CHAPTER 3 – AFFECTED ENVIRONMENT AND ENVIRONMENTAL CONSEQUENCES

INTRODUCTION

Chapter 3 describes the physical, biological, social, and economic resources of the environment that may be affected by the alternatives presented in Chapter 2, as well as the effects that the alternatives may have on those resources. Affected environment and environmental effects have been combined in this chapter to give a more concise and connected depiction of what the resources are and what may happen to them under the different alternatives. The environmental effects analysis forms the scientific and analytic basis for the comparison of alternatives that appears at the end of Chapter 2.

CHAPTER STRUCTURE

The remainder of this chapter is organized into four sections: A) Physical Environment; B) Biological Environment; C) Social and Economic Environment; and D) Federal Oil and Gas Leasing Availability Decision. Each resource section is organized and presented in the format described below. Since Alternative I is identical to Alternative H with the exception of oil and gas leasing availability, the effects for Alternative I are the same as those for Alternative H in Sections A, B, and C, except where specifically noted. The effects for Alternative I are the same as those for Alternative C in Section D, except where specifically noted.

Affected Environment - Describes the current conditions of the resources. This section may also include history, development, past disturbances, natural events, and interactions that have helped shape the current conditions. It can also describe the geographic area or areas for the analysis of effects. Areas may vary in size depending on the resource, issue, or anticipated activities. This section also describes the time frame over which effects were assessed.

Environmental Consequences
Direct and Indirect Effects – Analyzes the amount and intensity of direct and indirect effects by alternative. Direct effects are caused by an action and occur at the same time and place as that action. Indirect effects are caused by an action but occur later in time or farther removed in distance. Direct and indirect effects are focused on Federal actions. This section also looks at the relationship of temporary (typically 0-3 years), short-term (3-10 years), and long-term (>10 years) effects.

Cumulative Effects – Analyzes the cumulative effects to the resource that may result from the incremental impacts of the alternatives when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes the other actions.

SECTION A – PHYSICAL ENVIRONMENT

The physical environment is the non-living portion of the environment upon which the living organisms depend—air, soil, water, geology, and climate. This section begins with a description of the ecological classification of the GWNF. The ecological classification is a system that classifies land and water at various scales through integrating information about climate, geology, landform, soils, water, and vegetation. This classification is a tool to provide a more ecological and scientific basis in land and resource management planning.
Ecological classification is useful for:

- Evaluating the inherent capability of land and water resources.
- Predicting changes occurring over time.
- Evaluating effects of management.
- Allocating land to management areas.
- Selecting appropriate management indicators.
- Discussing and analyzing ecosystems and biodiversity at multiple scales.

A1 - DESCRIPTION OF ECOLOGICAL UNITS

The National Hierarchical Framework of Ecological Units is a classification and mapping system for dividing the Earth into progressively smaller areas of increasingly similar ecology. Ecological units are mapped based on patterns of climate, soils, hydrology, geology, landform and topography, potential natural communities, and natural disturbances. These various components take on greater or lesser importance as the mapping scale changes. Conditions dominant at broad scales such as climate and geology are continually related to conditions at finer scales such as biologic communities and soil characteristics.

The GWNF lies within the Central Appalachian Broadleaf Forest - Coniferous Forest - Meadow Province of the Humid Temperate Domain, Hot Continental Division. Most of the James River, Warm Springs, North River and Lee Ranger Districts are located within the Northern Ridge and Valley Section (Ridge and Valley Subsection). Massanutten Mountain lies within the Great Valley Subsection of the Northern Ridge and Valley Section. The western portion of the James River and Warm Springs Districts lie in the Eastern Allegheny Mountain and Valley Subsection, Laurel Fork lies in the Northern High Allegheny subsection of the Allegheny Mountains section. The Blue Ridge Mountain Section contains the Pedlar Ranger District (Northern Blue Ridge Mountains Subsection).

Northern Ridge and Valley Section (M221A)

RIDGE AND VALLEY SUBSECTION (M221AA), GREAT VALLEY SUBSECTION (M221AB)

The Ridge and Valley sections are characterized by long belts of parallel mountains and valleys, the landforms being closely related to the lithology and structure of the bedrock. The ridges consist of sandstone, shales, and siltstone with the occasional bands of limestone on the lower slopes. The valleys are composed of limestone, dolomite and shales. Agriculture and urban areas dominate the valleys, while forestry is the primary use on the oak-hickory covered ridges. These Appalachian oak-hickory and oak-pine forests forming many high gradient, deeply incised streams. Extensive areas of metamorphosed sedimentary rocks occur on the western flank. Deeply weathered bedrock, called saprolite, occurs in some areas of the Blue Ridge. Mesic oak forests predominate, but large pockets of northern hardwoods and spruce-fir can also be found at the highest elevations. Ice, wind and fire are major natural disturbances throughout this section.

Blue Ridge Mountains Section (M221D)

NORTHERN BLUE RIDGE SUBSECTION (M221DA)

The Blue Ridge Mountains Section is the oldest on the Forest. These tectonic uplifted mountain ranges are composed of Proterozoic-Paleozoic igneous and metamorphic rock, forming many high gradient, deeply incised streams. Extensive areas of metamorphosed sedimentary rocks occur on the western flank. Deeply weathered bedrock, called saprolite, occurs in some areas of the Blue Ridge. Mesic oak forests predominate, but large pockets of northern hardwoods and spruce-fir can also be found at the highest elevations. Ice, wind and fire are major natural disturbances throughout this section.

Allegheny Mountains Section (M221B)

NORTHERN HIGH ALLEGHENY MOUNTAINS SUBSECTION (M221BA), EASTERN ALLEGHENY MOUNTAIN AND VALLEY (M221BD)

This Section comprises part of the Appalachian Plateaus geomorphic province. It is a maturely dissected plateau characterized by high, sharp ridges, low mountains, and narrow valleys. It has a prominent structural and topographic grain created by broad, northeast to southwest trending folds in the bedrock. Sandstone and some of the tougher carbonates hold up most of the upland portions; weaker carbonates and shale underlie most valleys. Soils are dominantly Ultisols, Inceptisols, and Alfisols, with mesic temperature regime and udic moisture regime. They are derived from heavily weathered shales, siltstones, sandstone residuum and colluvium, and limestone residuum. Spodosols with frigid temperature regime and aquic moisture regime occur in isolated pockets at the highest elevations. Strongly influenced by elevation and aspect, the vegetation of the Allegheny Mountains can be placed in four broad groups: red spruce, northern hardwoods, mixed mesophytic, and oaks. On average, this Section is notably moister than the Northern Ridge and Valley Section.

A2 – GEOLOGIC RESOURCES

AFFECTED ENVIRONMENT

Geology

Geology is the foundation for a variety of ecosystems. Geologic processes, geologic materials and geologic structures control or influence a host of ecological factors, such as slope aspect, slope steepness, the areal extent of landforms and associated vegetation, the distribution and composition of soil parent material, the structure and composition of vegetation, the physical character of floodplains, wetlands, riparian area, and stream substrates, the quantity and quality of stream water and groundwater, natural disturbance regimes, and the nature and condition of watersheds. Geological diversity is the foundation of ecosystem diversity and biological diversity (Anderson and Ferree 2010).

Surface geologic processes are an important part of the natural disturbance regime in the Forest. These processes include: the erosion, transport and deposition of sediment; mass wasting or landslides; flooding; stream processes; groundwater movement; and the formation of caves, sinkholes and other karst features. These processes are part of the natural disturbance regime in the mountains and affect the Forest in varying degrees every year. Some processes are geologic hazards that create risks to the public.

The interaction of the surface geologic processes with the different geologic formations and geologic structures produced different landforms and different geological settings. The Forest is subdivided into physiographic or geomorphic provinces based on landform, rock types and geologic structure.

VALLEY AND RIDGE PHYSIOGRAPHIC PROVINCE

Most of the Forest is in the Valley and Ridge Physiographic Province, which is a long belt of parallel mountain ridges and valleys trending in a northeast direction. Geologic forces squeezed the originally flat-lying sedimentary layers and folded them into a series of arches (anticlines) and troughs (synclines). Erosion of these folds over geologic time has produced a distinctive repeating landscape of ridges and valleys.

Most of the Forest is located on the strike ridges, which are linear, asymmetric ridges formed by the differential erosion of inclined bedrock layers. One flank of the strike ridge is a steep slope cutting across several bedrock layers (anti-dip or scarp slope). In contrast, the other side of the ridge is a less steep slope conforming to the slope of the underlying bedrock layer (dip slope).

Resistant sandstone or conglomerate forms the top of strike ridges and the mid-to-upper area of the dip slopes. In contrast, the lower flanks of the ridges are underlain by shale, and in some areas, by carbonate bedrock (limestone and dolomite). The valleys are underlain by shale and carbonate bedrock. Some limestone areas contain caves, sinkholes, and other karst features.

Along the western edge of Valley and Ridge Province on the Forest, such as along the Virginia/West Virginia border in Highland County, is a transition zone to the Appalachian Plateau Physiographic Province.

BLUE RIDGE PHYSIOGRAPHIC PROVINCE

The eastern portion of the Forest (Pedlar Ranger District) is located in the Blue Ridge Physiographic Province, in which the northeast-trending Blue Ridge Mountains tower above the eastern border of the Valley and Ridge Province. Granite and other igneous rocks dominate the upper slopes of the Blue Ridge Mountains. Quartzite, sandstone, shale occur on the western slopes of the Blue Ridge as well as large alluvial fans on the lowest slopes.

Geologic Resources

The Forest has a wide range of geologic resources including, but not limited to, groundwater, groundwater-dependent ecosystems, springs, caves, sinkholes, disappearing streams, unusual landforms, waterfalls, fossils (paleontological resources), field records of catastrophic events (floods, landslides, ground collapses, and other geologic hazards), and field records of climatic changes and Quaternary ecosystems. Geologic resources are geologic features, areas, or conditions that are significant to natural resource management or human health and safety or have use or value to society. Geologic resources are identified and managed for scientific, ecological, educational, interpretative, scenic, paleontological, recreational, historic, and other values.

The diversity of geologic processes, structures, and materials are the basis for the diversity of ecosystems. Twenty-four ecological systems, as defined by NatureServe's International Ecological Classification Standards, are identified for the analysis of biological resources. Because many of these ecological systems have similar key attributes, indicators, species associates and resulting forest plan components, the biological analysis combined the 24 ecological systems into 9 major forest communities. As discussed in the biological sections, some of these major forest communities (Alkaline and Mafic Glade and Barrens; Cliff, Talus and Shale Barrens; Floodplains, Wetlands and Riparian; Cave and Karstlands) highlight the geologic foundation of the ecological systems.

KARST AND GROUNDWATER

The Forest's geologic resources include karst terrain underlain by carbonate bedrock (limestone and dolomite). Caves, sinkholes, and sinking streams are characteristic of karst terrain, and provide direct access for surface water to flow directly into the ground water. The geologic resource of groundwater, including groundwater in karst areas, is discussed in the Water section.

Karst terrain is widely distributed across the Forest and occurs on every Ranger District (Figure 3A2-1). These geologic map units containing karst (carbonate bedrock) are estimated to encompass 109,300 acres in Virginia and 9,900 acres in West Virginia. Karst areas may be less than 100% of the geologic map unit because other types of bedrock may be present. These geologic map units indicate 11% of the Forest (about 119,200 acres) with geologic formations containing karst and karst-related groundwater.

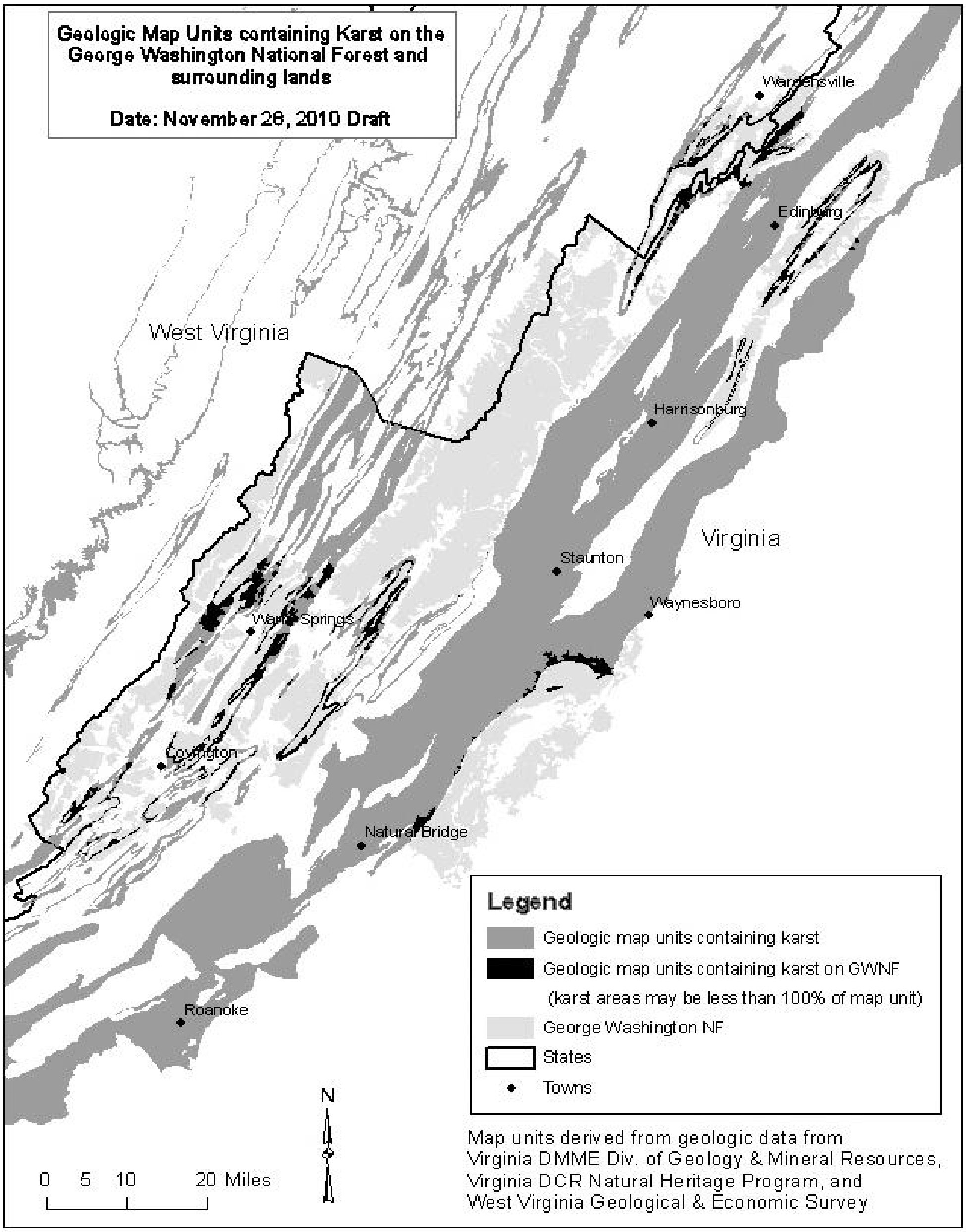


Figure 3A2-1. Geologic Map Units Containing Karst

Trout Pond, a sinkhole pond, may be the only natural lake or pond in West Virginia, and is part of the karst landscape interpreted at the Trout Pond Recreation Area. Maple Flats sinkholes ponds are unusual karst features in an alluvial fan overlying carbonate bedrock. Augusta Springs is a featured nature walk in a karst spring area. Several caves are found on the Forest. The Virginia Department of Conservation and Recreation, Natural Heritage Program, identified 19 cave (and surrounding karst landscape) conservation sites on the Forest. The biological section has more information on cave resources.

Karst groundwater systems are complex, and are even more complex when surficial deposits, such as alluvial fans, mantle the karst bedrock. A notable example is the large alluvial fan along the Coal Road in the Maple Flats area on the north end of the Pedlar District. Thick deposits of sand and gravel overlie Shady dolomite in the Maple Flats sinkhole ponds area and create a complex karst groundwater setting. Another example of a complex karst groundwater setting is the Trout Pond Recreation Area on the Lee District where alluvial deposits overlie karst bedrock.

Geologic Features and Special Interest Areas

Under the current Forest Plan, the Forest has designated two Geologic Special Interest Areas (176 acres total): Devils Garden on the Lee Ranger District (unusual rock pillars, separated by deep fissures); and Rainbow Rocks on the James River Ranger District (huge rainbow of sedimentary strata: anticline).

Some examples of the variety of interesting geologic features on the Forest are:

- Ice Age block fields on Massanutten Mountain are featured in "Glimpses of the Ice Age from I-81" brochure in Geologic Wonders of the Forest series published by U.S. Geological Survey.
- Massanutten Mountain Geologic Story Trail has interpretive displays telling the geologic story of mountain-building, erosion, and geologic history of Massanutten Mountain.
- The Woodstock Observation Tower provides the classic view of the famous Seven Bends of the North Fork Shenandoah River, a geologic text book example of river meanders.
- Jingling Rocks are talus rocks that jingle like wind chimes when wind blows.
- Crabtree Falls, the highest falls in Virginia, has five major cascades and a number of smaller ones that fall a total of distance of 1200 feet.

The Forest has worked in partnership with the U.S. Geological Survey to develop interpretative and education brochures on the Forest's geologic resources in a Geologic Wonders of the Forest series of brochures.

Paleontological Resources

The Forest contains paleontological resources, primarily Paleozoic invertebrate fossils such as brachiopods, crinoids, coral, gastropods, and scolithus. Recently Congress passed the Paleontological Resources Preservation Act of 2009 which establishes a framework for management and protection of paleontological resources on federal lands. In the Act, the term 'paleontological resource' means "any fossilized remains, traces, or imprints of organisms, preserved in or on the earth's crust, that are of paleontological interest and that provide information about the history of life on earth, except that the term does not include--

> (A) any materials associated with an archaeological resource (as defined in section 3(1) of the Archaeological Resources Protection Act of 1979 (16 U.S.C. 470bb(1)); or
>
> (B) any cultural item (as defined in section 2 of the Native American Graves Protection and Repatriation Act (25 U.S.C. 3001))."

The Act requires a permit to collect paleontological resources on federal lands except no permit is required for casual collecting where such collection is consistent with the laws governing the management of the federal land and the Act. In the Act, the term 'casual collecting' means "the collecting of a reasonable amount of common invertebrate and plant paleontological resources for non-commercial personal use, either by surface

collection or the use of non-powered hand tools resulting in only negligible disturbance to the Earth's surface and other resources." The Forest Service is preparing draft regulations for the Act.

Geologic Hazards

Geologic hazards are geologic conditions or phenomena (naturally occurring or altered by humans) that present a risk or are a potential danger to life and property. Forest Service planning regulations require evaluation of existing or potential watershed conditions that will influence hazardous events (36 CFR 219.23(e)). Geologic conditions are part of watershed conditions. Geologic hazards on the National Forests, like fire hazards, affect public safety and property on the Forest and off the Forest in adjacent communities (Collins 2005). The increase in population and infrastructure next to the Forest increases the risks to public safety from geologic hazards associated with the Forest and adjacent private land.

The Forest's main geologic hazards relate to floods, landslides (especially debris flows), landslide dams or woody debris dams, waterfalls, abandoned mines, and karst hazards (sudden ground collapse, sinkhole flooding, and groundwater pollution).

FLOODS

Flooding is a geologic process and natural disturbance that plays a major role in the Forest's watersheds. Flooding also is a key part of geologic processes such as erosion, sediment transport and deposition, and in formation and dynamic changes of floodplains, alluvial fans, and riparian areas. When intense rainfalls occur in the mountains, the steep slopes allow rapid runoff of storm water; the storm waters can overflow creek banks, and then flood across narrow floodplains in narrow valleys. The forests and soils covering the Forest's watershed do moderate runoff and flooding to some extent, but major floods, including flash floods, still occur in the Forest's watersheds. Because the Forest's watersheds are mainly mountainous watersheds with rapid runoff and narrow floodplains, flooding is a geologic hazard on this Forest.

The Water section discusses floods, and mentions notable floods in 1936, 1942, 1949, 1969, 1972, 1985, and 1996. Past floods have damaged Forest roads, trails, developed recreation sites, dams, and other facilities on the Forest. Floods, especially flash floods, create risks to public safety on the Forest, for example, people camping overnight at some developed recreation sites, or people driving roads subject to flash flooding. Preliminary assessments indicate several developed recreation sites are subject to flooding.

Flooding in the mountains of the George Washington Forest is part of a larger geologic process and natural disturbance regime where flooding in mountains contributes to flooding in the valleys and to related geologic processes in the valleys such as erosion, sediment transport and deposition, and changes in floodplains, alluvial fans, and riparian areas. Flooding on the Forest contributes to flooding off the Forest downstream in the watershed. The Forest's watersheds are mainly mountainous watersheds where streams discharge flood waters, bed load, and large woody debris onto private lands in the valleys. As a result, flooding, including flash flooding, on the Forest is a geologic hazard potentially affecting people and infrastructure downstream on private lands.

A debris flood is a flood that incorporates, transports, and deposits so much solid material (such as landslide debris, valley fill, bed load, and/or large woody debris) that the solid material is a major component of the flood, drastically increasing the destructive power of the flood and the resulting flood damage. When infrequent, intense rains fall on the Forest and cause flooding, the mountain watersheds can add into the flood waters both inorganic (rocky debris) and organic (woody debris) materials that can increase the destructiveness of the flood on the Forest and off the Forest.

The role of landslides in creating debris floods was discussed in the Landslide section. The role of woody debris during floods is complex and sometimes contradictory. Large logs and whole trees in flood waters can act as battering rams, eroding the stream banks. This woody debris can form log jams and dams causing severe scour of the channel, mass failure of the stream bank, dam-induced flooding outside of stream channel banks, and debris flood surges due to dam failure. During floods, logs and trees are geologic agents of erosion, just as the flood waters, the suspended load, and the bed load are geologic agents of erosion. However, logs and trees

are also normal components of the stream system. At lower stream flows they can provide stability to the stream channel, reduce the sediment load in streams and improve aquatic habitat. This increase in stability and sediment reduction can also allow the stream system to withstand higher stream flows. Stream channels that are capable of transporting higher flows under stable conditions can reduce the amount of rocky and woody debris that enters the system from eroding stream banks and adjacent landslides.

LANDSLIDES

Because the Forest's watersheds are mainly mountainous watersheds, landslides are an important natural disturbance that plays a major role in flooding, sedimentation, and the functioning of riparian areas. Landslides include a wide range of mass movements such as debris slides, debris flows, slumps, rockslides, rockfall, and stream channel bank failures.

Virginia's deadliest natural disaster occurred on the night of August 19, 1969, when swarms of landslides triggered by the remnants of Hurricane Camille swept down the Blue Ridge and killed 153 people. Hundreds of landslides (debris slides/debris flows) originated on the steep slopes on intermingled private lands and National Forest lands in Nelson, Amherst, and Rockbridge Counties. The landslides scraped the rock, soil and trees off the mountainsides and dumped these deadly landslide masses into storm-swollen streams and valleys. Countless buildings were destroyed and more than a hundred bridges were swept away in parts of Nelson, Amherst, and Rockbridge Counties (Virginia Division of Minerals and Geology 2006).

These Hurricane Camille landslides are a particularly dangerous type of landslide, called a "debris flow". A debris flow typically originates high on a mountainside as a debris slide that gouges down the mountainside (scraping off the soil, weathered bedrock, and trees) and snowballs into a much larger landslide; as this landslide mass sweeps down slope it liquefies into a highly destructive debris flow that can travel hundreds or thousands of feet down slope and downstream from its source area. The Forest typically occupies the steep mountains above populated valleys. As a result, the Forest is a source area for natural debris flows that are a risk to people and infrastructure on and off the Forests.

For example, a June 27, 1995 rainstorm triggered more 40 landslides (debris flows) on the Pedlar Ranger District between Buena Vista and Glasgow on the west side of the Blue Ridge. The debris flows originated on the steep slopes of the National Forest, swept down Belle Cove and other drainages, and discharged destructive masses of rock, earth, and woody debris onto private lands and public roads, including State Highway 501. Sas and Eaton (2008) studied geologic factors affecting these debris flows in Rockbridge County.

The June 27, 1995 rainstorm triggered similar debris flows in the Shenandoah National Park and private lands on the east side of the Blue Ridge in Madison County, Virginia. The U.S. Geologic Survey (USGS) conducted field investigations and produced a series of scientific reports to understand the conditions that cause debris flows and to suggest methods to mitigate future events (Morgan et al. 1997). The USGS also produced a Fact Sheet to help the public and government officials understand and plan for debris flow hazards (U.S. Geological Survey 1996). One purpose for this major scientific effort by the USGS is to help government officials at all levels (federal, state, and local) in Virginia and other parts of the Appalachians understand the important role that land-use planning can have in avoiding or mitigating landslide hazards.

The debris flow hazard also exists on ridges of the Valley and Ridge Province throughout the Forest. For example, June 17-18, 1949 storm triggered more than 100 debris slides/debris flows in the Little River watershed on the North River Ranger District in Augusta and Rockingham Counties, Virginia (Hack and Goodlet 1960)

Debris slide/debris flow landslides originating in the Forest have a potential to cause mass fatalities. These fast-moving landslides start on a steep slope as a failure of colluvium and weathered bedrock (debris slide), and then liquefy and accelerate to speeds as great as 35 miles per hour or more (debris flow), flowing down slope into stream channels, and then downstream. As the debris slide/debris flow moves down slope, it often gouges into the mountainside, scrapping the slopes bare, becoming a much larger landslide, a fast-moving destructive mass that can destroy infrastructure and kill people down slope and in valleys more than two miles

from debris slide source. In the mountainous watersheds typical of the Forest, the destructive power of debris flows is even greater than floods or flash floods. When debris flows occur, they often occur at the time of floods or flash floods; as a result, much of the damage and fatalities due to debris flows sometimes is hidden under the general rubric of "floods", "flood damage", and "flood fatalities". But debris flows are a different type of geologic hazard than water floods or flash floods, and require a more comprehensive geologic assessment. Research in the Appalachian region (Jacobson et al. 1989) indicates that the most catastrophic of geomorphic events will be "those in which conditions simultaneously promote landslides and high flood discharges."

In addition to natural landslides, some landslides may be caused or influenced by human activities. For example, excavation for road construction on a steep slope can undercut and remove some support from the hillside. In some geologic settings (adverse bedrock structures or weak surficial materials), this undercut and removal of support may lead to failure of the road cut-slope. Or, construction of a road fill or log landing fill on a steep slope may lead to a failure of the fill-slope. Slope failures of road cut-slope or fill-slope occur occasionally, generally during intense rainstorms when natural landslides also occur. A geologic hazard related to management activities of special concern are debris flows caused by failure of fill slopes. Destructive debris flows that can sweep hundreds or thousands of feet down slope can be caused not only by failure of natural slopes but also by failure of fill slopes (roads, log landings). On the National Forests of North Carolina in September 2004 Hurricanes Frances and Ivan triggered many road fill failures on Forest Service roads as well as on the Blue Ridge Parkway that resulted in debris gouging destructive paths long distances, endangering people and damaging infrastructure (Collins 2008). Road fills (or log landings fills) on steep slopes may be marginally stable, but vulnerable to failure during intense rainstorms. As demonstrated in September 2004, road fills on a steep slope high on a mountain are a special concern because of the snowball effect as the fill failure transforms to a debris flow and bulldozes the soil, weathered rock, and trees into a larger destructive mass as it gouges down the mountainside. Such debris flows caused by fill failures can travel a mile or two down slope just like debris flows caused by natural slope failures, endangering people and infrastructure down slope and in the valleys.

LANDSLIDE DAMS AND WOODY DEBRIS DAMS

The landslide dams and woody debris dams can occur during intense rainfall, often at times of flooding. In the mountainous terrain with narrow valleys typical of most of the Forest, when a landslide, such as a debris slide, sweeps down slope into a drainage, there is a potential for a landslide dam to form, and soon, to fail as storm water fills upstream of the unstable dam. Woody debris dams also can form and then fail during flooding in forested mountain drainages. The failure of temporary landslide dams or woody debris dams can send a surge of water and debris downstream, and create a different type of "flash flood".

KARST

Karst geology (sinkholes, caves, disappearing streams, etc.) creates multiple geologic hazards:

- Ground collapse at existing sinkholes or new sinkholes can occur at any time, but certain events create elevated threat of catastrophic ground collapse, such as during or shortly after intense rainstorms, or when a new groundwater well or sewage disposal system is placed in operation.
- Sinkholes create unique flood and flash flood hazards. Intense storm waters can suddenly turn dry depressions into ponds or lakes.
- Karst geology creates risk of contamination of ground water and water wells at a developed recreation site as well as down gradient from the site, including private land. Contamination can result from operation and maintenance of the recreation site, such as sewage leakage, or from certain events such as flooding carrying polluted storm water into sinkholes.

For example, sinkhole activity (ground collapse) has occurred in part of these developed recreation sites: Trout Pond Recreation Area on Lee RD; Locher tract on the Glenwood/Pedlar RD; Augusta Springs on the North River RD.

WATERFALLS

Waterfalls are a geologic hazard with a recurring incidence of death or injury to individuals on the Forest. The slick rock, strong current, steep slopes, hidden rocks in the pool beneath the waterfalls, rockfall, ice-covered

rocks, and icicle or ice falls are natural hazards at waterfalls. Visitors who venture too close to the waterfalls have a risk of serious injury or death. Crabtree Falls on the Pedlar RD is a popular recreation site with these natural hazards.

ABANDONED MINES

The Forest has hundreds of abandoned mine workings, primarily from historic mining of iron. Most abandoned mines are in remote locations where Forest visitors generally do not venture. Some abandoned workings, such as shafts or adits, are physical hazards with a risk of falling into a deep shaft or being hit by falling rock in an adit. The Forest has reclaimed hazardous mine workings, and continues this work every year as funding allows. Some reclamation involves bat gates to provide bat habitat.

DIRECT, INDIRECT AND CUMULATIVE EFFECTS

Geologic Resources

Management activities that involve ground disturbance, such as construction of roads and developed recreation facilities, have the potential to adversely affect geologic resources. All the alternatives have Forest Plan standards to protect the Forest's geologic resources, including groundwater, groundwater-dependent ecosystems, springs, caves, sinkholes, disappearing streams, unusual landforms, waterfalls, and fossils (paleontological resources). The Forest Plan standards to protect geologic resources are in various sections of the Forest Plan, including Geologic Resources, Geologic Hazards, Water, Soil, Caves and Karstlands, and Indiana Bat Management. Standards under all alternatives provide that the location and design of management activities will evaluate measures to avoid, minimize, or mitigate adverse effects on geologic resources with identified values (scientific, scenic, paleontological, ecological, recreation, drinking water, groundwater and groundwater-dependent ecosystems).

Under all alternatives, those management prescriptions that severely restrict or prohibit ground disturbing activity also protect geologic resources located in those management prescription areas, for example, Wilderness, Recommended Wilderness Study Areas, National Scenic Areas, Special Biological Areas, and Remote Backcountry Areas. The measures addressing Terrestrial Viability Evaluation under all alternatives also protect geologic resources because geologic resources are a prominent foundation of several ecosystems such as Alkaline and Mafic Glade and Barrens; Cliff, Talus and Shale Barrens; Floodplains, Wetlands and Riparian; and Cave and Karstlands.

Each Alternative also has a Geologic Area management prescription (4C1) which highlights and provides additional protection for unique geologic resources. Under the current Plan (Alternative A), the Forest has designated two Geologic Special Interest Areas (176 acres total): Devils Garden on the Lee Ranger District and Rainbow Rocks on the James River Ranger District. Alternatives E, G, H and I would add more areas as cave conservation sites to this prescription. The Virginia Department of Conservation and Recreation, Natural Heritage Program, identified 19 cave and surrounding conservation areas on the Forest. Two sites are already within Special Biological Areas (4D), two are within Indiana bat protection areas (8E4), and one is in Wilderness (1A). Alternatives E, G, H and I would add 14 cave and surrounding conservation areas as management prescription 4C1 - Geologic Areas, for a total of about 3,000 acres.

The potential ground-disturbing activities associated with management activities will be used as an indicator of potential impact on geologic resources. Using the acres of Cumulative Long-Term Effects (Table 3A4-3) as an indicator, Alternative C has the lowest potential and Alternative D has the highest potential for impact on geologic resources; Alternatives F, B, E, G, H and I, and A have intermediate levels of potential impact. More analysis on potential effects on groundwater is in Water and Aquatics section.

Geologic Hazards

Geologic hazards are geologic processes or conditions (naturally occurring or altered by humans) that present a risk or potential danger to public safety, infrastructure, and resources. Geologic hazards may affect or be

affected by Forest management activities. Thus, Forest management activities have potential for two types of effects relating to geologic hazards:

> Type 1 effect - Forest management activities have the potential to increase risk to public safety, infrastructure, and resources by not considering natural geologic hazards in the location, design, operation, and maintenance of Forest management activities. Different geologic settings on this Forest have different geologic hazards and different potential for hazards. Geologic science can identify high hazard zones; engineering geologic techniques can be used to avoid, reduce or minimize risks to public safety and infrastructure. But if siting, design, operation, and maintenance of Forest management activities do not consider the geologic setting and potential geologic hazards, then public safety and infrastructure may be inadvertently and unnecessarily put at risk. In the case of facilities, such as campgrounds, the assessment of geologic hazards would apply not only to the facility but also to the access (evacuation route and emergency response route).

> Type 2 effect - Forest management activities have the potential to increase risk to public safety, infrastructure, and resources by not considering human-induced geologic hazards in the location, design, operation, and maintenance of Forest management activities. Forest management activities have the potential to 1) trigger or aggravate natural geologic hazards, or 2) create human-induced geologic hazards. In addition to natural landslides, some landslides are caused or influenced by human activities. For example, excavation for road construction on a steep slope can undercut and remove some support from the hillside. In some geologic settings (adverse bedrock structures or weak surficial materials), this undercut and removal of support may lead to failure of the road cut-slope and hillside upslope. Or, construction of a road fill or log landing fill on a steep, geologically unstable slope may lead to a failure of the fill-slope. Such fill failures can transform into a debris flow and travel hundreds or thousands of feet down slope, endangering people and infrastructure on and off the Forest. If siting, design, and maintenance of Forest management activities do not consider the geologic setting and potential geologic hazards, then public safety and infrastructure may be inadvertently and unnecessarily put at risk.

Executive Order 11988 for floodplains is a useful tool that can help mitigate potential effects related to floods, but it does not cover the entire range of geologic hazards and associated risks to public safety and infrastructure. To address the wide range of geologic hazards and to reduce the potential for impacts from management activities, each Alternative has the following forestwide standards:

- When locating, designing, and maintaining trails, roads, other facilities, and management activities, avoid, minimize, or mitigate geologic hazards and potential impact on infrastructure and public safety.
- Site characterization prior to ground disturbance on slope gradients of 40% or greater will: 1) identify existing geologic slope stability conditions; 2) evaluate how construction would alter the existing conditions; and 3) assess potential for slope failures (from cut slopes, fill slopes, disposal sites for excess excavation, and sidecast material).
- For ground-disturbing projects on slope gradients of 40% or greater located upslope and within one-half mile of Forest external boundary, conduct a geologic hazard and risk assessment of off-Forest public safety for landslides, including debris flows.

Each Alternative varies the treatment of developed recreation sites, from no new sites to adding new sites, from expanding sites to closing sites. Using this treatment as an indicator for potential impacts (Type 1) relating to geologic hazards at developed recreation sites, Alternatives E and C have the lowest risk and Alternative A has the highest risk relating to Type 1 geologic hazards effects; Alternatives D, F, B, G, and H and I have intermediate levels of risk to public safety relating to Type 1 geologic hazards effects.

For Type 2 geologic hazards effects, the potential ground-disturbing activities associated with management activities will be used as an indicator of potential to 1) trigger or aggravate natural geologic hazards, or 2) create human-induced geologic hazards that can affect public safety, infrastructure, and resources. Using the acres of Cumulative Long-Term Effects (Table 3A4-3) as an indicator, Alternative C has the lowest potential and

Alternative D has the highest potential for impacts relating to Type 2 geologic hazards; Alternatives A, B, E, F, G, H and I have intermediate levels of potential impact.

Most of the Forest's permanent road system is already constructed. The Forest's road system currently is about 1,800 miles. One indicator of the cumulative effects on geologic resources and geologic hazards is the amount of past, present, and future ground-disturbing management activity on the Forest. The miles of roads are an indicator of the amount of ground-disturbing management activity. Using the miles of road in the minimum road system at end of 10 years (Table 3C8-1) as an indicator, Alternative C has the least cumulative impact and Alternative A has the most cumulative impact; Alternatives B, D, E, F, G, H and I have intermediate levels of cumulative impacts.

About 281 miles of the 1,800 miles of Forest Service System roads are within the 11% of the Forest with geologic formations containing karst. Road construction in Alternatives A, B, D, E, F, G, H and I would add small increments to the 281 miles within the 11% of the Forest with geologic formations containing karst and karst-related groundwater. Alternatives E, F, G, H and I would designate 14 cave and surrounding conservation areas (about 3,700 acres total) as Geologic Special Interest Areas, and thus increase protection of karst groundwater areas.

Over the decades, past Forest management actions included construction and/or expansion of developed recreation facilities, some of which are in areas subject to one or more geologic hazards, such as flooding, landslides and sinkhole ground collapse. Examples of such facilities are Trout Pond Recreation Area, North River Campground, Hone Quarry Campground, Oronoco Campground, and Elizabeth Furnace Campground. Access roads that provide for evacuation or emergency response may also be located in areas subject to geologic hazards. Past management actions include approval of Special Use Permits for organization sites (Camp May Flather and Nature Camp) also subject to one or more geologic hazards. The unintended result or effect of past management has been: 1) recurring damage and costs to repair facilities located in areas of active geologic hazards, such as floodplains, and 2) a legacy of risks to public safety associated with geologic hazards at multiple sites on the Forest. These cumulative effects are part of all of the alternatives, though processes are in place to recognize and reduce potential impacts of geologic hazards.

A3 – CLIMATE

AFFECTED ENVIRONMENT

For the George Washington National Forest and much of the southeastern United States, climate variability and weather events such as strong winds and heavy rains from hurricanes, droughts, heat waves, episodes of warm winters, floods, ice storms, and lightning storms have long been part of the natural environment. From a climate perspective, the southeast has some of the warmest temperatures, generally receives more rainfall than any other region, and experiences many extreme climate events (U.S. Global Change Research Program 2001).

These climate variables and associated disturbances have always influenced the makeup and geographical distribution of many ecological communities and landscapes across the South. However, the increasing changes in climate and disturbances projected for the future are expected to lead to substantial alterations in our forests and the services they provide (U.S. Climate Change Science Program 2008a). The International Panel on Climate Change (IPCC 2007) has identified future impacts of temperature warming, changes in precipitation, extreme weather events, severe droughts, earlier snowfall, rising sea levels and other changes that could significantly affect forest ecosystems.

Forest Service scientists have been studying various aspects of climate change on forests for many years. Yet, our knowledge of how plants and ecosystems respond to the threats of a changing climate and how to react appropriately at local levels where management actions are most effective is still very limited (Solomon 2008). Uncertainties about outcomes will require flexibility, and land management strategies based on current or historical conditions will need to be adjusted or replaced with approaches that support adaptation to changing conditions (USDA Forest Service October 2008).

It has been recognized that forests can play an important role in both mitigating and adapting to climate change. Mitigation measures focus on strategies such as carbon sequestration by natural systems, ways to increase carbon stored in wood products, ways to provide renewable energy from woody biomass to reduce fossil fuel consumption, and ways to reduce environmental footprints. Adaptation measures address ways to maintain forest health, diversity, productivity, and resilience under uncertain future conditions. Adaptation and mitigation activities must also complement each other and balance with other ecosystem services (USDA Forest Service October 2008).

At this time, the science of climate change modeling is at the stage of stepping down global models to regional scales (Davis 2007), so a combination of national projections, regional-level climate trends for the southeastern United States, and a recent report prepared for the state of Virginia provides the most reliable context for describing expected climate changes and impacts for the George Washington National Forest. Specifics regarding many mitigation measures, such as the appropriate calculations for carbon offsets and how to consider carbon sequestration rates, are still being developed, so most of our focus at the forest level for now will be on using management options to improve resilience and adaptability of native ecosystems under changing conditions. Then, over the 15-year life of the Plan, as issues are better understood and appropriate measures are identified, climate change strategies can be adjusted through the adaptive management process.

National Climate Change Trends and Expectations

Warming temperatures, altered precipitation patterns, rising sea levels, and increases in the number and intensity of extreme weather events are already causing observed ecological responses across the United States (U.S. Climate Change Science Program 2008a). Although there are variations by region, overall temperatures across the nation warmed during the 20th century, with 11 of the 12 years from 1995-2006 among the warmest since instrumental record keeping was started in 1850 (U.S. Climate Change Science Program 2008b; IPCC 2007). Precipitation patterns and distribution also vary regionally, but the total annual precipitation in the contiguous United States has increased 6.1 percent over the last century, with about half of

the increase attributed to increased storm intensity (U.S. Climate Change Science Program, 2008b; Karl and Knight, 1998). Warming temperatures, along with land subsidence, contribute to sea level rise. Relative sea levels have risen 3-4 mm per year in the Mid-Atlantic States and 5-10 mm per year in the Gulf states (U.S. Climate Change Science Program 2008b; U.S. Environmental Protection Agency 2007).

Anticipated increases in extreme weather events outside the historic range of natural variability may alter the frequency, intensity, duration, and timing of disturbances such as fire, drought, invasive species, and insect and pathogen outbreaks. Changes in forest composition and growth may also have associated impacts on wildlife habitats, the supply of wood products, specialty markets, and recreational opportunities (U.S. Climate Change Science Program 2008b; Marques 2008).

Researchers from The Nature Conservancy examined species diversity in Virginia, West Virginia and other northeastern states and determined that conservation of a full spectrum of geologic classes could offer an approach to conservation that protects diversity under both current and future climates. Anderson and Ferree (2010) found that geological diversity, elevation range, latitude and the amount of calcareous bedrock significantly predicted species diversity. They suggested that protecting geophysical settings would conserve the stage for current and future biodiversity and could be a robust alternative to species-level predictions of effects from climate change.

Forests provide a wealth of services and products including clean water, clean air, biological habitats, recreation opportunities, carbon storage, timber, specialty commodities, fuel, and aesthetic and cultural values. Scientists have indicated that a changing climate can affect the future biodiversity and alter the function of the forest ecosystems that support these services and products (U.S. Climate Change Science Program 2008a). Species distributions may shift, some species are likely to decline while others expand, and whole new communities may form. Forest productivity may be reduced in some instances due to a decline in photosynthesis caused by increased ozone, and productivity may be enhanced in other settings where elevated levels of carbon dioxide (CO_2) have a fertilizing effect on overall tree growth.

The overwhelming majority of studies of regional climate effects on terrestrial species reveal consistent responses to warming trends, including poleward and elevational range shifts of flora and fauna. Responses of terrestrial species to warming across the Northern Hemisphere are already well documented by changes in the timing of growth stages (i.e., phenological changes), especially the earlier onset of spring events, migration, and lengthening of the growing season (IPCC 2007).

Mammalian responses to rising temperatures and other climate changes are diverse. Many small mammals are coming out of hibernation and breeding earlier in the year than they did several decades ago, while others are expanding their ranges to higher altitudes. Some show trends toward larger body sizes, probably due to increasing food availability and higher temperatures. On the other hand, reproductive success in polar bears has declined due to melting Arctic sea ice (IPCC 2007).

Birds are an important part of many functioning ecosystems because of their roles in seed dispersal, pollination, and as both predator and prey. Scientists have observed that birds are breeding and laying their eggs earlier and that migratory species have altered their wintering and/or critical stopover habitats. For example, warmer springs have led to earlier nesting for 28 migrating bird species on the east coast of the U.S. (IPCC 2007).

A range shift toward the poles (northward in the Northern Hemisphere) or to higher elevations has occurred among many invertebrates that are considered pests or disease organisms (IPCC 2007).

Habitat ranges for butterflies in North America have shifted northward and in elevation as temperatures increased. In some cases, such as the Edith‘s Checkerspot Butterfly, local populations have become extinct in the southern portion of their range (IPCC 2007).

Fishing is highly valued in the U.S. as both a commercial enterprise and as a recreational sport. Fish populations and other aquatic resources are likely to be affected by warmer water temperatures, changes in

seasonal flow regimes, total flows, lake levels, and water quality. These changes will affect the health of aquatic ecosystems, with impacts on productivity, species diversity, and species distribution (IPCC 2007).

Stream habitats are projected to decline across the U.S. by 47 percent for coldwater, 50 percent for coolwater, and 14 percent for warmwater species. In the southern Great Plains, summer water temperatures already approach the limits for survival of many native stream fish (IPCC 2002). An 8°F increase in average annual air temperature is projected to eliminate more than 50 percent of the habitat of brook trout in the southern Appalachian Mountains. The Northern pike, which spawn in flooded meadows in early spring and whose young remain in the meadows for about 20 days after hatching, would be especially affected by low spring water levels. Higher winter temperatures have been observed to decrease the survival rate of the eggs of yellow perch (a coldwater species). On the other hand, one study found that higher winter temperatures (by 2ºC) were beneficial for rainbow trout but the same temperature increase in summer caused negative effects (IPCC 2007).

The ability of reptiles and amphibians to adapt to changes in climate depends in part on their ability to move to more suitable habitat. A European study found that most reptile and amphibian species could expand their ranges in a warmer climate if dispersal were unlimited, but if they were unable to disperse then the ranges of nearly all species (more than 97 percent) would become smaller (IPCC 2007).

Southern Region Climate Change Trends and Expectations

Over the past decade, a number of models have been developed to simulate climatic effects anticipated in the future. These scenarios are based on historical data, trends, and analysis of different plausible assumptions. While climate model simulations are continuing to be developed and refined, climate projections typically do not yet accurately address expected conditions below the regional scale in the United States. In the report by the United States Global Change Research Program on Climate Change Impacts on the United States (2001), the two principal models that were found to best simulate future climate change conditions for the various regions across the country were the Hadley Centre model (developed in the United Kingdom) and the Canadian Climate Centre model. Unless otherwise noted, the following discussions of climate change expectations for the southeastern United States are based on findings from the 2001 U.S. Global Change Research Program report and more recent projections in the U.S. Climate Change Science Program Reports (SAP 4.3 May 2008a; SAP 4.4 June 2008b).

The climate is going to get warmer, especially warmer minimum winter temperatures. Both the Hadley and Canadian models show increased warming in the southeast but at different rates (see inset on Future Climate Scenarios for the southeast). Overall regional temperature changes are projected to be equivalent to shifting the climate of the Southern U.S. to the central U.S. and the central U.S. climate to the northern U.S.

The heat index, which is a measure of comfort based on temperature and humidity, is going to rise. The principal climate model simulations agree that the heat index will increase more in the southeast than in other regions. By 2100, the heat index under the Hadley model is projected to increase by as much as 8-10°F and by over 15ºF in the Canadian model. The Northeast may feel like the southeast does today, the southeast is likely to feel more like today's south Texas coast, and the south Texas coast is likely to feel more like the hottest parts of Central America.

Threats to coastal areas will increase, including rising sea levels, beach erosion, subsidence, salt water intrusion, shoreline loss, and impacts to urban development.

Precipitation is more likely to come in heavy, extreme events.

For other aspects, models tend to differ on expectations. The southeast is the only region where climate models are simulating large and opposite variations in precipitation patterns over the next 100 years. The Canadian model projects more extensive and frequent droughts in the southeast, starting with little change in precipitation until 2030 followed by much drier conditions over the next 70 years. The Hadley model, in contrast, suggests there will be a slight decrease in precipitation over the region during the next 30 years

followed by increased precipitation. There is also uncertainty over the extent of effects of El Nino and La Nina cycles. El Nino events typically result in cooler, wetter winters in the southeast and fewer Atlantic tropical storms, while La Nina events tend to have the opposite effects with warmer, drier winters and more hurricanes.

Unexpected interactions among multiple disturbances happening at the same time add to the level of uncertainty. For example, tree growth is generally projected to be stimulated by increases in CO_2, but limits on availability of water and soil nutrients during droughts often weaken tree health leading to insect infestations or disease, which in turn promotes future fires by increasing fuel loads and further weakening tree health (Marques 2008).

Based on current projections, the following discussion highlights some of the potential impacts of a changing climate on forests in the southeastern United States and on the George Washington National Forest.

Forest productivity. In general, biological productivity of southeastern forests will likely be enhanced by increased levels of CO_2, as long as there is no decline in precipitation and as long as any increases in moisture stress due to higher air temperatures are low enough to be offset by CO_2 benefits. Hardwoods are more likely to benefit from increased CO_2 and modest temperature increases than pines, since pines have greater water demands than hardwoods on a year-round basis. Without management adaptations, simulations using the Hadley model show pine forest productivity will likely increase 11 percent by 2040 and then exhibit a declining trend to an 8 percent increase by 2100 compared to 1990 productivity estimates. Hardwood productivity will likely continue to rise, with projections of a 22 percent increase by 2040 and 25 percent by 2100. This shift in productivity could have significant effects in the South. Forest productivity increases may be offset, however, by escalating damage from forest pests and more extreme weather disturbances.

Forest pests. The potential for a changing climate to increase the distribution of forest insect and disease pests is a concern, particularly for pests that already cause widespread damage such as Southern pine beetles. Higher winter temperatures are expected to increase over-wintering beetle survival rates, and higher annual temperatures will produce more generations each year leading to increased beetle infestations. Other factors, however, complicate projections of future infestation levels. Field research has demonstrated that moderate drought stress increases pine resin production thus reducing colonization success, while severe drought stress reduces resin production and increases pine susceptibility to beetle infestation. Insufficient evidence currently exists to predict which of these factors will control future beetle populations and impacts (McNulty et al. 1998).

Fires. Fire frequency, size, intensity, and seasonality are directly influenced by weather and climate conditions. Nationwide projections show seasonal fire severity is likely to increase by 10 percent over the next century, with possibly larger increases in the southeast. At least two ecosystem models run under the Canadian climate change scenario suggest a 25-50 percent increase in fires, and a shift of some southeastern pine forests to pine savannas and grasslands due to moisture stress. Under a hotter, drier climate, an aggressive fire management strategy could prove critical to maintaining regional vegetation patterns.

Shifts in major vegetation types for the Southeast. The broad variety of ecosystem types found across the southeast ranges from coastal marshes to mountaintop spruce-fir forests. Although the South is one of the fastest growing population regions in the country, forests are still common in many parts of the southeast, and forestland averages approximately 30 percent of each state. Potential changes in vegetation distribution due to climate change vary with different model scenarios. Under the Hadley model, forests remain the dominant natural vegetation in the southeast, but the mix of forest types changes. Under the Canadian model, savannas and grasslands expand and replace parts of the southeastern pine forests along the Coastal Plain due to increased moisture stress. In this scenario, the current southeastern forest moves into the north-central part of the United States. Both drought and increased fire disturbance play an important role in the potential forest breakup.

Weather-related stresses on human populations. Low-lying Gulf and Atlantic coastal areas are particularly vulnerable to flooding. With floods already the leading cause of death from natural disasters in the southeast, increased flooding from more active El Nino/La Nina cycles could have greater adverse impacts. Even if storms

do not increase in frequency or intensity, sea level rise alone will increase storm surge flooding in virtually all southeastern coastal areas. Another concern is the prolonged effect of elevated summertime heat events, which coupled with drought conditions, not only causes elevated heat stress to humans but also increases smog levels.

Increased forest disturbances. Increases in extreme events and changes in disturbance patterns may have more significant impacts, at least in the near future, than long-term changes in temperature or precipitation. Natural disturbances that may be associated with climate change include hurricanes, tornadoes, storms, droughts, floods, fires, insects, diseases, and non-native invasive species. Although disturbances are a natural and vital part of southern ecosystems, it is the change in frequency, intensity, duration, and timing exceeding the natural range of variation that is a concern (Marques 2008). Multiple disturbances interact and further exacerbate damages. Hurricanes can cause severe disturbance that not only results in direct loss of biological communities and habitat, but the widespread damages can also shift successional direction leading to higher rates of species change and faster biomass and nutrient turnover. Invasive species and insect pests often have high reproductive rates, good dispersal abilities, and rapid growth rates enabling them to thrive in disturbed environments.

Water stresses. The difficulty in predicting whether precipitation will increase or decrease in the southeast over the next 30-100 years extends to uncertainties over future water quantity and quality conditions. Current water quality stresses across the southern region of the country are primarily associated with intensive agricultural practices, urban development, and coastal processes such as saltwater intrusion. Although water quality problems are generally not critical under current conditions, stresses are expected to be more frequent under extreme conditions, particularly in low stream flow situations associated with droughts. Under the Hadley model, stream flow in the southeast has been projected to decline as much as 10 percent during the early summer months over the next 30 years. The Chattahoochee and Tombigbee River basins are projected to have decreased water availability over the next 50 years, and as stream flow and soil moisture decrease, agricultural fertilizer applications and irrigation demands tend to increase creating further stress and conflicts over competing uses. Parts of the southeast that depend more on ground water are particularly vulnerable to depletion of aquifers, which can take centuries to recharge after chronic drought conditions (Hoyle 2008).

Outdoor recreation. Outdoor recreation opportunities are likely to be impacted by climate change but would vary by location and activity. Higher summer temperatures could extend summer activities such as swimming and boating but may also reduce other outdoor activities such as hiking and trail use in hot, humid sections of the South. Warmer waters would increase fish production and fishing opportunities for some species but decrease fishing for other cold water species. Summer recreation activities are likely to expand in cooler mountainous areas as temperatures warm along the coastal plain and lowland elevations. Skiing opportunities are likely to be reduced in the South, and some marginal ski areas may close due to fewer cold days and snow events.

Local Level Climate Change Trends and Expectations

The Template for Assessing Climate Change Impacts and Management Option (TACCIMO) was used to estimate the range of changes in precipitation and temperature that can be expected on the GWNF. The template uses models from Canadian Centre for Climate Modeling & Analysis (Canadian-CGCM3), Hadley Centre for Climate Prediction and Research (Hadley-HadCM3), and US Dept. of Commerce/NOAA/Geophysical Fluid Dynamics Laboratory (Commerce-GFDL-CM2.0). The models are run using three scenarios regarding the level of carbon emissions.

Table 3A3-1. Climate Change Model Scenarios

Emissions Path	Description
"Higher" emissions path	Technological change and economic growth more fragmented, slower, higher population growth
"Middle" emissions path	Technological change in the energy system is balanced across all fossil and non-fossil energy sources, where balanced is defined as not relying too heavily on one particular energy source
"Lower" emissions path	Rapid change in economic structures toward service and information, with emphasis on clean, sustainable technology. Reduced material intensity and improved social equity

Based on data from TACCIMO, the predicted changes in precipitation and temperature are shown in the following tables:

Table 3A3-2. Predicted Changes in Precipitation on the GWNF

Precipitation, annual average from 2009-2099 (in)			
Emissions Path	Commerce GFDL-CM2.0 Model	Canadian CGCM3 Model	Hadley HadCM3 Model
Middle Emissions	46.3	43.9	47.7
Higher Emissions	47.0	43.9	44.7
Lower Emissions	44.4	44.8	45.8
Average of all emission options	45.9	44.2	46.1
Historical Average (PRISM 1970-2000)	43.5	43.5	43.5

Table 3A3-3. Predicted Changes in Temperature on the GWNF

Average temperature (ºF, Monthly Average spanning 2009 – 2099)			
Emissions Path	Commerce GFDL-CM2.0 Model	Canadian CGCM3 Model	Hadley HadCM3 Model
Middle Emissions	56.3	56.8	57.7
Higher Emissions	56.8	57.0	57.2
Lower Emissions	55.2	55.2	56.1
Average of all emission options	56.1	56.5	57.0
Historical Average (PRISM 1970-2000)	52.5	52.5	52.5

All of the models predict an increase in precipitation ranging from less than a half inch to more than four inches per year. All of the models also predict an increase in temperature ranging from 2.7^{o} F to 5.2^{o} F.

In December 2008, the Governor‘s Commission on Climate Change released a “Final Report: A Climate Change Action Plan” for the state of Virginia. The report included expected impacts of climate change on Virginia‘s natural resources, the health of its citizens, and the economy which included the industries of forestry and tourism. It also identified what Virginians can do to prepare for the likely consequences of climate change as well as an estimation of the amount of, and contributors to, the state‘s greenhouse gas emissions through 2025. The Governor‘s Executive Order 59 (2007) set a greenhouse gas emission target of 30% below the business-as-usual projection of emissions by 2025.

The Governor‘s Commission on Climate Change used the Intergovernmental Panel on Climate Change‘s (IPCC) Fourth Assessment Report as the primary reference point on the science of climate change, and also included testimony of a variety of experts. Estimates provided in the recent Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC) report, “Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations” (Pyke et al. 2008) were also incorporated because of its regionally-specific nature. The findings of the expected impacts of climate change for Virginia from the Commission‘s report, as they relate to national forest management in Virginia include the following. These impacts could be further compounded by Virginia‘s growing human population. As of July 2009, the Virginia Employment Commission estimates that, between 2010 and 2030, Virginia‘s human population will increase by almost 23 percent (http://www.vec.virginia.gov/vecportal/lbrmkt/plugins/lmiapp.cfm/popproj#).

Virginia should prepare for a minimum of a 3.6^{o}F increase in air and water temperatures but these temperatures could increase as high as 10.8^{o}F by 2100. Changes in precipitation and weather patterns are more difficult to estimate, although there has been scientific consensus that most of Virginia will experience a slight (0-10%) increase in precipitation and an increase in coastal storm intensity (IPCC 2008; Pyke et al. 2008).

There will likely be a projected sea level rise for coastal Virginia of 2.3–5.2 feet by 2100. Oxygen levels in the Chesapeake Bay are expected to decrease due to increasing temperatures and increasing storm runoff. Acidification of the Bay and Atlantic Ocean also is a concern as waters absorb more carbon dioxide (CO_2). Though the George Washington National Forest lies along the western mountains of Virginia, all of the forest is in the headwaters of the Chesapeake Bay watershed.

At varying rates, vegetation ranges will move from current locations to higher altitudes and latitudes, such that suitable habitat for some species will decline, other species will become extirpated, and other species will become extinct. Virginia‘s freshwater streams and high elevation areas currently offer essential habitat to many species that require cooler conditions. As temperatures increase and precipitation patterns change, these habitats will no longer support the same suite of species they do today.

Threats already faced by Virginia‘s ecosystems, such as invasive species, pathogens and pollution will become exacerbated. Many new exotic or invasive species may move into Virginia and existing pest species may flourish and cause more widespread damage than they are now.

There is a lack of research and specific information on the impacts of climate change on Virginia‘s forestry industries, and commercial and sport fishing industries.

Virginia‘s forestlands sequester approximately 23 million metric tons of CO_2 per year but an average of 27,000 acres of forestland is lost annually to development. The George Washington National Forest encompasses about 1 million acres (or seven percent) of the forestlands in the state. The Jefferson encompasses another five percent, making both forests the largest land manager in the state. The GW also includes about 105,000 acres in West Virginia.

Extreme weather events could lead to compromised water and food supplies for people. Unstable weather patterns could also cause periods of drought that threaten municipal water supplies.

Climate change is expected to increase the incidence of human diseases associated with air pollutants and aeroallergens that exacerbate other respiratory and cardiovascular conditions.

The three largest sources of greenhouse gas emissions in Virginia are electricity generation, transportation, and non-utility uses of fuel in industrial, commercial and residential facilities. Demands for electricity, transportation and fuel would likely increase as population increases.

The Virginia Department of Mines, Minerals and Energy (DMME) projects that natural gas consumption will grow 3.6 percent from 2007 through 2016 under a business-as-usual scenario. Natural gas increasingly is being used for electric generation because it is the cleanest of the fossil fuels, which may cause an even greater increase in demand for natural gas supply.

DIRECT, INDIRECT AND CUMULATIVE EFFECTS

Based on current projections, the primary regional-level and state-level predicted effects of climate change that would impact the Forest include: (1) warmer temperatures; (2) extreme weather events; and (3) increased outbreaks of insects, disease, and non-native invasive species.

Increased variation in temperature and moisture can cause stress and increase the susceptibility of forest ecosystems to invasions by insects, diseases, and non-native species. New environmental conditions can lead to a different mix of species and tend to be favorable to plants and animals that can adapt their biological functions or are aggressive in colonizing new territories (Whitlock 2008). However, changes in adaptability may be too slow given the predicted rate of change. Species that are already broadly adapted may become more prevalent, and species with narrow adaptability may become less prevalent. Disturbance factors that create more vulnerability in native ecosystems or require extensive controls to maintain the status quo are likely to affect desired conditions for healthy and diverse forests.

Desired conditions for healthy forests include resilience to dramatic change caused by abiotic and biotic stressors and mortality agents (particularly the southern pine beetle, gypsy moth, hemlock woolly adelgid and emerald ash borer on the GWNF) and a balanced supply of essential resources (light, moisture, nutrients, growing space). For the GWNF, gypsy moth epidemics have caused the greatest insect damage to date. The hemlock woolly adelgid affects only one species of trees but the loss of hemlocks in the riparian corridors has had widespread impacts, especially when coupled with the continuing effects of acid deposition. The forest has experienced several localized outbreaks of southern pine beetle. Emerald ash borer has been found in the northern parts of Virginia so far.

One of the natural disturbances that are an integral part of the forest is fire. Many of the native ecosystems that make up the George Washington National Forest, such as the pine and pine-oak forests, are adapted to or dependent on some level of periodic fire. Fire frequency, size, intensity, seasonality, and severity are highly dependent on weather and climate. As noted earlier, model results predict that seasonal severity of fire hazard is likely to increase by 10 percent over much of the United States during the 21st century, with possibly larger increases in the southeast (U.S. Global Climate Change Program 2001). The warmer Canadian model scenario which anticipates increased drought stress, projects a 30 percent increase in fire severity for the southeast. If extreme events such as hurricanes further increase forest fuel levels with widespread downed trees, there is a potential for larger, more catastrophic fires that could impact many of the desired conditions for the George Washington National Forest.

Warmer temperatures may lead to increased visitation to the George Washington National Forest for cooler, mountainous temperatures or for water-based recreational opportunities. A longer warm season could lengthen the recreation season on the Forest. Hunting and fishing seasons may be longer. Maintenance needs for roads and infrastructure could be greater. Demand for more highly developed recreation facilities (electricity) may increase. These effects would also be exacerbated by increasing population levels.

Scenery is one of the most valued quality of life benefits for life in the mountains of Virginia and West Virginia. Climatic effects on air quality could alter the visibility of landscapes.

Increases in extreme weather events have the potential for the occurrence of landslides and debris flows. The potential effects may be more important as the population and infrastructure continue to increase in areas adjacent to the National Forest.

The expected effects of climate change to aquatic systems can be described by predicted changes to physical processes and the potential impacts to physical and biological systems (Bakke 2008). For the area covered by the George Washington National Forest, these include:

1) Increased storm intensity, including intensity of precipitation, would increase surface erosion, increase the magnitude and variability of peak flows, and increase sediment load to rivers;

2) Changes to total annual precipitation amount and seasonal distribution, could cause an increase in winter precipitation, a decrease in summer precipitation, an increase in average runoff in winter and spring months, and decreased summer base flows;

3) Increased flood risk and resultant channel instability, would increase channel migration and associated streambank erosion, and shift 100 year floodplain boundaries;

4) Increase in average water temperature would shrink usable habitat for cold water species and shift habitat types. Warmer water temperatures would mean lower dissolved oxygen, and there would be a disproportionate importance of groundwater-fed systems to cold water species. A recent study (Flebbe et al. 2006) projects that rising temperature changes from climate change (and the loss of hemlock along streams) will shrink native trout habitat. Using the Hadley Centre model (2.5^{o}C air temperature increase) and the Canadian Centre model (5.5^{o}C air temperature increase), Flebbe found that between 53 and 97 percent of wild trout habitat could be lost as streams become warmer by the year 2100. However, Trumbo (2010) used a direct measurement approach pairing air and water temperature relationships to classify the sensitivity and exposure (vulnerability) of individual brook trout populations to various climate change scenarios. Trumbo and others (2010) identified potential refugia for brook trout at lower elevations and with higher air temperatures than previous larger scale modeling efforts. Site specific characteristics such as watershed area, percent riparian canopy, solar insolation, percent groundwater, elevation, and percent watershed in forest cover were useful for predicting individual brook trout population persistence.

5) Increased evapotranspiration and loss of soil moisture would reduce baseflow in rivers, reduce groundwater recharge, and result in loss of wetland area, including conversion of perennial to seasonal wetlands;

6) Changes in vegetation cover and species composition could change long-term wood dynamics, alter erosion rates, and change riparian cover and energy inputs (Bakke 2008).

Aquatic systems may not only be affected by changes in the above physical processes in response to climate change, but also by the following changes in human management of land and natural resources:

- Increased demand for structural streambank protection
- Increased groundwater withdrawals in response to declining surface water resources
- Increased demand for irrigation water
- Increased demand for surface water storage and flood control reservoirs
- Increased renewable energy development, impacting new areas on the landscape (Bakke 2008)

Even with more stringent air quality controls, acid deposition is expected to continue to impact the Forest. Research is currently evaluating the link between soil acidification and the nesting success of high elevational birds since female songbirds need large amounts of calcium (from snail shells) to produce eggs (SRS Compass Issue 10). Much of the high elevational habitat for songbirds is found on the GWNF and is one of the more vulnerable habitats to acid deposition on the forest.

In the Aquatic Sustainability Analysis report, watersheds on the Forest were categorized for their sensitivity to acidification. About 67% of the perennial streams on the Forest were found to be within highly sensitive watersheds, based on underlying geology and deposition rates. The smallest streams at the highest elevations, with non-carbonate bedrock were the most susceptible to acidification.

In summary, our more vulnerable ecosystems include:

- Spruce forests (sensitive to acid deposition, occupy higher elevations, habitat for sensitive species)
- Trout streams (sensitive to stream temperatures)
- Pine ecological systems (declining now, susceptible to southern pine beetle, fire-dependent)
- Higher elevation habitats
- Acid sensitive streams
- Acid sensitive soils

We have always experienced droughts, flooding, extreme weather events, catastrophic fire, insects and diseases, and to a more gradual degree, movement in the ranges of flora and fauna species. Many of our current management strategies already strive to maintain or enhance the health and resiliency of various forest resources to better withstand environmental stresses and human-induced pressures. However, the effects of an accelerated rate of change and an increase in the intensity of these impacts on forest resources and ecosystems are still unpredictable. Climate change effects are multiple, varied, and interact with many other stressors/variables. Therefore, an adaptive management approach that monitors forest resource conditions, and monitors the current state of scientific knowledge related to responses to climate change, is needed to allow us to proactively adjust current strategies or adopt new strategies as needed.

The effects of the alternatives focus on both adaptation (ways to maintain forest health, diversity, productivity, and resilience under uncertain future conditions) and mitigation (such as carbon sequestration by natural systems, ways to provide renewable energy to reduce fossil fuel consumption, and ways to reduce environmental footprints). These effects focus on: 1) reducing vulnerability by maintaining and restoring resilient native ecosystems; 2) providing watershed health; 3) providing carbon sinks for sequestration; 4) reducing existing stresses; 5) responding to demands for cleaner energy including renewable or alternative energy; and 6) providing sustainable operations and partnerships across landscapes and ownerships.

Reduce Vulnerability by Maintaining and Restoring Resilient Native Ecosystems

Alternative C focuses on passive restoration and relies predominantly on natural processes to reduce vulnerability. Passive restoration is an important component to any management strategy, but reliance as the main tool is problematic for several reasons. Disturbance regimes do not currently operate at the large scale they did in the past. For example, due to the intermixed ownership, naturally ignited fires do not spread very far on the landscape or remain burning for a very long time period. Without large scale disturbances, large blocks of forest tend towards the same age and condition, making them more susceptible to damage by insects or disease. In addition, the rapid change in climate that is predicted may result in changes in community composition and natural processes may not be able to adapt to these changes due to the rapid pace.

Alternative C will do some active restoration by reducing roads which may improve the ability for some species to disperse, reduce sedimentation in streams, and reduce the spread of non-native invasive species. The reduction of roads would also reduce access to areas for management activities that could improve diversity and address recreation needs.

Alternatives A, B, D, E, F, G, H and I all use a mix of active and passive restoration strategies. Alternative E has the most aggressive approach to active restoration with the largest prescribed fire program and active vegetation management through timber harvest and maintenance of grasslands and shrublands.

Alternatives A, B, D, E, G, H and I maintain management options to address changes in the sensitive spruce system in Laurel Fork. It also allows for opportunities to expand the spruce ecosystem.

Alternatives B, C, D, E, F, G, H and I all utilize the Ecological Sustainability Evaluation tool to develop strategies to maintain and restore the nine ecological systems and the species with special needs. All of these alternatives incorporate the use of unplanned fire ignitions as a tool for achieving resource management desired conditions. All of these alternatives utilize planting of blight-resistant American chestnuts as a restoration tool (Alternatives B, D, E, F, G, H and I allow for more opportunities for planting in open conditions which are likely more conducive to establishment of stands of American chestnut).

Alternatives B, D, E, F, G, H and I all maintain or restore ecological conditions that are rare on the GWNF, such as high elevation grasslands and early successional habitat, open woodlands, and old fields. These alternatives all identify the need to address shortleaf pine restoration opportunities.

Watershed Health

Projected climate changes to the hydrologic cycle through warmer water temperatures, more intense storms, and greater inter-annual variability in precipitation, indicate the importance of maintaining and protecting healthy watersheds. Bakke (2008) describes three key components relating climate change processes to management and conservation of aquatic resources: resilient habitat, refugia, and restoration.

Alternative A places a high priority on protecting water quality through the identification of riparian areas and standards that fully protect water quality. This alternative did not address many of the practices and objectives discussed for the other alternatives, but these practices and objectives would be in keeping with the goals of Alternative A.

In Alternatives B, C, D, E, F, G, H and I:

- Beaver meadows, wetlands, and floodplains are protected and restored to improve natural storage, reduce flood hazards, and prolong seasonal flows. Beaver ponds and wetlands recharge groundwater, raise the water table, retain sediment and organic matter, store water during floods and release it slowly, mitigate low flows and drought, reduce carbon turnover rate, raise pH and ANC, while reducing SO_2, Al, and NO_3 .
- Riparian forests are protected and restored to moderate changes in stream temperature, maintain stream bank stability, and provide instream habitat.
- Aquatic migration barriers are removed and habitat connectivity re-established so that species can move to more suitable habitat, or move to or from refugia.
- Flood and wildfire risks are reduced in vulnerable watersheds to prevent increased surface erosion and mass wasting leading to aggradation of river channels.
- Roads are improved or decommissioned to reduce adverse impacts during large storms to prevent surface erosion and fill slope failure and landslides. Stream crossings and bridges are constructed to withstand major storm and runoff events.
- Standards are included to assess geologic hazards for management activities, including potential landslide hazards and risks, particularly as the population and infrastructure continue to increase in areas adjacent to the National Forest.
- Bare soil is revegetated as soon as possible and suspend or eliminate recreation uses that are causing elevated sediment levels to streams and large areas of long-term loss of soil productivity outside the designated use area.
- Riparian buffers are increased and standards included for protecting channeled ephemeral streams.
- Soils highly sensitive to acid deposition and nutrient loss are identified. Small diameter utilization is limited in those areas.

Alternative C would have fewer opportunities to restore stream channels, address acidified streams, address geologic hazards and address fire risks than the other alternatives due to the greater acreage in wilderness.

Carbon Sequestration

Trees and forests represent major biological "carbon sinks," places where carbon is sequestered. Carbon accrues in trees, soil, and wood products and the use of wood-based substitutes for fossil fuel-based products decreases the amount of greenhouse gas emissions.

The single most important aspect for sequestering carbon is to keep forests as forests. All of the alternatives meet this objective. Older forests sequester large quantities of carbon. Forests (particularly older forests) generally store carbon better than forest products, so harvesting old-growth forests for their forest products is not an effective carbon conservation strategy (Harmon et al. 1990). However, harvest and regeneration of young to middle-aged forests for long-lived forest products can help with carbon storage (Ryan 2008). Alternative C relies on old-aged forests to sequester carbon. The other alternatives use a mix of old-aged forests and harvest to regenerate new forests. The regeneration also has the advantage of creating a diversity of ages and structure in the forest to provide multiple strategies for addressing carbon storage. All of the alternatives are skewed to emphasize a substantial portion of the forest to be in older aged stands.

Forest management in Alternatives A, B, D, E, F G, H and I can increase the ability of forests to sequester atmospheric carbon while enhancing other ecosystem services, such as improved soil and water quality. Planting new trees and improving forest health through thinning and prescribed burning will increase forest carbon in the long run.

The issue of carbon balance in the forest is complicated and affected by many factors. While it is true that forest management activities such as prescribed burning release carbon dioxide into the atmosphere, growing forest vegetation recaptures carbon dioxide. A prescribed burn is, by definition, a low-severity fire that leaves the large trees alive and intact where they continue to store carbon. These fires also tend to stimulate re-growth of grasses and other herbaceous vegetation, which recapture carbon. And low-intensity fires have little effect on the large stores of carbon in the soil. The Environmental Protection Agency (US Environmental Protection Agency 2010) has concluded that when forest management activities (including fire emissions) are considered together with storage/sequestration activities (reforestation, etc.) the cumulative result is a net sequestration of carbon dioxide. This assumes that the proposed activity does not change the land use and the area remains forested, as is the case with prescribed burning on the George Washington National Forest.

Existing Stresses

Aside from the stresses identified in watershed health and restoring resilient native ecosystems, non-native invasive species is a key existing stress on systems. Alternatives B, C, D, E, F, G, H and I, all take an aggressive approach to controlling non-native invasive species and preventing their introduction and spread. An early detection and response strategy associated with non-native invasive species will be critical to limit new introductions. Aggressive treatment of established invasive species, along with the control of insects and diseases, are likely to become more critical to maintaining desired conditions for healthy forests under a changing climate. Due to the fragmented land ownership patterns, success in reducing forest pests will sometimes require going beyond national forest boundaries, and continued work with partners will be needed. In addition, management practices (such as thinning and age class diversity) that sustain healthy forests and provide adequate nutrients, soil productivity, and hydrologic function promote resilience and reduce opportunities for disturbance and damage.

Alternative C would reduce the spread of many non-native invasive species by restricting management that creates openings in the forest canopy. However, it also restricts the ability to use some control activities in wilderness and to use silvicultural techniques to manage pests like the southern pine beetle.

Alternative Energy Demands

Using cleaner energy reduces greenhouse gases. Renewable energy development plays a significant role in the agency's implementation of the Energy Policy Act of 2005, Public Law 109-58 (Testimony by Sally Collins, Associate Chief Forest Service, before the Committee on Energy and Natural Resources, United States Senate,

Renewable Energy on Federal Lands July 11, 2006). The sources of renewable or alternative energy that can be provided on national forest system lands include: wind energy, solar energy, and natural gas leasing.

Alternative A has the largest area of the GWNF available for gas leasing. (See Minerals Section for details) Alternatives C and I allow no gas leasing. The other alternatives allow for an intermediate level of development.

Development of wind energy is allowed in some areas of the GWNF in Alternatives B, D, F G, H and I with the most area available in Alternative D. Alternatives C and E do not allow the development of wind energy on the GWNF.

Sustainable Operations and Partnerships

Under all of the alternatives the GWNF work with States to incorporate the greenhouse gas emissions from our management activities into State inventories, just as we have done with the fine particulates inventory. The Forest will continue striving to reduce its environmental footprint and decrease the greenhouse gases emitted through day-to-day operations, including the use of more fuel-efficient vehicles, reducing the number of miles driven and making facilities more energy-efficient. The Forest will also continue working with partners, including other federal agencies, State and local governments, non-governmental organizations and other stakeholders to be more effective in efforts to adapt lands, ecosystems, and species to climate change. Examples are the Nature Conservancy in the Fire Learning Network and the Chesapeake Bay Partnership.

A4 – SOILS

AFFECTED ENVIRONMENT

The soils are essential to the viability of all organisms occurring on the Forest. Soil develops slowly from various parent materials and is modified by time, climate, macro- and micro-organisms, vegetation and topography. Soils are complex mixtures of minerals, organic compounds, living organisms, air and water. They are a primary component of all ecosystems on the George Washington National Forest.

Past land use has impacted many of the soils on the Forest. Intensive logging, mining, grazing and farming occurred on these lands in the late 1800s and early part of the 1900s. Clearcutting and roading to remove timber for sawmills, iron furnaces and mine props were commonly done over vast acreages. Mining and exploration for iron, manganese, sand, and coal occurred throughout the Forest during the same time period, resulting in many acres being affected by these uses. Some areas were timbered and farmed or grazed prior to Forest Service management, sometimes resulting in soils with gullies and thin topsoil due to erosion.

The distinct surface geology and topography of each Major Land Resource Area (MLRA) occurring on the Forest are described below. These are important factors in the formation of soils on the Forest.

Northern Blue Ridge

The Pedlar Ranger District is located within this area. Roanoke is the southern extent of this MLRA. The rugged mountains of this area have steep slopes, sharp crests and narrow valleys. The soils are mainly derived from metamorphic and igneous rocks. Igneous soil parent material is from granite and gneiss rock types. The metamorphic material is quartzite and shale rocks.

The soils of the ridgetops and upper one-third of the slopes generally have less depth and are less productive than soils forming on the lower slopes. Rock outcrops are common. Aspect plays a key role in site productivity and available moisture, as northerly aspects tend to be moister and more productive. This is because there is less evapotranspiration and lower soil temperatures on these slopes. Ridgetops and slopes of the higher elevations have soils with a thick, dark organic surface layer. The growing season is shortened at these higher elevations, in part because of lower mean annual soil temperatures.

Some soils derived from granite on upper slopes on the Pedlar Ranger District are underlain by highly weathered granite rock (saprolite). This material has no structure and is unstable on steep slopes when exposed. Soils forming in areas underlain by quartzite have lower productivity on most upper slopes because of low fertility associated with this rock type. Upper slopes on the western front of this area have rock outcroppings and soils are shallow and very droughty. Lightning strike fires are common due to dry conditions.

Many of the lower and gentler slopes have deeper soils and higher productivity than the soils on the upper slopes. Clay content tends to be higher, as is moisture holding capacity in soils on lower landscapes. Some of these soils have a high rock content, both in surface and subsurface layers. Hardened layers (fragipans) have formed in some colluvial (gravity deposited) soils that produce seasonal high (perched) water tables.

Alluvial (water deposited) soils, associated with larger streams, have some floodplain areas where soil drainage is slow. Watertables may be seasonally high, or have small wetlands occurring. Larger floodplains have a variety of drainage conditions. The smaller drainages have alluvial soils that have very narrow floodplains and better drainage. Rock content in soils of the smaller drainages can be high. Productivity of the alluvial soils in this section is usually high. Plant species are influenced by fluctuating soil watertables and varying soil drainage conditions.

Northern Appalachian Ridges and Valleys

The remainder of the Forest is located within this MLRA. It is a folded and faulted area of parallel ridges and valleys. Sandstone and shale ridges are separated by narrow to moderately broad limestone and shale valleys.

The topographic orientation of these valleys and ridges is dominantly northeast to southwest. Soils have developed from sedimentary rocks, such as shales, sandstones and limestones. Residual soils of the ridgetops and upper slopes are predominantly derived from sandstone. Soil depths are generally 10-to-40 inches to hard bedrock. Productivity is low, water holding capacity is low and soils are very porous. Rock outcrops and high rock content within the soil are common. Upper slopes, dominated by shale rocks, have very shallow soil depths. This causes rapid water runoff during storm events. Most of the shale bedrock is rippable (easily broken when excavated) and not hard.

Midslopes are mixed shales and sandstones, relating to extensive folding and faulting of the bedrock layers. The Forest has very little area with soils derived from limestone. Where they occur, these soils have more clay, are variable in depth and very productive. Other midslope soils are generally 20-to-60 inches deep to sandstone and less deep when underlain by shale. Soils derived from the shale have low pH and a high runoff potential due to shallow depths and steep slopes. Productivity varies as deeper shale-derived soils and soils on northerly aspects have moderate-to-high productivity, and sandstone derived soils and southerly aspects have moderate-to-low productivity.

Lower slopes have deeper soils and more clay in the subsoil. Water-holding capacity is better and productivity is generally higher. Some colluvial soils on gentle slopes have formed cemented layers (fragipans), which cause perched watertables during the winter and early spring months. Many of the colluvial soils on toeslopes and along drainages have very high rock content throughout the soil profile. Surface stones and boulders are common.

Alluvial soils are commonly well drained along most streams. Larger streams have broader areas of floodplain soils with various drainage conditions. Small areas of organic soils are associated with upland bogs and slackwater areas, which generally form at the edges of floodplains and nearly level headwater areas of some watersheds. Wetlands are usually small in areal extent, and some have been formed behind old beaver dams.

Riparian and Wetland Soils

In the lowest parts of the landscape are the soils associated with riparian areas and wetlands. These soils are of limited extent on the Forest, but important for biodiversity and water quality. Riparian-wetland soils constitute one of the largest freshwater reservoirs on Earth. They are an important component of both standing water (lentic) systems, such as swamps, marshes, bogs, and running water (lotic) systems such as rivers, streams, and springs. Riparian-wetland areas are the “green zones” or links, between aquatic environments and upland, terrestrial ecosystems. Healthy riparian-wetland areas provide several important ecological functions. These functions include water storage and aquifer recharge, filtering of chemical and organic wastes, sediment trapping, streambank building and maintenance, flow energy dissipation, and primary biotic (vegetation and animal) production.

Riparian-wetland areas are intimately related to their adjacent waterways since the presence of water for all or part of the growing season is their distinguishing characteristic. In fact, the nature and condition of a riparian-wetland area fundamentally affects the aquatic ecosystem. In addition to water, there are three other essential components of the riparian-wetland areas: soil, vegetation, and landform. In a healthy riparian-wetland ecosystem, the four are in balance and mutually supporting one another.

Because of the presence of water, riparian-wetlands have soil properties that differ from upland areas. For example, most upland areas are derived from in-place weathering processes and relatively little soil material is derived from offsite sources. In contrast, riparian–wetland soils are constantly changing because of the influx of new material being deposited by different storm events and by overland flow. As a result, great variability in soil types can occur in short distances.

This great variation in soils has an effect on hydrology, vegetation, as well as on erosion and deposition. The soil in streambanks and floodplains and the substrate under the channel act as a sponge to retain water. This stored water is released as subsurface water or ground water over time, extending the availability of water in the watershed for a longer period during the summer or recharging the underground aquifer. Water flow restricting soil features such as clay or hardpans often have layers that support perched water tables of

standing water in riparian-ecosystems. Water movement over, into, and through the soil is what drives surface hydrology in our streams and filters our ground water.

Vegetative composition of riparian-wetland areas is also strongly influenced by the amount of moisture and oxygen levels in the soil. For example, the type of riparian-wetland soil, the amount of soil organic matter, the depth to which the water table will rise, the climate, and the season and duration of high water all determine the kinds of plants that will grow in riparian-wetland areas.

Erosion, though natural in some amounts, must be in balance with the amount of water and vegetation to prevent excessive erosion and sediment. Soils, interacting with geology, water, and vegetation, play a critical role in determining watershed health and, thus, the rate of erosion on uplands and deposition in riparian and wetland areas.

Soil Resource Issues

Research indicates that soil productivity is sustained through nitrogen and carbon fixation, mineral release from weathering parent material, decaying organic matter, and translocation of nutrients. Soil displacement, erosion and compaction can affect long-term and short-term productivity. The Forest has a completed detailed soil survey. Soil productivity improvement opportunities exist in watersheds with deteriorating soil conditions associated with human causes. Many of these conditions are caused by eroding abandoned roads, eroding trails, abandoned minespoils, illegal vehicle use, trash dumps, and dispersed camping.

The soils on the Forest are important to local and regional communities in several ways:

- Soils support vegetation, which supports wildlife, timber, and varied vegetative ecosystems.
- Soils in good condition produce little sediment to streams and reservoirs.
- Suitable soils are essential to any recreation use and development.
- Suitable soils are essential to a successful road and trail system.
- Watershed improvement project work can help local economies through purchases of supplies, equipment and labor.
- Soils on the Forest are an essential ecosystem component to consider in all the multiple uses the Forest provides to communities in our region.

Specific issues regarding impacts to soils were identified during public scoping for this Forest Plan. They are summarized here.

- Effects to soil productivity from motorized access use, soil movement (erosion), changes in dedicated use of the land, road decommissioning, illegal vehicle use, ATV and OHV use areas, dispersed recreation use.
- Management activities on the Forest may affect soil productivity. Soils could be impacted by acid deposition, road construction and decommissioning, trails and dispersed recreation use, watershed improvements, soils low in natural fertility, steep slopes and conservation of soil organic matter.
- Wind energy development. Construction and operation of wind farms on ridgetops and steep slopes.
- Prescribed fire management and containment with dozers.
- Recreation impacts from trail use, construction and closure, illegal motorized use and dispersed use in riparian corridors.
- Timber management impacts from small diameter utilization harvest, nutrient cycling and wood product transport from stump to roads.
- Climate change and impacts from using carbon sequestration within wetlands (beaver and restoration of artificially drained land), woody biomass harvest and biomass harvests for energy production.

The most important soil resource issue/concern regarding the effects from the management activities proposed in the various alternatives of the Forest Plan Revision is soil productivity. Ensuring that the quality of the soil resources across the George Washington National Forest is maintained or improved is what will be

discussed and displayed in this EIS. We will describe impacts to soil productivity with estimates of areal extent (acres). Some of the impacts will be short-term (<100 years) and some will be longer-term.

We will show how each alternative will impact the long-term productivity of the soil and to what extent. A significant impact to soil productivity will be an estimated fifteen percent reduction in productivity for areas that we actively manage. The threshold for allowable impacts to soil productivity has been identified by most regions of the Forest Service as 15 percent of an activity area. Long-term soil productivity must be maintained on at least 85 percent of an activity area. The activity area for this EIS varies by alternative since each one proposes different levels of management on different areas of the Forest. When long-term soil productivity is reduced on fifteen percent or more of an area, then this would not be in compliance with the laws and policy guiding FS protection of soil productivity and ecosystem sustainability.

DIRECT, INDIRECT AND CUMULATIVE EFFECTS

By determining the acres of long-term effects to soil productivity for each alternative, we can compare the alternatives and show how extensive the effects are. Each alternative affects long-term soil productivity to some degree. Key indicators used for determining effects to the soil resource are:

- Acres of timber harvest
- Miles of road construction
- Acres of prescribed burning
- Miles of trail construction
- Acres of soil improvement
- Acres of mineral lease development (used in Section D, Soils Resource)
- Acres of dispersed recreation
- Miles of road decommissioning

The scope for the soil resource effects analysis for the proposed actions and the alternatives is calculated using potential areas of disturbance (activity areas) below. These vary by alternative and will be used as a basis to display the percent of the activity area that is estimated to have long-term impacts to soil productivity. Activity Areas will be used to describe the scope of this analysis.

Table 3A4-1. Activity Area Acres Considered for Potential Soil Disturbance on GWNF

	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G	Alts H and I
GW Acres included in Activity Area*	1,021,551	1,002,447	636,140	1,008,299	998,601	910,782	1,002,612	995,202

* Activity Area calculated by subtracting acres in: Prescription Areas: 1A Designated Wilderness and 1B, Recommended Wilderness Areas, from the total Forest acres (1,065,918). The prescription areas vary by alternative. Other land allocations of prescriptions with low levels of potential disturbance, such as 2C2, 4B1, 4C1, 4F, 4FA, 8E4a, 8E7 and 12D, could be impacted by fire line construction associated with prescribed fire management, so these areas were not subtracted.

The Forest Service is directed by a number of laws, executive orders and policies to protect or enhance long-term soil productivity, while providing for the various uses of the National Forests. The Forest and Rangeland Renewable Resources Planning Act (RPA 1974) requires an assessment of the present and potential productivity of the land. Regulations are to specify guidelines for land management plans developed to achieve the goals of the program that "…insure that timber will be harvested from National Forest System lands only where …soil, slope or other watershed conditions will not be irreversibly damaged." The National Forest Management Act (1976) amended RPA by adding sections that stressed the maintenance of productivity, the protection and improvement of soil and water resources and avoidance of permanent impairment of the productive capability of the land.

Soil productivity is the inherent capacity of the soil to support the growth of plants and can be measured in terms of biomass produced. We will not measure impacts to soil productivity with biomass, since it is difficult to

quantify. We will describe impacts to soil productivity with estimates of areal extent (acres). Some of the impacts will be short-term (<100 years) and some will be long-term. We want to show how each alternative will impact long-term soil productivity and if these cumulative impacts will be extensive. A significant impact to soil productivity will be a fifteen percent reduction in productivity in areas where we do management. When long-term soil productivity is reduced on fifteen percent or more of the GWNF activity area by any alternative, then this would be a significant impact to the soil resource and would not be in compliance with the laws guiding FS policy on protecting soil productivity. By identifying impacts to soil productivity and minimizing the extent of the impacted area, we can protect the soil's ability to function as an important part of the Forest's ecosystems.

The threshold for significant impacts to soil quality/productivity has been identified in Forest Service Handbook 2509.18 Sec.2.05 as 15 percent of an activity area. Long-term soil productivity must be maintained on at least 85 percent of an activity area. Activity areas are where potential soil disturbances are most likely to occur and they are also expected to produce biomass in the future. By determining the extent (acres) of long-term effects to soil productivity for each alternative, we can compare the alternatives and show how extensive the effects are. Each alternative affects long-term soil productivity to some degree. Soil productivity can be affected by various factors and conditions resulting from management activities on the Forest. Compaction, erosion, topsoil removal (displacement), land use changes (i.e. forestland to trailhead parking) and soil improvement (fertilization/liming) can result from actions we take and all of these impacts the local productivity of the soil. Natural geologic weathering processes (rock to soil), organic decomposition (breakdown of dead biomass), fire, nutrient cycling and atmospheric (precipitation) additions are also influencing soil productivity across the Forest. All effects to soils from proposed actions will also be analyzed at the project level.

Table 3A4-2. Types of Effects to Soil Productivity

Direct Effects	Indirect Effects
Compaction	Erosion/soil movement
Land use change	Nutrient cycling
Displacement (Topsoil removal)	Prescribed fire use
Soil improvement	

Compaction. Soil compaction is dependent upon soil texture, soil structure, soil moisture, ground cover, rock content and the type of activity. Soils are most susceptible to compaction when moisture content is high. Fine textured soils without rock fragments are more at risk. Research has shown that biomass production (a measure of soil productivity) is reduced on compacted soils in the early stages of site recovery. Rutting, increased runoff, erosion and reduced root/plant growth can occur on severely compacted soils. Large areas of the Forest have surface soil characteristics that reduce their susceptibility to compaction. Low clay content and high rock content of the surface soil layers help reduce impacts to soil productivity from compaction. If topsoil removal occurs, generally compaction is more likely, since the subsoil layers of many soils on the Forest have higher clay content and have less rockiness. However, if topsoil removal has occurred, then soil productivity has already been reduced on the area. Compaction is considered a short-term (less than 100 years) effect on soil productivity, since research has shown even severely compacted soils can recover in ten to sixty years where mitigation measures of tilling and reestablishing vegetation have been used. Depth of compaction does not commonly exceed six inches with the kinds of equipment being used on the Forest. Actions that can produce soil compaction associated with Forest Plan Alternatives are skid trail (unbladed access routes) use, timber harvesting, grazing and trail use.

Land Use Change. If a soil on the Forest has the ability to produce biomass, it then has soil productivity. If this same soil, for example, is converted to a parking lot, building site, road or into some other use that prevents it from producing biomass, then it has lost some or all of its productivity for a long time. Land use change will be considered a long-term impact to soil productivity at this planning level.

Displacement (Topsoil Removal). Topsoil removal is considered a long-term effect to soil productivity because it involves the loss of the most fertile part of the soil. The organic layer and the mineral A-horizon beneath it are where most of the feeder roots are located for plants and where most of the nutrients needed for soil productivity are found. Many of the Forest's soils are formed in sandstones and shales that are naturally low in nutrients used by plants. Many are also acidic (low in soil pH). This means the upper layers of soil, where most of the organic material and microorganisms are found, are very important in maintaining the soil's productivity. Many years are needed for the soil to recover its original productivity when the upper layers are removed. Soil formation typically occurs at a rate of one inch per 200-1000 years and depends on many local environmental factors.

However, areas where topsoil is disposed will be enriched with this added soil material and organic matter. Productivity on these topsoil disposal areas will be improved by increasing soil depth, rooting depth, moisture holding capacity and organic matter. This is not to say that where topsoil is removed (long-term reduced soil productivity), soil productivity will be offset by areas where topsoil is deposited (long-term improved soil productivity). It is mentioned here as an indirect effect of excavation activities and to document that not all effects from excavation are negative. Topsoil disposal areas will not be used to show any positive effects of excavation, since the extent of these areas is not easily estimated or displayed. Actions which can produce topsoil removal associated with Forest Plan Alternatives are temporary road and skid road construction, log landing construction, developed recreation construction and use, new trail construction and relocation, and fireline construction using bulldozers.

Soil Improvement. The Forest works to improve soil conditions and reduce soil movement on about 40 acres per year. The Forest also decommissions roads annually. Special emphasis is given to riparian areas to help reduce sediment delivery to stream channels, floodplains and wetlands. Some watersheds may be targeted for this work to tie in with priority watersheds, watershed partnerships, species habitats and public water sources. The effects of soil improvement will be considered a long-term positive effect on soil productivity and an improvement of existing soil conditions. Soil improvement work will help these treated soils toward recovery of their inherent soil productivity. Actions which would be considered soil improvement associated with Forest Plan Alternatives include, road decommissioning, slope stabilization, erosion control structures and vegetation, road and trail decommissioning, illegal traffic use areas treated for compaction and erosion, abandoned mined land reclamation and trash dumpsite cleanups.

Prescribed Fire Use. Prescribed burning impacts soils in two ways. One way the fire itself burns up portions of the soil's organic layer, an important part of soil productivity. Hotter fires with large fuel loads will burn up more of the organic matter than cooler fires. A few soils on the Forest, with thin organic layers, can lose their entire organic layer when a fire burns hot. Typically, these would be shallow, rocky soils at or near ridge tops on steep slopes. In most cases, on this Forest, the effects of fire on the soil are a short-term effect. Organic layers are replenished by leaf fall and native vegetation takes advantage of a temporary increase in available soil nutrients from the fire, and an existing root system to recover. Also associated with prescribed burning is the construction of bladed firelines to control the burned area boundary. This is considered topsoil removal and is a long-term impact to soil productivity. Not all firelines are bladed with dozers.

Erosion/Soil Movement. An indirect effect of removing a soil's vegetative cover and its organic layer is erosion, meaning soil movement. An undisturbed soil with soil layers intact and covered with growing biomass is not very susceptible to erosion. When soils are disturbed in some way to expose bare mineral soil (A-horizon and lower), then soils on slopes become susceptible to raindrop impact, soil displacement and downslope flow of soil with water. These forces can cause soil to move, sometimes into stream channels, where it then becomes sediment and is incorporated into the bed load of the stream channel. Exposed slopes with low clay soils and soils without many rock fragments are most susceptible to soil movement.

Erosion is considered here as soil movement and not soil loss. Soil material may or may not move from a site or to a stream channel. Many factors influence soil movement and when soil moves, it is deposited somewhere. Depositional areas may benefit from the addition of this eroded soil. Gully erosion is the extreme case of soil movement and would be considered a long-term effect to soil productivity. Gully erosion is evidence that large amounts of soil have moved away and will not be replaced in the short-term (<100 years). Other forms of erosion are not as impactive and would only last until a vegetative cover is established. Gully

erosion is difficult to predict and depends on several factors. Erosion will be considered a short-term effect and will be estimated mainly to consider sediment delivery to stream channels.

Nutrient Cycling. When vegetation is removed from a site, a portion of the potential organic matter and its available nutrients to the soil is removed with it and the resulting condition of a reduced canopy (shade) can have an effect on soil temperature, soil moisture and nutrient cycling. This situation will normally occur with a timber harvest. The bole of the tree is removed from the site and the forest canopy opens up to allow more sunlight and moisture to reach the soil surface. Other parts of the tree will remain onsite to recycle into the soil nutrient system over time. Loss of trees will reduce canopy cover and evapotranspiration and increase soil moisture. Loss of canopy will increase soil temperature in the topsoil. These conditions will increase soil organic matter decomposition and increase available nutrients on the treated area. Much of this increase in plant available nutrients will be taken up by the stump sprouting of hardwood trees and by the root systems of the remaining vegetation on the treated area. Some nutrients may be leached from the site and reach local streams in ground water. This leaching effect is short-term and research has shown that removal of the tree main stem alone will not reduce long-term soil productivity. Most tree nutrients are in smaller branches and leaves, which normally remain on site after a timber harvest. Short-term losses are made up by leaf fall, atmospheric additions and weathering of parent material. Any increased leaching of nutrients from the soil would be very short-term (<5 years).

Long-term productivity can be reduced with unlimited small diameter utilization with short rotations on soils with poor natural fertility so small diameter utilization is limited on these soils.

The cumulative effects to soil productivity from the actions taken during the first decade of a new Forest Plan by each alternative are displayed in Table 3A4-3 below. Table 3A4-3 is based on the levels of timber harvest and prescribed fire displayed in Table 3B2-10. As shown, the alternatives vary in their impact to long-term soil productivity on the Forest. It shows that soil productivity is being maintained on more than 99% of the Forest area. Cumulative effects to the soils considered past management actions taken prior to plan implementation and anticipated actions taken by the alternatives for the first 10 years including watershed condition improvement work.

Table 3A4-3. Cumulative Effects to Soil Productivity by GWNF Forest Plan Alternatives over first 10 years of the Plan, acres

Effects to Soil Productivity	Alt A	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G	Alts H and I
Cumulative Long-Term Effects*	6,754	6,653 – 6,983	6,118	7,036 – 7,556	6,688 – 6,968	6,476 – 6,716	6,688-7,018	6,668 – 7,018
Cumulative Improved Soil Productivity***	1,378	1,547	1,823	1,362	1,647	1,593	1,647	1,647
Adjusted Cumulative Long-Term Effects	5,376	5,106 – 5,436	4,295	5,674 – 6,194	5,041 – 5,321	4,883 – 5,123	5,041-5,371	5,041 – 5,371
Percent of the GWNF Activity Areas** with Long-Term Effects after 10 yr	0.53%	0.51-0.54%	0.68%	0.56-0.61%	0.50-0.53%	0.54 – 0.56%	0.50 – 0.54%	0.51 – 0.54%

*Cumulative Long-Term Effects generated by alternative actions plus Existing Long-Term Effects.
**Activity Area explained in the Scope of Analysis section above.
*** Decommissioned roads and watershed improvement project acres.

A5 – AIR

AFFECTED ENVIRONMENT

The 1977 and 1990 Amendments to the Clean Air Act (CAA) afford special protection from air pollution to designated Class I areas. The George Washington National Forest (Forest) does not manage any Class I areas, however James River Face Wilderness, managed by the Jefferson National Forest, is adjacent to the Forest to the south. Other Class I areas near the George Washington National Forest are the Shenandoah National Park, and Dolly Sods and Otter Creek Wildernesses on the Monongahela National Forest. The Prevention of Significant Deterioration section of the Clean Air Act (CAA) requires Federal Land Managers to identify Air Quality Related Values (AQRV), or resources important to the Class I areas that might be affected by air pollution. For the Class I areas near the Forest these include visibility, water quality and vegetation. The term AQRV will be used broadly to apply to any resources within the Forest boundary that might be affected by air pollution.

Through a series of legislative and regulatory requirements, federal land management agencies have the unique responsibility to not only protect the air, land, and water resources under their respective authorities from degradation associated with the impacts of air pollution emitted outside the borders of Agency lands (Clean Air Act 1990), but to protect those same resources from the impacts of air pollutants produced within those borders (Clean Air Act 1990, Organic Act 1977, Wilderness Act 1997). Activities from within the forest such as prescribed burning, road construction/maintenance, oil and gas development, recreational use, and timber harvesting all have an impact on the air quality of the forest. It is the responsibility of federal land managers to minimize the impact of these activities on the forest’s AQRV, as well as the forest’s contribution to air pollution. In light of this responsibility, it is important for federal land managers to understand the impacts of pollution from activities within the National Forest, and also to be familiar with the impacts from pollution sources outside the forest boundary.

The George Washington National Forest is located in an area of the United States that continues to grow in population with an associated demand for electricity and transportation. The Forest is located downwind of two major areas of coal-fired power generation, the Ohio River Valley and the Tennessee Valley Authority; and within a day’s drive of a large percentage of the United States population and numerous major cities. Washington DC and Richmond are among the larger urban areas within 125 miles of the Forest. The heavily traveled Interstate Highway 81 runs the length of the Forest. Nitrogen oxide, sulfur dioxide and fine particulates are the main pollutants emitted from these sources that are affecting resources on the Forest.

Nitrogen oxides are an important contributor to the formation of ground-level ozone on hot sunny days (Chameides and Cowling 1995). The Forest operates an ozone monitor at the Glenwood/Pedlar District office in cooperation with the Virginia Department of Environmental Quality (VDEQ). Data collected since 1999 indicates this area is currently in compliance with the one-hour and 8-hour ozone National Ambient Air Quality Standards (NAAQS). The NAAQS are regularly reviewed and modified by EPA, and a reduction in the ozone standard is expected in the fall of 2013. Final attainment/nonattainment decisions will be made sometime in the future and will be based on monitoring data that has not yet been collected. However, current ozone concentrations at monitors near the Forest exceed at least the most stringent proposed 8-hour ozone NAAQS (Figure 3A5-1 - 2009 AQ Report to Forest). There is also a proposed secondary ozone standard in the form of a seasonal exposure index, W126; a measurement that recognizes the cumulative impacts that ozone concentrations have on sensitive vegetation. Recent monitoring results show that some sites could exceed the proposed secondary NAAQS, indicating pollution levels high enough to be harmful to vegetation.

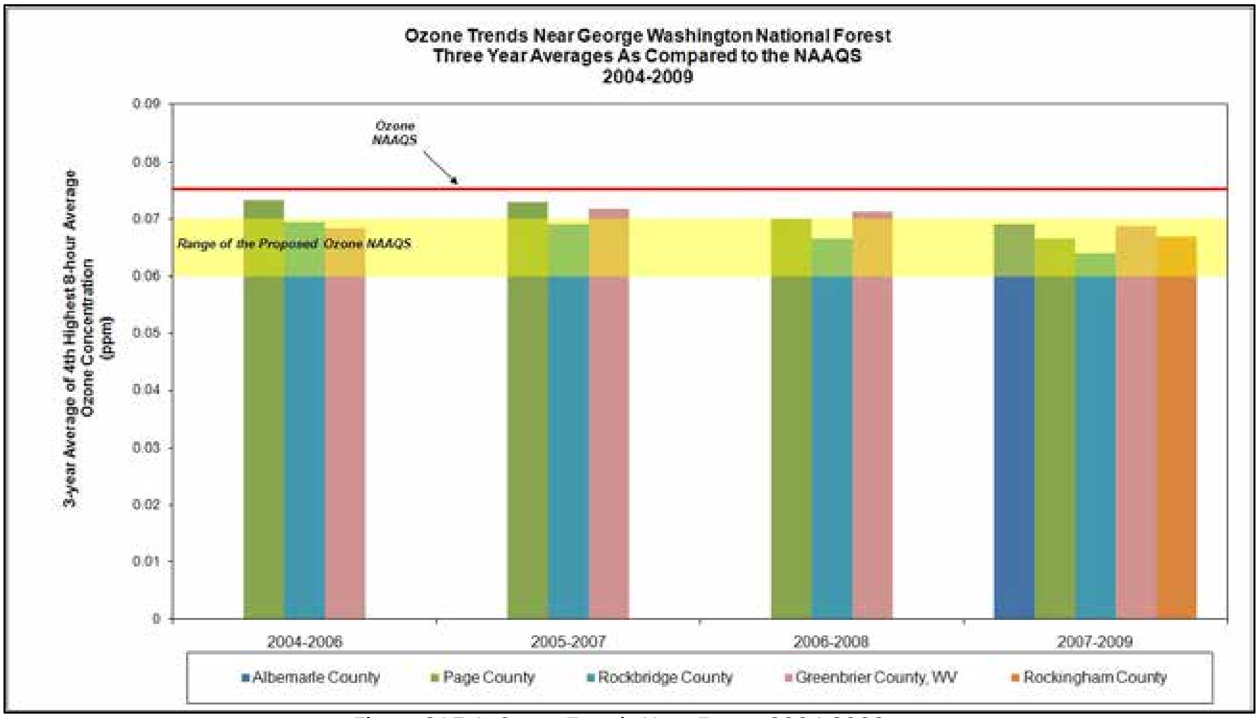


Figure 3A5-1. Ozone Trends Near Forest 2004-2009

About a third of nitrogen oxides affecting the Forest are from power plants (especially during hot summer days when electricity is needed to cool homes and businesses), and another third are from highway vehicles. The rest are from industrial sources.

Laws, rules, and regulations are in place that are resulting in lower nitrogen oxide emissions in Virginia and neighboring states. Annual NO_x emissions from sources in Virginia and West Virginia have declined 68 percent from 2000 levels (about 147,000 to 47,000 tons in 2008) and 76 percent from 1990 levels (200,000 tons) (EPA 2008). These reductions have resulted from implementation of the Acid Rain Program and the NO_x Budget Trading Program. Further nitrogen oxide reductions are anticipated as State and local air pollution control agencies seek ways to attain new ozone standards in urban areas near the Forest, and in cities to the south and west of the Forest. These further reductions in nitrogen oxides will benefit the health of people visiting or living within the Forest, as well as the vegetation.

Acid compounds in clouds, fog, rain and haze are having an adverse impact on visibility and the ability of the soils and streams to buffer acid inputs. Further discussion of the current effects of acid deposition on aquatic resources can be found in the Water Resources and the Fisheries and Aquatic Habitats Sections. Sulfates (sulfur compounds that originate from sulfur dioxide) are the predominant pollutants causing these impacts. Approximately 80% of the sulfur dioxide emissions affecting the Forest are released from coal-fired power plants. Power plants in the Ohio River Valley, Virginia, and West Virginia are most likely to be influencing the acidity and sulfate concentration of rainfall on the George Washington National Forest (SAMI 2002). However, as a result of Title IV of the Clean Air Act Amendments of 1990 (the Acid Rain Program) and the 1999 Regional Haze Rules, power plants throughout the United States, including those near the George Washington National Forest, have installed pollution control devices to reduce emissions of sulfur dioxide and other pollutants that cause acidic deposition such as nitrogen oxides. Emissions of sulfur dioxide declined by roughly 50% between 2005 and 2009 (EPA CAMD), with about half of that reduction occurring in 2009. Part of the emissions decline is attributed to reduced energy demand in 2009 related to the recession. Additional emission reductions are expected in the future as the provisions of the Regional Haze Rule are implemented, as discussed below.

With the reduction of sulfur dioxide and nitrogen oxide emissions, sulfate and nitrate deposition has also decreased, as would be expected. Wet deposition monitors located near the Forest show that annual sulfate

deposition was about 8 kg/ha in 2009; down from about 15 kg/ha in 2000. Even though sulfur deposition is decreasing, acid neutralizing capacity, or the stream's ability to buffer acid inputs, is predicted to continue to decrease in high elevation headwater streams (SAMI 2002; Sullivan et al. 2010). This happens because most soils on the Forest continue to retain at least part of the sulfur that is deposited. Even though sulfur deposition may decrease, soils have been retaining sulfates that will continue to be released and move out of the soil into the stream water. As sulfates are released into the soil water, base cations, such as calcium, may also be removed from the soils. Removal of calcium and other base cations can lead to nutrient depletion and a reduction in soil productivity.

The beautiful mountain scenery is one of the reasons tourists visit the George Washington National Forest and other areas in Appalachia. However on many days of the year a uniform haze-like white or gray veil obscures the scenery. In 1997 Congress determined that all Class I areas in the nation were suffering from some level of visibility impairment; that there has been a significant reduction in how far a person can see distant views, as well as the clarity of that view. The estimated natural background visibility for the eastern United States is 93$\pm$28 miles (NAPAP 1991) and median visibility measured at James River Face Wilderness in 2008 was only 38 miles. While this still represents impairment from the natural condition, it is an improvement over the median visibility in the late 1990s of 26 miles. Median visual range at Shenandoah National Park has been improving as well and was about 47 miles in 2008. This improvement in visibility is a direct result of emissions reductions achieved through the Acid Rain program and other efforts. Further reductions are expected as the Regional Haze State Implementation Plans are adopted and implemented (Virginia Regional Haze State Implementation Plan, 2010). The Regional Haze SIP sets goals for improving the worst visibility conditions while preserving the clearest conditions.

Regional haze and reduced visibility observed in the mountains is caused mostly by air pollution, primarily sulfates that originate from coal-fired power plants. The fine particles ($PM_{2.5}$) primarily responsible for visibility impairment are formed when combustion gases are chemically transformed into particles. In the eastern United States, sulfate particles (transformed sulfur dioxide) from coal-fired power plants comprise the largest component of measured fine particle mass (IMPROVE 2001) affecting visibility. The clearest days in 2008 at James River Face had 69 miles visibility and the lowest fine particle mass (4.48 ug/m3). The days with the highest concentration of mass (16.31 ug/m3) showed visibility was reduced significantly to only 19 miles. The days with the poorest visibility are most likely to occur starting in May and continue through September (http://views.cira.colostate.edu/web/Trends/), during the time when most people are visiting the Forest. Sulfates are still the most important fine particles contributing to visibility impairment. On the clearest days they comprise 30% of the total mass while on the haziest days the sulfates are 38% of the total. Organics (released primarily from vegetation as volatile organic compounds) are the second most important fine particles measured, and if organics were the most abundant particulate species, then there would be a bluish cast to the mountains, hence the name Blue Ridge Mountains.

The fine particles that cause visibility impairment can also be unhealthy for people, because high concentrations aggravate respiratory conditions, such as asthma. Fine particles are closely associated with increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory disease and symptoms such as asthma, decreased lung function, and even premature death (EPA 1997). Sensitive groups at greater risk include the elderly, individuals with cardiopulmonary disease, and children. For this reason, fine particle levels are monitored. Monitoring results for fine particulates include both primary particulate (that are emitted directly from a source) and secondary particulate (resulting from transformation of gases in the atmosphere). The Environmental Protection Agency has established NAAQS for fine particles ($PM_{2.5}$) based on three-year averages of monitored data. Monitors near the Forest indicate that both the annual average $PM_{2.5}$ and the 24-hour average standard are not exceeded (Figure 3A5-2 - 2009 Air Quality Report for the George Washington and Jefferson National Forests), however EPA is required to reassess the standards every few years and proposal of a more stringent standard is anticipated.

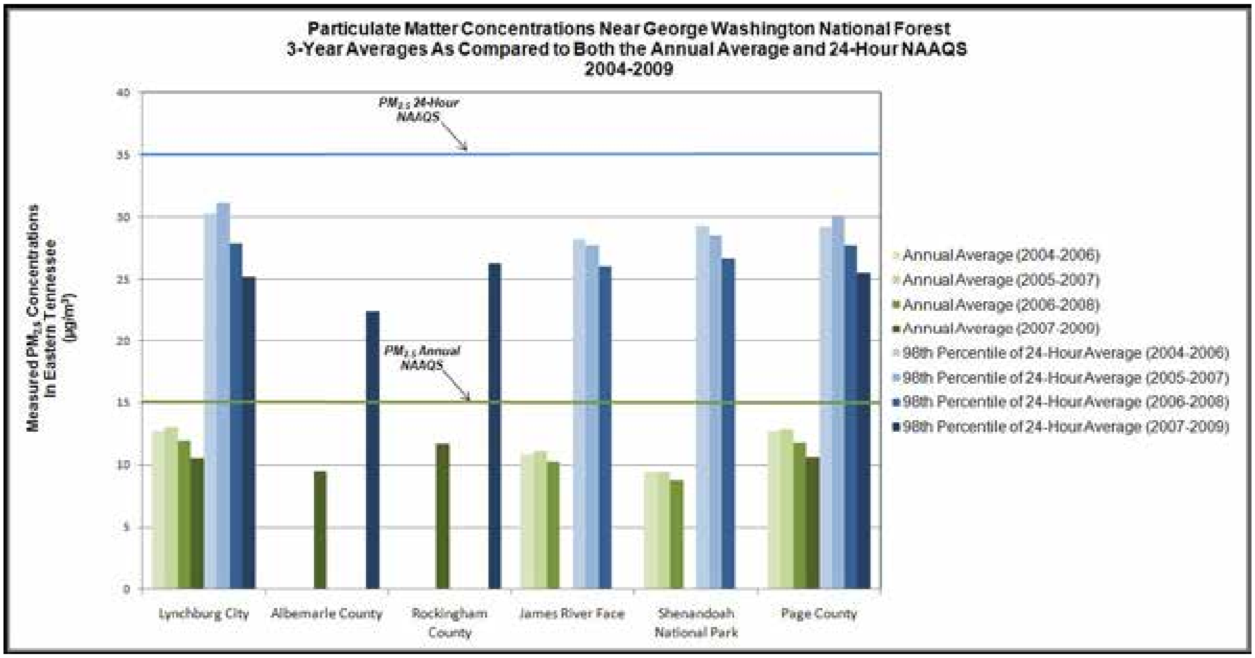


Figure 3A5-2. Particulate Matter Concentrations Near the Forest 2004-2009

The Environmental Protection Agency will ultimately decide if any other areas affecting the Forest will be designated as non-attainment for fine particles or ozone. It is of particular importance for fire managers to mitigate prescribed fire emissions, to the greatest extent practical, during those days characterized by existing or predicted high ambient air pollution. The $PM_{2.5}$ standard may require fire managers to be even more vigilant in smoke management to protect the health and welfare of citizens on and off Forest lands from the effects of particulate matter emissions associated with prescribed fire.

Once an area is designated non-attainment, a State Implementation Plan (SIP) is developed in an attempt to bring the area back into attainment of the standard. This usually involves placing controls on various sources that contribute to the pollutant of concern in order to lessen or minimize their emissions. SIPs are developed based on emission inventories of contributing sources of pollution. Considering that 70% of the particulate emissions from prescribed fires are fine particles, and nitrogen oxides and volatile organic compounds are also released, state air regulators will be interested in these emissions. The Forest will need to continue to interact closely with the Virginia Department of Environmental Quality to ensure that Forest prescribed fire emissions (and perhaps other Forest activities) are accurately considered in State Implementation Plan development.

DIRECT AND INDIRECT EFFECTS

As an ecological process, wildland fire is essential in creating and maintaining functional ecosystems and achieving other land use objectives. However, smoke is a byproduct of prescribed fire that affects air quality. All emissions from wildland fires are generated from the incomplete combustion of fuel, and include: particulate matter, carbon monoxide, carbon dioxide, nitrogen oxides and hydrocarbons (Hardy et al. 2001). The single-most important emission in smoke is fine particulate matter less than 2.5 microns in diameter ($PM_{2.5}$) because it limits visibility, absorbs harmful gases, and aggravates respiratory conditions in sensitive individuals. Fine particulates ($PM_{2.5}$) make up more than 70% of the mass of particulate matter produced by wildland fire. Environmental Protection Agency (EPA) routinely reviews air quality standards for ozone and $PM_{2.5}$ and adopts more stringent standards to protect human health, if research indicates this is necessary. In 2006 the $PM_{2.5}$ standard was reduced, and lower ozone standards are expected to be finalized in 2014. The challenge in using wildland fire is balancing the public interest objectives of protecting human health and welfare (from air pollution) and sustaining ecological integrity. The EPA recognizes this challenge and developed an interim air quality policy on wildland and prescribed fires with the public policy goal to allow fire

to function as much as possible in its natural role in maintaining healthy wildland ecosystems, and to protect public health and welfare by mitigating the impacts of air pollutant emissions on air quality and visibility (EPA 1998).

In order to minimize the negative effects of smoke and associated pollutants on human health and visibility, smoke management plans are a required part of every prescribed fire burn plan. The negative effects of smoke can be reduced by planning and executing prescribed fires on days that maximize smoke dispersion and avoid smoke-sensitive areas. For each prescribed burn conducted, the Forest Service determines smoke dispersion characteristics that must be met in the weather forecast for the day of the burn. These characteristics include: the depth of the atmosphere available for smoke mixing (dispersion), transport wind speed and direction, and the probability of air mass stagnation during the day. Forest Service smoke management guidelines include:

- Predicting smoke behavior for the weather conditions anticipated during the burn.
- Determining if there are smoke-sensitive targets (public or private ownership) within the probable smoke impact area and coordinating with them to avoid or mitigate problems.
- Monitoring the actual weather conditions and smoke behavior to make sure the burn continues to be within the prescription.
- Being prepared to cease ignition and/or initiate suppression if the weather changes from the forecast and causes smoke behavior problems that cannot be mitigated.

Application of the precautionary and mitigation measures described above will limit the risk and severity of any problems that might occur from prescribed fire smoke.

Fine particulate emissions were estimated for each alternative and compared to current prescribed fire emissions and the background condition. Background condition is the fine particulate from all sources of primary fine particulate emissions within the counties containing national forest system lands. These counties are referred to as the "analysis area".

Direct effects on air quality were assessed by comparing $PM_{2.5}$ emissions estimates from each alternative to emissions from the current prescribed fire program. Emissions were calculated for the minimum and maximum number of planned acres in each alternative using best estimates of fuel type, fuel consumption and emissions rates. Actual acres burned in any given year, and resulting $PM_{2.5}$ emissions, will depend on weather conditions and other factors that must be considered prior to initiating a prescribed fire. Background $PM_{2.5}$ emissions are from the 2005 National Emissions Inventory (EPA 2005).

On average, the Forest has burned 5,800 acres annually since 2006, and estimated $PM_{2.5}$ emissions from this program would be 406 tons. Alternatives B, D, E, F, G, H and I propose increasing the use of prescribed fire which would result in an emissions increase of roughly 100 - 250 percent over current levels (Table 3A5-1). Alternatives A and C would actually use prescribed fire on fewer acres and result in less emissions than the current program.

Table 3A5-1. Annual Fine Particulate Matter ($PM_{2.5}$) Emissions by Alternative (compared to current fire program and inventoried background primary $PM_{2.5}$ emissions within counties containing George Washington National Forest system lands)

Alternative	Estimated Annual $PM_{2.5}$ Emissions, in tons		Percent Change in $PM_{2.5}$ Emissions: Direct/Indirect Effects: Alternatives Compared to Current Fire Program		Percent Change in $PM_{2.5}$ Emissions: Cumulative Effects: Alternatives Compared to All Other Sources	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
A	210	210	-48	-48	-2	-2
B	1,089	1,425	168	251	7	10
C	25	25	-94	-94	-4	-4
D	375	865	-8	113	0	5
E	1,448	1,448	257	257	10	10
F	865	1,425	113	251	5	10
G	865	1,425	113	251	5	10
H and I	865	1,425	113	251	5	10
Current Fire Program	406	406				

The largest prescribed fire program on the Forest occurred in 2009 when 9,526 acres were burned. $PM_{2.5}$ emissions that year were estimated at approximately 670 tons. Emissions from the minimum burn program for any proposed Alternative would be equal to or less than those in 2008. The maximum program for all alternatives, except E, would exceed the 2008 emissions by 20-65%.

CUMULATIVE EFFECTS

Emissions from prescribed fire are only one of many sources of $PM_{2.5}$ pollution. Fine particulates can be emitted directly into the atmosphere or can be created from gaseous pollutants that are chemically transformed into particulates (sulfur dioxide is transformed into sulfate particles). Only those particulates emitted directly into the atmosphere (primary pollutants) are tracked in emission inventories. The most recent emissions inventory available from the Environmental Protection Agency estimates primary $PM_{2.5}$ emissions within the analysis area at 10,067 tons (EPA 2005). Emissions from proposed Alternatives B, D, E, F, G, H and I could account for 5-10% increase in primary $PM_{2.5}$ emissions in the analysis area (Table 3A5-1). Alternatives A and C could result in a slight decrease (2-4%) in $PM_{2.5}$ emissions in the analysis area. In reality the changes in ambient $PM_{2.5}$, the pollution that people are exposed to, would be even less. This is because a large amount of monitored $PM_{2.5}$ is secondary particulate formed from gaseous pollutants such as sulfur dioxide. Secondary particulates are not included in the emission inventory. If they were, the contribution of emissions from prescribed fires would be reduced.

Another way to evaluate the cumulative effects of prescribed fire on air quality is to compare monitored fine particulate concentrations to prescribed fire emissions. Figure 3A5-3 (2009 Air Quality report to Forest) shows that although there were periods of increased prescribed fire emissions from 2005 through 2009, there was a decrease in monitored fine particulate concentration for both the annual and 24-hour averaging periods. This shows that local and regional $PM_{2.5}$ concentrations do not appear to be correlated with $PM_{2.5}$ emissions from prescribed fires on the Forest.

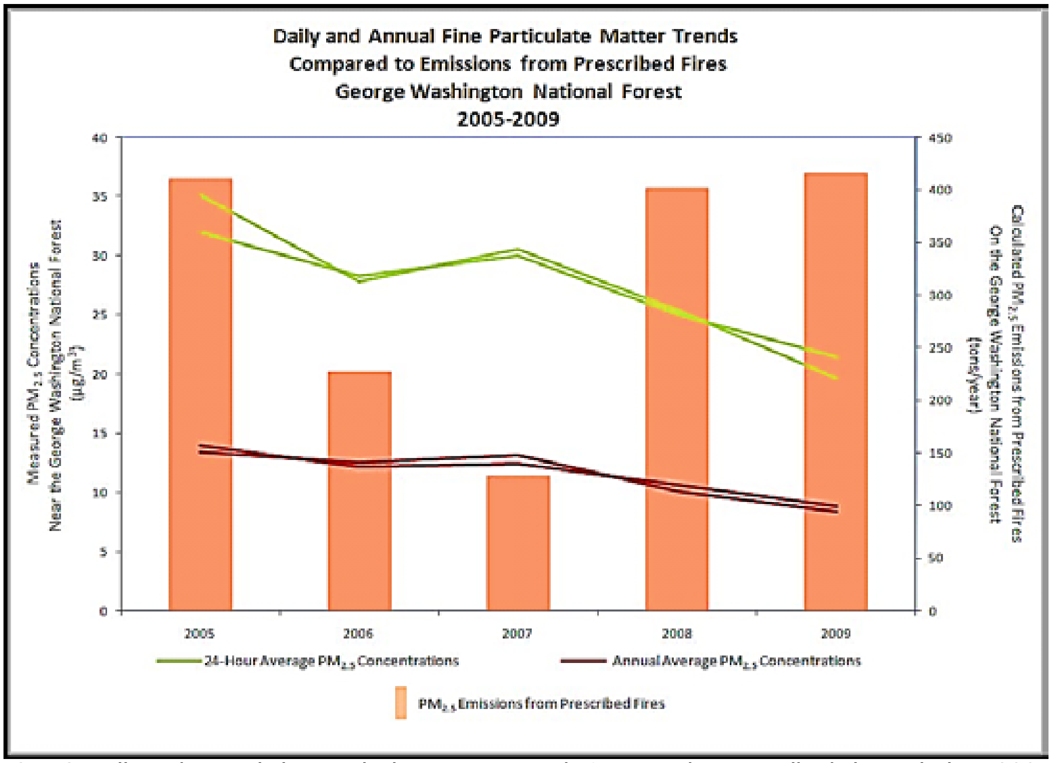


Figure 3A5-3. Daily and Annual Fine Particulate Matter Trends Compared to Prescribed Fire Emissions 2005-2009

The projected emissions from prescribed fires are not expected to be a large contributor to total fine particulate matter mass nor any exceedence of the fine particle National Ambient Air Quality Standard (NAAQS). However, the Forest will be expected to follow Conformity Determination rules and disclose any prescribed fire emissions for activities planned in designated non-attainment areas.

A6 – WATER

AFFECTED ENVIRONMENT

The Forest is almost equally divided between the Potomac and James River basins. Tributaries of the Potomac in the vicinity of the Forest include South Fork South Branch of the Potomac and the Lost, Cacapon, Shenandoah (North and South forks), Dry, North, and Middle Rivers. Rivers tributary to the James include the Jackson, Bullpasture, Cowpasture, Calfpasture, Maury, South, St. Mary's, Pedlar, Buffalo, and Tye.

National forest system lands are typically the mountainous headwaters in each of these systems. As such, the streams on the national forest are typically small high-gradient, high-energy systems. Water yield for the Forest averages 16.6 area-inches per year. This is not distributed uniformly in time or space. Based on streamflow information from the U.S. Geological Survey stream gauging stations, the average annual runoff from the Forest varies from approximately 11 area-inches to over 27 area-inches.

Streamflow represents a "leftover" of precipitation minus evaporation and water use by growing vegetation. As such, it is extremely variable. Streamflow varies by year and by time of year. May and July are the months most likely to have the highest precipitation. However, in a typical year, March is the month with highest streamflows. This occurs because the high precipitation months are also during the growing season when much of the precipitation is used by vegetation. Streamflows are typically lowest in late summer and early autumn at the end of the growing season. January and February are the months with lowest precipitation.

Floods and Droughts

The watersheds of the George Washington National Forest periodically experience extreme flow events. Virginia lies in the path of cyclone storms that originate in the Gulf of Mexico and the Atlantic Ocean and carry large amounts of moisture. Flooding is common in the state, especially in the western mountain regions, where high precipitation and steep topography produce rapid runoff. The lands of the Forest have been touched by floods of magnitude greater than 50 year recurrence interval in 1936, 1942, 1949, 1969, 1972, 1985, and 1996. Most of these were produced by hurricanes. The potential for flooding is greatest when soils are near saturation as they are in the spring or at any time of year following several days of rain. The presence of a forest canopy in a watershed can reduce flood peaks from small-to-moderate storms during the growing season because the growing trees utilize soil moisture and transpire it to the atmosphere. This soil moisture difference becomes negligible during large-storm events. Thus forest harvesting has no substantive effect on large floods (Hewlett 1982; Eisenbies et al. 2006).

A small mountain watershed on the George Washington National Forest can produce flood peaks approaching 1,000 cubic feet per second, per square mile. In contrast, a larger river basin like the James River at Holcomb Rock will have a maximum peak discharge of only 50 cubic feet per second, per square mile.

Low flows typically occur during late summer and early autumn when precipitation is low and soil moisture is utilized by growing vegetation. Water in the stream represents the release of water from groundwater and soil storage. Because of the wide range in topography, rock types, and soils, there is a wide variation of low flows in the streams of the George Washington National Forest. Where soils are deep, slopes are gentle, and drainage density is low, precipitation can be stored within the watershed and released slowly. Thus, peak flows are moderated and low flows are sustained. As greater flow contributions are from groundwater, water temperature is usually lower and less variable. Based on years of data from USGS stream gages across the Forest, low flows are higher in the Blue Ridge.

Water Quality

Water quality on the George Washington National Forest is affected by nonpoint sources of pollution that can affect the physical, chemical, or biological integrity of Forest streams. Collectively, these factors make up the water's aquatic ecological integrity. Nonpoint sources of pollution on the Forest can include road construction and maintenance, timber harvest, dispersed and developed recreation management, and fisheries and wildlife habitat improvement. The largest potential impact on water quality from our management activities is from an

increase in sediment in streams which can affect the physical integrity of streams. Monitoring has not been conducted to characterize stream condition or trend relative to sediment from management activities. Activities off the Forest are affecting the chemical integrity of Forest streams. Acid deposition from industry and automobiles are causing many streams to become more acidic. See the discussion in the Fisheries and Aquatic Habitat section. A more extensive monitoring program is underway to characterize the chemistry and stream insects of most of the Forest's streams.

Impaired Waters

The 2010 303d reports for Virginia and West Virginia list 56 streams and 4 reservoirs on the Forest as being impaired. The sources of these impairments are off-Forest (including acid deposition), or are described as "natural." None of the impairments are attributed to Forest management activities.

Table 3A6-1. Impaired Waters on the George Washington National Forest

Water Name	Cat.	Use	Impairment	Source
Pedlar River	5A	Recreation	E. coli	Non-point source (NPS)
Big Run	5A	Recreation	E. coli	Agriculture, NPS, wildlife
North River	5A	Aquatic Life	pH	Atmospheric deposition
Thorny Branch	4A	Recreation	Fecal coliform	Non-point source
Briery Branch	5C	Aquatic Life	pH	Natural conditions
Narrow Passage Creek	5A	Recreation	Fecal coliform	Agriculture, NPS, wildlife
Cedar Creek	5A	Aquatic Life	Benthic macro bioassessments	Unknown
Loves Run	5A	Aquatic Life	pH	Atmospheric deposition
Pine Run	4A	Recreation	E. coli	NPS, wildlife
Back Creek [Augusta Co.]	5A	Aquatic Life	Benthic macro bioassessments	Unknown
South Fork Shenandoah R	5A	Fish Consumption	Mercury in fish tissue	Contaminated sediments
North Fork Shenandoah R	5A	Aquatic Life	Benthic macro bioassessments	Non-point source
Crab Run	5A	Recreation	E. coli	Agriculture, NPS, wildlife
Shoemaker River	4A	Recreation	E. coli	Agriculture, NPS, wildlife
Runion Creek	4A	Recreation	E. coli	Agriculture, NPS, wildlife
Sours Run	4A	Recreation	E. coli	Agriculture, NPS, wildlife
Falls Hollow	4C	Aquatic Life	Benthic macro bioassessments	Drought-related impacts
Tunnel Hollow x-trib	4C	Aquatic Life	Benthic macro bioassessments	Drought-related impacts
Beaver Creek	4A	Recreation	Fecal coliform	NPS, wildlife
Beaver Creek	4C	Aquatic Life	Temperature	Natural conditions
Rocky Run	5A	Aquatic Life	pH	Atmospheric deposition
Union Spring Run	5A	Aquatic Life	pH	Atmospheric deposition
Wolf Run	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Wolf Run	5A	Aquatic Life	pH	Atmospheric deposition
Dry River	5A	Aquatic Life	pH	Atmospheric deposition
Skidmore Fork	4C	Aquatic Life	Benthic macro bioassessments	Drought-related impacts
Coles Run	5A	Aquatic Life	pH	Atmospheric deposition
Johns Run	5A	Aquatic Life	pH	Atmospheric deposition
Kennedy Creek	5A	Aquatic Life	pH	Atmospheric deposition
Mills Creek	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Orebank Creek	5A	Aquatic Life	pH	Atmospheric deposition
Toms Branch	4C	Aquatic Life	Benthic macro bioassessments	Drought-related impacts
Cub Run [Elkton W quad]	5A	Recreation	Fecal coliform, E. coli	Agriculture, NPS, wildlife
Boone Run	5A	Recreation	Fecal coliform	NPS, wildlife

Water Name	Cat.	Use	Impairment	Source
Little Dry River	4A	Recreation	Fecal coliform	NPS, wildlife
Little Dry River	5A	Aquatic Life	pH	Atmospheric deposition
Fridley Run	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Fridley Run	5A	Aquatic Life	pH	Atmospheric deposition
Mountain Run	4A	Recreation	Fecal coliform, E. coli	Agriculture, NPS, wildlife
Mountain Run	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Mill Creek [R'ham Co.]	4A	Recreation	Fecal coliform	Agriculture, NPS, wildlife
Mill Creek [R'ham Co.]	4A	Aquatic Life	Benthic macro bioassessments	Unknown
Laurel Run [Shen Co.]	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Little Stony Creek	5A	Aquatic Life	Benthic macro bioassessments	Atmospheric deposition
Stony Creek	4A	Recreation	Fecal coliform	Agriculture, NPS, wildlife
Stony Creek	5A	Aquatic Life	Benthic macro bioassessments	Agriculture, NPS, wildlife
Stony Creek	5A	Aquatic Life	Temperature	Unknown
Passage Creek	5A	Recreation	Fecal coliform	Agriculture, NPS, wildlife
Passage Creek	5A	Aquatic Life	pH	Atmospheric deposition
Jackson River	5C	Aquatic Life	Temperature	Natural conditions
Jackson River	5A	Recreation	E. coli	NPS, wildlife
Back Creek [Bath Co.]	5A	Aquatic Life	Temperature	Unknown
Laurel Run [Bath Co.]	5A	Aquatic Life	pH	Atmospheric deposition
Panther Run	4C	Aquatic Life	Benthic macro bioassessments	Drought-related
Pheasanty Run	4A	Aquatic Life	Benthic macro bioassessments	Aquaculture (permitted)
Porters Mill Creek	5A	Aquatic Life	pH	Atmospheric deposition
South Fork Pads Creek	4C	Aquatic Life	Benthic macro bioassessments	Drought-related
Calfpasture River	5A	Recreation	E. coli	Agriculture, NPS, wildlife
Little Calfpasture River	5A	Recreation	Fecal coliform	NPS, wildlife
Saint Mary's River	5A	Aquatic Life	pH	Atmospheric deposition
Irish Creek	5A	Aquatic Life	Temperature	Unknown
Wilson Creek	5C	Aquatic Life	Temperature	Drought-related impacts; unknown
Potts Creek	5A	Recreation	E. coli	Livestock, septic systems, wildlife
Potts Creek	5C	Aquatic Life	pH (> 9.00)	Unknown
Coles Run Reservoir	5A	Aquatic Life	pH	Atmospheric deposition
Elkhorn Lake	5A	Aquatic Life	Temperature	Unknown
Staunton Dam Lake	5A	Aquatic Life	pH	Atmospheric deposition
Switzer Lake	5A	Aquatic Life	pH	Atmospheric deposition
Switzer Lake	5A	Aquatic Life	Temperature	Unknown
Capon Run	5		Biological	Unknown
Hawes Run	5		Biological	Unknown
Miller Run	5		Biological	Unknown

Category 4A - water is impaired or threatened for one or more designated uses; TMDL has been completed.
Category 4C - impairment is not caused by a pollutant and/or is caused by natural conditions; no TMDL is required.
Category 5A - water is impaired or threatened for one or more uses by a pollutant(s); TMDL is required.
Category 5C - water quality standard is not attained due to "suspected" natural conditions; may require a TMDL; WQ Standard may be reevaluated due to the presence of natural conditions.
Category 5 - water is impaired, and a TMDL is needed (West Virginia).

The 2010 Water Quality Assessment for Virginia lists 69 impairments on the Forest, affecting 53 streams and four reservoirs. For 11 of the stream impairments, the cause is a natural condition, and no Total Maximum Daily Load (TMDL) allocation is required; or the cause is a "suspected" natural condition, and a TMDL may or may not be required. For an additional 18 stream impairments, the source is atmospheric deposition.

For all the other 33 stream impairments, much more of the stream's length is on private land than on Forest Service land, and almost all the samples on which these impairments were based were collected miles downstream from Forest Service land. The predominant sources for these impairments are agriculture, nonpoint sources, and wildlife. For six impairments, the source is listed as unknown.

TMDL reports have been completed for twelve of the impairments. One deals with aquaculture. The other eleven, which are for bacteria, identify agriculture as the main source of pollution, with wildlife as a secondary source. None of these TMDL reports identify activities related to forest management as a significant source.

For Coles Run Reservoir, Staunton Dam Lake, and Switzer Lake, the impairment is low pH, due to atmospheric deposition. Elkhorn Lake and Switzer Lake are also listed with a temperature impairment, with the source being unknown.

The 2010 West Virginia Integrated Water Quality Monitoring and Assessment Report lists three impaired streams that are on the Forest: Capon Run, Hawes Run, and Miller Run. For all of these streams, the criterion affected is biological, the source is unknown, and a TMDL is needed. For each of these, most of the stream's length is on private land, and the impairment cannot be attributed to Forest management activities.

Drinking Water

Water quality in streams is a priority on the National Forest. Since 1988, almost 6,000 water samples have been analyzed from George Washington and Jefferson National Forest streams. Some streams have been part of a long-term monitoring program and are sampled quarterly; others have had only one or two samples taken to characterize their chemical habitat. In response to concerns over the quality of water from the George Washington National Forest related to drinking water, Virginia water quality standards (State Water Control Board 2008) were compared to 5,532 water samples collected from streams on the national forest. To get a complete picture related to the public water supply water quality standards, measurements from both the George Washington and Jefferson National Forests, during all seasons, and all years were included in the analysis.

There are three chemical parameters listed in the Virginia Water Quality Standards (VA WQS) that have been sampled consistently across the Forests; they are chloride, nitrate, and sulfate. A box and whisker plot was developed for each of these parameters from the National Forest dataset; in addition, the VA WQS was shown as a horizontal bar in the charts. The top and bottom of the boxes in the plots represent the 25th and 75th percentiles (50% of all values fall within the box), the bar in the center of the box represents the median, whiskers represent the 10th and 90th percentiles (80% of all values fall within the whiskers), and closed circles represent the entire range of the data.

As seen in Charts 1-3, none of the 5,532 samples exceeded VA water quality standards for public water supply. In fact, as shown by the box, 90% of the samples are far below the water quality standard threshold.

Chart 1. Chloride measurements from 5,532 stream water samples taken on the GWJ National Forest related to the VA water quality standards for public water supply.

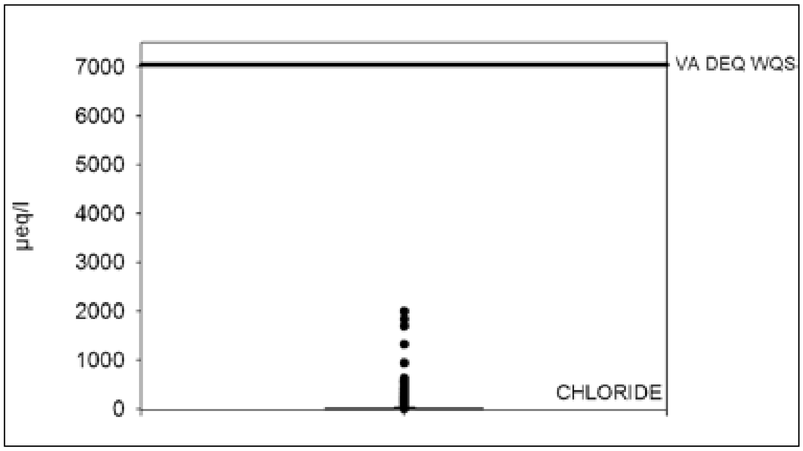


Chart 2. Nitrate measurements from 5,532 stream water samples taken on the GWJ National Forest related to the VA water quality standards for public water supply.

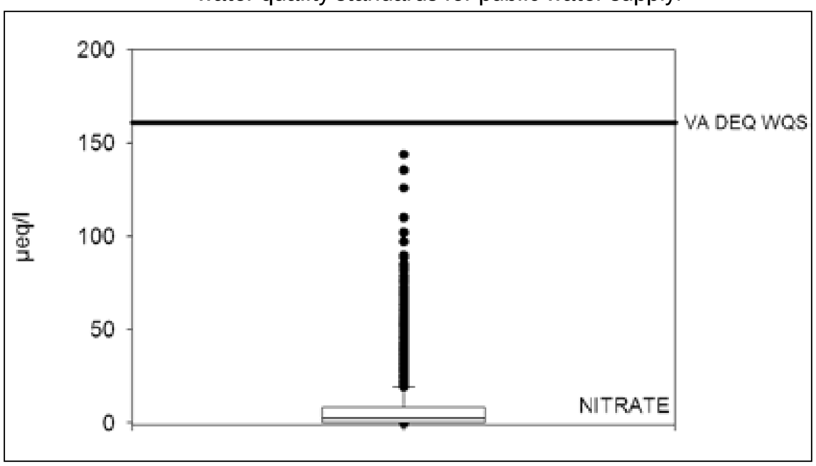
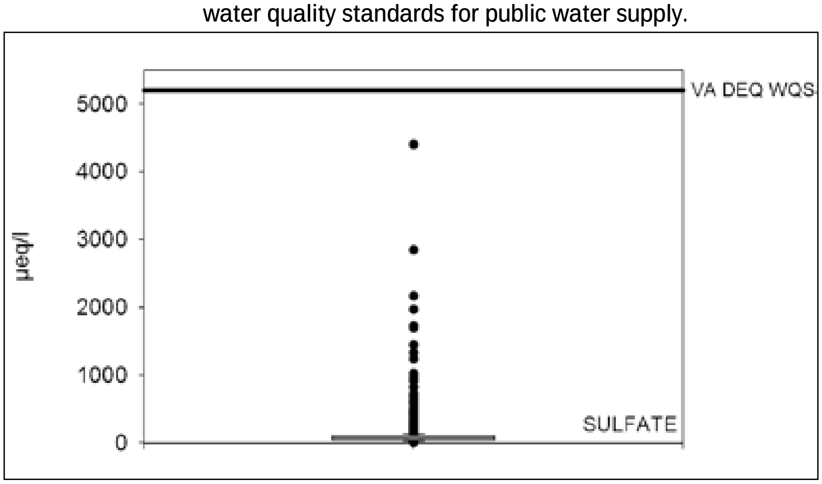


Chart 3. Sulfate measurements from 5,532 stream water samples taken on the GWJ National Forest related to the VA water quality standards for public water supply.



Reference: 2008. STATE WATER CONTROL BOARD. 9 VAC 25-260 Virginia Water Quality Standards. Statutory Authority: § 62.1-44.15 3a of the Code of Virginia. WITH AMENDMENTS EFFECTIVE October 2008

Outstanding National Resource Waters

Other streams are recognized for their high quality waters. As part of the anti-degradation provisions of Virginia water quality standards, waters which constitute an outstanding national resource or waters of exceptional recreational or ecological significance are designated as "Tier III" waters. Currently, there are 14 Virginia streams on the Forest that have been so designated: Brown Mountain Creek, Laurel Fork, North Fork of the Buffalo River, Pedlar River, Ramsey's Draft, Blue Suck Branch, Downy Branch, North Branch Simpson Creek, Roberts Creek, Shady Mountain Creek, Cove Creek, Little Cove Creek, Rocky Branch, and North River. In West Virginia, all high quality waters or naturally reproducing trout streams located within national forests are designated Tier III waters. There are 13 of these streams on the Forest: Capon Run, Lower Cove Run, Waites Run, Trout Run, Hawks Run, Lick Run, Kettle Creek, Rough Run and an unnamed tributary, Stony Run, Road Run, Hawes Run, and Little Fork.

Water Uses

Water on the George Washington National Forest is needed for recreation, wildlife, domestic livestock watering, and administrative uses by the Forest Service. Additionally, instream flow quantities and timing are necessary to maintain the capacity of the channels to transport water and sediment, for fisheries, recreation, and visuals. Water sources on the Forest and adjacent to it are utilized for individual water supplies. Individual supplies for human consumption generally come from shallow-drilled wells or springs.

About 6 billion gallons of water per year are withdrawn directly from the Forest for municipal uses. Another 6 million are withdrawn for use at Forest recreation areas and administrative sites. These uses are about 1.3 percent of the Forest's water yield. Additional water is withdrawn farther downstream.

Numerous communities withdraw drinking water from streams and reservoirs on the Forest or from rivers downstream from the Forest. The Virginian Water Quality Standards designate as Public Water Supplies the following waters that are at least partially on George Washington National Forest land:

- Coles Run from Augusta County's raw water intake to its headwaters
- Dry River from Harrisonburg's raw water intake to a point 5 miles upstream
- North River from Staunton Dam to its headwaters
- North Fork Shenandoah River and its tributaries from the Winchester raw water intake to points 5 miles upstream (to include Cedar Creek and its tributaries to their headwaters)
- North Fork Shenandoah River and its tributaries from Strasburg's raw water intake to points 5 miles upstream
- North Fork Shenandoah River and its tributaries from Woodstock's intake to points 5 miles upstream
- Pedlar River and its tributaries from Lynchburg's raw water intake (near Lynchburg Reservoir) to points 5 miles upstream
- Smith Creek and Clifton Forge Reservoir from Clifton Forge's raw water intake to their headwaters
- Jackson River and its tributaries from Covington's raw water intake to points 5 miles upstream

Five water supply reservoirs are located in the George Washington National Forest:

- Coles Run Reservoir
- Switzer Lake (located seven miles upstream from Harrisonburg's intake)
- Clifton Forge Reservoir
- Staunton Reservoir
- Lynchburg Reservoir

Additional downstream drinking water supplies were noted in comments. These have intakes on rivers in the vicinity of the Forest, and their watersheds are partially within the Forest:

- Broadway (North Fork Shenandoah River)
- Food Processors Water Cooperative Inc. (North Fork Shenandoah River)
- Front Royal (South Fork Shenandoah River)
- Harrisonburg (North River)
- Bridgewater (North River)
- Lynchburg (James River)
- Amherst (Buffalo River)
- Maury Service Authority (Maury River)

Areas upstream of all of these drinking water supplies were identified in comments, and total approximately 425,874 acres of George Washington National Forest land. In reality, the entirety of the Forest is encompassed in watersheds of rivers from which drinking water is withdrawn downstream (e.g., the James and Potomac Rivers).

Groundwater

In 2006 the Forest Service established new direction for ground water resource management, with an objective (FSM 2882.02) to: Protect, manage, and improve ground water and ground-water dependent ecosystems, recognizing their unique values, while implementing land management activities. Ground Water-dependent Ecosystems (GDEs) are communities of plants, animals, and other organisms whose extent and life processes are dependent on access to or discharge of ground water in areas such as:

- Springs, seeps and wetlands
- Ground water-fed streams/lakes and associated riparian areas
- Shallow water table areas
- Cave and karst systems

Groundwater-dependent Ecosystems relating to biological resources are discussed in biological sections of Chapter 3. This section focuses on groundwater.

The groundwater resources of the Forest vary depending on the different hydrogeologic characteristics of the physiographic provinces and associated bedrock and surficial deposits, such as alluvium and colluvium. Most of the Forest is located on the ridges in the Valley and Ridge Province, where the ridges are dominated by sandstone and shale (Devonian, Silurian, and Mississippian); limestone, such as the Helderberg group, occurs less commonly. The Forest valleys in this Province are dominated by limestone or shale (deep aquifers) overlain by alluvium (shallow aquifers). Shale and sandstone generally are poor to fair groundwater producers. The carbonates are highly variable groundwater producers but where water has dissolved the rock into underground solution channels, the carbonates are moderate-to-large groundwater producers.

In the Valley and Ridge Province, geologic structures (fold, faults, and fractures) are important influences on the occurrence of groundwater. Hinkle and Sterrett (1978) in a groundwater study of Rockingham County noted, "Anticlines (up-folds in the rock strata) may bring good water-bearing beds near the surface along their axes and bury them along the flanks (Plate 5A). Similarly, synclines (down-folds in rock beds) may bring water-bearing units near the surface on the flanks or may cause them to descend to great depths along the axis (Plate 58)."

The Forest's Pedlar District is in the Blue Ridge Province, dominated by granitic bedrock except on the western flank underlain by quartzite, sandstone, and shale. Granitic bedrock generally has small amounts of good quality groundwater available from the fractured crystalline bedrock. The quartzite and other clastic bedrock (Chilhowee Group) are poor aquifers due to cementation. Catoctin Greenstone, a basaltic lava flow, along the crest of the Blue Ridge also is a poor water producer (Hinkle and Sterrett 1978).

Surficial deposits, such as alluvium, alluvial fans, and colluvium, are found in all the Physiographic Provinces, and may serve as aquifers as well as recharge zones to underlying bedrock.

Quality of groundwater varies depending on whether the well is drilled in shale, sandstone, granite, limestone, or surficial deposits. Most of the rural population near the Forest receives water supplies from groundwater. Since most of the population is in the valleys, most of the water wells are also in the valleys. The Forest generally is located in the sparsely populated mountains. So the few drilled wells on the Forest are primarily for recreation and administrative facilities. Because the Forest occupies the mountains above the valleys, the Forest is a part of the recharge area for groundwater in valleys.

The Forest has 21 active groundwater wells supplying water to recreation sites. Groundwater withdrawals range from about 40 gallons per day to 2,000 gallons per day. The Forest also has 9 inactive groundwater wells.

The Forest has 26 active special use authorizations for groundwater wells or springs supplying water to non-federal users, a mixture of public water supply districts and private users. For example, in 2002 the Forest issued a Permit for a groundwater well to a public water supply district; for the period 2007-2009 the annual pumpage (groundwater withdrawal) ranged from 34-41 million gallons per year. In 1996 commercial use of two springs for water bottling was authorized as part of a special use permit. The use of the two springs for commercial bottling or potable water was rescinded in 2009.

Requests for groundwater wells for public water supply on the Forest are expected to continue due to several factors: 1) State restrictions on use of springs as public water supply sources, 2) recognition of stress on reservoirs, streams, or other sources during periods of drought, 3) dam safety requirements and expenses, 4) increase in population in counties near the Forest. For example, in 2009 a public water service authority requested the Forest consider exploration and development of groundwater sources.

Groundwater in Karst

The Forest's groundwater resource that is most vulnerable to contamination is groundwater in karst geologic terrain underlain by carbonate bedrock (limestone and dolomite). Caves, sinkholes, and sinking streams are examples of openings in karst terrain that provide direct access for surface water to flow directly into the ground water. In karst terrain the flow of surface water into openings into the groundwater is a natural geologic process in the formation and development of karst terrain. Karst terrain where surface waters flow into sinkholes or disappearing streams is a groundwater recharge area. Karst terrain can also be groundwater discharge areas, such as where springs are present. A karst map with more discussion about karst is in Geology section.

Karst terrain and associated groundwater is widely distributed across the Forest and occurs on every Ranger District (Geologic Map Units Containing Karst figure in Geologic Resources section). These geologic map units indicate 11% of the Forest (about 119,000 acres) with geologic formations containing karst and karst-related groundwater.

Karst groundwater systems are complex, and are even more complex when surficial deposits, such as alluvial fans, mantle the karst bedrock. A notable example is the large alluvial fan along the Coal Road in the Maple Flats area on the north end of the Pedlar District. Thick deposits of sand and gravel overlie Shady dolomite in the Maple Flats sinkhole ponds area and create a complex karst groundwater setting. Another example of a complex karst groundwater setting is the Trout Pond Recreation Area on the Lee District where alluvial deposits overlie karst bedrock.

DIRECT AND INDIRECT EFFECTS

The following discussion provides some background information regarding the environmental effects common to soil and water resources from management activities. Any activity that disturbs the land surface, decreases

cover or alters vegetation can affect soils, water yield and water quality. The primary management activities that could affect the soil resource, water yield, and water quality are:

- Roads and Trails
- Vegetation Management
- Mineral Exploration and Development
- Fire Management
- Wind Energy Development

Roads and Trails. Roads and trails can directly and indirectly affect water by increasing sedimentation and concentrating runoff. Roads and trails can expose and compact soils, alter surface and subsurface water flow, and alter stream channels during construction. When left open they can contribute to higher erosion and sedimentation rates than closed roads and trails.

Vegetation Management. Vegetation management activities that typically affect soil and water are timber harvesting and associated landing and skid trail construction. Loss of the protective soil cover (litter) from ground disturbance can increase erosion and sedimentation while decreasing soil productivity. Water yield also increases because of reduced transpiration and raindrop interception.

Mineral Exploration and Development. Mineral exploration and development can affect soil and water by increasing erosion and sedimentation, soil compaction, and water yield. In many cases soil productivity is reduced and sediment can affect water quality. The potential seepage or spillage of toxic substances from mining facilities or disposal areas may also pose a threat to water quality. Effects of oil and gas exploration and development are discussed separately in Section D of this Chapter.

Fire Management. Prescribed burning directly affects soil and water by removing a portion of the vegetative cover, which exposes soil to erosion. Control lines also expose mineral soil. These factors can reduce soil productivity and increase stream sedimentation. The magnitude of effect varies widely depending on the soils, topography and the intensity of burn.

Wind Energy Development. Development of wind energy requires clearing the turbine sites, constructing or improving roads to the sites, and constructing power transmission lines. These activities can increase erosion and sedimentation and can concentrate runoff.

There is a great deal of variability in sediment yield from year to year, which is termed "interannual variability." In part, this is because sediment yield is much greater during high runoff years with more stormflow to erode and transport sediment. Conversely, sediment yield is much less during drought years when high flows may be less than bankfull. However, interannual variability is a function of much more than the weather.

Data from the USGS gage on the Rappahannock River at Remington provides an expression of the variability of annual sediment yield. For the 42 years with flow and sediment data, each year's percent difference from the long-term mean ranges from plus 184 percent to minus 82 percent. A change of annual sediment yield of plus or minus 60 percent represents one standard deviation from the long-term mean. This value is also termed the coefficient of variation. According to Bunte and MacDonald (1999), "very few records of annual sediment yield have a coefficient of variation of less than 50%, and most values are closer to 100%." Therefore, the data from the Rappahannock provide a good but conservative estimate of the coefficient of variation for watershed systems on the George Washington National Forest. Figure 3A6-1 displays the interannual sediment variability for the Rappahannock River at Remington.

The interannual variability of sediment determines the magnitude of change that can be detected during a given time period. Bunte and MacDonald (1999) state that the number of years of monitoring needed to detect a sediment increase of "z" percent at the 95% confidence interval is given by the formula:

$$\text{Number of sampling years} = \{(1.96/\text{"z"}) \times (\text{coefficient of variation})\}^2$$

This responds to the question of whether there will be a detectable change in the sediment load of any of the rivers considered in this analysis. For example, it would take at least 556 years of monitoring data to detect a 5 percent increase in sediment in the Rappahannock River or in other rivers in Virginia. For a sediment increase to be detectable, it would have to exceed the range of interannual variability for the watershed. According to the formula, it would require four years of annual sediment data to detect an increase of 59 percent at the 95% confidence interval, and more than a year to detect an increase of 100 percent. Sediment increases would have to exceed the interannual variability before they become reasonably detectable.

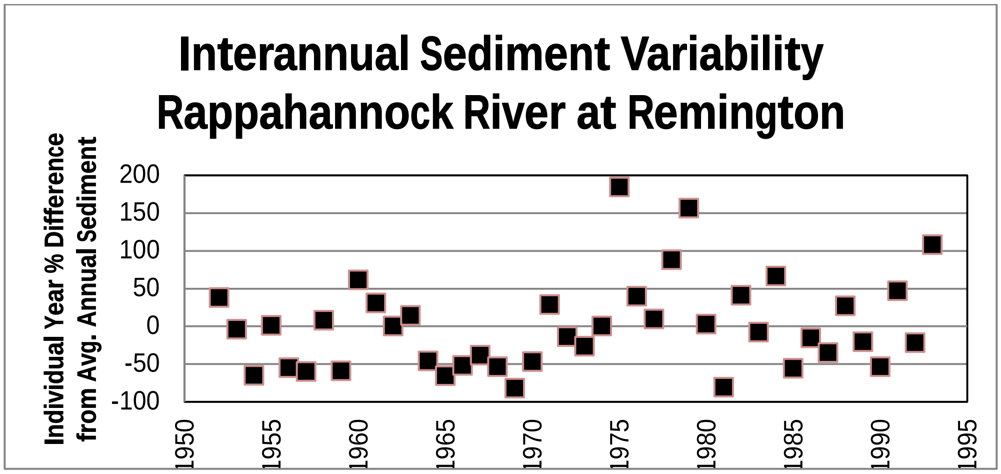


Figure 3A6-1. Interannual Sediment Variability Rappahannock River at Remington

Shorter sediment records from the James River at Buchanan and the South Fork Shenandoah River at Front Royal also show the high degree of variability in sediment yield from year to year (Table 3A6-2).

Table 3A6-2. Annual Sediment (tons), James River and South Fork Shenandoah River

River	1952	1953	1954	1955	1956
James River	198,056	214,575	157,450	378,870	41,028
South Fk Shenandoah			77,129	591,805	4,871

There are many difficulties associated with modeling sediment. Even the best of models have many limitations, and numerous assumptions must be made. The results will be, at best, within plus or minus 50% of the true value.

In view of the high interannual variability of sediment and the difficulty in accurately modeling sediment production, sediment, as such, will not be used as a measure of effects. Rather, acres of disturbance are used as a measure to indicate the relative effects of the alternatives on sediment and water quality (Table 3A6-3). Table 3A6-3 is based on prescribed fire levels of 3,000 acres in Alternative A, 7,400 acres in Alternative A^1, 12,000 acres and 5,000 acres in Alternative D, and 20,000 acres in Alternatives B, E, F, G, H and I. Timber harvest levels are based on levels generated by the Spectrum model and are 2,400 acres in Alternative A, 700 acres in Alternative A^1, 3,000 acres in Alternative B, 0 acres in Alternative C, 4,258 acres in Alternative D, 1,800 acres in Alternative E, 1,000 acres in Alternative F, and 3,000 acres in Alternatives G, H and I.

Table 3A6-3 Acres of Soil Disturbance by Alternative

Alt A	Alt A^1	Alt B	Alt C	Alt D	Alt E	Alt F	Alt G	Alts H and I
182	72	178 – 262	66	276 – 413	175 – 254	138 – 200	183 - 267	183 - 267

A^1 represents the actual implementation level of the 1993 Revised GWNF Plan

Drinking Water

Alternative A specifies wider riparian areas when they are adjacent to or within one mile upstream of municipal water supply reservoirs.

In Alternatives B, D, E, F, G, H and I Public Water Supplies are identified. Public Water Supply watersheds are included among those watersheds that are a priority for restoration.

In Alternative C, management areas are assigned for drinking water watersheds as identified in comments. Drinking water watersheds are included among those watersheds that are priority for restoration.

In project implementation, the application of standards for the riparian management prescription and channeled ephemeral stream standards should fully protect drinking water quality. No measureable direct or indirect effects on water quality should occur. In order to verify that these standards are adequate, some ground disturbing projects will be monitored for implementation of standards and for effectiveness of standards.

Aquatic macroinvertebrates integrate the physical, chemical, and biological components of aquatic systems and have been successfully used as biological indicators of change and impacts. Aquatic macroinvertebrate monitoring is being used as an effective surrogate for monitoring sediment and other water quality parameters, thus providing an indication of the effectiveness of standards. A Macroinvertebrate Aggregated Index for Streams (MAIS) (range of scores 0-18) incorporates nine ecological aspects (metrics) of the aquatic macroinvertebrate community to evaluate the current condition of a stream relative to others within that ecological section (see the Aquatic Species Diversity section in this chapter). Pre-harvest MAIS scores were compared with post-harvest MAIS scores for 18 streams located below timber harvests at various locations across the Forest. There was no significant difference between the pre- and post-harvest MAIS score (USDA Forest Service, 2004).

Groundwater

Management activities that involve ground disturbance, such as construction of roads and developed recreation facilities, have the potential to adversely affect groundwater, particularly in karst geologic areas. All the alternatives have Forest Plan standards to protect the Forest's groundwater, including groundwater-dependent ecosystems. The Forest Plan standards to protect groundwater are in various sections of the Forest Plan, including Geologic Resources, Geologic Hazards, Water, Soil, and Caves. Standards under all alternatives provide that the location and design of management activities will evaluate measures to avoid, minimize, or mitigate adverse effects on geologic resources such as groundwater and groundwater dependent ecosystems.

Under all Alternatives, those management prescriptions that severely restrict or prohibit ground disturbing activity also protect groundwater located in those management prescription areas, for example, Wilderness, Recommended Wilderness Study Area, National Scenic Areas, Special Biological Areas, and Remote Backcountry Non-Motorized areas. Also, the measures addressing Terrestrial Viability Evaluation under all alternatives also protect groundwater indirectly because groundwater is part of ecosystem or protected habitat in such areas as Alkaline and Mafic Glade and Barrens; Cliff, Talus and Shale Barrens; Floodplains, Wetlands and Riparian; and Cave and Karstlands.

Each Alternative also has a Geologic Area management prescription (4C1) which highlights and provides addition protection for geologic resources. Under the current Plan (Alternative A), the Forest has designated two Geologic Areas (176 acres total): Devils Garden on the Lee Ranger District and Rainbow Rocks on the James River Ranger District. These two Geologic Areas (176 acres total) also would be designated in Alternatives B, C, D, E, F, G, H and I. Alternative E, G, H and I would add more Geologic Special Interest Areas in karst and karst groundwater areas. The Virginia Department of Conservation and Recreation, Natural Heritage Program, identified 19 cave and surrounding conservation areas on the Forest. Two sites are within Special Biological Areas, two are within Indiana bat protection areas, and one is in Wilderness, leaving about 3,700 acres outside of these protected areas. Alternatives E, G, H and I would allocate 14 cave and surrounding

conservation areas (about 3,700 acres total) to Management Prescription 4C1 - Geologic Areas, and thus increase protection of karst groundwater areas.

Karst groundwater areas are widely distributed across the Forest on every District. Potential road construction miles, reflecting ground-disturbing activities associated with management activities will be used as an indicator of potential impact on groundwater. Using this indicator, Alternative C has the lowest potential and Alternative D has the highest potential for impact on groundwater; Alternatives F, B, E, G, H, I, and A have intermediate levels of potential impact.

The potential groundwater withdrawals for Forest use (primarily for developed recreation sites) and/or for authorizations for non-federal groundwater use varies by alternative. Alternative C has the lowest potential and Alternative A has the highest potential for groundwater withdrawals; Alternatives F, D, B, E, G, H and I have intermediate levels of potential for groundwater withdrawals.

CUMULATIVE EFFECTS

Cumulative effects address the environmental consequences from activities implemented or projected within the watersheds in the past, present and reasonably foreseeable future. The combination of activities on NFS, state and private lands can create an effect at a watershed scale that otherwise would not be perceived as a problem at the project or sub-watershed scale. In addition to their natural variability, watersheds differ by their management history, ownership patterns, and the types and levels of contemporary management activity. The combination of natural variables, ownership patterns and management activities contribute to the cumulative effects on water quality within the analysis area. Given the variability in watershed conditions, both natural and management related, the discussion of cumulative effects will be general in nature.

Current water quality in the analysis area is a reflection of the cumulative effects of past and present actions. Future activities can contribute to these effects or alleviate some of the problems. On NFS lands, the reasonably foreseeable future actions are considered to be the continuation of existing programs such as timber management, roads, developed and dispersed recreation, gas and mineral development, grazing allotments, special uses, and other activities. On a broad scale, the effects of future management on NFS lands may result in some localized effects, but overall should not contribute to any measurable downstream impacts. This is due in part to Forest Plan direction for the protection of soil, water, and riparian resources, the continued natural recovery of watershed conditions across the Forest, and the implementation of watershed restoration projects. The level of potential harvest, and its distribution across watersheds, should not result in any measureable water quality effects at the watershed scale. Opportunities also exist to improve watershed conditions.

One concern is that future ground-disturbing activities have the potential to contribute to existing sediment sources, primarily associated with the Forestwide transportation system. Roads continue to be a chronic source of sediment and additional inputs may be detrimental to water quality. The recovery of disturbed soils can be relatively quick, which reduces the erosion potential following the disturbance. But sediment that enters a channel can remain in the system for years, even decades, depending on the level of inputs and channel characteristics. Potential new sources could be off-set, in part or wholly, by correcting existing problems and reducing current inputs.

The influence of NFS land on cumulative effects for waters draining the analysis area largely depends on the level of ownership. NFS lands are typically located in the higher elevations and headwaters, and the influence of state and private lands increases going downstream. In watersheds where NFS lands are limited, the influence of state and private activities is greater.

Water quality is affected by activities on state and private lands, including roads, rural and agricultural developments, logging, mining, and housing developments. State and local Watershed Improvement Plans developed to meet pollution limits for the Chesapeake Bay have the potential to reduce pollutants (nutrients and sediment).

Implementation of Forestwide standards would minimize the potential effects of land management activities on NFS lands and the Forest's potential contribution to cumulative effects. The existing transportation system continues to affect water quality, and foreseeable actions that improve road-related problems can reduce the potential effects and the contribution to cumulative effects. Foreseeable harvest activities have the potential to contribute to sedimentation and cumulative effects associated with conventional logging and road-related impacts. Future harvest activities also provide an opportunity to correct or reduce existing road-related problems and sediment source. Alternative C has the lowest potential for ground-disturbing activities associated with management activities, followed by Alternatives F, A, E, B, G, H, I and D.

One indicator of the potential cumulative effects on groundwater is the amount of past, present, and future management activity in karst, the geologic areas most sensitive to groundwater impacts. The amount of roads is an indicator of the amount of ground-disturbing management activity. The Forest has about 1,800 miles of Forest Service System roads, of which about 281 miles are within the 11% of the Forest with geologic formations containing karst. Alternative C would not construct any system road, and would not add to existing cumulative impacts. Alternatives A, B, D, E, F, G, H and I would add small increments to the existing 1,800 miles of Forest Service System roads, and small increments to the 281 miles within the 11% of the Forest with geologic formations containing karst and karst-related groundwater. Alternatives E, G, H and I would designate 14 cave and surrounding conservation areas (about 3,700 acres total) as Geologic Special Interest Areas, and thus increase protection of karst groundwater areas.