Tussocky Branch-Broad Creek	High	High	High	High
31	Upper Cedar Creek	High	High	High	High
4	Butler Mill Branch-Nanticoke River	High	High	High	High
10	Gales Creek-Nanticoke River	High	High	High	High
19	Lower Nassawango Creek	High	High	High	High
22	Puckum Branch-Marshyhope Creek	High	High	High	High
29	Tonytank Creek-Wicomico River	High	High	High	High
7	Cow Bridge Branch-Indian River	High	High	High	High
18	Lower Deep Creek	High	High	High	High
13	James Branch	High	High	High	High
32	Upper Mispillion River	Moderate	Moderate	Moderate	Moderate
15	Long Drain Ditch-Betts Pond	Moderate	Moderate	Moderate	Moderate
26	South Prong Wicomico River	Moderate	Moderate	Moderate	Moderate
9	Elliott Pond Branch - (discovered)	Moderate	Moderate	Moderate	Moderate
12	Hitch Pond - (discovered)	Moderate	Moderate	Moderate	Moderate
14	Little Creek Broad Creek - (discovered)	Moderate	Moderate	Moderate	Moderate
23	Purnell Branch-Pocomoke River	Moderate	Moderate	Moderate	Moderate
6	Clear Brook-Nanticoke River	Moderate	Moderate	Moderate	Moderate
24	Round Pole Branch-Broadkill River	Low	Low	Low	Low
	HUCS That Are Expected to Change in the Future				
2	Barren Creek-Nanticoke River	High	High	Moderate	Moderate
5	Chicone Creek-Nanticoke River	High	High	Moderate	Moderate
21	Primehook Creek	High	Moderate	Moderate	Moderate
25	Shiles Creek-Wicomico River	High	Moderate	Moderate	Moderate
11	Herring Creek-Rehoboth Bay	Moderate	Low	Extirpated	Extirpated
8	Cypress Swamp-Pocomoke River	Low	Low	Extirpated	Extirpated
20	Newport Bay	Low	Low	Extirpated	Extirpated

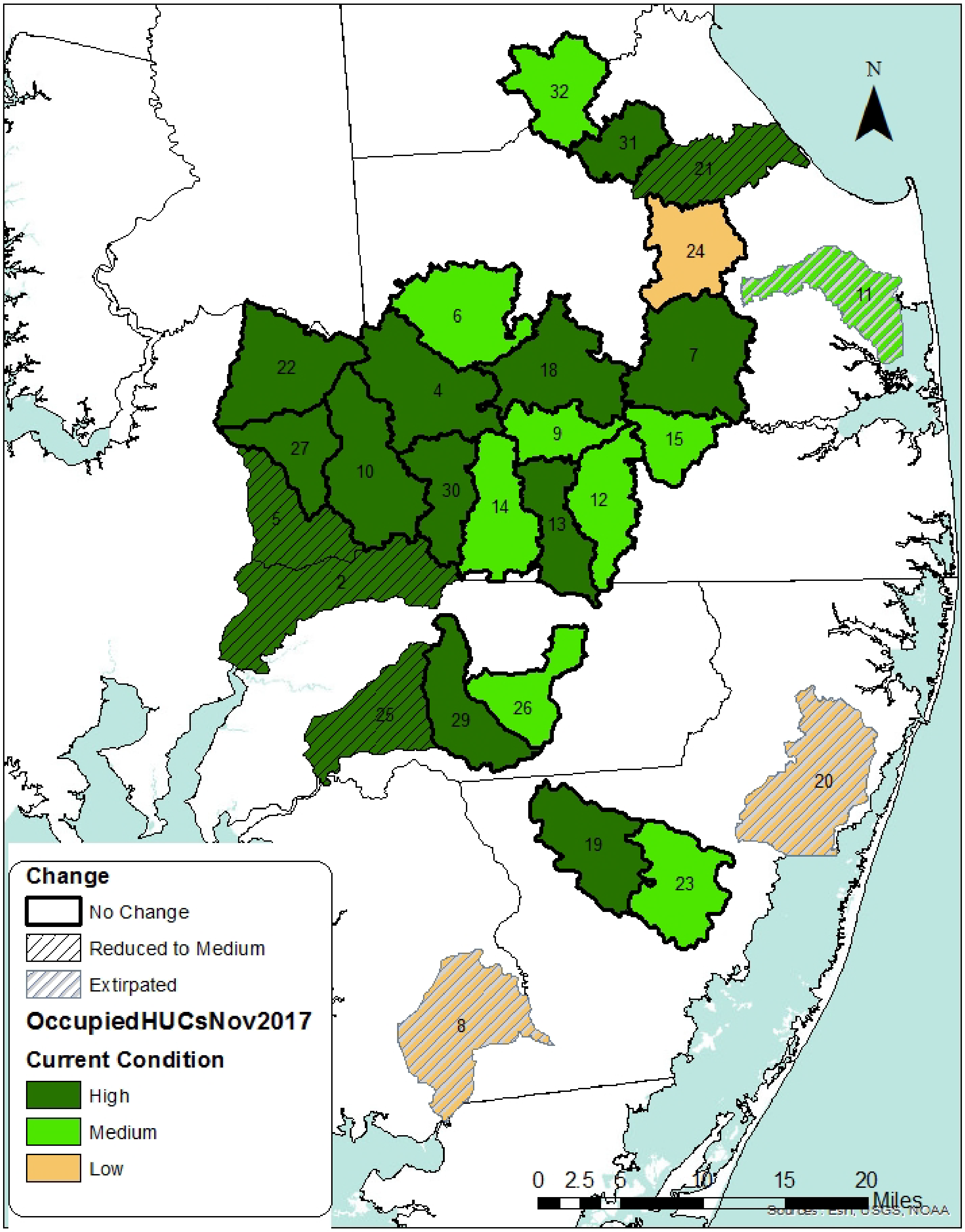


Figure 38. Current and future conditions of HUC 12 watersheds (i.e., analysis units) under the Major Impacts 2050 scenario. Note that three HUC's (ID # 11, 20, and 8) are considered extirpated under this scenario.

By 2050, our analyses suggest some analysis units will be diminished even under the Continuation Scenario (table 19), but all are extant. However, in the Moderate Impacts and Major Impacts Scenarios, three analysis units become extirpated.

In contrast to the extirpations, 20 analysis units exhibit no change in their original condition using these definitions, even under the Major Impacts Scenario, because they are in the center of the Peninsula, have no estuarine marsh, and are considered not affected by sea level rise (table 20). These include the Nanticoke River drainage in the center of the Delmarva Peninsula and many ponds and upper reaches of the Delaware River. While there is some uncertainty regarding the future of the upper reaches of the Nanticoke River, the wide meander marshes of the Nanticoke are unique compared to other watersheds on the Delmarva and are thought to provide greater buffers from sea level rise than other watersheds (Kearney 2018). In addition, future climate in the mid-Atlantic is likely to be cooler and wetter (Najjar *et. al*. 2009, entire) and the additional freshwater from precipitation would push the salinity gradient further downstream, counteracting the effects of saline storm surge. Given the best available information, we conclude that within these 20 analysis units, small changes in individual sites may occur from other types of stressors, but not at levels that influence the condition of the entire analysis unit.

Table 19. Summary of analysis unit conditions estimated in each of the future scenarios.

Mean Scenario	Current Condition	CONTINUATION OR MINOR IMPACTS 2050	MODERATE IMPACTS 2050	MAJOR IMPACTS 2050
# High	15	13	11	11
# Moderate	9	10	12	12
#Low	3	4	1	1
# Extirpated	0	0	3	3
TOTAL	27	27	27	27

Redundancy

The total number of extant analysis units occupied is expected to range between 24 and 27 depending on whether the Major Impacts Scenario or Continuation Scenario of sea level rise occurs. The losses are on the periphery of the range and the 24 analysis units remaining under the Major Impacts Scenario are all adjacent to at least one other analysis unit in high or medium condition. Thus, under the Major Impacts Scenario for 2050 (or the Continuation Scenario for 2100) there would be 11 highly resilient analysis units, 12 of moderate resiliency, and 1 of low resiliency. Overall, we consider the Delmarva alder to retain high redundancy in the future.

Representation

By 2050, even under the Major Impacts Scenario, the remaining analysis units would span the range of habitats available on the Delmarva and would include all currently occupied types of wetland habitats. Thus, representation is expected to be high under the Major Impact 2050 Scenario (or the Continuation 2100 Scenario).

Resiliency

By 2050, under the Major Impacts Scenario, there would be 11 highly resilient analysis units, 12 moderately resilient analysis units, and 1 analysis unit with low resiliency. While this is a decrease from current conditions, we consider the overall resiliency of Delmarva alder to remain high. The alder has many strategies for coping with a wide range of water conditions, from droughts to floods, and being able to reproduce asexually and sexually should help it to continue to persist in those areas where saline waters are not expected to occur.

Summary of Delmarva alder future condition:

Overall, by 2050, we anticipate continued persistence of Delmarva alder in at least 24 analysis units with most of these analysis units being in high or moderate condition. These analysis units are relatively connected with all having at least one adjacent analysis unit to provide connectivity. While saline storm surges combined with sea level rise may result in extirpation of three analysis units, the remaining populations are expected to continue to persist.

5.1.2 Georgia Alder

There are three main drivers likely to affect the future condition of the Georgia alder: urbanization (including human population growth), changing climatic conditions (i.e., precipitation patterns [drought] and temperature), and conservation measures.

Urbanization and Human Population Growth

Urbanization and human population growth are expected to have significant impacts to Georgia alder habitat conditions in the future. Specifically, degradation of water quality at local and watershed scales due to runoff and contamination, reduced water quantity due to human water demand, and changes in sunlight conditions due to shifts in water quantity and vegetation changes, especially invasive species (e.g., Chinese privet), that affect the competitive ability of Georgia alder.

To forecast future urbanization, we developed future scenarios that incorporate the SLEUTH (Slope, Land use, Excluded area, Urban area, Transportation, Hillside area) model, which simulates patterns of urban expansion that are consistent with spatial observations of past urban growth and transportation networks, including the sprawling, fragmented, "leapfrog" development that has been the dominant form of development in the Southeast (Terando *et al*. 2014, p. 2). Terando *et al*. (2014, entire) projected urban sprawl changes for the next 50 years for the fast-growing Southeastern United States, using simulations that point to a future in which the amount of urbanized land in the Southeast is projected to increase by 101 percent to 192 percent. We describe three scenarios below that incorporate three different probabilities of urbanization at two time steps 2050 and 2100, a current rate of urbanization predicts areas that have an 80 percent or greater probability of development, a moderate rate of urbanization that predicts 30 percent or greater probability of development, and a high rate of urbanization that predicts areas that have any probability of development according to the Southeast Regional Assessment Project (SERAP) (Jantz *et al*. 2010, entire; Terando *et al*. 2014, p. 1).

Climate Conditions

Changing drought and precipitation patterns: Changes in precipitation and drought may be the biggest influencing factors for Georgia alder, due to the importance of rainfall on maintaining Georgia alder. Schrader and Graves (2002, p. 393) suggests that rainfall may be more important than saturated soils from ground water because the Georgia alder were located significantly higher from the water table than the Delmarva and Oklahoma populations. Changing climate conditions (table 21) are likely to exacerbate the impacts of urbanization and human population growth on Georgia alder. For the effects of climate change, we used projected impacts based on the International Panel on Climate Change's (IPCC) Representative Concentration Pathway RCP 8.5 emissions scenario, as the latest data indicates that this is the current trajectory (Brown and Caldeira 2017, entire).

Table 20. Predicted changes in percent (%) urbanized area within the analysis unit and climate conditions for Bartow County, GA across two time steps.

Scenario	Year	Change in % Urbanized HUC 12 (total % urbanized)	Change in Water Demand (total MGD)	Change in Temperature	Change in Precipitation	Change in Evapo-transpiration	Change in Soil Water Storage
Continuation (RCP 8.5 and Moderate Urbanization)	2050	+18.8 (22.86)	+325 MGD (574 to 899)	+2.9°F	+0.2 inches per month	+0.2 inches per month	-0.1 inches
	2100	+46.8 (50.89)	No data	+8.1°F	+0.3 inches per month	+0.3 inches per month	-0.5 inches
Increased Impact (RCP 8.5 and High Urbanization)	2050	+21.48 (25.58)	+426 MGD (574 to 1,000)	+2.9°F	+0.2 inches per month	+0.2 inches per month	-0.1 inches
	2100	+52.2 (56.30)	No data	+8.1°F	+0.3 inches per month	+0.3 inches per month	-0.5 inches
Conservation Focused (RCP 8.5 and Current Rate Urbanization)	2050	+16.1 (20.19)	+325 MGD (574 to 899)	+2.9°F	+0.2 inches per month	+0.2 inches per month	-0.1 inches
	2100	+41.2 (45.30)	No data	+8.1°F	+0.3 inches per month	+0.3 inches per month	-0.5 inches

Conservation Management

Conservation measures such as land protection, land management, restoration, wetland buffers and conservation horticulture (safeguarding) all play an important role in ensuring the viability of Georgia alder into the future. These measures may help offset the impacts of increasing human population and urbanization which are exacerbated by changing climate conditions. We consider the role conservation measures may have under three plausible scenarios which include continuation of current conservation actions, reduced conservation actions and accelerated conservation actions.

Scenarios

The Georgia alder has remained relatively stable over potentially a very long time. However changing climate conditions and urbanization may have significant influences on the Georgia alder in the future. Therefore, three scenarios were used to characterize plausible futures for the Georgia alder. Resiliency, representation and redundancy were forecasted for each scenario under the 8.5 RCP climate predictions with variable levels of urbanization and conservation management.

Predictions of Georgia alder resiliency, redundancy and representation were forecasted using two time steps, 2050 and 2100. These time steps were chosen to correspond to the range of available urbanization and climate model forecasts. The 2050 time step represents a time frame during which the effects of conservation management can be implemented and realized and is a reasonable timeframe for the species to respond to potential changes on the landscape. The 2100 time step represents a potential longer-term trajectory for the species but lower confidence in the outcome, than the 2050 projection.

The three scenarios and their impact on Georgia alder resiliency, redundancy and representation are described in the following sections and summarized in table 22. In general, these scenarios are (1) *Continuation*: where current conservation management is coupled with potential effects of changing climate condition and urbanization; (2) *Increased Impact*: where conservation management regresses and synergistic impacts of changing climate and urbanization increase; and (3) *Conservation Focused*: where conservation management increases and strategically targets actions to abate impacts of changing climate and urbanization.

Table 21. Summary of Georgia alder future scenarios.

Scenario Name	Climate Future	Urbanization	Conservation Management	Water Quality Condition	Water Quantity Condition	Sunlight Availability	Species Condition
(1) Continuation	Current climate effects continue, resulting in increased temperature, drought, storms and flooding (8.5 RCP)	Urbanization continues on at a moderate rate. Considers areas with at least 30% or more probability of development to occur.	Current conservation practices continue, such as reforestation in the uplands owned by GPC surrounding Drummond Swamp and these lands remain in natural condition. Safeguarding populations continues. Water conservation measures in developed areas continue. Resources needed to continue conservation efforts are sustained.	Minimum BMPs for vegetative buffers adjacent to wetlands are implemented, current water quality conditions are maintained, low degradation of water quality	Decreased spring-flow conditions resulting from climate change. Water usage (surface and groundwater) increases as human population grows. Current level of water conservation practices are implemented to help off-set impacts.	Habitat structure experiences some modifications that may increase or decrease sunlight availability	Species response to synergistic impacts from urbanization and climate change result in low to moderate population decline but may be offset by conservation management; species safeguarding continues
(2) Increased Impact	Current climate effects continue, resulting in increased temperature, drought, storms and flooding (8.5 RCP)	Urbanization continues at a high rate. All probabilities of development to occur.	Current conservation practices regress. Land protections are lifted and management surrounding Drummond Swamp degrades or destroys habitat for Georgia alder. Safeguarding sites fail and/or lose support from conservation organizations due to limited resources	Minimum BMPs for vegetative buffers adjacent to wetlands are not implemented, water quality declines	Decreased spring-flow conditions resulting from climate change. Water usage increases as human population grows. Current water conservation practices are not sufficient to off-set impacts	Habitat structure experiences increased modifications that may increase or decrease sunlight availability	Species response to synergistic impacts from urbanization and climate change result in significant population decline coupled with limited or no conservation management
(3) Conservation Focused	Current climate effects continue, resulting in increased temperature, drought, storms and flooding (8.5 RCP)	Urbanization continues on at current rate. Considers areas with at least 80% or more probability of development to occur.	Conservation practices are expanded beyond current condition actions, such as additional land protection in strategic areas, invasive species removal and management, site specific water quantity and quality data are monitored. Resources are increased.	BMPs for vegetative buffers adjacent to wetlands are implemented above minimum standards, minimal degradation of water quality	Decreased spring-flow conditions resulting from climate change. Targeted strategies to protect (or improve) water resources in priority areas	Habitat structure is maintained (or improved) to provide adequate sunlight availability	Species response to synergistic impacts from urbanization and climate change result in low population decline but may be offset by land protection and conservation management; species safeguarding (augmentation) expands

Scenario 1: Continuation Scenario

Under the Continuation scenario, factors that influence the Georgia alder analysis unit were assumed to remain constant over both time steps. In general the Climate Model (8.5 RCP) predicts an increase in temperature and precipitation, however the precipitation may be offset by increased evapotranspiration. Soil water storage also decreases. Urbanization is predicted to increase at a moderate rate (at least 30 percent or greater probability) over time with 23 and 51 percent of the watershed urbanized in 2050 and 2100 respectively (table 21, above; figure 39, below). These levels of urbanization will degrade water quality within the watershed. The degree of changes in climate and urbanization conditions increases between the two time steps (table 20). Water demand in the North Georgia Water Planning District is predicted to increase from 574.5 to 899.0 Average Annual Day–Million Gallons per Day (AAD-MGD) by 2050 (WMP 2017). This water demand (usage) assumes enhanced efficiency standards. In this scenario other conservation measures are also maintained at current levels, including existing land protections and management.

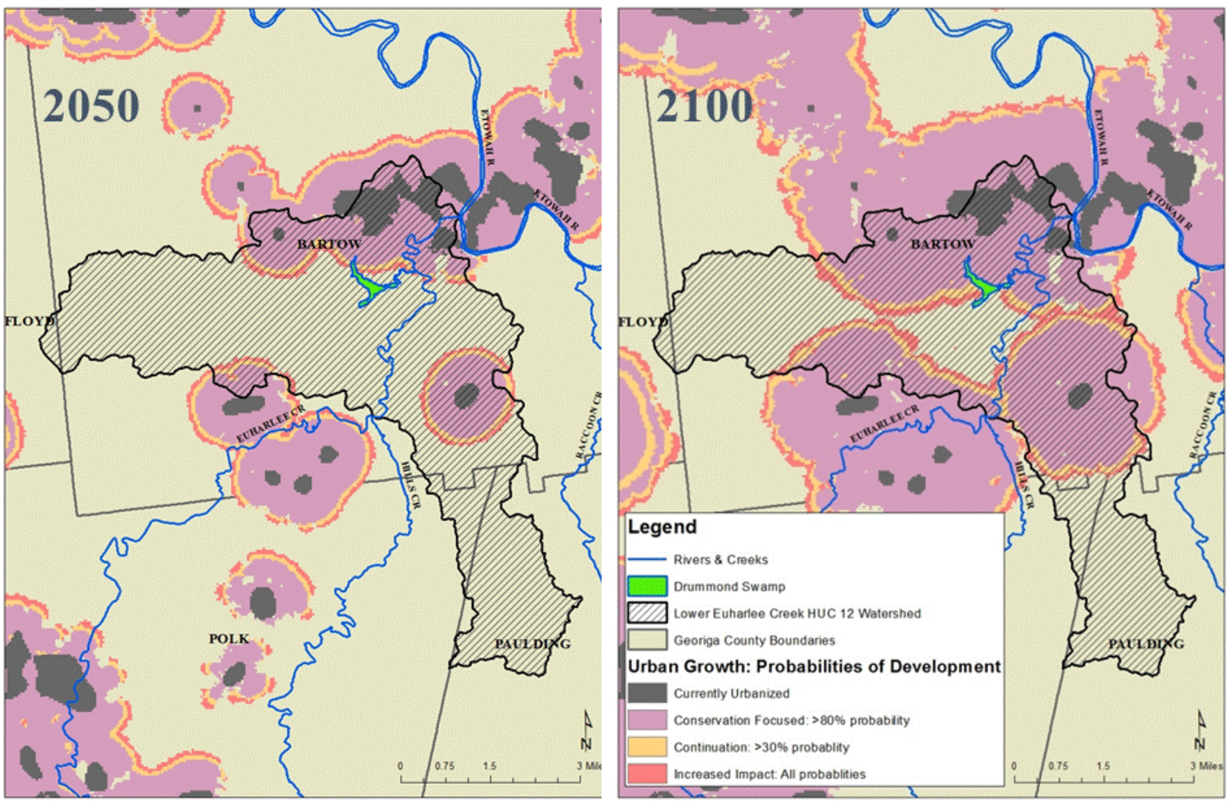


Figure 39. Probabilities of urbanization within the Lower Euharlee Creek watershed based on SLEUTH model for years 2050 and 2100. Conservation Focused: >80% probability of development; Continuation: > 30% probability of development; Increased Impact: all probabilities of development.

Resiliency

Based on projections for 2050, in this scenario, overall resiliency of the Georgia alder is expected to decrease due to degraded water quality and quantity (table 22). While most of the urbanization occurs downstream from the Georgia alder site, and therefore impacts of runoff from impervious surface may be minimal, some development, such as single family homes, adjacent to Drummond Swamp is probable. Increased water demand combined with more frequent and serve droughts will likely constrain water availability for the Georgia alder. Projections for 2100 have the same trajectory, but due to increased urbanization within the overall watershed, both upstream and downstream from the Georgia alder, water quality and quantity are expected to degrade further such that abundance and recruitment of the Georgia alder are diminished to low levels. Sunlight availability may increase due to development; however, invasive species, such as Chinese privet, may become more widespread with development and reduce sunlight availability over time.

Table 22. Summary of Georgia alder future condition under Continuation Scenario.

Scenario 1: Continuation		Demographic Factors				Habitat Factors				Overall Condition Score
HUC 12 Name	Year	Approximate Abundance	Persistence	Recruitment	Overall Demographic Score	Water Quality	Water Quantity	Sunlight Availability	Overall Habitat Score	
Lower Euharlee Creek	2050	Moderate	High	Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate
	2100	Low	Moderate	Low	Low	Low	Low	Moderate	Low	Low

Representation and Redundancy

Under the Continuation scenarios, it is predicted that representation will remain the same (moderately-low) by 2050. Georgia alder is expected to persist within both sag pond and spring-run habitat types at Drummond Swamp. However by 2100, it is possible that habitat conditions shift dramatically due to impacts from human population growth and urbanization and Georgia alder are no longer represented in multiple habitat types. We assume that safeguarding analysis units persist with active conservation management and therefore redundancy remains low across both time steps.

Scenario 2: Increased Impact

Under the Increased Impact scenario, factors that influence the Georgia alder analysis unit were assumed to increase at high rates over both time steps. The Climate Model (8.5 RCP) is the same as in the Continuation Scenario and predicts an increase in temperature and precipitation; however the precipitation may be offset by increased evapotranspiration. Soil water storage also decreases. Urbanization is predicted to increase at a higher rate (all probabilities of urbanization) over time with 26 and 56 percent of the watershed urbanized in 2050 and 2100 respectively (table 21 and figure 39, above). These levels of urbanization are expected to degrade water quality within the watershed. The degree of changes in climate and urbanization conditions increases between the two time steps (table 21, above). Water demand in the North Georgia Water Planning District is predicted to increase from 574.5 to 1,000 (AAD-MGD) by 2050 (WMP 2017, pp. 4–17). This water demand (usage) assumes enhanced efficiency standards are not effectively implemented. In this scenario other conservation measures are also diminished or removed due to lack of resources, including existing land protections, land management and safeguarding.

Resiliency

Based on projections for 2050, in this scenario, overall resiliency of the Georgia alder is expected to decrease further than the Continuation Scenario due to higher levels of degraded water quality and quantity that will be exacerbated by future climate conditions (table 23). While most of the urbanization occurs downstream from the Georgia alder site, and therefore impacts of runoff from impervious surface may be minimal, development (residential and/or commercial) adjacent to Drummond Swamp is probable. Vegetative buffers adjacent to wetlands are not implemented and increased water demand combined with more frequent and severe droughts will likely constrain water availability for the Georgia alder. Projections for 2100 have the same trajectory, but due to increased urbanization within the overall watershed, both upstream and downstream from the Georgia alder, water quality and quantity are expected to degrade further such that abundance and recruitment of the Georgia alder are diminished to low levels, which may lead to reduced likelihood of persistence. Sunlight availability may increase due to development; however, invasive species, such as Chinese privet, may become more widespread with development and reduce sunlight availability over time

Table 23. Summary of Georgia alder future condition under Increased Impact Scenario.

Scenario 2: Increased Impact		Demographic Factors				Habitat Factors				Overall Condition Score
HUC 12 Name	Year	Approximate Abundance	Persistence	Recruitment	Overall Demographic Score	Water Quality	Water Quantity	Sunlight Availability	Overall Habitat Score	
Lower Euharlee Creek	2050	Low	Moderate	Low	Low	Low	Low	Moderate	Low	Low
	2100	Low	Moderate	Low	Low	Low	Low	Low	Low	Low

Representation and Redundancy

Under the Increased Impact scenario, it is predicted that representation will decrease by 2050 and 2100. Georgia alder is expected to decline such the species will not persist within both sag pond and spring-run habitat types at Drummond Swamp due to changes in habitat such that the alder is out-competed in one or both these habitat types. We assume that safeguarding analysis units do not persist due to lack of resources and therefore redundancy becomes zero (0).

Scenario 3: Conservation Focused

Under the Conservation Focused scenario, climate factors that influence the Georgia alder analysis unit were assumed to remain constant over both time steps predicting an increase in temperature and precipitation (RCP8.5). However precipitation may be offset by increased evapotranspiration. Soil water storage also decreases. Urbanization is predicted to increase at a business as usual (BAU) rate (at least 80 percent or greater probability) over time with 20 and 45 percent of the watershed urbanized in 2050 and 2100, respectively (table 22 and figure 39, above). These levels of urbanization will degrade water quality within the watershed. The degree of changes in climate and urbanization conditions increases between the two time steps (table 20, above). Water demand in the North Georgia Water Planning District is predicted to increase from 574.5 to 899.0 Average Annual Day – Million Gallons per Day (AAD-MGD) by 2050 (WMP 2017). This water demand (usage) assumes enhanced efficiency standards. In this scenario conservation management increases and strategically targets actions (land protection, management, and safeguarding) to abate impacts of changing climate and urbanization.

Resiliency

Based on projections for 2050, in this scenario, overall resiliency of the Georgia alder is expected to remain relatively high due to increased conservation measures to protect water quality and quantity (table 24). Habitat impacts from urbanization and changing climate conditions could be actively managed at the watershed and site specific scales. Overall water conservation via enhanced water efficiency standards and strategic protection of land within the watershed could maintain adequate water quality conditions. Active site specific management actions, such as invasive species control and vegetative buffers can protect water quality and habitat (sunlight availability). Projections for 2100 have the similar trajectory, but due to increased urbanization within the overall watershed, both upstream and downstream from the Georgia alder, water quality and quantity are expected to degrade such that abundance and recruitment of the Georgia alder are diminished to moderate levels.

Table 24. Summary of Georgia alder future condition under the Conservation Focused Scenario.

Scenario 3: Conservation Focused		Demographic Factors				Habitat Factors				Overall Condition Score
HUC 12 Name	**Year**	**Approximate Abundance**	**Persistence**	**Recruitment**	**Overall Demographic Score**	**Water Quality**	**Water Quantity**	**Sunlight Availability**	**Overall Habitat Score**	
Lower Euharlee Creek	2050	Moderate	High	Moderate	Moderate	High	High	High	High	High
	2100	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Representation and Redundancy

Under the Conservation Focused scenarios, it is predicted that representation will remain the same (moderately-low) by 2050 and 2100. Georgia alder is expected to persist within both sagpond and spring-run habitat types at Drummond Swamp. We assume that safeguarding analysis units persist (and possibly expand) with active conservation management, however since there are no other known naturally occurring Georgia alder analysis units, redundancy remains low across both time steps.

<u>Future Viability Summary for the Georgia alder:</u> The goal of this assessment was to describe the viability of the Georgia alder in terms of resiliency, representation, and redundancy by using the best science available at the time of the analysis. To capture the uncertainty associated with the degree and extent of potential future risks and their impacts on species' needs, each of the 3Rs were assessed using three plausible future scenarios (Continuation, Increased Impact, and Conservation Focused). These scenarios were based, in part, on the results of urbanization (Terando *et. al*. 2014, p. 1) and climate models (IPCC 2013, p. 7) that predict changes in habitat for the Georgia alder. The results of the predictive analysis describe a range of possible conditions for the sole Georgia alder analysis unit at Drummond Swamp (table 25).

The current condition of the Georgia alder is considered High. In the Continuation 2050 scenario the resiliency of the Georgia alder is predicted to decline to Moderate. In the Increased Impact 2050 and 2100 scenarios the Georgia alder's resiliency is expected to decline to Low. In the Conservation Focused 2050 scenario it is plausible that conservation efforts (water conservation, land protection and management, safeguarding, etc.) could maintain the resiliency at the High condition, but in the Conservation Focused 2100 scenario, the Georgia alder's resiliency is expected to be Moderate. The 2100 time step for all scenarios represents a further decline in resiliency due to increased exposure to effects of urbanization and drought. Representation within Drummond Swamp generally decreases over time and across all scenarios due to losses of clumps that currently maintain the Georgia alder's genetic and ecological diversity. While all scenarios present some risk of extirpation of the Drummond Swamp analysis unit due to stochastic events, risk of extirpation is greatest with the Increased Impact scenario. Since Georgia alder is only known from the Drummond Swamp location, extirpation of this analysis unit would result in the extirpation of the Georgia alder subspecies.

Table 25. Summary of Current and Future Scenario Outcomes.

Current Condition	Continuation 2050	Continuation 2100	Increased Impact 2050	Increased Impact 2100	Conservation 2050	Conservation 2100
High	Moderate	Low	Low	Low	High	Moderate

5.1.3 Oklahoma

There are three main drivers affecting the future condition of the Oklahoma alder: changing climate conditions, decreased water availability, and conservation management. During the peer and partner review of the draft SSA, we received information regarding an additional analysis unit. However, this additional HUC is not considered in our future scenarios below. Therefore, this analysis is likely an under-estimation of the future viability of Oklahoma alder

Because we have significant uncertainty regarding: (1) how much climate will change in the future, which in turn will have an effect on rainfall and severity of future periods of drought and flooding; (2) the number mines and water consumption due to mines that will occur in the future; (3) future groundwater withdrawal from other sources than mining; and (4) conservation measures implemented and effectiveness, we have forecast what Oklahoma alder may have in terms of resiliency, redundancy, and representation under two plausible future scenarios. Each scenario uses the climate projections under the 8.5 RCP emissions scenario (IPCC 2017, p. entire).

In general these scenarios are: (1) Continuation: where current groundwater withdrawal continue as in the recent past and continuing climate condition changes as projected into the future; and (2) Conservation Focused: where current groundwater withdrawal continue as in the recent past and continuing climate condition changes as projected into the future with conservation management and augmentation to analysis units. Table 26 demonstrates the change in average base flow for the major streams where the Oklahoma alder occurs.

Table 26. The projected river base flow effects of 12.5 percent, 25 percent, and 40 percent aquifer withdrawal simulations (Christenson *et al.* 2011, p. 87).

Simulation	Stream									
	Blue River	Buckhorn Creek	Byrds Mill-Spring	Delaware Creek	Mill Creek	Pennington Creek	Sheep Creek	Travertine Creek	All other streams combined	Total
5-year average base flow (ft^3/s)										
Reported water use	61.34	2.65	12.95	4.92	8.53	32.19	4.44	15.41	10.18	152.60
EPS = 0.125 (A-F/A)/Yr	44.96	1.79	11.97	4.47	6.12	24.42	3.76	13.59	8.57	119.64
EPS = 0.250 (A-F/A)/Yr	28.21	0.61	9.46	3.98	3.39	16.72	2.08	9.28	6.74	80.49
EPS = 0.392 (A-F/A)/Yr	11.60	0.00	4.54	3.34	1.04	8.03	0.42	2.61	4.54	36.12
Depletion of 5-year average base flow (percent)										
EPS = 0.125 (A-F/A)/Yr	26.7	32.6	7.6	9.1	28.3	24.1	15.3	11.8	15.8	21.6
EPS = 0.250 (A-F/A)/Yr	54.0	76.8	26.9	18.9	60.2	48.0	53.1	39.8	33.8	47.3
EPS = 0.392 (A-F/A)/Yr	81.1	100.0	64.9	32.1	87.9	75.1	90.6	83.1	55.4	76.3

Scenario 1: Continuation

Under the Continuation scenario, impacts from factors that influence the Oklahoma alder analysis unit were assumed to continue as they have in the recent past over both time steps, 30 and 80 years in the future.

As discussed earlier (Chapter 3), the major habitat stressors that influence the Oklahoma alder are the effects of changing climate conditions, groundwater withdrawal, and alteration of flood regime (i.e., vegetation encroachment as a proxy for sunlight). Data from Arbuckle-Simpson Aquifer Report (Christenson *et al.* 2011, p. 82) were used to project groundwater withdrawal (table 28). This projection includes public water supply, mining, power, irritation and other (small withdrawals compiled together, figure 34 above). There are additional proposed mines within the aquifer area. The precise amount of water demand for proposed mining in the area is not known but this would be an increased demand on the aquifer and we consider this in our analysis. It is projected that groundwater withdrawal at the 2050 time step will not be much of an increase. In the 2100 time step, groundwater withdrawal is projected to increase. The maximum annual yield for the Arbuckle-Simpson aquifer is 78,404 AFY (Bill 288 2013, p. 19), meaning that 75 percent of the annual base flow remains. Consequently, this is approximately the amount of groundwater pumping we estimate for the 2100 time step. For recharge, we used Liuzzo *et al.* (2010, p. 107), which incorporates temperature, precipitation, vegetation (i.e., evapotranspiration), and runoff, and projects a 1.5 ± 16.5 percent decrease in recharge for 2050 and a 9.5 ± 24.3 percent decrease in recharge for the southern region of the study (Oklahoma and Texas). For the effects of climate change, we used projected impacts based on the RCP 8.5 emissions scenario, as the latest data indicates that this is the current trajectory (Brown and Caldeira 2017, entire).

Table 27. Reported and projected groundwater withdrawal for Blue River and Pennington Creek.

Simulation	5-year total groundwater withdrawal (A-F)	5-year average annual groundwater withdrawal (A-F/Yr)	5-year average gaged streamflow (ft^3/s)	5-year average MODFLOW-simulated streamflow (ft^3/s)	5-year average PART base flow (ft^3/s)	5-year average MODFLOW-simulated base flow (ft^3/s)	Streamflow depletion (percent)	Base-flow depletion (percent)
			Blue River near Connerville (07332390)					
Reported water use	27,818	5,564	92.92	92.98	61.28	61.34	0.00	0.00
EPS=0.125 (A-F/A)/Yr	141,974	28,395	NA	76.60	NA	44.96	17.62	26.71
EPS=0.250 (A-F/A)/Yr	283,949	56,790	NA	59.85	NA	28.21	35.63	54.01
EPS=0.392 (A-F/A)/Yr	445,232	89,046	NA	43.24	NA	11.60	53.49	81.08
			Pennington Creek near Reagan (07331300)					
Reported water use	27,818	5,564	42.97	42.69	32.47	32.19	0.00	0.00
EPS=0.125 (A-F/A)/Yr	141,974	28,395	NA	34.93	NA	24.42	18.18	24.14
EPS=0.250 (A-F/A)/Yr	283,949	56,790	NA	27.23	NA	16.72	36.22	48.04
EPS=0.392 (A-F/A)/Yr	445,232	89,046	NA	18.53	NA	8.03	56.59	75.06

Flood and drought regime was estimated for future conditions using data from Liu *et al.* (2011, p. 26) and Climatological Survey (2018, entire) as described in Chapter 3. As stated above, flood and drought regimes are already demonstrating change. Droughts and floods have already increased in severity and duration, and are projected to increase throughout the 2050 time step.

Table 28. Resiliency Scores for Continuation Scenario future conditions of the Oklahoma alder for time steps 2050 and 2100.

River	Analysis Unit*	Current Condition	Continuation 2050	Continuation 2100
Pennington	Lower Pennington Creek	High	High	Moderate
Blue	Desperado Spring Falls-Blue River	High	High	Moderate
Blue	Pecan Creek-Blue River	Moderate	Moderate	Moderate
Blue	Little Blue Creek-Blue River	High	High	High
Clear Boggy	Sandy Creek	Moderate	Moderate	Moderate
Clear Boggy	Sheep Creek	High	High	Moderate
Clear Boggy	Bois d' Arc Creek (Mill Cr)	Moderate	Moderate	Low
* As of April 17, 2018.				

Scenario 2: Conservation Focused

Under the Conservation Focused scenario, impacts from factors that influence the Oklahoma alder analysis unit were assumed to continue as they have in the recent past over both time steps, 30 and 80 years in the future, but with conservation actions implemented.

Conservation actions under this scenario include the augmentation of Oklahoma alder along the Blue River riparian area. An estimated 700 Oklahoma alder individuals will be planted, with a 50 percent expected survival rate (Levesque 2018). The Oklahoma alder will be planted in the Little Blue Creek-Blue River analysis unit, which is currently scored as High for the abundance of Oklahoma alder. It will remain high in all future scenarios.

Under the Conservation Focused Scenario, we assume that individuals from the restoration site in the Little Blue Creek-Blue River analysis unit will wash downstream into the Pecan Creek-Blue River analysis unit to create at least one new site for the Oklahoma alder, thus increasing the score for abundance for years 2050 and 2100 in that site. However, the overall Demographic scores remain the same.

The only known conservation efforts being conducted on lands above the Arbuckle-Simpson Aquifer are occurring on The Nature Conservancy lands. This would impact redundancy in both 2050 and 2100.

If moderate conservation efforts were to take place for both surface and groundwater pumping, there would be an estimated 1.5 percent reduction in aquifer recharge rate in the year 2050 (Niraula *et al.* 2017, p. 10411) and 9.5 percent in 2100. Based on this, 10,370 AFY is approximate water demand in 2050 and 56,700 AFY water demand for 2100. See table 29 for 3Rs and habitat scores.

Table 29. Resiliency Scores for Conservation Focused Scenario future conditions of the Oklahoma alder for time steps 2050 and 2100.

River	Analysis Unit*	Current Condition	Conservation 2050	Conservation 2100
Pennington	Lower Pennington Creek	High	High	Moderate
Blue	Desperado Spring Falls-Blue River	High	High	Moderate
Blue	Pecan Creek-Blue River	Moderate	Moderate	Moderate
Blue	Little Blue Creek-Blue River	High	High	High
Clear Boggy	Sandy Creek	Moderate	Moderate	Low
Clear Boggy	Sheep Creek	High	High	Moderate
Clear Boggy	Bois d' Arc Creek (Mill Cr)	Moderate	Moderate	Low
* As of April 17, 2018.				

Summary of future condition for the Oklahoma alder:

Under all scenarios the Oklahoma alder overall averaged score is a Moderate condition for 2050 and a Moderate condition for 2100 (data not shown). However, resiliency will change within the individual analysis units over time (tables 30 and 31). For instance, in the 2050 Continuation Scenario there will be three analysis units with a resiliency score of High, and in the 2100 Continuation Scenario there are zero analysis units with a resiliency score of High (table 30). In general, the resiliency scores of the Oklahoma alder decrease as time goes on (from 2050 to 2100) regardless of the scenario. Notably, the 2050 Continuation Scenario does not differ from the current condition, though it is 30 years in the future. All of the analysis units will be impacted by changing climate conditions and decreased water availability. However, looking at “overall data” can be misleading because overall, the Oklahoma alder is scored as moderate for all future scenarios. Many of the analysis units had a habitat score move from a High to a Low score, which averages to a Medium. Analysis units with both a low demographic score and habitat score are most vulnerable: Bois d' Arc and Sandy Creek.

Table 30. Demographic and Habitat Scores for each Oklahoma alder analysis unit under the Continuation Scenario (years 2050 and 2100) and for the Conservation Focused Scenario (years 2050 and 2100).

River	Analysis Unit*	Current Condition	Continuation 2050	Continuation 2100	Conservation 2050	Conservation 2100
Pennington	Lower Pennington Creek	High	High	Moderate	High	Moderate
Blue	Desperado Spring Falls-Blue River	High	High	Moderate	High	Moderate
Blue	Pecan Creek-Blue River	Moderate	Moderate	Moderate	Moderate	Moderate
Blue	Little Blue Creek-Blue River	High	High	High	High	High
Clear Boggy	Sandy Creek	Moderate	Moderate	Moderate	Moderate	Low
Clear Boggy	Sheep Creek	High	High	Moderate	High	Moderate
Clear Boggy	Bois d' Arc Creek (Mill Cr)	Moderate	Moderate	Low	Moderate	Low
* As of April 17, 2018.						

Table 31. Summary condition table for number of Oklahoma alder analysis units in the current and future scenarios.

Scenarios	High	Moderate	Low	Extirpated
Current Condition	3	4	0	(1) historical record, not analysis unit
Continuation Scenario 2050	3	4	0	(1) historical record, not analysis unit
Continuation Scenario 2100	0	4	3	(1) historical record, not analysis unit
Conservation Focused Scenario 2050	0	7	0	(1) historical record, not analysis unit
Conservation Focused Scenario 2100	0	5	2	(1) historical record, not analysis unit

5.2 Seaside Alder Future Condition Summary

The seaside alder's future viability can be summarized as having moderate to high resiliency, redundancy, and representation. The species is projected to be extant in a total of the 35 analysis units (i.e., HUCs) known as of April 17, 2018, under the most favorable suite of scenarios and in 32 analysis units under the least favorable suite of scenarios. Although there are other suites of scenarios we analyzed at the subspecies scale (e.g., Moderate Impacts 2050 for Delmarva alder and Continuation for Georgia alder), we do not summarize them here at the species scale because their results are contained within and bracketed by the results in the most favorable and least favorable suite of scenarios discussed below. However, we do note that all of the potential scenarios are considered plausible, and that there likely are additional locations of seaside alder in Delaware and Oklahoma that are not incorporated into our analysis due to insufficient data. Therefore, the summary below likely underestimates the species' future condition.

By 2050:

- Under the most favorable suite of scenarios (Continuation 2050 for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders):
    - 35 analysis units are anticipated to be categorized as: 14 in high condition, 17 in moderate condition, and 4 in low condition; thus ensuring the species' ability to withstand stochastic events (resiliency).
    - These 35 analysis units are distributed across 3 disjunct areas of the country (27 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma), thus ensuring the species' ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
    - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment (representation).

- Under the least favorable suite of scenarios (Major Impacts 2050 for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder):
    - 35 analysis units are anticipated to be categorized as: 14 in high condition, 16 in moderate condition, 2 in low condition, and 3 extirpated. Thus, despite some losses in the Delmarva region, the species retains the species' ability to withstand stochastic events (resiliency).
    - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
    - Within these geographic areas, the species retains representation by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted

to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

By 2100:

- Under the most favorable suite of scenarios (Major Impacts 2050 (as proxy since the effect to the subspecies is the same in 2100) for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders):
  - 35 analysis units are anticipated to be categorized as: 11 in high condition, 18 in moderate condition, 3 in low condition, and 3 are extirpated; thus ensuring the species' ability to withstand stochastic events. Thus, despite some losses in the Delmarva region, the species retains the ability to withstand stochastic events (resiliency).
  - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
  - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh, and spring-fed rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

- Under the least favorable suite of scenarios (Major Impacts 2050 (as proxy since there is only one 2100 scenario available) for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder):
  - 35 analysis units are anticipated to be categorized as: 11 in high condition, 16 in moderate condition, 5 in low condition, and 3 are extirpated; thus ensuring the species' ability to withstand stochastic events (resiliency).
  - These 32 extant analysis units are distributed across 3 disjunct areas of the country (24 in Maryland/Delaware, 1 in Georgia, and 7 in Oklahoma). Thus, despite some losses in the Delmarva region, the species retains the ability to withstand catastrophic events (redundancy). Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs, with the exception of Georgia.
  - Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in three separate freshwater habitat types (tidal rivers, marsh, and spring-fed rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest). While the plants in the Delmarva alder HUCs that are closest to saline waters have been extirpated by sea level rise and

the effect of storm surge, the species retains the ability to adapt to further changes in its environment (representation).

The seaside alder's (rangewide) future viability can be summarized as having moderate to high resiliency, redundancy, and representation depending upon the timeframe (2050 vs. 2100) and scenarios. By 2050, the species is projected to be extant in a total of 35 analysis units (i.e., HUCs) under the most favorable suite of scenarios (Continuation 2050 for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders) and in 32 analysis units under the least favorable suite of scenarios (Major Impacts 2050 for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder). Under the most favorable suite of scenarios, the 35 analysis units include 40 percent (n=14) in high condition, 49 percent (n=17) in moderate condition, and 11 percent (n=4) in low condition (note: totals may not sum to 100 due to rounding). Under the least favorable suite of scenarios, the 35 analysis units include 40 percent (n=14) in high condition, 46 percent (n=16) in moderate condition, and 5 percent (n=2) in low condition, and 8 percent extirpated (n=3) (note: totals may not sum to 100 due to rounding). In each of these cases, while the resiliency has some minor fluctuations, the species' retains the ability to withstand stochastic events, despite some losses in the Delmarva region. Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs (with the exception of Georgia). Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment.

By 2100, the species is projected to be extant in a total of 32 out of 35 analysis units (i.e., HUCs) under the most favorable suite of scenarios (Major Impacts 2050 (as proxy since the effect to the subspecies is the same in 2100) for Delmarva alder and Conservation Focused for the Georgia and Oklahoma alders) and in 32 out of 35 analysis units under the least favorable suite of scenarios (Major Impacts 2050 (as proxy since there is only one 2100 scenario available) for Delmarva alder, Increased Impact for Georgia alder, and Continuation for Oklahoma alder). Under the most favorable suite of scenarios, the 35 analysis units include 31 percent (n=11) in high condition, 51 percent (n=18) in moderate condition, 9 percent (n=3) in low condition, and 9 percent (n=3) extirpated (note: totals may not sum to 100 due to rounding). Under the least favorable suite of scenarios, the 35 analysis units include 31 percent (n=11) in high condition, 46 percent (n=16) in moderate condition, and 14 percent (n=5) in low condition, and 9 percent extirpated (n=3) (note: totals may not sum to 100 due to rounding). In each of these cases, while the resiliency has some minor fluctuations, the species' retains the ability to withstand stochastic events, despite some losses in the Delmarva region. Within each of the regions, most of the analysis units (HUCs) are connected to other occupied HUCs (with the exception of Georgia). Within these geographic areas, the species is represented by three genetically diverse subspecies which occur in many types of freshwater habitat (tidal rivers, marsh and pond, and spring-fed streams and rivers) that are adapted to three distinct climates (mid-Atlantic, Southeast, and Southwest), thus ensuring the species' ability to adapt to changes in its environment.

At the subspecies level, the total number of Delmarva alder analysis units occupied is expected to range between 24 and 27 depending on whether the Major Impacts Scenario or Continuation/Minor Impacts Scenario of sea level rise occur. The losses are on the periphery of the range and the 24 analysis units remaining under the Major Impacts Scenario are all adjacent to at least one other analysis unit in high or medium condition. Thus, under the Major Impacts Scenario for 2050 (or the Continuation Scenario for 2100) there would be 11 highly resilient analysis units, 12 of moderate resiliency, and 1 of low resiliency. Overall, we consider the Delmarva alder to retain high redundancy in the future. By 2050, even under the Major Impacts Scenario, the remaining analysis units would span the range of habitats available on the Delmarva and would include all currently occupied types of wetland habitats. Thus, representation is expected to be high under the Major Impacts 2050 Scenario (or the Continuation 2100 Scenario). By 2050, under the Major Impacts Scenario, there would be 11 highly resilient analysis units, 12 moderately resilient analysis units, and 1 analysis unit with low resiliency. While this is a decrease from current conditions, we consider the overall resiliency of Delmarva alder to remain high.

In the *Continuation Scenario* the resiliency of the Georgia alder is predicted to decline but overall future condition remains moderate. In the *Increased Impact Scenario* all 3Rs are expected to decline and overall condition in the future is low. In the *Conservation Focused* scenario it is plausible that conservation efforts (water conservation, land protection and management, safeguarding, etc.) could maintain the resiliency (high), representation (low to moderate) and redundancy (low) of the Georgia alder at current conditions at least through 2050. While all scenarios present some risk of extirpation of the sole Georgia alder analysis unit due to stochastic events, risk of extirpation is greatest with the Increased Impact scenario. Since Georgia alder is only known from the Drummond Swamp location, extirpation of this analysis unit would result in the extirpation of the Georgia alder subspecies.

Under all scenarios the Oklahoma alder's overall average score is a Moderate condition for 2050 and a Moderate condition for 2100. However, resiliency will change within the individual analysis units over time. For instance, in the 2050 Continuation Scenario there will be three analysis units with a resiliency score of High, and in the 2100 Continuation Scenario there are zero analysis units with a resiliency score of High. In general, the resiliency scores of the Oklahoma alder decrease as time goes on (from 2050 to 2100) regardless of the scenario. Notably, the 2050 Continuation Scenario does not differ from the current condition, though it is 30 years in the future. All of the analysis units will be impacted by changing climate conditions and decreased water availability. However, looking at "overall data" can be misleading because overall, the Oklahoma alder is scored as moderate for all future scenarios. Many of the analysis units had a habitat score move from a High to a Low score, which averages to a Medium. Analysis units with both a low demographic score and habitat score are most vulnerable: Bois d' Arc and Sandy Creek. In addition, our analysis underestimates the current population of Oklahoma alder due to a reported location that became known to us subsequent to the completion of the analysis.

REFERENCES CITED

Atlanta Botanical Garden (ABG) 2012. Northwest Georgia Wetland Restoration and Rare Species Recovery. A Final Programmatic Report submitted to the National Fish and Wildlife Foundation.

Bartow County (Georgia) Code § 7.17. Etowah Valley Historic District. Available at (*http://bartowcounty.elaws.us/code/coor_apxid22870_apxa_artvii_sec7.17*). Last accessed April 16, 2018.

Bauer, B.O., M.S. Lorang, and D.J. Sherman. 2002. Estimating boat-wake-induced levee erosion using sediment suspension measurements. Journal of Waterway, Port, Coastal and Ocean Engineering 128: 152-162.

Bentley, M. 2002. "Fight stirs over southern aquifer." NewsOK, September 15, 2002. Available online at: *http://newsok.com/article/2807344*. Last accessed April 6, 2018.

Bilkovic, D., M. Mitchell, J. Davis, E. Andrews, A. King, P. Mason, J. Herman, N. Tahvildari, J. Davis. 2017. Review of boat wake wave impacts on shoreline erosion and potential solutions for the Chesapeake Bay. STAC Publication Number 17-002, Edgewater, MD. 68 pp.

Bowen 2017. Georgia Power Plant Bowen. Ash Pond Dewatering Plan. NPDES Permit NO. GA0001449. Revised December 2017. Available online at: *(https://www.georgiapower.com/content/dam/georgia-power/pdfs/company-pdfs/plant-bowen/bowen-ash-pond-dewatering-plan-dec2017.pdf*). Last accessed April 16, 2018.

Brian, M., Hickey, C. and Doran B. 2004. A review of the Efficiency of Buffer Strips for the maintenance and Enhancement of Riparian Ecosystems. Water Qual. Res. J. Canada. Vol 39, No 3: 311-317.

Brown, C., E. and Pezeshki, S.R. 2000. A study on waterlogging as a potential tool to control *Ligustrum sinense* populations in western Tennessee. *Wetlands*. Vol. 3 pp 429-437.

Brown, P.T. and K. Caldeira. 2017. Greater future global warming inferred from the Earths recent energy budget. Nature: 552, December 7, 2017.

Brown, R.G., and M.L. Brown. 1972. Woody plants of Maryland. University of Maryland, College Park, MD, p. 60-65.

Burton, M.L. and Samuelson, L.J. 2008. Influence of urbanization on Riparian Forest Diversity and Structure in the Georgia piedmont, US. *Plant Ecology.* 195:99-115.

Byrd. R. 2018. Electronic mail record, 09/19/2017. Conservation Coordinator, Atlanta Botanical Gardens. Email to Michele Elmore, USFWS.

Center for Watershed Protection (CWP). 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph No. 1. Ellicott City, MD. 158pp.

Ceska, J. 2018. Electronic mail record, 05/02/2018. GPCA Coordinator, State Botanical Garden of Georgia, Athens, Georgia. Email to Michele Elmore, USFWS.

Chafin, L. 2017. Alnus maritima status assessment provided to the US. Fish and Wildlife Service, Georgia Ecological Services, Athens, GA.

Chesapeake Bay Program. 2017. Environmental Protection Agency. Available online at: *https://www.chesapeakebay.net/discover/ecosystem/physical_characteristic*s. Last accessed April 16, 2018.

Chesapeake Research Consortium (CRC). 1976. The effects of tropical storm Agnes on the Chesapeake Bay Estuarine Ecosystem. CRC Publication No. 54. John Hopkins Press. (*http://www.vims.edu/GreyLit/CRC/crc054.pdf*) Last accessed April 16, 2018.

Christenson, S., Osborn, N.I., Neel, C.R., Faith, J.R., Blome, C.D., Puckette, J. and Pantea, M.P., 2011. Hydrogeology and simulation of groundwater flow in the Arbuckle-Simpson aquifer, south-central Oklahoma. U. S. Geological Survey.

Cressler, C.W., Blanchard, H.E. Jr., Hester. W.G. 1979. Geohydrology of Bartow, Cherokee, and Forsyth Counties, Georgia. U.S. Geological Survey. Information Circular 50. 58pp.

Del Tredici, P. 1996. A nitrogen fixation: the story of the Frankia symbiosis. Arnoldia (Jamaica Plain), 1995(55), 26-31.

Douhovnikoff, V., McBride, J. R., and Dodd, R. S. 2005. Salix exigua clonal growth and population dynamics in relation to disturbance regime variation. Ecology, 86(2), 446-452.

Edwards, L., Ambrose, J. and Kirkman L.K. *The Natural Communities of Georgia*. University of Georgia Press, 2013.

Ehardt, Cassie S. “Establishment of a rare riparian tree, Alnus maritima.” University of Oklahoma, 2016, pp. 1–103.

Ellstrand, N.C. and Roose, M. L. 1987. Patterns of genotypic diversity in clonal plant species. American Journal of Botany, 123-131.

Environmental Protection Agency (EPA) 2016a. What climate change means for Georgia. U.S. Environmental Protection Agency. August 2016. EPA 430-F-16-012.

Environmental Protection Agency (EPA) 2016b. What climate change means for Oklahoma. U.S. Environmental Protection Agency. August 2016. EPA 430-F-16-038.

Environmental Protection Agency (EPA) 2005. Protecting Water Quality from Agricultural Runoff. US Environmental Protection Agency. Fact Sheet EPA 841-F-05-001. Available online at: *https://www.epa.gov/sites/production/files/2015-09/documents/ag_runoff_fact_sheet.pdf*. Last accessed April 16, 2018.

Etowah River Basin Profile (ERBP) 2017. Water Resource Management Plan. Attachment 5. Etowah River Basin Profile (ERBP). Metropolitan North Georgia Water Planning District. Prepared by Ch2M and Black and Veatch.

Ezer, T., and Atkinson, L. P. 2014. Accelerated flooding along the US East Coast: on the impact of sea-level rise, tides, storms, the Gulf Stream, and the North Atlantic oscillations. Earth's Future, 2(8), 362-382.

Fauk, J., G. Alan, K. Bungee, and E. Camp. 1997. Nanticoke River Watershed Boating Assessment Study. DEL-SG-04-97. University of Delaware, Sea Grant College Program, Newark DE. 130pp.

Frye, C. 2016. Statement made during November 16, 206 meeting. Botanist, Maryland Department of Natural Resources.

Frye, C. and McAvoy, W. 2017. Electronic mail communications; April 17-25, 2017. Between Cherry Keller, USFWS, Botanist, Maryland Department of Natural Resources, and Botanist, Delaware Department of Natural Resources and Environmental Control.

Froelich and Lesley 2001. Tracing germanium contamination from coal-fired power plants down the Chattahoochee-Apalachicola River: Implications for the toxic metalloids arsenic and selenium. Proceedings of the 2001 Georgia Water Resources Conference, held march 26-27, 2001 at the University of Georgia.

Furlow, J.J. 1979. The systematics of the American species of Alnus (Betulaceae). Rhodora 81:1-121, 151-148.

Georgia Department of Natural Resources (GDNR). 2017. Georgia Department of Natural Resources. Final Performance Report to the U.S. Fish and Wildlife Service on 15 priority plant species. Grant Agreement No.: F12AC01342.

Georgia Department of Natural Resources (GDNR). 2014. A Survey for Georgia Alder. Georgia Wild: News of Nongame and Natural Habitats. Georgia Department of Natural Resources, Social Circle, Georgia. *http://content.govdelivery.com/accounts/GADNR/bulletins/decec7*. Last accessed April 16, 2018.

Georgia Forestry Commission. 2009. Georgia's Best Management Practices. Water Quality Program. 75 pp.

Georgia Forestry Commission (GFC) 2016. Emerald Ash Borer Spreading in Georgia. August 31, 2016 New Release.

Georgia Office of Planning and Budget (GOPB) 2015. Georgia Residential Population Projections by County: Georgia Counties, 2013-2050.

Georgia Plant Conservation Alliance (GPCA) 2008. Policy Statement Regarding in situ and ex situ Plant Conservation Between Members of the Georgia Plant Conservation Alliance. Available online at: *http://botgarden.uga.edu/wp-content/uploads/2017/01/GPCA-Safeguarding-Policy-Statement-.pdf*. Last accessed April 16, 2018.

Georgia Power 2018. Plant Bowen Groundwater Monitoring and Dewatering Information. Available online at: *https://www.georgiapower.com/company/research-conservation-and-stewardship/management-closures/ground-monitoring-dewatering/groundwater-monitoring-dewatering-plant-list/plant-bowen.html*. Last accessed April 16, 2018.

Georgia Power Company (GPC) 2018a. Telephone Record between Jim Ozier, Environmental and Natural Resources, Georgia Power Company and Michele Elmore, USFWS.

Georgia Power Company (GPC) 2018b. Electronic mail record, 04/13/2018, Jim Ozier, Environmental and Natural Resources, Georgia Power Company. Email to Michele Elmore, USFWS.

Georgia Soil and Water Conservation Commission (GSWCC). 2007. Best Management Practices for Georgia Agriculture. Conservation Practices to Protect Surface Water Quality.

Gibson, P. 2018a. Electronic mail record, 02/09/2018, Oklahoma University. Email to Cherry Keller, USFWS.

Gibson, P. 2018b. Peer Review Comments on the April 17, 2018, Draft Species Status Assessment for the Seaside Alder.

Gibson, J. P., S. A. Rice, and C. M. Stucke. 2008. Comparison of population genetic diversity between a rare, narrowly distributed species and a common, widespread species of Alnus (Betulaceae). American Journal of Botany 95:588–596.

Glick, P., Clough, J., and Nunley, B. 2008. Sea-level rise and coastal habitats in the Chesapeake Bay region: technical report. National Wildlife Federation.

Graves, W. R., and Gallagher, J. L. 2003. Resistance to salinity of *Alnus maritima* from disjunct wetlands: symptoms of salt injury, comparison to other shrubs, and effect of inundation. Wetlands, 23(2), 394-405.

Graves, W. R., and James A. Schrader. 2004. "'September Sun'." HortScience 39.2: 438-439.

Hanula, J.L., Horn, S. and Taylor, W., 2009. Chinese privet (*Ligustrum sinense*) removal and its effects on native plant communities of riparian forests. Invasive Plant Science and Management 2:292-300.

Harrison, J. W. and P. Stango III. 2003. Shrubland tidal wetland communities of Maryland's Eastern Shore: identification, assessment, and monitoring. Maryland Department of Natural Resources, Natural Heritage Program, Annapolis, Maryland. Unpublished report submitted to the Environmental Protection Agency. 118 pp.

Hennessey, T. C., Bair, L. K., and McNew, R. W. 1985. Variation in response among three Alnus spp. clones to progressive water stress. In Frankia and Actinorhizal Plants (pp. 135-141). Springer, Dordrecht.

Herms, D. A., and McCullough, D. G. 2014. Emerald ash borer invasion of North America: history, biology, ecology, impacts, and management. Annual review of entomology, 59, 13-30.

Howery, M. 2018. Partner Review Comments on the April 17, 2018 Draft Species Status Assessment for the Seaside Alder.

Intergovernmental Panel on Climate Change (IPCC) 2018. The Main Characteristics of the Four SRES Storylines and Scenario Families. Available online at: *http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=3*. Last accessed April 16, 2018.

Intergovernmental Panel on Climate Change (IPCC). 2013. Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jones, J. M. 2013. The Strange Range of Seaside Alder. Arnoldia, 71(2), 2–11.

Jones, J. M. and J. P. Gibson. 2011. Population genetic diversity and structure within and among disjunct populations of Alnus maritima (seaside alder) using microsatellites. Conservation Genetics 12:1003–1013.

Jones, J. M. and J. P. Gibson. 2012. Mating System Analysis of Alnus maritima (Seaside Alder), a Rare Riparian Tree. Castanea 77: 11–20.

Juwarkar A.A., Yadav S.K. 2010. Bioaccumulation and Biotransformation of Heavy Metals. In: Fulekar M.H. (eds) Bioremediation Technology. Springer, Dordrecht

Karrenberg, S., Edwards, P. J., and Kollmann, J. 2002. The life history of Salicaceae living in the active zone of floodplains. Freshwater Biology, 47(4), 733-748.

Kearney, M. S., Grace, R. E., and Stevenson, J. C. 1988. Marsh loss in Nanticoke Estuary, Chesapeake Bay. Geographical Review, 205-220.

Kearney, M. S. (2013). Coastal risk versus vulnerability in an uncertain sea level future. In *Coastal Hazards* (pp. 101-115). Springer, Dordrecht.

Kratsch, H. A. 2004. Biology of the Frankia-*Alnus maritima* spp. *maritima* symbiosis. Retrospective Theses and Dissertations. 1104. Iowa State University

Kratsch, H. A. 2008. Alnus maritima ssp. Oklahomensis; Performance in Non-Irrigated Landscapes in the Intermountain West1. J. Environ. Hort, 26(4), 229-234.

Kratsch, H.A. and W.R. Graves. 2004. Location and Anatomy of Nodules on Alnus maritima Subjected to Flooding. J Amer. Soc. Hort. Sci. 129:775-780.

Kratsch, H. A. and W.T. Graves. 2005. Oxygen concentration affects nodule anatomy and nitrogenase activity of Alnus maritima. Plant, Cell & Environment, 28(5), 688-696.

Kundell, James E., and Margaret E. Myszewski. 2017. “Urban Sprawl.” New Georgia Encyclopedia. 08 June 2017. Web. 05 February 2018.

Laws, M.T. and Graves W.R. 2005. Nitrogen inhibits nodulation and reversibly suppresses nitrogen fixation in nodules of *Alnus maritima*. J. Amer. Soc. Hort. Sci.130(4):496-499.

Layden, L. 2017. “Action To Protect Small Creek Pits Mining Companies Against Oklahoma Community Worried About Water Supply.” NPR State Impact, March 23, 2017. Available online at: *https://stateimpact.npr.org/oklahoma/2017/03/23/action-to-protect-small-creek-pits-mining-companies-against-oklahoma-community-worried-about-water-supply/*. Last accessed April 6, 2018.

Lesley M. P. 2002. The Fluxes and fates of Arsenic, Selenium, and Antimony from Coal Fired Power Plants to Rivers. Masters of Science Thesis in Geochemistry in the School of Earth and Atmospheric Sciences. Georgia Institute of Technology.

Levesque. G. 2018. Record of telephone conversation, February 20, 2018, Alisha Autio, USFWS, with Gina Levesque, ecologist, The Nature Conservancy.

Liuzzo, L., Noto, L.V., Vivoni, E.R. and La Loggia, G., 2010. Basin-scale water resources assessment in Oklahoma under synthetic climate change scenarios using a fully distributed hydrologic model. Journal of Hydrologic Engineering, 15(2), pp. 107-122.

Liu, L., Hong, Y., Bednarczyk, C.N., Yong, B., Shafer, M.A., Riley, R. and Hocker, J.E., 2012. Hydro-climatological drought analyses and projections using meteorological and hydrological drought indices: a case study in Blue River Basin, Oklahoma. *Water resources management*, *26*(10), pp. 2761-2779.

Marshall, H. 1785. Arbustrum Americanum: The American Grove. J. Crukshank, Philadelphia. As described and cited in Stibolt *et al*. 1977.

Maryland 1984. Critical Area Law. Available online at: *http://dnr.maryland.gov/criticalarea/Pages/background.aspx*. Last accessed February 18, 2018.

Maryland Dept. of Agriculture. 2017. Emerald Ash Borer. Available online at: *http://mda.maryland.gov/plants-pests/Pages/eab.aspx.* Last accessed February 18, 2018.

Maryland Dept. of the Environment. 2018. Sediment and erosion control. Available online at: *http://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/erosionsedimentcontrol.aspx*. Last accessed February 18, 2018.

Maryland Natural Heritage Program. 2018. Rare, Threatened, and Endangered Plants of Maryland, C. Frye Ed., Maryland Department of Natural Resources, 580 Taylor Avenue, Annapolis, MD 21401. DNR 03-010418-43

McNees, J. 2017. Electronic mail record. 06/05/2017. Conservation Data Analyst, Nature Serve. Email to Cherry Keller, USFWS.

Middleton, B. A. 2016. Differences in impacts of Hurricane Sandy on freshwater swamps on the Delmarva Peninsula, Mid-Atlantic Coast, USA. Ecological Engineering, 87, 62-70.

Moffett, M. and Pattavina, P. 2017. Telephone record on 08/23/17 between Dr. Mincy Moffett, Botanist, Georgia Department of Natural Resources, Pete Pattavina, USFWS, and Michele Elmore, USFWS.

Morton Arboretum. 2018. (*http://www.mortonarb.org/trees-plants/tree-plant-descriptions/seaside-alder*). Last accessed February 8, 2018.

Najjar, R. G., Pyke, C. R., Adams, M. B., Breitburg, D., Hershner, C., Kemp, M., and K. Sellner. 2010. Potential climate-change impacts on the Chesapeake Bay. Estuarine, Coastal and Shelf Science, 86(1), 1-20.

National Climate Assessment. 2014. Climate Change Impacts in the United States, Chapter 19 Great Plains. Available online at: *https://nca2014.globalchange.gov/report/regions/great-plains*. Last accessed March 2018.

National Drought Mitigation Center (NDMC). 2018. United States Drought Monitor. U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Association. (NOAA). *http://droughtmonitor.unl.edu.* Last accessed: February 28, 2018).

National Oceanic and Atmospheric Association (NOAA). 2018. What Is Bathymetry? *https://oceanservice.noaa.gov/facts/bathymetry.html*. Last accessed April 9, 2018.

NatureServe. 2017. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available at: *http://explorer.natureserve.org*. Last accessed: February 9, 2018).

O'Driscoll, M., S. Clinton, A. Jefferson, Alex Manda, and S. McMillan, 2010. Urbanization Effects on Watershed Hydrology and In-Stream Processes in the Southern United States. Water 2010, 2:605-648, doi:10.3390/w2030605.

Oklahoma Climatological Survey. 2018. Climate of Oklahoma. Available online at: *http://climate.ok.gov/index.php/site/page/climate_of_oklahoma*. Last accessed April 16, 2018.

Oklahoma Natural Heritage Inventory. 2018. ONHI working list of rare Oklahoma Plants. *http://www.oknaturalheritage.ou.edu/content/biodiversity-info/tracking-list/index.php*. Last accessed April 3, 2017.

Oklahoma Water Resources Board (OWRB). 2012. *Oklahoma Comprehensive Water Plan*; Executive Report; Oklahoma Water Resources Board: Oklahoma City, OK, USA, pp. 1-131

Otto, S. P., and Lenormand, T. 2002. Evolution of sex: resolving the paradox of sex and recombination. Nature Reviews Genetics, 3(4), 252.

Paschke, M. W., and Dawson, J. O. 1993. Avian dispersal of Frankia. Canadian journal of botany, 71(8), 1128-1131.

Peck, M.F., and Painter, J.A. 2016. Groundwater conditions in Georgia, 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5161, 55 p., *https://doi.org/10.3133/sir20165161*.

Poland, T. M., and D.G. McCullough. 2006. Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. Journal of Forestry, 104(3), 118-124.

Ranger, S. 1997. Four exciting fall '97 state records. Bot Soc News, 71:7.

Rice, W. R. 2002. Experimental tests of the adaptive significance of sexual recombination. Nature Reviews Genetics, 3(4), 241-251.

Rice, W.R. 2017. Expert meeting on August 4, 2017. Mental Modeler Oklahoma alder influence discussion.

Rice, S.A. and Gibson, J.P., 2009. Is seedling establishment very rare in the Oklahoma seaside alder, Alnus maritima ssp. oklahomensis? Oklahoma Native Plant Record, 9(1).

Richards. M. 2017. Electronic mail record,09/15/2017, Conservation Horticulture Manager, Atlanta Botanical Gardens. Email to Michele Elmore, USFWS.

Ryder, P.D. 1996. Ground Water Atlas of the United States; Segment 4; Oklahoma, Texas. U.S. Geological Survey Hydrologic Investigations Atlas 730-E.

Sargent, C.S. 1947. Silva of North America Vol. IX: 81-82. Peter Smith, New York.

Schrader, J.A. 1999. Propagation of *Alnus maritima* from its three disjunct populations. MS Thesis, Dept. of Horticulture, Iowa State Univ., Ames.

Schrader, J. A. and W. R. Graves. 2000a. *Alnus maritima*: a rare woody species from the New World. The New Plantsman 7: 74–82.

Schrader, J. A. and W. R. Graves. 2000b. Seed germination and seedling growth of Alnus maritima from its three disjunct populations. Journal of the American society for Horticultural science, 125(1), 128-134.

Schrader, J. A. and W.R. Graves. 2000c. Timing of seed dispersal may limit the reproductive success of Alnus maritima. Castanea, 69-77.

Schrader, J. A. and W. R. Graves. 2002. Intraspecific systematics of Alnus maritima (Betulaceae) from three widely disjunct provenances. Castanea 67: 380–401.

Schrader, J. A. and W. R. Graves. 2003. Phenology and Depth of Cold Acclimation in the Three Subspecies of *Alnus maritima. Journal of the American Society for Horticultural Science*128: 330–336.

Schrader, J. A. and Graves, W. R. 2004. Systematics of *Alnus maritima* (seaside alder) resolved by ISSR polymorphisms and morphological characters. Journal of the American Society for Horticultural Science, 129(2), 231-236.

Schrader, J. A., W. R. Graves, S. A. Rice, and J. P. Gibson. 2006. Differences in shade tolerance help explain varying success of two sympatric *Alnus* species. International Journal of Plant Sciences 167: 979–989.

Schrader, J.A. and Graves, W.R., 2008. Nodulation and Growth of *Alnus nitida* and *Alnus maritima* Inoculated with Species-specific and Nonspecific Frankia. Journal of Environmental Horticulture, 26(1), pp. 29-34.

Schwinning, S. and Ehleringer, J.R., 2001. Water use trade-offs and optimal adaptations to pulse-driven arid ecosystems. Journal of Ecology, 89(3), pp. 464-480.

Shreve, F., Chrysler, M. A., Blodgett, F. H., and Besley, F. W. 1910. The plant life of Maryland (Vol. 3). Johns Hopkins Press.

Sills, T. and Phillips, M. 2018. Telephone record between Tom Sills, Bartow County Government Transportation Planner, Melissa Phillips, Assistant Sustainability Coordinator Bartow County Government, and Michele Elmore, USFWS.

Silvertown, J. 2008. The evolutionary maintenance of sexual reproduction: evidence from the ecological distribution of asexual reproduction in clonal plants. International Journal of Plant Sciences, 169(1), 157-168.

Smith, D.R., N.L. Allan, C.P. McGowan, J.A. Szymanski, S.R. Oetker, and H.M. Bell. 2018. Development of a Species Status Assessment Process for Decisions under the U.S. Endangered Species Act. Journal of Wildlife Management, 9(1), 19 pp.

Southern Environmental Law Center (SELC). 2018. Tri State Water Wars (AL, GA, FL) Available at: *https://www.southernenvironment.org/cases-and-projects/tri-state-water-wars-al-ga-fl*. Last accessed: April 5, 2018.

Stibolt, V. M. 1981. The distribution of Alnus maritime Muhl. ex Nutt. (Betulaceae). Castanea 46: 195–200.

Stibolt, V. M., Broome, C. R., and Reveal, J. L. 1977. Alnus maritima Muhl. ex Nutt., not Alnus metoporina Furlow. Annals of the Missouri Botanical Garden, Vol. 64:373-374.

Stritch, L. 2014. *Alnus maritima* (Marshall) Muhl. ex Nutt. In: The Red List of Betulaceae. Botanic Gardens Conservation International. Richmond, Surrey, United Kingdom.

Stooksbury. D.E. 2003. Historical Droughts in Georgia and Drought Assessment and Management. In. Proceedings of the 2003 Georgia Water Resources Conference, held April 23-24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Sun, G. and B.G. Lockaby, 2012. Water Quantity and Quality at the Urban-Rural Interface. In: Urban-Rural Interfaces: Linking People and Nature, D.N. Laband, B.G., Lockaby, and W. Zipperer (Editors), Chapter 3, pp. 26-45. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, Wisconsin

Sweet, W., Zervas, C., and Gill, S., 2009. Elevated East Coast Sea Levels Anomaly: June–July 2009. Silver Spring, Maryland: National Ocean Service, NOAA Technical Report, NOS CO-OPS 051, 30p.

Tatnall, R. R. 1946. Flora of Delaware and the Eastern Shore: an annotated list of the ferns and flowering plants of the peninsula of Delaware, Maryland and Virginia. Society of Natural History of Delaware. Full text of this document is available at: *https://archive.org/stream/floraofdelawaree00tatn/floraofdelawaree00tatn_djvu.txt*. Last accessed October 15, 2017.

Tebaldi, C., Strauss, B. H., and Zervas, C. E. 2012. Modelling sea level rise impacts on storm surges along US coasts. Environmental Research Letters, 7(1), 014032.

Tejan, E.C. and Haase, C.S., 2008. Indicators of Hydrologic Alteration (IHA) Analysis of Selected Streams on the Arbuckle-Simpson Aquifer, South Central Oklahoma.

Terando, A.J., J. Costanza, C. Belyea, R.R. Dunn, A. McKerrow, and J.A. Collazo. 2014. The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S. PLoS ONE 9(7): e102261. doi:10.1371/journal.pone.0102261

Tucker, J. 2017. Personal communication during Oklahoma alder site visit in April 14, 2017.U.S. Geological Survey (USGS) Gap Analysis Program. 2011. GAP/LANDFIRE National Terrestrial Ecosystems 2011. *http://gapanalysis.usgs.gov/gaplandcover*/. doi:10.5066/F7ZS2TM0.

U.S. Geological Survey (USGS). 2006. "Georgia's Ground-Water Resources and Monitoring Network, 2006." Available online at: *https://water.usgs.gov/GIS/huc.html*. Last accessed February 8, 2018.

United States National Vegetation Classification (USNVC). 2017. United States National Vegetation Classification Database, V2.01. Federal Geographic Data Committee, Vegetation Subcommittee, Washington DC. At: *usnvc.org*. Last accessed February 27, 2018).

Vallejo-Marín, M., Dorken, M. E., & Barrett, S. C. 2010. The ecological and evolutionary consequences of clonality for plant mating. Annual Review of Ecology, Evolution, and Systematics, 41, 193-213.

Williams, G.C. 1975. Sex and evolution. Princeton University Press, Princeton, NJ.

Wills, L. 2015. "Georgia Power protects rare shrub in ancient swamp."

Winter, T.C., Harvey, J.W., Franke, O.L and Alley, W.M. 1998. Ground Water and Surface Water A Single Resource. U.S. Geological Survey Circular 1139.

Water Resource Management Plan (WRMP). 2017. Metropolitan North Georgia Water Planning District. Prepared by Ch2M and Black and Veatch.

APPENDIX A–Condition Methods, Metrics, and Condition Scoring

A-1 Delmarva Alder

1. **Background Definitions and Descriptions**
2. **Data used in this assessment**
3. **Current Condition Definitions for Analytical Units**
4. **Future Condition Methodology**

1. Background Definitions and Descriptions – the following provides some explanations of terms used throughout the Status Assessment.

Individual Plant/Shrub = one stem with leaves or a multi-stemmed clump (generally stems within a 6 foot diameter or 3 foot radius circle). Most observations will be several shrubs 6 foot or more in diameter. Most will appear shrubby with leaves from top to bottom. In some cases where adjacent vegetation begins to create shade the seaside alder will have all leaves at the top of a tall stem and appear to reach out to the sunny areas. If saline water has entered the area – evidence of salt stress will cause leaf edges to be brown on lower leaves and individuals are likely to be present. This is uncommon and most sites are occupied by single or multiple clumps of shrubs that appear healthy and have leaves from top to bottom. Thus, unless otherwise noted, we will assume that individual plants are healthy at occupied sites.

Occupied Site – Record -Shrub community = a record in the GIS data base which refers to the location or site where several shrubs or a complex of multiple shrubs have been observed and recorded by a biologist on a particular day. The location of this observation is the **site** and the **record** is what was seen at that site on a particular day and is indicated by a (dot) in the GIS. There can be multiple records for one location if sites are revisited over the years and this continued occupancy *indicates persistence* of seaside alder at that site. The locations of these observations are generally recorded as a point but often represent a more linear area of shrub occurrence along a stream or the edge of a pond. The geographic extent of the shrub community is not generally mapped with precision (except for Georgia alder where the shrub community is mapped in greater detail). In Oklahoma and the Delmarva Peninsula, the point locations can refer to large or small patches of shrubs with some notes available to describe this. For example, in Maryland, "stand sizes range from very small patches of shrubs to large (>10 ha) stands" (Harrison and Stango 2003, p. 19). We can describe occupied sites as persisting with recent observations and there are often some notes to describe relative abundance or size of the stand. Descriptors of occupied sites: persisting, abundant.

HUC 12 Watershed - Analytical Unit = The boundaries of the HUC 12 watershed as described by USGS which we are using as a surrogate delineation for a population. This area includes the stretch of stream where seaside alder records occur and the adjacent uplands that may drain into the stream. They often include multiple occupied sites and the relative number of sites reflects the overall abundance of seaside alder in the watershed. These areas are the drainage basins or watersheds that are occupied by this shrub and are reasonable geographic units for analyzing the resiliency of this species in a consistent way across its range. The resiliency of the populations in a watershed are reflected in the abundance of occupied sites and the persistence of seaside alder at those sites.

Resiliency describes the ability of populations to withstand stochastic events (arising from random factors). We can measure resiliency based on metrics of population health; for example, germination versus death rates and population size. Highly resilient populations are better able to withstand disturbances such as random fluctuations in germination rates (demographic stochasticity), variations in rainfall (environmental stochasticity), or the impacts of anthropogenic activities.
Representation *describes the ability of a species to adapt* to changing environmental conditions. Representation can be measured by the breadth of genetic or environmental diversity within and among populations and gauges the probability that a species is capable of adapting to environmental changes. The more representation, or diversity, a species has, the more it is capable of adapting to changes (natural or human caused) in its environment. In the absence of species-specific genetic and ecological diversity information, we evaluate representation based on the extent and variability of habitat characteristics across the geographical range.
Redundancy describes the ability of a species to withstand catastrophic events. Measured by the number of populations, their resiliency, and their distribution (and connectivity), redundancy gauges the probability that the species has a margin of safety to withstand or can bounce back from catastrophic events (such as a rare destructive natural event or episode involving many populations; for example, wildfire or flooding).

2. Distribution - Sources of GIS and other data providing records of occurrence for Delmarva Alder

<u>Current Data on Delmarva Alder locations—survey effort and time frames:</u> Most of the data from Maryland (MD) and Delaware (DE) are somewhat dated, due to changing priorities. For example, while initial concern for this species in the 1990's influenced the level of survey efforts, after abundant records subsequently accumulated, it was no longer a priority for State surveys. Thus, about 65 percent of the records in MD and DE were recorded before 2000, and 35 percent of the records were reported between 2000 and 2011. A 2002 study of MD freshwater tidal shrub communities (Harrison and Stango 2003) increased the number of records for Delmarva alder in that year, but records since then were sparse.

As part of this SSA, Service staff conducted site visits to as many sites as possible in an attempt to document the subspecies' presence. In 11 field days, we were able to confirm its presence in 69 percent of the U.S. Geological Survey (USGS) hydrologic unit code (HUC) 12 watersheds delineated as analysis units (see Chapter 4—Methodology for more details) and found some new sites not presently included in the State records.

Datasets are primarily point locations that indicate the location of a patch of seaside alder that may range from a small patch to an area greater than 10 hectares (ha) (25 acres (ac)). However, not every plant can be mapped and according to the State botanists collecting this data, it should be assumed that individual plants occur in between locations as well (Frye and McAvoy 2017).

In summary, while additional locations may exist in areas of suitable habitat, many areas are difficult to access and not all potential sites can be surveyed. Therefore, the best available information on the distribution of the Delmarva alder includes the aforementioned survey data.

3. Current Condition Definitions for Analytical Units

Population in the Analytical Units were defined as having High, Moderate or Low Resiliency as follows:

> **High resiliency—**Delmarva alder occurs in three or more sites; at least one site is considered large; evidence of persistence (recent records since 2000).
> **Moderate Resiliency—**Occupies one or two sites; at least one considered good or medium in size; evidence of persistence (recent records since 2000) at one or both sites.
> **Low Resiliency—**Occupies one site; not considered large or no data on size; low or no evidence of persistence, no recent records (since 2000). Provides no redundancy within the HUC.

The Environmental features of the Analytical Units were defined as having High, Moderate or Low Condition based on their vulnerability to saline storm surges as follows:

> Current vulnerability is basically an understanding of their future vulnerability to saline storm surge. Thus we defined their current habitat condition as follows:
> - High Vulnerability (Low Condition) = HUC12 watersheds with more than 20% of NWI wetlands being estuarine and no obvious barriers to storm surge;
> - Medium Vulnerability (Moderate Condition) = HUC12 watersheds with 1-20% of NWI wetlands being estuarine or with some obvious barriers to storm surge;
> - Low Vulnerability (High Condition) = HUC 12 watershed with <1% of NWI wetlands being estuarine and sites are either too far or protected by obvious barriers to storm surge.

We assume that the proximity to estuarine wetlands has determined the frequency of past storm surges and the populations that remain have been determined by this factor in the past. Thus, the current abundance and persistence of occupied sites in the HUC is the determining factor in the overall current condition score.

4. Future Condition Methodology

To characterize the future condition of HUC 12 watersheds we considered their vulnerability to saline storm surge following the steps below.

1) We used the relative proportion of the NWI wetlands that are estuarine as a measure of proximity to saltwater. Values ranged from 58 percent to 0 percent. HUC 12 watersheds that have 0% estuarine marsh are considered too far from coastal marshes to be affected by sea level rise in the future scenarios.

2) For HUC 12 watersheds that do contain estuarine marsh and could be affected by sea level rise, we next considered:

- How much estuarine marsh is present and how close occupied sites are to estuarine marsh
- Whether the site had been affected by Super storm Sandy using the GIS layer available from FEMA – and the SLOSH model. Note that this predictive model is not perfect and

there were a few places where the model suggested a site was inundated with saltwater, but it was in fact behind a dam and Delmarva alder continues to thrive there because it was observed in 2017. Also note that the Chesapeake Bay side was not affected by Sandy – and water was actually pulled downstream out of those areas.
- Whether they were on the Chesapeake Bay side of the Delmarva where waters are less saline than the Atlantic side of the Peninsula,
- Whether the site was behind a road or dam that formed an obvious barrier to saline waters.

We then rated the HUC's as most likely to be affected (and thus reduced in condition in the Continuation Scenario), second most likely to be affected (and thus reduced in the Moderate Impacts Scenario) and third most likely to be affected (and thus reduced in condition in the Major Impacts Scenario). This is in addition to the HUC's that were not considered to be affected.

Sources of Information for Future Condition Analysis

SLAMM (Sea level Affecting Marshes Model) – report and website
Glick, P., Clough, J., and Nunley, B. 2008. *Sea-level rise and coastal habitats in the Chesapeake Bay region: technical report*. National Wildlife Federation.
http://warrenpinnacle.com/prof/SLAMM/index.html

The Sandy storm surge GIS layer developed by FEMA (Source: ArcGIS Map Service; http://tiles.arcgis.com/tiles/DO4gTjwJVIJ7O9Ca/arcgis/rest/services;)

***NWI data for Maryland and Delaware* -** Image year for the Delmarva is described as in the 2000's. Data were obtained from: https://www.fws.gov/wetlands/data/data-download.html.

A-2 Georgia Alder

Demographic Factors

Demographic factors were assessed using survey records acquired from the Georgia Natural Heritage Program, associated field reports and personal communications with field biologists (add citations). Survey methods differ from survey to survey, but they provide information that allows assessment the population factors. Metrics used to assess the population factors of abundance, persistence and recruitment were similar for all 3 subspecies (table A-1). Abundance is measured by number of sites (or records) occupied within each HUC 12 watershed and the relative size (small or unknown, medium, or large) of each site. Persistence can be measured by documentation of extant populations over time. Specifically we determined a population to be persistent if it was last documented since the year 2000. Recruitment was measured by evidence (or observation) of high, medium or low to no recruitment present.

There is currently only one known population of Georgia alder which is found in Drummond Swamp located in Bartow County, Georgia within the Lower Euharlee Creek Watershed. Original survey data indicated two areas of Georgia alder density within the swamp containing about 200 plants or clumps. A 2014 aerial (helicopter) survey conducted by the State of Georgia found at least areas of density and about 3,000 plants or clumps. According to these survey data, Georgia alder appears to be spreading into new areas around Drummond Swamp that have recently been converted from pasture to wetland by beaver damming (Chafin 2017, p. 2). Whether the Georgia alder is spreading sexually or vegetatively is well understood, although some seedlings have been observed (Moffett and Pattavina 2017). The Drummond Swamp site likely represents the largest stand of *Alnus maritima* in the world (Schrader and Graves 2002, p. 393) with an extent over 124 to 173 acres and occupying over 35 acres (Chafin 2017, p.2).

Table A-1. Demographic and habitat characteristics used to create condition categories in tableA-2.

Condition Category	Demographic Factors				Habitat Factors		
	Abundance	**Abundance**	**Persistence**	**Recruitment**	**Water Quality**	**Water Quantity**	**Sunlight Availability**
High	Occupies 3 or more sites (records or polygons)	At least one record described as large in size	Evidence of persistence at most sites (since 2000)	High evidence of recruitment (sexual and/or asexual)	Average wetland buffer width is >100ft; no or minimal evidence of water degradation; impervious surface within HUC 12 watershed is 0-5%	Water flow/ spring discharge is optimal to allow hydric soils; no known flow issues; isolated low flow or drought periods (about every 40 years)	Full sunlight conditions, minimal habitat modifications that decrease sunlight availability
Moderate	Occupies 1 or 2 sites (records or polygons)	At least one record described as medium or large in size	Evidence of persistence at 1 or both sites (since 2000)	Moderate evidence of recruitment (sexual and/or asexual)	Average wetland buffer width is between 100-35ft; minimal or periodic evidence of water degradation; impervious surface within HUC 12 watershed is 5-10%;	Water flow/ spring discharge not consistently optimal to allow hydric soils; moderate flow issues, more frequent (intervals much less than 40 years) long-term (3+ years) droughts	Full to partial sunlight conditions, moderate habitat modifications that decrease sunlight availability
Low	Occupies 1 site (record or polygon)	Unknown size	Limited evidence of persistence - No recent records (since 2000)	Low to no evidence recruitment	Average wetland buffer width is between <35ft; periodic to frequent evidence of water degradation; impervious surface within HUC 12 watershed is >10%;	Water flow/ spring discharge not flowing to allow hydric soils; Severe flow issues; more frequent (intervals much less than 40 years) longer-term (4+ years) droughts	Partial sunlight or shaded conditions, severe habitat modifications that would decrease sunlight availability

Table A-2. Resiliency of Georgia Alder. See table A-1 for condition categories.

	Demographic Factors					Habitat Factors						
	Persistence	**Abundance**		**Recruitment**	**Demographic Score**	**Water Quality**			**Water Quantity**		**Sunlight**	**Habitat Score**
HUC 12 Name	**Total # of sites observed in HUC 12 since 2000**	**Number of occupied sites in HUC 12**	**Size of population**	**Observed Recruitment**		**Wetland Buffer**	**HUC 12 Land Cover**	**HUC 12 Impervious Surface**	**Average Climate Conditions Precipitation, Drought and Temperature**	**Aquifer Condition**	**Sunlight**	
Lower Euharlee Creek	1	One site at Drummond Swamp	1997: 2 areas with about 200 clumps 2014: 6 areas with about 3,000 clumps	Moderate evidence of recruitment (sexual and/or asexual)	High to Moderate	Over 95% of swamp has >100ft forested buffer	>30% forested; > 45% agriculture; and <15% developed	0-5% Impervious surface, 4.1% Urbanized (SERAP)	Precipitation 52.8-53.98 inches per year; Long-term Drought about every 40 years; Temperature 71-73°F max to 47.3-49.2°F min	Mean water levels are highly variable & reflect changes in precipitation and pumping; Bartow County population (2013) 101,273	Mostly full sun	High
Condition Score	High	Moderate	High	Moderate		High	High	high	High	Moderate	High	

Habitat Factors

Metrics used to assess the Georgia alder habitat factors are described below and in Table GACC.

Water quality was assessed by the average wetland buffer width, the percent of impervious surface within the Lower Euharlee Creek watershed (HUC 12), and any evidence of overall water degradation. Wetland buffers (aka riparian buffers or streamside management zones SMZ) serve an important role in protecting water quality by reducing soil erosion, maintaining cooler stream temperatures and filtering sediment, nutrients and other pollutants. There is no uniform formula to determine the appropriate width of a wetland buffer due to variability in soils and topography. However the steeper the slope and more erosive the soil, the wider the buffer should be. Georgia's Best Management Practices for Forestry recommends between 40 to 100 feet for perennial streams and wetlands (GFC 2009, entire). In a review of the efficiency of buffer strips for riparian ecosystems, Brian *et al*. (2004) suggest that wide buffer strips over 30 meters (~100 feet) provide the best protection from non-point source pollution, however many agricultural settings have buffers less than 10m (or ~30 feet) and these may only provide minimal reduction in non-point source pollution. Additionally, water quality is measured by the percent (%) impervious surfaces within a watershed. Watersheds that exceed 10% have been documented to show declines in water quality, as well as water quantity (CWP 2003, p. 1). Therefore water quality condition categories were determined to be: "High" if average wetland buffer width is >100ft, there is no or minimal evidence of water degradation and impervious surface within HUC 12 watershed is 0-5%; "Moderate" if average wetland buffer width is between 100-35ft, there is minimal or periodic evidence of water degradation, and impervious surface within HUC 12 watershed is 5-10%; and "Low" if average wetland buffer width is <35ft, there is periodic to frequent evidence of water degradation, and impervious surface within HUC 12 watershed is >10%.

We examined (GoogleEarth 2017) aerial imagery to measure the average buffer width adjacent to the Georgia alder site and assess prevalence of land use practices that are known to affect water quality (e.g. urban areas, agriculture/cattle, forestry, other uses). Land cover was estimated for the HUC 12 watershed and within a half mile buffer of the Georgia alder site using the 2011 GAP/LANDFIRE (USGS GAP Analysis Program 2011).

In the past Drummond Swamp had limited buffering from adjacent land uses, such as cattle grazing. This is especially evident in the 1955 aerial photo. Over time the forested (or shrub) buffer increased in width and in 2017 over 95% of Drummond Swamp has more than 100 foot-wide forested/shrub buffer (figure A-1). Adjacent land use (or land cover) is pastureland, natural forest or has been replanted with loblolly pine. Cattle grazing in the adjacent pastureland appears to be less than in the past, especially on lands acquired by the Georgia Power Company where cattle have been removed (Ozier 2018a). Landcover within the Lower Euharlee Creek HUC 12 watershed and within a half-mile buffer of Drummond Swamp is similar, with >30% forested, >45% agriculture (pastureland), <15% developed and < 10% wetland (figure A-2). The "developed" landcover category includes impervious surfaces as well as vegetation of urban, suburban and rural cities and villages, typically lawns, parks, gardens, and urban ponds (USNVC 2017).

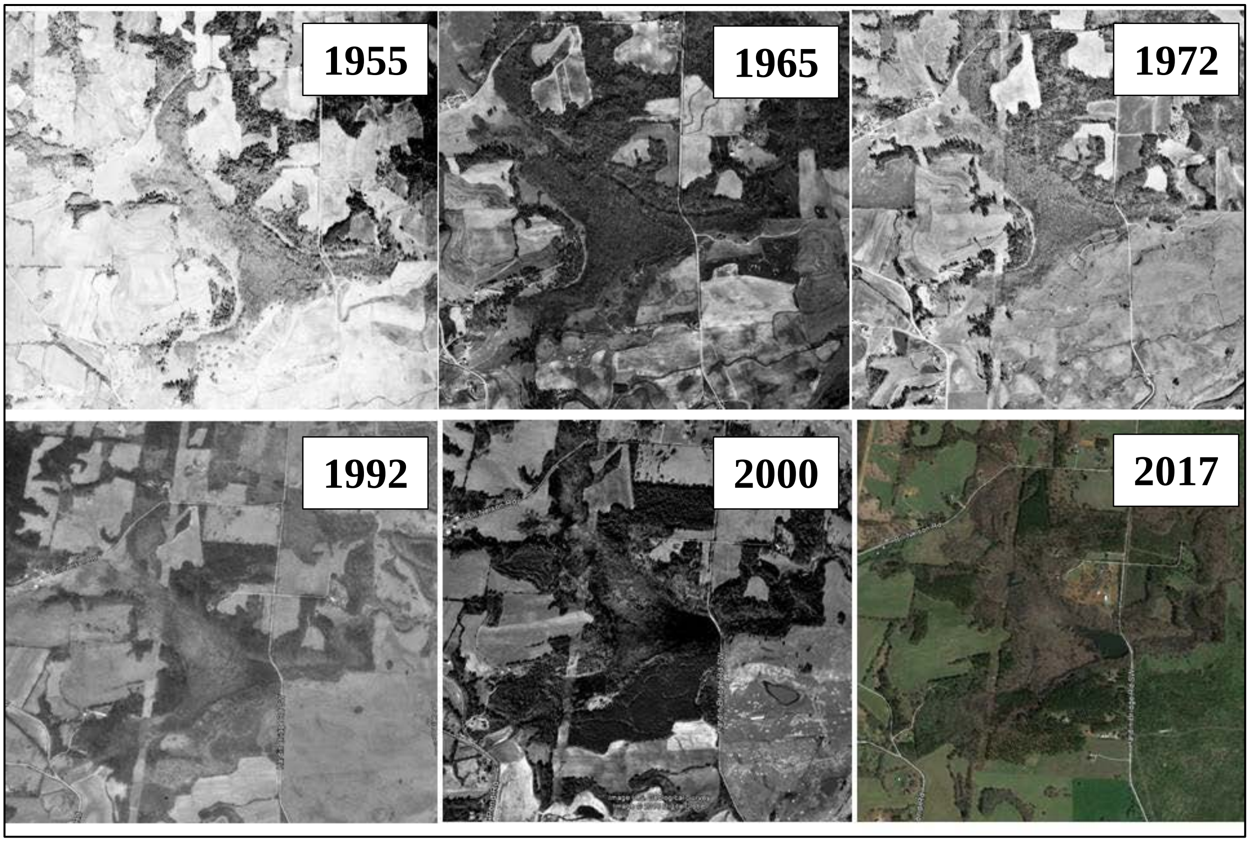


Figure A-1. Aerials over time showing change in the landscape at Drummond Swamp. Photos from years 1955, 1965, and 1972. Photos from 1992, 2000 and 2017 were obtained from Google Earth (2017).

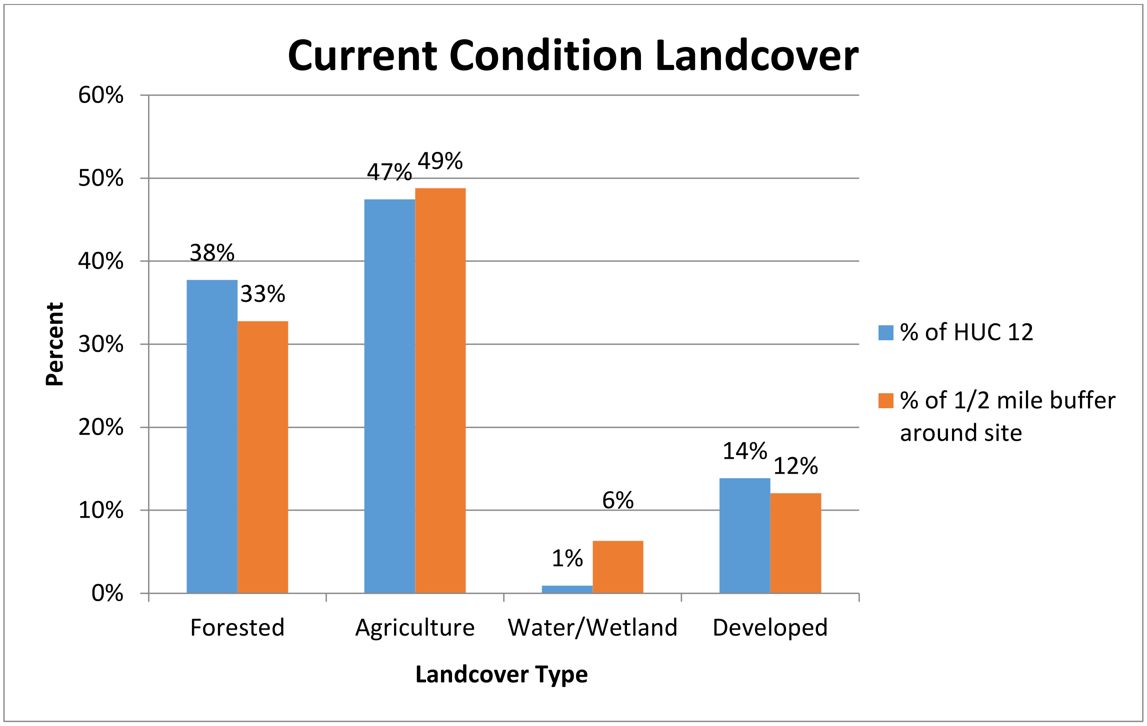


Figure A-2. Percent landcover within the Lower Euharlee Creek HUC 12 watershed and within a half mile buffer surrounding Drummond Swamp. Landcover was derived from the 2011 GAP/LANDFIRE (USGS GAP Analysis Program 2011).

Urbanization and impervious surface cover within the watershed was assessed using the SLEUTH model (Terando *et. al*. 2014, p .2). The Lower Euharlee Creek HUC 12 watershed was about 4.1% "urbanized" in 2010, which is consistent with the 0-5% impervious surface reported in the Metropolitan North Georgia Water Planning District's Water Resource Management Plan, Etowah River Basin Profile for the Lower Euharlee Creek Watershed (ERBP 2017, p. 13). However, watersheds immediately to the east have higher impervious surface cover as development is growing from the Cartersville, GA area (figure A-3).

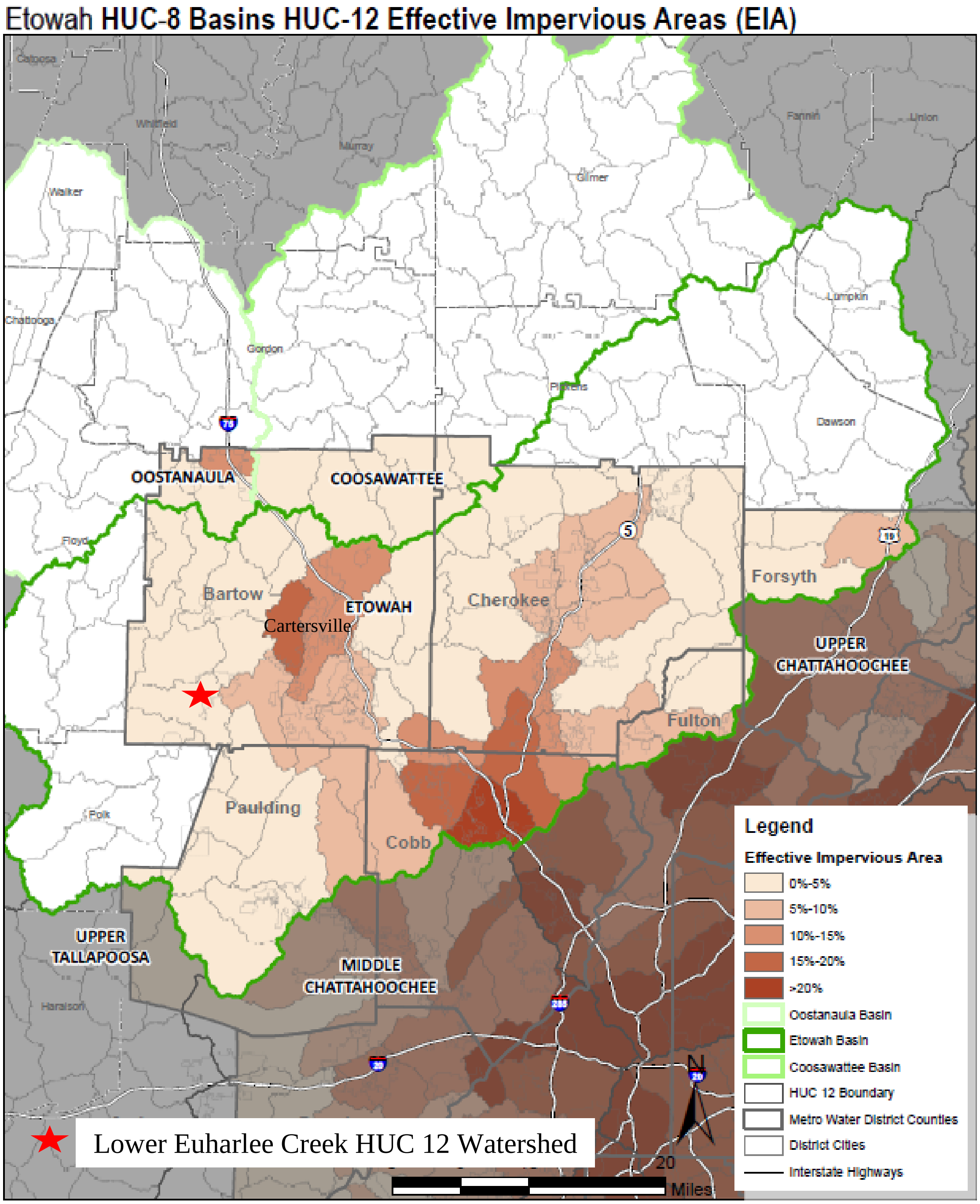


Figure A-3. Effective impervious surface cover for HUC 12 watersheds within the Etowah River Basin. Map adapted from the North Metropolitan District Water Management Plan, Etowah River basin profile (ERBP 2017).

Water quantity current condition was assessed by researching past weather records (i.e. drought and precipitation patterns) and groundwater monitoring data for the region. We also considered any land use or resource use that is known to affect groundwater flow such as human population or urbanization and water use data.

Compared to Delmarva and Oklahoma populations of seaside alder, the Georgia alder receives significantly more annual precipitation (52.8 to 53.98 inches per year) and Schrader and Graves (2002, p. 393) suggested that the Georgia alder may be more dependent on precipitation than on saturated soils from groundwater. Drought is a normal component of the southeastern United States and many of Georgia's native ecosystems depend on drought for health and survival. A summary of historical drought in Georgia by Stooksbury (2003, pp. 1–2) reveals that Georgia has experienced major long-term droughts (3 or more years) eight times since 1680 and these droughts occurred about once every 40 years and droughts of two or more years occurred on average about every 25 years. However, post 2002 data show drought frequency may be increasing. Georgia and the Etowah River Basin have experienced more frequent (much less than 40 years) long-term droughts (3 or more years). After the 1998 to 2002 drought another long-term drought occurred four years later in 2006 to 2009 and then again two years later in 2011 to 2013 (figure 23 in Chapter 3, above).

Sunlight Availability was determined by examining March 2017 aerial imagery (Google Earth), recent photos of the site and communication with field biologists familiar with the Georgia alder site. In general the majority of the Georgia alder at Drummond Swamp is growing in open, full sun conditions (figure 37 in Chapter 4, above). Schrader and Graves (2002, p. 390) describe the Georgia alder to be growing in less shade than the Delmarva and Oklahoma populations and may exhibit greater sun tolerance. Some clusters of the alders are along the swamp and stream edges and may receive some shading during parts of the day, but Schrader and Graves (2002, p. 393) suggest the overall large size and rapid growth of Georgia alder make it very competitive with other tree species in Drummond Swamp. Site visits and discussions with biologists familiar with Drummond Swamp confirm that shading is not significant, and that site conditions from impoundments (beaver and road) and boggy conditions due to underground springs keeps the site open and prevents canopy closure by other species (Moffett and Pattavina 2017).

Table A-3. Summary table of current population and habitat condition of the Georgia alder

CURRENT CONDITION RESILENCY SUMMARY	**Demographic Factors**				**Habitat Factors**				**Overall resiliency Score**
HUC 12 Name	**Persistence**	**Abundance**	**Recruitment**	**Demographic Resiliency Score**	**Water Quality**	**Water Quantity**	**Sunlight Availability**	**Habitat Resiliency Score**	
Lower Euharlee Creek	High	Moderate	Moderate	Moderate	High	High	High	High	High

Overall *Resiliency* of the Georgia alder population at Drummond Swamp is **High**

A-3 Oklahoma Alder

Demographic Factors

While there are multiple demographic factors that can affect resiliency, we focused on those factors that influence the analysis unit and for which we have sufficient data: abundance, persistence, and recruitment. For some analysis units the specific information was not available; however, using our best professional judgement we made assumptions to complete our analysis based on what we do know about this species, habitat conditions, and the data reported. Demographic factors were assessed with survey data from the Oklahoma Natural Heritage Inventory. These surveys include data from 1946 to 2016 in which notes from each record were infrequently available. Survey data was collected as records. Each record could be a single plant, many individual plants, clumps, or multiple clumps. The information associated with each record varies. Systematic, regular surveys have not been conducted throughout the full range of this species; however, many surveys were conducted between 1946 and 2016 which covered areas within our seven analysis units. It is unclear as to why Desperado Spring Falls-Blue River subpopulation was extirpated, but the other two subpopulations of the Oklahoma alder persist within the analysis unit. Survey information within and among analysis units varies in timing, data collected, and surveyor. To assess abundance for each analysis unit we used all survey data available.

Table A-4. Population factors used to score the current conditions of the Oklahoma alder.

Main River	Analysis Unit*	Year of Earliest Record	Year of most Recent Record	Sum of Records to 2000	Sum of Records 2001 to present	Total # of sites	Abundance Score	Distribution Score	Demographic Score
Pennington	Lower Pennington Creek	1978	2015	4	7	6	2	3	2.5
Blue	Desperado Spring Falls-Blue River	1978	2007	2	2	2	2	2	2.0
Blue	Pecan Creek-Blue River	1990	2007	1	1	1	2	1	1.5
Blue	Little Blue Creek-Blue River	1958	2016	2	3	3	3	3	3.0
Clear Boggy	Sandy Creek	2013	2013	0	1	1	1	1	1.0
Clear Boggy	Sheep Creek	1946	2016	3	4	4	2	3	2.5
Clear Boggy	Bois d' Arc Creek (Mill Cr)	1978	2007	1	1	1	1	1	1.0

* As of April 17, 2018.

Habitat Factors

We used sunlight, soil, water withdrawals, river base flow, and aquifer recharge as habitat metrics to characterize the Oklahoma alder's resiliency. Water quantity was assessed using a combination of average annual precipitation, drought regime, stream base flow, and aquifer recharge and discharge. For sunlight availability, we assessed flood regime.

Table A-5. Habitat factors used to score the current conditions of the Oklahoma alder.

Main River	Analysis Unit	Saturated Soils	Sunlight	Flood Regime	Groundwater withdrawal (af)	Base flow Ac-F	Aquifer Recharge (ac-f)	natural Aquifer discharge (ac-f)	Soil Score	Sunlight Score	Withdrawals Score	Base flow Score	Recharge Score	Habitat Score
Pennington	Lower Pennington Creek	Counts loam, 0 to 1 percent slopes; flooded	assuming full sunlight since alders are present	Every 13 years	5,712	23,304	115,104	9,681	2	3	3	3	3	2.8
Blue	Desperado Spring Falls-Blue River	Boggy fine sandy loam, 0 to 1 percent slopes, frequently flooded	assuming full sunlight since alders are present	Every 13 years	5,712	44,408	115,104	9,681	2	3	3	3	3	2.8
Blue	Pecan Creek-Blue River	Guyton-Elysian complex, 0 to 3 percent slopes; flooded	assuming full sunlight since alders are present	Every 13 years	5,712	44,408	115,104	9,681	2	3	3	3	3	2.8
Blue	Little Blue Creek-Blue River	Verdigris silty clay loam, 0 to 1 percent slopes, occasionally flooded	assuming full sunlight since alders are present	Every 13 years	5,712	44,408	115,104	9,681	2	3	3	3	3	2.8
Clear Boggy	Sandy Creek	Dougherty fine sand, 0 to 3 percent slopes; depression	assuming full sunlight since alders are present	Every 13 years	5,712	23,304	115,104	9,681	2	3	3	3	3	2.8
Clear Boggy	Sheep Creek	PIT	assuming full sunlight since alders are present	Every 13 years	5,712	23,304	115,104	9,681	2	3	3	3	3	2.8
Clear Boggy	Bois d' Arc Creek (Mill cr)	Verdigris and Cleora soils, 0 to 3 percent slopes, frequently flooded	assuming full sunlight since alders are present	Every 13 years	5,712	23,304	115,104	9,681	3	3	3	3	3	3

Table A-6. Sources of data used for current condition analysis.

Influencing variable	Data source 1	Data source 2	Data source 3
Land Ownership			
Oklahoma populations data	Oklahoma National Heritage Inventory		
Geology	Analyzed, but not considered		
Soils	*https://casoilresource.lawr.ucdavis.edu/soil_web/ssurgo.php?action=list_mapunits&areasymbol=tx187*	SSURGO data	
Precipitation	okclimate.gov		
Stream Flow	Christenson, Scott; N.I. Osborn; C.R. Neel, J.R. Faith, C.D. Blome; James Puckette, and M.P. Pantea. 2011 Hydrogeology and simulation of groundwater flow in the Arbuckle-Simpson aquifer, south-central Oklahoma: U.S. Geological Survey Scientific Investigation Report 2011-5029, pp. 104.	p. 25, average annual precipitation based on 5 year average from 1907-2008	5 year average from 1907-2008
Temperature	Christenson, Scott; N.I. Osborn; C.R. Neel, J.R. Faith, C.D. Blome; James Puckette, and M.P. Pantea. 2011 Hydrogeology and simulation of groundwater flow in the Arbuckle-Simpson aquifer, south-central Oklahoma: U.S. Geological Survey Scientific Investigation Report 2011-5029, pp. 104.	p. 25, average annual precipitation based on 5 year average from 1907-2008	5 year average from 1907-2008
Evapotranspiration	Christenson, Scott; N.I. Osborn; C.R. Neel, J.R. Faith, C.D. Blome; James Puckette, and M.P. Pantea. 2011 Hydrogeology and simulation of groundwater flow in the Arbuckle-Simpson aquifer, south-central Oklahoma: U.S. Geological Survey Scientific Investigation Report 2011-5029, pp. 104.	annual evapotranspiration for blue river near Connerville, OK (07332390), and Pennington Creek near Reagan, OK (07331300) for water years 2004-2008	
Flooding and Runoff	Christenson, Scott; N.I. Osborn; C.R. Neel, J.R. Faith, C.D. Blome; James Puckette, and M.P. Pantea. 2011 Hydrogeology and simulation of groundwater flow in the Arbuckle-Simpson aquifer, south-central Oklahoma: U.S. Geological Survey Scientific Investigation Report 2011-5029, pp. 104.	annual runoff for blue river near Connerville, OK (07332390), and Pennington Creek near Reagan, OK (07331300) for water years 2004-2008	

Table A-7. Condition factors for the Oklahoma alder.

	Population Factors		Habitat Factors	
Condition Category	**Distribution**	**Abundance**	**Saturated Soil**	**Sunlight Availability**
High	Occupies 3 or more sites (records or polygons)	At least one record described as large in size	Water/ spring discharge is optimal to allow hydric soils; no known flow or water level issues; isolated low flow or drought periods	Full sunlight conditions, minimal habitat modifications that decrease sunlight availability, flood regime creates/maintains open canopy
Moderate	Occupies 1 or 2 sites (records or polygons)	At least one record described as medium in size	Water / spring discharge not consistently optimal to allow hydric soils; moderate flow issues, including multiple consecutive years 3-4? of low flow or drought periods	Full to partial sunlight conditions, moderate habitat modifications that decrease sunlight availability, flood regime only creates/maintains partial open canopy
Low	Occupies 1 site (record or polygon)	of unknown size	Water / spring discharge not flowing to allow hydric soils; severe flow issues, including more than 4 consecutive years of low flow or drought periods	Partial sunlight or shaded conditions, severe habitat modifications that would decrease sunlight availability, flood regime does not create/maintain open canopy

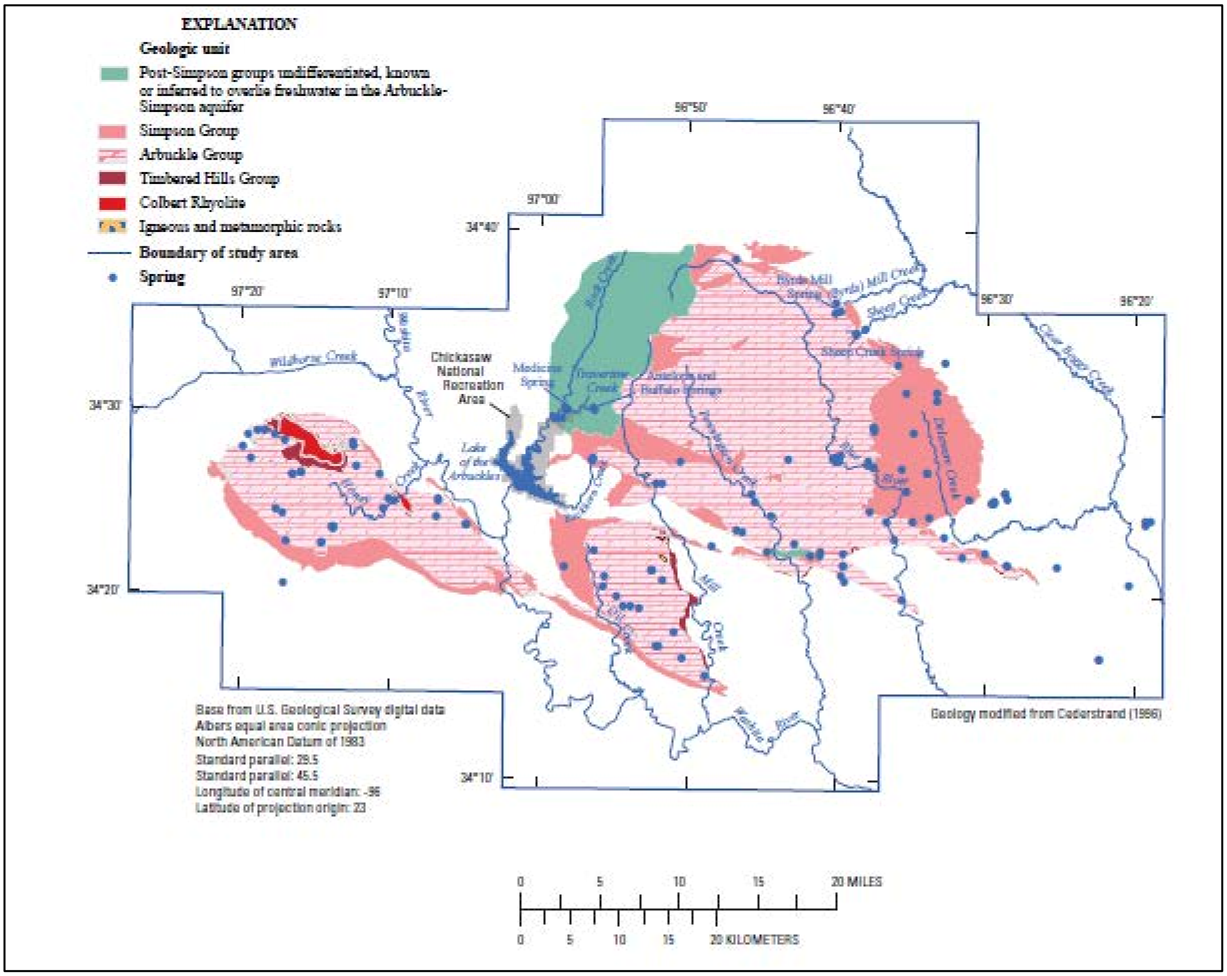


Figure A-4. Spring-fed rivers above the Arbuckle-Simpson Aquifer.

Table A-8. Base flow estimates of Rivers in which the Oklahoma Alder live.

Station number	Station name	Period of record	Mean flow (ft³/s)	Minimum flow (ft³/s)	25th percentile flow (ft³/s)	Median flow (ft³/s)	75th percentile flow (ft³/s)	Maximum flow (ft³/s)
07329780	Honey Creek below Turner Falls near Davis	2004-10-01 to 2008-09-30	19.1	0.47	3.7	6.8	15	655
07329849	Antelope Spring at Sulphur	1985-11-20 to 1989-09-30; 2002-10-01 to 2008-09-30	2.74	0	1.1	2.7	4.0	11
07329852	Rock Creek at Sulphur	1989-10-01 to 2008-09-30	54.0	1.4	9.0	17	36	3,450
07331200	Mill Creek near Mill Creek	2006-09-07 to 2008-09-30	28.3	0.14	3.8	7.5	15	1,490
07331295	Pennington Creek east of Mill Creek	2006-09-09 to 2008-09-30	23.8	3.8	6.2	13	19	930
07331300	Pennington Creek near Reagan	2003-10-01 to 2008-09-30	43.0	9.9	18	24	38	2,560
07332390	Blue River near Connerville	1976-10-01 to 1979-09-30; 2003-10-01 to 2008-09-30	82.7	21	40	49	67	6,330
07334200	Byrds Mill Spring near Fittstown (combined flow)	1989-12-20 to 2008-09-30	18.5	4.6	15	18	22	43