APPALACHIAN POWER COMPANY

ROANOKE, VIRGINIA

SMITH MOUNTAIN PROJECT No. 2210

SMITH MOUNTAIN PROJECT SEDIMENTATION STUDY REPORT - REVISION 2 -

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SMITH MOUNTAIN PROJECT SEDIMENTATION STUDY REPORT – REVISION 2

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PREFACE TO REVISION 2

This is the second revision of the Smith Mountain Lake Sedimentation Study Report for the relicensing of the Smith Mountain Hydroelectric Project, FERC Project# 2210. The purpose of this revision is to incorporate and address comments received from stakeholders regarding the study and first revision, dated January, 2007. The comments and feedback from stakeholders were obtained during a series of working group and study report meetings. These meetings are summarized below with minutes available via the FERC e-filing library, www.ferc.gov, or on the project website, www.smithmtn.com.

Smith Mountain Lake Sedimentation Study Update Meeting, September 27, 2006, Hardy, VA

The first Sedimentation Study Update meeting was conducted September 27, in Moneta, VA. During this meeting, a presentation on study progress, current findings, future work efforts to be conducted, compliance with the Objectives and Methods in the Sedimentation Study document, and anticipated project completion dates was made to stakeholders, representatives of the FERC, and the general public. Comments and requests for study changes were received from the FERC and stakeholders. Feedback to comments was provided by APC, agreement to accept certain comments was made, and both filed with the FERC. The agreed upon comments and changes were incorporated into the first revision of the Sedimentation Study Project Report. The FERC published its findings on comments as the "Determination of requests for modifications to existing studies" on January 10th, 2007. The FERC concluded that no modifications to the Sedimentation Study scope were necessary as the study was being conducted in accordance with the Sedimentation Study Plan, specifically;

- Request for coring of sediments failed to provide legitimate reason that coring be conducted and, even if coring were conducted, it would not add benefit to the study,
- Request for measures of remediation for sediment input to the reservoirs failed to recognize these were in the report.

Smith Mountain Lake Draft Sedimentation Study Report and Working Group Meeting, March 21, 2007, Rocky Mount, VA

The purpose of this meeting was to present the first revision of the Sedimentation Study Report to stakeholders. The first revision of the report had been distributed to stakeholders in February and they were given opportunity to provide comments and feedback. Additional copies of the report were brought to the meeting and freely distributed. This meeting focused on presentation of study methods, findings, and the drafting of the report. Few additional comments and feedback were received from stakeholders. The meeting announcement and minutes are filed with the FERC.

Smith Mountain Lake Sedimentation Study Report Update and Working Group Meeting, April 25, 2007

The purposes of this meeting were to provide an opportunity for additional feedback from stakeholders, to obtain clarification on stakeholder comments, to respond to written comments filed with the FERC, and to present changes and revisions that had been made to the report in response to the March meeting. A number of discussions were held with stakeholders and APC received requests and suggestions for additional report edits.

Smith Mountain Lake Sedimentation Study Working Group Meeting, July 19, 2007, Rocky Mount, VA

The purpose of the meeting was to review the bathymetric information that has been collected for the Smith Mountain and Leesville reservoirs and to become more familiar with the information that is available on GIS. An inquiry was made to APC regarding the feasibility of determining the thickness of sediment deposits in the reservoirs.

Formal Comments for the Smith Mountain Lake Sedimentation Study Filed with the FERC

In addition to feedback and comments received at these meeting, comments from stakeholders that were filed with the FERC, received by APC, and agreed to have project nexus have been incorporated into this revision of the report. Formal comments were received from the Virginia Department of Game and Inland Fisheries, the Federal Energy Regulatory Committee, the Smith Mountain Lake Association, and the Tri-County Relicensing Committee. No changes have been made to address comments that were addressed previously or ruled outside of project nexus by the FERC in their “Determination on requests for modifications to existing studies”, dated January 10, 2007.

Summary of Edits Incorporated into the Second Revision

The following specific edits have been incorporated into this revision in response to comments. General comments, minor edits, and grammatical changes have been addressed throughout the report but, are not specifically noted below.

1. Directly addressed Objectives 1 and 3. Have added clarification, significant text and referenced other studies to satisfy this request,
2. Updated Executive Summary to reflect revisions,
3. Enlarge main watershed figure to improve readability and clarity (Figure 68),
4. Add index map identifying specific areas of concern for sedimentation as noted by stakeholders (Figure 14),
5. Develop estimates and maps illustrating thickness of sediment deposits in coves, tributaries, and bays of concern including; Beaverdam Creek, Becky's Creek, Betty's Creek, Big Indian Creek, Blackwater Creek, Gills Creek, Little Indian Creek, Lynville Creek, Pigg River, Roanoke River (river mouth, through public boat landing and marina, to downstream near railroad bridge), and Staniford Creek (numerous Figures created),
6. Write methods for above (see Estimated Changes in Project Bathymetry, Page 27)
7. Increase size of shoaling maps from 8.5x11 to 11x17 (numerous Figures updated),
8. Shoaling maps modified to include photographs and site locations to illustrate areas where sedimentation has been particularly problematic (numerous Figures updated),
9. Revise sedimentation figure to show erosion hot-spots (t/ha) (Figure 68),
10. Reanalyze sediment yield data and update table (Table 5) with results from figure, above,

11. Revise storage volume curves (Figure 2 and Figure 3),
12. Add text to mitigation section regarding stabilization of shoals and sedimentation areas to provide habitat, reduce disturbance and resuspension, and reduce turbidity (comment from VDGIF),
13. Construct 3 figures showing changes in sediment sources from pre-settlement, 1992, and 2001, and erosion hot-spots (Figure 69 - Figure 68),
14. Additional analyses of storage/volume and bathymetric data conducted to identify the contribution of shoreline erosion to sedimentation in the reservoirs (Figure 44 and Figure 45),
15. Clarify language describing "cove" areas and what constituted "shoaling" in areas of sedimentation,
16. Numerous minor comments regarding text in report, and
17. Develop two page "fact-sheet" summarizing study report in "lay" terms – this task is currently underway and technically beyond the scope of this study. The "fact-sheet" will be made available to stakeholders via the project website.

EXECUTIVE SUMMARY

This report summarizes the results of the Smith Mountain Project Sedimentation Study. The study was conducted to meet the integrated relicensing process requirements for Appalachian Power Company (APC), Smith Mountain Project, FERC no. 2210. These requirements are summarized in the Smith Mountain Project Sedimentation Study Proposal (AEP, 2005) and the Project Pre-Application Document (PAD) (AEP, 2004a, 2004b). The purpose of the Smith Mountain Project Sedimentation Study was to satisfy the objectives raised during the Smith Mountain Project Integrated Licensing Process. The Sedimentation Study objectives are:

Objective 1. Update the storage volume curves for the Smith Mountain and Leesville Developments.

Objective 2. Determine those areas where sediment accumulation may be most prevalent.

Objective 3. Identify the extent of problems associated with the accumulation of sediments within the project reservoirs, including impacts on recreation, the fisheries, and other project features.

Objective 4. Determine the rate of sediment accumulation over time of the existing license.

Objective 5. Identify the sources of sediments discharging into the reservoirs.

Objective 6. Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

While the physical sedimentation impacts component of Objective 3 are also addressed by this report, impacts to ecological, recreation, and other resources are addressed in the *Recreation and Angler Use Study*, *Native and Exotic Aquatic Vegetation Study, Littoral Zone Habitat Study*, *Fish Spawning and Rearing Assessment Study, Water Quality Study*, *Debris Study,* and the *Navigational Aids Study.* The results of all of these studies will be consolidated in the License Application and Environmental Assessment documents to provide for the most comprehensive and holistic treatment of sedimentation impacts on the project reservoirs and amenities.

A combined approach including literature review, stakeholder meetings and interviews, field reconnaissance and survey, watershed sedimentation modeling, and reservoir bathymetric analyses was used to satisfy the objectives in this report. The key findings of these efforts are:

Objective 1: Update the storage volume curves for the Smith Mountain and Leesville developments,

- The storage volume curves were updated.

Objective 2: Determine those areas where sediment accumulation may be most prevalent,

- Storage volume has decreased 6% and 11% in Smith Mountain and Leesville Lakes, respectively.
- While sedimentation occurs throughout the vast majority of Smith Mountain Lake, it is most pronounced in bays, coves, and tributary inlets where deposits frequently exceed 10 feet of depth.
- Sediments in bays, coves, and inlets of Smith Mountain and Leesville Lakes are a mixture of coarser sand and gravel from upstream channel sources, fine sediments from upland soil erosion, and organic matter deposits from terrestrial and aquatic sources. The majority of mineral sediments are in the silt or larger size fractions with clays being deposited in the more quiescent waters of Smith Mountain Lake.
- A relatively thin veneer of fine sediment, ranging from ½ to 3 feet, exists throughout Smith Mountain Lake.
- Sedimentation in Leesville Lake occurs primarily as dynamic storage of fine to medium grained sand dunes in bed form deposits. The sands are introduced from the Pigg River and move downstream during project generation. Transport of sand may occur by suspension and/or bed load movement.
- The vast majority of sedimentation occurs beneath the minimum operational pool limit of the reservoirs.
- Historical shoreline erosion accounts for approximately 35% and 50% of observed sedimentation (as reductions in reservoir storage capacity) in Smith Mountain and Leesville Lakes, respectively. These numbers represent historical averages and are not

representative of current or future conditions as past shoreline erosion, shoreline stabilization and management efforts have greatly reduced shoreline erodibility.

- Sedimentation from shoreline erosion in Smith Mountain Lake is concentrated around the reservoir margin with little extension into the body of the reservoir as compared to sedimentation from tributary sources such as the Roanoke River and Blackwater Creek.

Objective 3: Identify the extent of problems associated with the accumulation of sediments within the project reservoirs, including impacts on recreation, the fisheries, and other project features.

- The temporal and spatial nature of sedimentation within the project reservoirs have been identified in this study. The relative amounts and locations of sedimentation areas that will affect other resources have been identified. The amount of sedimentation in specific coves has been estimated and mapped.
- The most severe sedimentation has occurred in bays, coves, and inlets where sediment laden tributaries deposit there sediment loads upon reaching the quiescent reservoirs,
- Specific areas of concern for sedimentation and shoaling include Beaverdam Creek, Becky's Creek, Betty's Creek, Big Indian Creek, Blackwater Creek, Gills Creek, Little Indian Creek, Lynville Creek, Pigg River, Roanoke River (river mouth, through public boat landing and marina, to downstream near railroad bridge), and Staniford Creek,
- The impacts of identified sedimentation on recreation are being determined by the *Recreation and Angler Use Study, Littoral Zone Habitat Study, Fish Spawning and Rearing Assessment Study,* and the *Navigational Aids Study.*
- The impacts of identified sedimentation on fisheries are being determined by the *Recreation and Angler Use Study, Littoral Zone Habitat Study,* and the *Fish Spawning and Rearing Assessment Study.*
- The impacts of identified sedimentation on other project features, specifically areas subject to coverage by sedimentation are addressed in Objectives 2 and 4. Remaining impacts on project features are being addressed in the *Littoral Zone Habitat Study, Water Quality Study, Debris Study* and *Navigational Aids Study.*

- The combined impacts of sedimentation on project amenities and resources will be comprehensively summarized in the License Application and Environmental Assessment documents.

Objective 4: Determine the rate of sediment accumulation over time of the existing license.

- Sedimentation in Smith Mountain Lake has occurred at an average rate of 1,650 acre-feet per year. Conceptually, this would be equivalent to a uniform sedimentation depth of 0.96 inches across the reservoir,
- Sedimentation in Leesville Lake has occurred at an average rate of 260 acre-feet per year. Conceptually, this would be equivalent to a uniform sedimentation depth of 0.95 inches across the reservoir. The similarity to Smith Mountain Lake is purely coincidental.

Objective 5: Identify the sources of sediments discharging into the reservoirs.

- Historically, shoreline erosion was the source of a significant amount of sedimentation in Smith Mountain and Leesville Lakes.
- By far, the single largest source of contemporary sediment to Smith Mountain and Leesville Lakes is soil erosion from watershed disturbances. Current sedimentation rates are many times higher than background, or natural, rates predicted for pre-settlement conditions.
- Current sediment yields from the most disturbed watersheds are 10 to over 100 times higher than background,
- Large tracts of forest land with very low sediment yield mask “hot-spots” of sediment yield from land disturbing activities.

Objective 6: Investigate methods and/or programs to reduce the introduction of sediments into and/or the amounts of sediments in the project reservoirs.

- Methods stipulated in current soil erosion and sediment control ordinances can greatly reduce soil erosion and sedimentation.
- A lack of implementation, improper implementation, and design limitations result in significant amounts of sedimentation from disturbed agricultural, developed, and timber lands.

- Anticipated rates of future watershed development were predicted to dramatically increase reservoir sedimentation rates. The impacts would be most pronounced in coves and inlets where existing shoals were predicted to expand in breadth and depth.
- On a site-by-site basis, proper implementation and strict adherence to existing ordinances will greatly reduce current rates of sedimentation.
- In areas subject to sedimentation, it is recommended they be considered as locations for potential stabilization with wetland vegetation and bio-engineering methods. These areas can provide spawning, rearing, and critical habitat landscapes for numerous aquatic and terrestrial species.
- Efforts to mitigate existing sediment problems within Smith Mountain and Leesville Lakes by dredging are discouraged as watershed sediment sources to the most problematic areas have only increased over the past ten years.
- The identification of specific areas for dredging was beyond the scope of this study. If dredging is to be considered, a thorough review of how dredging may potentially impact all project amenities should be conducted. Prior to conducting a dredging review, consultation must be made with appropriate state and federal authorities to insure compliance with water quality, threatened and endangered species, wetland protection, or other relevant regulations.

In summary, accelerated sedimentation of Smith Mountain and Leesville Lakes is predominately caused by watershed disturbing activities. While shoreline erosion did account for a significant amount of past sedimentation, current sedimentation rates are far higher than natural conditions, and are attributed to upland disturbing activities. The rates of watershed sedimentation have increased over the past ten years with increased development pressure and are predicted to increase further with additional development. The overall current trend in sedimentation is predicted to increase with shoaling and subaqueous sedimentation spreading further into coves and deeper into the reservoirs. Proper implementation and enforcement of existing soil conservation practices will produce a significant reduction in future sediment yields and greatly slow reservoir sedimentation rates. More stringent development ordinances that reduce soil exposure, increase BMP design limits, reduce impervious surfaces, and disconnect runoff from developments into the natural drainage network would provide even greater benefits.

INTRODUCTION

This report describes the methodologies and results of the sedimentation study for Smith Mountain and Leesville Lakes (Figure 1). This study was conducted to meet the integrated relicensing process requirements for the Smith Mountain Project, FERC no. 2210 (The Project). These requirements are summarized in the Smith Mountain Project Sedimentation Study Proposal (Appendix I; AEP, 2005) and the Project Pre-Application Document (PAD) (AEP, 2004a, 2004b). The general purpose of the sedimentation study was to determine the sources and fates of eroded sediments in the project watershed and how resultant sedimentation would affect Project reservoirs, amenities, and longevity. The fate of eroded sediments, whether it be deposition on land, in floodplains, or within the project, was determined. Sediment deposition within Smith Mountain and Leesville Lakes was quantified and methods of reducing future sedimentation and their effectiveness were reviewed.

PROJECT RELEVANCE

Sedimentation accumulation within the project reservoirs can have a significant impact on recreational uses, shoreline development, and project generation. Identification of where sediment accumulation may be most pronounced will provide information relative to the development of potential control measures, if needed.

SMITH MOUNTAIN PROJECT SEDIMENTATION STUDY DESCRIPTION

The goal of the Study was to meet the needs of Appalachian Power, the FERC, and community stakeholders as identified in the Study document and the Smith Mountain Project PAD. The six study objectives are:

Objective 1. Update the storage volume curves for the Smith Mountain and Leesville Developments.

Objective 2. Determine those areas where sediment accumulation may be most prevalent.

Objective 3. Identify the extent of problems associated with the accumulation of sediments within the project reservoirs, including impacts on recreation, the fisheries, and other project features.

Objective 4. Determine the rate of sediment accumulation over time of the existing license.

Objective 5. Identify the sources of sediments discharging into the reservoirs.

Objective 6. Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

LITERATURE REVIEW

A comprehensive literature review was performed for this study to gather the background and supporting information necessary for gathering data, conducting analyses, and interpreting results to meet the study objectives. All reviewed literature is reported in the Cited Literature or Reviewed Literature sections of this report. Cited Literature are sources integral to this study and are cited by author and date within the body of the report. Reviewed Literature are sources that provided limited background and supporting information. These are provided as additional sources of information for the reader. Results of the literature review are incorporated throughout the report.

Background Reports

Prior to commencing the field work and scientific components of the study, background reports relevant to the lakes, rivers and tributaries of the Project Study region were obtained from a variety of sources. The majority of these were obtained from APC, State Agencies, and Federal Government Agencies and include project reports, Total Maximum Daily Load (TMDL) documents, water quality and fisheries reports, water supply studies, land use change reports, and soil surveys.

Relevant Watershed Erosion and Reservoir Sedimentation Studies

A review of existing scientific literature relevant to sedimentation processes and the relicensing of Smith Mountain and Leesville hydropower facilities was conducted. This included journal articles, technical papers from federal agencies, and manuscripts from scientific conferences.

Digital Data

Relevant digital data and supporting documentation necessary for the completion of the sedimentation study were obtained from a variety of sources. These have been summarized in the Methods section of the report.

Sediment Control Regulations

Standards and regulations governing the selection, design, implementation, and maintenance of soil conservation and sediment control measures are mandated by the Commonwealth of Virginia in the Virginia Erosion and Sediment Control Law, Regulations, and Certification Regulations (VESCL&R). These regulations will be fully discussed in context with reviewed sedimentation remediation measures.

Background Information

Given the inherent scale and complexity of the Project, there is a wealth of background information that is relevant to the sedimentation study. Rather than repeating the immense volume of this information here, the reader is directed to the Smith Mountain Project Sedimentation Study Plan (Appendix I, AEP, 2005) and the Smith Mountain Project Relicensing Pre-Application Document, Volume 1 (AEP, 2004a). Where necessary, specific information regarding physical setting and Project characteristics are included for the reader.

STUDY METHODS

OBJECTIVE 1: UPDATE THE STORAGE VOLUME CURVES FOR THE SMITH MOUNTAIN AND LEESVILLE DEVELOPMENTS

Existing Physical Data

High resolution digital bathymetry data were obtained from AEP. The data were gathered with a multi-beam side scanning sonar during reservoir surveys conducted in 2005. The data were processed and underwent rigorous quality assurance and quality control (QA/QC) protocols during early 2006 before being used for analytical purposes. These data were provided in xyz grid cell format with a horizontal grid spacing of approximately 10 feet. High resolution, color aerial photographs were obtained from the USDA Farm Service Agency. These images had a spatial resolution of 1 meter and were flown in October, 2005. Historical storage volume data tables were also obtained from AEP. These provided tabular summaries and graphs of reservoir area and storage capacity at various pool elevations.

Historical Storage Volume Curves

The historical storage volume data were originally developed in 1964 when the Project was constructed by using a “dot-grid” method to estimate the hypothetical surface area of the reservoirs at different pool levels (AEP, 2004a). In this approach, a grid sampling protocol was used to measure the area at various elevations. Typical error estimates from grid sampling are on the order of + or – 3% of true area and errors are random when proper techniques are employed. Corresponding elevations were obtained from contour intervals on topographic maps. These intervals were typically on the order of 20 to 40 feet in the central Appalachians. The contour intervals were drawn using a process known as Stereo Imagery Interpretation. In this method, overlapping pairs of aerial photographs were mated on a zoom-transfer stereoscope. This allowed the user to observe a simulated three dimensional aerial image on a map, as if flying over the region. Hundreds, or even thousands of ground surveyed elevation points (control points) were then plotted to establish elevation control on the maps. These points, combined with the simulated three dimensional image, were used by the photographic interpreter to draw contour intervals. While this method was subject to error, it was actually quite accurate when performed by an experienced technician and is still in use today (Lillesand and Kiefer, 1994). The United States Geological Survey maintains a regular quality assurance program in which they randomly sample at least 10% of all maps and check the horizontal and vertical accuracy. At least 90% of checked features must meet mapping standards or the maps are rejected. Since this protocol was established in 1941, fewer than 3% of maps have been found to deviate from the standards (U.S.G.S, 1999). For maps in the Smith Mountain Lake region, vertical accuracy standards for contour elevations dictate at least 90% of sampled intervals are within 10 feet of the true elevation. This protocol controls error such that, error terms are random and thus unbiased; any positive error terms would be balanced by negative error terms. For the current project, we illustrated the maximum acceptable error for the elevation contours (10 feet) to create uncertainty intervals for the historical storage volume curves. These data and uncertainty bars were plotted in a spreadsheet using 10 foot contour intervals that extended from the bottom of the reservoirs to the upper limit of the operating pool range. Additional contour intervals were computed at higher vertical resolution over the operating pool range to facilitate interpretation of storage capacity in the dynamic pool elevations of the reservoirs (Tables 1, 2). The results were plotted as the historical storage volume curves (Figure 2, Figure 3).

Current Storage Volume Curves

A comprehensive project GIS was built from the updated bathymetry and imagery data. The updated bathymetry data were used to create a three dimensional (3D) model of Smith Mountain and Leesville Lakes. Under normal conditions, the bathymetric data have a vertical accuracy of + or – ½ foot, or 0.7% (OSI, 2006). However, error terms could have been significantly higher in regions where biodegradation of organic material produce trapped bubbles of carbon dioxide in organic reservoir sediments. In such situations, error terms would be on the order of 1% to 2%, or data may be unavailable. While these conditions are quite limited in spatial extent, they are most likely to occur in cove areas where watershed runoff enters shallow and still waters. It is in these areas where the vast majority of Project sedimentation has been reported to occur.

The 3D Project model was brought into ARCGIS Spatial Analyst and 3D Analyst (ESRI, www.esri.com). These were then used to create horizontal, two dimensional planes that were sliced into the Project reservoirs at various elevations (Figure 4). The surface area of the planes were computed. The computational accuracy was a function of grid cell spacing. For this project, grid centers were nominally spaced on 10 foot intervals which, when compared to the surface area of the planes, was negligible (< 1/100th %). The elevation at which the planes were sliced corresponded to those used for the historical storage capacity curves. The surface areas were integrated across respective elevation changes from the bottom of each reservoir to the elevation planes to determine the respective storage volume beneath each plane. The elevation and storage volume data were plotted as current storage volume curves along with respective error terms (Figure 2, Figure 3).

OBJECTIVE 2: DETERMINE THOSE AREAS WHERE SEDIMENT ACCUMULATION MAY BE MOST PREVALENT.

Literature Review

A review of literature relevant to reservoir sedimentation in the central Appalachian Mountain Valley and Ridge physiographic region was conducted. Reviewed literature included peer-reviewed publications, federal and state agency reports, public documents from the Project re-licensing process, information from AEP, media reports, and public input during the integrated licensing process. The most pertinent results of the literature review served to identify the cove areas of Smith Mountain and Leesville Lakes subject to visual sedimentation (AEP, 2005; AEP, 2004a). The most problematic areas commonly mentioned were (in no particular order) Big Indian Creek, Little Indian Creek, Grimes Creek, Lynville Creek, Blackwater Creek, the mouth of the Roanoke River, the mouth of Pigg River, Gills Creek, Staniford Creek, Beaverdam Creek, Becky's Creek, and Betty's Creek. These are illustrated in the results section.

Data Analyses

The present day storage volume curves were subtracted from the historical storage volume curves to estimate the change in reservoir volume over time (Tables 1, 2). These values were then plotted along with the storage volume curves to illustrate elevations within the reservoir where storage changes had occurred (Figure 2, Figure 3).

The above results, combined with the sub-bottom sediment profiling data (OSI, 2006) were used to determine the relevant contributions of the two primary project sedimentation sources; sediment transported to the project via tributary streams and shoreline erosion adjacent to the project. The changes in the storage capacity of Smith Mountain and Leesville Lakes is a function of elevation in each reservoir. Inundation of hill slopes with relatively linear profiles leads to a “natural” erosion process where the new lake shoreline profile takes on an “S” shape. This erosion process is modulated by lake level fluctuation related to peaking/ponding operations, but is usually not exacerbated (depending on the soil type and groundwater conditions) and sometimes the total lateral retreat rate is actually less for a wider range of fluctuations (by distributing the erosion over a larger vertical range). Without shore protection the shoreline retreat and “elongation” of the “S” shape will continue until a stable form is reached. Figure 5 provides a schematic of natural shoreline development in a reservoir moving towards the “S” shape profile. For Smith Mountain and Leesville Lakes, shorelines were eroded above the lower pool limit, creating a near vertical retreating beach face(see Smith Mountain Lake Erosion Study Report for a full description). The eroded sediments were deposited below the lower pool limit, forming the newly developing beach and littoral zone (near shore, shallow-water bench). The volume of eroded shoreline was estimated from the change in storage capacity curves; this same volume of sediment was then deposited within the project and represents the contribution of historical shoreline erosion to project sedimentation. The vertical distribution of these sediments was estimated from the storage volume curves while the spatial extent was determined from the sub-bottom sediment profiling study (OSI, 2006).

Reservoir Shoaling

Maps of potential areas subject to shoaling were also generated using ARCGIS software. Elevation planes representing the minimum, normal, and maximum reservoir operating levels were created from historical pool elevation data. These were 800 feet, 795 feet, 793 feet and 620 feet, 613 feet and 612 feet for Smith Mountain and Leesville Lakes, respectively. These planes were then superimposed on the reservoir bathymetry models to illustrate the exposure of sediments at the reservoir margins. These were used to create tiles of “shoaling maps” for Smith Mountain and Leesville Lakes to highlight the areas of each reservoir were shoaling would be anticipated during lower operating pool conditions. Additional shoaling with even lower water levels (e.g. during drought conditions) can also be inferred from the shoaling maps.

Subaqueous Sedimentation

For the vast majority of reservoir lake bed, the bathymetric data were quite clear and revealed the locations of submerged building foundations, bridges, roadways, woodlands, and original river channels (Figure 6). Moving up each submerged valley and cove, the clarity of features was reduced as the veneer of sediment increased in thickness with contributions from upland soil erosion and the reservoir margins. Thus, it was possible to map the approximate extent of submerged sediment deltas in the lakes. These were delineated as lines of subaqueous sediment extent on the shoaling maps. These lines extend from the deepest location of subaqueous sedimentation up to 787.6 feet for Smith Mountain Lake and 600 feet for Leesville Lake.

Estimated Changes in Project Bathymetry

To estimate the thickness of sediment deposits within the project boundary, historical topographic data from U.S. Geological Survey topographic maps were compared to the bathymetric data. The historical maps had been scanned from circa 1950's paper maps by an independent cartographer and were provided in unregistered format. These maps were originally developed at a scale of 1:62,500 and feature contour intervals of 20 feet and adhere to the federal map standards (U.S.G.S, 1999). The contour intervals from these maps were transferred to the 1:24,000 scale U.S.G.S. 7.5 minute series base quadrangle maps. The maps were georegistered and shifted, as necessary, to match the locations of observed road intersections and significant geologic features. The contour intervals and locations of pre-project river channels for the coves, bays, and tributary areas were then digitized in ARCGIS. Digital terrain models known as TINs (triangular, irregular network) were developed from the contours and used to create historic elevation grids for each area. These grids were subtracted from the current bathymetric data to develop spatially explicit estimates of sediment depth as the change in project bathymetry since project inception. Given the inherent uncertainty of the original contour data, changes in sediment depth of less than 10 feet may not be reliable and should be validated with field data. Maps showing estimated changes in project bathymetry since project inception were developed.

In addition, a process known as "sub-bottom profiling" was employed on Smith Mountain and Leesville Lakes to characterize the nature of sediments submerged beneath the reservoirs. In this process, a type of sonar (often called hydro-acoustic surveying or "chirp") is used in an attempt to characterize and infer sediment layers, types, and thickness. Twelve sediment cores were also collected during the chirp process to facilitate the interpretation and validation of the chirp results. The interpretation of chirp data is quite subjective in nature and problematic when reflective deposits such as dense clay layers or gas pockets and organic matter block the sonar signals. Findings from the sub-bottom profiling will be summarized in the results section. The reader is directed to the bathymetric report for a comprehensive description of the chirp methodology and results (OSI, 2006).

OBJECTIVE 3: IDENTIFY THE EXTENT OF PROBLEMS ASSOCIATED WITH THE ACCUMULATION OF SEDIMENTS WITHIN THE PROJECT RESERVOIRS, INCLUDING IMPACTS ON RECREATION, THE FISHERIES, AND OTHER PROJECT FEATURES

The extent of physical impacts of sedimentation on project amenities affected by shoaling and other sediment depositional patterns was determined from the results of Objectives 2 and 4. Series of maps, developed in consultation with stakeholders at working group meetings and stakeholder feedback, were developed to explicitly map the spatial extent of exposed sediments, the spatial extent of submerged sediment, and the general depositional features of sedimentation throughout the project. These are fully described in the results section of this report.

The impacts of sedimentation on non-physical amenities are addressed in the *Recreation and Angler Use Study, Native and Exotic Aquatic Vegetation Study, Littoral Zone Habitat Study, Fish Spawning and Rearing Assessment Study, Water Quality Study, Debris Study,* and the *Navigational Aids Study.* The results of all the project studies will be consolidated and used to develop a comprehensive summary in the License Application and Environmental Assessment documents. This is the most appropriate treatment as the scopes and complex scientific nature of the ecological and socioeconomic impacts are best addressed by the respective experts conducting the other studies.

OBJECTIVE 4: DETERMINE THE RATE OF SEDIMENT ACCUMULATION OVER THE TERM OF THE EXISTING LICENSE.

This objective was completed by computing the difference between the most current and original storage volume curves. The change in volume over time represented reservoir capacity lost to sedimentation. Changes in reservoir capacity and sediment storage were computed across the entire range of reservoir operations, from the base of the reservoir to the project boundary elevation.

OBJECTIVE 5: IDENTIFY THE SOURCES OF SEDIMENTS DISCHARGING INTO THE RESERVOIRS.

As mentioned previously, the first step in identifying reservoir sediment sources was conducting a literature review and gathering information from local media sources (e.g. *Roanoke Times, Smith Mountain Laker, Smith Mountain Lake News, Smith Mountain Lake Association*). Specific information of locations of sedimentation within coves and other localized locations in the Project area was obtained from individual stakeholders during the Project Study meetings in January 2006 (AEP, 2006a), March 2006 (AEP, 2006b), and September 2006 (AEP, 2006c). The relative contributions of upland watershed and shoreline sediment sources was determined in Objective 2. Objective 5 focuses on identifying the spatial distribution, magnitude, frequency, and impacts of upland watershed sediment sources.

Field Work

Site visits and field reconnaissance were conducted in June 2006. The purposes were to survey tributary river characteristics for model parameterization (Keaton, et. al., 2005), verification of land use data, visiting sites identified by stakeholders, determining watershed sediment sources, and cataloging reservoir sedimentation. A number of photographs were taken during field work. Some of these photos will be presented in this report and all photographs will be in the digital study archive. Stakeholders also provided aerial imagery and aerial movies of the project to facilitate the identification of sedimentation source and deposition areas. These were utilized to plan additional site visits.

Watershed Sedimentation Modeling

The purpose of this study task was to develop a spatially explicit, GIS based, watershed erosion and sedimentation model. After reviewing potential models and data limitations, the USDA

Agricultural Research Service Soil and Water Assessment Tool (SWAT), was selected to develop the watershed erosion and sedimentation model for the project.

SWAT Model Description

The Soil and Water Assessment Tool is a watershed-scale numerical model for the simulation of water, sediment, nutrient and pesticide movement in surface and subsurface systems. SWAT was developed to aid in prediction of the impacts of climate and vegetative changes, reservoir management, groundwater withdrawals, water transfer, land use change and watershed management practices on water, sediment and chemical dynamics in complex watershed systems. Land use and management conditions can be varied over long time periods, making the model a particularly useful tool to aid in the evaluation of BMPs. SWAT is a continuous-time model, intended for the prediction of long-term water and sediment yields from a watershed (Neitsch, et. al., 2002a; Neitsch, et. al., 2002b).

SWAT is a physically-based numerical model requiring input of climatic, soil property, topographic, vegetation, land use and land management data. SWAT uses these data to predict water, nutrient and sediment movement through the watershed, along with vegetation growth. SWAT uses a daily time step, continuous for one to hundreds of years. There are several advantages of this approach that make SWAT especially useful for the Study:

- SWAT may be used to quantitatively predict the long-term effects of land use, climate or vegetation changes on watershed sediment delivery and water quality. It is therefore highly useful in the analysis of soil erosion and sedimentation BMPs,
- The use of Hydrologic Response Units (HRUs; see below) is computationally efficient, allowing for large watersheds to be simulated over long periods of time,
- Most data inputs are available free-of charge from government agencies,
- SWAT is designed to address not only soil erosion but also sediment transport, fluvial sediment dynamics, and reservoir sedimentation.

A comprehensive explanation of SWAT, its background, computational methodologies, and SWAT model processes is included in Appendix II.

SWAT Model Development for the Smith Mountain Sedimentation Study

Climatic Data

Climatic data are required to develop a SWAT model. AVSWAT has a built-in national climate database that contains statistics for over 11,000 stations within the US that can be used to generate the SWAT model climate data requirements, which include rainfall, temperature, solar radiation, wind speed and relative humidity. In order to calibrate the SWAT model to a study watershed, measured local climate data for precipitation and temperature are necessary. Local precipitation, temperature, and wind measurements for the National Weather Service climatic observation station in Rocky Mount were obtained from the Virginia State Climatologist. These data were supplemented with synthetic solar radiation and relative humidity data generated by extraction from nearby stations in the national climate database. Figure 7 shows the locations of climatic and stream flow gauging stations used in this project.

The precipitation data used in the simulations were developed using an Inverse-Distance-Squared weighted average technique for each SWAT model subbasin. This process involves the computation of a stochastically identical (same mean, variance, and skew) precipitation record using all available NOAA precipitation records in and around the subbasin. The resulting record is derived by taking all of the nearby gage records and weighting the values proportionately to the inverse of the squared distance from the centroid of the subbasin to the location of the rain gage. This process ensures each subbasin has a complete precipitation record, as missing data is supplemented with values from other nearby gages. The reason for generating the stochastic climatic data is that it provides a similar climatic environment for the modeling while preserving natural variability of the historical record. This is especially useful for long-term simulations and analysis of trends such as land use change.

Soils Data

There are two potential sources of soil data that may be used in spatially explicit watershed modeling, the Soil Survey Geographic Database (SSURGO) and State Soil Geographic Database (STATSGO). Both of these sources may be obtained from the USDA Natural Resources Conservation Service, http://www.ncgc.nrcs.usda.gov/products/datasets/

There are two primary differences between these data sets. First, SSURGO provides higher resolution and quality soils data. Second, SSURGO data are available on a limited basis whereas STATSGO data are complete for the conterminous United States. As of July 1, 2006, SSURGO data were only available for a portion of the Smith Mountain Project Area. The differences in quality are described below.

STATSGO: Soil maps for the State Soil Geographic (STATSGO) database are produced by generalizing the detailed soil survey data. The mapping scale for STATSGO is 1:250,000 (with the exception of Alaska, which is 1:1,000,000). The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multi-state areas. SSURGO: Field mapping methods using national standards are used to construct the soil maps in the Soil Survey Geographic (SSURGO) database. Mapping scales generally range from 1:12,000 to 1:63,360; SSURGO is the most detailed level of soil mapping done by the Natural Resources Conservation Service (NRCS). SSURGO digitizing duplicates the original soil survey maps. This level of mapping is designed for use by landowners, townships, and county natural resource planning and management. The user should be knowledgeable of soils data and their characteristics.

Land Cover Data

There are two potential sources of publicly available land use data that may be used in spatially explicit watershed modeling. These are the 1992 and 2001 versions of the National Land Cover Databases (NLCD) developed by the federal level, multi-agency, Multi-Resolution Land Characteristics Consortium (MRLC). Both of these data sources may be obtained from the MRLC, http://landcover.usgs.gov/classes.php.

There are three primary differences between the NLCD1992 and NLCD2001 databases. First, NLCD2001 data are of generally higher quality because the 2001 initiative took advantage of "lessons learned" during the production of the 1992 data. This includes improved coordination and timing of satellite flights, improved processing methods, and optimized land cover classifications. Second, NLCD2001 data are more current as they were developed using satellite imagery from 2001 whereas NLCD is based upon 1992 satellite imagery. Third, the NLCD2001 database is currently in development and not expected to be complete until the end of 2006.

NLCD1992 are available for the conterminous United States. The differences in production methods and database quality between the NLCD1992 and NLCD2001 are extensive. Complete descriptions of each database may be found at;

NCLD1992 - http://landcover.usgs.gov/natllandcover.php

NLCD2001 - http://www.mrlc.gov/mrlc2k_nlcd.asp

The NCLD1992 includes 21 specific land uses that represent a variety of urban, agricultural and natural landscapes. The physiology of the vegetation for these landscapes is represented in SWAT and includes typical characteristics necessary to simulate hydrologic and erosional processes including, but not limited to, growing season length, phyto-productivity, leaf area, plant water use, organic matter accumulation, nutrient uptake, and soil protection.

While the NLCD2001 database coverage for the Smith Mountain Project was partially incomplete as of July 1, 2006, it was decided that the portion of missing data was so small, and the value added too great to exclude the available NLCD2001 data from the Study. For example, the NLCD1992 data showed none of the recent development in the Bridgewater or Moneta area. The NLCD1992 data were used to develop a 1992 based SWAT model. The NLCD2001 data were then brought into the Project GIS, superimposed on the NLCD1992 data, and spatial algebra used to "fill in the gaps" of the NLCD2001 data with the NLCD1992 data. These gaps were exclusively in Buford County and occurred in areas where there had been relatively little land use change since 1992. The end result was an NLCD2001 data set for the Project area that was comprised of approximately 98% NLCD2001 data and 2% NLCD1992 data.

Terrain Data

There are three potential sources of digital terrain data that may be used in spatially explicit watershed modeling. These data are Digital Elevation Models (DEM) and differ in grid spacing as 1 arc second (90 meter), 1/3 arc second (30 meter), and 1/9 arc second (10 meter) grid cell size data. These are all developed by the U.S. Geological Survey and distributed through the National Elevation Database, http://ned.usgs.gov/.

There are three primary differences between these data sets. First, the resolution and accuracy of the terrain data improves with finer grid spacing. Second, the quality of the databases improved with each generation. As with the land use data, subsequent generations of the elevation data improved upon previous versions. The 1 arc second data have lowest accuracy whereas the 1/9 arc second data have the highest accuracy. Third, only the 1 arc second and 1/3 arc second databases were complete for the entire U.S. as of Jul 1, 2006. The 1/9 arc second data were not available for the Smith Mountain Project Area. Complete descriptions of each database may be found at;

NCLD1992 - http://landcover.usgs.gov/natllandcover.php

NLCD2001 - http://www.mrlc.gov/mrlc2k_nlcd.asp

Hydrography Data

There are four potential sources of hydrography data that may be used in spatially explicit watershed modeling. These are Reach-File 1 (RF1), Reach-File 3 (RF3), National Hydrography Dataset (NHD) databases along with hydrography derived from terrain data. The earliest version, RF1, was derived from 1:250,000 scale topographic maps and is the oldest. RF3 improved upon RF1 and was developed from 1:100,000 scale topographic maps. The most current and potentially highest quality data are in the NHD database. The NHD was developed originally from RF3 data and is updated with hydrography data from 1:24,000 scale topographic maps as these finer resolution data are interpreted and developed. All of these sources may be obtained from the U.S. Geological Survey;

http://nhd.usgs.gov/

The 1/3 arc second terrain data were used to develop digital hydrography for the Smith Mountain Project as this method allowed for finer resolution hydrography data than were available from the NHD. The 1/3 arc second data are of the same scale that could be obtained from 1:24,000 scale topographic maps whereas the NHD data were from 1:100,000 topographic maps and partially augmented with finer resolution data. The NHD data were used to validate the terrain-derived hydrography.

Dams

There are several dams and reservoirs in the Smith Mountain and Leesville watersheds. A summary of these dams and their physical characteristics as extracted from the National Inventory of Dams is presented in Table 3 and shown in Figure 8. Aside from Smith Mountain and Leesville, the existing dams were assumed to have minimal impact on Project scale sediment yield because of the following conditions:

- The vast majority of dams were relatively small, old sedimentation basins. The majority of these visited were either full of sediment or had failed. While approximately six functioning basins were identified, their sizes and locations were such that they would not have a measurable effect on watershed scale sediment yield.
- Residence time of the impoundment was such that no significant sedimentation would occur in the silt and clay size fractions. For example, the Niagra Dam has a negligible sediment trapping capacity due to low residence time and high flow rates (AEP, 2006a).
- The Carvins Cove, Spring Hollow, Falling Creek, and Beaverdam Reservoirs are operated as a water supply reservoirs. These watersheds are protected as water supply watersheds, they are relatively small watersheds compared to reservoir size, and project scale much smaller than that of Smith Mountain, and therefore, these reservoirs would be exposed to relatively small amounts of sedimentation (RVARC, 2003). Land use in the watersheds is also almost entirely forested and has changed little since the "pre-settlement" condition. Therefore, it was assumed the impact of these reservoirs on total project sediment yield would be minor.

Model Limitations

While a calibrated model can provide useful insight into watershed processes, it is important to remember the limitations inherent in this type of modeling as listed below:

- The SWAT model is designed to simulate long term processes and thus it is not intended for event-based analysis;
- Due to the large scale of the model and limited calibration information, detailed subbasin results (especially in areas away from the calibration gages) should be treated as preliminary until additional data is collected to verify their accuracy;

- Certain model parameters were not changed from their default values due to a lack of specific data; this can lead to a certain degree of uncertainty in model results.
- Model results are strongly dependent upon the availability and quality of input and calibration data.

SWAT Model Calibration

Model calibration is an iterative process of tuning model parameters such that predicted output values best match observed data. The SWAT model is physically based and was developed for simulating un-gauged watersheds, so model calibration is possible without adjustment of every parameter. For the Study, the calibration process consisted of obtaining observed discharge and sediment data for the region and adjusting the hydrologic components of SWAT to match the observed frequency, duration, magnitude, and pattern of stream flow and sediment flux. Unfortunately, the sediment data from the Commonwealth of Virginia and the U.S. Geological Survey were not of sufficient quality and duration to provide a sediment calibration. While this is a desired feature, it is not nearly as critical as a hydrologic calibration and does not prevent the development of a calibrated watershed model. The period of 1976 to 1978 was chosen as the calibration period because the climatic regime was typical for the period of record and paired climatic data and discharge data for the same portion of the Smith Mountain Lake watershed were available. Discharge data were from the USGS gauging station on the Blackwater River near Rocky Mount, VA. Climatic data were from the National Weather Service Cooperative Observer's Station, Rocky Mount, VA (Figure 7). Calibration was performed by running the model from 1970 to 1978. Model results from 1970 to 1976 were not used in calibration as these represented the "priming" phase of the model (1970-1975 climatic data were "synthetic data" while 1976 data were observed). This is the period over which the model processes are allowed to essentially "equilibrate" to those observed in the natural watershed. Climatic and streamflow data from 1977 and 1978 were typical of record and used for the calibration process.

The first step in model calibration matched predicted annual water yield, surface runoff, and baseflow (groundwater contribution to streamflow) to observed data. The purpose of this phase was to accurately determine the partitioning and processing of precipitation into the appropriate flow pathways. The "default" SWAT model water yield results very closely matched observed. The results of the annual calibration matched predicted values to observed (Figure 9).

Final calibration consisted of adjusting subsurface flow, infiltration, and vegetation parameters to match seasonal flow patterns and adjusting channel and overland flow resistance factors to best match predicted flow routing to observed values. This was first conducted using seasonal and monthly water yields and then refined to daily flows. The time series of calibration flow data are shown in Figure 10. Observed data represent daily average flows so large peaks are often averaged over two days. Consequently, they do not match peaks predicted by the model. A frequency distribution of flow data better illustrates the calibration results; predicted flows tended to slightly underestimate flows during low flow periods while high flow periods were slightly overestimated (Figure 11). Flow data were transformed using a standard log-normal transformation for hydrologic data (Haan, 1994); statistical results are summarized in Table 4. The calibrated model explained 90% ob the observed variance in discharge data (r^2 = 0.9). Further calibration could not performed because model performance was limited by multi-day averaging of large observed flows and the lack of observed relative humidity and solar insolation data at the calibration climate station. Final calibrated model output for March 10, 1975 shows the spatial distribution of runoff and predicted sediment concentrations for the Blackwater Creek watershed (Figure 12). While the watershed sedimentation modeling was calibrated to observed flow records, the model itself was designed and optimized for surface hydrology, hydraulics, and the prediction of soil erosion and sediment transport. Consequently, these results should not be used to make inferences about hydrogeology or ground water processes.

SWAT Model Implementation

The calibrated model was scaled to the entire Smith Mountain Lake and Leesville Lake watersheds. The model was run for 2001 land use conditions, 1992 land use conditions, pre-settlement conditions, and a series of alternative future scenarios. The alternative scenarios will be discussed in Objective 6.

Objective 6: Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

A review of soil conservation, erosion and sediment control practices, and sedimentation remediation measures relevant to reservoir sedimentation in the central Appalachian Mountain Valley and Ridge physiographic region was conducted. Reviewed literature included peer-reviewed publications, federal and state agency reports, public documents from the Project re-licensing process, information from AEP, media reports, and public input during the integrated licensing process. All sources are listed in the Cited Literature and Reviewed Literature sections of this report.

Literature Review

The Virginia Soil Erosion and Sediment Control law is codified as Title 10.1, Chapter 5, Article 4 of the Code of Virginia. Regulations are found in Section 4VAC30-50, and certification regulations are found at Section 4VAC50-50 of the Virginia Administrative Code. This law was amended in July, 2006 with publication of Chapter 8, "Virginia Erosion and Sediment Control Law, Regulations, and Certification Regulations". Minimum standards are summarized in Section 4VaC50-30-40 and included in Appendix III. General exemptions from VESCL&R potentially exclude a number of small-scale construction and development activities that are common in developing areas (VDCR, 2004; VDCR, 1992);

> "A land-disturbing activity is "any land change on private or public land that may result in soil erosion from water or wind and the movement of sediments into state waters or onto lands in the commonwealth, including, but not limited to, clearing, grading, excavating, transporting, and filling of land." This definition includes land-disturbing activities equal to or exceeding 10,000 square feet in area; however, the following 13 activities are specifically *exempt* from the definition:
>
> 1. Disturbed land areas of less than 10,000 square feet in size; however, a local ESC program may reduce this exception to a smaller area of disturbed land or qualify the conditions under which this exception shall apply;
> 2. Minor land-disturbing activities and individual home landscaping, repairs and maintenance work;
> 3. Individual service connections;
> 4. Installation, maintenance or repair of underground public utility lines when such activity is confined to an existing hard surfaced road, street or sidewalk;
> 5. Septic tank lines or drainage fields unless included in an overall plan for land-disturbing activity relating to construction of the building to be served by the septic tank system;
> 6. Surface or deep mining;
> 7. Exploration or drilling for oil and gas including the well site, roads, feeder lines and off-site disposal areas;
> 8. Tilling, planting or harvesting of agricultural, horticultural or forest crops, or livestock feedlot operations; including a specific list of engineering operations;
> 9. Repair or rebuilding of the tracks, right-of-way, bridges, communication facilities and other related structures, and facilities of a railroad company;

10. Agricultural engineering operations including but not limited to the construction of terraces, terrace outlets, check dams, desilting basins, dikes, ponds not required to comply with the provisions of the Virginia Dam Safety Act, ditches, strip-cropping, lister furrowing, contour cultivating, contour furrowing, land drainage and land irrigation;
11. Installation of fence, sign, telephone, electric, or other kinds of posts or poles;
12. Shore erosion control projects on tidal waters when the projects are approved by local wetlands boards, the Marine Resources Commission or the U. S. Army Corps of Engineers; and
13. Emergency work to protect life, limb or property, and emergency repairs."

The administration and enforcement of VESCL&R falls under the jurisdiction of the Virginia Department of Conservation and Recreation, Soil and Water Conservation Program (Program) and is fully documented in the "Virginia Erosion and Sediment Control Handbook" (VDCR, 1992). The program is implemented at the local level by government planning departments or commissions with technical guidance and assistance available from Soil and Water Conservation Districts (SWCD). As part of this study, the local implementation of erosion and sediment control practices was discussed with a number of personnel representing various jurisdictions in the Smith Mountain Lake and Leesville Lake project areas including Franklin County (Blue Ridge SWCD), Bedford County (Peaks of Otter SWCD), Pittsylvania County (Pittsylvania SWCD), Roanoke/Salem (Blue Ridge SWCD), and appropriate local government planning personnel. Additional information was obtained from the New River Watershed Soil Conservation Yellow Pages (DCR – New River Watershed). Relevant literature and erosion and sediment control methods have been summarized in the Methods section and relevant agency contact information is provided in Appendix IV.

The VESCL&R either stipulates or recommends soil erosion and conservation measures that are consistent with common practice and standards recommended for forestry (recommended), construction (mandatory with certain exemptions), and agricultural (recommended) activities by federal agencies of the United States (Aust and Blinn, 2004; Jackson, et. al., 2004; Riedel and Vose, 2002; VDF, 2002; NRCS, 1999; EPA, 1995a; EPA, 1995b; FHWA, 1995; CWP, 1994; NRCS, 1994).

Erosion Control and Sedimentation Remediation Measures

It is important to note the differences and relationships between forest land, agricultural land, developing land, and developed lands. From an erosion and sediment yield perspective, forest land (and natural grassland) has by far the lowest sediment yield (Jenks, et. al., 2006; Riedel and Vose, 2004; Dudley and Stolton, 2003; Lacie and Hermansen, 2002; Bolstad and Swank, 1997; Kochenderfer, et. al., 1987; Patric, et. al., 1984). This is because a multilayered forest canopy intercepts rainfall and reduces raindrop energy. Beneath the forest canopy, the herbaceous and litter layers (often called "duff") provide additional interception layers to totally absorb the energy of rain drop impact. Forest litter also fosters small animals, invertebrates, and soil microorganisms that maintain soil tilth, infiltration capacity, and surface water storage. Numerous studies of forested watersheds in the central and southern Appalachians found background sediment yields from mountain forests are typically on the order of 0.01 ton/ha (0.02t/acre) (Wear and Greis, 2002; Kochenderfer, et. al., 1987; Patric, et. al., 1984). The conversion of forest to agricultural lands significantly alters the hydrologic pathway of water and typically produces a chronic sediment source, the effect of which grows over time (Jackson, et. al., 2005; Dudley and Stolton, 2003; Swanson, et. al., 2000). Sediment yield from poorly managed agricultural lands in the Appalachians may be 2 or 3 orders of magnitude higher than natural, forested conditions (Jenks, et. al., 2006; Kochenderfer, et. al., 1987). However, agricultural lands offer the greatest flexibility for soil conservation because the land is not "locked" into small parcels with constricted uses and land owners are typically more connected to the land. When development pressures encroach into a region, it is often the agricultural lands that are most intensively developed. This is because agricultural lands already have heavy equipment access points, offer development friendly grades, and can be developed with minimal site preparation costs. The development of agricultural land often includes an important shift in land ethic; farmers are more likely to view land as a long-term investment and maintain it as they would maintain expensive machinery whereas developers have typically viewed land as a short-term investment with little or no associated maintenance. When development begins, sediment loading shifts from a chronic source to an acute source of significantly higher magnitude; erosion from construction sites can easily increase soil loss 2 to 4 times when compared to crop lands and up to 10 times as compared to pasture land (Jenks, et. al., 2006; Riedel and Vose, 2004; Riedel, et. al., 2003; Bolstad and Swank, 1997; USDA, 1997; Van Lear, et. al., 1995; USDA, 1992a; USDA, 1976). This condition will exist until the soils are stabilized and site runoff controlled. Once development is complete, soils have been covered by buildings, impervious surfaces, or protected with landscaping and cultivated plants (grass, trees, gardens, etc.). Developed land behaves very differently because soil sources have been reduced to nearly insignificant levels. Sedimentation from developed lands typically occurs from "build-up and wash-off" processes and erosion within the drainage network caused by increased storm water runoff frequency, volume, and peak flows (CWP, 1994).

There are three approaches to dealing with sedimentation issues; erosion prevention, sedimentation control, and sedimentation remediation. Erosion prevention practices protect exposed soil surfaces from raindrop impact, concentrated flow, and soil disturbing activities such as construction vehicle traffic. This approach stops sedimentation at the source. The most common methods include:

Construction and development

- Minimization of soil disturbance during construction activities
- Use of mulch to protect exposed soil
- Seeding and mulching exposed soil
- Control of construction traffic patterns
- Armoring of conveyance channels

Agriculture

- Conservation tillage (minimum till)
- No-till
- Grassed waterways
- Crop residue management (e.g. stalk mulch)
- Field and stream buffers

Forestry

- Minimize site disturbance
- Contain skidding and loading activities
- Retain forest litter on forest floor
- Proper hauling road construction

Sedimentation control practices address the issue of eroded soil that is being transported through the hydrologic network. These methods typically rely upon settling and/or filtration methods to induce sedimentation in a controlled environment to protect downstream resources. The most commonly used methods include:

Construction and development

- Silt fences
- Hay bales
- Broad based dips and turn-outs on unpaved roads
- Brush barriers
- Sedimentation ponds
- Raised inlet detention cells

Agriculture

- Contour tillage
- Field berms
- Raised tile inlets
- Field runoff ponds
- Field and riparian buffers and filter strips

Timber Harvesting

- Silt fences
- Hay bales
- Broad based dips and turn-outs on unpaved roads
- Brush barriers and buffers

Sedimentation remediation measures address resources that have been impacted by excessive sedimentation. These represent an "end-of-pipe" solution and are typically the most expensive, complicated, and temporary approach to addressing sedimentation problems. Due to the inherently site disturbing nature of sedimentation remediation measures, these practices may exacerbate sedimentation problems. Sedimentation remediation measures do not prevent further sedimentation nor do they "restore" degraded resources. The success, benefits and longevity of sedimentation remediation measures are entirely dependent upon the cessation of upstream/upslope sediment sources. Hence, these measures are only recommended when watershed management and soil conservation practices have been implemented to minimize upland soil erosion and fluvial sedimentation.

- Sediment stabilization – this method is used to prevent re-erosion and transport of deposited sediments. There can be numerous ecological and water quality benefits associated with the stabilization of shallow sediment environments. These environments behave as littoral or riparian wetlands and provide spawning, rearing, and forage habitat for numerous fish, amphibian, and avian species. In addition, they encourage further deposition and stabilization of suspended solids, improving water clarity and often serving as nutrient sinks. While a full discussion of the ecological importance of such habitats is beyond the scope of the sedimentation study, it is presented in the *Aquatic Resource Assessment* and *Littoral Habitat* studies.
- Dredging – this method is used to remove sediments from the affected resource. Dredging poses a particular threat to lakes and reservoirs in that the re-suspension of stable sediments into the water column causes secondary pollution and risks the degradation of a larger area. These threats my be reduced and managed through the use of floating dredge screens

While it was well beyond the scope of the Sedimentation Study objectives, four alternative watershed management scenarios were simulated with the SWAT model to illustrate the potential benefit of soil erosion and sedimentation control measures. These scenarios were status quo, worst-case, 50% improvement, and 80% improvement. Each was compared to existing and pre-settlement results to illustrate the effects of different watershed management scenarios on future sediment yield. Descriptions of each scenario are provided below:

1. Status quo – this is the default, or no change alternative. Soil disturbing activities from development, agriculture, and forestry would continue as in the past. The use of soil erosion control BMPs such as conservation tillage and riparian buffers was specified to match observed implementation in upland watershed areas.
2. Worst-case scenario – this alternative assumed reduced enforcement and compliance with erosion and sedimentation control standards and regulations. It was assumed disturbed sites and exposed soil would be subject to rainfall and best management practices were non-existent or not maintained. This is important because poorly maintained BMPs provide little or no soil erosion control as compared to bare soil areas (Clinton and Vose, 2003).
3. 50% improvement – this scenario simulated a 50% improvement in soil erosion control and sedimentation best management practices compliance, over existing conditions. This is based upon field observations of erosion practices that indicated approximately 50% of visited sites had proper and functioning erosion and sedimentation control practices. Thus, under this scenario, 50% of sites (existing) plus a 50% improvement (25%) would generate 75% compliance scenario.
4. 80% improvement – this scenario simulated an 80% improvement in soil erosion control and sedimentation best management practices compliance. This is based upon field observations of erosion practices that indicated approximately 50% of visited sites had proper and functioning erosion and sedimentation control practices. Thus, under this scenario, 50% of sites (existing) plus an 80% improvement (40%) would generate 90% compliance scenario.

Development under Scenarios 2 to 4 was simulated to occur in areas based upon existing transportation and socio-economic patterns. This is consistent with existing socio-economic studies for the region that have shown areas most subject to development (including urban, development and residential uses) are focused on/around agricultural lands in close proximity to existing development and transportation corridors (Figure 13) (Weir and Greis, 2002). For example, remaining parcels in Indianhead cove, and along the Hwy 122 corridor between Rocky Mount and Moneta would be fully developed. Performance of erosion and sediment control measures were specified to be consistent with published data (Clinton and Vose, 2003; Riedel and Vose, 2002; NRCS, 1999; USDA, 1997; CWP, 1996; NRCS, 1994; Neitsch, et. al., 2002a; Wischmeier and Smith, 1978; Wischeimeir, 1976; USDA, 1976).

RESULTS

OBJECTIVE 1: UPDATE THE STORAGE VOLUME CURVES FOR THE SMITH MOUNTAIN AND LEESVILLE DEVELOPMENTS

The storage volume curves for Smith Mountain and Leesville Lakes were updated using the newly developed, high resolution bathymetric data, Figure 2 and Figure 3, respectively. Changes in reservoir storage capacity are discussed in Objectives 2 and 4, below.

OBJECTIVE 2: DETERMINE THOSE AREAS WHERE SEDIMENT ACCUMULATION MAY BE MOST PREVALENT.

Field reconnaissance on Smith Mountain and Leesville Lakes and sediment accumulation mapping revealed areas subject to shoaling and subaqueous sedimentation. The most extensive areas of shoaling were located at inflow points from major tributaries and in smaller tributaries where extensive near-shore development had contributed large sediment loads to bays, tributary inlets, and coves Figure 14. The most pertinent results of the literature review identified the cove areas of Smith Mountain and Leesville Lakes as areas most subject to visible sedimentation. These included Big Indian Creek, Little Indian Creek, Grimes Creek, Lynville Creek, Blackwater Creek, the mouth of the Roanoke River, the mouth of Pigg River, Gills Creek, Staniford Creek, Beaverdam Creek, Becky's Creek, and Betty's Creek (Figure 15 to Figure 25). The deposition patterns generally reflected reservoir pool elevations with little or no shoaling occurring above normal pool levels. Shoaling increased as pool levels declined for power generation or during periods of reduced inflow (Figure 2, Figure 3). Shoaling of larger tributaries such as the Blackwater Creek (Figure 21), Pigg River (Figure 27 and Figure 28), and Lynville Creek (Figure 17) was exposed for many times the channel width with lower water levels.

Subaqueous sediment deltas were apparent on even the smallest tributaries and coves and extended for up to a mile below the largest tributaries into Smith Mountain Lake, the Roanoke River (Figure 15 and Figure 16) and Blackwater Creek (Figure 21), and as transient sand dune deposits in the bottom of Leesville Lake below the confluence of the Pigg River (Figure 27 and Figure 28). In Leesville Lake, higher reservoir currents generally prevented the deposition of fine materials and allowed for the formation of dynamic sand dunes (OSI, 2006). These dunes were restricted to the deepest part of Leesville Lake.

In both reservoirs, sedimentation near river mouths and in coves was generally comprised of silt size and coarser mineral sediments along with organic materials (OSI, 2006). In these areas, the decomposition of buried organic matter (leaves, twigs, etc.) generated carbon dioxide pockets that inhibited the penetration of sonar signals and prevented the estimation of sedimentation depths. Estimated depths of sediment deltas and subaqueous sediment deposits from the historic and current bathymetric data were quite high near river mouths, often exceeding ten feet or more (Figure 34 to Figure 43). Areas shown to have sedimentation thicknesses of less than 10 feet should be considered “rough estimates” due to the limitations of pre-project data resolution. In areas estimated to have greater thicknesses, the actual thickness of sediments may vary by 5 to 10 feet of estimated. The patterns and estimated sediment depths do agree well with the other methods used to quantify project sedimentation. Sediment deposits are clearly thicker at the outfall of tributary sources and generally thin to a sediment veneer of ½ foot to 3 feet within the calm waters of Smith Mountain Lake (OSI, 2006). Subaqueous sedimentation in the body of Smith Mountain Lake was dominated by clays and verified by sharp reflections of the sonar and sediment cores (OSI, 2006). There was little shoaling along shoreline areas away from tributary and cove areas.

The relative contributions of watershed and shoreline erosion sediment sources to past sedimentation was determined for Smith Mountain and Leesville Lakes, Figure 44 and Figure 45, respectively. Historically, watershed sediment sources accounted for 65% and 50% of sedimentation in Smith Mountain and Leesville Lakes, respectively. The large disparity between the values may be attributed to a couple of factors. First, Smith Mountain Lake traps the vast majority of sediments from its watershed, preventing them from reaching Leesville Lake. Second, currents in Leesville Lake greatly inhibit the deposition of fine sediments within the main lake channel (OSI, 2006). In this area, sedimentation is dominated by coarser sand deposits sourced primarily from the Pigg River, and other tributaries, to a lesser extent. The contemporary contribution of shoreline erosion to current and future sedimentation is anticipated to be greatly reduced to relatively minor levels as compared to current upland sources. This is due to three reasons. First, the past erosion of shorelines has allowed for the development of more stable shoreline profiles and near-shore benches that dissipate erosive energy. Second, stabilization of shorelines has reduced erodibility. Third, active shoreline management combined with the establishment of littoral submerged and semi-emergent aquatic plant communities has further reduces shoreline erodbility.

The depositional patterns of the near-shore sediments associated with shoreline erosion appear as white fringes along the reservoir margins in the shoaling figures. These represent the formation of incipient benches and littoral habitat along the reservoir margins. For a full discussion of the process of shoreline erosion and shoreline profile development, the reader is referred to the Smith Mountain Lake Erosion Study Report. Additional information regarding the important roles of littoral habitat and aquatic vegetation in developing healthy shoreline areas may be found in the Aquatic Habitat and Vegetation Study Reports.

The estimated changes in project bathymetry revealed general patterns and estimates of sediment deposition and erosion areas within the bays, coves, and tributary inlet areas. These are illustrated in

OBJECTIVE 3: IDENTIFY THE EXTENT OF PROBLEMS ASSOCIATED WITH THE ACCUMULATION OF SEDIMENTS WITHIN THE PROJECT RESERVOIRS, INCLUDING IMPACTS ON RECREATION, THE FISHERIES, AND OTHER PROJECT FEATURES

The spatial extent of sedimentation and shoaling was determined and illustrated, as discussed in Objective 2. These areas represent the physical locations at which sedimentation has, is currently, and will likely continue to occur. Thus, the maximum extent of problems associated with sedimentation may be directly inferred from these maps. The specific impacts of sedimentation on project amenities such as socioeconomic and ecological resources are fully discussed in the reports of the *Recreation and Angler Use Study, Native and Exotic Aquatic Vegetation Study*, *Littoral Zone Habitat Study, Fish Spawning and Rearing Assessment Study, Water Quality Study*, *Debris Study,* and the *Navigational Aids Study.*

OBJECTIVE 4: DETERMINE THE RATE OF SEDIMENT ACCUMULATION OVER THE TERM OF THE EXISTING LICENSE.

The net change in storage capacity for Smith Mountain and Leesville Lakes represents the difference in volume from that gained by shoreline erosion to that lost by near-shore sedimentation and sedimentation from fluvial sources. As mentioned previously, there is uncertainty associated with the historical and current storage volume estimates. This uncertainty has been accounted for in the elevation data and the volume estimate data. In theory, differences in volume may not exist in areas where these error bars overlap. However, if the error terms are randomly distributed, then over-estimates will balance under-estimates and the elevation / storage volume relationship will follow the plotted lines. As this may be a reasonable assumption, the change in storage volume may be estimated as the differences between the lines with the understanding that there is uncertainty associated with the results. The estimated changes in reservoir storage capacity for Smith Mountain and Leesville Lakes are summarized in Table 1 and Table 2. It is important to note the cumulative changes in storage capacity exceed the uncertainty thresholds; the estimated reductions in storage capacity for Smith Mountain and Leesville Lakes are 6.0% and 11%, respectively. Taking the volume of capacity lost over the life of the reservoirs, this equates to net, volumetric sedimentation rates of 1,650 acre-feet per year for Smith Mountain Lake and 260 acre-feet per year for Leesville Lake. Averaged over the normal pool elevation surface areas of these reservoirs, this conceptually equates to a historic average depth of 0.96 and 0.95 inches per year of lost volume, respectively. The lost storage capacity may be attributed wholly to subaqueous sedimentation in cove and inlet areas, as the thin sediment veneer in Smith Mountain Lake, and in transient sand deposits in Leesville Lake; it is almost entirely below the lower pool operating limits.

OBJECTIVE 5: IDENTIFY THE SOURCES OF SEDIMENTS DISCHARGING INTO THE RESERVOIRS.

Erosion from land disturbing activities adjacent to Smith Mountain and Leesville Lakes is a potentially significant, yet localized source of reservoir sedimentation. While sedimentation caused by erosion and runoff from shoreline development of a single small parcel was not identified as a significant source, concentrated runoff from land disturbing activities in small cove areas was a significant source of cove sedimentation. The cumulative effect of multiple developments or disturbances on separate land parcels draining to the same cove or bay areas was additive in nature and produced significant increases in predicted sediment yields. Due to differences in soil types across the project area, soil sensitivity to disturbance varies across the project area. Soil erodibility refers to the inherent stability or instability of soil aggregates and their resistance to detachment by raindrop impact. Erodibility is a function of soil properties such as chemistry and organic matter content. All other things being equal (slope, land use, climate, etc), an increase in erodibility will cause a proportionate increase in the likelihood of observing actual soil erosion. Soil erodibility in the Project area ranges from less than 0.1 (very stable soils) to more than 0.4 (sensitive) with typical soils having erodibility in the range of 0.2 to 0.3 (Kinnell, 2004). Maps of soil erodibility illustrate the sensitivity of soils surrounding Smith Mountain (Figure 46 - Figure 57) and Leesville Lakes (Figure 58 -Figure 65).

While shoreline erosion results in a net transfer of sediment within the operational limits of the reservoir pools, sedimentation sources with origins external to the Project reduce reservoir storage capacity and cause extensive shoaling and subaqueous sedimentation. The results from the watershed based erosion and sedimentation SWAT modeling provided estimates of soil erosion, sediment transport, and sediment yield for three scenarios; a simulated pre-settlement condition, 1992 land cover conditions, and 2001 land cover conditions. The simulated pre-settlement condition represents a best estimate of what sediment yield might have been when the lands draining to Smith Mountain and Leesville Lakes were under natural land cover for the region. The 1992 and 2001 land cover scenarios provide boundary conditions for a decade over which a significant amount of land was converted from forest and agricultural uses to residential and commercial development. The average annual sediment yields for these scenarios are shown in Figure 66. In this figure, low sediment yield from large forested areas can mask the influence of “hot spots” of high sediment yield from disturbed lands. This is because low yield from extensive forest lands offsets high yields from relatively small pockets of disturbance.

Predicted average sediment yield plotted by sub-watershed clearly illustrates locations of sediment source “hot-spots” in using the 1992 and 2001 data, Figure 67 and Figure 68, respectively. The subwatersheds that appear as “hot-spots” are dominated by land disturbing activities. Under pre-settlement conditions (all land disturbing activities replaced with native forest types), the “hot-spots” were predicted to have very low soil erosion and sediment yield (Figure 69). Watershed labels in these figure may be used to look up predicted sediment yields in Table 5. For example, high sediment production from agriculture and construction in the rapidly developing Indianhead Creek cove, #73, would predominate over low yields from forest lands (Figure 70). At the subwatershed level, current sediment yield rates for the most disturbed areas are 10 to 100 times higher than that expected from pre-settlement conditions (Table 4). The differences in Project-scale sediment yield (where yields are averaged across the entire project area) caused by development can be approximated by looking at the cumulative impact predicted for the current license term; sediment yield from tributaries to Smith Mountain and Leesville Lakes has increased 3 to 4 times over that expected from background conditions (Figure 71).

The results of the model calibration appear to indicate the model tends to slightly over-estimate the frequency of above average flows while slightly under-estimating the frequency of below average flows. The calibrated model was consistent in explaining 90% of the variability in observed flows. Given the multi-day averaging of peak flows in observed data and limitations in observed climatic data, there are no means of accounting for this source of error. Any potential affect on model outcome would be quite low and expected to follow the frequency distribution in Figure 11; there may be a few storms where the model slightly over-estimates peak flows and a few dry periods where the model under-estimates low flows. As the calibrated model was used to generate all of the scenarios, slight discrepancies that may occur would be consistent across all watershed sedimentation modeling scenarios. Thus, comparisons of the relative differences in predicted sediment yields will most accurately represent the anticipated response in predicted sediment yields. These are listed in Table 5 and illustrated as differences in sediment yield in Figure 66 - Figure 71.

Objective 6: Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

Perhaps the most important tenant of soil conservation is preventing soil erosion. This is simply due to the Laws of Thermodynamics, specifically the Law of Entropy – all things tend to the lowest possible energy state (water flows down hill). Interpreted in “lay terms” this means it is far more expensive (in energy, labor, time, and materials) to clean-up a sedimentation problem than to prevent soil erosion from occurring (Jackson, et. al., 2004; Sun, et. al., 2004; Dudley and Stolton, 2003; Brady, 1990). Many of the soil conservation practices mandated by the

Commonwealth of Virginia and encouraged by local SWCD staff follow this concept by "keeping the soil on the land". During field work conducted in May and June 2006, excessive sedimentation was observed under three common scenarios that are directly relevant to the Erosion and Sediment Control regulations. These are described below and examples from construction sites, agricultural lands, and timber harvesting are shown in Figure 72, Figure 73, and Figure 74, respectively:

Construction sites:

1. At a number of sites, soil conservation and construction BMPs were not being implemented on regulated sites (note large scale of site, steep slopes, and no erosion control practices),
2. While soil conservation and construction BMPs were being utilized, they were not constructed or maintained properly (note silt fence and drainage swale destroyed by machinery access point),
3. While soil conservation and construction BMPs were being utilized, the measures were of inadequate design to handle larger rainfall and runoff events (note over-topping of properly installed and designed silt-fences).

Agricultural lands:

1. Proper agricultural best management practices were not used in many pasture sites and in some crop lands that were visited,
2. While agricultural best management practices were being utilized on many pasture land and most crop lands, they were often not employed properly,
3. In sites where good practices were being implemented, site location was such that runoff from large storm events would overwhelm BMPs and directly enter the drainage network.

Timber harvesting:

1. In some cases, no forestry best management practices were implemented on sites; soil was exposed to rain, runoff entered drainage networks, and harvesting operations severely disturbed the soil and riparian areas,
2. For most of the visited sites, forestry BMPs had been implemented, however, not to the fullest extent possible,
3. As with agricultural and developing land, there were sites where good practices were being implemented. However, site proximity to surface waters allowed for sedimentation from larger storm events to overwhelm BMPs and enter streams and lakes.

While these situations are quite typical and observed in all regions of the nation, they are especially important in areas such as the Appalachian Mountains where rainfall excess is higher than average, slopes are steeper, drainage density is higher, and high clay and mica soils are more easily eroded (Leigh, 1996; Van Lear, et. al., 1995; USDA, 1997; Feldman, et. al., 1991a; Feldman, et. al., 1991b; USDA, 1976). This fact is evident in Figure 75 which shows the same types of land uses in this region with well designed and implemented soil erosion and sedimentation BMPs.

Examples of BMPs relevant to the Project are available from a variety of sources in the Cited and Reviewed Literature sections of this report. Typical agricultural BMPs have been developed by the United States Department of Agriculture (NRCS, 1999; NRCS, 1994; Brady, 1990). There are a number of publications, guidebooks, and BMP manuals with relevant forestry BMPs for this region (Tew, et. al., 2005; Aust and Blinn, 2004; VDF, 2002; Swanson, et. al., 2000; Martin and Hornbeck, 1996;). Best management and soil conservation practices for construction are available from a variety of sources (Tew, et. al., 2005.; EPA, 1995a; EPA, 1995b; FHWA, 1995; VDCR, 1992; USDA, 1976). While unpaved roads can be an exceptionally problematic source of erosion and sediment in mountains, specific best practices for road construction and maintenance have been shown to be very successful (Tew, et. al., 2005; Keller and Sherar, 2003; Riedel and Vose, 2002; USDA, 1992a).

Summary of current and planned sediment reduction measures

In addition to the mandated regulations governing soil erosion and sediment controls, there are funding opportunities to facilitate the implementation and maintenance of soil conservation best management practices. For example, the Virginia State Best Management Practices cost-sharing conservation program is available to residents of Franklin and Roanoke counties and residents within the Roanoke corporate limits. The Lower Blackwater River Total Maximum Daily Load (TMDL) Implementation Program is available to residents in the lower portion of the Blackwater River, Gills Creek, Maggodee Creek, and the shorelines of these watersheds located on Smith Mountain Lake. Additional programs are available for residents and businesses in other portions of the project area; further information may be obtained from the appropriate SWCD (see Appendix V for a listing of local agencies and contact information).

To facilitate the dissemination of the results of the current study to stakeholders throughout the region, an educational fact-sheet is being prepared. This fact-sheet will emphasize the results of this study and present findings in "lay terms" to improve accessibility. The fact-sheet will be made available to stakeholders, and the general public, in the Smith Mountain and Leesville Lakes region.

Results of sedimentation control measures analysis

Predicted differences in average annual sedimentation rates for alternative future scenarios are shown in Figure 76 and summarized by watershed in Table 5. As with earlier results, low yields from forest lands mask the effects of "hot spots" on sediment yield. Figure 77 shows the predicted, cumulative sediment yields for Indianhead Creek cove under pre-settlement, existing, and the alternative future scenarios. This figure emphasize the importance of cumulative effects of land disturbing activities on localized sedimentation rates in coves under high degrees of land disturbing activities. Average annual rates for Indianhead Cove were shown previously in Figure 70. Similarly, the impact of land disturbing activities and effectiveness of BMPs for other watersheds may be found by identifying the watershed of concern in Figure 68 and looking up the predicted sediment yield results in Table 5.

CONCLUSIONS

The purpose of the Smith Mountain Project Sedimentation Study was to satisfy some of the objectives raised during the Smith Mountain Project Integrated Licensing Process.

Objective 1. Update the storage volume curves for the Smith Mountain and Leesville Developments.

Objective 2. Determine those areas where sediment accumulation may be most prevalent.

Objective 3. Identify the extent of problems associated with the accumulation of sediments within the project reservoirs, including impacts on recreation, the fisheries, and other project features.

Objective 4. Determine the rate of sediment accumulation over time of the existing license.

Objective 5. Identify the sources of sediments discharging into the reservoirs.

Objective 6. Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

Objective 2 was satisfied by; mapping the areas of shoaling and subaqueous sedimentation in Smith Mountain and Leesville Lakes, and determining the relative extent and magnitude of shoreline erosion and upland watershed sediment sources. Results from the mapping indicated a significant amount of sedimentation and shoaling were occurring at the outlets of tributary rivers, streams, and coves to the lakes. In the cases of shoaling and sedimentation below coves, it was evident simply from visual inspection, field surveys, and shoreline reconnaissance that land disturbing activities such as development, golf course, agriculture, and poor timber harvesting practices were the direct causes of reservoir sedimentation. In these areas, sediment deposits at tributary outfalls were estimated to range anywhere from less than 10 feet (most areas) to potentially as much as 30 to 40 feet thick in isolated areas. These values represent "best estimates" using available pre-project bathymetric data and should not be interpreted as being factual rather, their best use would be to guide prioritization of sites for field validation of the thickness of sediment deposits. In forested coves, shoaling and sedimentation were relatively insignificant. Results from the sub-bottom profiling indicated a relatively thin, though substantial veneer of clay sized sediment deposits in the body of Smith Mountain Lake. In

Leesville Lake, significant amounts of sand were identified as beds of submerged sand dunes in areas downstream of the Pigg River confluence. These deposits are significant in scale with maximum dune heights and deposit thicknesses up to six feet and extending for a distance of many channel widths. While the exact nature of the features could not be specifically determined, they were dynamic and indicate a significant amount of sand was being transported as suspended and/or bed load sediments (OSI, 2006. Within the Pigg River itself, sediment deposits from watershed sources were estimated to be anywhere from 10 to 30 feet thick.

Sedimentation from shoreline erosion was concentrated along nearly the entire reservoir margins. It was concentrated as bench deposits in the littoral areas beginning below the normal low water pool elevation in both Smith Mountain and Leesville Lakes. In areas adjacent to tributaries, sedimentation from shoreline erosion and tributary loadings were interspersed in complex deposits. Sub-bottom profiling data were not useful in these areas because the prevalence of organic matter and decomposition gases in deposits blocked the acoustic signals.

Objective 3 was partially satisfied within the scope of the sedimentation study. Specifically, results from Objectives 1, 2, and 4 identified the primary impacts of sedimentation on project bathymetry and the those areas subject to shoaling. Secondary impacts of sedimentation such as potential loss or creation of littoral habitat, water quality, or boating impacts are specifically addressed in the appropriate companion studies listed below:

- *Debris Study*
- *Fish Spawning and Rearing Assessment Study*
- *Littoral Zone Habitat Study*
- *Native and Exotic Aquatic Vegetation Study*
- *Navigational Aids Study*
- *Recreation and Angler Use Study:*
- *Water Quality Study:*

The results of these combined studies will be synthesized in the License Application and Environmental Assessment documents to present a comprehensive assessment of how sedimentation is affecting these environmental and socioeconomic resources.

Objectives 1 and 4 were satisfied by comparing current and historical reservoir bathymetric data to determine the rate of storage capacity decline during the project life. While some sedimentation has occurred through all depths of Smith Mountain and Leesville Lakes, the vast majority has occurred in depths just below low water levels. These results are consistent with sediment deposition patterns observed in the mapping of shoaling and subaqueous sediment deposits. Historic rates of sediment accumulation from upland sources was relatively low in comparison to contemporary levels due to immense reservoir volume and rapidly increasing land disturbance. The absolute magnitude of sedimentation and the corresponding sediment yields were quite high when compared to background or natural levels. This fact is obscured to the casual observer because the sedimentation is hidden beneath the water surface in backwater cove areas and as expansive deposits in deep-water portions of Smith Mountain Lake – creating the illusion that the majority of the project is unaffected. While the historic contributions of shoreline erosion to reservoir sedimentation were quite significant, the current contributions have declined sharply.

Objective 5 required a combination of watershed reconnaissance and watershed sedimentation modeling to determine the frequency, magnitude, and location of runoff, soil erosion, and sedimentation across the 1,500+ square mile area contributing to the Project. These results showed excessive rates of sedimentation were caused by a combination of land disturbing activities including poor agricultural practices, rapid and poorly planned development, and substandard timber harvesting operations. Sediment yields in the most disturbed watersheds were frequently 10 to 100 times greater than background, or natural, conditions. This is especially important as the sedimentation only affects the receiving cove areas rather than the entire reservoir. Under the current development conditions within the region, average annual sediment yield has nearly tripled since 1992. If current development practices and pressures continue at this rate, cove sedimentation will only accelerate.

Objective 6 was perhaps the most important objective in this study. Alternative development and watershed conservation strategies clearly indicated the importance of enforcing existing soil erosion and sedimentation control regulations. Predicted sediment yields from development conditions without soil conservation practices were many times greater than those for existing agricultural lands. However, consistent and strategic application of watershed best management practices could reduce sediment yield significantly; well below current levels. A review of existing programs and resources indicated a variety of programs and resources available to land owners and managers including state funding of BMP projects and federal resources and funding opportunities available from local Soil and Water Conservation Districts.

Sedimentation within Smith Mountain and Leesville Lakes was found to be widespread in those bays, coves and tributary river outfalls where upland watersheds had been disturbed by human activity. Conversely, sedimentation and shoaling were minor, or even largely absent, in those near shore areas such as Smith Mountain Lake State Park where human impacts to upland soils have been prevented.

It is noted that the identification of specific locations and practices for dredging, or decisions as to whether or not dredging should occur, were beyond the scope of this study. While dredging may be a viable solution for remediating areas subject to nuisance sedimentation, the benefits may not out weigh the costs. Dredging treats a symptom rather than preventing a cause thus, until watershed sediment sources are reigned in, frequent and repeated dredging would be needed to maintain any benefits, dredging costs would be high and increase with anticipated sediment yields, and coves and bays would be exposed to nutrient enrichment and potential eutrophication. If dredging is desired, the identification and prioritization of areas for potential dredging should be a deliberative process involving all pertinent stakeholders and technical experts so that secondary damages may be avoided or minimized. For example, while dredging may be desired in a particular location, care should be used to determine what is causing the sedimentation, which types of dredging would be most appropriate, and how sediment removal might degrade valuable resources such as critical fish habitat and weed beds, potential avian foraging sites, riparian wetlands, or water quality. Care must also be used to insure that no state or federal wetland protection laws would be violated by dredging activities because, even though sedimentation may be caused by human activities, the natural establishment of functional wetlands in response to such activities, over sufficient periods of time, may afford them protected status. In particular, the U.S. Army Corps of Engineers and the Virginia Department of Environment Quality have wetland regulatory authority over the project reservoirs.

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TABLES

Table 1: Storage volume data for Smith Mountain Lake. Values in the cumulative columns are rounded to the appropriate number of significant digits. The cumulative volume change at elevation 795 feet represents the total loss of storage capacity to sedimentation.

Elevation (ft)	*1964 Volume (acre-ft)*	*2006 Volume (acre-ft)*	*Volume Change Per Contour (acre-ft)*	*Cumulative Volume Change (acre-ft)*	*Cumulative Reduction in Volume (%)*
795	1,150,000	1,080,740	15,159	**-69,300**	**-6.0%**
790	1,070,000	985,581	9,178	-84,400	-7.9%
787	1,025,000	931,403	-30,270	-93,600	-9.1%
785	960,000	896,673	-12,708	-63,300	-6.6%
780	865,000	814,381	-8,360	-50,600	-5.8%
770	710,000	667,741	-4,495	-42,300	-6.0%
760	580,000	542,236	-3,870	-37,800	-6.5%
750	470,000	436,105	-913	-33,900	-7.2%
740	380,000	347,019	4,053	-33,000	-8.7%
730	310,000	272,965	-14,153	-37,000	-11.9%
720	235,000	212,118	-22,882	-22,900	-9.7%

Table 2: Storage Volume Data for Leesville Lake. Values in the cumulative columns are rounded to the appropriate number of significant digits. The cumulative volume change at elevation 615 feet represents the total loss of storage capacity to sedimentation.

Elevation (ft)	*1964 Volume (acre-ft)*	*2006 Volume (acre-ft)*	*Volume Change Per Contour (acre-ft)*	*Cumulative Volume Change (acre-ft)*	*Cumulative Reduction in Volume (%)*
615	101,400	90,533	-7,141	**-10,900**	**-10.7**%
613	94,960	8,9210	-5,570	1,580	-5.67%
610	85,300	77,970	-2,170	-7,300	-8.6%
605	70,600	65,440	-1,434	-5,200	-7.4%
600	57,200	53,474	-415	-3,700	-6.5%
597	50,300	46,989	-878	-3,300	-6.6%
595	45,700	42,924	-299	-2,800	-6.1%
590	36,000	33,523	-44	-2,500	-6.9%
585	27,800	25,367	352	-2,400	-8.6%
580	21,300	18,515	-2,785	-2,800	-13.1%

Table 3: National Inventory of Dams

Dam	RIVER	Purpose	Storage (acre feet)	Area (sq miles)	Watershed (sq miles)
BEAVERDAM CREEK DAM	BEAVERDAM CREEK	WATER SUPPLY	1363	71	1.4
BENNETTS DAM	TR-SMITH CREEK	RECREATION	53	0	0.0
BERNARD DAM	TR-STANDIFORD CREEK	RECREATION	18	0	0.0
BLUE RIDGE ESTATES DAM	LAYMANTOWN CREEK	RECREATION	88	4	0.6
BOWMANS DAM	TR-WHITE OAK CREEK	RECREATION	34	0	0.0
BURTON DAM	TOMAHAWK CREEK	RECREATION	730	68	7.7
CARVIN COVE DAM	CARVINS CREEK	WATER SUPPLY	20500	640	17.9
FALLING CREEK RESERVOIR DAM	FALLING CREEK	WATER SUPPLY	218	19	1.4
FUZZYS DAM	FRYING PAN CREEK	RECREATION	41	0	0.0
HAMMOCK DAM	TR-PIGG RIVER	RECREATION	45	0	0.0
HOLDRENS DAM	KATES CREEK	RECREATION	62	0	0.0
JONES DAM	TR-CHESTNUT CREEK	RECREATION	22	0	0.0
LEESVILLE	ROANOKE R	HYDROELECTRIC	94960	3270	1505.0
LITTLE FALLING RIVER DAM #1	LITTLE FALLING RIVER	FLOOD CONTROL	232	43	14.1
LOCH HAVEN LAKE DAM	TR-DEER BRANCH CREEK	RECREATION	83	6	1.3
MELODY LAKE DAM	TR-MAGGODEE CREEK	RECREATION	80	10	1.0
MEYER DAM	TR-TERRAPIN CREEK	RECREATION	48	0	0.0
MINK DAM		RECREATION	0	0	0.0
NIAGARA	ROANOKE R	HYDROELECTRIC	425	75	511.0
ORCHARD DAM	TRIB-GLADE CREEK	IRRIGATION	67	9	0.1
ORCHARD LAKE DAM	TR-TINKER CREEK	RECREATION	53	0	0.0
PIGG RIVER DAM	PIGG RIVER	OTHER	50	0	0.0
RAINBOW FOREST DAM		RECREATION	0	0	0.0
SAUNDERS POND DAM	MATTOX CREEK	WATER SUPPLY	36	0	0.0
SMITH MOUNTAIN	ROANOKE R	HYDROELECTRIC	1142000	20600	1024.0
SPRING HOLLOW DAM	TRIB. TO ROANOKE RIVER	WATER SUPPLY	9800	131	0.8
SPRING VALLEY LAKE DAM		RECREATION	0	0	0.0
SUNSET LAKE DAM	TR-BLACKWATER RIVER	RECREATION	48	0	0.0
UPPER BLACKWATER RIVER DAM #4	TRIB-N.F.BLACKWATER RIVER	FLOOD CONTROL	65	9	1.9
UPPER BLACKWATER RIVER DAM #6	TR-BLACKWATER RIVER	FLOOD CONTROL	77	9	2.6
WATSON DAM	TR-HARPEN CREEK	FIRE/FARM POND	33	0	0.0
WINDSOR LAKE DAM	TRIB - BARNHARDT CREEK	RECREATION	79	5	0.2

Table 4: Summary of model calibration results. Median flow values were used for comparison rather than means due to the inherent skew of hydrologic data. Standard log-normal transformations for hydrologic time series data were used to compute statistical moments (Haan, 1994). Model efficiency, estimated as the coefficient of determination r^2, indicated 90% of observed variability was explained by the model.

Moment	Predicted	Observed
median (mm)	1.0	0.7
st. dev. (mm)	3.7	2.4
skew (mm)	10.8	10.3
r^2	0.9	

Table 5: Pre-settlement, 1992, 2001, and alternative Best Management Practices (BMP) scenario sediment yields by subwatershed (tons/ha). The "Change" column is the ratio of "Current" to "Pre-settlement" sediment yield.

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
1	3,447	0.57	1.68	2.9	1.68	1.16	2.33
2	2,732	1.52	2.97	2.0	2.04	1.49	4.33
3	2,789	0.18	0.66	3.6	0.57	0.52	0.90
4	2,377	0.34	0.95	2.8	0.86	0.80	1.25
5	2,851	0.17	0.80	4.7	0.71	0.65	1.05
6	2,511	0.43	1.88	4.3	1.65	1.50	2.64
7	8,932	0.02	0.05	2.4	0.05	0.05	0.06
8	2,221	0.01	0.01	2.0	0.01	0.01	0.01
9	3,556	1.05	2.12	2.0	1.91	1.79	2.42
10	11,824	0.00	0.03	6.0	0.02	0.02	0.03
11	11,388	0.60	1.80	3.0	1.57	1.43	2.26
12	623	0.47	1.46	3.1	1.44	1.43	1.49
13	4,293	0.24	1.15	4.7	0.95	0.83	1.70
14	2,850	0.19	0.45	2.4	0.34	0.28	0.74
15	2,792	0.41	1.15	2.8	1.05	0.99	1.44
16	6,370	0.56	0.82	1.5	0.81	0.81	0.84
17	111	0.46	1.19	2.6	1.17	1.16	1.25
18	8,160	0.49	2.12	4.3	1.91	1.78	2.75
19	456	0.60	1.69	2.8	1.65	1.63	1.77
20	4,792	0.76	2.11	2.8	2.07	2.04	2.24
21	2,444	0.01	0.03	4.2	0.03	0.03	0.03
22	1,382	1.14	3.08	2.7	2.95	2.87	3.37
23	3,518	0.29	0.81	2.8	0.80	0.79	0.84
24	2,852	0.67	2.19	3.3	1.98	1.86	2.68
25	5,176	0.46	1.22	2.7	1.16	1.13	1.34
26	162	0.93	1.97	2.1	1.97	1.97	1.98
27	2,592	0.37	1.07	2.9	0.97	0.91	1.34
28	491	0.70	1.51	2.2	1.40	1.33	1.84
29	93	1.06	1.91	1.8	1.83	1.78	2.09
30	2,384	0.97	2.71	2.8	2.62	2.56	2.92
31	850	0.16	0.45	2.8	0.32	0.25	0.82

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
32	6,317	0.23	0.56	2.4	0.44	0.37	0.89
33	5,181	0.38	1.03	2.7	0.99	0.96	1.13
34	4,016	0.71	1.71	2.4	1.65	1.62	1.84
35	404	0.79	2.02	2.6	1.97	1.94	2.13
36	5,345	1.20	2.98	2.5	2.89	2.84	3.20
37	4,191	1.26	2.67	2.1	2.63	2.61	2.76
38	6,376	0.01	0.06	4.6	0.05	0.05	0.07
39	2,501	0.01	0.05	5.5	0.04	0.04	0.06
40	2,325	1.10	2.87	2.6	2.83	2.80	2.97
41	7,886	0.22	0.93	4.2	0.84	0.79	1.17
42	2,940	0.22	0.86	3.9	0.81	0.78	1.02
43	893	0.17	0.59	3.4	0.49	0.44	0.85
44	2,623	0.19	0.63	3.3	0.47	0.37	1.13
45	13,092	0.00	0.03	6.5	0.03	0.02	0.04
46	2,671	0.18	0.78	4.3	0.73	0.70	0.92
47	363	0.17	0.31	1.8	0.26	0.24	0.45
48	2,732	0.00	0.01	2.8	0.01	0.01	0.02
49	943	0.01	0.05	4.2	0.05	0.05	0.06
50	2,811	0.01	0.07	5.6	0.06	0.06	0.08
51	2,806	0.08	0.28	3.7	0.26	0.25	0.29
52	9,228	0.06	0.22	3.7	0.21	0.20	0.24
53	3,705	0.20	1.65	8.2	1.45	1.32	2.29
54	10	0.01	0.02	1.6	0.02	0.02	0.02
55	1,398	0.10	0.48	4.8	0.44	0.42	0.61
56	719	0.08	0.21	2.6	0.19	0.17	0.28
57	6,657	0.01	0.09	6.8	0.08	0.08	0.10
58	2,522	0.01	0.07	4.7	0.06	0.06	0.07
59	2,459	0.29	0.64	2.2	0.53	0.46	0.94
60	788	0.37	0.64	1.7	0.56	0.51	0.85
61	2,842	0.06	0.08	1.4	0.08	0.08	0.09
62	1,592	0.09	0.31	3.4	0.29	0.27	0.34
63	7,529	0.38	0.78	2.1	0.66	0.58	1.11
64	2,398	0.50	0.98	2.0	0.73	0.58	1.63
65	2,666	0.08	0.15	2.0	0.15	0.14	0.16
66	1,550	0.06	0.16	2.8	0.15	0.14	0.19

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
67	4,485	2.67	4.72	1.8	4.66	4.63	4.80
68	7,436	0.13	0.26	2.0	0.25	0.25	0.27
69	10,632	0.02	0.07	4.2	0.07	0.07	0.08
70	258	3.31	9.83	3.0	8.97	8.46	10.71
71	4,175	0.23	0.88	3.8	0.76	0.69	1.22
72	2,310	0.01	0.02	2.2	0.02	0.02	0.03
73	4,649	0.33	0.97	2.9	0.78	0.67	1.48
74	4,021	0.01	0.05	6.3	0.04	0.04	0.06
75	3,265	0.01	0.07	5.3	0.07	0.06	0.07
76	5,595	0.06	0.17	2.6	0.15	0.14	0.21
77	11,768	0.01	0.04	7.8	0.04	0.04	0.05
78	2,268	0.01	0.02	2.0	0.01	0.01	0.02
79	3,000	0.13	0.38	3.0	0.36	0.35	0.45
80	3,227	0.31	0.72	2.3	0.53	0.43	1.23
81	2,879	0.33	0.71	2.1	0.53	0.43	1.18
82	8,147	0.13	1.04	8.3	0.97	0.93	1.26
83	2,363	0.16	0.43	2.6	0.32	0.25	0.79
84	3,421	0.13	1.84	14.4	1.72	1.66	2.19
85	5,575	0.09	0.77	8.2	0.71	0.67	0.95
86	6,972	0.28	0.51	1.8	0.47	0.45	0.61
87	9,561	0.14	0.78	5.4	0.67	0.60	1.12
88	2,973	3.68	7.30	2.0	6.81	6.51	7.82
89	10,547	5.03	10.75	2.1	9.69	9.05	11.84
90	21	0.33	0.94	2.9	0.92	0.90	0.98
91	3,600	0.10	0.21	2.0	0.20	0.19	0.22
92	3,495	0.10	0.19	2.0	0.18	0.17	0.20
93	4,898	0.05	0.22	4.1	0.21	0.20	0.24
94	2,601	0.78	0.98	1.3	0.97	0.97	0.99
95	5,536	0.45	0.61	1.4	0.58	0.57	0.68
96	2,508	0.01	0.02	3.1	0.02	0.02	0.03
97	10,951	0.01	0.03	5.2	0.03	0.02	0.04
98	3,478	0.01	0.11	13.0	0.11	0.11	0.12
99	3,851	0.24	7.11	29.2	6.91	6.80	7.66
100	2,284	3.03	7.17	2.4	6.59	6.25	7.77
101	2,225	3.42	5.40	1.6	5.21	5.10	5.61

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
102	511	0.58	3.81	6.6	3.31	3.00	5.13
103	3,194	0.55	2.24	4.0	1.78	1.50	3.44
104	2,451	0.01	0.01	1.3	0.01	0.01	0.01
105	286	0.01	0.12	19.0	0.12	0.12	0.13
106	3,704	0.69	2.38	3.5	1.91	1.63	3.53
107	2,269	0.81	2.40	2.9	1.77	1.39	3.91
108	5,049	0.12	2.19	19.0	2.14	2.11	2.35
109	2,439	0.09	0.47	5.4	0.46	0.45	0.50
110	2,378	0.01	0.10	14.7	0.09	0.09	0.11
111	4,592	0.01	0.21	27.7	0.21	0.20	0.23
112	4,997	0.03	0.56	16.2	0.53	0.52	0.64
113	2,632	0.10	0.57	5.9	0.52	0.50	0.69
114	5,113	0.00	0.01	3.7	0.01	0.01	0.02
115	2,467	0.00	0.01	#DIV/0!	0.01	0.01	0.01
116	18,253	0.34	1.06	3.2	0.83	0.69	1.68
117	6,581	0.23	0.67	3.0	0.52	0.42	1.10
118	9,014	0.19	0.75	3.9	0.58	0.48	1.29
119	2,887	0.18	0.60	3.3	0.42	0.31	1.16
120	682	0.08	0.44	5.8	0.41	0.40	0.52
121	3,439	0.12	0.71	5.7	0.64	0.60	0.91
122	2,905	0.03	0.18	5.4	0.15	0.13	0.27
123	690	0.01	0.13	20.0	0.11	0.10	0.18
124	8,248	0.59	1.20	2.0	1.12	1.07	1.40
125	1,598	0.10	0.40	3.9	0.36	0.34	0.53
126	2,773	0.25	0.90	3.6	0.64	0.48	1.67
127	6,894	0.27	0.99	3.7	0.78	0.65	1.54
128	4,653	0.13	0.58	4.6	0.47	0.41	0.89
129	2,488	0.14	0.83	5.9	0.76	0.72	1.03
130	908	0.01	0.02	3.2	0.02	0.02	0.03
131	2,539	0.06	0.21	3.4	0.20	0.19	0.23
132	6,100	0.02	0.07	4.5	0.07	0.07	0.08
133	1,540	0.01	0.12	9.9	0.12	0.11	0.13
134	2,480	0.14	0.41	3.0	0.34	0.29	0.64
135	2,564	0.20	0.56	2.9	0.41	0.32	1.02
136	3,798	0.33	1.00	3.0	0.72	0.55	1.81

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
137	627	0.38	2.04	5.4	1.67	1.45	3.02
138	3,105	0.01	0.04	3.5	0.04	0.03	0.05
139	2,648	0.01	0.08	7.7	0.08	0.08	0.09
140	402	0.13	0.46	3.5	0.38	0.34	0.65
141	3,579	0.30	0.98	3.3	0.73	0.58	1.67
142	5,674	0.32	1.20	3.7	0.91	0.73	2.06
143	2,778	1.72	1.88	1.1	1.51	1.30	2.92
144	2,434	0.01	0.08	12.8	0.08	0.08	0.10
145	3,049	0.01	0.01	1.5	0.01	0.01	0.01
146	11,867	0.46	2.26	4.9	1.90	1.68	3.10
147	1,452	0.31	1.49	4.8	1.22	1.06	2.29
148	4,250	0.51	0.98	1.9	0.88	0.82	1.23
149	386	0.09	0.18	2.0	0.16	0.15	0.24
150	7,443	0.01	0.07	6.7	0.06	0.06	0.07
151	3,984	0.01	0.04	3.9	0.04	0.03	0.05
152	1,027	0.10	0.23	2.3	0.17	0.14	0.42
153	3,855	0.14	0.54	4.0	0.47	0.43	0.77
154	4,344	0.88	10.31	11.7	9.79	9.48	11.58
155	4,047	0.74	9.55	12.9	9.13	8.88	10.59
156	417	0.13	0.32	2.5	0.25	0.20	0.56
157	2,644	0.13	0.73	5.7	0.65	0.59	1.00
158	2,969	0.15	0.92	6.3	0.79	0.71	1.33
159	2,202	0.12	0.44	3.6	0.35	0.29	0.73
160	2,268	0.69	3.16	4.6	2.92	2.77	3.76
161	3,697	0.48	2.19	4.5	1.84	1.63	3.06
162	2,959	0.19	0.67	3.5	0.56	0.49	1.00
163	898	0.14	0.62	4.5	0.52	0.46	0.95
164	10,668	0.28	1.22	4.3	1.00	0.87	1.84
165	15,729	0.01	0.04	7.4	0.03	0.03	0.06
166	1,477	0.11	0.33	3.0	0.29	0.26	0.47
167	4,850	0.14	1.03	7.1	0.88	0.78	1.51
168	2,631	0.47	1.54	3.3	1.33	1.20	1.99
169	1,027	0.10	0.53	5.1	0.44	0.39	0.80
170	2,583	0.33	1.16	3.5	1.12	1.09	1.31
171	2,554	0.18	0.97	5.3	0.81	0.71	1.43

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
172	2,471	0.31	0.63	2.1	0.53	0.47	0.89
173	5,933	0.19	0.63	3.3	0.53	0.46	0.95
174	3,524	0.11	0.62	5.7	0.53	0.48	0.89
175	10,201	0.13	1.01	8.0	0.90	0.83	1.37
176	3,046	0.19	0.93	5.0	0.83	0.78	1.23
177	119	0.08	0.16	1.9	0.12	0.10	0.27
178	2,918	0.17	0.91	5.3	0.76	0.67	1.37
179	318	0.19	0.61	3.3	0.42	0.30	1.19
180	2,475	0.13	1.17	8.9	1.08	1.02	1.45
181	513	0.13	1.06	7.8	0.94	0.86	1.45
182	7,208	0.19	0.94	4.9	0.75	0.63	1.50
183	4,261	0.21	0.78	3.8	0.56	0.43	1.39
184	853	0.14	0.43	3.1	0.27	0.17	0.94
185	2,936	0.24	1.04	4.2	0.77	0.61	1.80
186	815	0.19	0.85	4.6	0.75	0.69	1.14
187	2,255	0.16	0.39	2.5	0.31	0.27	0.61
188	5,328	0.20	1.21	6.1	1.04	0.93	1.72
189	9,887	0.22	1.03	4.8	0.89	0.80	1.46
190	5,284	0.14	1.27	8.9	1.13	1.04	1.72
191	672	0.14	1.28	9.2	1.18	1.11	1.62
192	3,001	0.19	0.51	2.7	0.39	0.32	0.83
193	2,557	0.26	0.82	3.2	0.75	0.71	1.03
194	1,909	0.11	0.46	4.3	0.36	0.30	0.79
195	4,642	0.00	0.03	7.3	0.03	0.02	0.04
196	7,465	0.18	0.68	3.8	0.59	0.54	0.94
197	2,445	0.00	0.02	5.7	0.02	0.01	0.03
198	17,473	0.13	0.62	4.8	0.53	0.47	0.93
199	2,996	0.10	0.70	6.9	0.62	0.57	0.96
200	1,454	0.21	2.55	12.4	2.40	2.31	2.97
201	3,772	0.25	0.51	2.1	0.43	0.38	0.75
202	5,740	0.19	0.69	3.7	0.54	0.45	1.14
203	3,007	0.20	0.84	4.1	0.68	0.59	1.29
204	5,113	0.14	0.59	4.2	0.47	0.40	0.95
205	2,327	0.10	0.28	2.9	0.24	0.21	0.42
206	2,751	0.14	0.96	7.0	0.83	0.75	1.38

Watershed	Area (ac)	Pre-settlement	Current	Change	50% BMPs	80% BMPs	No BMPs
207	4,925	0.15	0.63	4.3	0.53	0.46	0.98
208	1,318	0.11	0.47	4.2	0.35	0.27	0.88
209	16,705	0.15	0.55	3.7	0.44	0.37	0.90
210	2,637	0.14	0.38	2.6	0.27	0.21	0.70
211	664	0.10	0.41	3.9	0.32	0.26	0.70
212	8,534	0.19	0.73	3.9	0.58	0.49	1.24
213	3,387	0.15	0.62	4.0	0.51	0.44	0.97

APPENDICES

APPENDIX I: SMITH MOUNTAIN PROJECT SEDIMENTATION STUDY PLAN

SEDIMENTATION

STUDY PLAN

Smith Mountain Project

Application for New License

FERC Project No. 2210

October 2005

1. Introduction

Appalachian Power Company (Appalachian) is making application to the Federal Energy Regulatory Commission (FERC) for a new license for the Smith Mountain Project (No. 2210), located on the Roanoke River in south-central Virginia. The process selected by Application for applying for a new license is the Integrated Licensing Process (ILP), as defined under the rules and regulations of the FERC (18 CFR Part 5). As part of this licensing process, Appalachian has solicited input from stakeholders including government agencies, local governments, non-governmental organizations, and the public to identify potential project-related issues needing to be addressed during the licensing process.

Appalachian filed preliminary study plans on April 11, 2005. Initial study plan meetings were held on May 12th and 13th to review and discuss proposed study plans. Study plan work groups were established and a follow up meeting was held June 24th, 2005 to further review and discuss the Sedimentation Study Plan. Appalachian filed its revised study plan on August 11, 2005. The FERC issued its Study Plan Determination for the Smith Mountain Project on September 9, 2005. This study plan addresses the issue of Sedimentation for both Smith Mountain and Leesville lakes and reflects the comments of the FERC as contained in the September 9, 2005 Study Plan Determination.

2. Background

The Smith Mountain Project is an existing two dam, two reservoir, combination conventional hydroelectric and pumped storage project located on the headwaters of the Roanoke River in Bedford, Campbell, Franklin, and Pittsylvania Counties in Virginia. The conventional hydroelectric development is identified as the Lower or Leesville Development, whereas the pumped storage development is identified as the Upper or Smith Mountain Development. The Smith Mountain Development has five generating units, with a combined generating capacity of 586 MW. The Leesville Development has two generating units, with a combined generating capacity of 50 MW.

The Smith Mountain Dam has a maximum height of 235 feet above the streambed. The reservoir behind the dam has a surface area of 20,600 acres at an operating pool elevation of 795.0 NGVD. At that elevation, the estimated storage volume of the Smith Mountain Reservoir is 1,142,000 acre-feet. The Leesville Dam has a maximum height of 94 feet above the streambed. The reservoir surface area is 3,270 acres and storage capacity is 94,900 acre-feet at an operating pool elevation of 613.0 NGVD. Figures 1-4 and 1-5 of the Pre-Application Document (PAD) filed by Appalachian with the Commission October 25, 2004 respectfully show the surface areas and storage volumes for each reservoir at various elevations. Those curves were developed prior to construction of the facilities for the Smith Mountain and Leesville Developments and were based upon the mapping available at that time.

The Roanoke River Basin includes large areas of steep, denuded hillsides, from which intense rains wash sizable quantities of debris. In addition, the main streams carry large quantities of silt. The soils through the basin are developed from a variety of parent bedrock. Within the upper reaches of the watershed, soils are developed from sedimentary bedrock and colluvium deposited along the riverine riparian zones located above the confluence of Tinker Creek and the Roanoke River. These soils form on gentle to steep slopes developing soil profiles with high infiltration rates.

In general, deep residual soils are characteristic of the igneous and metamorphic rocks below the confluence of Tinker Creek and the Roanoke River. These soils reflect a parent source of saprolite with a considerable portion being sandy in nature. Around the boundary for the Smith Mountain and Leesville developments, the Cecil-Madison soil complex is the dominant type of soil. The Madison soil is for the most part classified as "highly erodibile" having a surface of approximately 7-inches of thick brown loam and a subsoil of 7 to 54 inches consisting of yellowish red clay loam with common fine and medium mica.

Smith Mountain is mantled by Goldston-Tatum soil complex with both soil types developed along moderate to steep slopes and having a high erosion potential. The Goldston soil makes up 60% of the complex and is characterized as a very channery silt loam with moderately rapid permeability. Bedrock is generally 22 inches deep while the Tatum soil may extend to a depth of 54 inches. The Tatum soil is characterized as a silty clay loam that also has low natural organic material and fertility and makes up 30 % of the soil complex. The remaining 10% is predominantly rock outcrop and other minor soil types.

The Cecil-Madison-Cullen soil complex is dominant downstream of Smith Mountain dam along the Leesville Reservoir. The Cecil-Madison soils are similar to the previous soil descriptions and comprise 60% and 25% of the soil complex, respectively. The Cullen soil type comprises 10% of the soil complex and is a very deep soil with depth to bedrock in excess of 90 inches. The soil is characterized as a red silty clay with brownish mottles and moderate permeability. It exhibits a medium erosion potential that transitions to a high potential with slopes greater than 7% to 15%. The remaining is predominantly rock outcrop and other minor soils.

Downstream of the Leesville development, soils are similar to those described above for the soils surrounding the project reservoirs. They are highly erodible containing silts, sands, and fine clays. These soils are of the type that would easily slump during rapid drawdown and be easily eroded by flowing water. The streambed contains small gravels along with some bars of large boulders.

Observations indicate that sediment deposits have formed within Smith Mountain and Leesville lakes, especially in the back areas of coves. There is no available information regarding the extent that sediment has deposited within the reservoirs over the years the Smith Mountain Project has been in existence or where the sediments may primarily be coming from.

3. Study Objectives

1. Update the storage volume curves for the Smith Mountain and Leesville Developments.
2. Determine those areas where sediment accumulation may be most prevalent.
3. Identify the extent of problems associated with the accumulation of sediments within the project reservoirs, including impacts on recreation, the fisheries, and other project features.

4. Determine the rate of sediment accumulation over the term of the existing license.
5. Identify the sources of sediments discharging into the reservoirs.
6. Investigate methods and/or programs to reduce the introduction of sediments into and/or amounts of sediments in the project reservoirs.

4. Relicensing Relevance

Sedimentation accumulation within the project reservoirs can have a significant impact on recreational uses, shoreline development, and project generation. Identification of where sediment accumulation may be most pronounced will provide information relative to the development of potential control measures, if needed.

5. Methods and Geographic Scope

Appalachian will have bathymetric maps of the bottom contours of both Smith Mountain and Leesville lakes prepared, and will also simultaneously have the portions of the reservoirs from the water surface to elevation 800 ft. NGVD mapped. The contours will be at 2-feet intervals extending below elevation 800 ft. NGVD for the Smith Mountain Development and 620 ft. NGVD for the Leesville Development. The geographic scope of the mapping will be the project boundaries as defined by the above referenced contour elevations for each development.

The bathymetry mapping of the reservoirs will be accomplished utilizing boats mounted with single beam and multi-beam sonar equipment to measure water depths along with mobile GPS receivers to establish coordinates. The data will be acquired and processed using hydrographic software. The shoreline mapping from waters edge to elevations 800 ft. NGVD and 620 ft. NGVD at Leesville will be done using aerial photography. The aerial photographs will be digitized and developed using 1”=100’ scale contour maps with 2 foot contours.
From the mapping, Surface Area and Storage Volume Capacity curves will be generated. Those curves will be similar to those contained under the Figures 1-4 and 1-5 from the Pre-Application Document (PAD) filed by Appalachian with the FERC on October 25, 2004. The curves based upon existing conditions will be compared to those contained under Figures 1-4 and 1-5 to determine if there has been a loss of storage volume and at what elevation within the reservoirs those losses occur. By identifying at what elevation the storage losses occur, it may be possible to identify where accumulations are most apparent.

The mapping generated for this study plan will be compared to any mapping available that shows the contours of the areas encompassed by the Smith Mountain and Leesville reservoirs prior to their being formed. Existing mapping could include contour mapping prepared for the construction of the Smith Mountain and Leesville facilities, USGS mapping of the site prior to construction of the facilities, or other mapping that is available. The new contour mapping will be compared to existing mapping for areas that show significant change. The areas where changes are noted will be identified and the volume of sediment deposits calculated. The rate of sediment accumulation at each area will also be determined based upon the volumes calculated and the time the project has been in operation.

Appalachian will also consult with other hydroelectric project operators, the U.S. Army Corps of Engineers, state agencies and others with experience regarding the control of the introduction of sediment into waterways to determine possible methods that could be utilized at the Smith Mountain Project. These consultations should include the ongoing cooperative effort between the U.S. Army Corps of Engineers and Appalachian whereby the control of debris and sediments entering Appalachian's Claytor Hydroelectric Project are being studied.

Aerial photography of the Smith Mountain Project extending to just beyond Route 40 to the south, U.S. Route 29 to the east, the Blue Ridge Parkway to the west, and towards Bedford, Virginia on the north will be utilized to identify potential sources of debris migrating to Smith Mountain and Leesville lakes. Information from related studies being performed by others (i.e. government agencies, local governments, and non-governmental organizations) during the period this study is taking place will also be obtained to provide data regarding sources of sedimentation.

6. Analysis and Reporting of Results

The field surveys will be accomplished in 2005 and/or 2006. Periodic meetings with the stakeholders having a direct interest with the Sedimentation Study Plan will be held as data becomes available. Data collected will be conveyed through update reports and at progress meetings. The data will be made available in printed form or electronically depending on the amount of data to be made available at any time.

The results of the field work will be detailed in a final report. The final report will be prepared in consultation with the appropriate stakeholders and include a review of literature, explanations of any analyses made, and the conclusions reached. The results of the report will be utilized to determine the need for remedial measures and where those measures may be most effective and the types of measures that should be considered.

At a minimum, progress reports will be provided to the FERC as well as the stakeholders involved in the relicensing of the Smith Mountain Project in March 2006 and September 2006. Additional progress reports will be provided to the stakeholders as information becomes available and meetings will be scheduled with stakeholders at key decision points to seek input and recommendations. All information will be made available in printed format as well as electronic format in accordance with the Information Distribution Protocol for the relicensing of the Smith Mountain Project. Meetings will be scheduled and stakeholders notified in accordance with the Communications Protocol for the relicensing of the Smith Mountain Project. Individuals, agencies, governments, etc… will be given at least thirty (30) days time prior to a meeting to review the information to be discussed. Information will also be posted on the web site established for the relicensing of the Smith Mountain Project (www.smithmtn.com) as appropriate.

APPENDIX II: COMPREHENSIVE SWAT MODEL DESCRIPTION AND METHODS

SWAT was developed at the USDA-Agricultural Research Service (ARS) and is based on the SWRRB (Simulator for Water Resources in Rural Basins; Arnold et al., 1990) model for application to large, complex rural basins. SWRRB is a distributed version of CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems; Knisel, 1980), which can be applied to a basin with a maximum of ten subbasins. SWAT is an extended and improved version of SWRRB, running simultaneously in several hundred subbasins. SWAT also includes elements of GLEAMS (Groundwater Loading Effects on Agricultural Management Systems; Leonard et al., 1987), and EPIC (Erosion-Productivity Impact Calculator; Williams et al., 1984). The ArcView pre- and post-processor interface for SWAT, AVSWAT, has been developed by Blackland Research Center, a Texas Agricultural Experiment Station part of Texas A&M University System in Temple, Texas, in collaboration with Grassland Soil and Water Research Lab, a USDA-ARS laboratory in Temple, Texas (Di Luzio, et al., 2004).

SWAT divides a watershed into subbasins. The use of subbasins in a simulation is beneficial when different areas of the watershed are dominated by land uses or soils dissimilar enough in properties to impact hydrology. Input data for each subbasin are grouped into the following categories:

- climate;
- hydrologic response units (HRUs);
- ponds and wetlands;
- groundwater;
- main channel draining the subbasin;
- soils;
- vegetation (land cover); and
- land use and land management.

Hydrologic response units are areas within each subbasin that have been lumped together to comprise a single land cover, soil and management combination.

The water balance equation is the driving force behind all the processes accounted for in the watershed simulation. In order to accurately predict the movement of pesticides, sediments or nutrients, the hydrologic cycle simulated by the model must conform to what is happening in the watershed. SWAT simulates the hydrology of a watershed in two distinct phases:

- Land Phase -The land phase of the hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings to the main channel in each subbasin;
- Water Phase -The water or routing phase of the hydrologic cycle, which can be defined as the movement of water, sediments, etc. through the channel network of the watershed to the outlet.

A distributed SCS curve number is generated for the computation of overland flow runoff volume, given by the standard SCS runoff equation (USDA, 1986). A soil database is used to obtain information on soil type, texture, depth and hydrologic classification. In SWAT, soil profiles can be divided into ten layers. Infiltration is defined in SWAT as precipitation minus runoff and evaporation. Infiltration moves into the soil profile where it is routed through the soil layers. A storage routing flow coefficient is used to predict flow through each soil layer, with flow occurring when a layer exceeds field capacity. When water percolates past the bottom layer, it enters the shallow aquifer zone (Arnold et al., 1993).

Channel transmission loss and pond/reservoir seepage replenishes the shallow aquifer while the shallow aquifer interacts directly with the stream. Flow to the deep aquifer system is effectively lost and cannot return to the stream (Arnold et al., 1993). Based on surface runoff calculated using the SCS runoff equation, excess surface runoff not lost to other functions makes its way to the channels where it is routed downstream. Sediment yield used for instream transport is determined from the Modified Universal Soil Loss Equation (MUSLE) (Arnold, 1992). For sediment routing in SWAT, deposition calculations are based on fall velocities of various sediment sizes. Rates of channel degradation are determined from Bagnold's (1977) stream power equation. Sediment size is estimated from the primary particle size distribution for soils the SWAT model obtains from the STATSGO (USDA 1992b) database. Stream power also is accounted for in the sediment routing routine, and is used for calculation of re-entrainment of loose and deposited material in the system until all of the material has been removed.

AVSWAT (ArcView SWAT) is a complete preprocessor, interface and postprocessor of the hydrological model SWAT (Di Luzio, 2004). The current version of AVSWAT runs in conjunction with ArcView 3.x. The user is provided with a set of numerical routines for watershed delineation, definition and editing of the hydrological and agricultural management inputs, running and calibration of the model. The extension and the model are user-friendly tools for the watershed scale assessment and control of the agricultural and urban sources of water pollution.

AVSWAT is organized in several linked tools grouped in the following categories:

- Watershed delineation;
- Land use and soil definition;
- Editing of model databases;
- Definition of weather stations;
- Input parameterization and editing;
- Model run;
- Read and map-chart results; and
- Calibration tool.

A more detailed description of these tools is provided in the SWAT users manual (Nietsch, et. al., 2002).

APPENDIX III: MINIMUM STANDARDS FOR EROSION AND SEDIMENT CONTROL

- ❑ Adequacy of all channels and pipes shall be verified:
  - ➢ Natural Channels – use 2-year storm event
  - ➢ Manmade Channels – use 2- and 10-year storm event
  - ➢ Pipe and Pipe Systems – use 10-year storm event
- ❑ If existing natural receiving channels or previously constructed man-made channels or pipes are not adequate, the applicant shall provide channel, pipe, or pipe system improvement or provide a combination of channel improvement, site design, stormwater detention, or other measures that is satisfactory to the program authority to prevent downstream erosion.
- ❑ Provide evidence of permission to make the improvements
- ❑ If the applicant chooses an option that includes stormwater detention he shall obtain approval from the locality of a plan for maintenance of the detention facilities. The plan shall set forth the maintenance requirements of the facility and the person responsible for performing the maintenance.
- ❑ Outfall from a detention facility shall be discharged to a receiving channel, and energy dissipators shall be placed at the outfall of all detention facilities as necessary to provide a stabilized transition from the facility to the receiving channel.
- ❑ Increased volumes of sheet flows that may cause erosion or sedimentation on adjacent property shall be diverted to a stable outlet, adequate channel, pipe or pipe system, or to a detention facility
- ❑ In applying these stormwater runoff criteria, individual lots or parcels in a residential, commercial or industrial development shall not be considered to be separate development projects. Instead, the development as a whole shall be considered to be a single development project.
- ❑ All measures used to protect properties and waterways shall be employed in a manner that minimizes impacts on the physical, chemical and biological integrity of rivers, streams and other waters of the state

The complete, unedited version of the Virginia Erosion and Sediment Control Regulations (4VAC50-30) as codified in the Virginia Administrative Code is available through the Commonwealth of Virginia website at www.vipnet.org/vipnet/portal/government. Additional information on Virginia's Erosion & Sediment Control and Stormwater Management Programs is available on DCR's website at www.dcr.state.us or from DCR Watershed Offices.

Questions? Comments?

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Division of Soil & Water Conservation

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DCR
Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL AND RECREATIONAL RESOURCES

Virginia Erosion and Sediment Control Regulations

Minimum Standards
Section 4VAC50-30-40

All land-disturbing activities undertaken on private and public lands in the Commonwealth of Virginia must meet the 19 "minimum standards" for erosion and sediment control (ESC) in Section 4VAC50-30-40 of the Virginia Erosion and Sediment Control Regulations. The applicant who submits the ESC plan to the program authority for approval is responsible for ensuring compliance with the minimum standards that apply to his/her activities. A condensed version of the minimum standards is provided below. Please refer to the Regulations for a complete, unedited copy of the minimum standards.

(1) Soil Stabilization.

- ❑ Permanent or temporary soil stabilization shall be applied to denuded areas within seven days after final grade is reached on any portion of the site
- ❑ Temporary soil stabilization shall be applied within seven days to denuded areas that may not be at final grade but will remain dormant for longer than 30 days, but less than one year
- ❑ Permanent stabilization shall be applied to areas that are to be left dormant for more than one year

(2) Soil Stockpile Stabilization. During construction, soil stockpiles and borrow areas shall be stabilized or protected with sediment trapping measures. Temporary protection and permanent stabilization shall be applied to all soil stockpiles on site and borrow areas or soil intentionally transferred off site.

(3) Permanent Stabilization. Permanent vegetative cover shall be established on denuded areas not otherwise permanently stabilized.

Permanent vegetation shall not be considered established until a ground cover is achieved that is:

- Uniform
- Mature enough to survive
- Will inhibit erosion

(4) Sediment Basins & Traps. Sediment basins, sediment traps, perimeter dikes, sediment barriers, and other measures intended to trap sediment shall be constructed as a first step in any land-disturbing activity and shall be made functional before upslope land disturbance takes place.

(5) Stabilization of Earthen Structures. Stabilization measures shall be applied to earthen structures such as dams, dikes, and diversions immediately after installation.

(6) Sediment Traps & Sediment Basins. Sediment traps and basins shall be designed and constructed based upon the total drainage area to be served by the trap or basin as follows:

Sediment Traps

- Only control drainage areas less than three acres
- Minimum storage capacity of 134 cubic yards per acre of drainage area

Sediment Basins

- Control drainage areas greater than or equal to three acres
- Minimum storage capacity of 134 cubic yards per acre of drainage area
- The outfall system shall, at a minimum, maintain the structural integrity of the basin during a twenty-five year storm of 24-hour duration

(7) Cut and Fill Slopes Design & Construction. Cut and fill slopes shall be designed and constructed in a manner that will minimize erosion. Slopes found to be eroding excessively within one year of permanent stabilization shall be provided with additional slope stabilizing measures until the problem is corrected.

(8) Concentrated Runoff Down Slopes. Concentrated runoff shall not flow down cut or fill slopes unless contained within an adequate temporary or permanent channel, flume, or slope drain structure.

(9) Slope Maintenance. Whenever water seeps from a slope face, adequate drainage or other protection shall be provided.

(10) Storm Sewer Inlet Protection. All storm sewer inlets made operable during construction shall be protected so that sediment-laden water cannot enter the stormwater conveyance system without first being filtered/treated to remove sediment.

(11) Stormwater Conveyance Protection. Before newly constructed stormwater conveyance channels or pipes are made operational, adequate outlet protection and any required temporary or permanent channel lining shall be installed in both the conveyance channel and the receiving channel.

(12) Work in Live Watercourse. When work in a live watercourse is performed:

- Precautions shall be taken to minimize encroachment, control sediment transport, and stabilize the work area to the greatest extent possible during construction
- Nonerodible material shall be used for the construction of causeways and cofferdams
- Earthen fill may be used for these structures if armored by nonerodible cover materials

(13) Crossing Live Watercourse. When a live watercourse must be crossed by construction vehicles more than twice in any six-month period, a temporary vehicular stream crossing constructed of nonerodible material shall be provided.

(14) Regulation of Watercourse Crossing. All applicable federal, state and local regulations pertaining to working in or crossing live watercourses shall be met.

(15) Stabilization of Watercourse. The bed and banks of a watercourse shall be stabilized immediately after work in the watercourse is completed.

(16) Underground Utility Line Installation. Underground utility lines shall be installed in accordance with the following standards in addition to other applicable criteria:

- No more than 500 linear feet of trench may be opened at one time
- Excavated material shall be placed on the uphill side of trenches
- Effluent from dewatering operations shall be filtered or passed through an approved sediment trapping device, or both, and discharged in a manner that does not adversely affect flowing streams or off-site property
- Material used for backfilling trenches shall be properly compacted in order to minimize erosion and promote stabilization
- Restabilization shall be accomplished in accordance with these regulations
- Comply with applicable safety regulations

(17) Vehicular Sediment Tracking. Where construction vehicle access routes intersect paved or public roads:

- Provisions shall be made to minimize the transport of sediment by vehicular tracking onto the paved surface
- Where sediment is transported onto a paved or public road surface, the road surface shall be cleaned thoroughly at the end of each day
- Sediment shall be removed from the roads by shoveling or sweeping and transported to a sediment control disposal area. Street washing shall be allowed only after sediment is removed in this manner

(18) Removal of Temporary Measures. All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization or after the temporary measures are no longer needed, unless otherwise authorized by the program authority. Trapped sediment and the disturbed soil areas resulting from the disposition of temporary measures shall be permanently stabilized to prevent further erosion and sedimentation.

(19) Stormwater Management. Properties and waterways downstream from development sites shall be protected from sediment deposition, erosion, and damage due to increases in volume, velocity, and peak flow rate of stormwater runoff for the stated frequency storm of 24-hour duration in accordance with the following standards and criteria:

- Concentrated stormwater runoff leaving a development site shall be discharged directly into an adequate natural or man-made receiving channel, pipe, or storm sewer system. For those sites where runoff is discharged into a pipe or pipe system, downstream stability analyses at the outfall of the pipe or pipe system shall be performed.

New River Watershed Yellowpage

A

Agriculture

Conservation plans and assistance

Dept. of Conservation & Recreation (DCR), Dublin.............. (540) 643-2590

USDA Natural Resources Conservation Service (NRCS) State office (804) 287-1671

Christiansburg Service Center (540) 382-3262

Galax Service Center (540) 236-7191

Wytheville Service Center (540) 228-3164

Big Walker Soil & Water Conservation District (SWCD)........... (540) 228-3164

New River SWCD......... (540) 236-7191

Skyline SWCD .... (540) 382-3262

Tazewell SWCD .... (540) 988-9588

Virginia Cooperative Extension Service (VCE) - see local county govt. listing

Cost-share funding

DCR, Kelly Baker .... (540) 643-2591

DCR, state office ...... (804) 371-7330

NRCS – Conservation Reserve Program (CRP), Environmental Quality Incentive Program (EQIP), Wildlife Habitat Incentive Program (WHIP) – see above

SWCDs – BMP Cost-share program, BMP tax credit program, Nutrient Management Equipment Tax Credit Program, Conservation Reserve Enhancement Program (CREP) – see listings above

Agricultural Stewardship Act

SWCDs – see listing above

Va. Dept. of Agriculture and Consumer Services (VDACS) ... (804) 786-2658

Nutrient Management

DCR, Dublin, Dean Gall (540) 643-2592

DCR state office .... (804) 371-0061

Virginia Cooperative Extension - see local govt. listing

Air Quality

Dept. of Environmental Quality (DEQ) Air programs, DEQ state office ... (804) 698-4140 or 1(800) 592-5482

DEQ Southwest Regional Office, Abingdon .... (540) 676-4800

DEQ West Central Regional Office, Roanoke .... (540) 562-6700

D

Dams

DCR, Dam Safety Program (804) 786-1369

NRCS-PL566 Watershed Protection Projects, State Office Engineering Team .... (804) 287-1688

Local SWCD – see previous listing

Army Corps of Engineers, Huntington District - Ben Borda.... (304) 529-5712

E

Easements

Canaan Valley Institute, Staunton office (540) 887-9898

Local SWCDs – see Agriculture listings

The Nature Conservancy (804) 295-6106

Virginia Outdoors Foundation (804) 225-2147

Western Virginia Land Trust (540) 985-0000

Endangered Species and Habitat Protection

DCR, Natural Heritage programs, state office .... (804) 786-7951

Dept. of Game & Inland Fisheries state office .... (804) 367-1000

VDACS .... (804) 371-0209

U.S. Fish & Wildlife Service, Virginia office............................(804) 693-6694

Environmental Education

Agriculture in the Classroom Virginia Farm Bureau Federation (804) 784-1374

Envirothon, Va. Association of Soil and Water Conservation Districts (804) 559-0324 or local SWCDs

Project Learning Tree, Dept. of Forestry.....................(804) 834-2300

Project WET, Dept. of Environmental Quality..........................(804) 698-4442

Project WILD, Dept. of Game and Inland Fisheries..........(804) 367-1000

Project Underground ... (540) 831-4057

Virginia Cooperative Extension 4-H Program, local Extension office, see local govt. listing

Virginia Museum of Natural History, Blacksburg .... (540) 231-4080

Virginia Naturally

Environmental Education website: http://www.VaNaturally.com

Erosion Control and Stormwater Management

DCR, Chuck Dietz .... (540) 643-2593

DCR, Tom Roberts ..... (540) 643-2594

Local SWCD – see previous listing

Bland Co. .... (540) 688-4622

Blacksburg .... (540) 961-1126

Carroll Co. .... (540) 728-3331

Christiansburg .... (540) 382-6128

Dublin .... (540) 674-4798

Floyd Co. .... (540) 745-9359

Galax .... (540) 236-7297

Giles Co. .... (540) 921-2525

Grayson Co. .... (540) 773-2471

Montgomery Co. .... (540) 384-2090

Narrows .... (540) 726-2423

Patrick .... (540) 694-4143

Pearisburg .... (540) 921-1222

Pulaski .... (540) 994-8617

Pulaski Co. .... (540) 980-7710

Radford .... (540) 731-3604

Roanoke Co. .... (540) 772-2080

Tazewell Co. .... (540) 988-7441

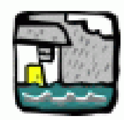
Wythe Co. .... (540) 223-6020

Wytheville .... (540) 223-3339

F

Flood Protection and Flood Plain Management

DCR - Dam Safety Program (804) 371-6135



NRCS – Emergency Watershed Protection (804) 287-1688

USDA, Farm Service Agency, state office...................(804) 287-1500

Forestry

Virginia Dept. of Forestry (DOF), state office, Charlottesville (804) 977-6555

Area .... see local government listings

George Washington/Jefferson National Forest .... (540) 265-5100

NRCS (Forest Incentive Program – FIP), NRCS State office ..... (804) 287-1671

Virginia Forestry Assoc. (804) 741-0836

Virginia state government homepages

http://www.state.va.us

DCR webpage: www.dcr.state.va.us

G

Grants & incentive programs

DCR, state office .... (804) 786-2064
Virginia Environmental Endowment
(804) 644-5000
DEQ, state office............(804) 698-4330
NRCS, state office .... (804) 287-1671
DOF, state office .... (804) 977-6555
DGIF, state office .... (804) 367-1000
Canaan Valley Institute...(540) 887-9898
New River-Highlands RC&D Council
(540) 228-2879

Groundwater

DEQ, Water Programs....(804) 698-4109
DCR, Virginia Karst Program
(540) 831-4056
Virginia Dept. of Health, state office
(804) 786-6277
Local Health Dept. - see local govt. listing
Virginia Water Resources Research Center, Blacksburg ..... (540) 231-5624

H

Historical resources

Dept. of Historical Resources
(804) 786-3143
Local museum, courthouses.....see local listings
State Library of Virginia
(804) 786-7117

L

Landscape management for the homeowner

Virginia Cooperative Extension - see local government listing

M

Maps, including geographic information systems (GIS)

Virginia Dept. of Mines, Minerals and Energy - State office, Charlottesville (topo maps and geographical information) ....(804) 951-6340
Local Planning District commissions
NRCS - see previous listing
U.S. Geological Survey
(800) USA-MAPS, USGS homepage: http://www.usgs.gov

P

Planning

Mt. Rogers Planning District Commission (PDC) ..... (540) 744-2231
New River PDC .... (540) 639-9313
Local County Planning Dept. - see local govt. listing

R

Recreation – camping

DCR, Virginia State Parks toll-free information number
(800) 933-7275
Local Parks & Recreation Dept. .... see local govt. listing

S

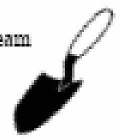
Septic systems

Dept. of Health – State Office
(804) 786-6277
County Health Dept ..... see local govt. listings

Sinkholes and karst

DCR, Virginia Karst Program, Radford .... (540) 831-4056

Soils



NRCS State Soil Scientist Team
(804) 287-1687
Local SWCD .... see previous listing
Local county planning departments - see local govt. listing
Local Cooperative Extension Service office- see local govt. listing

Streambank restoration and riparian buffers

DCR, Dublin .... (540) 643-2590
DOF, state office .... (804) 977-6555
NRCS, Engineering Team
(804) 287-1688
Local SWCD - see previous listing
Izaak Walton League of America, Gaithersburg, MD (800) 543-5463

W

Waste management, litter & recycling

DEQ, Waste Programs
(804) 698-4147
Local litter control & recycling programs .... see local govt. listing
DCR Adopt-A-Stream Program
(540) 643-2591
VDOT Adopt-A-Highway Program
1(800) PRIDE-VA

DCR Department of Conservation & Recreation
CONSERVING VIRGINIA'S NATURAL & RECREATIONAL RESOURCES

DCR New River Watershed Manager
Charlotte Burnett
120 W. Broad St., Box 1606
Dublin, VA 24084
(540) 643-2586 fax: (540) 643-2587
cburnett@dcr.state.va.us

Water quality monitoring

DEQ, Citizen's Water Quality monitoring .... (804) 698-4026
DEQ, Water Programs .... see previous local DEQ office listings
Virginia IWLA Save Our Streams program .... 1(888) 656-6664
Virginia Museum of Natural History, Blacksburg .... (540) 231-4080

Watershed organizations

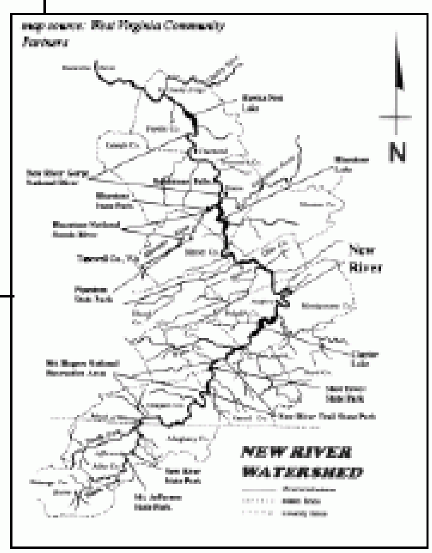
Friends of the Bluestone
(540) 988-9588
Friends of Claytor Lake
(540) 674-0166
Friends of the Rivers of Virginia
(540) 343-3693
National Committee for the New River
(336) 246-4871
New River Community Partners - Ben Borda, River Navigator
(540) 336-8118 or (304) 529-5712
New River Watershed Conservation Roundtable .... (540) 643-2595

Wetlands

DCR, Dublin office .... (540) 643-2590
DEQ (permits, applications & technical assistance) ....(804) 698-4109
U.S. Army Corps of Engineers delineation, permits .....(757) 441-7068
NRCS, Wetland Reserve Program - (804) 287-1687

Wildlife

DGIF............................ (804) 367-1000
DOF ....(804) 977-6555
U.S. Fish & Wildlife Service
(804) 693-6694



This document is available at http://www.dcr.virginia.gov/sw/docs/Newyellow.pdf

FIGURES

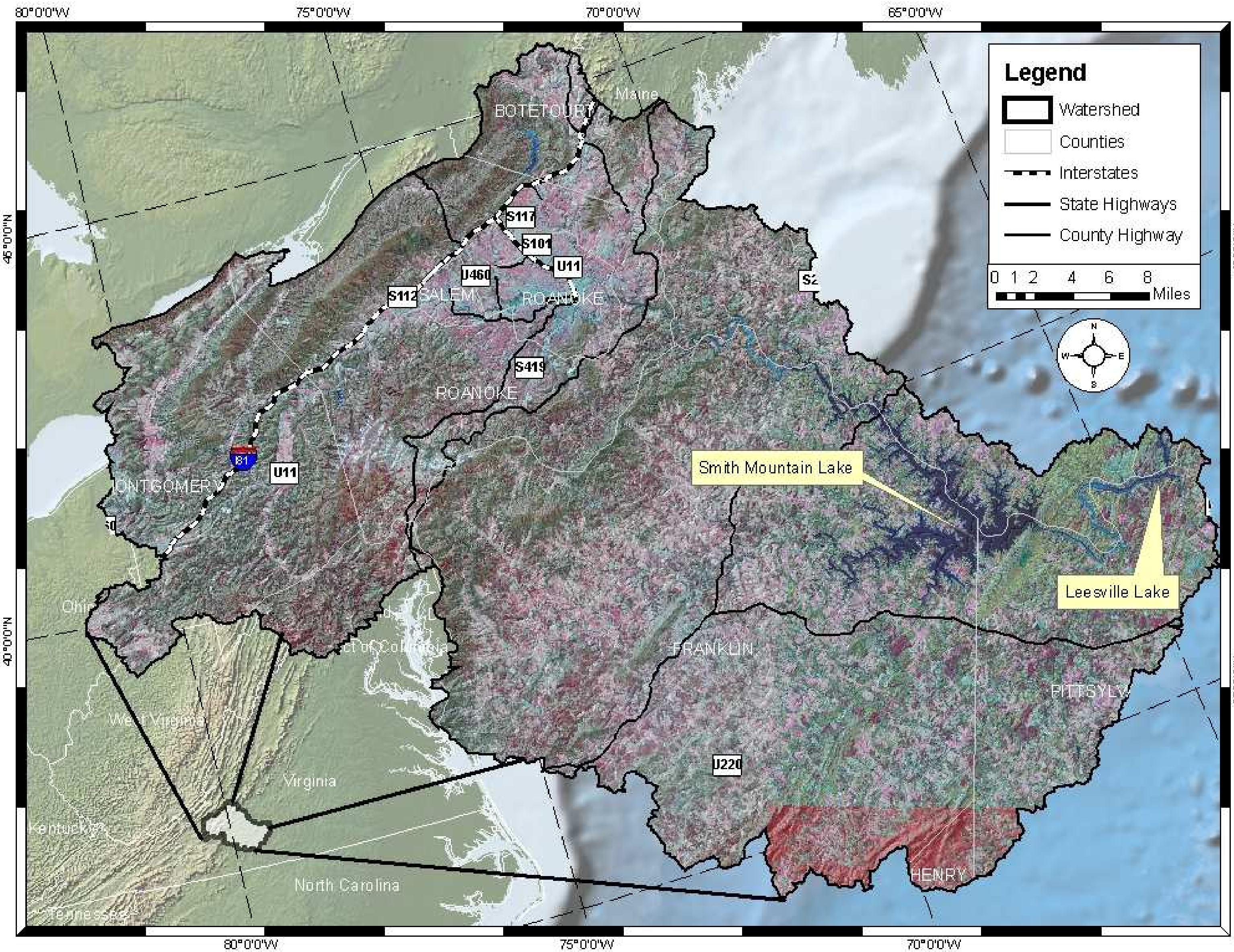


Figure 1: Location of Smith Mountain Lake, Leesville Lake near Roanoke, VA

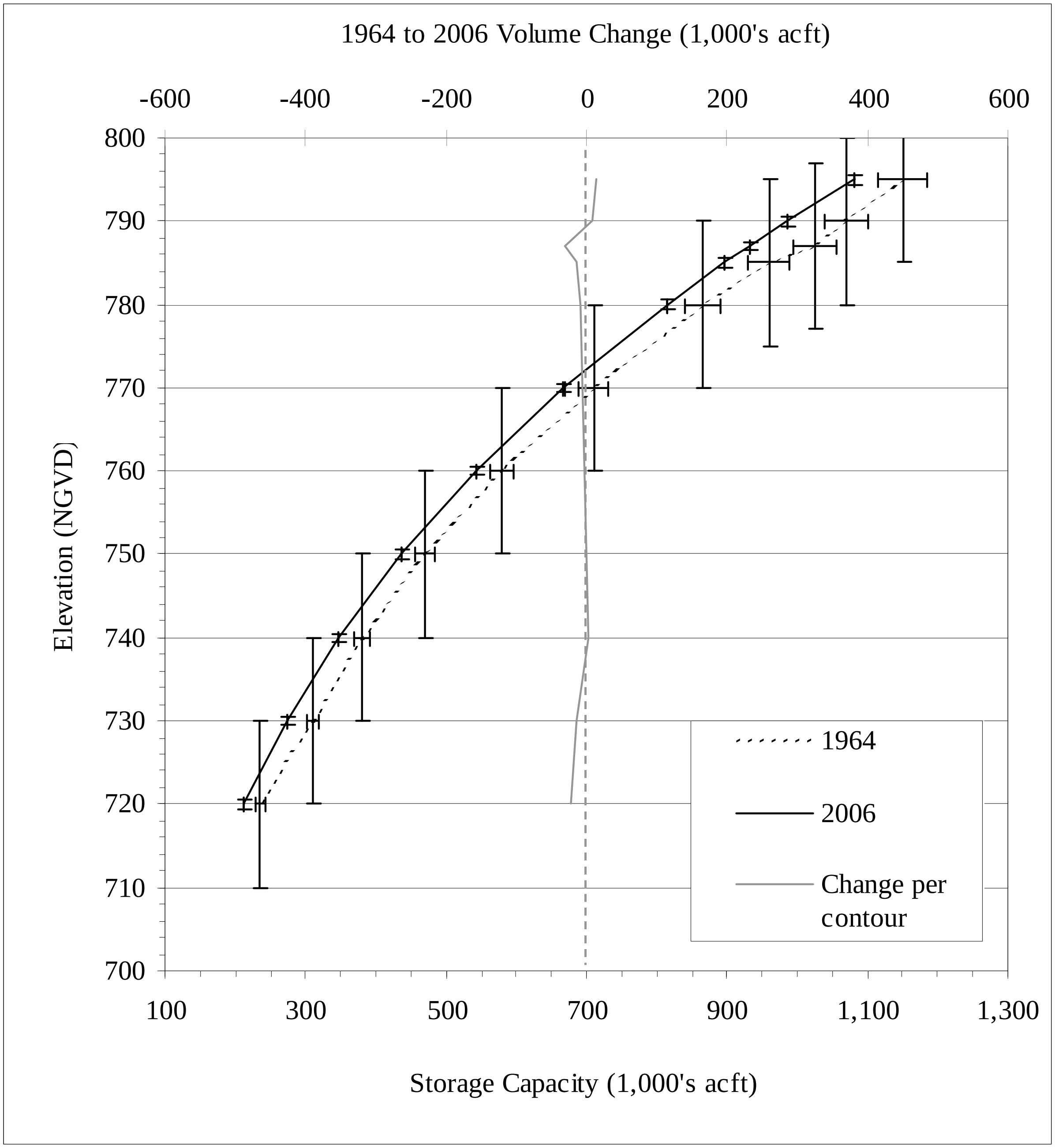


Figure 2: Smith Mountain Lake reservoir storage capacity. Horizontal and vertical "uncertainty" bars illustrate potential error about the plotted data.

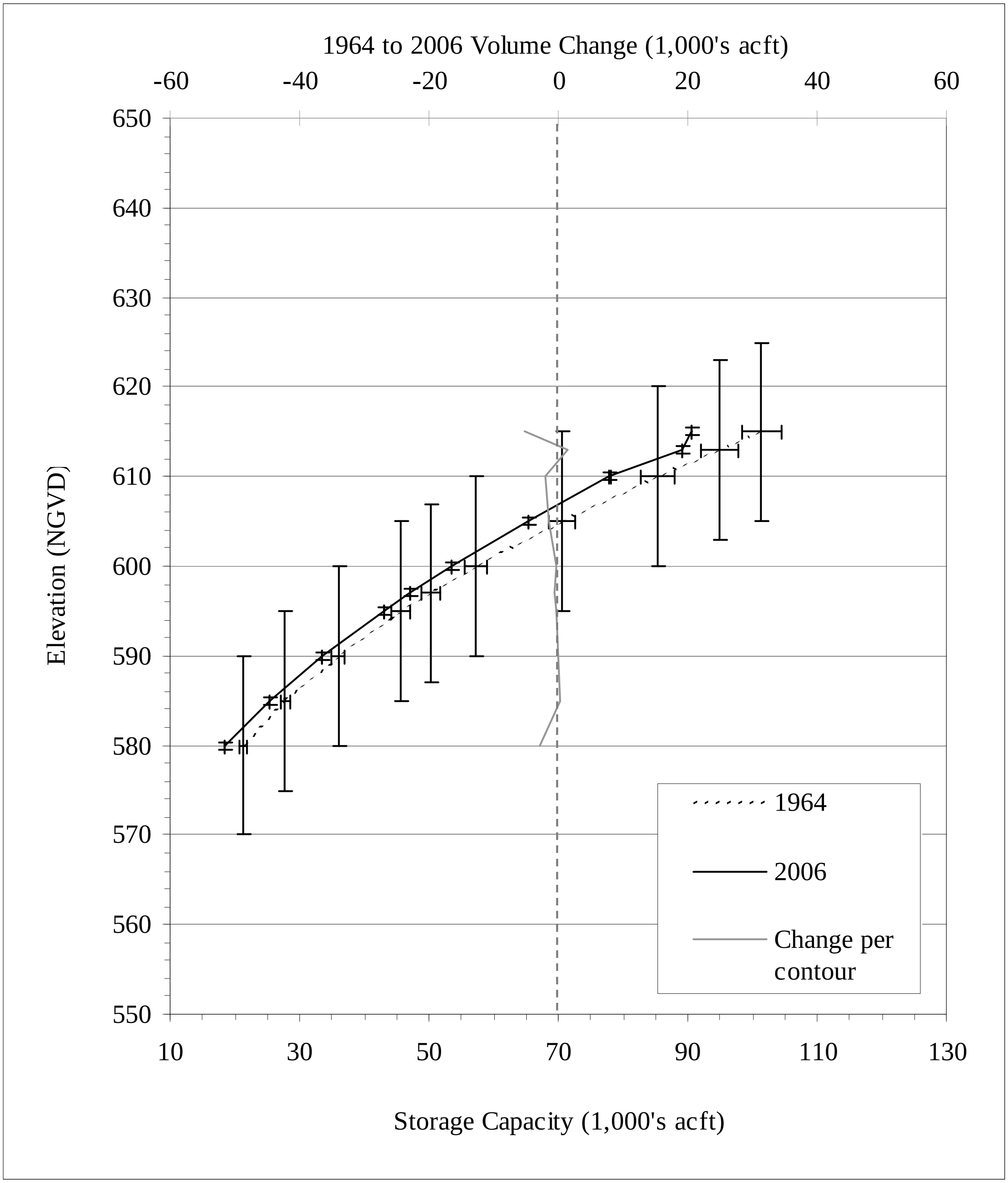


Figure 3: Leesville Lake reservoir storage capacity. Horizontal and vertical "uncertainty" bars illustrate potential error about the plotted data.

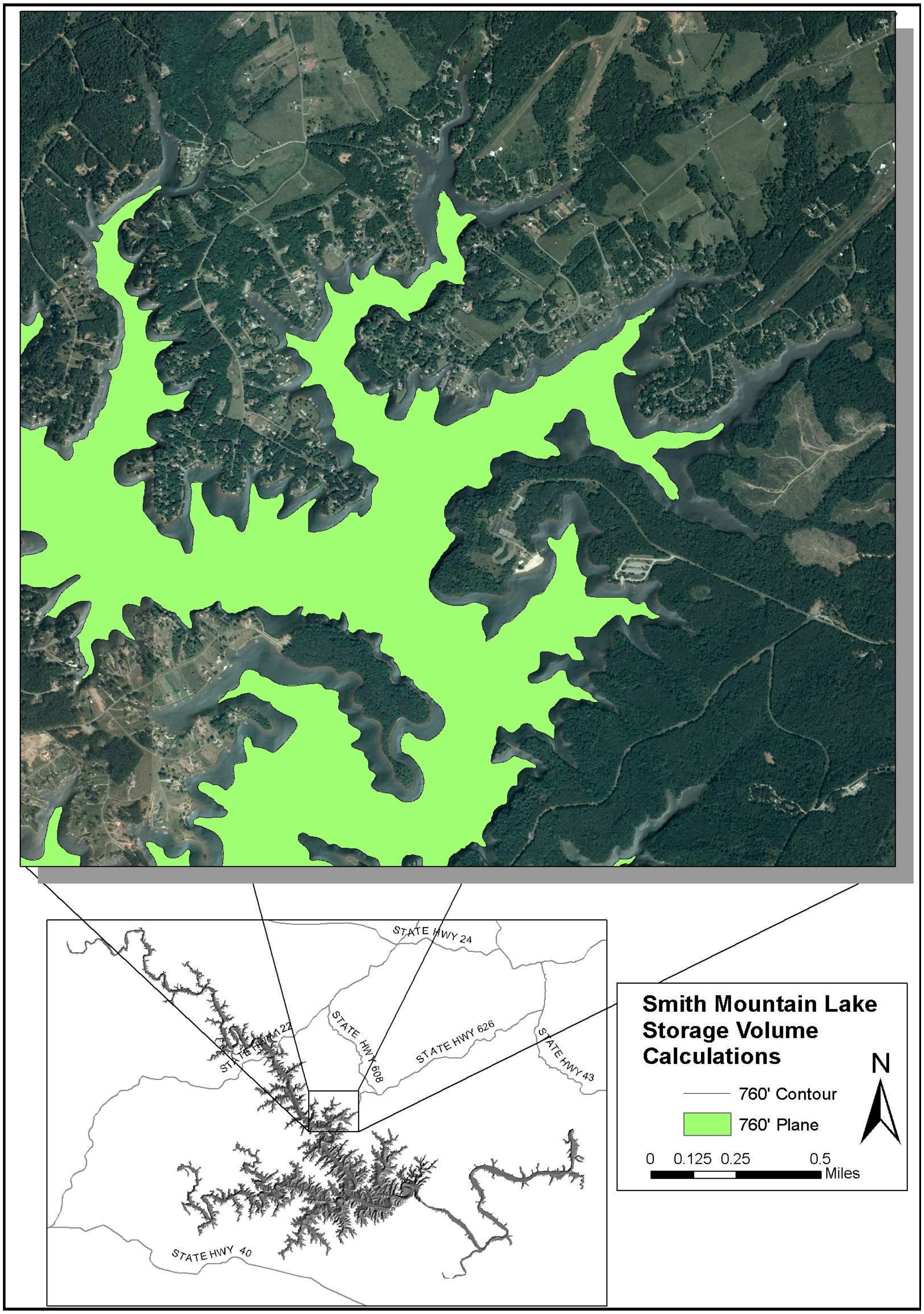


Figure 4: Image showing elevation plane cut into Smith Mountain Lake bathymetry.

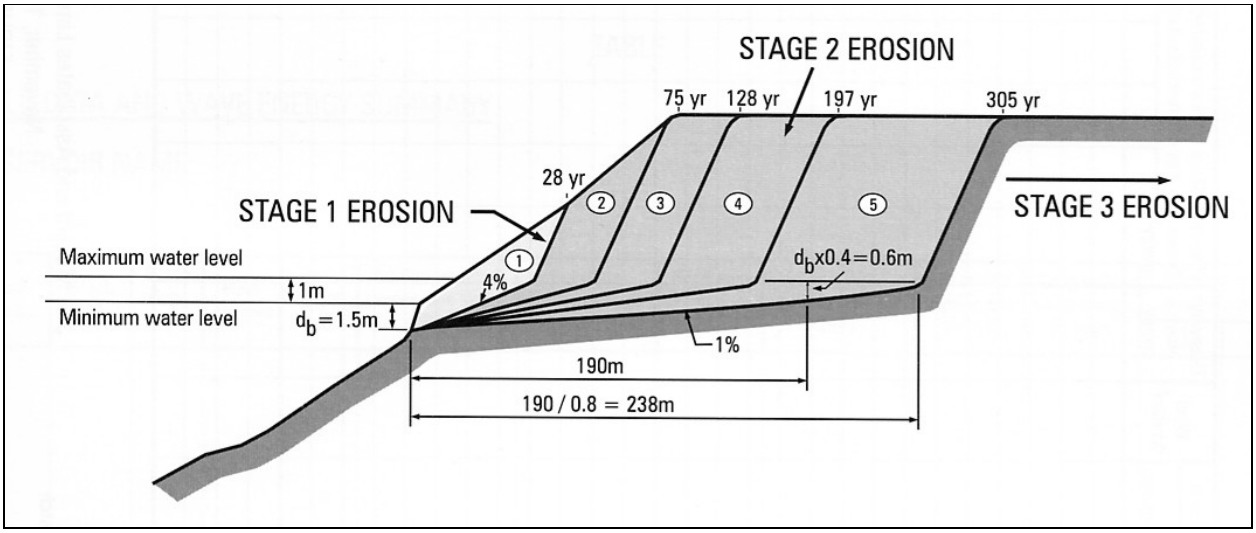


Figure 5: Typical stages of a developing reservoir/lake/ocean shoreline illustrating the 'S-shaped' profile.

Figure 6: Example of bathymetric data illustrating relic features submerged beneath Smith Mountain Lake and obfuscation of relic channels by subaqueous reservoir sedimentation. Features minimally affected by sedimentation such as the lower river channels, an old bridge, and a road bed are still visible. Approximate depth of sediment accumulation may be estimated by the height of lost features as estimated from the bathymetric data. For example, the stream banks in this figure are approximately 2 feet high. Thus, there must be at least two feet of sedimentation at the point where the channel "disappears" beneath the sediment.

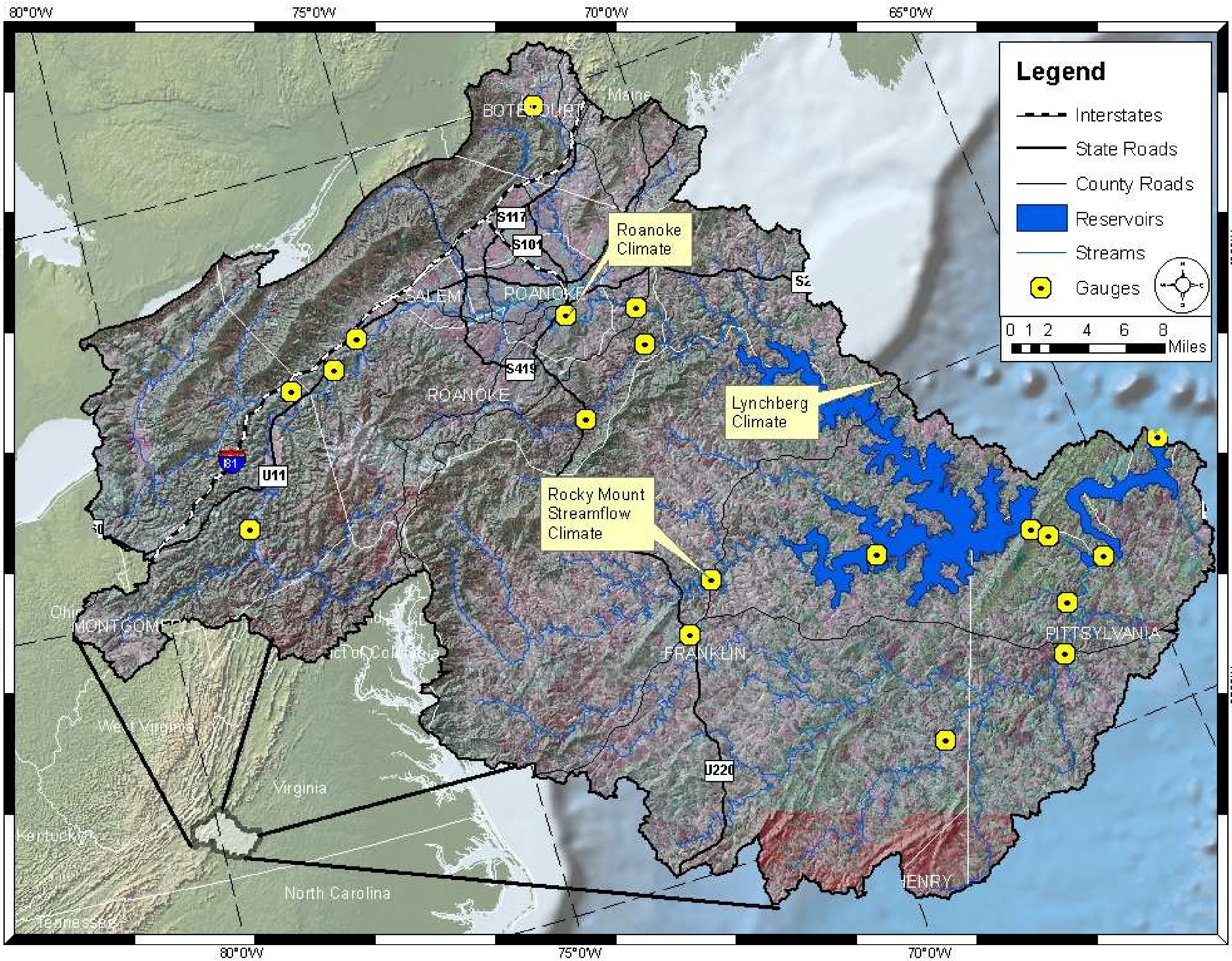


Figure 7: Locations of climatic stations and gauging stations for the sedimentation study.

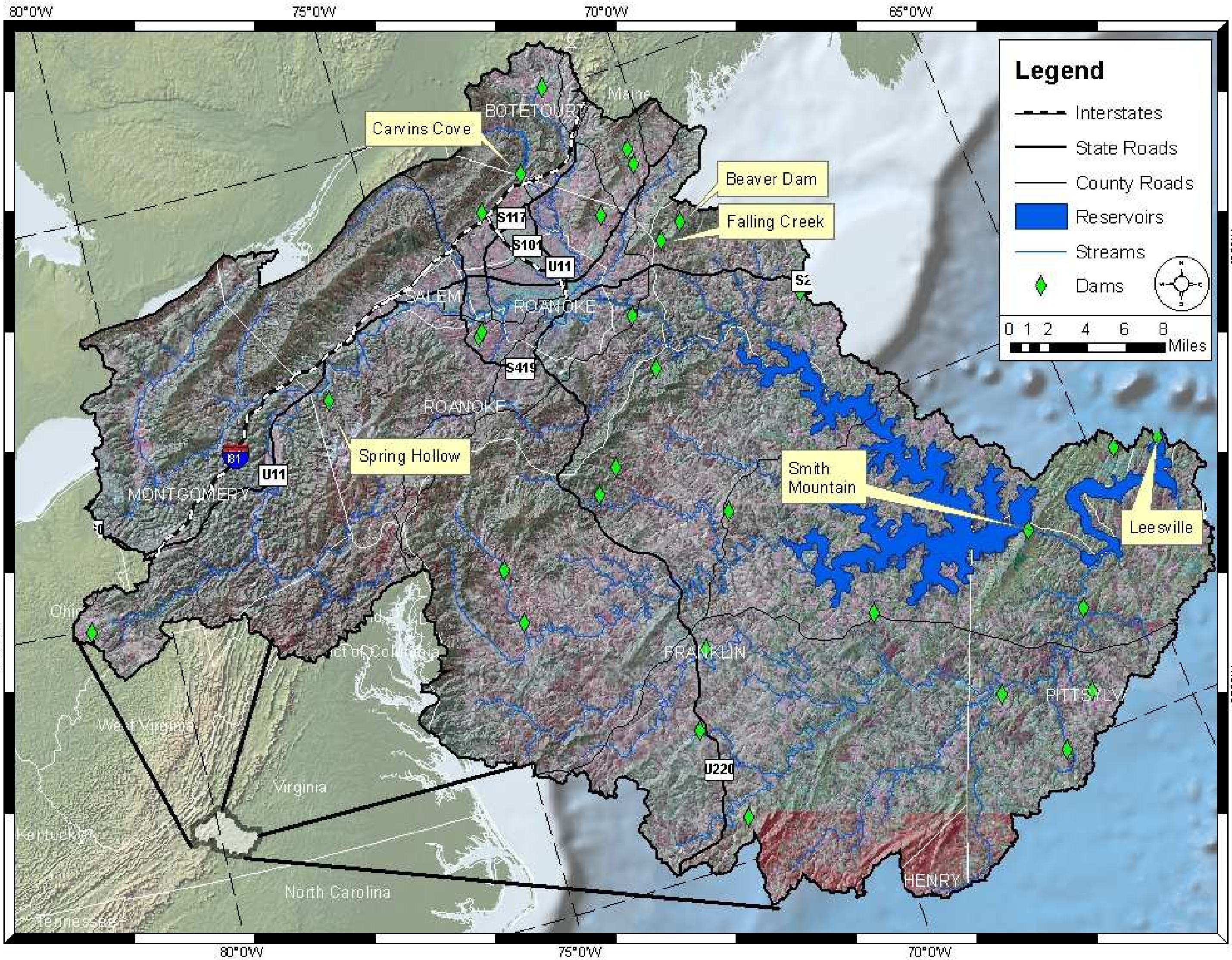


Figure 8: Dams located within the Smith Mountain and Leesville watersheds.

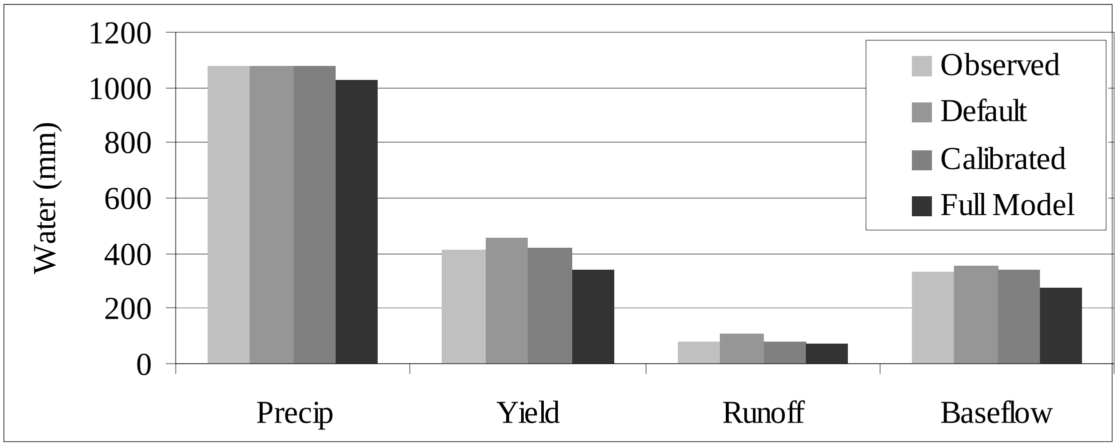


Figure 9: Average 1976 – 1978 results of the annual calibration of the SWAT model to the USGS gauge at Blackwater River. Default represents model results without calibration, "Calibrated" represent the model results following calibration to the Blackwater creek gauge, and the "Full Model" represents the results of the SWAT model for the entire Smith Mountain Watershed during the project life (1960 – 2005).

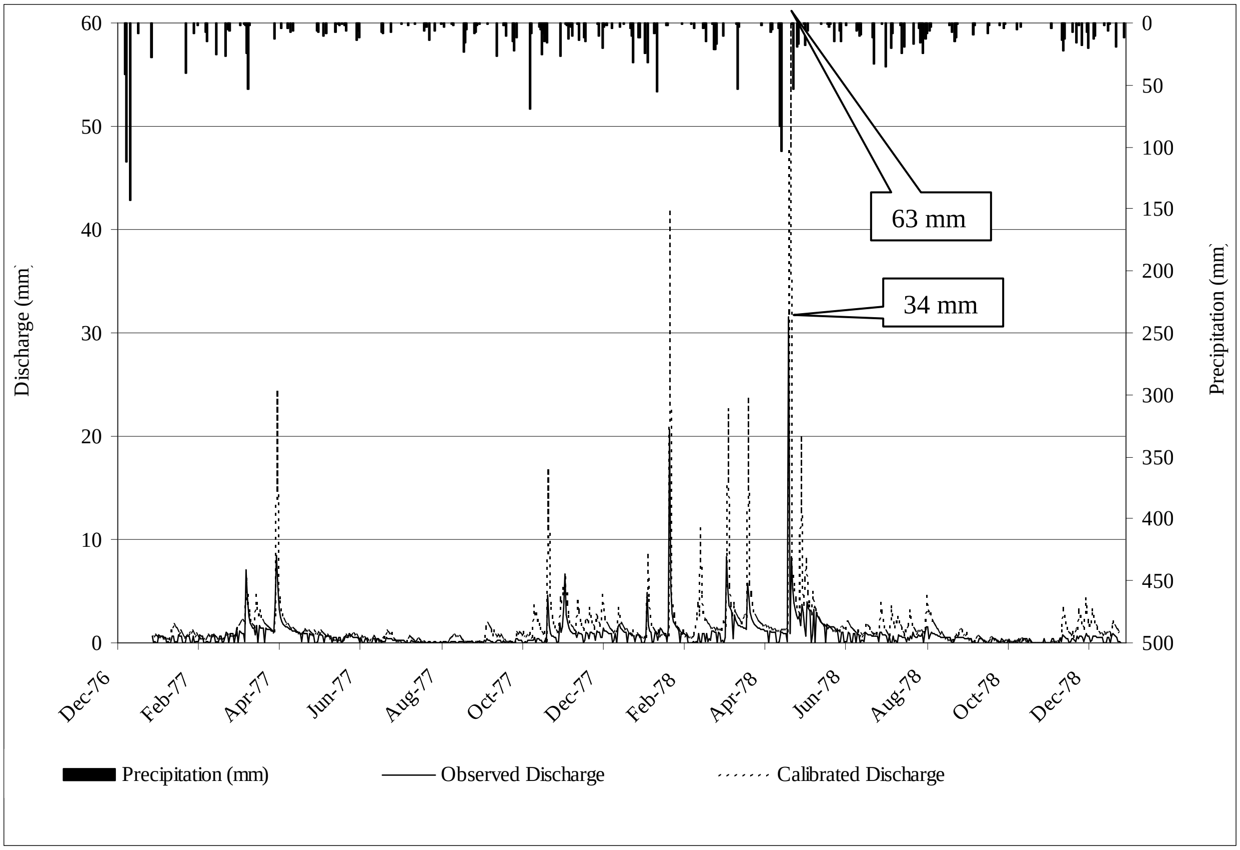


Figure 10: Predicted and observed flow for Blackwater Creek, Rocky Mount, VA. Predicted peaks represent daily flows whereas observed peaks may be averaged over two days. Consequently, large peak events do not match. For example, the observed peak flow for the largest storm was 63 mm while the mean was 34 mm.

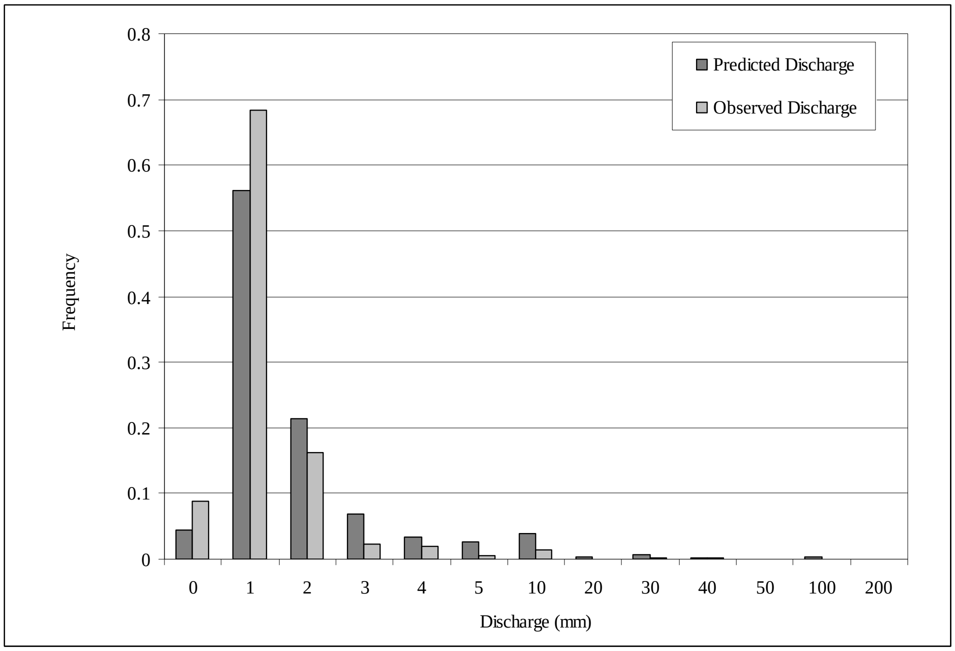


Figure 11: Frequency of observed and predicted flows for the calibration period. Predicted values tended to slightly underestimate low flow periods.

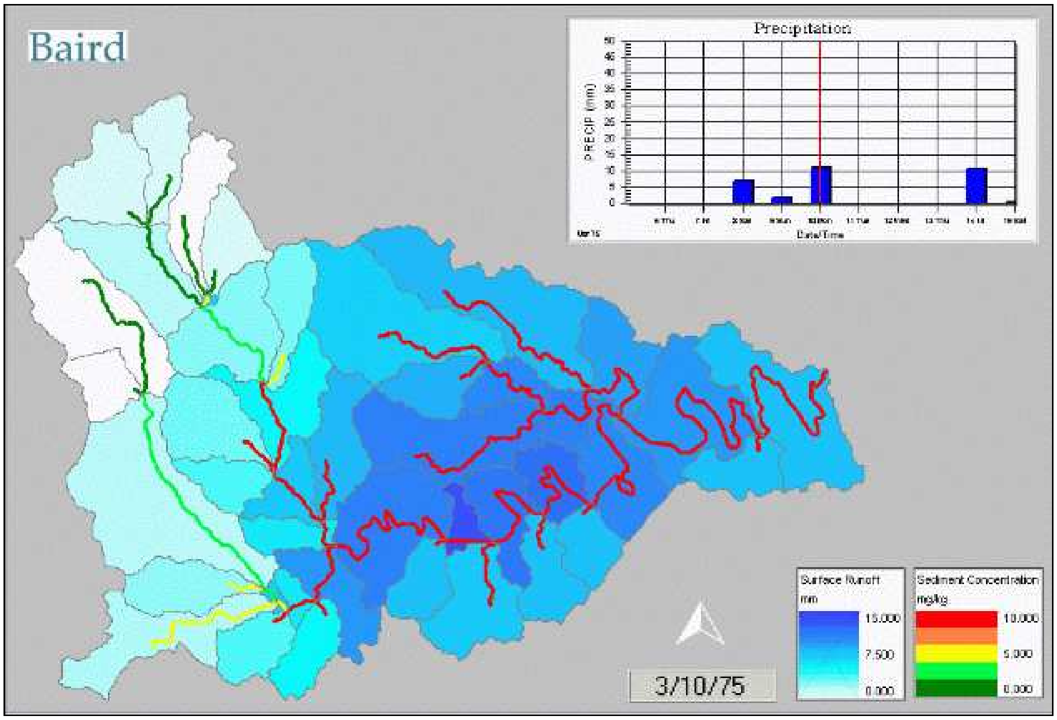


Figure 12: Example output from calibrated watershed sedimentation modeling results on Blackwater Creek. Darker shades of blue indicate increased overland flow (disturbed lands). Green-to-red color gradation indicates predicted suspended sediment concentrations. Precipitation is shown in the embedded bar graph.

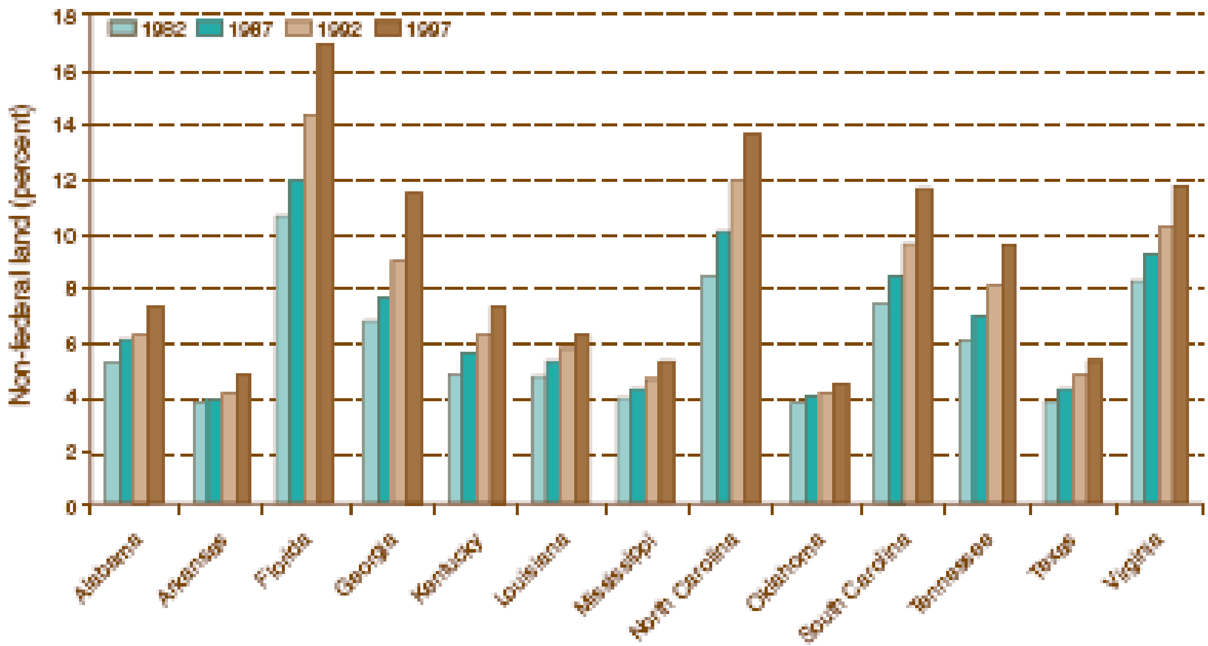


Figure 6.3—Percent of land in urban uses for Southern States 1982 to 1997 [National Resource Inventories (National Cartography and Geospatial Center 1998)].

Figure 13: Developed / Urban land use trends in the Appalachian Mountains (Weir and Greis, 2002).

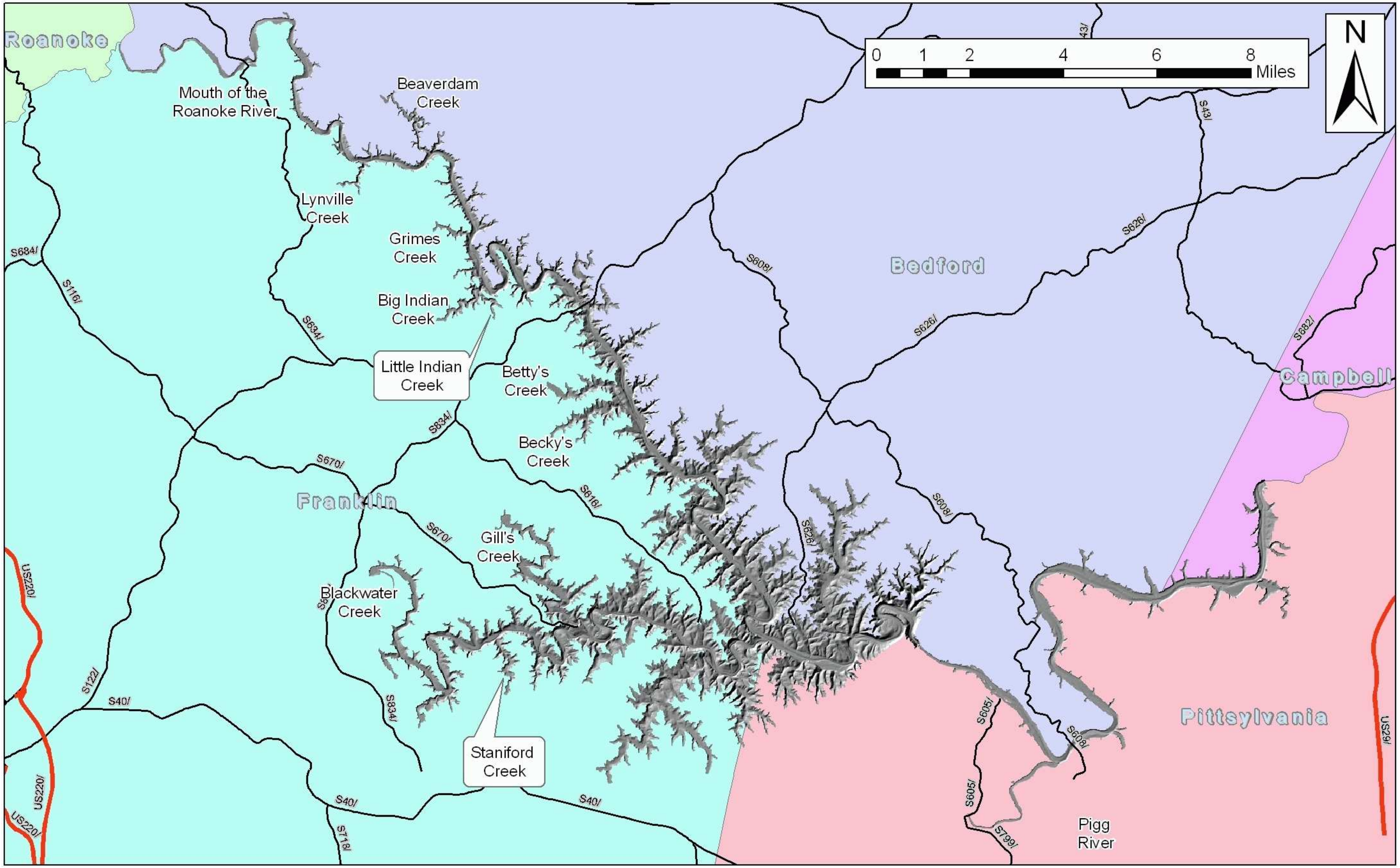


Figure 14: Index Map to Cove, Tributary, and Bays on Smith Mountain and Leesville Lakes.

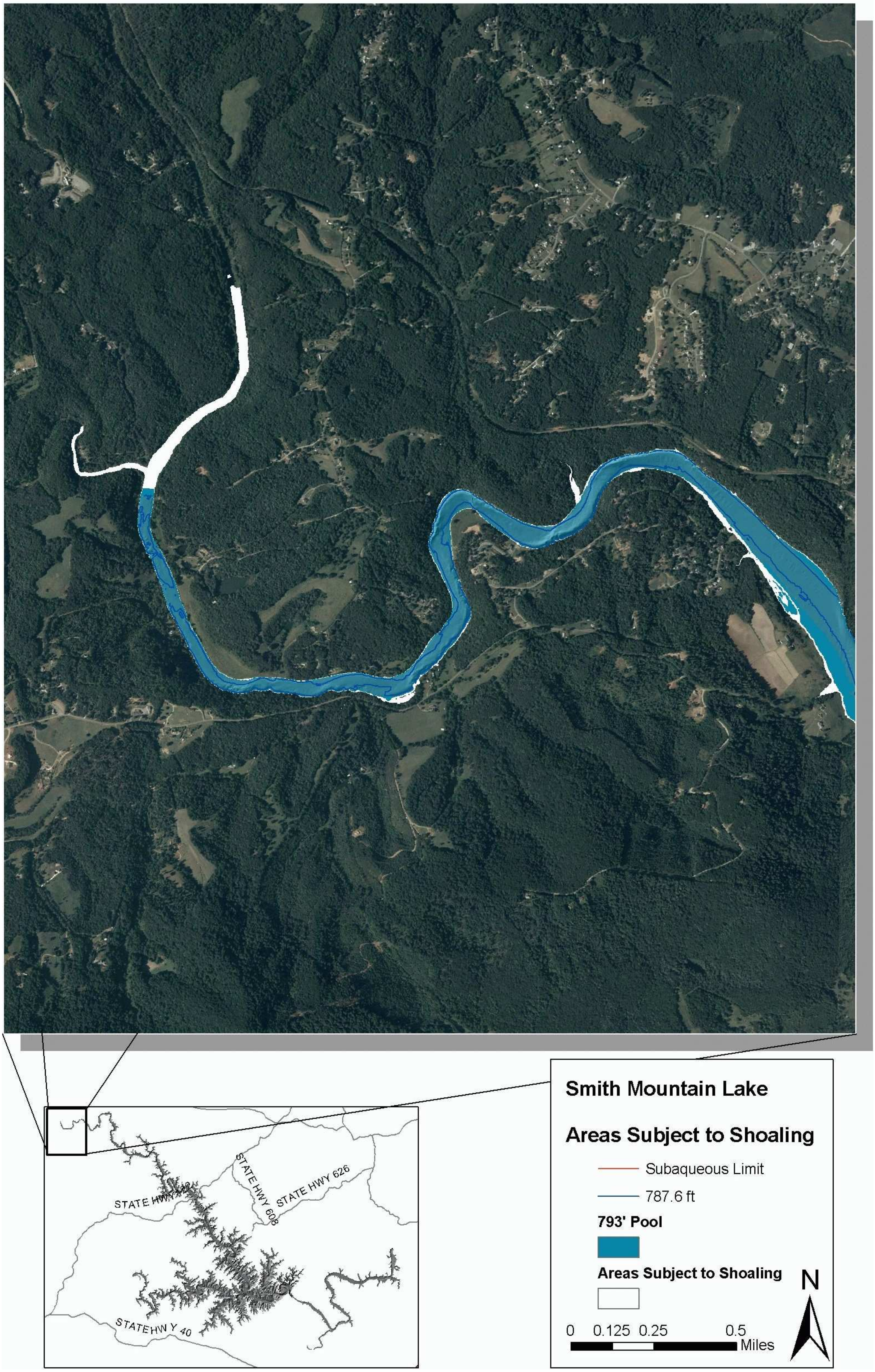


Figure 15: Shoaling and subaqueous sedimentation in Smith Mountain Lake (1 of 11).

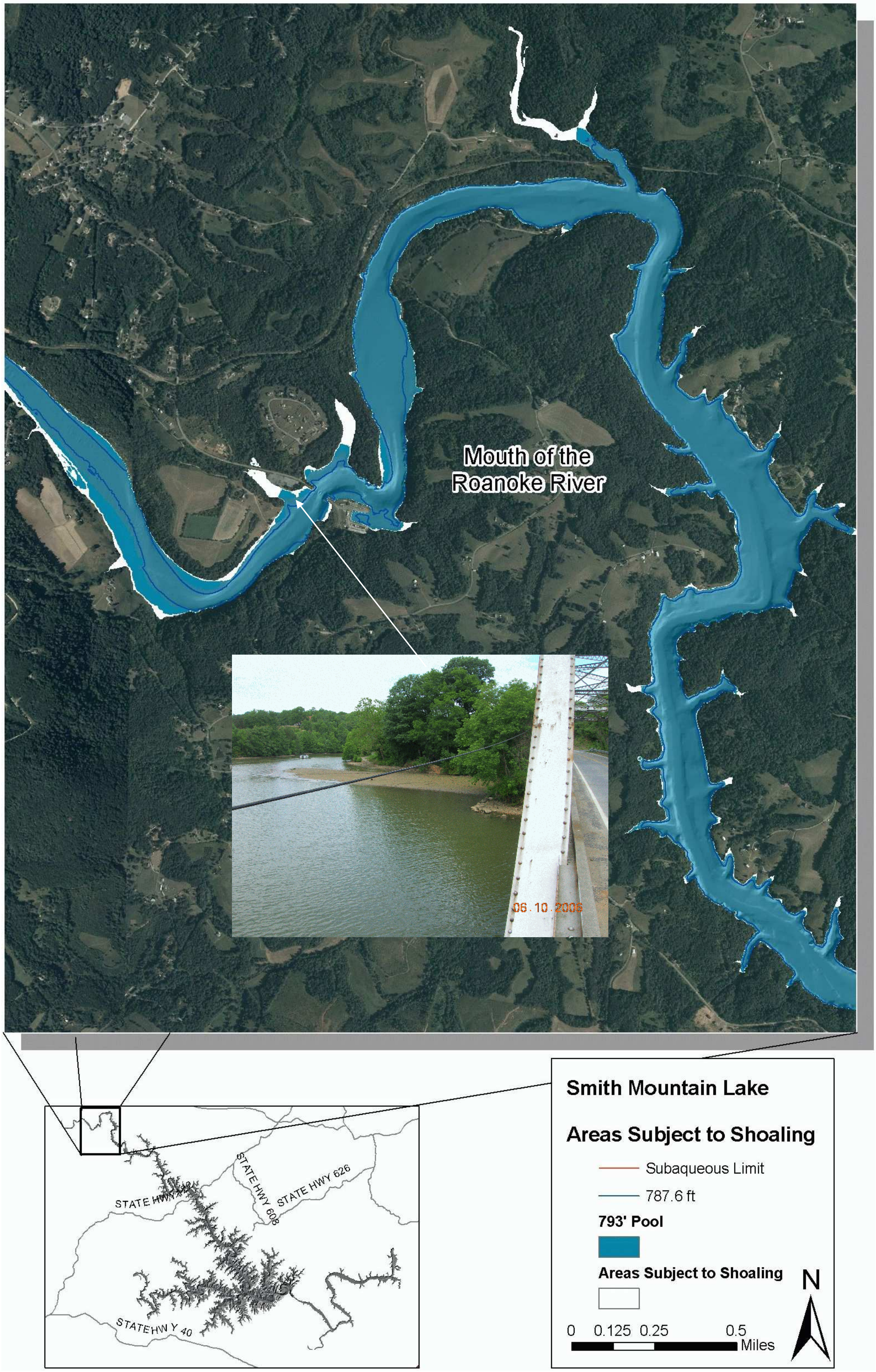


Figure 16: Shoaling and subaqueous sedimentation in Smith Mountain Lake (2 of 11).

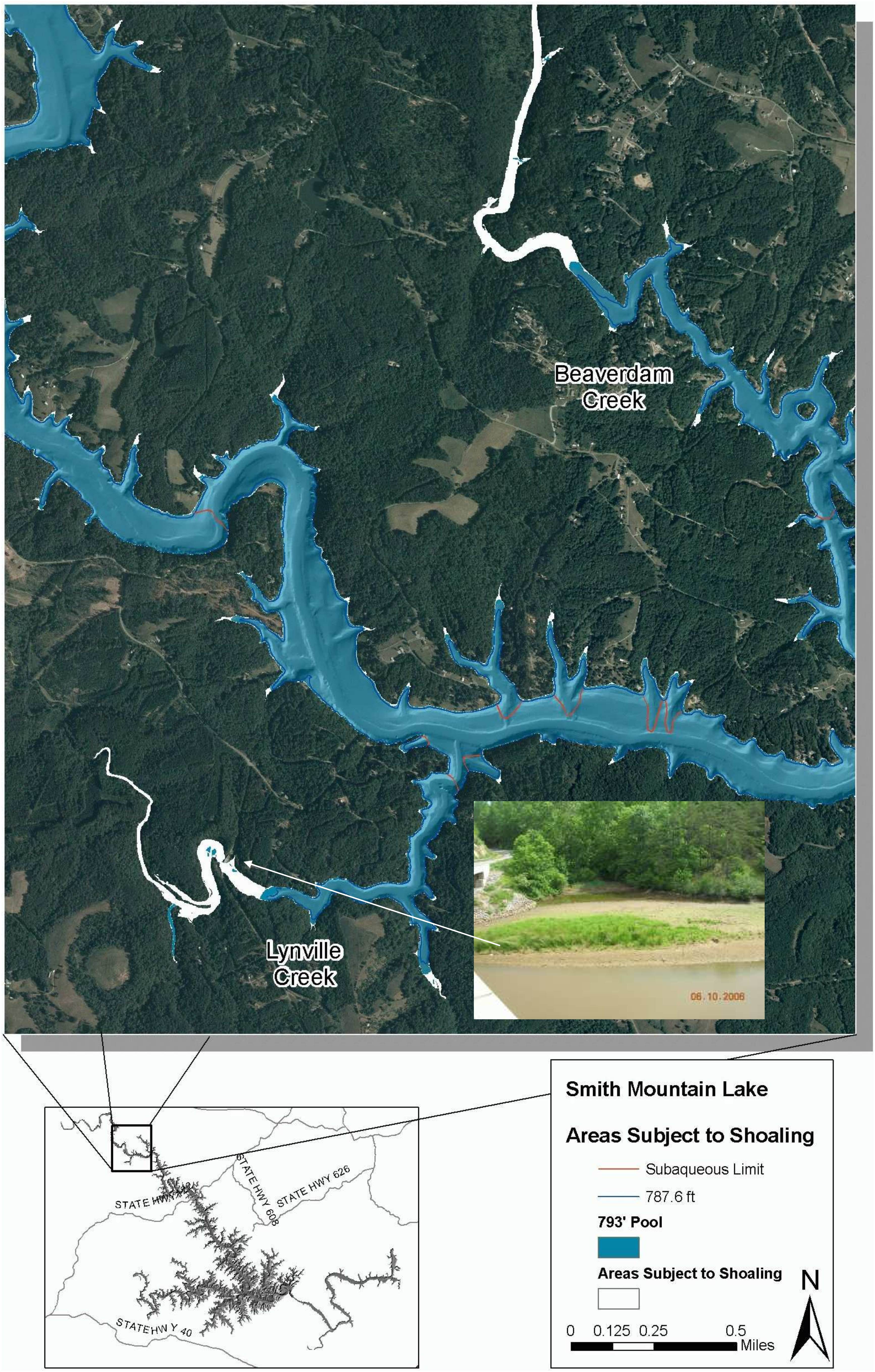


Figure 17: Shoaling and subaqueous sedimentation in Smith Mountain Lake (3 of 11). Inset photo illustrates observed reservoir sedimentation and shoaling from upland disturbance activities.

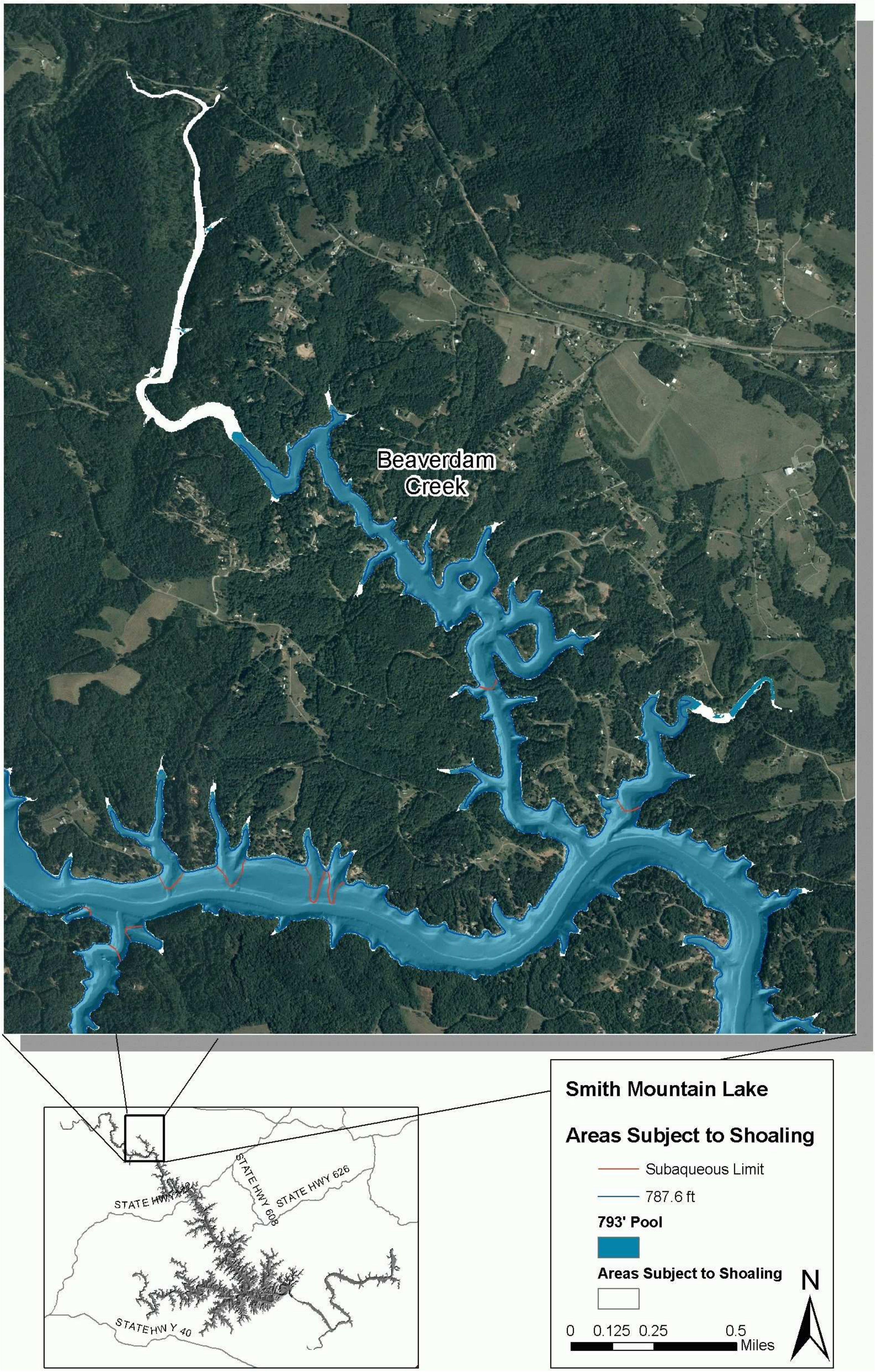


Figure 18: Shoaling and subaqueous sedimentation in Smith Mountain Lake (4 of 11).

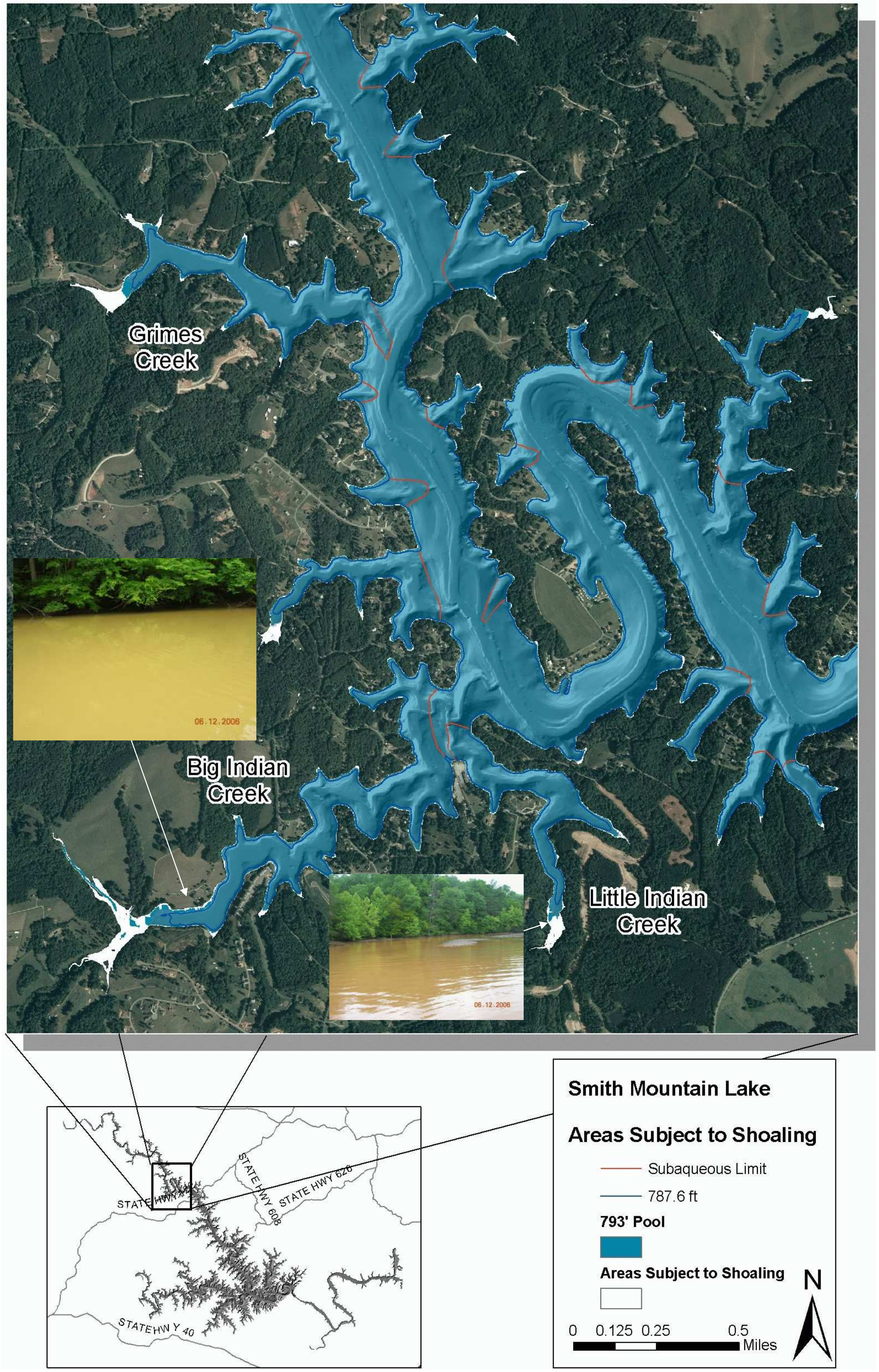


Figure 19: Shoaling and subaqueous sedimentation in Smith Mountain Lake (5 of 11).

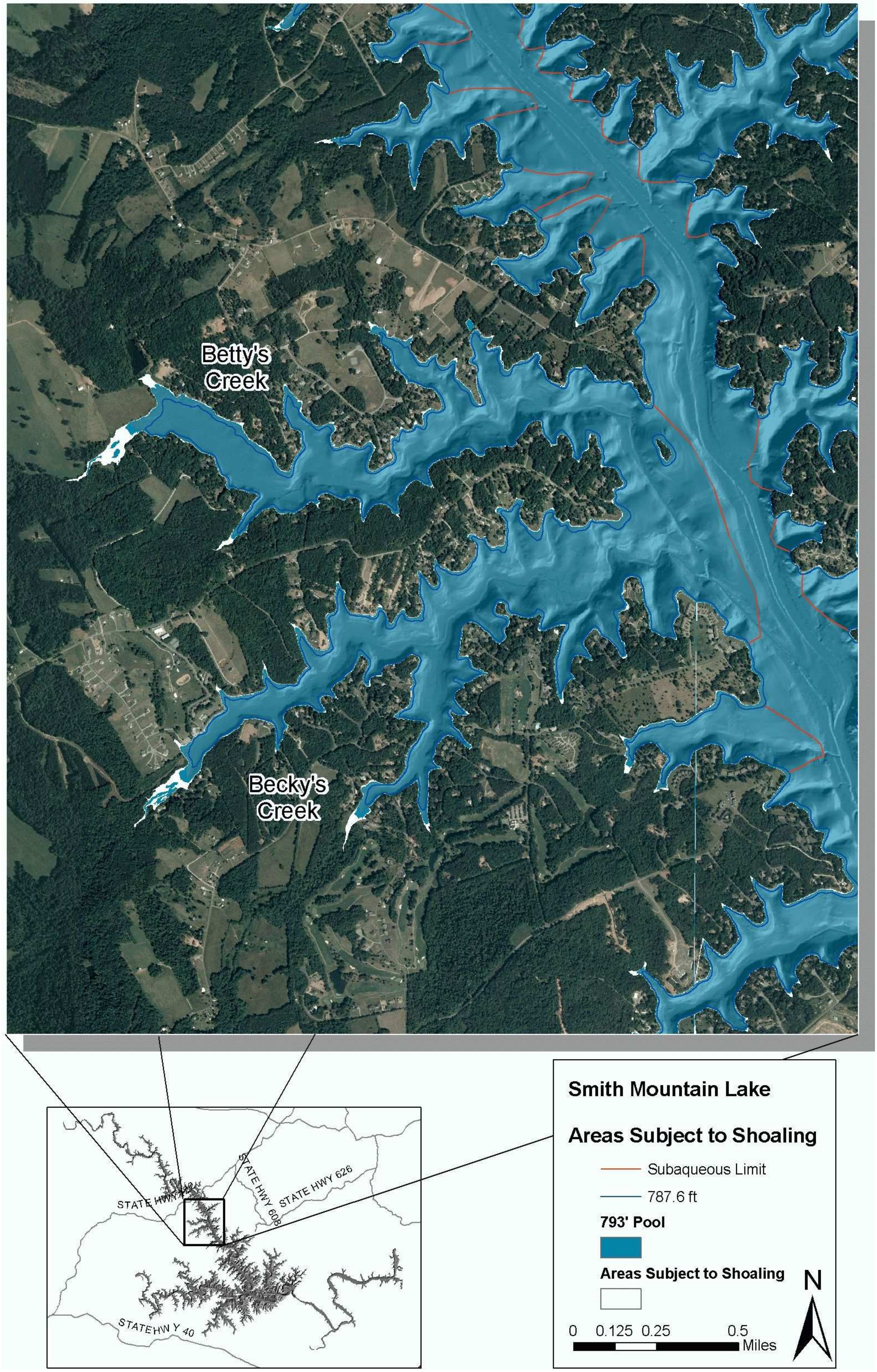


Figure 20: Shoaling and subaqueous sedimentation in Smith Mountain Lake (6 of 11).

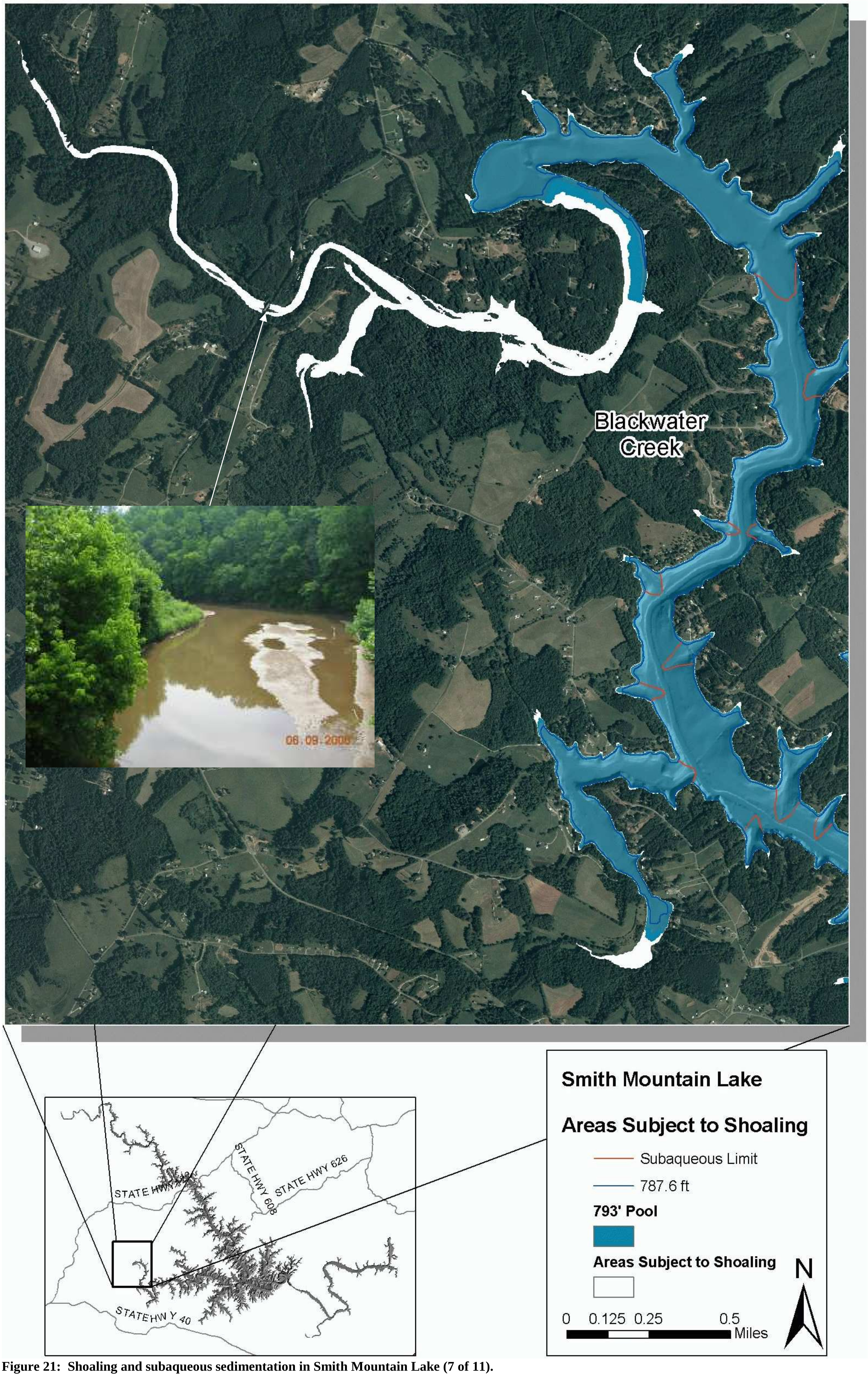


Figure 21: Shoaling and subaqueous sedimentation in Smith Mountain Lake (7 of 11).

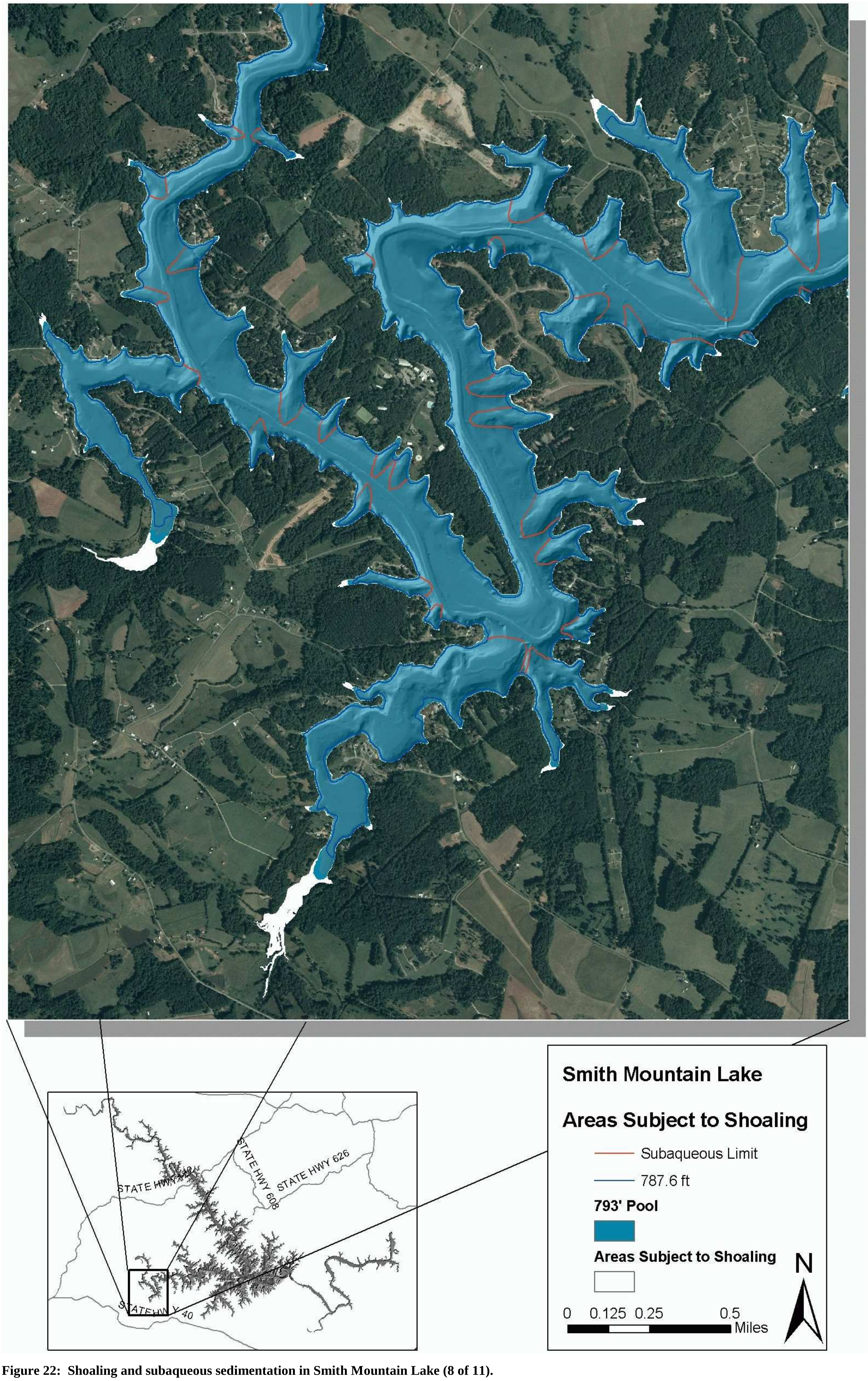


Figure 22: Shoaling and subaqueous sedimentation in Smith Mountain Lake (8 of 11).

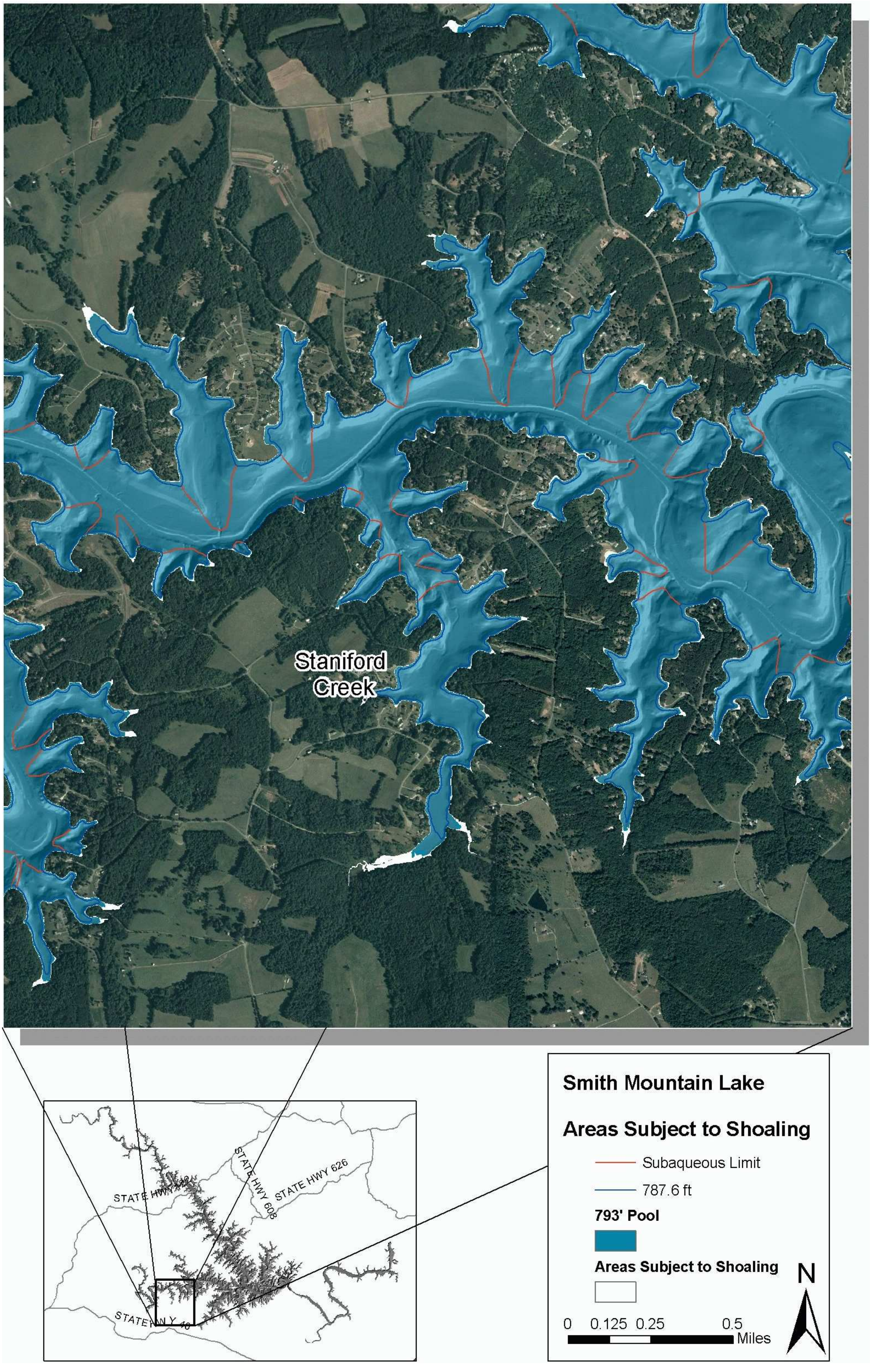


Figure 23: Shoaling and subaqueous sedimentation in Smith Mountain Lake (9 of 11)

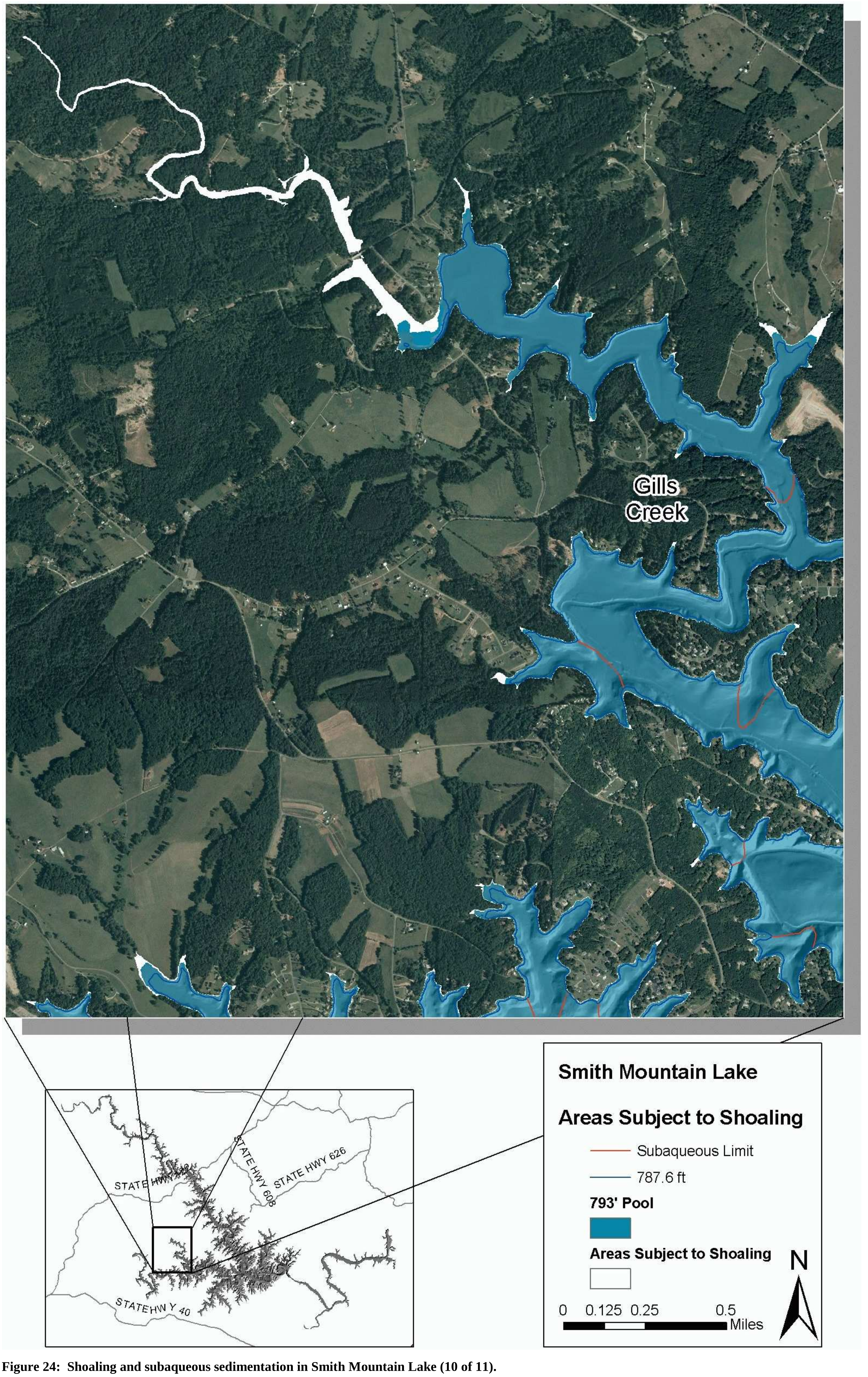


Figure 24: Shoaling and subaqueous sedimentation in Smith Mountain Lake (10 of 11).

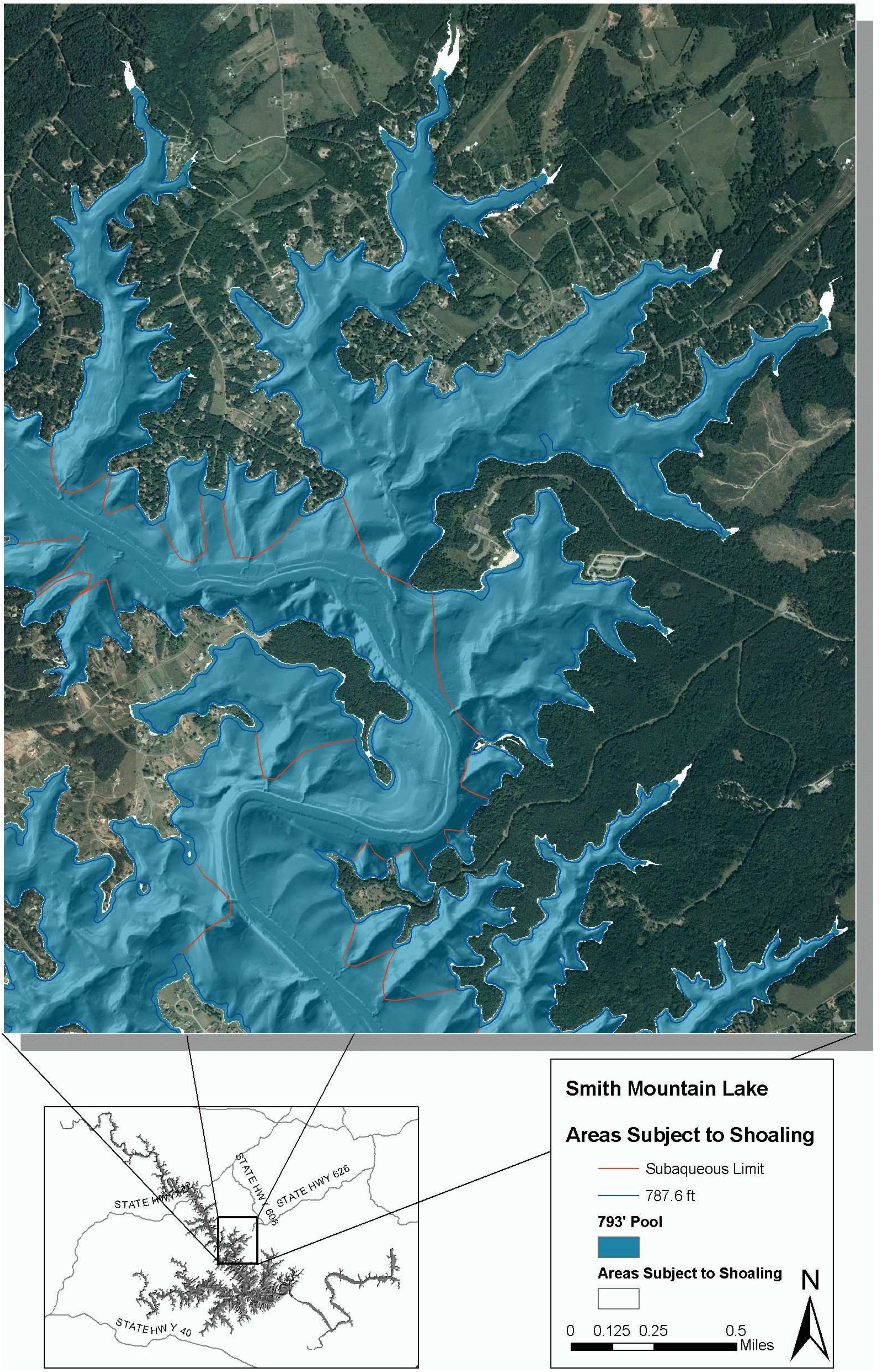


Figure 25: Shoaling and subaqueous sedimentation in Smith Mountain Lake (11 of 11).

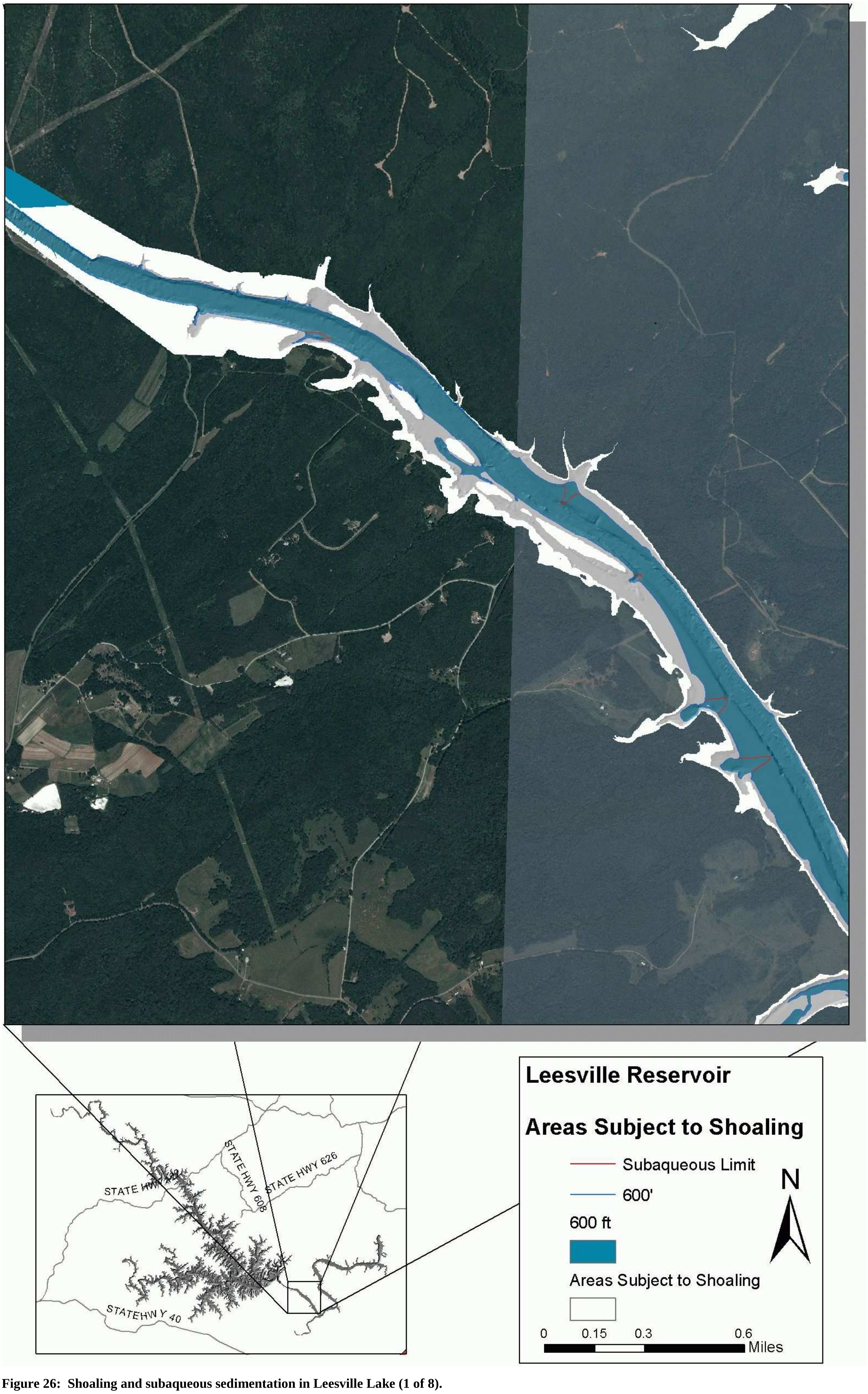


Figure 26: Shoaling and subaqueous sedimentation in Leesville Lake (1 of 8).

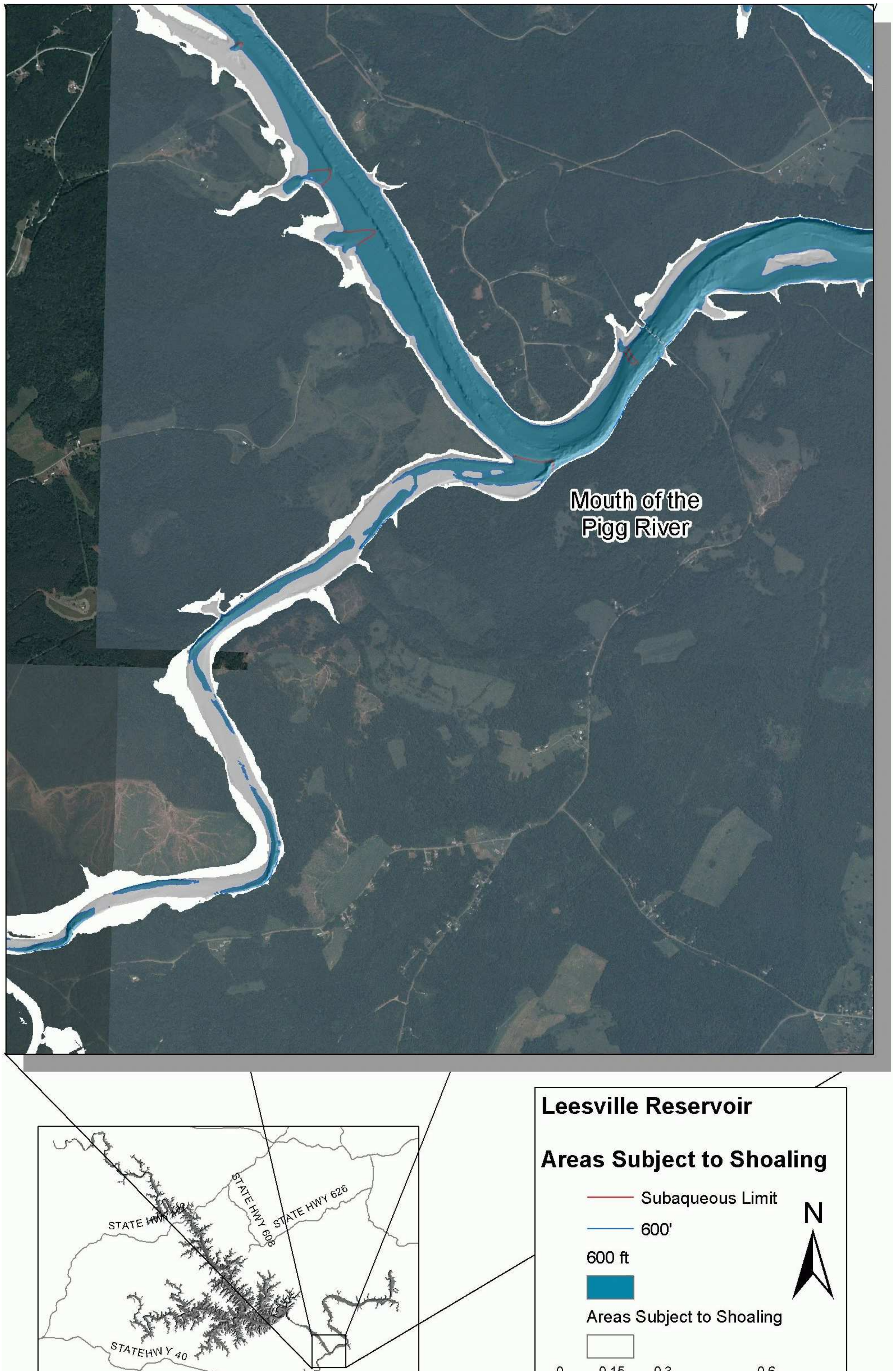


Figure 27: Shoaling and subaqueous sedimentation in Leesville Lake (2 of 8).

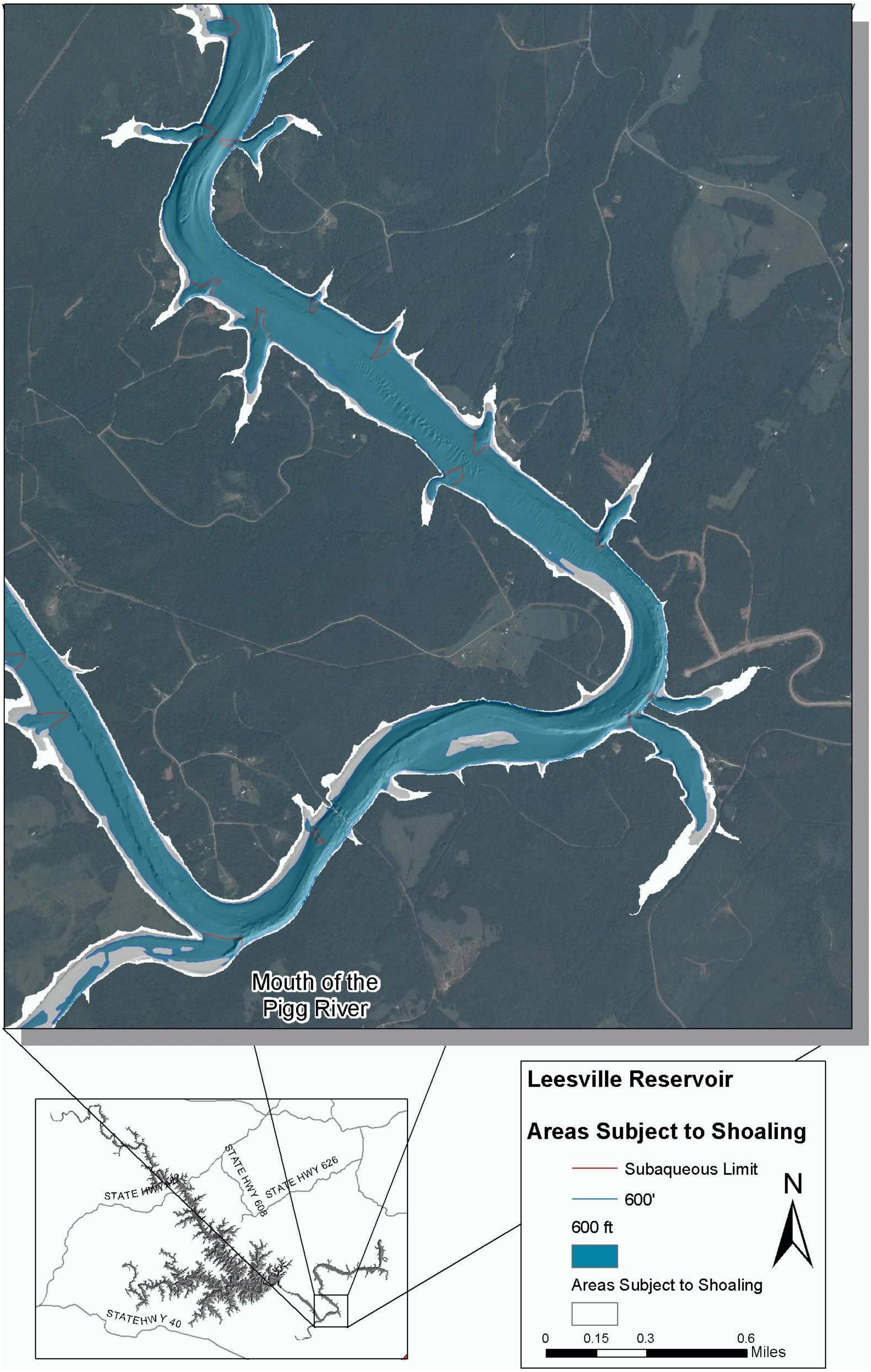


Figure 28: Shoaling and subaqueous sedimentation in Leesville Lake (3 of 8).

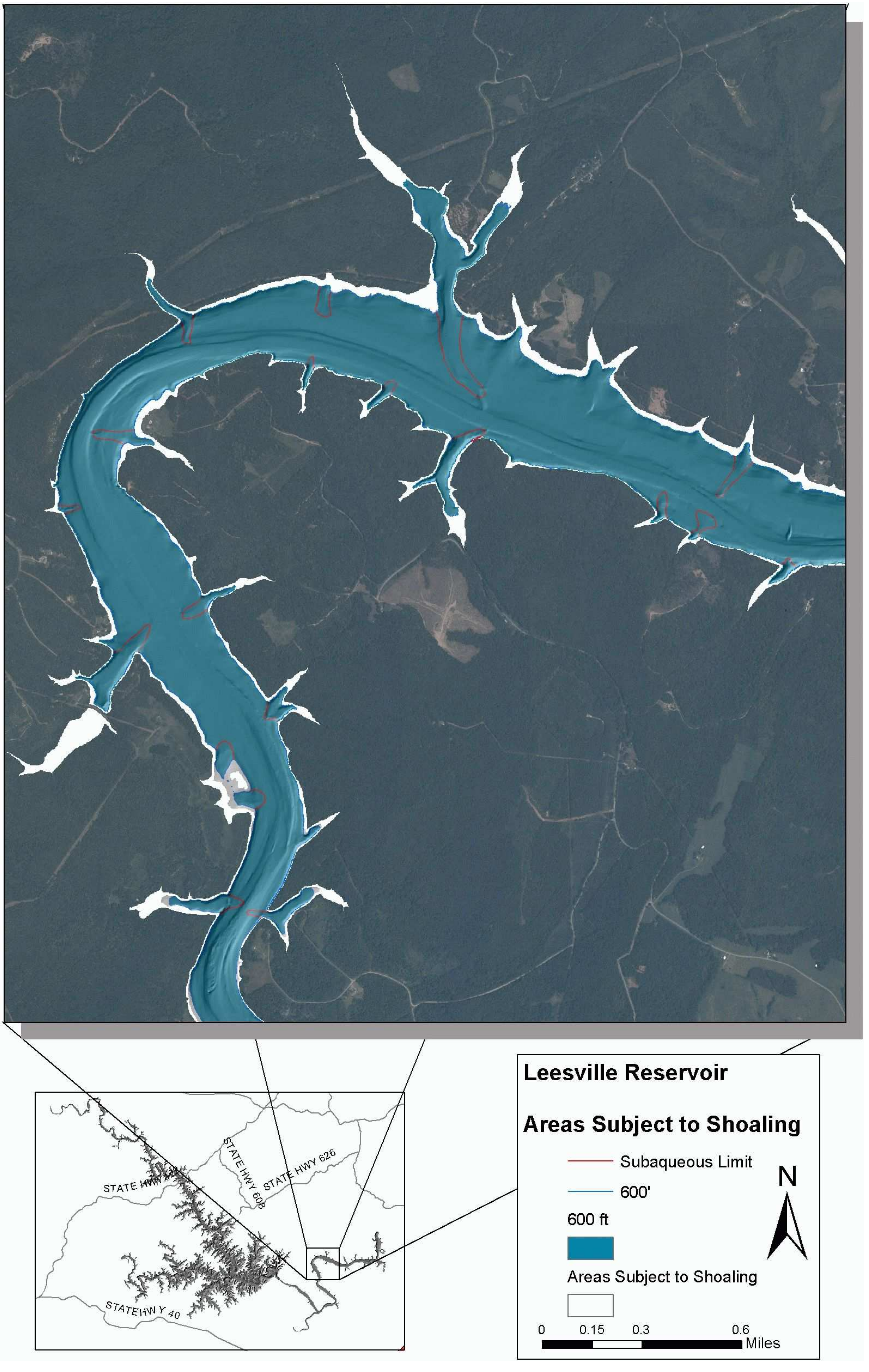


Figure 29: Shoaling and subaqueous sedimentation in Leesville Lake (4 of 8).

Figure 30: Shoaling and subaqueous sedimentation in Leesville Lake (5 of 8).

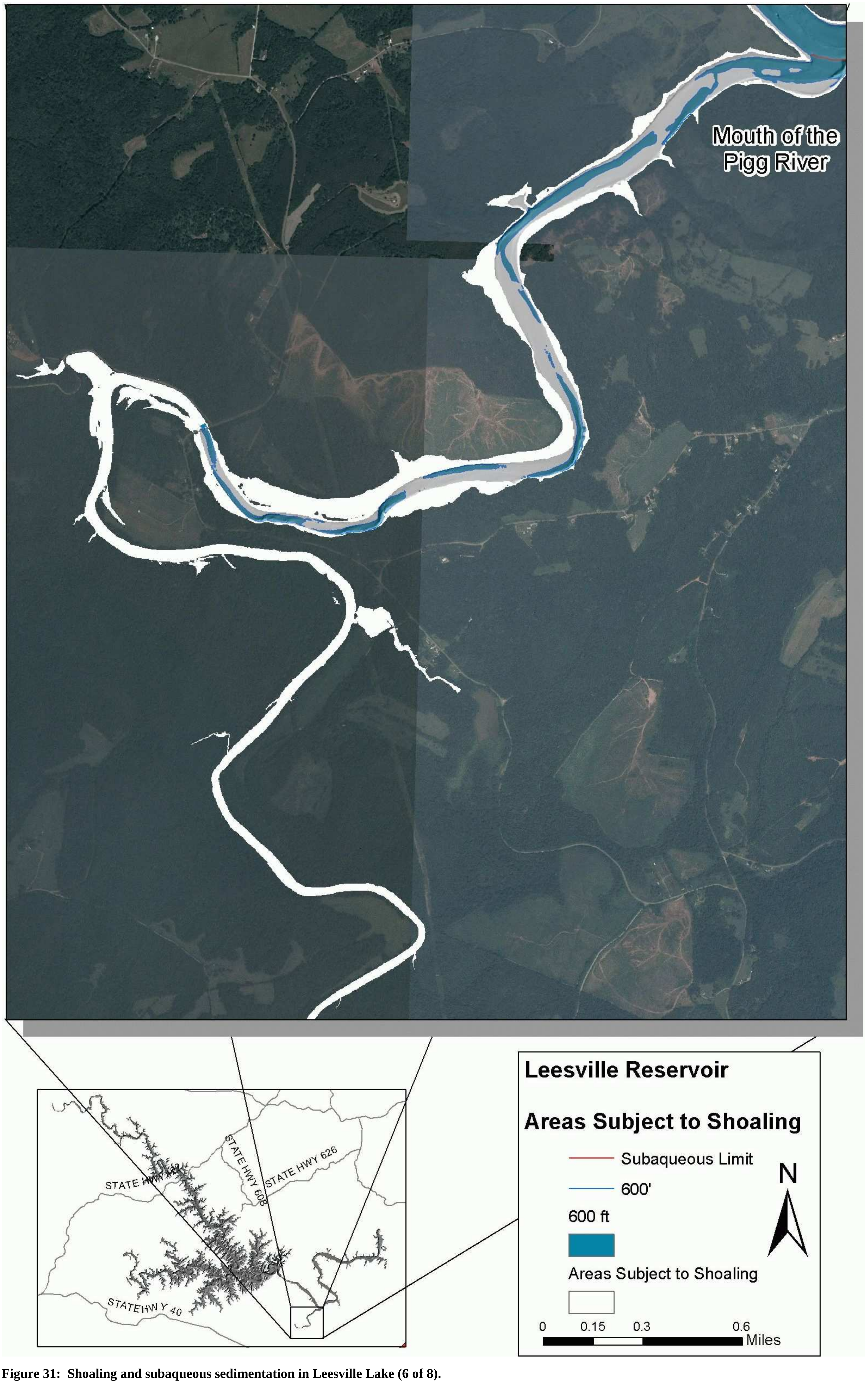


Figure 31: Shoaling and subaqueous sedimentation in Leesville Lake (6 of 8).

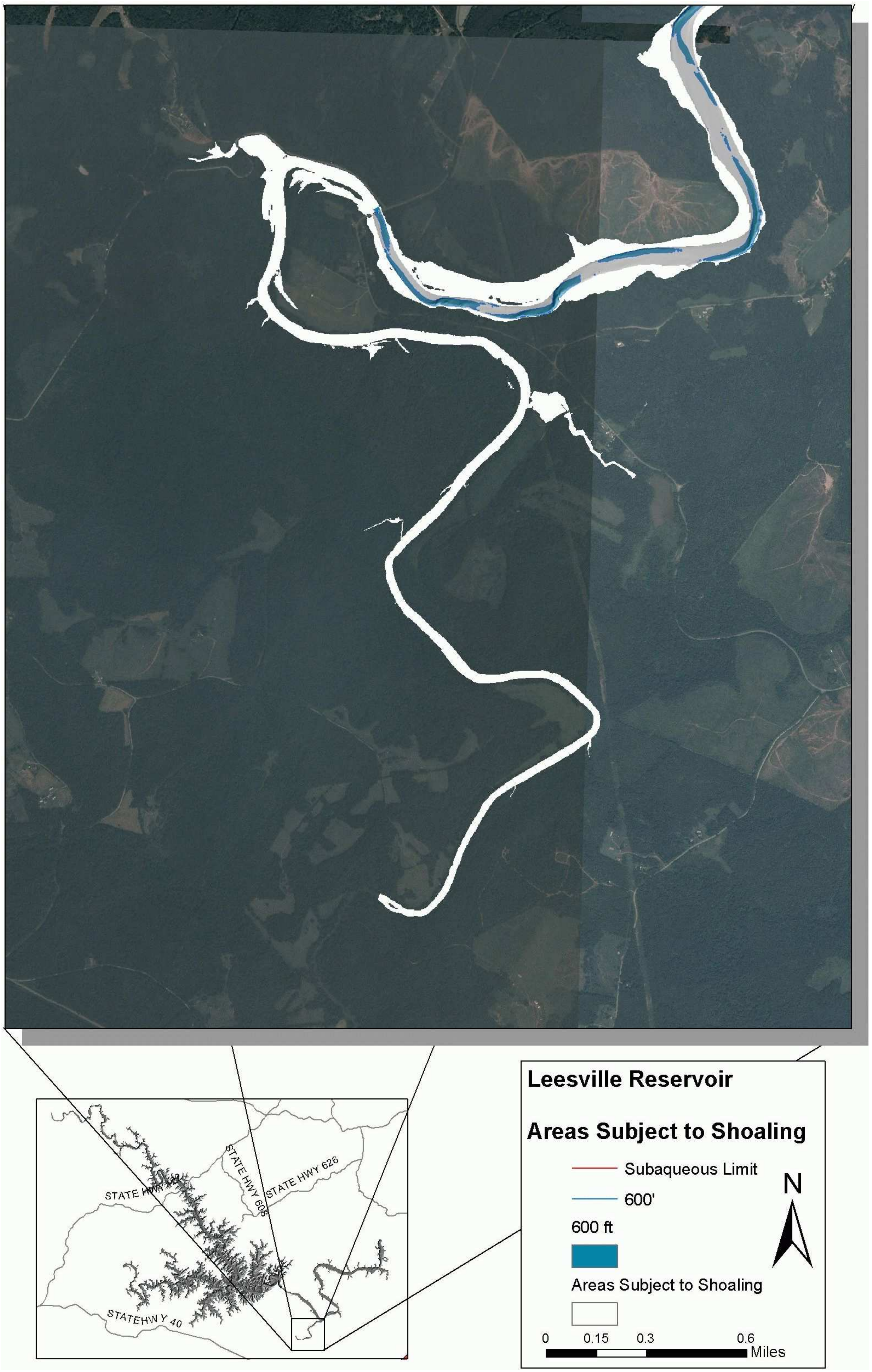


Figure 32: Shoaling and subaqueous sedimentation in Leesville Lake (7 of 8).

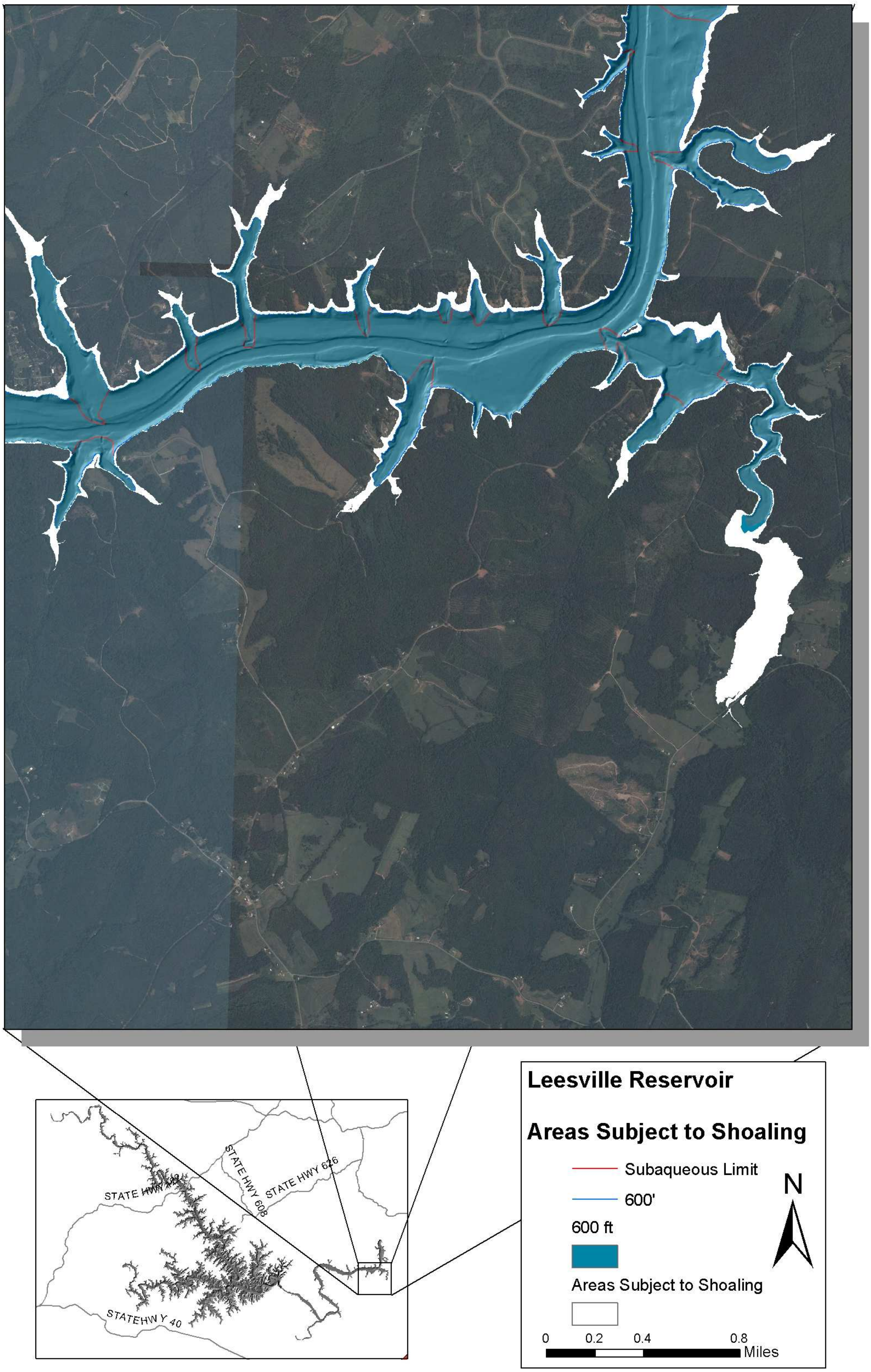


Figure 33: Shoaling and subaqueous sedimentation in Leesville Lake (8 of 8).

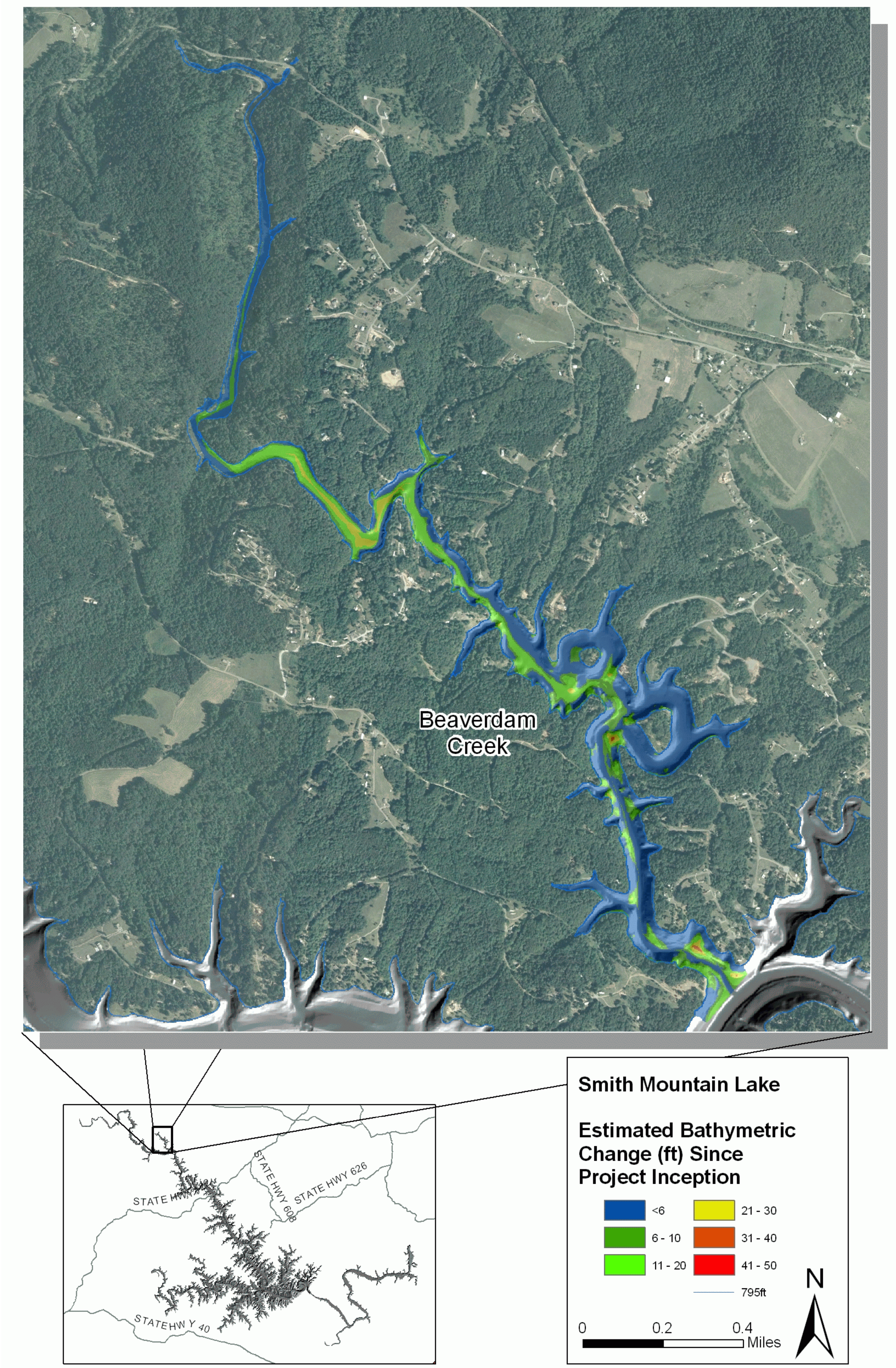


Figure 34: Estimated Changes in Project bathymetry for Beaverdam Creek Area

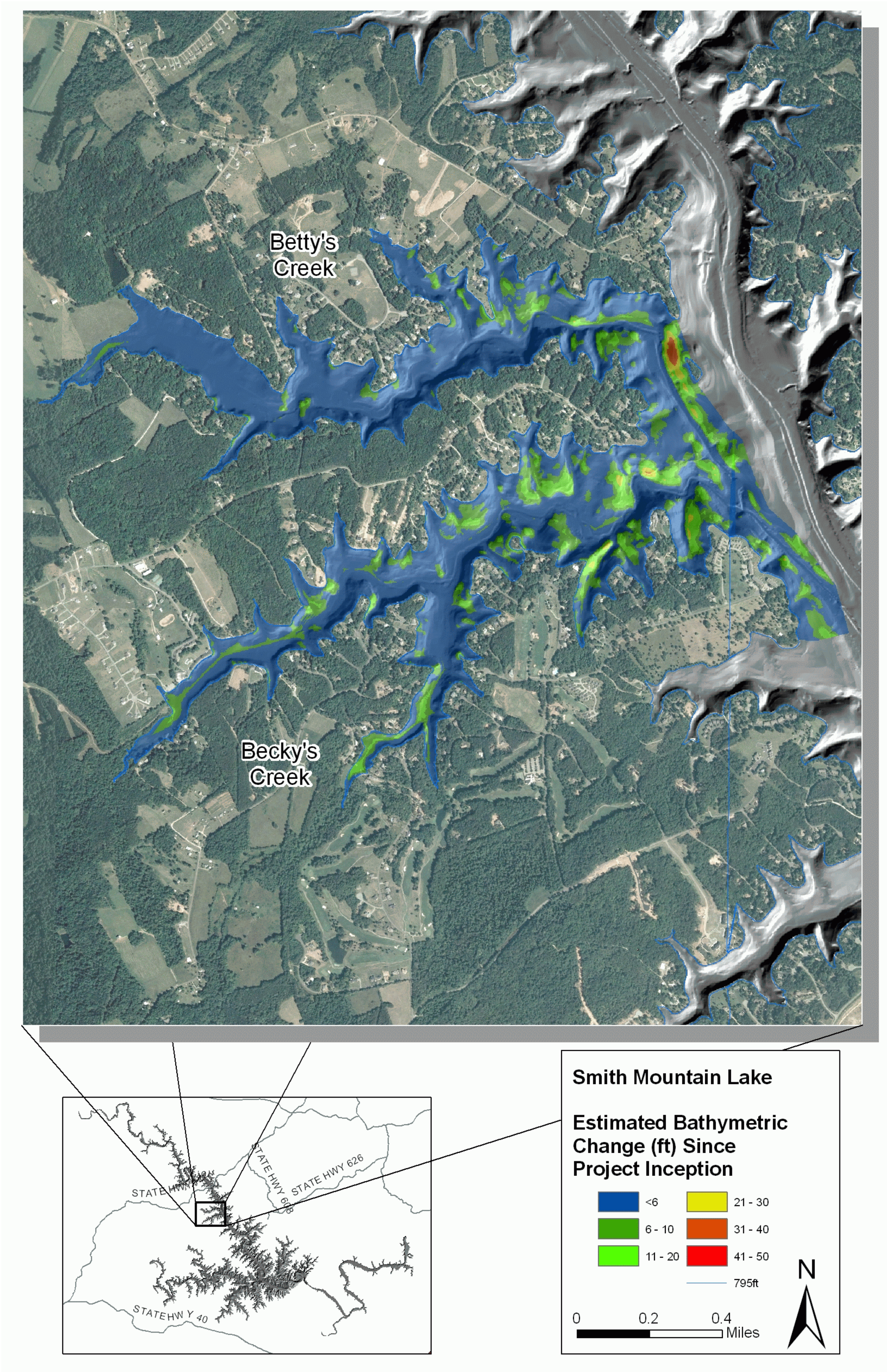


Figure 35: Estimated Changes in Project bathymetry for Becky's and Betty's Creek Area

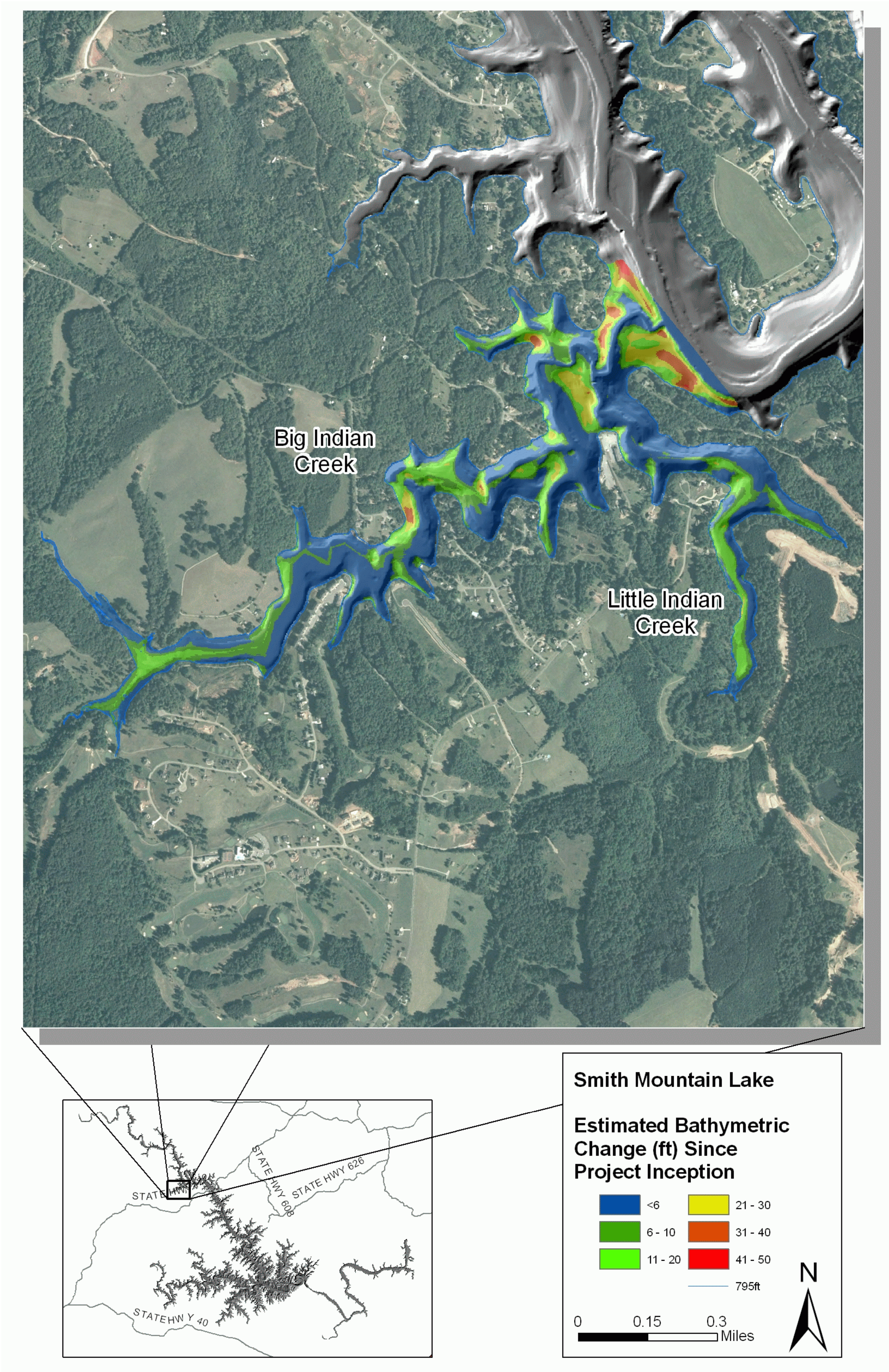


Figure 36: Estimated Changes in Project bathymetry for Big and Little Indian Creeks Area

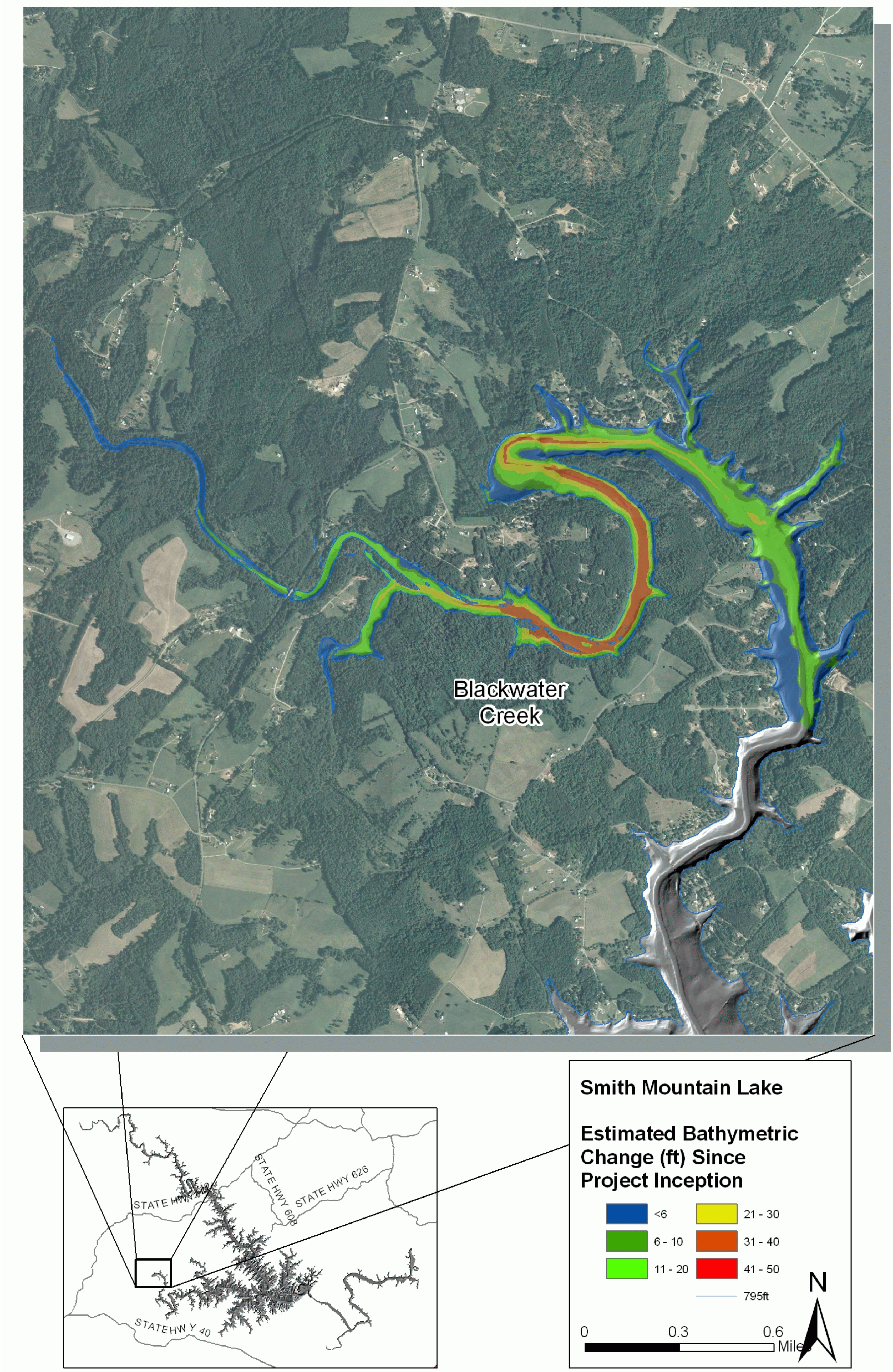


Figure 37: Estimated Changes in Project bathymetry for Blackwater Creek Area

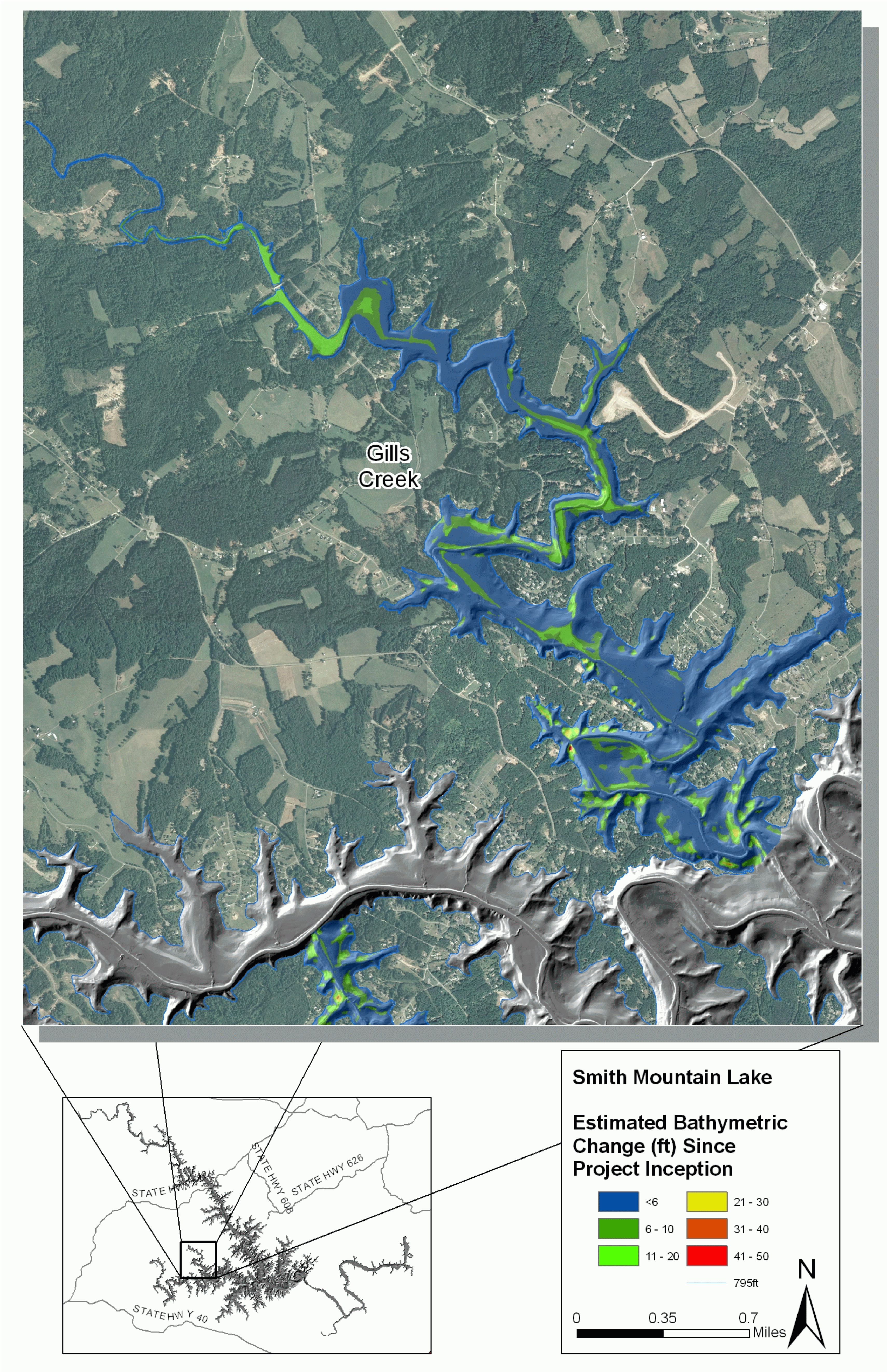


Figure 38: Estimated Changes in Project bathymetry for Gills Creek Area

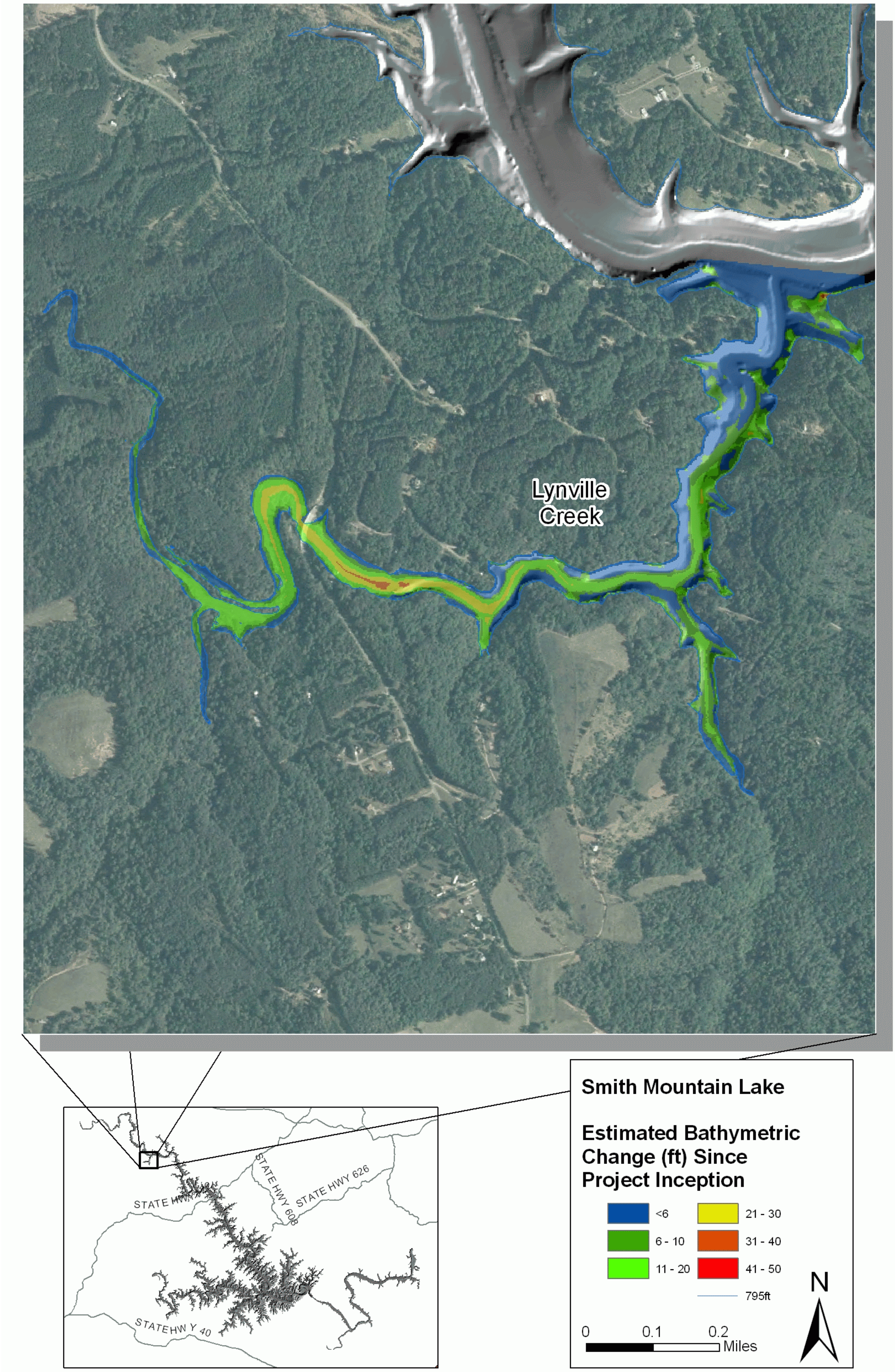


Figure 39: Estimated Changes in Project bathymetry for Lynville Creek Area

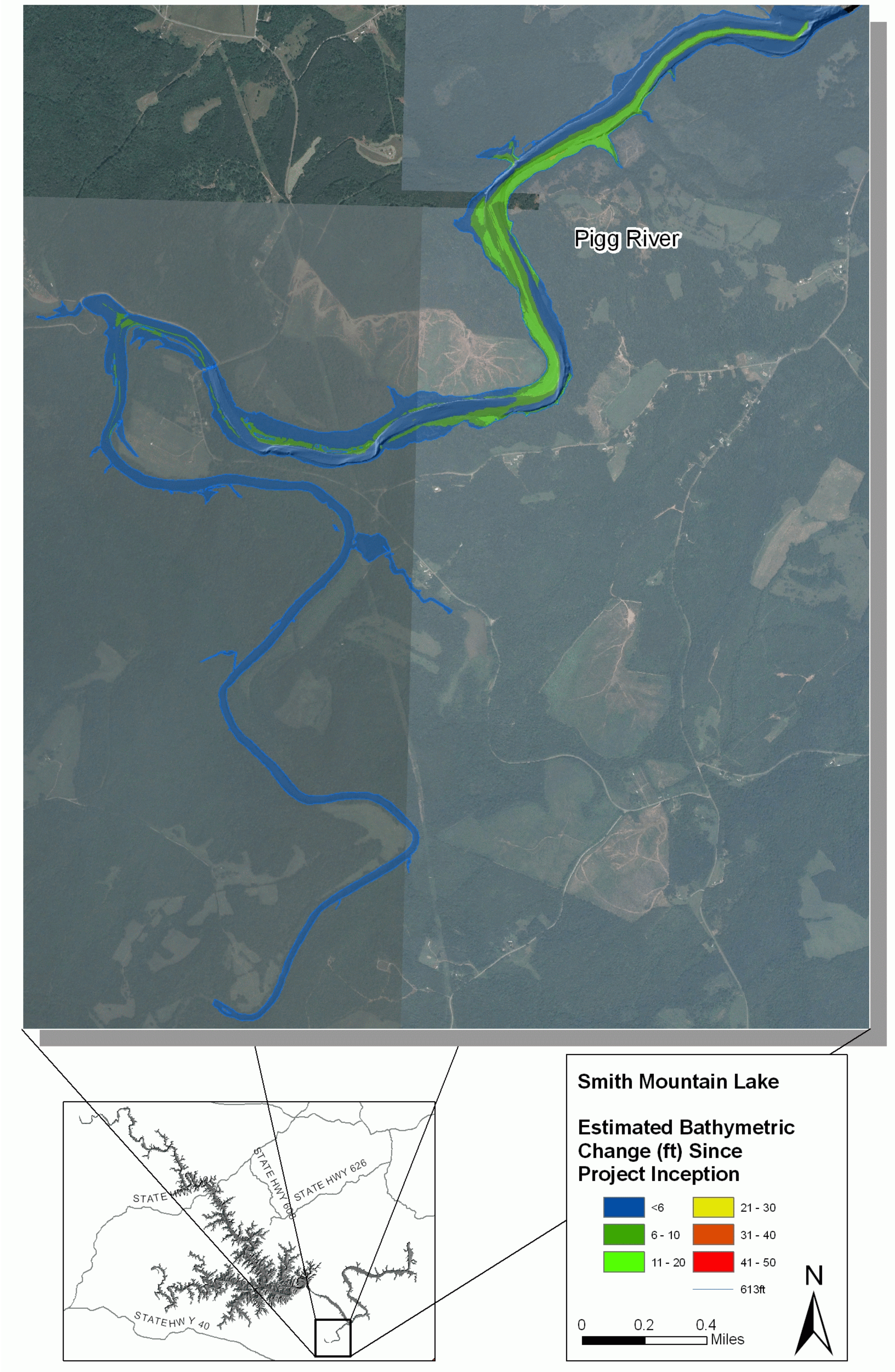


Figure 40: Estimated Changes in Project bathymetry for Pigg River Area

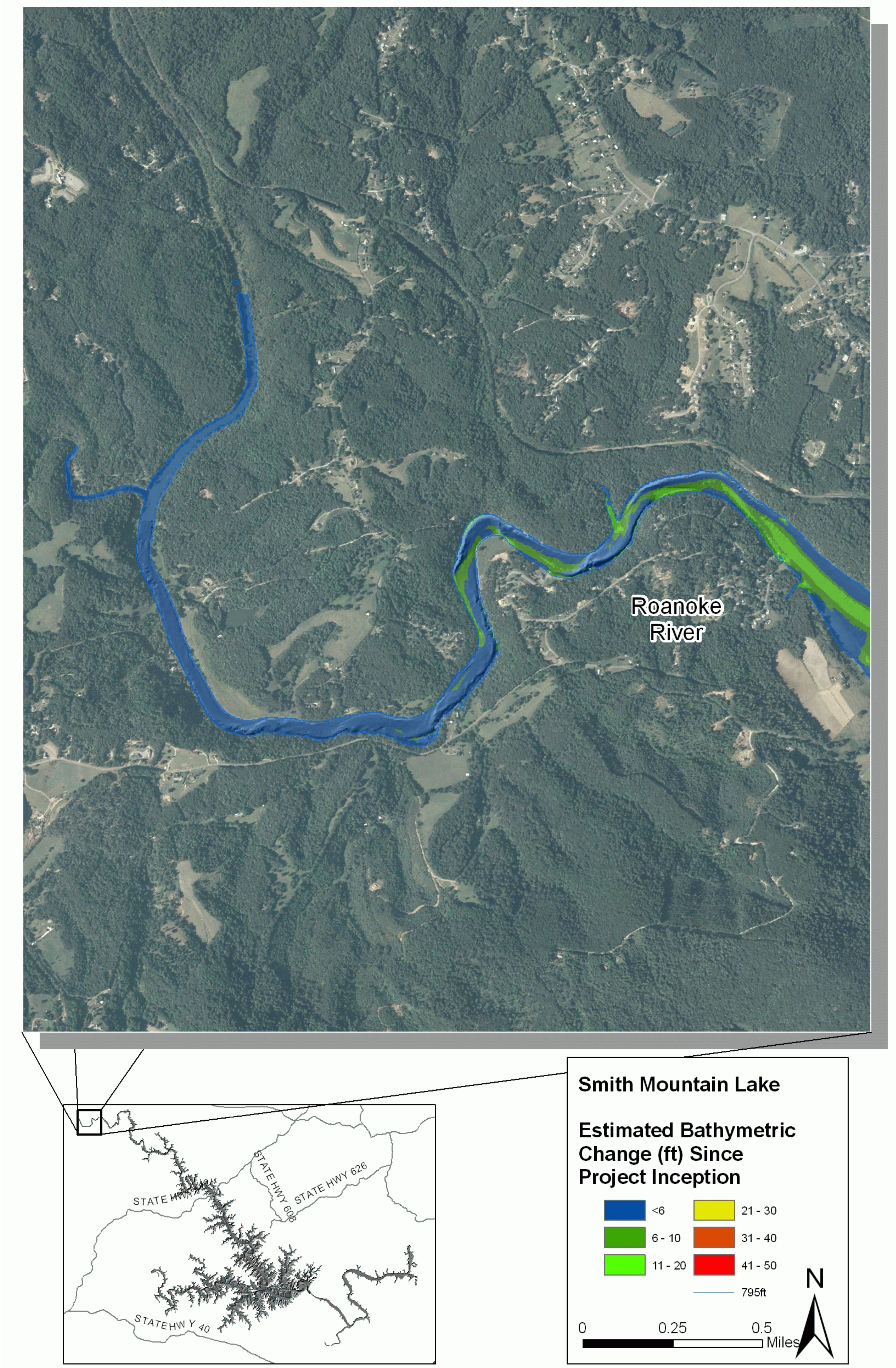


Figure 41: Estimated Changes in Project bathymetry for Roanoke River Area (1 of 2)

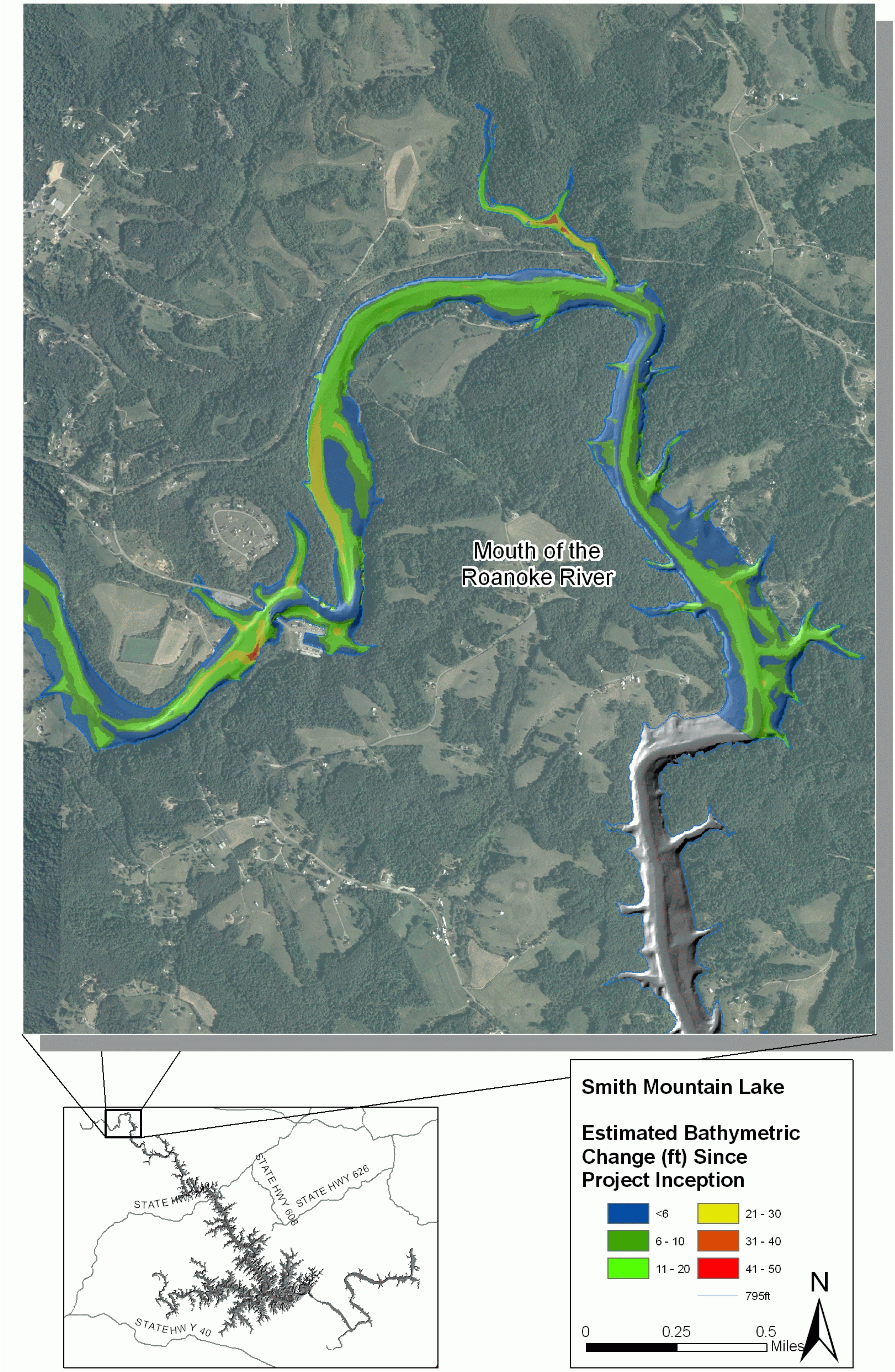


Figure 42: Estimated Changes in Project bathymetry for Roanoke River Area (2 of 2)

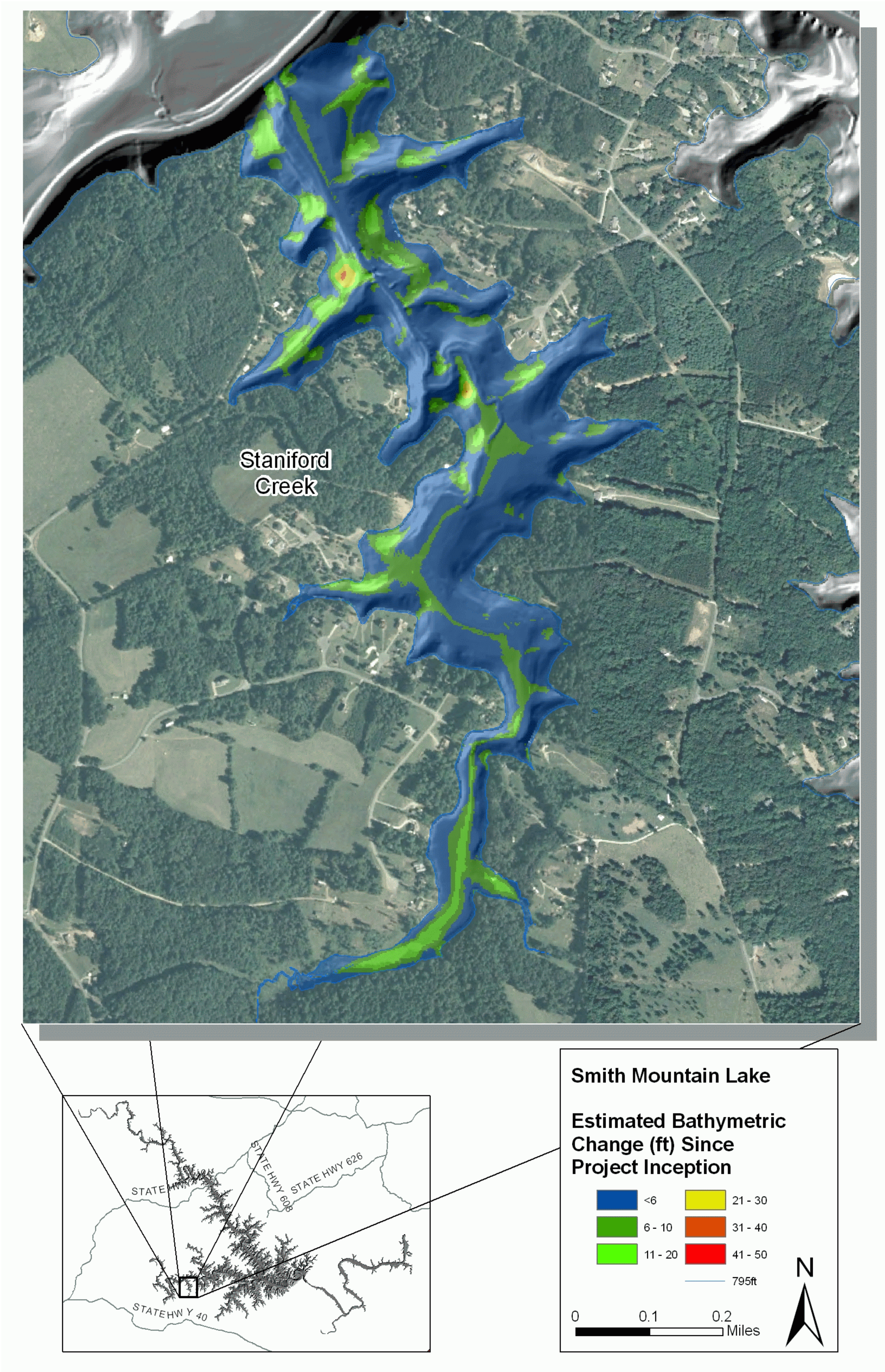


Figure 43: Estimated Changes in Project bathymetry for Staniford Creek Area

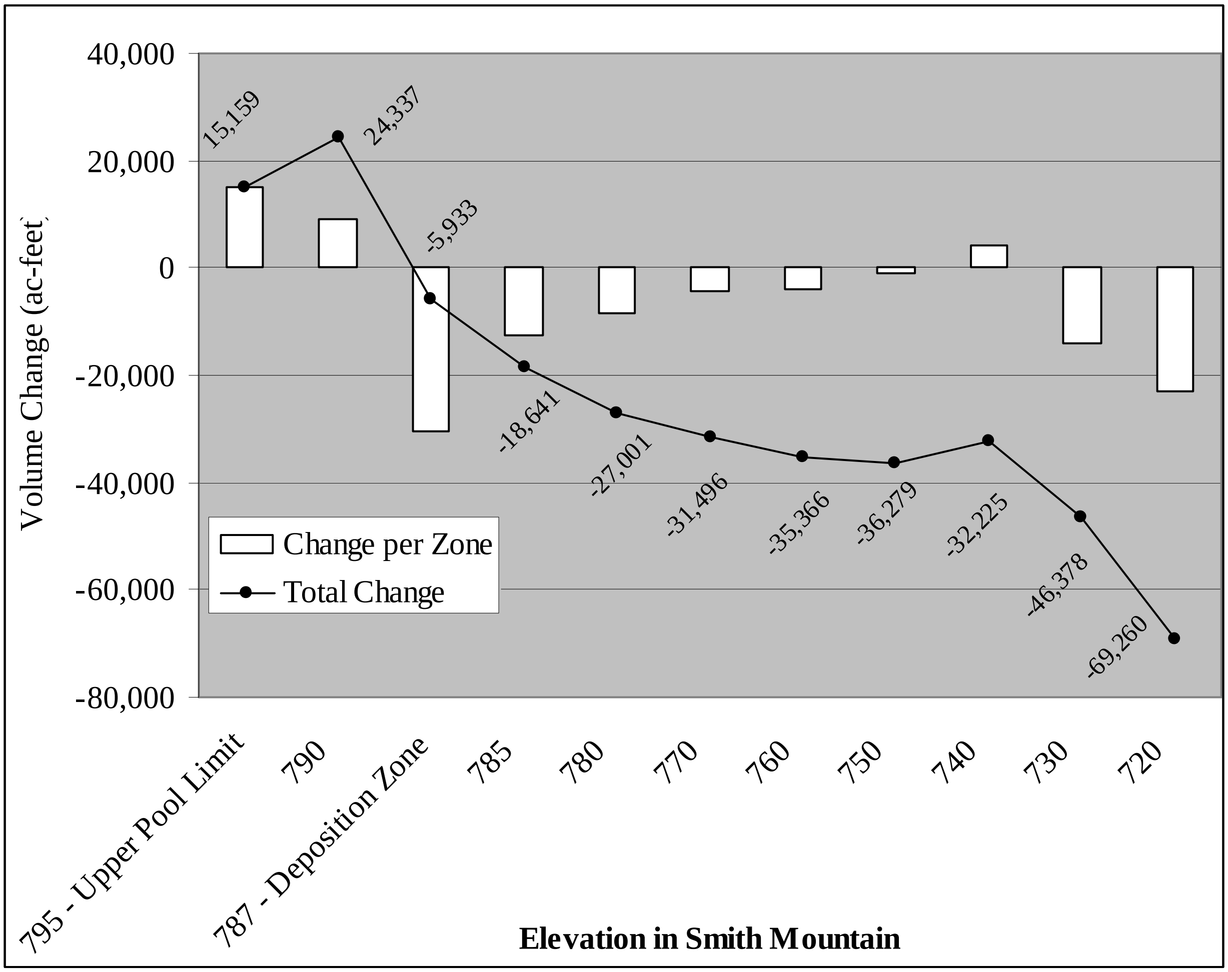


Figure 44: Sedimentation patterns by elevation zones in Smith Mountain Lake. Total shoreline erosion was approximately 24,300 acre-feet of sediment. According to OSI sediment surveys (OSI, 2006), these sediments were deposited near-shore, in the deposition zone from 787 feet and lower. The remaining sedimentation, approximately 44,900 acre-feet (65%), may be attributed to watershed sources.

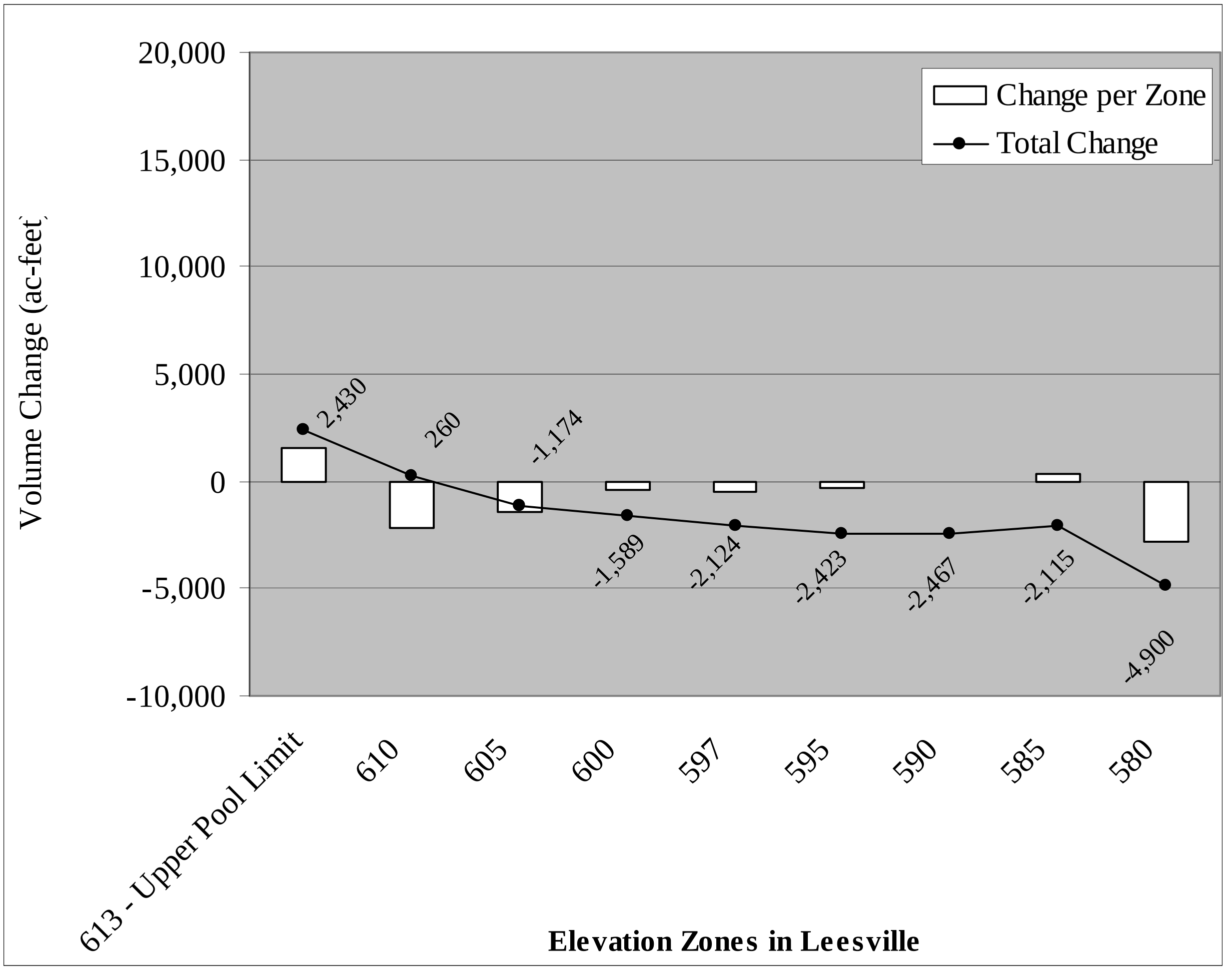


Figure 45: Sedimentation patterns by elevation zones in Leesville Lake. Total shoreline erosion was estimated as 2,430 acre-feet of sediment. Due to the larger range of pool elevations on Leesville, these sediments have been distributed over a larger elevation range, from 610 feet to below 600 feet. Given the higher currents in Leesville Lake, deposits within the channel of Leesville are dominated by coarser sand deposits. The remaining sedimentation, 2,470 acre-feet (50%), may be attributed to watershed sources.

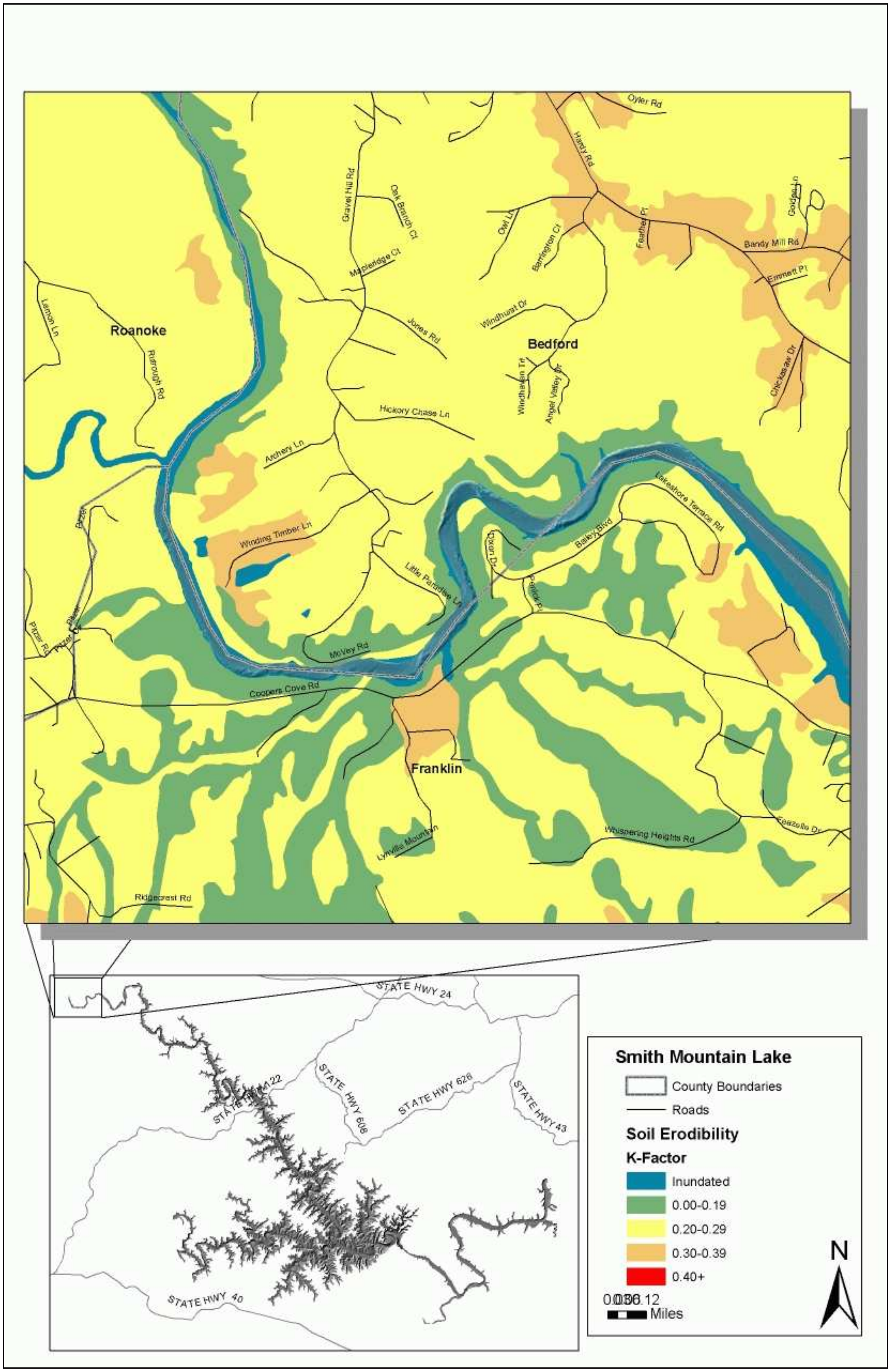


Figure 46: Soil erodibility map of Smith Mountain Lake (1 of 12).

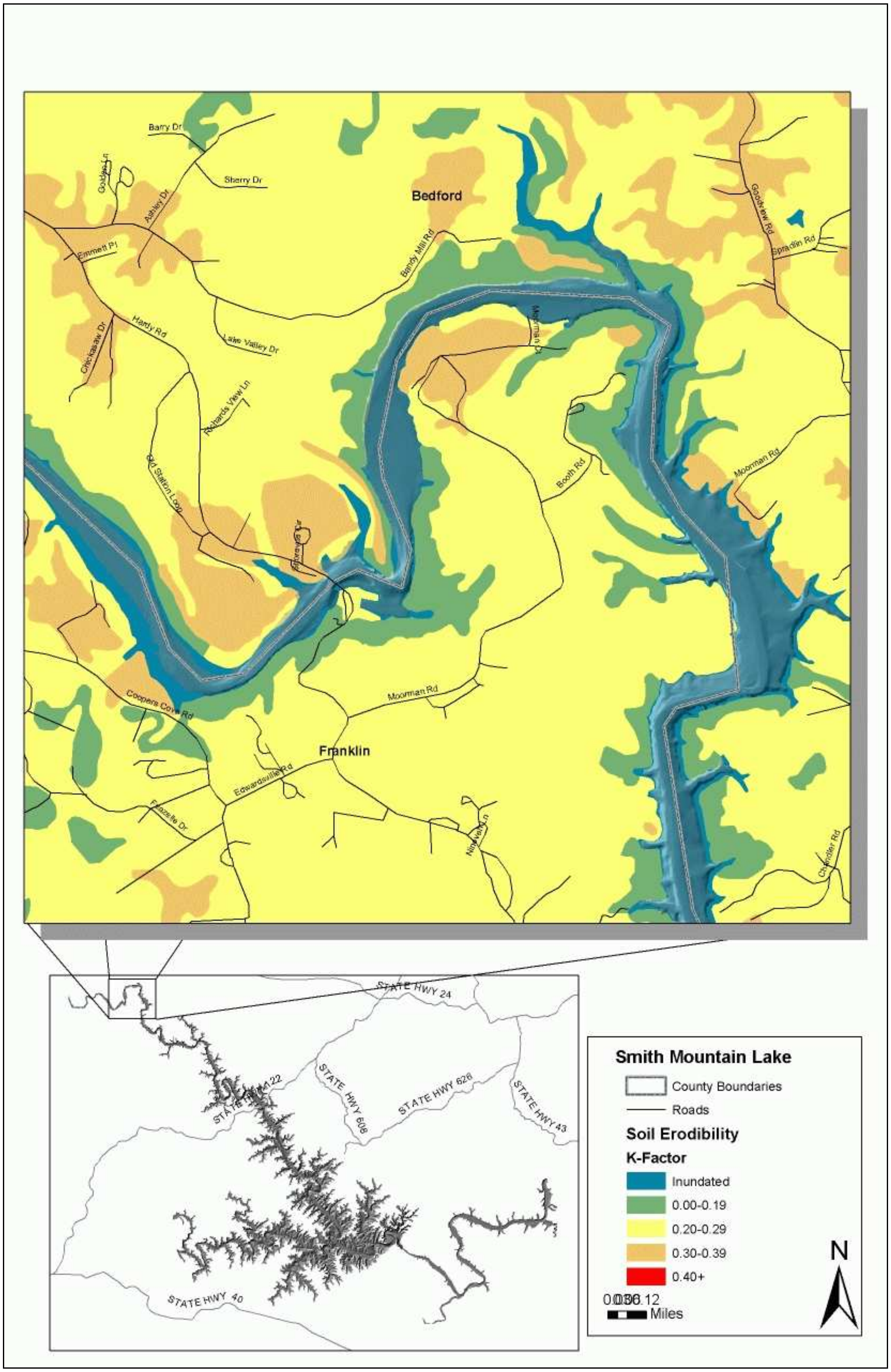


Figure 47: Soil erodibility map of Smith Mountain Lake (2 of 12).

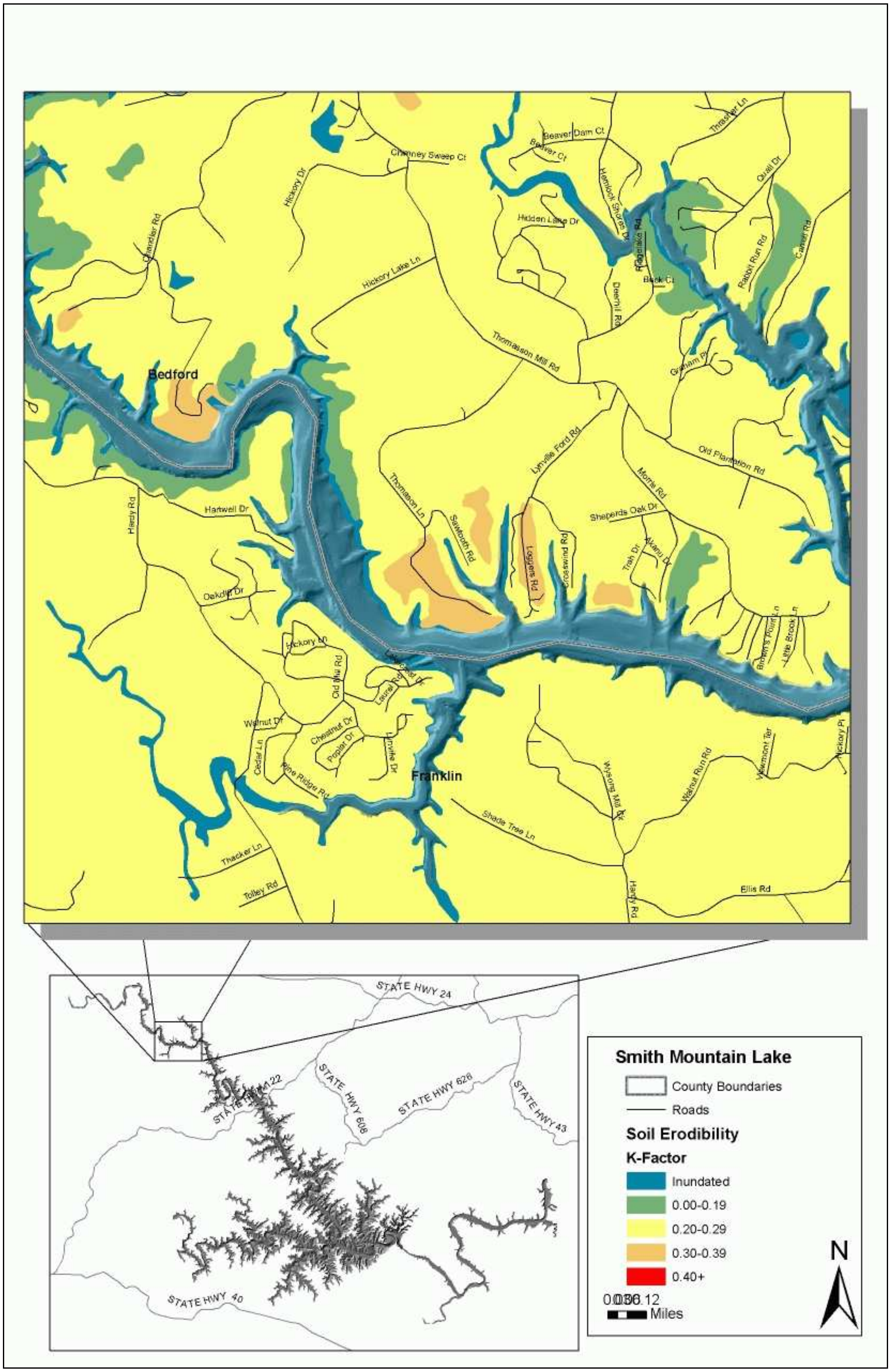


Figure 48: Soil erodibility map of Smith Mountain Lake (3 of 12).

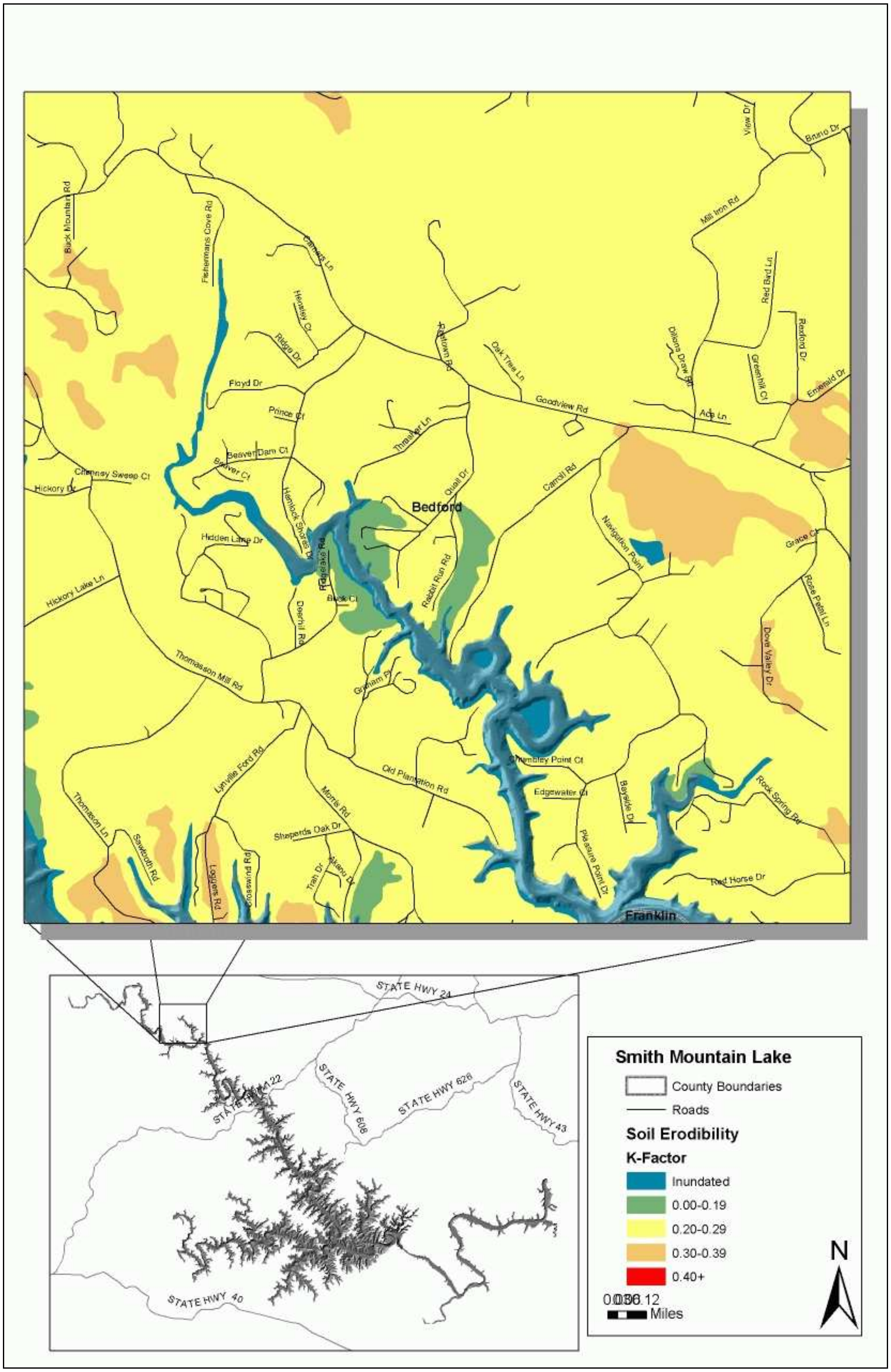


Figure 49: Soil erodibility map of Smith Mountain Lake (4 of 12).

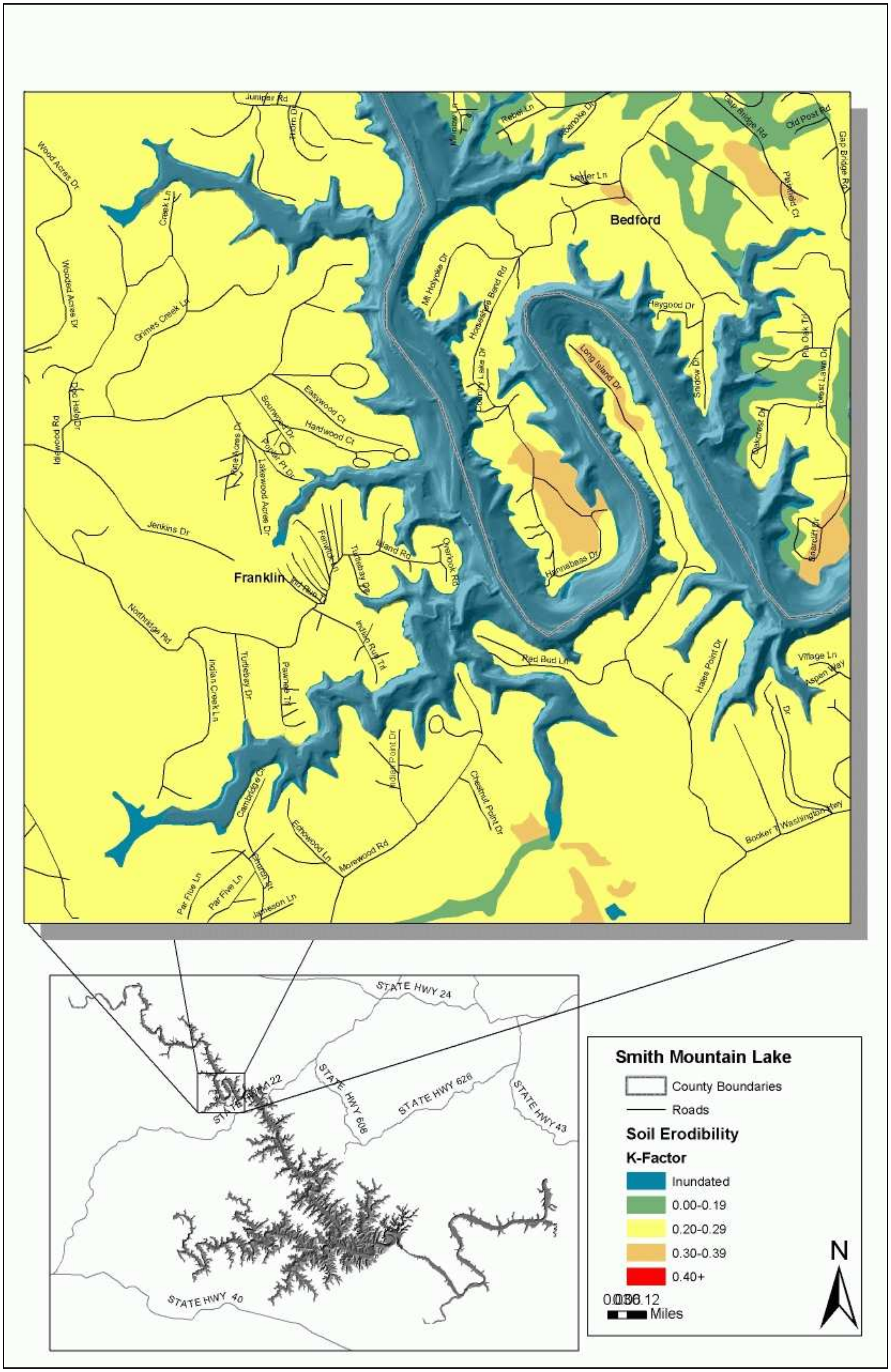


Figure 50: Soil erodibility map of Smith Mountain Lake (5 of 12).

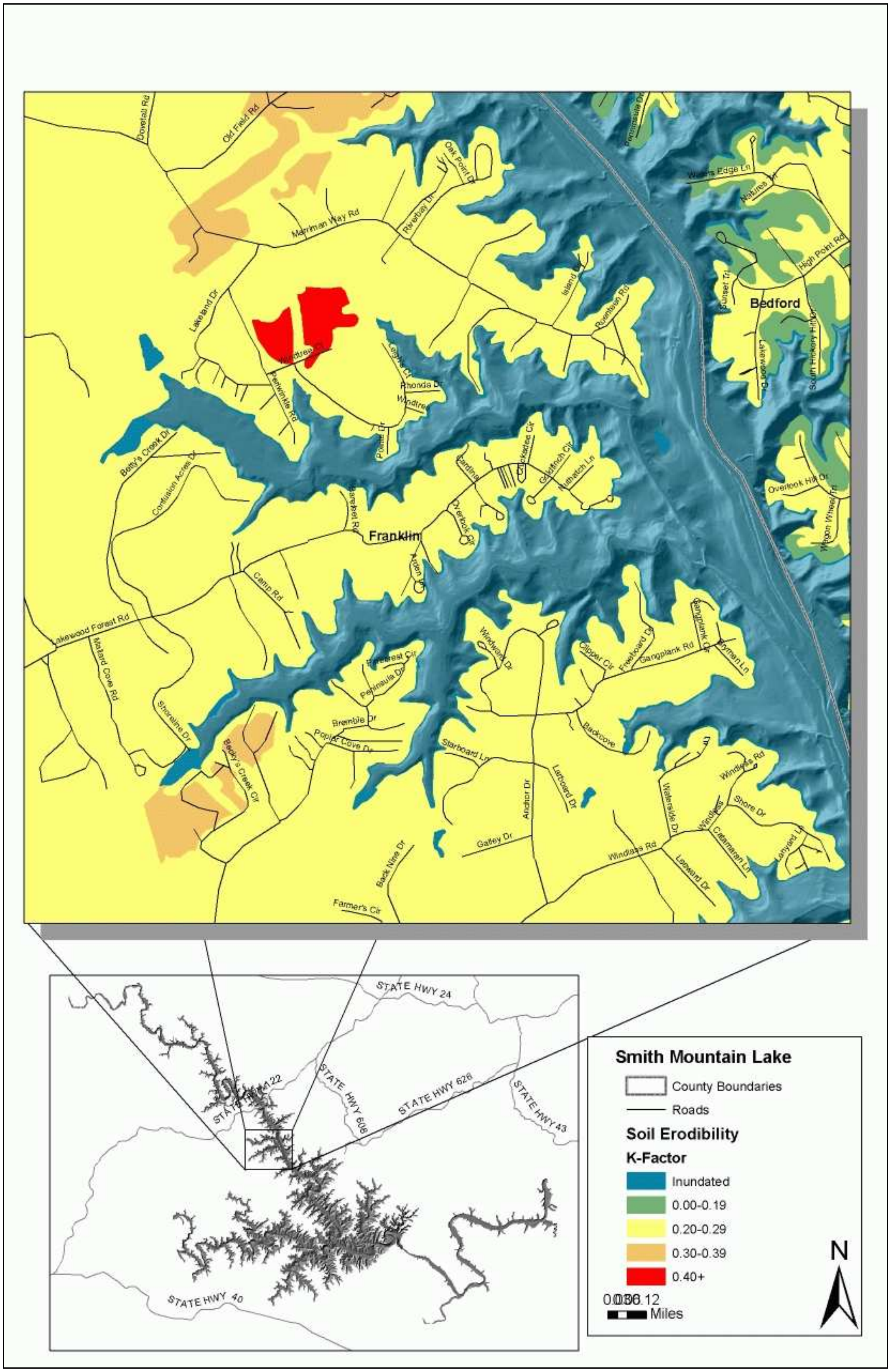


Figure 51: Soil erodibility map of Smith Mountain Lake (6 of 12).

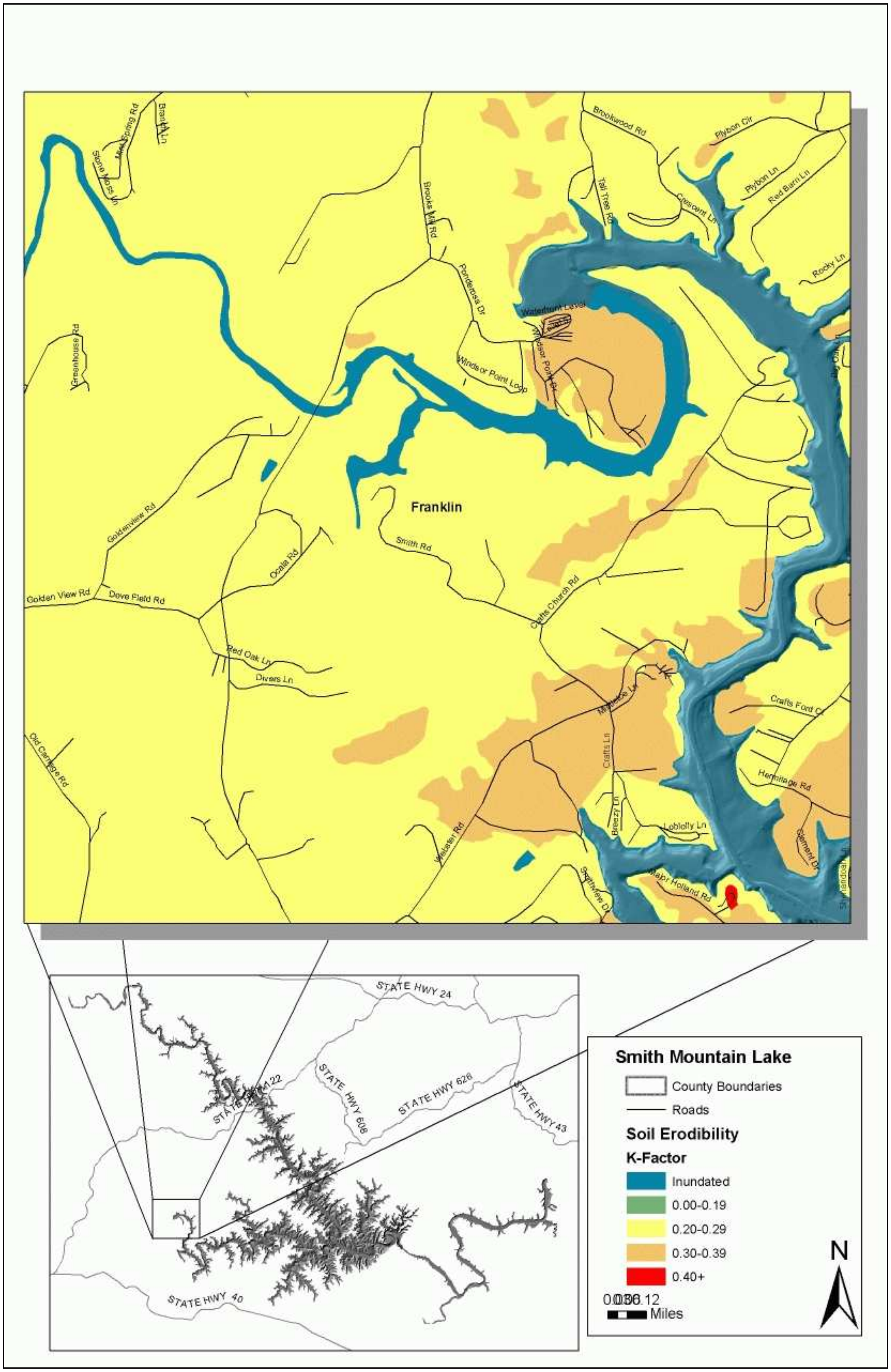


Figure 52: Soil erodibility map of Smith Mountain Lake (7 of 12).

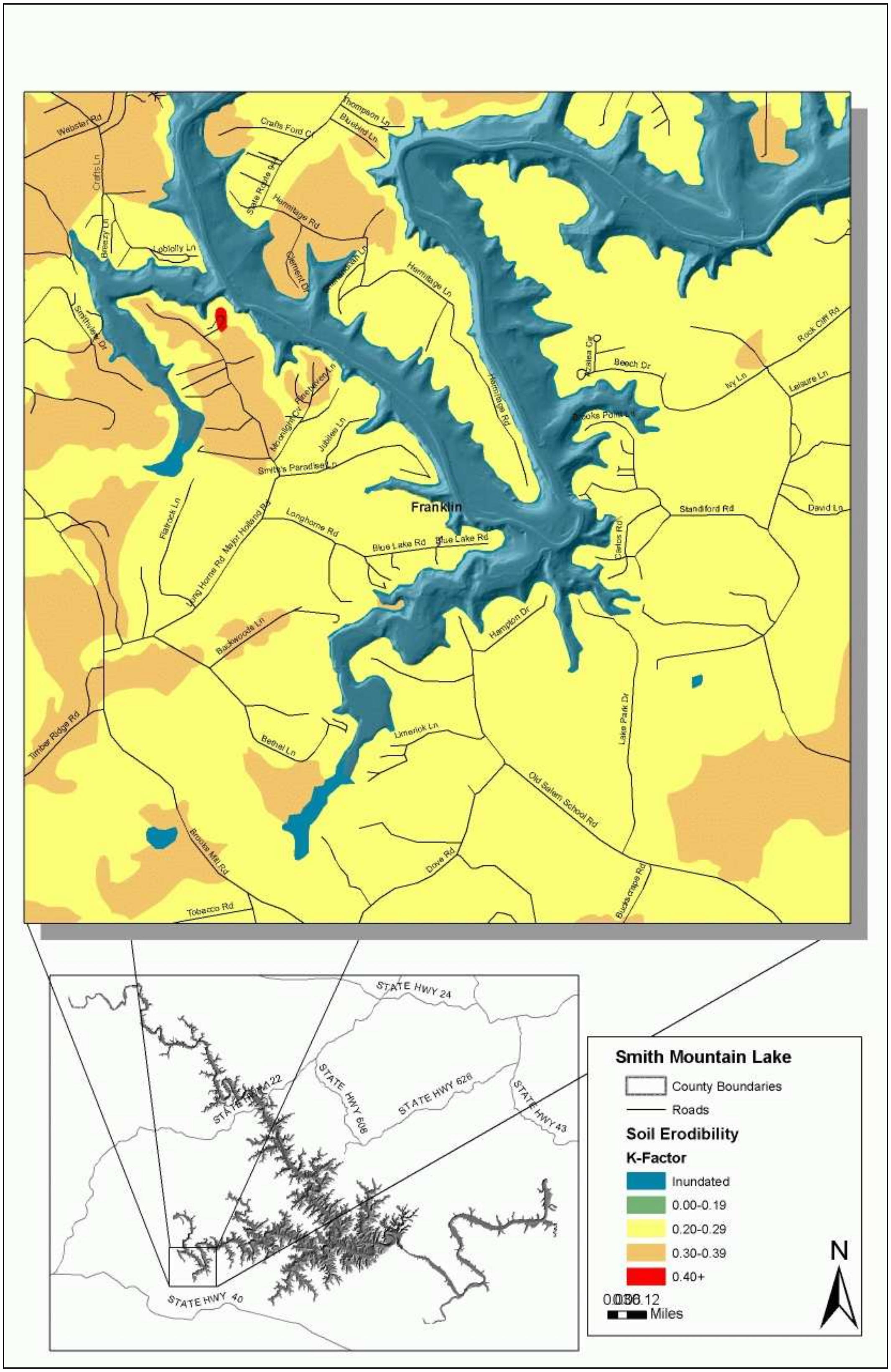


Figure 53: Soil erodibility map of Smith Mountain Lake (8 of 12).

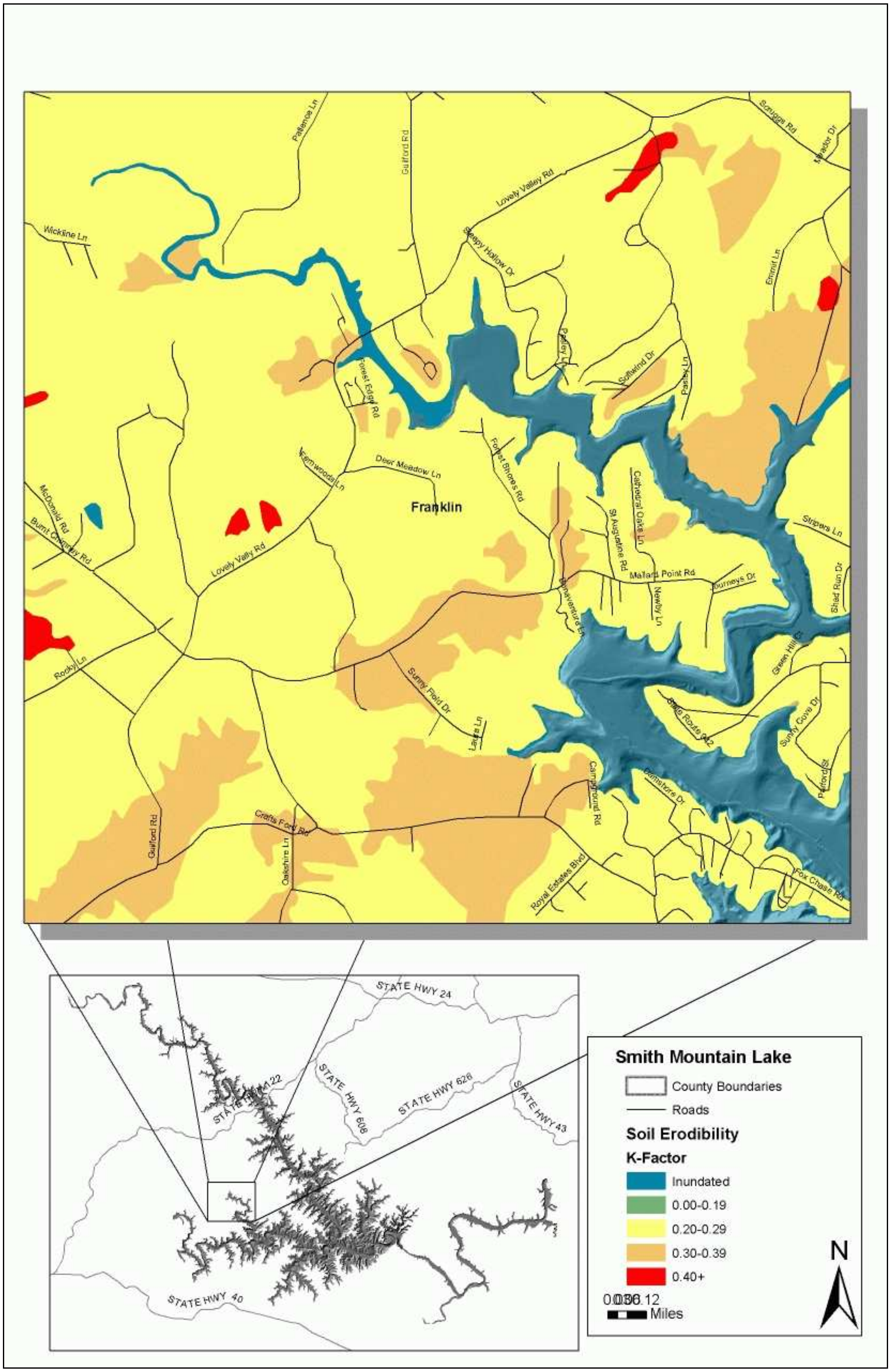


Figure 54: Soil erodibility map of Smith Mountain Lake (9 of 12).

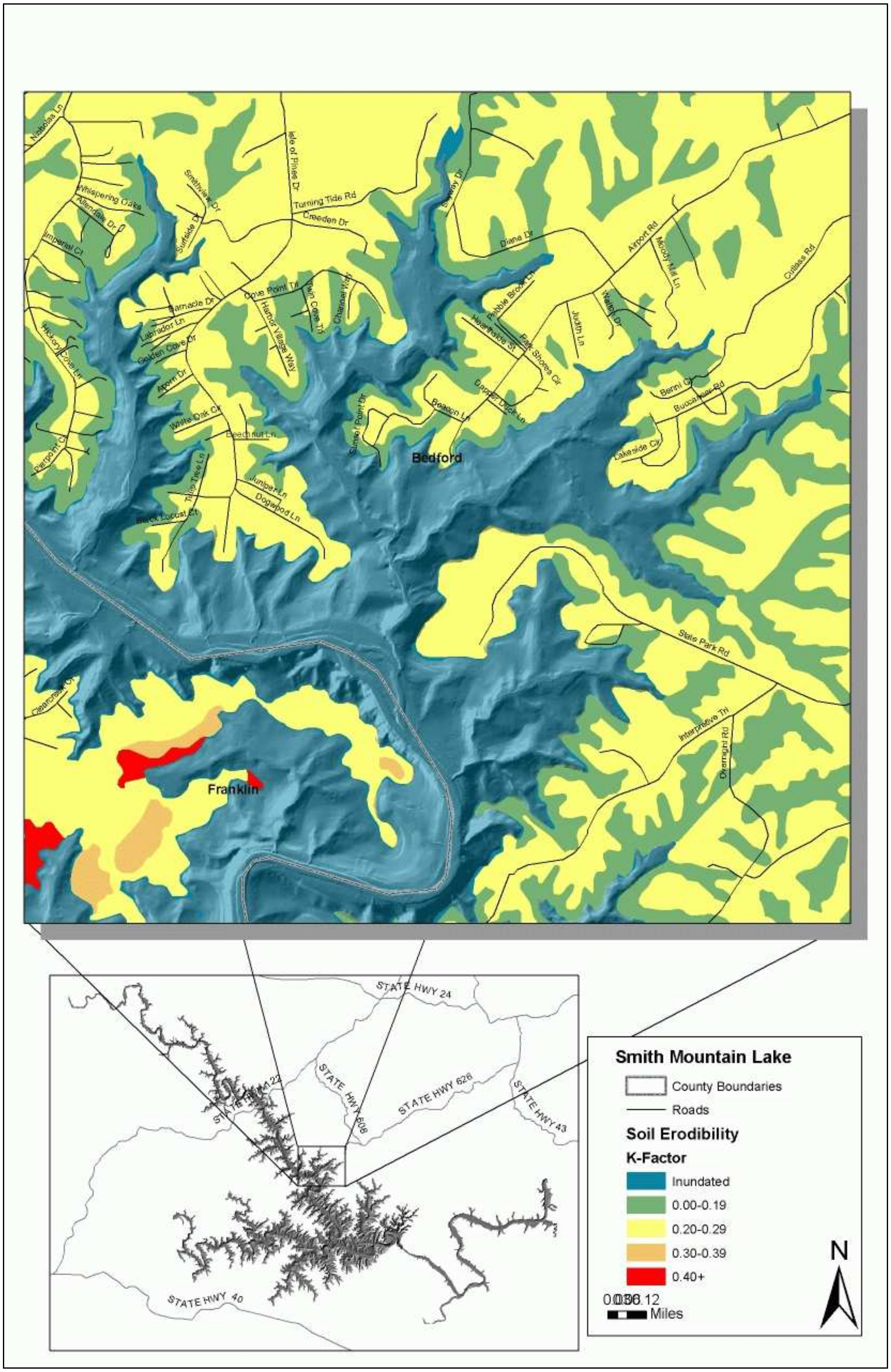


Figure 55: Soil erodibility map of Smith Mountain Lake (10 of 12).

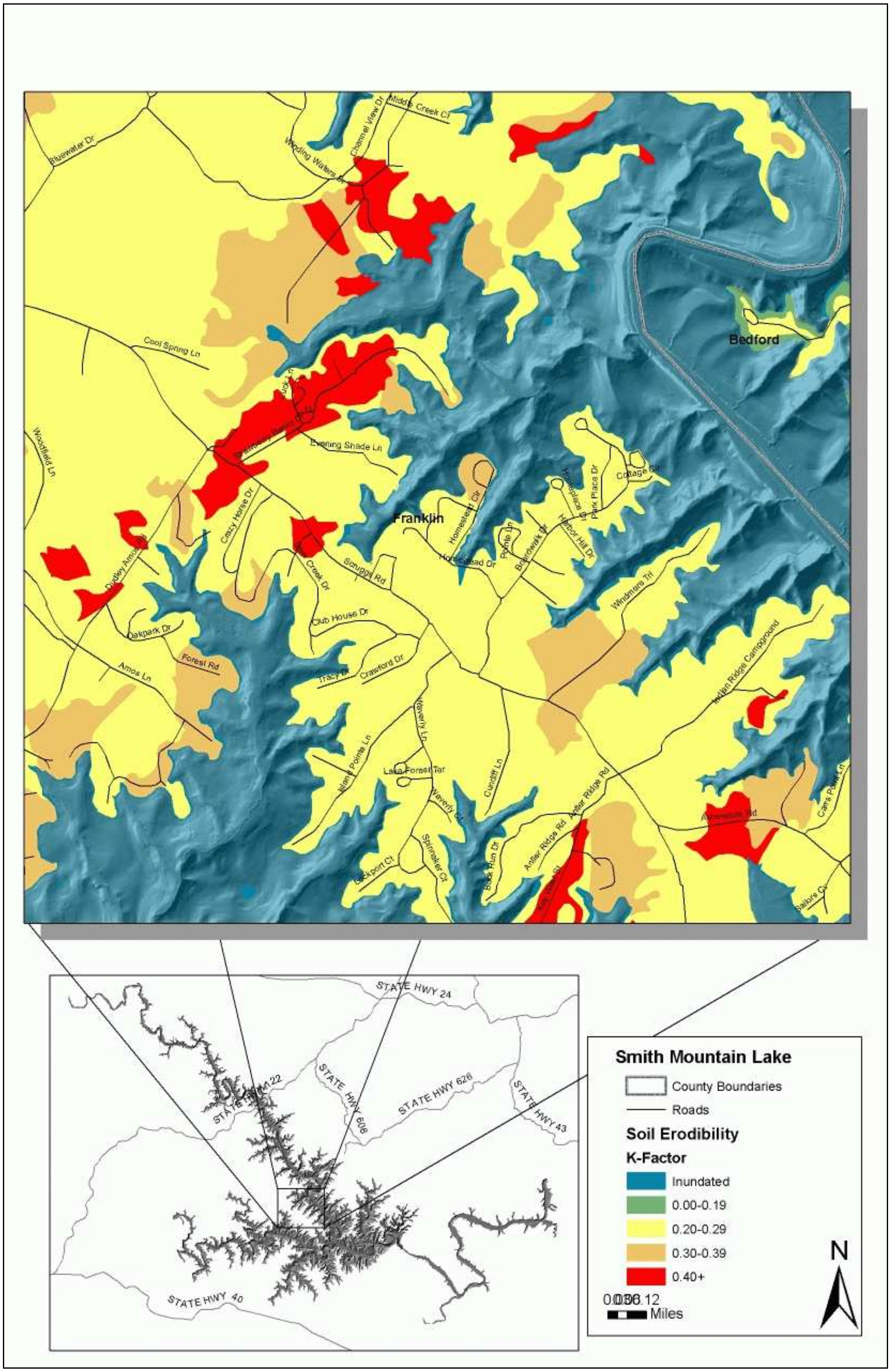


Figure 56: Soil erodibility map of Smith Mountain Lake (11 of 12).

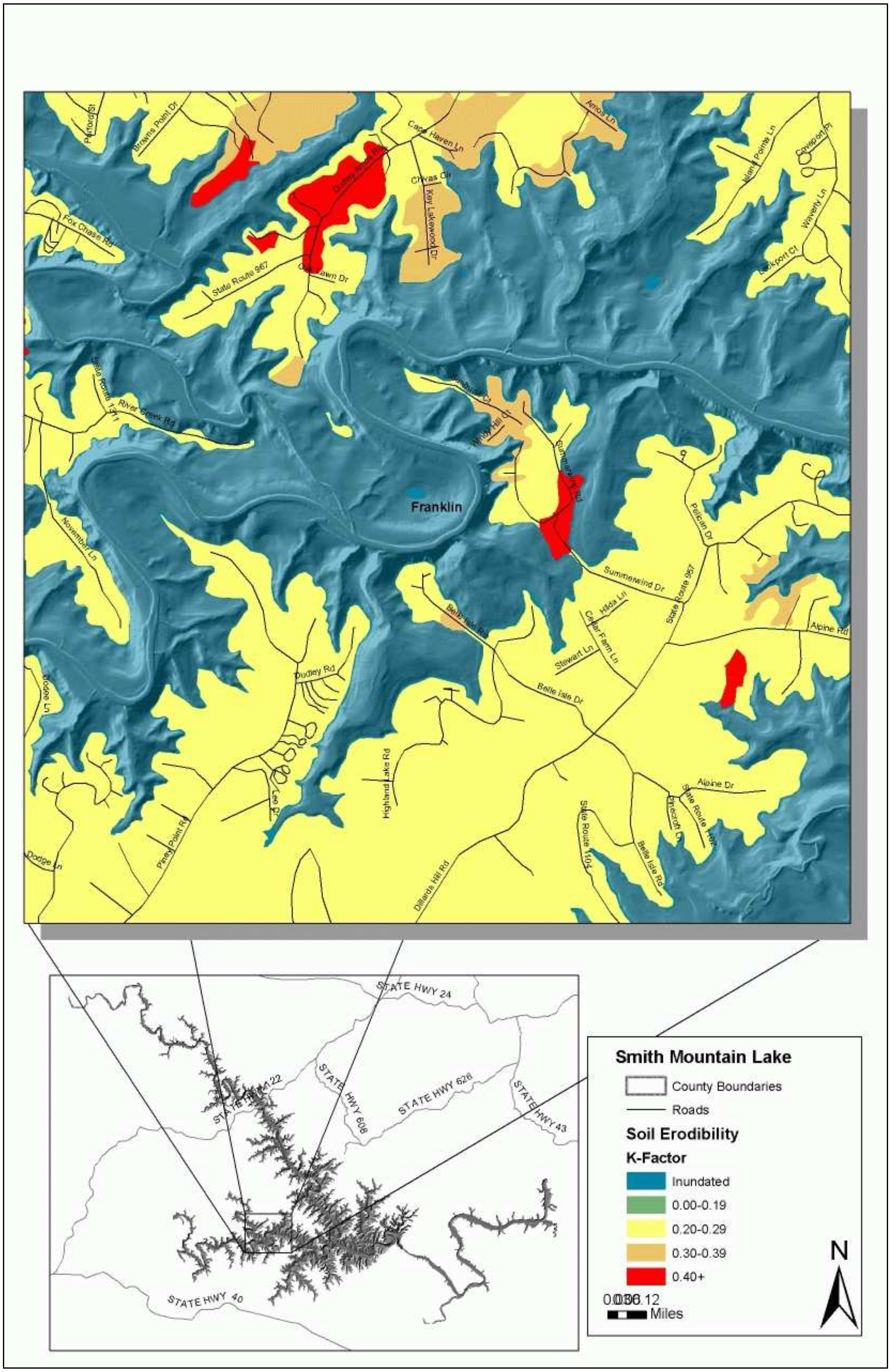


Figure 57: Soil erodibility map of Smith Mountain Lake (12 of 12).

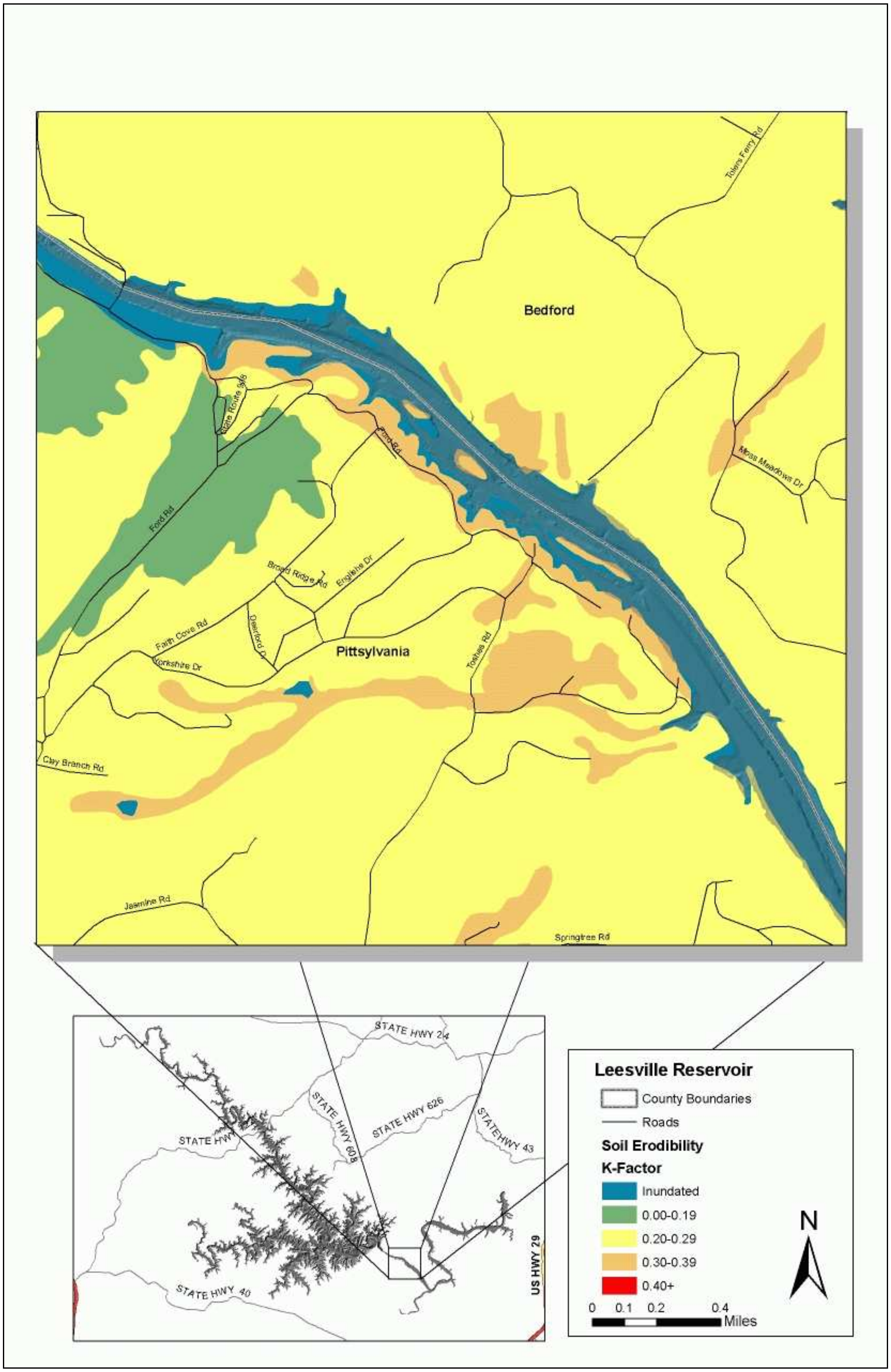


Figure 58: Soil erodibility map of Leesville Lake (1 of 7).

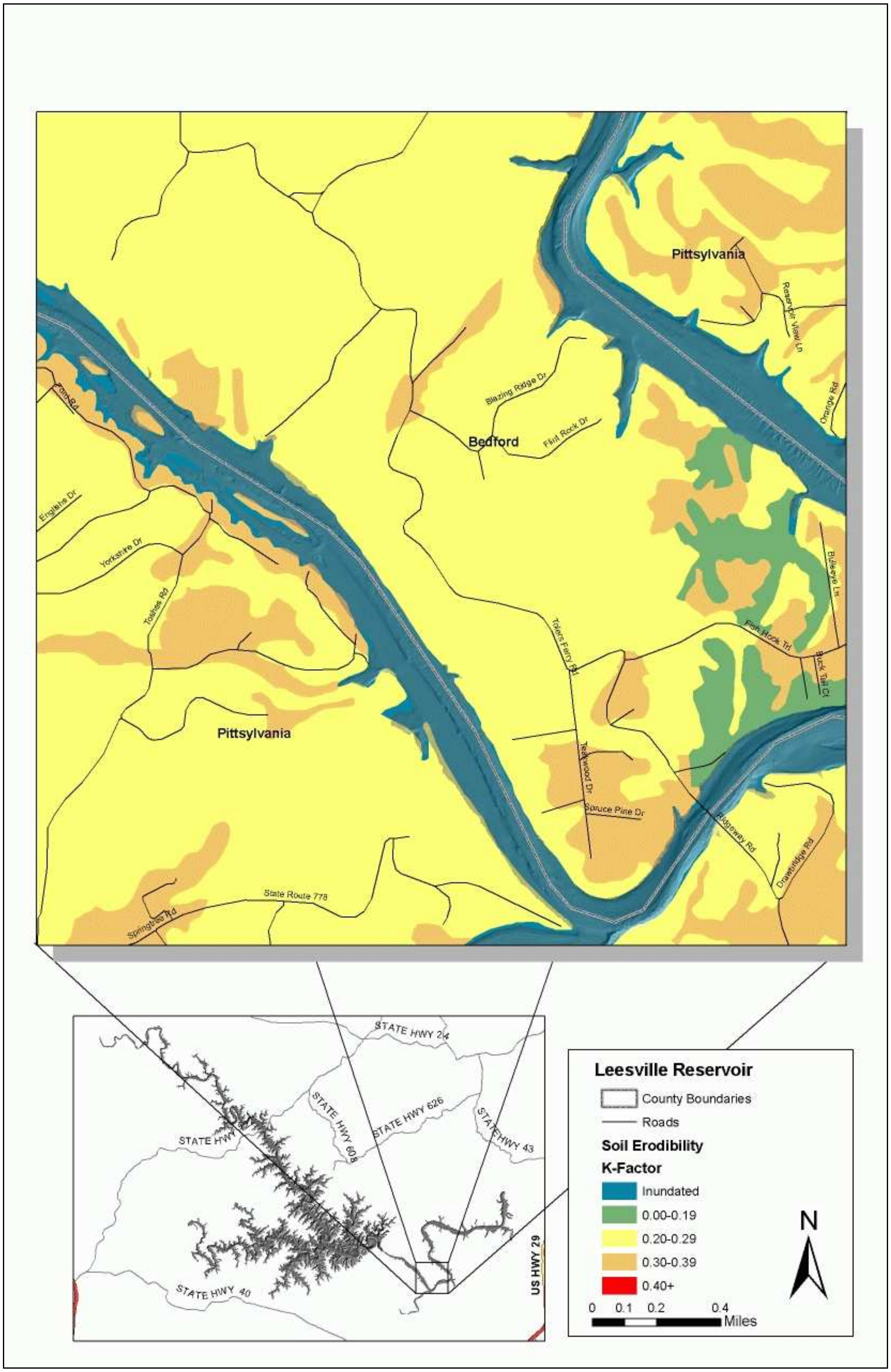


Figure 59: Soil erodibility map of Leesville Lake (2 of 7).

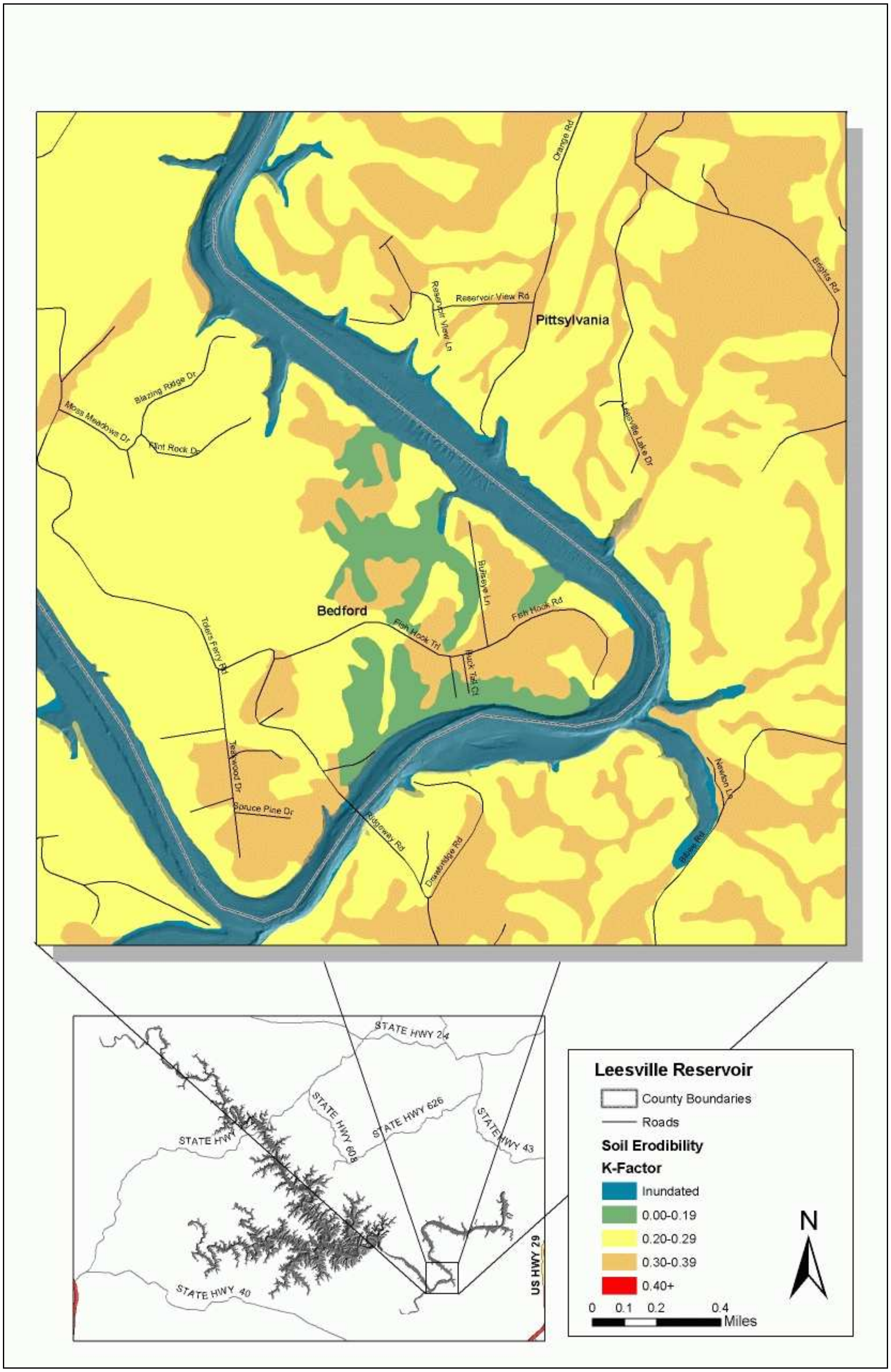


Figure 60: Soil erodibility map of Leesville Lake (3 of 7).

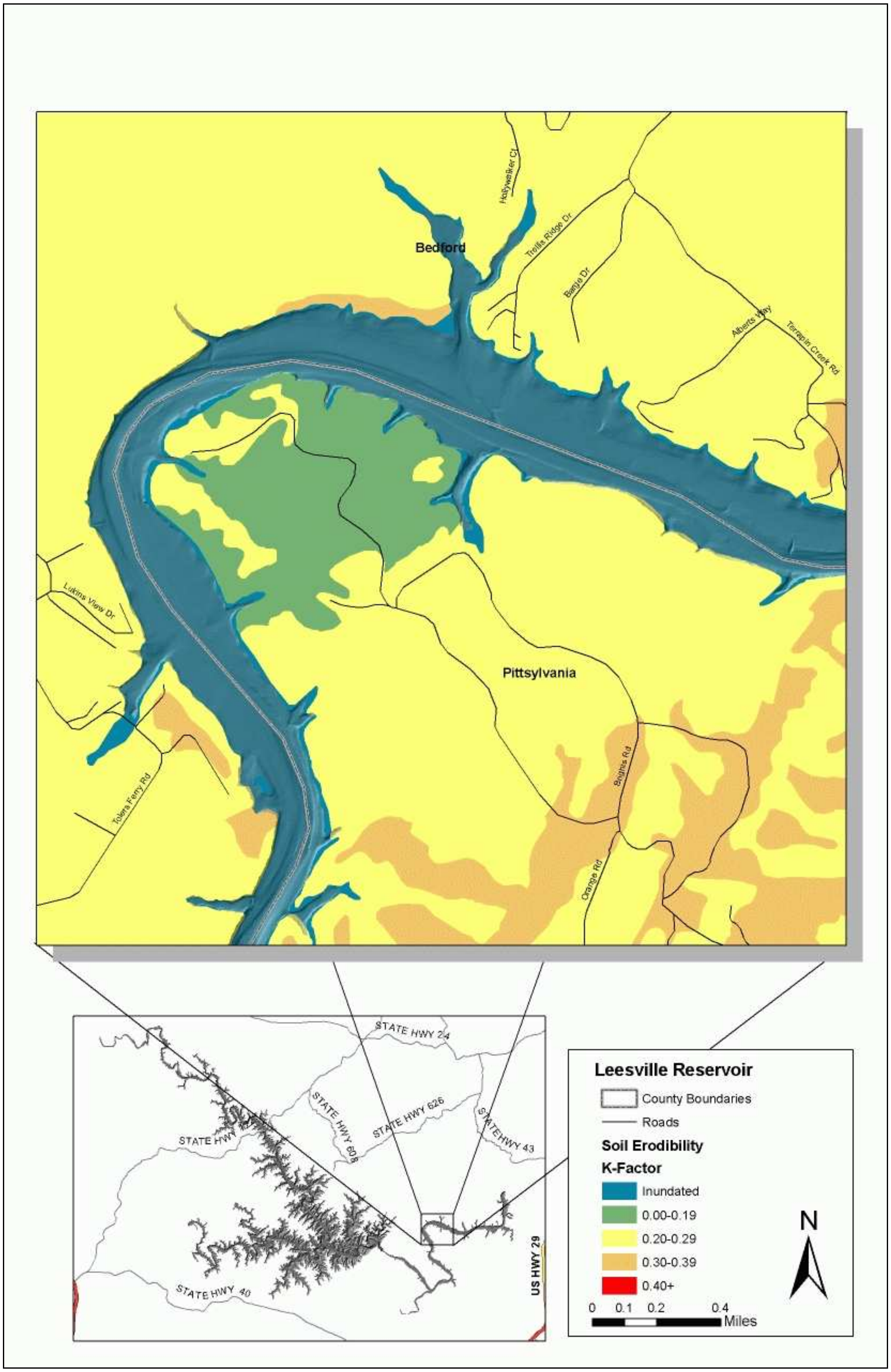


Figure 61: Soil erodibility map of Leesville Lake (4 of 7).

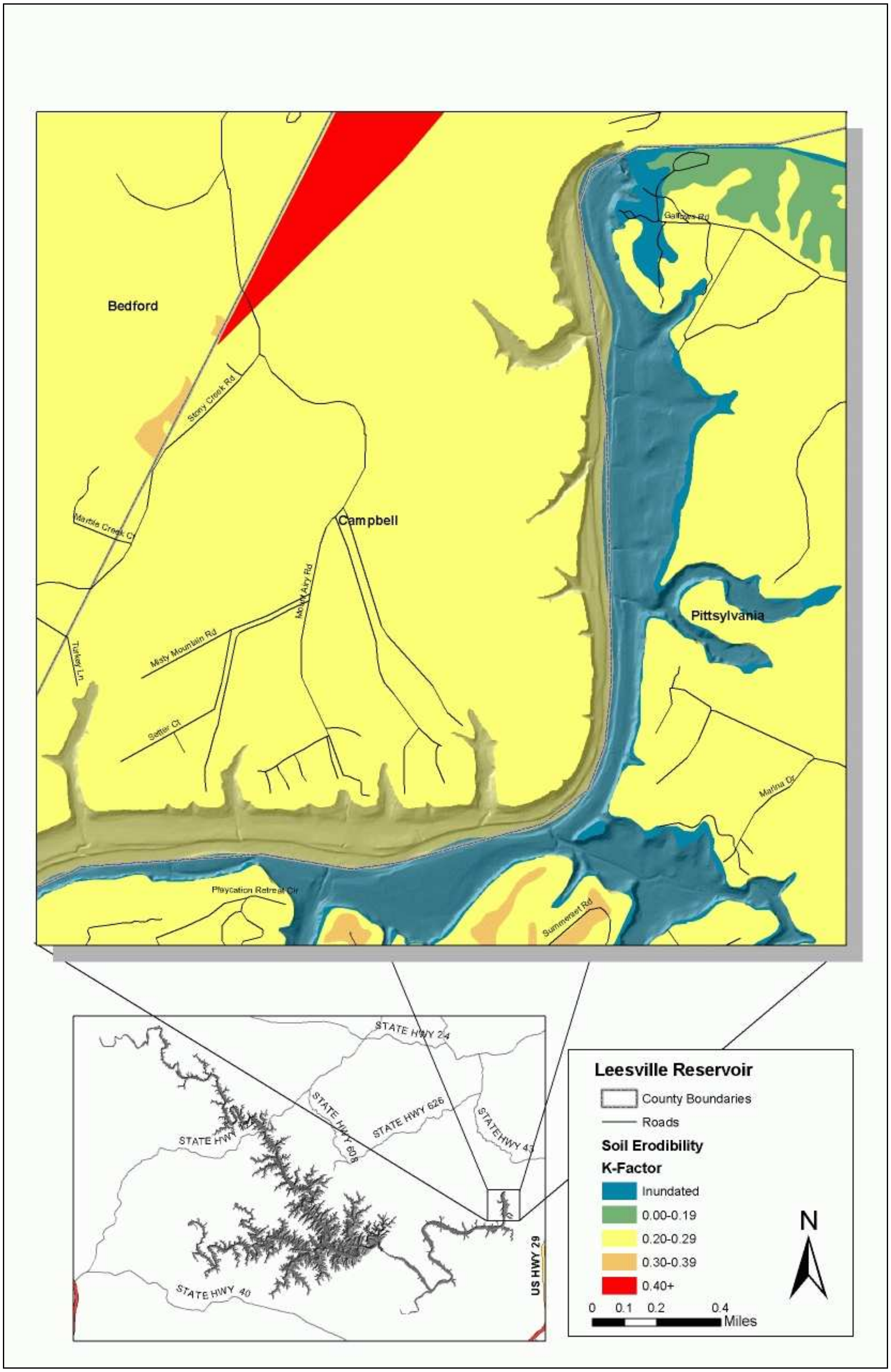


Figure 62: Soil erodibility map of Leesville Lake (5 of 7).

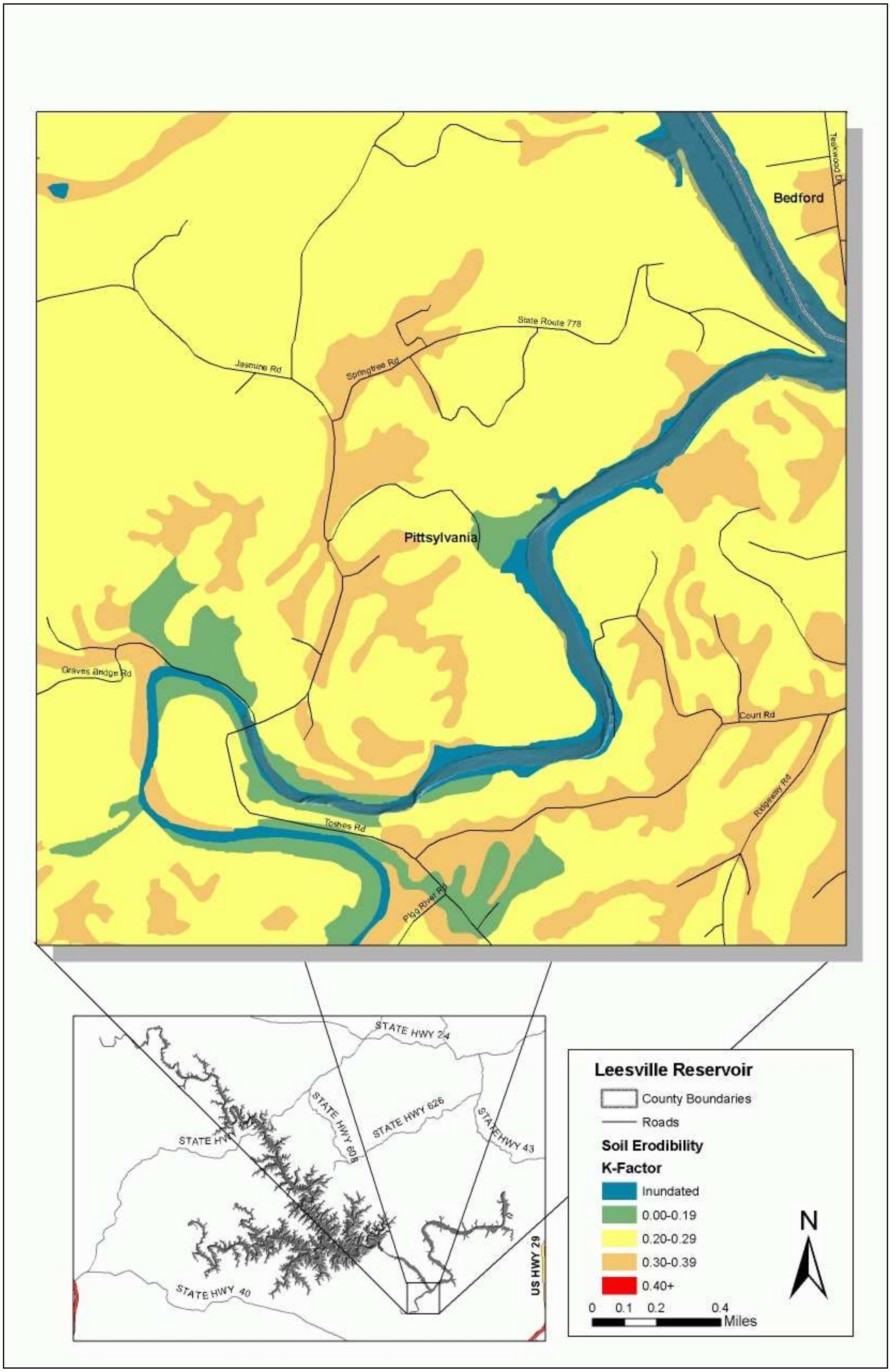


Figure 63: Soil erodibility map of Leesville Lake (6 of 7).

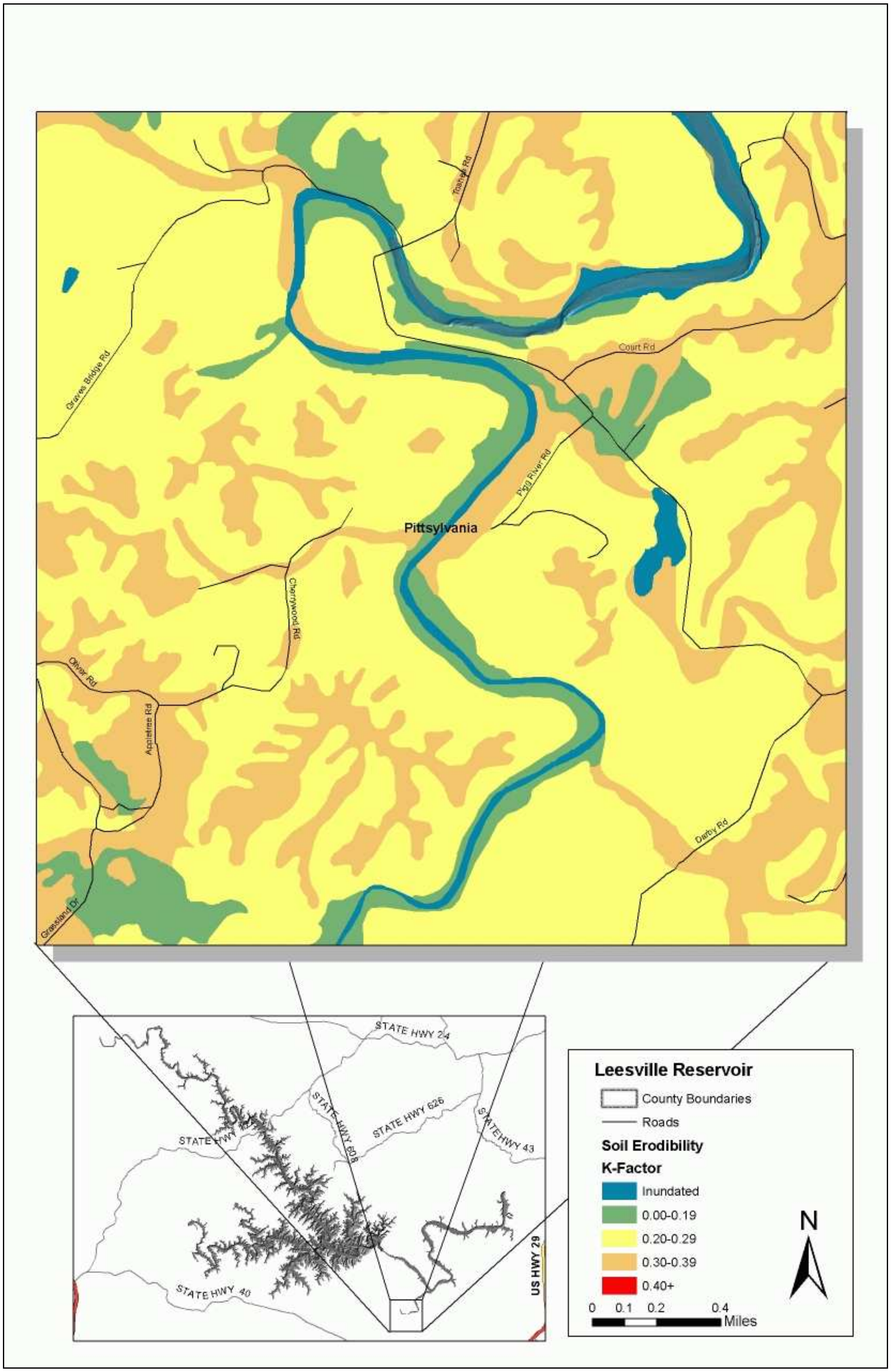


Figure 64: Soil erodibility map of Leesville Lake (7 of 8).

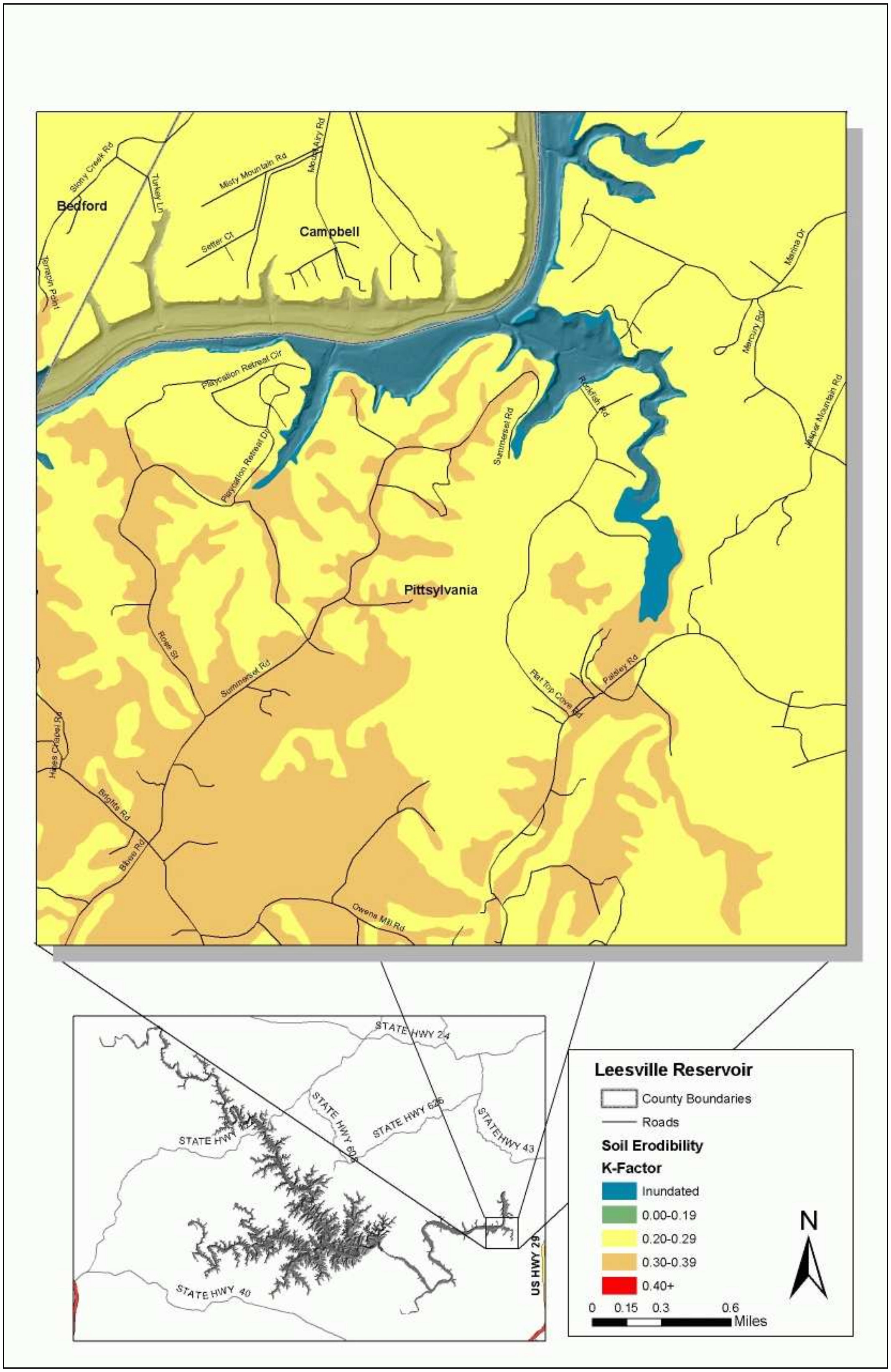


Figure 65: Soil erodibility map of Leesville Lake (8 of 8).

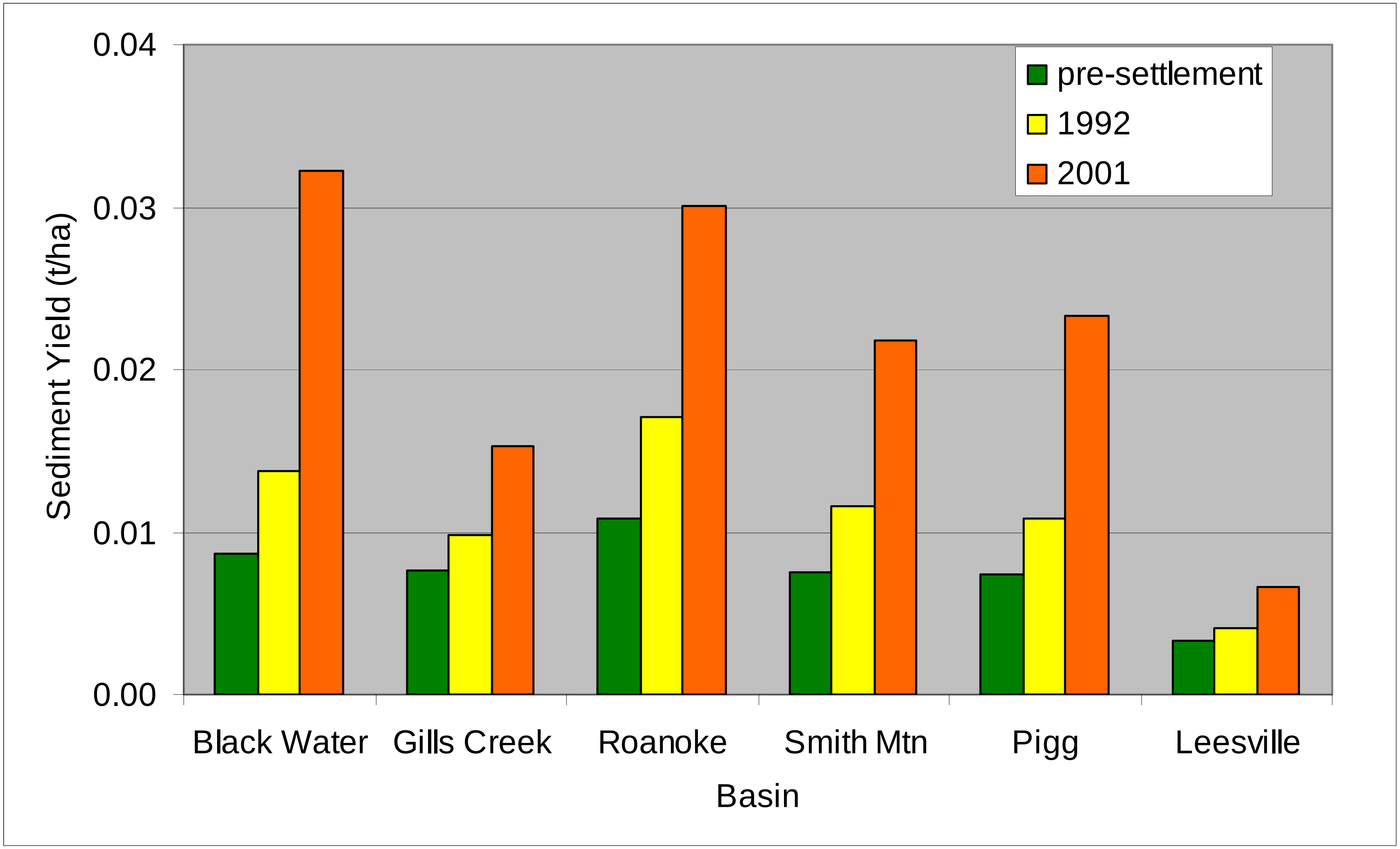


Figure 66: Predicted, average annual sediment yields for the major watersheds contributing to the Project.

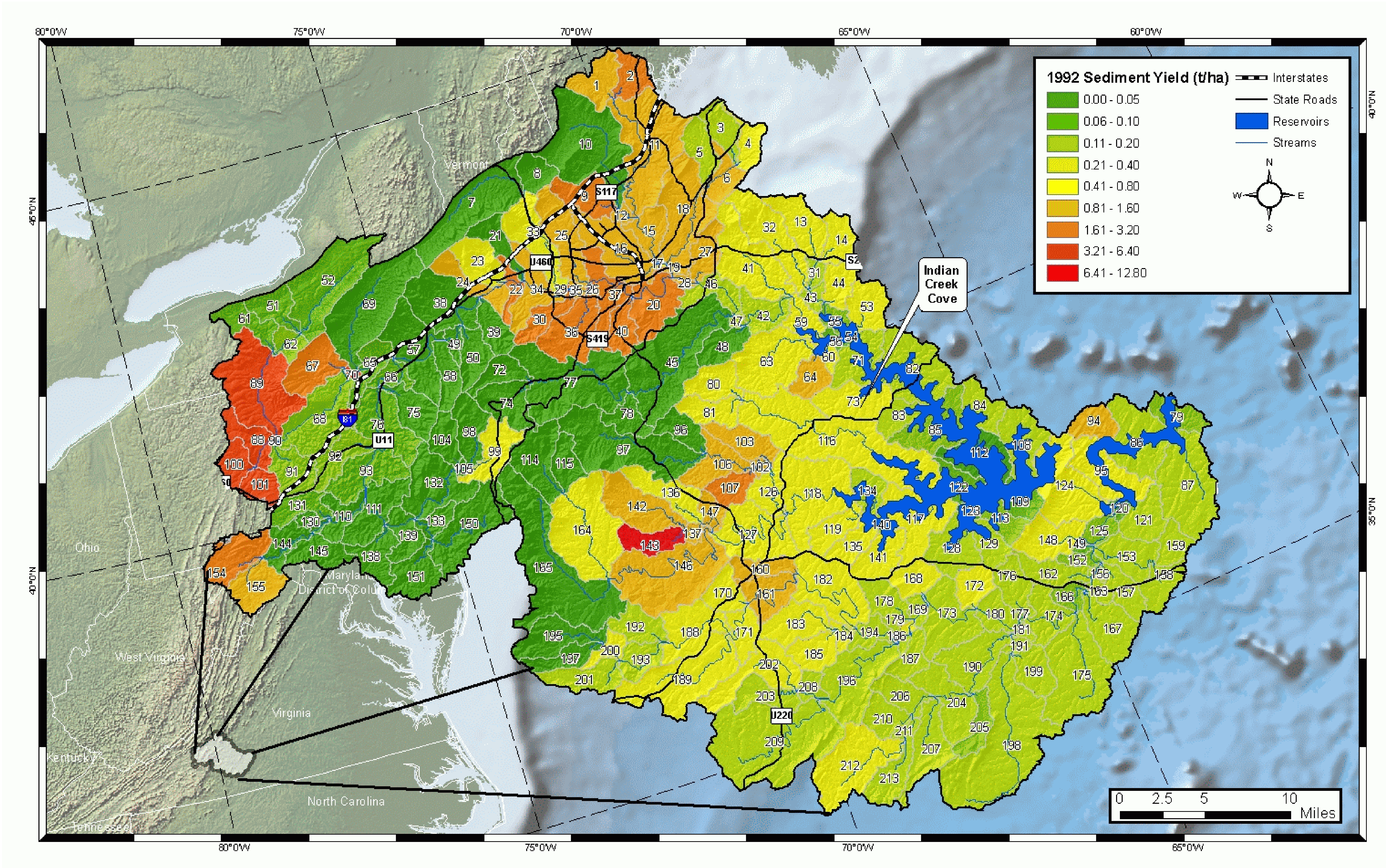


Figure 67: Predicted, average annual sediment yield under 1992 land cover conditions. Areas of background sediment yield are predominantly forested.

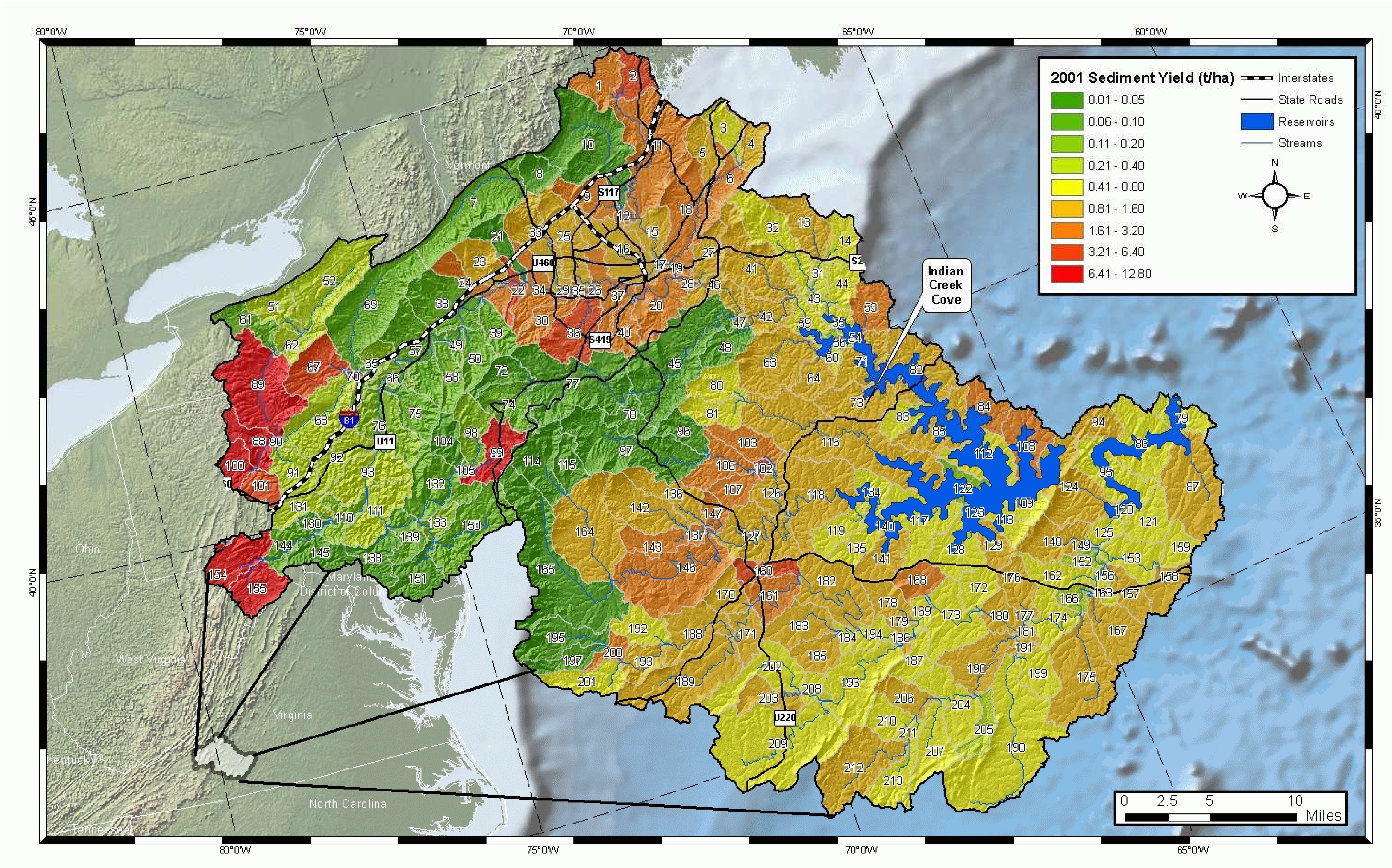


Figure 68: Predicted, average annual sediment yield under existing conditions. Areas of background sediment yield are predominantly forested.

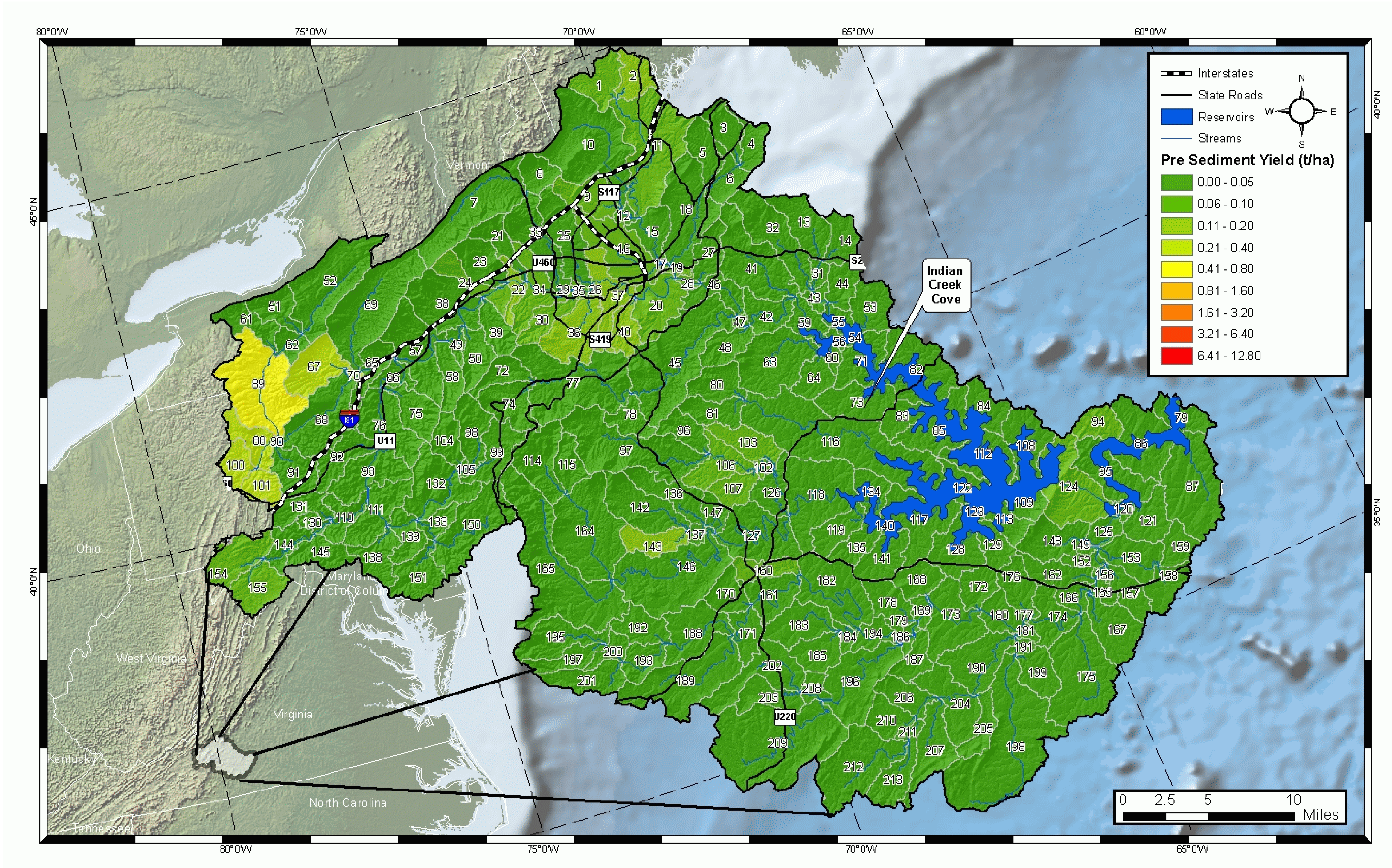


Figure 69: Predicted, average annual sediment yield under pre-settlement land cover conditions

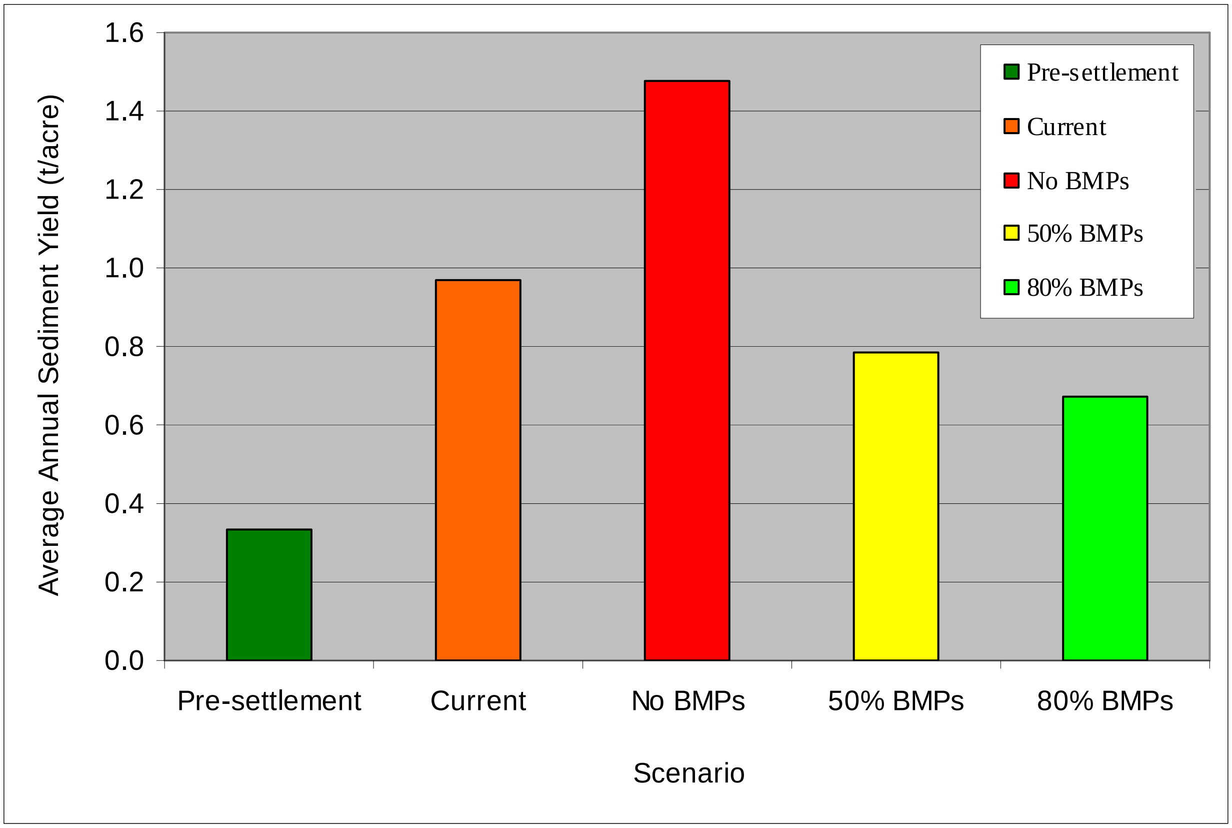


Figure 70: Predicted, average annual sediment yields for the Indianhead Creek cove under pre-settlement, current, and alternative future scenarios. Development was predicted to be extensive; high sediment yield from land disturbing activities was not significantly off-set by low yields from extensive forest land. BMPs could significantly reduce sediment yield while poor BMP implementation would increase sedimentation by 60% (5x background).

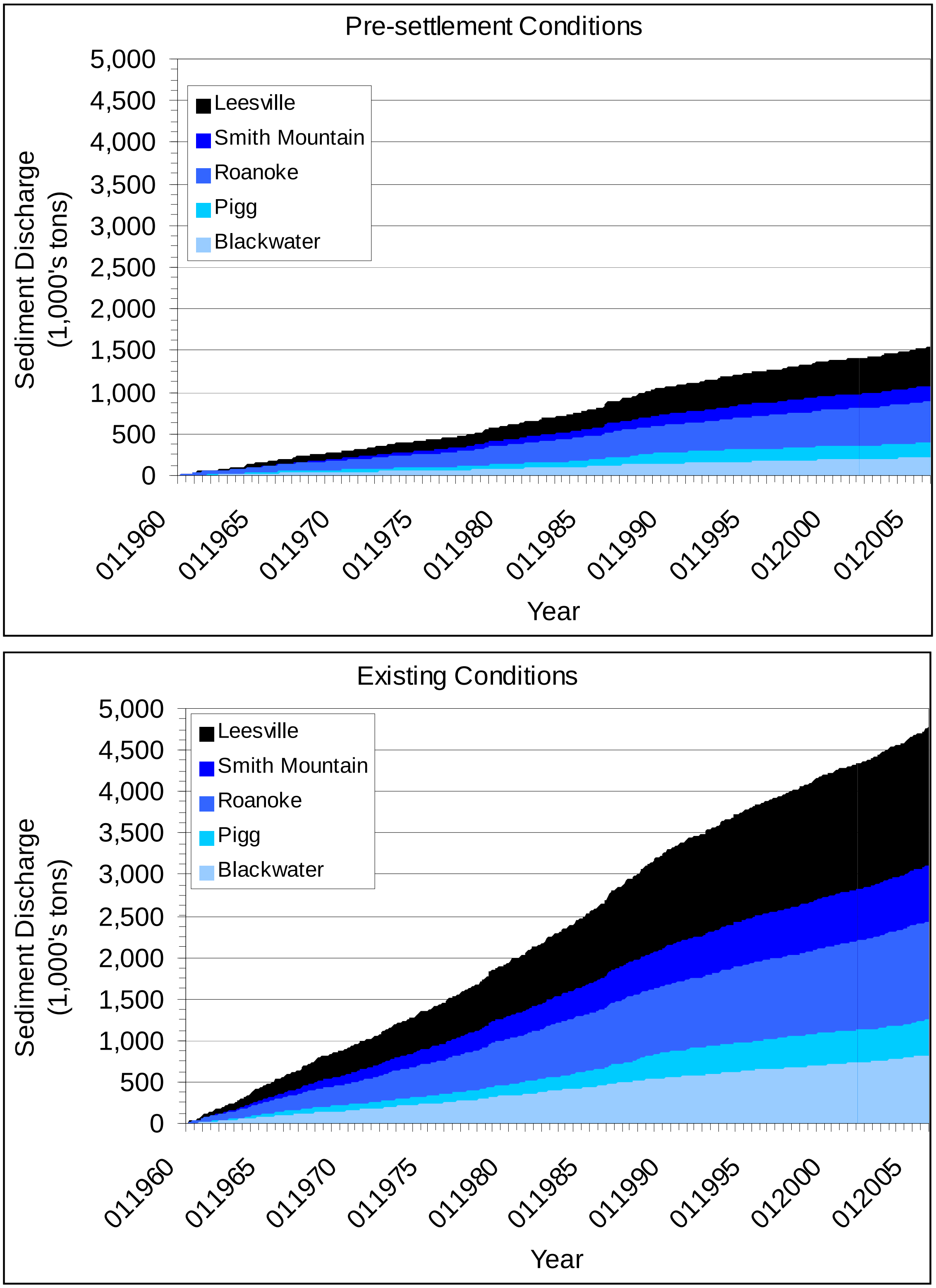


Figure 71: Estimated cumulative sediment yield under pre-settlement and 2001 land use scenarios over the existing license term. Static land use conditions were simulated over the period of record.

1. At a number of sites, soil conservation and construction BMPs were not being implemented on regulated sites (note large scale of site, steep slopes, and no erosion control practices),	
2. While soil conservation and construction BMPs were being utilized, they were not constructed or maintained properly (note silt fence and drainage swale destroyed by machinery access point)	
3. While soil conservation and construction BMPs were being utilized, the measures were of inadequate design to handle larger rainfall and runoff events (note over-topping of properly installed and designed silt-fences).	

Figure 72: Examples of construction site soil erosion

1. Excessive soil erosion from a cove pasture in the Blackwater creek watershed.	
2. Contour farming and a grassed buffer are used on this field however, cropping occurs into and through the drainage swale.	
3. Crop land planted on contour and with grassed waterways however, this land is within the riparian area. Large runoff events will deliver sediment directly to the stream.	

Figure 73: Examples of agricultural land erosion

1. In this example, there were no efforts to control soil erosion or sedimentation, skidding and yarding ran upslope, no slash or debris were left as mulch, and runoff was uncontrolled.	
2. While this example may be unsightly, coves and swales were not disturbed, forest litter was left to protect the soil, and yarding limited to a small area. However, skid trails channeled runoff to the drainage network.	
3. Timber land being harvested with proper use of silt fences and hay bales but, too close to the Lake. Sedimentation from large runoff events would immediately enter the lake.	

Figure 74: Examples of erosion from Timber Harvesting.

1. Development site – in this example, all disturbed soil has been seeded and mulched, site graded to prevent runoff from entering streams, and silt fences properly installed. Note – site will need to be over-seeded.	
2. Agricultural land – crops planted on contour and inm strips, riparian buffer intact, grassed and vegetated swales to protect the drainage network. This was a sustainable and well-maintained row-crop field.	
3. Timber harvesting – good litter layer protecting soil, coves not harvested and buffer preserved, skidding and yarding avoided the drainage network. This was a well-planned and executed harvesting operation.	

Figure 75: Examples of land disturbing activities with proper best management practices.

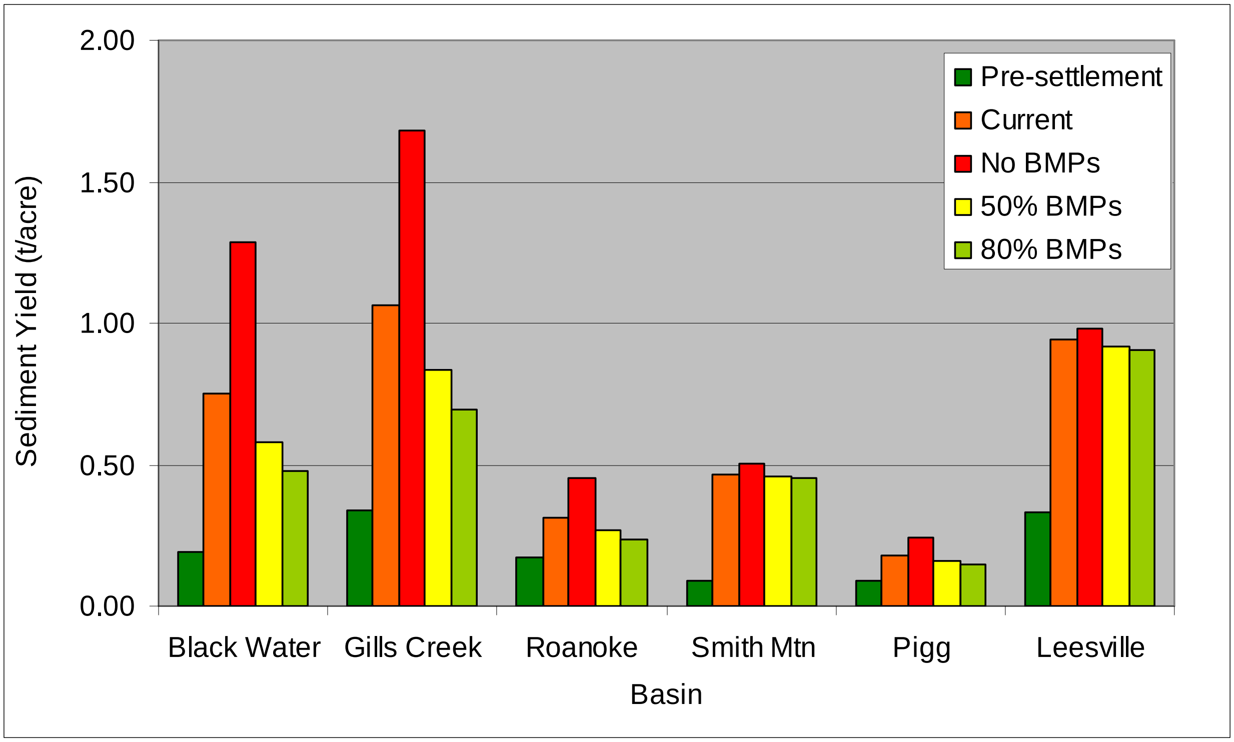


Figure 76: Predicted, average annual sediment yields for the major watersheds under pre-settlement, current, and alternative future scenarios. Average results mask "hot-spots" of high sediment yield from development with low yields from regions with extensive forest cover. This creates an illusion that BMPs are ineffectual. Sub-watershed specific values in Table 5 best represent results at the local scale.

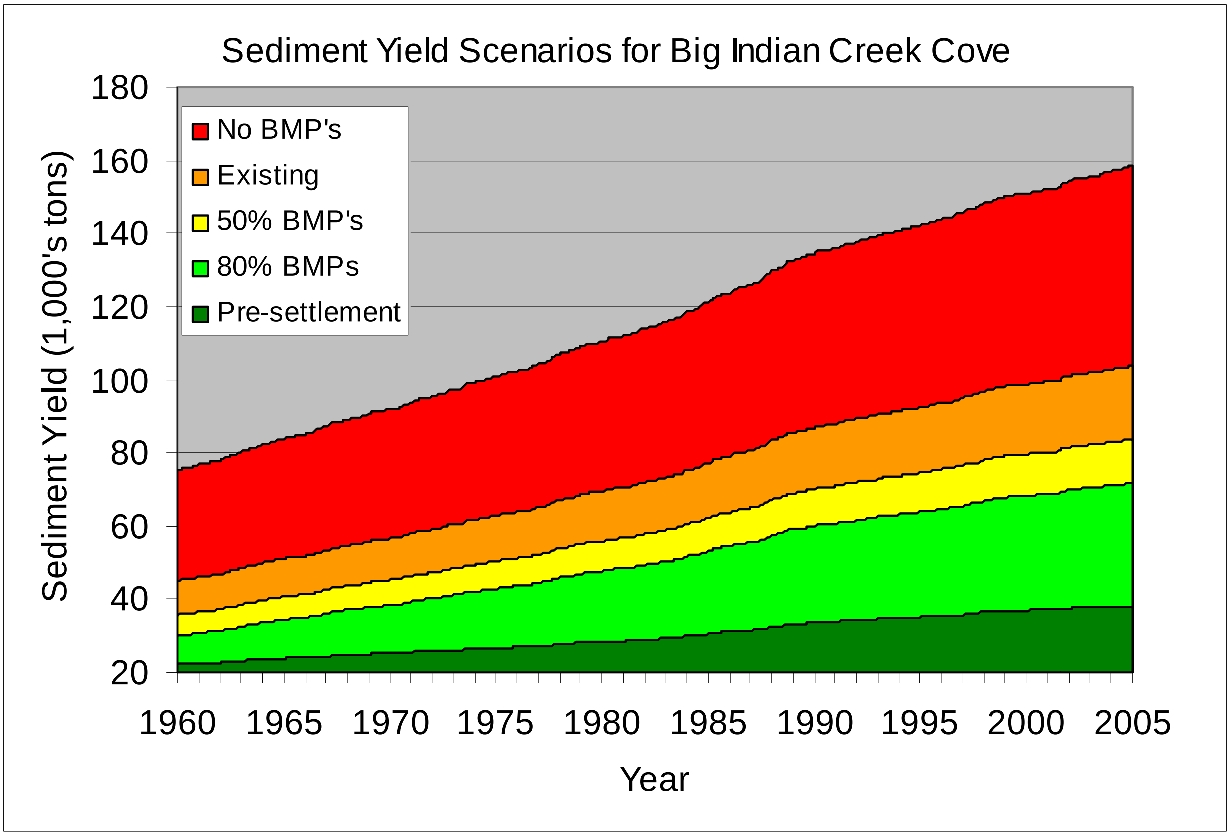


Figure 77: Cumulative sediment yield for Indianhead Creek cover under pre-settlement, existing, and alternative future development scenarios.