Oostanaula Creek Watershed Nonpoint Source Pollution Inventory and Pollutant Load Estimates

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List of Acronyms

BMP	Best Management Practice
EPA	Environmental Protection Agency
GIS	Geographic Information System
IPSI	Integrated Pollution Source Inventory
NPS	Nonpoint Source
NRCS	Natural Resources Conservation Services
RUSLE	Revised Universal Soil Loss Equation
TDA	Tennessee Department of Agriculture
TDEC	Tennessee Department of Environment and Conservation
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Sediment
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation

Nonpoint Source Inventory

This nonpoint source (NPS) inventory and assessment for Oostanaula Creek Watershed (OCW) is based upon a geographic and numeric database originally developed by the Tennessee Valley Authority (TVA) that consists of information on local watershed features such as land use/land cover, streambank erosion sites, and livestock operations that are known or suspected to be nonpoint pollution sources. Values of acreage and land management practices are applied to characterize nonpoint sources of pollution, and the impact which they have. The results of this analysis are meant to identify and estimate sources of pollution so as they can be addressed in supporting documents.

1.0 Methods

These databases are originally derived from remote sensing techniques used to acquire and interpret aerial photography and develop the NPS inventory and atlas. The structure of the GIS database and assumptions and equations used in the pollutant loading model are described below.

1.1 Aerial photography acquisition

The foundation of the NPS inventory was based on color infrared aerial photography taken in February 1999, with flight plan parameters determined by analysis of project requirements. The photography scale was 1:24,000 with the exposures overlapping to enable the interpreter to use stereoscopes to view the landscape in three dimensions, i.e. binocular parallax. The film type or emulsion was color infrared. The makeup of color infrared film is unique in that one of the three layers of the film’s emulsion is sensitive to the near infrared portion of the light spectrum. Healthy plant chlorophyll is highly reflective in the near infrared and this characteristic allows the interpreter to make inferences about vigor and type of vegetation not always possible with color or black and white film.

These photographic data were digitized into a GIS database that consists of information on watershed features such as land use, streambank and roadbank erosion sites, crop, pasture and forest lands, and livestock operations that are known or suspected to be nonpoint pollution sources. The desktop GIS uses ArcView software (ESRI, Redlands, CA) for managing and viewing the data generated by the NPS inventory. This combination of tools allows the user to investigate relationships among various geographic and/or land use features. This methodology also serves as a working verification as each image layer is related and must coincide with others.

A significant component of a NPS inventory is accurate knowledge of the natural and cultural characteristics of the study area. This knowledge can be used to confirm, or in some cases override, the aerial photography and GIS model, especially as land uses change with time. Whenever possible, the photographic interpretations offered for the study area were referenced and updated with site visits and consultation with city, county, and state personnel throughout the restoration process. These visits also provided observations of the relationships of terrain, land use, and stream network.

1.2 Land use classification

The OCW area was divided into unique polygons based on land use characteristics, as interpreted from aerial photography. Each polygon was assigned a land use code, after Anderson and colleagues (1971), as described in Table 1.1. Land use classes were grouped into 8 major headings of Residential, Commercial and Industrial, Agriculture Cropland, Pasture, Forest Lands, Open Water, Mined and Disturbed Lands, and Wetlands.

Table 1.1. Land use classification and code scheme used in NPS Inventory analysis of Oostanaula Creek watershed. Land use polygons were classified after Anderson et al. 1971.

Residential
- 11. Residential

Commercial / Industrial
- 12. Commercial, Service
- 13. Industrial
- 14. Transportation, Communication, Utility (Right-of-Way)

Row Crops
- 2101. Low Residue (0 to 10%)
- 2102. High Residue (> 30%)
- 2103. Strip Crop
- 2104. Medium Residue (10 to 30%)

Pasture
- 212. Good pasture (well maintained)
- 213. Fair Pasture (uneven growth and condition; minimal maintenance)
- 214. Woodland pasture (≥ crown cover)
- 215. Overgrazed Pasture
- 217. Feedlot and Loafing Area

Forest
- 22. Orchard
- 32. Shrub and Scrub (Old Field with volunteer woody growth)
- 4. Forest Land
- 45. Harvested Forest Land

Water
- 5. Open Water

Mine / Disturbed
- 75. Mines, Quarries and Borrow Areas
- 76. Disturbed Areas (little or no cover, non-agriculture land)

Wetland
- P. Palustrine Wetland

Urban land classes

Positioned within McMinn and Monroe Counties, the OCW is primarily an agriculture land area, with the city of Athens as a centrally located incorporated municipality. McMinn County's main industry is manufacturing, with 35 percent of the county's workforce employed making products including newsprint, fiberglass shingles, automotive components, electric motors, hosiery, clothing, furniture, farm machinery, plastic goods, spas and chemicals. Notable large firms within the area include DENSO Manufacturing, Bowater Newsprint, Mayfield Dairy Farms and Goody's Family Clothing.

Many customary urban structures, and their drainage basins, are located outside of the OCW and have no immediate impact on the watershed. McMinn County airport is positioned to the east of Athens, and three large industrial parks and the Southeast Tennessee Trade and Conference Center are to the north and west close to Interstate 75. These structures to the west are nested within the North Mouse Creek Watershed.

Estimates of residential numbers and densities were formulated by population numbers from US Census data that were later referenced with current aerial photography and consultation with city and county officials and agencies. The 2000 US Census had population figures for Athens at 13,220 and McMinn County at 49,015. As of 2006, there are 14,100 people, (Athens Chamber of Commerce, personal communication), however the city is dissected by a small ridge which separates out the northwestern part of the city from OCW. Due to this landform, only 54% of the city, or 4808 out of 8912 acres, lies within OCW.

The population density of Athens is 976 people/mi^2 with a housing unit average density of 450 units/mi^2 (US Census 2000). This density of course declines as one leaves the city limits. Estimated population density for the OCW immediately outside of Athens is 250 people/mi^2. Population density of the remaining area within the watershed is estimated at 61 people/ mi^2. Figure 1.1 displays 2005 census estimates of population densities of McMinn County. Through consultation with local officials, previous documents on the watershed, and Census data, we estimate the present population of the OCW at approximately 13,435.

It should be noted that a population of 13,435 people in the OCW is only an estimate and is certainly not static. Conflicting population values have been estimated for the area, however the absolute accuracy of this approximation is beyond the scope of this document. The Tennessee Center for Business and Economic Research projects 20% growth in this area from 2000 to 2025 (CBER 2003). Under this assumption, population estimates for the OCW will reach beyond 16,000 by 2025.

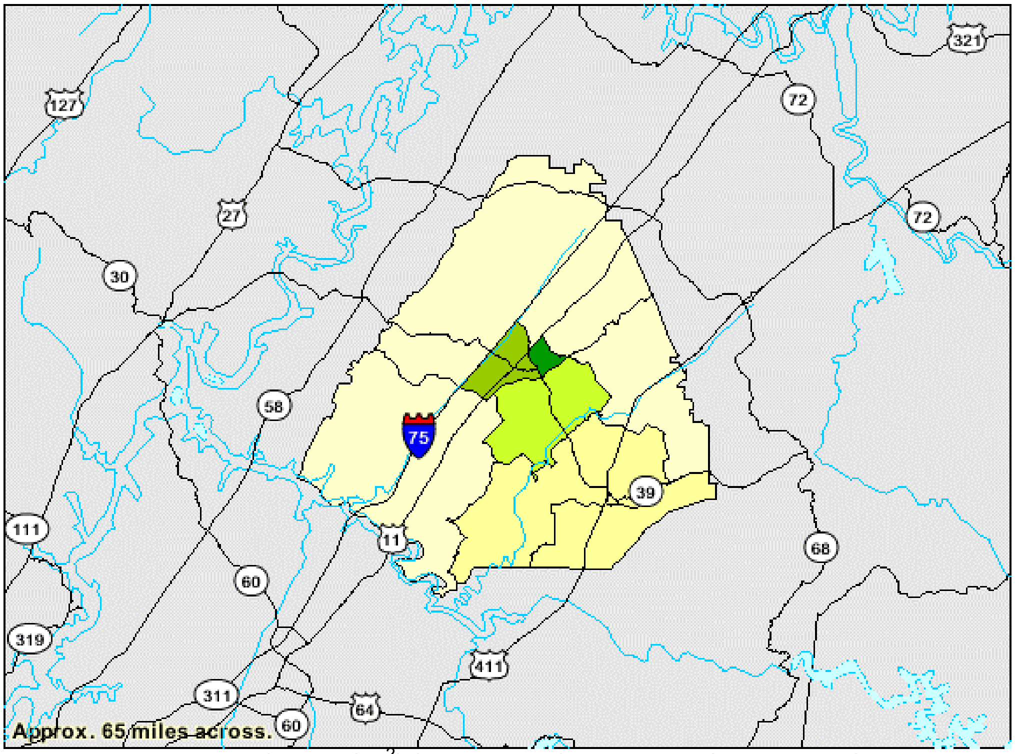

Figure 1.1. Population densities (people/mi^2) for McMinn County, with Oostanaula Creek running northeast-southwest south of US-11. Density estimates taken from 2000 US Census; Light yellow – 61-83 people/mi^2, Yellow – 110-129, Light green – 264-264, Med green – 563-563, Dark green – 1029-1029.

The present area of Athens is 13.925 mi^2 (October 2006) which is expected to increase in a short time. An urban growth boundary for the city extends to a total of 47.6 mi^2, suggesting that additional growth is permissible. Growth projects in review include a widening of SR 30 south of Athens extending towards Etowah (beginning Dec 2007), and a circumnavigating bypass of SR 30, either north or south of the city.

Discharges from NPDES-regulated construction activities are considered point sources of sediment loading to surface waters and occur in response to storm events. However, since construction activities at a site are of a temporary, relatively short-term nature, the number of permitted sites at any given time or location varies. Since 2000, nearly 100 new commercial construction permits and over 300 new residential permits have been awarded. As of June 2005, the OCW had seven construction sites covered by NPDES Permit for Storm Water Discharges Associated with Construction Activity (TNR10-0000, TDEC 2005b).

OCW has at least one known, designated point source, centrally located in Athens, TN. Athens Utility Boards (AUB) Oostanaula Creek Wastewater Treatment Plant (WWTP) has been issued a National Pollutant Discharge Elimination System (NPDES) permit for discharge of treated sanitary wastewater and discharges in to the creek at mile 30.1. This facility has a history of exceeding EPA its Clean Water Act permit limit for *E. coli* (US PIRG 2004), and is in the process of a $16 million upgrade. The EPA has designated that the facility has been identified as a “major discharger”.

The watershed also contains a number of Multi-sector general permits for industrial activities (TMSP), which monitors onsite stormwater management. These include Johnson Controls (metal products), Mayfield Dairy, Athens Woodcrafters and Athens Furniture, Inc.. Two Ready-mix Concrete Facilities (RMCF) with NPDES permits also reside in the area, Sequatchie Concrete and Bradley Concrete, both with maximum effluent limits set at 50 mg TSS/L. Effluent discharge over time is not available for these permitees and as such can not be adequately addressed in the present document.

On-site septic systems

Stressed on-site septic systems can contribute contaminants to surface water through overland flow, particularly when saturated soil conditions exist. Specifically, fecal coliform loading can be attributed to a failure of septic systems and illicit discharge of raw sewage. Estimates of total usable systems were developed using county and city census data along with consultation with local TDH personnel. Employing data from 1997, previous TDEC documents estimated 1675 systems in use in the watershed (TDEC 2005). Based on the number of permit applications submitted to local TDH offices, a new estimated number of households within the watershed with decentralized wastewater treatment systems is 2150 (Table 1.2).

The EPA states that “between 10 and 20%” of all septic systems “might not be functioning properly,” (EPA 2005) which may contribute bacterial contamination of surface and ground water. To verify this estimate, aerial photos were analyzed to identify specific signatures associated with on-site septic systems which would accurately assess suspect wastewater systems. The four common conditions identified are listed in Table 1.3. Evidence of these conditions likely indicates a stressed or potentially stressed system.

Table 1.2. Populations and household estimates for Oostanaula Creek Watershed. See text for methodology of estimates. na = not assessed.

	2006 est.	Number of Housing Units		
	Population	total	Public Sewer	Septic Tank
Athens	14100	5755	4900	855
McMinn Co.	50968	20803	na	na
Oostanaula watershed	13435	5483	3333	2150

Table 1.3. Septic system classification for use in NPS inventory for Oostanaula Creek watershed.

Condition	Observation(s)	Description / Implication
1	Distinctive moisture pattern	Effluent plume from visible drain field pattern, or prominent ponding downslope from drain field.
2	Suspicious moisture pattern	Visible plume pattern, but no drain field apparent; can be straight-pipe from septic system, roof drainage, or natural seepage / spring
3	Distinctive drain field	Visible drain field pattern, but no plume evident; may indicate slow leaching, but no apparent breakout of a seasonally or hydraulically stressed system.
4	Suspect location	No plume or drain field visible; home sites on very steep slopes, small lots, visible rock outcrops, or in close proximity to streams or reservoirs, especially those on heavily-wooded lots.

Roads, roadbanks and streambanks

Base information for road coverage was obtained from standard 1:24,000 USGS topographic maps. The road network was updated to the date of the photography (February 1999) and later georeferenced with local officials, and amended as needed. Road conditions interpreted for the NPS inventory were surface type and significant erosion features associated with the road. Road surfaces were classified as either paved or unpaved. Unpaved roads include all classes of unpaved surfaces from well-maintained gravel roads to off-road vehicle trails. Significant erosion features associated with roads include eroding cuts and fills, eroding road banks, and eroding roadside ditches.

A percent imperviousness, excluding paved roads, was assigned to each land use/land cover polygon based on interpretation of the photography. Impervious surfaces include parking lots, sidewalks, rooftops, and other impermeable surfaces of the urban landscape. For example, a residential area might have a percent imperviousness of 25%, based on the estimated coverage of structures, driveways, and sidewalks. The percentage of area covered by paved roads was calculated from the roads' coverage layer in the database.

The stream network was based on the blueline streams from the 7.5 minute USGS maps. The streams were entered into the GIS either by loading USGS Digital Line Graphics (DLG) or by digitizing the stream network from the maps. This base level of streams was then enhanced based on photo interpretation as near infrared wavelengths are absorbed by water, resulting in clear waterbodies appearing black in photographs. Drainage condition was delineated as perennial, with water present throughout most years, or intermittent, defined as a stream that has a well-defined channel although water is not present at all times. These streams were further defined as having eroded streambanks or no eroded streambanks.

Riparian condition in the NPS inventory is a characterization of the land cover buffer adjacent to a stream. The riparian conditions in the present inventory are mapped in two categories of 1) riparian areas dominated by woody vegetation, and 2) riparian area lacking woody vegetation. Category 2 includes stream segments adjacent to grass, bare ground, or urban land cover.

The following riparian buffer features were mapped for both the left and right (looking downstream) banks of perennial streams:

- Vegetative type identified as either woody, grass, or bare.
- Percent of coverage coded as 0 to 33%, 34 to 66%, or 67 to 100% for woody vegetation.
- Grass cover quality rated as poor, moderate, or good.
- Width of vegetation coded as 1 to 25 feet, 26 to 100 feet, or greater than 100 feet.

A riparian buffer classification matrix was used to rate the ability of the riparian buffer to filter runoff before entering the stream (Table 1.4). The assumption is that the quality and extent of the buffer zone has a direct relationship to the potential ecological health and water quality of a stream by reducing nonpoint source pollutants entering the stream. The riparian buffer was rated as adequate, marginal, or inadequate with regard to the ability to remove pollutants.

Table 1.4. Riparian buffer classification for woody and non-woody vegetation within Oostanaula Creek watershed.

Woody Vegetation

Width / Cover	0 to 33 %	34 to 66 %	67 to 100%
0 to 25 ft	Inadequate	Marginal	Marginal
26 to 100 ft	Marginal	Marginal	Adequate
Over 100 ft	Marginal	Adequate	Adequate

Non-Woody Vegetation

Width / Cover	Poor Quality	Moderate Quality	Good Quality
0 to 25 ft	Inadequate	Marginal	Marginal
26 to 100 ft	Inadequate	Marginal	Adequate
Over 100 ft	Inadequate	Adequate	Adequate

Crop, pasture, forest, mining and disturbed lands

Two major applications of remote sensing in agriculture are the identification and inventory of specific land use patterns. Color infrared photography allows quantification of land reflectivity that permits discrimination of vegetation types.

For plant foliage, visible (400-750 nm wavelengths) and near infrared (750-2500 nm) absorbance (or conversely reflectance) spectra are the product of complex patterns of scattering and absorption by numerous structural and biochemical components. Characteristics of leaf reflectance spectra are determined by the surface properties of the leaf, as well as internal structure and biochemical components.

Leaf reflectance at visible and near-infrared wavelengths is related primarily to pigmentation, leaf structure and water content, and is an important tool for studying stress physiology and relationships between plants and their growth environment. The amount of radiation absorbed by a leaf is largely a function of the foliar concentrations of photosynthetic pigments, which are generally dependent on available nitrogen. As such, the information content of a sample reflectance spectrum is very high, because it provides a concise and rich snapshot of the overall biochemical composition of vegetation.

Color infrared photography was used to distinguish between and among agriculture lands. Healthy chlorophyll appears deep red using color infrared photography and abnormal chlorophyll appears a lighter shade of red to white. The spongy mesophyll tissue of a healthy leaf, which is turgid, distended by water, and full of air spaces, is a very efficient reflector of any radiant energy and therefore of the near-infrared wavelengths (Knipling 1970). Based on this application, distinct land covers were identified through aerial photo color interpretation, and later verified via site visits.

Livestock operations

Livestock activity and density are important factors for structuring vegetation in silvopastoral systems. Livestock may influence vegetation through forage removal, manure deposition and trampling. These three activities have different impacts on the land, creating fine-scale mosaics within the landscape. The spatial pattern of foraging locations depends on herbage quality and quantity, water availability, relief, slope, natural and artificial barriers, herd social interactions, prior experience and climate. The spatial distribution of feces deposition is also not uniform and concentrations are often higher in areas near water sources, along gates or fences, and in shade areas (Davies-Colley et al. 2004). Trampling distribution depends not only on the number and pressure of foot steps in an area, but also on the sensitivity of the area.

The spatial patterns of grazing, dunging and trampling are not congruent and as such, efforts were made to account for fine-scale patterns within the landscape. Livestock operations were mapped by interpretation of facilities and their associations with features such as soil compaction, soil staining, soil moisture content, size and presence of barns and other structures, presence of hay bales, animal trails, water sources, fencing, and feedlots. These relationships and associated land cover were used to determine the relative size and type of livestock operation. The type of operation was identified by looking at clues such as exercise rings for horse operations, silos and loafing areas for dairies, and large open pastures for beef cattle operations. Sites of poultry operations were classified via photo identification of broiler houses which can be 250 feet long.

Aerial photographs dated from February 1999 were referenced with on-site visits throughout the restoration process. Field verification helped to identify number of animals per site size, delineated as small, medium, or large based on animal population. These sites were further delineated by being adjacent or nonadjacent to the stream, which included both intermittent and perennial streams.

Wildlife populations

Wildlife inputs typically represent natural background sources of pollutants, although they can be important in rural watersheds. Wildlife sources are often uncontrollable, however it is important to consider their potential impact on water quality and their loading relative to other sources. As with livestock, wildlife deposit bacteria and nutrients with their feces onto the land, where it can be transported during a rainfall runoff event to nearby streams. In the watershed model applied, the wildlife pollutant contribution is accounted for solely in the deer population, as population estimates of raccoons, waterfowl, and other wildlife are not readily available. Additionally, fecal contributions from most transitory wildlife and birds can rarely be properly monitored or controlled without significant on-the-ground activities and installations.

The Tennessee Wildlife Resources Agency (TWRA) estimates the deer population to be 23 animals per 640 acres in this area. It is assumed that the wildlife population remains constant throughout the year, and is uniformly distributed on all land uses classified in the NPS inventory as forest, cropland, and wetlands. Pasture lands are excluded as most of these lands house livestock and/or are fenced. Subwatersheds 05, 0501, 06, 07, 08, and 0801 will also be excluded from wildlife population estimations due to their highly urban settings

1.3 Soil loss estimates

Soil loss was calculated for select land use classes and other high-impact erosion features identified in the inventory. The amount of soil loss estimated was the total potential soil movement for the feature via detachment, transport and deposition. For example, the soil loss for a particular agricultural field was an estimate of the amount of soil movement on the field, in tons per acre per year, based on the Revised Universal Soil Loss Equation (RUSLE; Renard et al. 1997) originally developed by Wischmeier and Smith (1978).

In the United States, RUSLE is a reliable and accepted methodology for estimating soil loss erosion rates, and is required for assistance through conservation programs of the Federal Agriculture Improvement and Reform Act of 1996. Original coefficients from the RUSLE specific to the ecoregion were applied to the current model although several revisions to the equation have been developed, e.g. RUSLE 1.04 and RUSLE2. Such values were used as they are 1) easily recognizable in all regions, 2) easily defended due to their application use and history, and 3) they are easily accessible to users irrespective of location or condition. If the present pollutant loading model is to be justified and made available universally, the tools to import into the model must be made available.

The average soil loss computed by RUSLE is both a temporal (annual) and spatial (generally greater than 1 acre) average for a given field, based on the variability of both the landscape and soil types within it. On sites with considerable spatial variability, modelers exercised judgment in selecting values for individual parameters in the RUSLE algorithm. Accommodating field variability was best resolved by identifying land sub-units for separate analyses. This was done for OCW by identifying 18 subwatersheds delineated by source streams, which vary in area from 125 to 6260 acres (Figure 2.1). These individualized sub-units are still considered complex fields with multiple landscape features, so RUSLE users identified separate factors to compute soil loss within the area and then developed a weighted average for the entire subwatershed.

The overall aim of the present document is to quantify relative differences in pollutant loads pre- and post-BMP implementation. By applying basic coefficients to the default model, one may easily compare the two output values. As elevation, soil types and soil textures do not vary considerably within a sub-unit, the applied average factor is suitable for the purpose of the present management plan. Thus, in addition to the validations listed above, the utility of standard RUSLE values as imports into the model for simple identification of differences, justifies the application.

1.4 Pollution loading model

Biogeochemical models have increasingly been used to quantify and track local and regional nutrient budgets in order to determine whether specific areas are sources or sinks for certain nutrients. These local assessments, such as those of individual agricultural fields or a forest stand, significantly contribute to the comprehension of ecosystem function by further qualifying nutrient cycling. The objectives of this section were to develop a model that would simulate nitrogen, phosphorus and sediment budgets of OCW, and to evaluate the model in terms of specific land covers and/or land use practices

In general, the wash-off of pollutants from a land area towards another land area, or a waterway is a loading factor. Techniques to estimate pollutant loading include generalized relationships to hydrology and soil and sediment movement. A pollutant loading model was developed to estimate annual NPS pollutant loads of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) based on the NPS inventory. Nitrates are currently not a listed pollutant priority as defined by TDEC (2006), however the inclusion of TN loading estimates are provided as a proactive measure. The model was used to estimate pollutant loads for TSS, TN, and TP from the following sources: residential, commercial, industrial, transportation, WWTP, cropland, pasture, forests, beef cattle, dairy cattle, swine, horses, and poultry.

OCW is currently classified as not fully supporting all of its listed uses due to high pathogen, phosphorus and sediment levels; although these annual pollution loads are inherently difficult to estimate for large areas. Past work suggests that river TN loads are strongly related to river TSS loads (Ittekot and Zhang 1989, Ludwig and Probst 1996), and it is reasonable to infer that river TP loads would also scale with TSS loads. Since sediment has been recognized as a major nonpoint source problem for many years, several standards have been established for erosion on croplands. These standards are based on the loss of a soil resource rather than any downstream environmental impact. Many of these accepted formulaic standards, including the RUSLE, were used to estimate pollution loading. From these load estimates and published water quality sample data, we can then estimate pathogen levels.

The model uses a Microsoft Excel (Microsoft Corp. Redman, WA) workbook to perform the calculations and display the results in tabular and graphical form. The workbook consists of sheets for the land use inventory, RUSLE factors, other loading parameters (defined in subsequent headings below), and a calculation sheet for each loading parameter, accompanied by graphs to display results. These parameters were developed as discussed below. Treatment scenarios can be explored by changing model parameters in the original model and viewing the changes in the linked graphs and tables. These models can also be used to demonstrate the effect of potential nonpoint source management strategies on pollutant loads.

Several water quality models estimate nonpoint water pollution into watersheds based on the input of either event mean concentrations (especially for urban areas) or export coefficients (notably for rural and agriculture areas). Event mean concentrations represent the concentration of a specific pollutant contained in runoff originating from a particular land use, reported as mass per unit volume of water (usually mg/L). Export coefficients represent the average total amount of pollutant loaded annually into a system from a defined area, reported as mass per unit area per year. The present model attempts to utilize both approaches.

Due to the specific climatological and physiographic characteristics of individual watersheds, regional and local agricultural and urban land uses can exhibit a wide range of variability in nutrient export (Omernik 1977, Reckhow et al. 1980). Site-specific values of both input types are unavailable for the current project, as this is a relatively novice approach to local watershed-scale pollutant modeling. As such, there remain some reservations as to the applicability of employing export coefficients or event mean concentrations for different land uses developed from region to region. The coefficients included in this analysis were all screened using certain acceptance criteria, based on the accuracy, precision, local representativeness, and spatial and temporal extent of data sampling.

Not all data described in the Methods and Summary Section were used in the model. Population statistics, onsite waste system information and riparian buffer information were intended to support management activities, but were not used in the loading model.

Loads from urban land classes

Pollutant loads from urban land uses (residential, subdivisions under construction, commercial, industrial, and transportation) were estimated using a method described by the EPA (EPA 1990) using the following equation:

$$M = RainV \times Rv \times Area \times Conc \times 0.0001135 \qquad \text{Equation (1)}$$

Where:

M = mass load (tons)
RainV = average annual rainfall (inches)
Rv = runoff coefficient (unitless)
Area = drainage area (acres), derived from the inventory
Conc = average runoff concentration (mg/L)
0.0001135 = unit conversion factor

The areas used for each land class were generated by the NPS inventory. Annual rainfall estimates were obtained from a National Climatic Data Center weather station at Athens, TN (35°26’N, 84°35’W, 940 ft asl). Estimates of annual rainfall for the area are 58.39 inches over the 18 subwatersheds (NCDC 2001) and were applied at the sub-unit scale. Runoff coefficients for the different land-use classes were estimated using the following equation taken from the EPA (1990) report, “Urban Targeting and BMP Selection”:

$$Rv = 0.050 + 0.009\,(PI) \qquad \text{Equation (2)}$$

Where:

PI is percent imperviousness

The values used for PI by land use/land cover class were determined by remote sensing. Pollutant concentrations (mg/L) were taken from the EPA's National Urban Runoff Study (EPA 1982) in conjunction with local water conditions monitored and analyzed by various local, state and federal agencies. Values were determined based on median and 90th percentile urban concentrations presented by EPA, plus high and low values from on-site sampling to obtain pollutant concentrations presented in Table 1.5.

Table 1.5. Runoff coefficients and pollutant concentrations imported in to the pollutant load model for urban land uses within Oostanaula Creek watershed.

	Residential	**Commercial**	**Industrial**	**Transportation, communication, utility**
Runoff Coefficient	0.221	0.545	0.725	0.077
TSS Concentration (mg/L)	100	150	180	100
TN Concentration (mg/L)	2.76	4.2	3.45	2.0
TP Concentration (mg/L)	0.42	0.9	0.42	0.2
Percent Impervious	19	55	75	3

A selection of local, regional and national event mean concentrations (for urban land classes) previously developed and published has been provided in Table 1.6. This is not meant to be a complete or comprehensive list of all coefficients, nor does it communicate the full extent of knowledge related to pollutant fate in the environment. Coefficients applied to the present nutrient loading model vary from these published values based on the criteria listed above and are derived primarily from high water quality sampling data and land class condition, i.e., rate, frequency and intensity of management practices.

Table 1.6. Published event mean concentrations of total phosphorus and total nitrogen for urban areas as found through a non-exhaustive search of relevant articles, and concentrations applied to the present nutrient loading model. Numbers refer to references defined as 1. Baldys et al. 1998; 2. Guerard and Weiss 1995; 3. Los Angeles County 1999; 4. Harper 1998.

	Total Phosphorus (mg/L)					Total Nitrogen (mg/L)				
	1	2	3	4	Model Input	1	2	3	4	Model Input
Residential	0.38	0.75	0.25	0.30	0.42	2.10	3.80	2.23	2.29	2.76
Commercial	0.18	0.28	0.40	0.29	0.90	1.50	1.80	1.67	2.01	4.20
Industrial	0.28	0.36	0.50	0.31	0.42	1.50	2.90	3.09	1.79	3.45

Loads from point sources

Pollutant loading from the known point source within the OCW, AUB's WWTP, was estimated using discharge data from AUB along with general contaminant figures. 2006 effluent values were derived from TDEC Discharge Monitoring Reports which were originated from monthly AUB Reports of Operation. Values were set as an annual average, stemming from monthly averages as stated on these documents. These values were set as default discharge concentrations for the present loading model, using the equation below:

$$E = (L \times 3.785 \times D \times 365) / (908 \times 10^6) \qquad \text{Equation (3)}$$

Where:

E = effluent (tons/yr)
L = effluent (mg/L) values
D = discharge (million gallons per day)
908 = unit conversion factor

Discharge for AUB's WWTP in Athens is approximately 2.83 million gallons per day, and is a function of facility hydrologic capacity. While this discharge was not met on every date, this figure was used as a conservative estimate. Default effluent values were set at 2.614 mg/L for TP, 2.160 for TN, and 1.975 for TSS. It should be noted that these values fall below maximum limits as set forth by EPA.

Loads from roads, roadbanks and streambanks

Pollutant loads from streambanks, road banks, and roads are directly related to soil loss. Soil loss for streambanks, road banks, and roads were calculated using:

$$A = ER \times EA \qquad \text{Equation (4)}$$

Where:

A = soil loss from streambanks, road banks, or roads (tons/year)
ER = erosion rate for streambanks or road banks (tons/foot/year) and unpaved roads (tons/acre/year)
EA = eroding area for streambanks or road banks (feet) and unpaved roads (acres)

Values for streambank and road bank erosion rates were estimated from calculations based on the average bank height, recession rates of eroding banks and approximated soil bulk density. Values for each of these parameters were obtained by site visits and consultation with NRCS using critical erosion rates for the ecoregion. Road surface erosion rates were estimated from literature values and from NRCS staff. Watershed specific erosion rates and eroding area estimates are listed as:

Eroding perennial stream bank rate: 0.115 tons/ft/yr
Eroding intermittent stream bank rate: 0.0380 tons/ft/yr
Eroding (paved and unpaved) road bank: 0.0090 tons/ft/yr
Eroding unpaved road: 25 tons/ac/yr

Pollutant loads from streambanks, road banks, and roads were determined by:

$$M = A \times PC \times DR \qquad \text{Equation (5)}$$

Where:
M = mass load (tons/year)
A = soil loss (tons/year)
PC = pollutant coefficient (ton pollutant/ton soil)
DR = sediment delivery ratio (unitless)

The area-based sediment delivery ratio was estimated from the USDA National Engineering Handbook, Section 3 - Sedimentation, Chapter 6 - Sediment Sources, Yields and Delivery Ratios (USDA 1978) as:

$$DR = 0.417762 \times A^{-0.134958} - 0.127097 \qquad \text{Equation (6)}$$

Where:
DR = Delivery Ratio (unitless)
A = Area (sq smiles)

This equation was developed mainly from reservoir sedimentation data and therefore has been used mainly for sizing reservoir dams. This equation, however, does not account for watershed characteristics such as land use, relief, and flow direction. Because this equation has been used for many years and has appeared to provide reasonable “average” estimates of sediment yield, and because this value will not change from default it can be used as an additional basis for evaluating new practices (i.e., RUSLE C factors).

Loads from crop, pasture, forest, mining, and disturbed lands

The actual quantity of nutrients and other pollutant transported from any given site depends on many factors including precipitation intensity, runoff volume, time of precipitation relative to applications (fertilizers, pesticides), vegetation, soil characteristics, slope, and season, among others. The first step in estimating pollutant loads from crop, pasture, forest, mining and disturbed lands was determining the soil loss for each land class using the RUSLE (Wischmeier and Smith 1978, Renard et al. 1997):

$$A = R \times K \times LS \times C \times P \qquad \text{Equation (7)}$$

Where:

A = soil loss (tons/acre/year)
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = erosion control practice factor

The RUSLE factors for the watershed were established through referencing ecoregions 67f and 67i values, general RUSLE values for pasture (Wischmeier and Smith 1978) and through consultation with local NRCS personnel. The RUSLE factors employed for this analysis are listed in Table 1.7 below. The minimal variability in soil types and landscape position account for the uniformality in soil erodibility and slope-length factors respectively.

The pollutant loads from these lands within the watershed were estimated using the soil loss values calculated from Equation (7) and the following equation:

$$M = A \times Area \times DR \times PC \qquad \text{Equation (8)}$$

Where:

M = pollutant loading (tons/year)
A = soil loss (tons/acre/year) determined from RUSLE
Area = land class area (acre)
DR = sediment delivery ratio (unitless)
PC = pollutant coefficient (tons pollutant/ton soil)

Nutrient characteristics (pollutant coefficients) were based on literature values and calibrations to water quality data in previous studies of similar nature. TSS is estimated to be 70 percent of the eroded soil that reaches the stream for all agricultural, forest, and disturbed area land uses. This equates to 0.7 tons pollutant for each ton of soil. Pollutant coefficients for TN varied, with a value of 0.002 tons pollutant/tons soil for most agricultural land uses; 0.015 for animal feedlots and loafing areas; and 0.001 for forests, mining, and disturbed areas. The TP soil pollutant coefficient value for all agricultural land uses is 0.0002, and 0.0001 for forests and disturbed area land uses. Nutrient characteristics were based on Stewart et al. (1975) and Mills et al. (1985).

Pollutant loads from livestock operations

The pollutant loads from beef cattle, dairy, horse and swine operations were estimated using the following equation:

$$M_n = Na_n \times WT_n \times PR_n \times 0.0001825 \times DR_n \times NS_n \qquad \text{Equation (9)}$$

Where:
M = pollutant loading (tons/year)
NA = number of animals (number/site)
WT = animal weight (pounds)
PR = pollutant production rate (lb pollutant/day/1000 lb live wt)
0.0001825 = unit conversion factor
DR = delivery ratio (unitless)
NS = number of sites of type n
n = type of livestock operation

The number and type of livestock sites within the study area were identified by the nonpoint source inventory, including both aerial photographs and field verification. The (as excreted) pollutant production rates (PR above) for TN and TP were obtained from the NRCS Agricultural Waste Management Field Handbook (USDA 1996) and a non-exhaustive literature review. The production rate for TSS was based on values derived from “Livestock Manure Characterization Values from the North Carolina Database” (Barker et al. 1990).

This component of the loading model primarily accounts for the direct deposition of animal waste into streams, but also considers nutrient-rich material on pastures that is available for direct washoff. Differences in animal weights and size of individual operations were considered in pollutant load calculations. As animal weights are not static over time, space, or owner designated purpose, best judgments were applied to the present loading model. Livestock calculations differed in delivery ratios for each pollutant adjacent to stream sites and estimated time spent in streams. While these differences exist, the general process used to estimate delivery of animal waste was similar for each type of livestock. Values entered in to the pollutant model for each livestock class are displayed on Table 1.8.

Table 1.8. Values used to estimate pollutant loadings from livestock operations. See text for methodology.

		Beef Cattle	Dairy	Horse	Swine
Number of animals per site	Large	110	150	20	200
	Medium	50	100	10	60
	Small	15	35	5	12
Animal weight (lb/animal)		1000	1200	1000	375
Delivery Ratio - Adjacent	TSS	0.0466	0.0714	0.010	0.001
	TN	0.0486	0.0734	0.010	0.001
	TP	0.0467	0.0687	0.010	0.001
Delivery Ratio – Non-Adjacent	TSS	0.0060	0.0060	0.001	0.001
	TN	0.0085	0.0085	0.001	0.001
	TP	0.0025	0.0025	0.001	0.001
Pollutant Production	TSS	3.39	5.00	6.20	6.0
(lb/day/1000 lb live weight)	TN	0.31	0.45	0.31	0.45
	TP	0.11	0.07	0.16	0.15

Table 1.7. Values used for RUSLE (Revised Universal Soil Loss Equation) for each Oostanaula Creek subwatershed.

					Row Crops				Pasture					Forest					
Sub ID					**Low Residue**	**High Residue**	**Strip cropped**	**Medium Residue**	**Good**	**Fair**	**Woodland**	**Over-grazed**	**Feedlot/ Loafing**	**Orchard**	**Scrub/ shrub**	**Forest**	**Clearcut**	**Mine**	**Disturbed Areas**
	R	K	LS	P	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
01	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
02	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
0201	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
03	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
04	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
0401	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
05	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
0501	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
06	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
0601	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
07	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
08	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
0801	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
09	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
10	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
1001	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
11	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1
1101	220	0.27	0.346	1	0.551	0.149	0.125	0.300	0.003	0.013	0.013	0.200	0.750	0.003	0.003	0.002	0.150	1	1

Pollutant loads from beef cattle operations

Analyzing cattle behavior and producer management was critical in selecting delivery ratios for beef cattle operations. The patchiness of a pasture depends not only on the resource variability and the overall stocking rate, but also on patterns of livestock activity in space and time. Estimating the amount of time cattle spend loafing or drinking in or immediately adjacent to streams provided a basis for estimation of the direct delivery of waste. Pollutant delivery to the stream primarily depends on: (1) where the cattle are located in the watershed and (2) the fate of the pollutant once it is introduced into the environment (i.e., movement, adsorption, volatilization, etc.).

A certain amount of waste enters streams from inadequate waste management systems (overflowing lagoons, runoff from land application, runoff loafing areas). Because of the limitations of the remote-sensing process, waste treatment facilities were not considered in this model. A closer look at the individual operations would be needed to further refine these values.

Through consultation with local NRCS staff and relevant literature (Byers et al. 2004, Davies-Colley et al. 2004, Kleinman et al. 2005), time estimates for livestock proximity to water were derived based on the following estimates about cattle behavior:

1. The time spent in the stream is primarily in June through September; although year round accessibility is available.
2. Minimal time spent in stream at night, and essentially no waste is deposited.
3. Potential stream access occurs 12-18 hrs per day June through September.
4. One-third of 12 hrs is spent in stream or near stream (four hrs per day).
5. One-sixth of 12 hrs is spent in stream (two hours per day June through September).
6. For December, January, February, and March, minimal time spent in stream, and essentially no waste deposited.
7. Percent of time spent in stream is averaged over the year (0.833 hours per day for environmentally-sensitive animals and 0.417 hours per day for insensitive animals). This gives an average for all animals of 0.625 hours per day or 2.6 percent.

For those sites adjacent to the stream, it was estimated that the cattle spent time in one of three general areas as follows:

2.5 percent of the time in the perennial stream
16.7 percent of the time near the perennial stream
80.8 percent of the time in the pasture away from the perennial stream

For those sites nonadjacent to the stream, the following estimates were made for time spent:

0 percent of the time in the perennial stream
0 percent of the time near an intermittent drain
100 percent of the time in the pasture away from an intermittent drain

The following estimates were made about the fate of the pollutant once it was introduced into the environment:

1. When the animal is in the stream, 100 percent of all pollutants enters the stream with no losses.
2. When the animal is near the stream, 10 percent of nitrogen and phosphorus enters the stream.
3. Approximately 25 percent of ammonia is lost due to volatilization prior to it entering the stream, and 10 percent of the organic nitrogen is converted to ammonia prior to entering the stream.
4. When the animal is in the pasture, 0.85 percent of the nitrogen, and 0.25 percent of the phosphorus enters the stream. These numbers are based on values for land applied poultry litter (Kingery et al. 1994).
5. The delivery ratio used for TSS was 0.6 percent.

The delivery ratio was calculated by summing the products of the time spent in the general areas and the respective fates, or:

$$DR = \Sigma_{\text{area}} (\text{time x fate}) \qquad \text{Equation (10)}$$

Where:
Area = proximity to waterway (in, near or away)
Time = time spent in an area
Fate = fate of pollutant

Pollutant loads from dairy operations

The delivery of pollutants from dairy operations varies greatly from operation to operation. Factors which influence delivery of pollutants to the stream include type and amount of confinement, management of lagoons or waste storage ponds, proximity of cows to streams, and timing and amount of land application of wastes. The delivery ratio consists of a management component and a stream access component.

The delivery ratio for the stream access component for all pollutants was modified by 0.05. This is based on the assumption that lactating cows require a greater volume of water intake than do dry cows, calves and heifers (OSU 2004). A final estimate was developed so that dairy cows with stream access spend 5 percent of their time in the stream, 16.7% near the stream and 78.3% away from the stream. Pollutant fate was defined as beef cattle above.

A selection of published nutrient loads from beef and dairy contributions has been provided in Table 1.9, for comparison to present model inputs. Coefficients applied to the present nutrient loading model vary from these published values based on the criteria listed on page 11, and are derived primarily from high water quality sampling data and land class condition, i.e., rate, frequency and intensity of management practices and livestock behavior.

Table 1.9. Previously published and model applied nutrient loads of total phosphorus and total nitrogen contributions by beef and dairy cows with unrestricted access to the adjacent waterway. Numbered columns represent coefficient references: 1. Kleinman et al. 2005; 2. Byers et al. 2004; 3. Davies-Colley et al. 2004; values have been amended to represent constant animal behavior i.e., 14-18 hr/day of pasture grazing, over 300 days/year.

	Total Phosphorus (lb/cow/day)			Total Nitrogen (lb/cow/day)		
	1	2	Model Input	1	3	Model Input
Beef	0.93	0.89	1.76			5.5
Dairy	1.62	1.54	2.1	7.56	19	14.46

Pollutant loads from horse operations

The process used to estimate delivery of horse waste was similar to that used for cattle. According to observers, horses spend only long enough in the stream to drink, and their time in the stream does not change seasonally. Time in the stream for horses is estimated at 15 minutes per day, or 1% of time on an annual basis. Delivery ratio for horse sites adjacent to the stream was 0.01, and for non-adjacent sites this value was 10% of this, or 0.001.

Pollutant loads from swine operations

The equation used to estimate pollutant delivery from swine sites was similar to that used for cattle defined above. The process was simplified however for this model, in that it was assumed that swine do not have direct access to the stream, nor do they have deleterious impacts on the stream or streambank. As such, the delivery ratio for swine sites, adjacent or non-adjacent was set at 0.001.

Pollutant loads from poultry operations

Estimating poultry populations per site is difficult whether via aerial photo interpretation or diligent site visits. It is much easier to determine area occupied by such sites with a relatively high level of accuracy. To develop appropriate numbers for the present pollutant loading model, a general broiler population per square foot density figure was used at 1.25 birds/ft^2. Delivery ratio was set low at 0.002, and pollutant production rates were set relatively high at 20.0, 1.1, and

0.34 for TSS, TN, and TP respectively. These figures were based on data in the 1996 NRCS Agricultural Waste Management Field Handbook (USDA, 1996).

Using these values, the following equation was developed to estimate pollutant loads from poultry operations:

$$M = A \times D \times WT \times PR \times DR \times 0.0001825 \qquad \text{Equation (11)}$$

Where:
M = pollutant loading (tons/year)
A = Area of site (ft^2)
D = Density of animals (birds/ft^2)
WT = animal weight (pounds)
PR = pollutant production rate (lb pollutant/day/1000 lb live wt)
DR = delivery ratio (unitless)
0.0001825 = unit conversion factor

Pollutant loads from wildlife

Terrestrial and avian wildlife populations vary in habitat preferences, but for the purpose of the pollutant loading model, habitats were limited to forests, croplands and wetlands, and completely omitted from areas containing the city of Athens. The process used for calculations of pollutant loading is similar to livestock, but does not include limitations based on operational sites (size, proximity to waterway). The pollutant loads from wildlife were estimated using the following equation:

$$M = Na \times WT \times PR \times DR \times 0.0001825 \qquad \text{Equation (11)}$$

Where:
M = pollutant loading (tons/year)
NA = number of animals (number/subwatershed)
WT = animal weight (pounds)
PR = pollutant production rate (lb pollutant/day/1000 lb live wt)
DR = delivery ratio (unitless)
0.0001825 = unit conversion factor

A constant weight of 140 lbs was used for all wildlife, based primarily on information for deer (fawn = 100, doe = 140, and buck = 160 lbs or greater), although it is recognized that all species and sizes of wildlife are present in the watershed. Delivery ratio is set at a constant 0.001 for all pollutants. Pollutant production rate is set at 6.20, 0.31, and 0.16 for TSS, TN and TP respectively, assuming minimal watershed degradation caused by wildlife.

2.0 Nonpoint Source Inventory Summary

A NPS inventory is a geographic database of land use and features that contribute or have the potential to contribute NPS pollution. The database was generated from the interpretation of low-altitude, color-infrared aerial photography concurrent with recent field verification visits and consultation with city, county, and state officials. The data generated for this study were managed using ESRI's ARC/INFO and ArcView software along with applications of Excel spreadsheets.

Land use classification

The dominant land use in the OCW is forest, comprising 47.6% of the total land area, which occurs primarily in the hill and ridge areas of the watershed. A substantial amount of forested area is concentrated in southern subwatersheds 0201, 03 and 04, along Eledge Ridge, Gettys Ridge and Red Hills. In the valleys and flat regions of the OCW, pasture is dominant, occupying 30.7% of the total watershed area. Additional land uses of the valleys are croplands, representing 5.3% of the watershed.

Residential areas represent 12.5% of the OCW, mostly in Athens and surrounding areas. Commercial and Industrial land uses total 2.3% which is also congregated around Athens. Wetlands and open water make up an additional 0.5 and 0.5% respectively, with the remaining 0.3% of land use in the form of mined or disturbed areas. Figures 2.1 and 2.2 summarize general land use patterns in Oostanaula Creek watershed.

2.1 Urban land use classes

Of the total 44,864 acres within OCW, 6719.3 acres are classified as urban (Table 2.1). Subwatershed 0501 holds the largest number of residential units, followed by 06, both located in Athens. Subwatersheds that contain Athens metropolitan cumulatively account for 2539 acres of residences, or 45%. Area 04, which is the largest of all subwatersheds, contains 548 acres of residences. Residence acreage decreases going north and south from Athens, toward the watershed boundaries.

Applying data from TDEC, TDH, City of Athens, and McMinn County, the rate of new residential units being developed in the watershed is estimated at 50 per year with an average of 0.75 acres being converted from either forest or pasture to new residences, or 38 acres per year. This approximation was used to amend original 1999 aerial photographs.

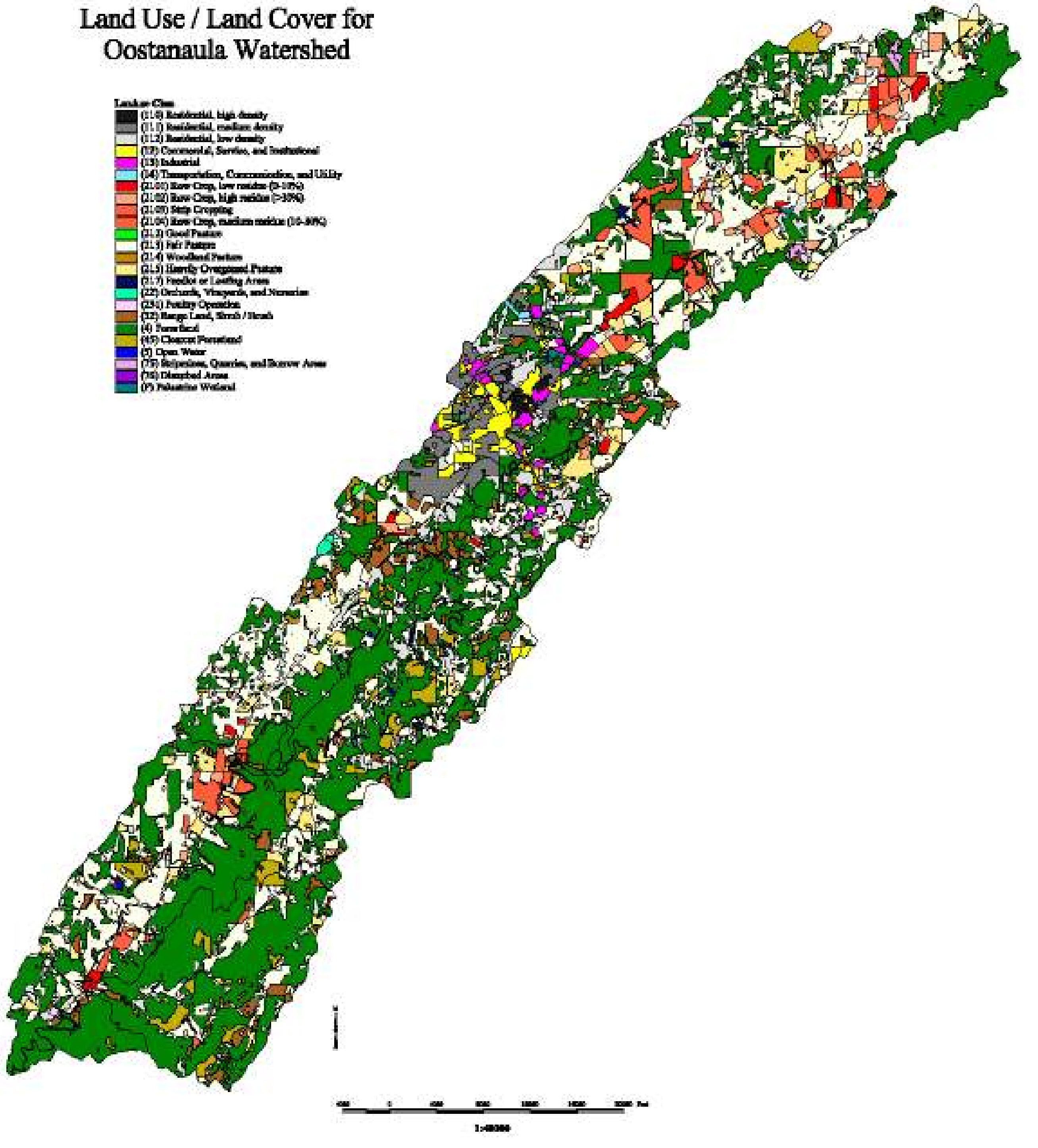

Figure 2.1. Land use classification map of Oostanaula Creek watershed. See text for methodology and delineations.

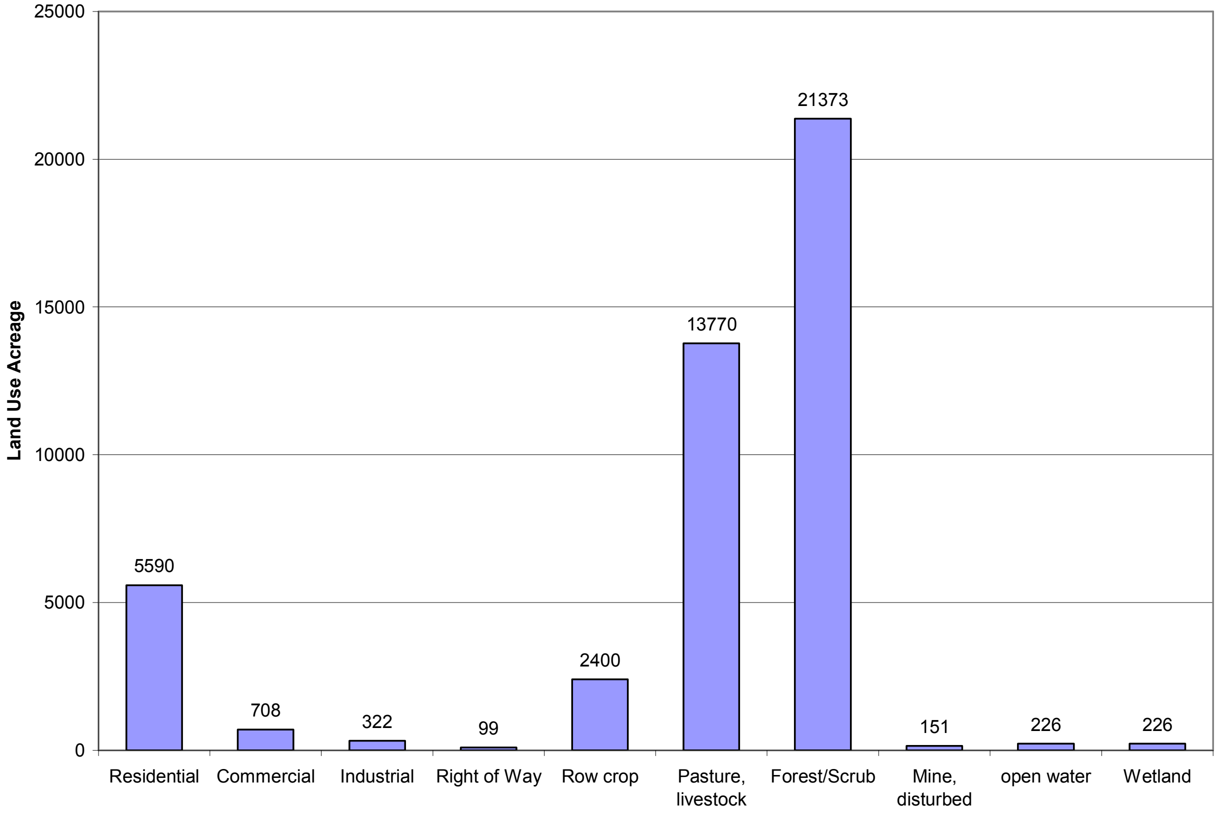

Figure 2.2. Major land use distribution (in acres) within Oostanaula Creek watershed.

Table 2.1. Urban land use areas, in acres, for Oostanaula Creek watershed, as defined in text.

Sub ID	Total Urban	Residential	Commercial	Industrial	Right of Way
01	106.7	106.7	0.0	0.0	0.0
02	75.0	73.3	1.7	0.0	0.0
0201	228.3	227.1	1.2	0.0	0.0
03	198.6	196.6	2.0	0.0	0.0
04	594.9	548.1	46.8	0.0	0.0
0401	451.8	448.4	3.4	0.0	0.0
05	297.6	290.9	6.4	0.2	0.0
0501	739.6	677.3	62.3	0.0	0.0
06	1109.0	557.8	409.4	88.5	53.2
0601	392.5	310.2	32.8	47.2	2.3
07	608.7	491.1	76.0	41.6	0.0
08	59.9	10.9	2.8	46.2	0.0
0801	617.8	491.5	41.5	53.9	30.9
09	374.3	310.7	6.8	44.1	12.8
10	276.7	262.7	13.9	0.0	0.0
1001	193.6	193.0	0.6	0.0	0.0
11	159.9	159.9	0.0	0.0	0.0
1101	234.4	233.9	0.5	0.0	0.0
Total	6719.3	5590.4	708.0	321.7	99.2

Subwatershed 06, a centrally located subwatershed in Athens, houses the largest area for commercial and industrial land uses. This area contains 58% of all commercial acreage for the watershed and 28% of industrial acreage. This is an area that serves the city of Athens and also allows easy access to Interstate-75 traffic. Right-of-way land class is also highly dependent on proximity to Athens and major roadways. Subwatersheds closest to US Highway 11 and the city of Athens have a substantially greater area of right-of-way land classification.

Urban areas also include impervious surfaces which are capable of changing the flow characteristics of streams within a watershed. Changes include increased amounts of water the stream must carry during rain events (peak flows), increased flooding frequencies, and lower base flows. These changes occur because more water runoff is created by the impervious surfaces. Impervious surfaces collect and accumulate pollutants deposited from the atmosphere, leaked from cars, during rain events, or derived from other activities which can transport pollutants to the nearest waterway. As runoff increases, so does stream flow, and the stream channel subsequently becomes unstable. The stream channel becomes deeper and wider in order to carry the increased flow. This results in increased sediment loads and loss of aquatic and riparian habitat as soil and vegetation are scoured from the bottom and banks cave into the stream.

As the amount of imperviousness within a watershed increases the amount of pollutants delivered to the stream likely increases. Percent imperviousness for OCW is estimated at 4.8%, or 2,153 acres. Most of the impervious area in the OCW is concentrated around the city of Athens in subwatershds 06, 07 and 0801 (Figure 2.3). These locations have select areas with greater than 50% imperviousness, which is classified as stressed after Schueler (1994a, b), and as such is considered here to be a major source of pollutant loading.

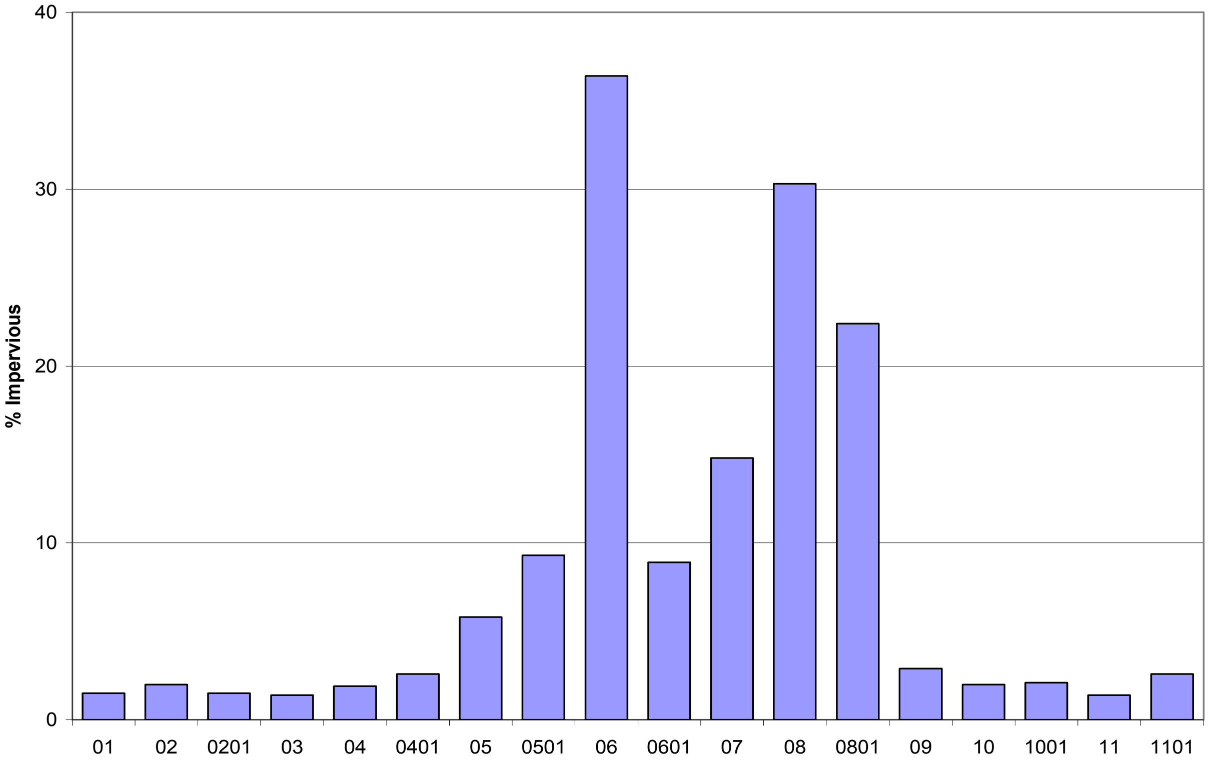

Figure 2.3. Estimated impervious locations throughout Oostanaula Creek watershed.

Suspect On-Site Septic Systems

The planning process estimated 2150 septic systems in use in the OCW, from which it is assumed that 10% are not “functioning properly.” Using the remote sensing process on aerial photographs dated from 1999, 103 sites were identified with on-site septic systems that may be contributing contaminants to the surface water through overland flow. Considering the upsurge in development of new homes in the region, this 1999 value supports a broader 10% number of 200 suspect septic tanks and systems. Field investigations should be conducted before concluding any absolute condition of these systems.

Very few houses with suspicious septic systems were located in Athens city limits where centralized sewage systems are in place, suggesting that the photo interpretation was accurate. Many systems were identified on the outskirts of city limits, where new development not online to the centralized WWTP is common. The majority of these suspect sites exhibited visible plume or drain field patterns, or both.

2.2 Roads, roadbanks and streambanks

The remote sensing process identified 116.5 miles of perennial stream contained within the watershed area, and a combined perennial and intermittent length of 258.5 miles. The interpretation process identified 25.7 miles of eroding streambank, or 22% out of a total 116.5 miles of digitized stream (Table 2.2). Due to the substantial amount of intermittent streams identified, these segments must not be overlooked. Nearly 142 miles of intermittent streams were determined by aerial photo interpretation, with 18 miles categorized as eroding. Collectively 17% of the 258.5 miles of streambanks are classified as eroding and having visible, collapsed banks.

A high degree of spatial variability is present regarding streambank condition and subwatershed, and locations of impaired streambank due to erosion can be visualized in Figures 2.4 and 2.5. Areas 08 and 0801, located in Athens, display less than 5% eroding streambank, while areas 9 and 10 in the northern section of the OCW display erosion sites on more than 25% of streambanks. Subwatershed 0601, due east of Athens, exhibited the greatest percent eroding streambank at 36%.

The recommended width for successful stream riparian buffer is 50 feet for flat lying areas in east Tennessee (Price and Karesh 2002). More than half of the stream sections evaluated for vegetation condition within the study watershed were found to have both left and right bank vegetation widths of less than 15 feet. Only 38% of the left and 30% of right banks are considered to have adequate vegetative buffers based on width. The vegetative cover density, however, was estimated as 67% or greater in the majority of the evaluated stream sections. Approximately 48% of left bank and 53% of right bank buffer are considered marginal based on insufficient vegetation cover. Hence, stream buffers were narrow yet dense.

Subwatersheds 06 and 0601 had stream sections classified as inadequate based on identification of bare ground, likely due to urban causes. Overall, 14% of left bank and 16% of right banks are considered to have inadequate riparian zones due to insufficient vegetation cover.

Table 2.2. Summary of streambank and roadbank conditions in Oostanaula Creek watershed. Values are length in feet.

Sub ID	Perennial Streambank	Eroding Perennial	Intermittent Streambank	Eroding Intermittent	Total streambank	Total Eroding	% eroding
01	44010	1631	19608	1932	63618	3562	5.6
02	28369	2528	30387	3053	58756	5581	9.5
0201	40860	6454	95687	14164	136547	20618	15.1
03	104321	24870	65117	11051	169438	35921	21.2
04	139863	34246	97593	10517	237456	44763	18.9
0401	32001	6799	70006	4753	102007	11552	11.3
05	19447	5729	13689	2014	33136	7743	23.4
0501	9054	2172	58404	3155	67458	5327	7.9
06	19119	5526	17231	80	36350	5605	15.4
0601	11002	2588	23582	9870	34584	12458	36.0
07	17416	4755	20166	394	37582	5149	13.7
08	2749	0	485	149	3234	149	4.6
0801	2903	0	19577	305	22480	305	1.4
09	37764	8454	55231	15342	92995	23796	25.6
10	36555	16556	45962	5440	82517	21996	26.7
1001	14034	603	35112	16	49146	619	1.3
11	38157	10638	48445	9862	86602	20500	23.7
1101	17711	2402	33147	3374	50858	5776	11.4
Total Feet	615,335	135,950	749,429	95,470	1,364,764	231,419	17.0
Total Miles	116.5	25.7	141.9	18.1	258.5	43.8	

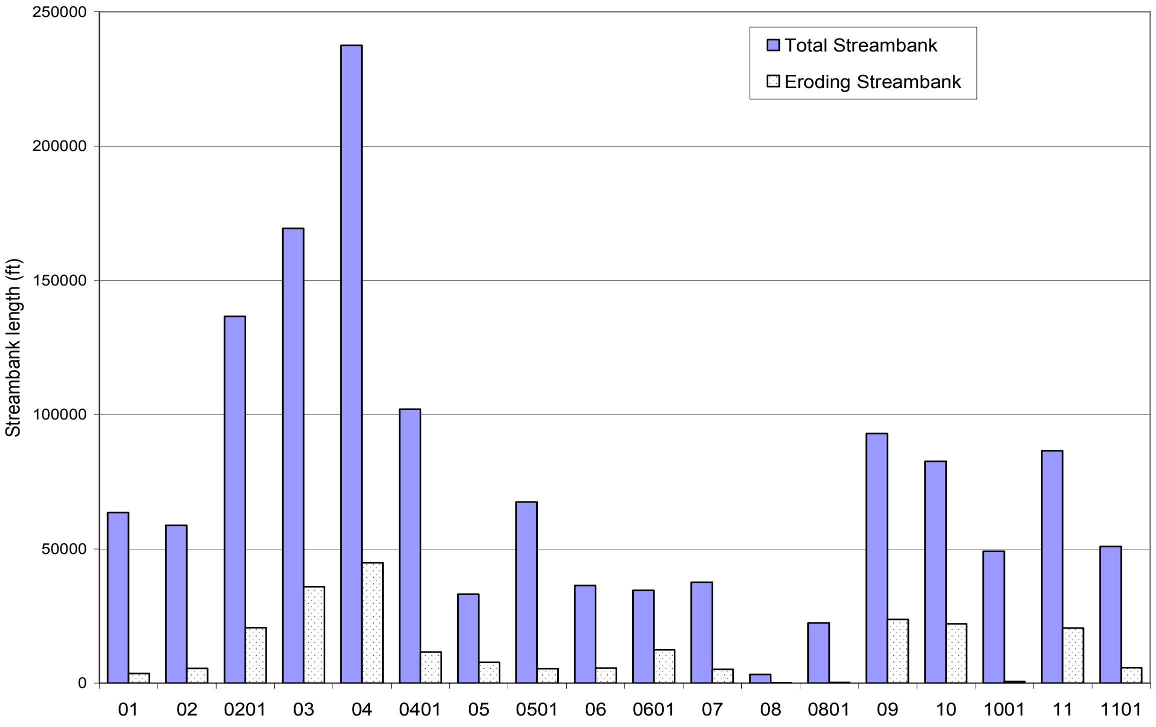

Figure 2.4. Locations of all and eroding streambanks within Oostanaula Creek watershed.

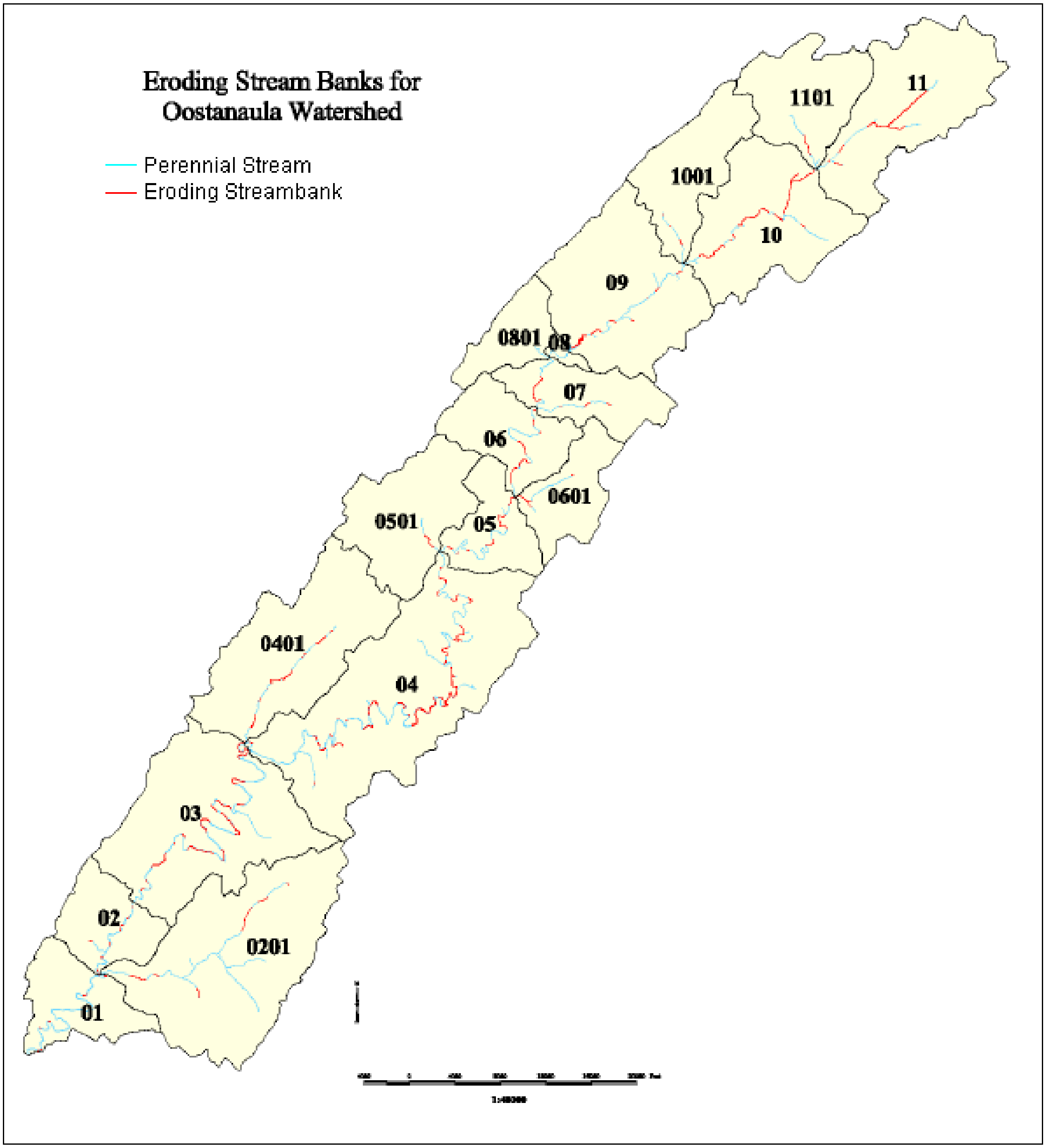

Figure 2.5. Oostanaula Creek watershed eroding streambank locations.

Within the 44,864 acres of OCW, a total of 244.1 linear miles are classified as paved roads, and 137.7 miles are unpaved roads (Table 2.3). A significant correlation exists between paved roads and commercial land use ($r^2 = 0.691$, $P \leq 0.001$) likely as a function of accessibility. A correlation also exists with paved roads and residences, likely a result of the concurrent high density of roads and residences in Athens. Of all paved roads in OCW, nearly 44% are in the six subwatersheds in or around Athens. Athens Public Works officials estimate 120 miles of city roads and 30 miles of state roads are located within the city limits (although not all of these are within the OCW boundary). It is also estimated that less than one mile of new roads are established each year, mostly for new residential subdivision development. The majority of unpaved roads are located in the southern section of the watershed, with nearly 60% in the bottom six subwatersheds. These roads are likely farm roads and/or residential driveways.

Estimated length of eroding paved roads is 21.4 miles, or 8.8% of total paved roads. Estimated length of eroding unpaved roads is 52.7 miles, or 38.3% of total unpaved roads. A standard unpaved road width of 10 feet is assumed; making the area occupied by unpaved surfaces at 167 acres, with 64 acres considered eroding. As with streambanks, roadbank erosion is unequally distributed throughout the study area, as seen in Figures 2.6 and 2.7. It should be noted that all areas contained in and around the city of Athens had low percentages of roadbanks considered eroding (<10%).

Table 2.3. Oostanaula Creek watershed eroding road bank totals (in feet) for paved and unpaved roads.

Sub ID	Paved Roads	Eroding roadbank	% Eroding	Unpaved Roads	Eroding unpaved	% Eroding	Total Roads	Total Eroding
01	26481	3220	12.2	36503	7916	21.7	62984	11136
02	30373	3112	10.2	14114	1453	10.3	44487	4565
0201	100251	11020	11.0	116282	58464	50.3	216533	69484
03	69321	9947	14.3	85303	37396	43.8	154624	47343
04	110543	18758	17.0	134145	62953	46.9	244688	81711
0401	92443	12954	14.0	46360	16226	35.0	138803	29180
05	45536	4348	9.5	5618	2415	43.0	51154	6763
0501	98698	2979	3.0	32355	14409	44.5	131053	17387
06	206586	7763	3.8	8355	1108	13.3	214941	8871
0601	67813	4354	6.4	14802	4912	33.2	82615	9266
07	93168	938	1.0	17519	11522	65.8	110687	12460
08	6725	0	0.0	3355	2347	70.0	10080	2347
0801	88956	4500	5.1	14838	780	5.3	103794	5280
09	70758	6729	9.5	52586	12621	24.0	123344	19350
10	59245	8701	14.7	24183	1806	7.5	83428	10507
1001	36171	2270	6.3	23927	0	0.0	60098	2270
11	40272	5946	14.8	69516	39332	56.6	109788	45278
1101	45548	5472	12.0	27384	2529	9.2	72932	8001
Total Feet	1,288,888	113,009	8.8	727,148	278,188	38.3	2,016,036	391,197
Total Miles	244.1	21.4		137.7	52.7		381.8	74.1

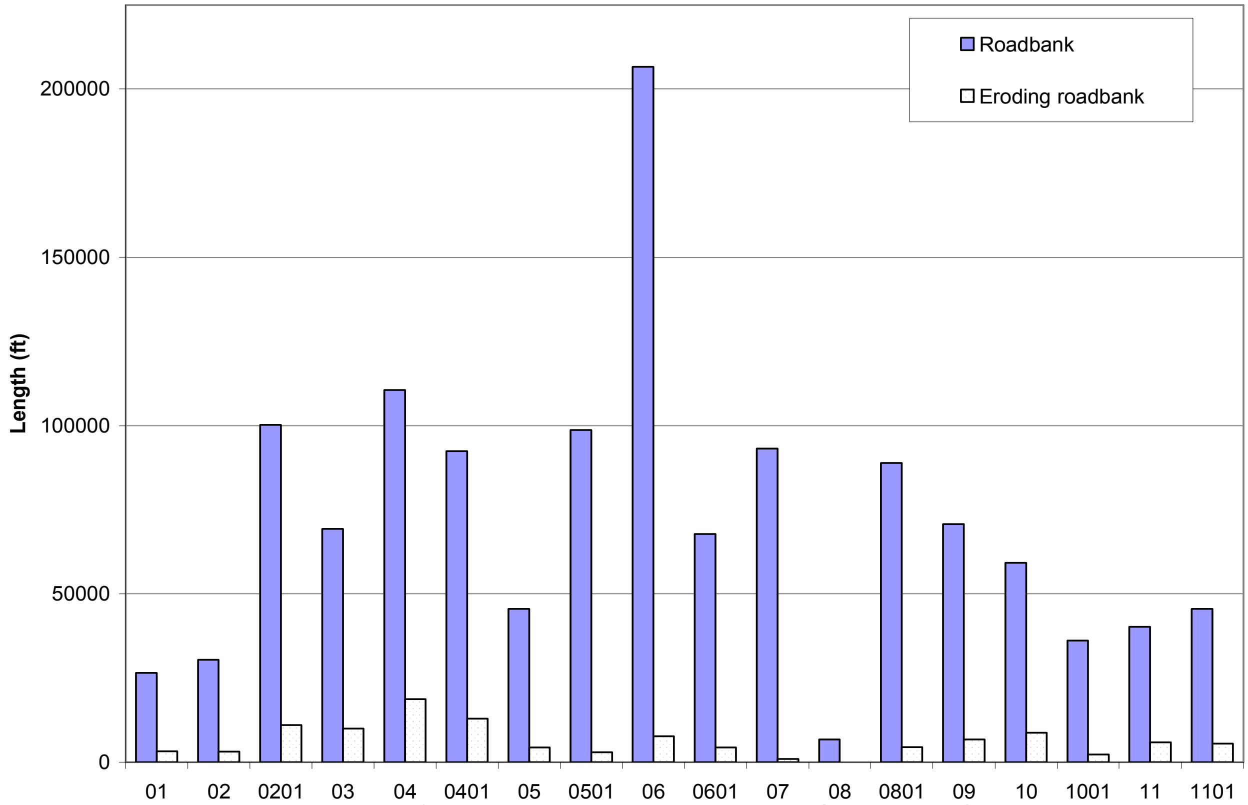

Figure 2.6. Locations and lengths of eroding paved roadbanks within Oostanaula Creek watershed.

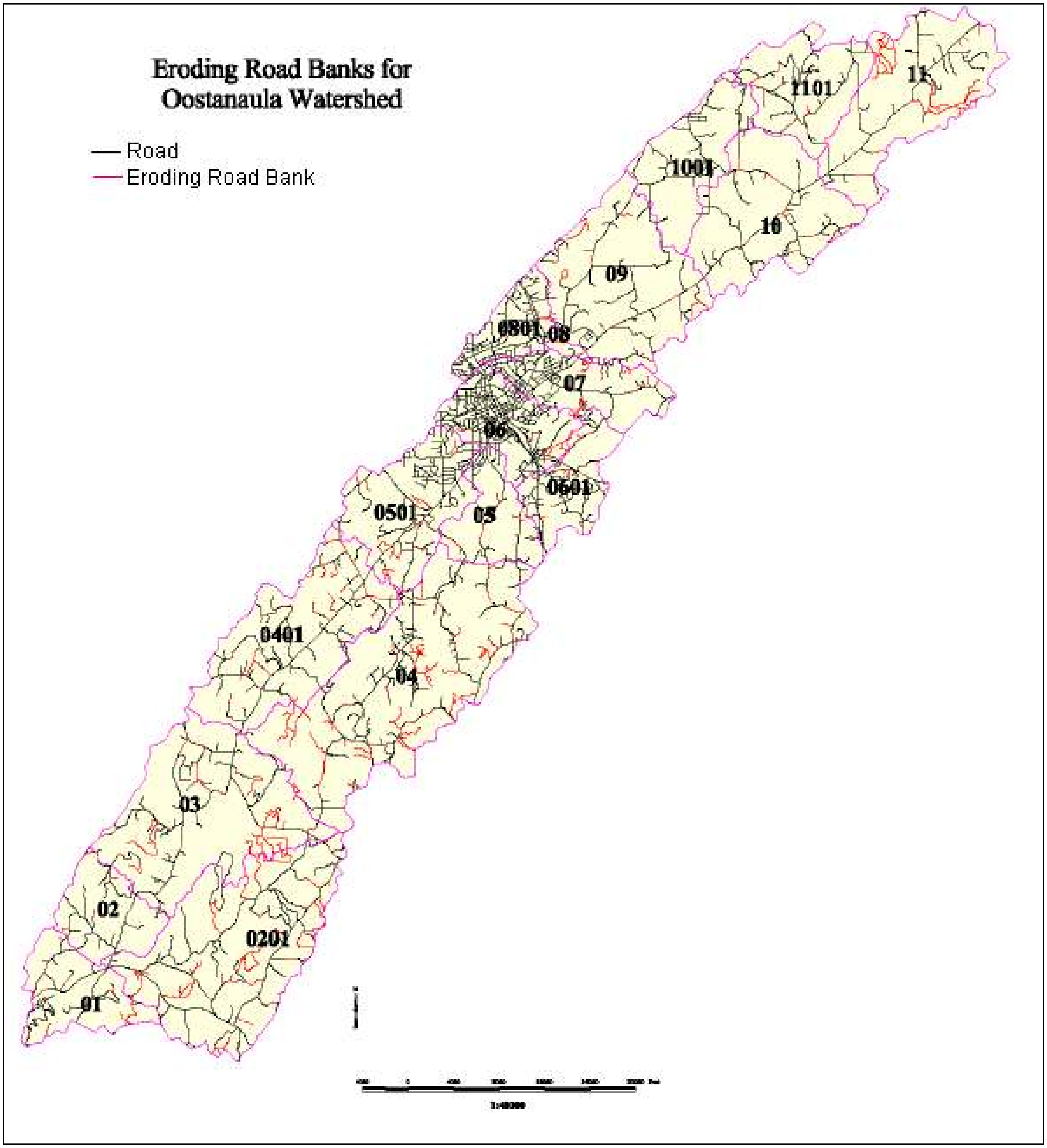

Figure 2.7. Oostanaula Creek watershed eroding paved and unpaved roadbank locations.

2.3 Crop, pasture, forest, mining and disturbed lands

Agriculture land use (cropland, pasture and farmsteads) is unevenly distributed throughout Oostanaula Creek watershed, as illustrated in Figure 2.1. Acreage of high residue crops, medium residue crops, low residue crops and the sum of all cropland by subwatershed is shown in Table 2.4. Subwatershed 09 had the highest amount of cropland acreage (550 acres), with 18% of the cropland in low residue and 65% in medium residue crops. This crop delineation trend is constant for the majority of all subwatersheds. Of the total 2400 acres of cropland, 21% was considered high residue, 59% medium, and 15% low residue. Strip cropping represents 147 acres or 6% of all croplands.

A breakdown of pasture condition as determined by the photo interpretation is shown in Table 2.4. Subwatersheds 0401 and 03 in the south and 10 and 09 in the north have the greatest amount of pasture within the OCW, all containing more than 1500 acres. Within the total watershed area, 13,770 acres are pasture with the majority (84%) in fair condition. Approximately 15% of all pasture was identified as heavily overgrazed or loafing area and 0.1% was classified as good.

Forested lands are scattered throughout the study area, with major concentrations located in the southern subwatersheds as part of the ridge terrain. The six subwatersheds south of Athens contain 62% of all 18,592 acres of forest found among the 18 areas of the watershed (Table 2.5). These subwatersheds also contain several clearcut sites, or areas of harvested forest, with an additional large site in area 1101.

Total mined and disturbed land classes within OCW were near 0.7% of the total watershed area. Mining sites existed in areas as of time of aerial photography (February 1999), mainly in areas 10 and 11 in the north. Excavation was likely for barite, as this area is part of the Sweetwater barite district. Land classes considered disturbed were limited to less than 12 acres per subwatersheds and scattered throughout the southern section, as seen in Table 2.5 below.

Table 2.4. Agriculture land use in acres for Oostanaula Creek watershed, delineated by land use condition. See text Section 3.1.2 for definitions.

		Row Crop				Pasture				
Sub ID	Total Agriculture	Low Residue	High Residue	Strip Crop	Medium Residue	Good	Fair	Woodland	Overgrazed	Feedlot/ Loafing
01	165	0.0	0.0	0.0	0.0	0.0	145.6	0.0	19.1	0.0
02	763	29.1	0.0	0.0	81.0	0.0	602.0	13.0	38.4	0.0
0201	803	15.9	0.0	0.0	23.5	0.0	696.0	9.8	58.0	0.0
03	1924	0.0	31.3	0.0	256.8	0.0	1358.2	1.6	263.5	13.2
04	1404	0.0	9.2	0.0	15.9	0.0	1166.8	0.0	190.9	21.5
0401	1784	21.4	11.4	0.0	16.9	0.0	1571.6	13.1	150.3	0.0
05	264	8.7	0.9	0.0	0.0	0.0	254.3	0.0	0.0	0.0
0501	534	24.2	39.3	0.0	0.0	16.3	364.3	46.3	43.3	0.1
06	37	0.0	0.0	0.0	0.0	0.0	29.8	5.2	2.5	0.0
0601	456	25.1	16.1	0.0	0.0	0.0	264.4	1.3	147.5	1.9
07	284	0.0	0.0	0.0	59.2	0.0	159.0	8.9	55.8	2.1
08	13	0.0	0.0	0.0	0.0	0.0	13.0	0.0	0.0	0.0
0801	34	0.0	0.0	0.0	0.0	0.0	39.3	1.2	3.7	0.0
09	2036	101.1	37.8	52.9	358.1	0.0	1217.9	9.7	227.4	31.8
10	2017	40.5	109.3	0.0	207.8	3.8	1233.9	0.0	413.6	8.0
1001	868	1.9	0.0	0.0	144.3	0.0	655.6	0.0	58.8	8.2
11	1745	83.1	154.9	94.1	219.5	0.0	985.8	0.0	201.7	5.7
1101	1007	0.8	82.0	0.0	26.1	0.0	763.1	7.9	127.0	0.0
	16152	352	492	147	1409	20	11521	118	2001	92

Table 2.5. Forest and Disturbed land classes for Oostanaula Creek watershed.

	Forest/Scrub/Shrub			Mining/Disturbed	
Sub ID	scrub/ shrub	Forest	Harvest Forest land	Mining	Disturbed Areas
01	42.5	1139.9	11.7	0.0	1.3
02	39.9	458.5	2.4	0.0	0.0
0201	257.9	3364.8	291.2	0.0	2.5
03	141.7	1971.3	163.9	0.0	12.1
04	271.2	3457.1	392.7	0.0	7.6
0401	104.6	1158.4	43.4	0.0	1.4
05	111.8	548.1	21.3	2.0	0.8
0501	295.6	737.1	36.1	0.0	2.5
06	12.1	370.9	12.4	22.4	2.6
0601	52.2	367.4	8.3	0.0	0.8
07	47.2	515.9	18.4	0.0	2.7
08	10.5	23.2	0.2	0.0	0.0
0801	29.6	253.5	13.5	0.0	0.0
09	35.3	1057.7	29.3	0.0	0.0
10	15.7	720.7	5.3	31.3	0.0
1001	49.1	749.3	7.7	0.0	0.0
11	32.9	1146.2	18.6	60.7	0.0
1101	9.6	552.3	102.1	0.0	0.0
	1559	18592	1178	116	34

2.4 Livestock operations

Tables 2.6 and 2.7 show the number and type (small, medium, or large and adjacent or nonadjacent to the stream) of beef cattle and dairy sites for OCW. The classification of small, medium, or large as reported here is a relative relationship among sites within the OCW area (Table 1.8) and is independent of any regulatory definitions regarding livestock operations. The classification is for the purpose of comparing potential water quality impacts among sites and subwatersheds.

Total estimated livestock numbers are: 3,770 beef cattle, 1,135 dairy cows (with no additional delineation such as calves, dry cows, or lactating cows), 35 horses, and 100,000 broilers. Additional animals also reside in the watershed such as sheep, donkeys, hogs and llamas; however their population numbers are not available at time of document production.

Beef cattle operations

Beef cattle sites (Table 2.6) are the most prevalent in the watershed, outnumbering dairy and horse operations. A total of 150 beef cattle sites were identified in the area, most classified as small operations (15-49 animals), and only two of the sites classified as large operations (110 animals). Cattle sites were further delineated by being located adjacent to the stream (33%) and nonadjacent to the stream (67%). The six subwatersheds south of Athens held nearly 60% of all cattle, and only a few sites were identified in the city limits. The two large beef sites are located in areas 03 and 10. Figure 2.9 further identifies locations of beef sites within the watershed.

Dairy operations

Few dairy operations (Table 2.7) were identified in the area. A total of 11 sites were reported, with five adjacent to the stream and six not adjacent. The majority of dairy sites in the study area are deemed medium; that is having approximately 100 animals per site. Two sites are classified as large, both in subwatershed 09. Unlike cattle operations, the majority of dairy sites are located north of Athens. Additional information on the location of dairy sites in the watershed can be seen in Figure 2.8.

Horse operations

The total number of horse site operations (Table 2.8) for the study area was 16, with 100% located on land not adjacent to the streams. As seen with beef cattle operations, most of the horse sites in the study area are small operations scattered throughout the watershed. These small sites representing two to three animals or less are likely recreational horse sites.

Swine operations

Aerial photo interpretation identified one hog site in subwatershed 07, just east of Athens. However recent site visits suggest that this site is not for hog production, but rather recreational farming. Along with a few roaming hogs, other livestock seen on the site include sheep, donkeys, and llamas. As these animals contribute to soil scarification and modification, and produce consistent and substantial manure loads, this site will remain to be included in the pollutant loading model, as defined in Section 1.0.

Table 2.6. Locations and classification of beef cattle sites within Oostanaula Creek watershed.

Beef Cattle		Adjacent to Stream				Nonadjacent to Stream			
Sub ID	Total	Large	Medium	Small	Subtotal	Large	Medium	Small	Subtotal
01	5			1	1			4	4
02	6			2	2		2	2	4
0201	12		2	1	3			9	9
03	21	1	2	2	5		1	15	16
04	19		3	4	7		3	9	12
0401	24		5	7	12		1	11	12
05	0				0				0
0501	6		2		2			4	4
06	0				0				0
0601	4		1	1	2			2	2
07	5				0			5	5
08	1				0			1	1
0801	1				0			1	1
09	8		1	1	2			6	6
10	11	1	2		3		4	4	8
1001	4		1		1			3	3
11	11		4	3	7		2	2	4
1101	12		2		2			10	10
total	150	2	25	22	49	0	13	88	101

Table 2.7. Locations and classifications of dairy sites within Oostanaula Creek watershed.

Dairy Cattle		Adjacent to Stream				Nonadjacent to Stream			
Sub ID	Total	Large	Medium	Small	Subtotal	Large	Medium	Small	Subtotal
01	0				0				0
02	1				0		1		1
0201	0				0				0
03	0				0				0
04	0				0				0
0401	0				0				0
05	0				0				0
0501	0				0				0
06	0				0				0
0601	1		1		1				0
07	0				0				0
08	0				0				0
0801	0				0				0
09	3	2			2		1		1
10	2		1		1		1		1
1001	1				0		1		1
11	2		1		1		1		1
1101	1				0			1	1
total	11	2	3	0	5	0	5	1	6

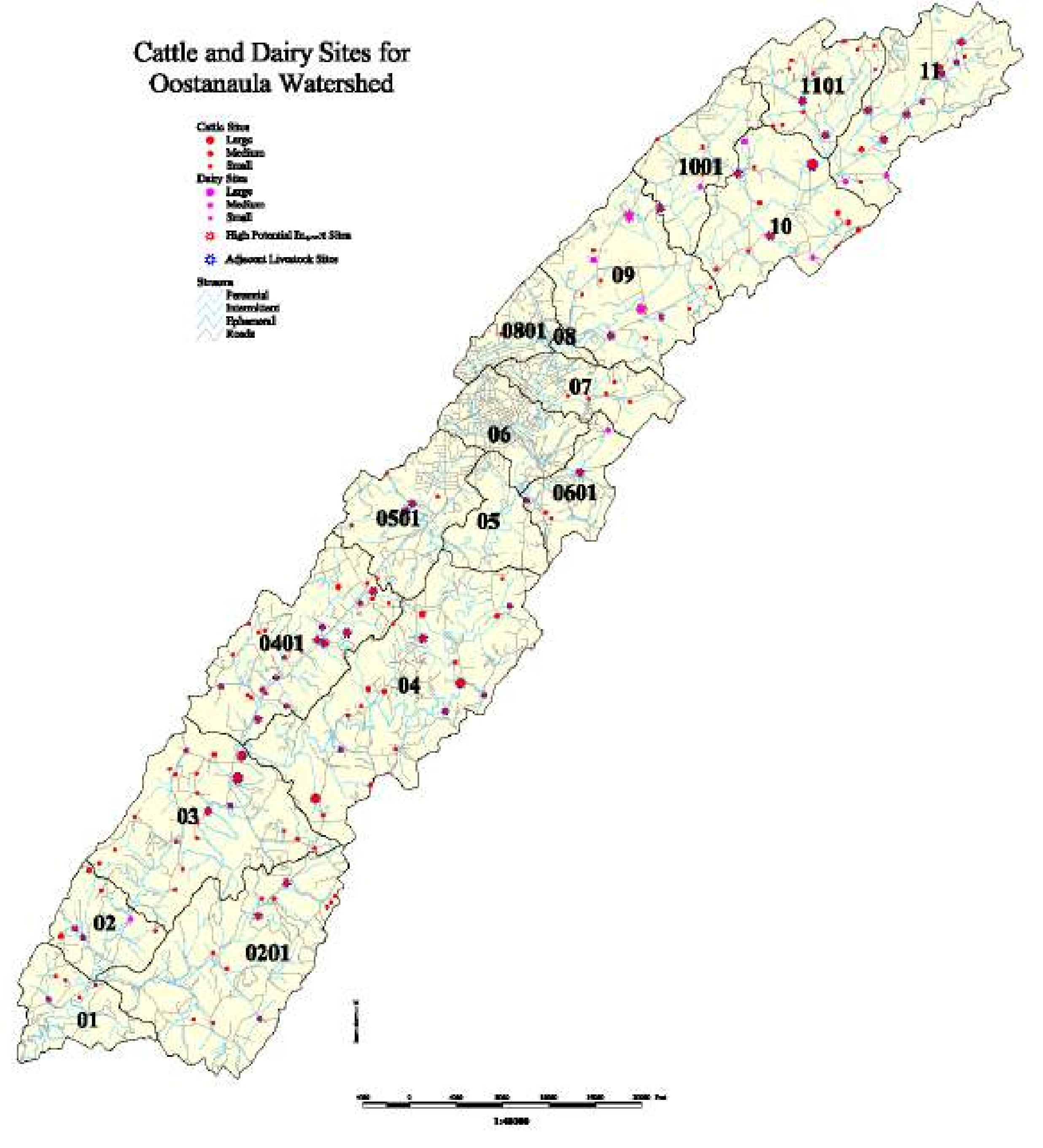

Figure 2.8. Locations and classifications of beef cattle and dairy sites within Oostanaula Creek watershed.

Table 2.8. Locations and classifications of horse sites within Oostanaula Creek watershed.

Horses		Nonadjacent to Stream		
Sub ID	Total	**Large**	**Medium**	**Small**
01	0			
02	1			1
0201	1			1
03	0			
04	4		1	3
0401	3			3
05	0			
0501	2			2
06	0			
0601	0			
07	0			
08	0			
0801	0			
09	0			
10	2			2
1001	0			
11	3			3
1101	0			
total	16	0	1	15

Poultry operations

Four poultry sites were identified by means of aerial photo interpretation and site visits: two sites in subwatershed 01 and one each in 03 and 04. The site in area 04 is located down County Road 658 on Underdown Road; however ground-truthing identified this location as no longer in production as was subsequently disregarded from the model. Carmichael Farms in area 01 contains four houses of layer chickens at about 15,000 birds per house for a total of 60,000 at a given time. This site located near CR 732, has been issued a TDEC allocated CAFO, as of May 2006. Mildred Prince, located on CR 700 in area 03, contains two houses, with a total capacity of about 42,000 birds. A CAFO (TNA000032) was terminated by TDEC for this site dated December 2004. Manure from these operations is removed and transported off-site.

Pate Enterprises in area 01, located down Highway 163 near Calhoun, TN, was classified as having 76,000 ft^2 of applicable land and producing approximately 100,000 broilers. A site visit identified five broiler houses and confirmed that this poultry site remains in operation, with broiler processing in Morristown, TN. As of December 2004, this CAFO permit TNA000018 was terminated and received a “No Potential to Discharge” determination, requiring no land application of litter or manure on this site. TDEC has since determined that the manure, litter, or cake is not land applied on this property but is removed from the house and sold to a third party.

As all poultry operations were identified as having poultry waste removed from the respective site, the pollutant loading model was amended to reflect this. Delivery ratios used in the equation for estimating pollutant loading was reduced 100%, from 0.002 to 0.0002.

Wildlife population

Estimates of local wildlife populations are presented in Table 2.9, with a total estimation of 728 animals. These figures, unlike livestock figures, are not static as most wildlife is transient with no regard to watershed boundaries. Subwatershed 04 is estimated to contain the largest population of wildlife at 152 animals, followed by 0201 with 143 animals. These areas hold the greatest area of forested land, which, in the current model, is the primary habitat for terrestrial wildlife. Other subwatersheds included in the approximation process all had less than 100 animals estimated. Subwatersheds containing and immediately surrounding Athens were not included in wildlife population estimates.

Table 2.9. Locations and population estimates for wildlife in Oostanaula Creek watershed. See text for methodology.

Sub ID	Row crop	Forest/ Scrub	Wetland	Total Applicable Land	Estimated wildlife population
01	0.0	1194.0	13.2	1207.2	43
02	110.1	500.9	0.0	611.0	22
0201	39.4	3915.8	23.7	3978.9	143
03	288.0	2276.8	4.7	2569.5	92
04	25.1	4120.9	74.6	4220.6	152
0401	49.7	1337.4	0.0	1387.1	50
09	549.8	1122.3	9.6	1681.7	60
10	357.6	741.7	29.2	1128.5	41
1001	146.2	806.1	0.6	952.9	34
11	551.6	1197.8	0.9	1750.3	63
1101	108.8	664.1	0.0	772.9	28
totals	2226.3	17877.8	156.5	20260.6	728

3.0 Soil Loss Estimates

Using RUSLE parameters and coefficients referenced in the methodology of Section 1, the estimated soil loss for OCW is 61,220 tons/year, which corresponds to 1.36 tons/acre/year. The estimated soil loss from select land use categories is given in Table 3.1 and Figure 3.1 below. The major source of soil loss in the watershed is eroding streambanks, as this land class accounts for 31% of local soil loss; followed by crop lands with 23% and pasture with 21%. Forests and disturbed areas contribute 7 and 5% of all soil loss, respectively.

Care should be taken when expressing differences in soil loss values across land use classes. That is, annual soil loss per acre is largely a function of C values, and total annual soil loss is largely a function of acreage. To better understand soil loss in these separate contexts, values will be further described in relative (tons/ac/yr) and absolute (tons/yr) terms below. Figures 3.2 and 3.3 display soil loss as both tons/ac/yr and tons/yr for Oostanaula Creek subwatersheds and land classes

Within the OCW, disturbed and mined areas contributed the greatest soil loss per acre, both at 20.17 tons/ac/yr (Table 3.1). These elevated values are likely due to high C-factors used in the RUSLE and the relatively small amount of acreage within the watershed area. Of the land classes categorized as agriculture, livestock feedlot/loafing areas (15.29 tons/ac/yr) and low-residue cropland (11.12) contributed the greatest per acre rate of soil loss. Rate of soil loss per acre for cropland nearly doubles from high- to medium-residue and from medium- to low-residue. Good pasture, orchards, forest, and scrub and shrub areas contributed the least amounts of soil loss for the study area, all less than 0.10 ton/ac/yr.

When expressed as absolute tons of soil loss per year over the entire watershed, heavily overgrazed pasture lands and medium-residue croplands were the dominant agricultural land class of soil loss, contributing 13 and 14% of all soil loss. The rate of soil loss (tons/ac/yr) for these land classes was less than those of bare and disturbed lands, each representing less than 6 tons of soil loss per acre. However, the area that these land classes occupy within the study area creates a high total loss per watershed (combined total of 16,600 tons/yr). Other significant sources of annual soil loss are low residue cropland and harvested forest land, both contributing about 6% of all soil loss for the watershed. Small estimates of soil loss per watershed come from disturbed (0.3%) and mined areas (2.8%); rising from the small percentage of area designated as these land classifications. Forests and fair pastures make up the dominant land use types for the watershed, however contribute relatively small amounts of soil loss.

Table 3.1. Soil loss estimates (tons/yr) for select land classes within Oostanaula Creek watershed.

			Row Crop				Pasture					Forest/Scrub/Shrub				Mining/Disturbed	
Sub ID	tons/ac/yr	tons/yr	Low Residue	High Residue	Strip Crop	Medium Residue	Good	Fair	Wood -land	Over-grazed	Feedlot/ Loafing	Orchard	scrub / shrub	Forest	Harvest Forest land	Mining	Disturbed Areas
01	0.165	227	0	0	0	0	0	38	0	77	0	0	3	46	35	0	26
02	0.911	1158	323	0	0	490	0	158	3	155	0	0	2	18	7	0	0
0201	0.385	1821	177	0	0	142	0	183	3	234	0	0	16	136	881	0	51
03	0.967	4095	0	94	0	1554	0	356	0	1063	200	0	9	80	496	0	244
04	0.545	3022	0	28	0	96	0	306	0	770	326	0	16	139	1188	0	153
0401	0.513	1611	238	34	0	102	0	412	3	606	0	2	6	47	131	0	28
05	0.330	315	96	3	0	0	0	67	0	0	0	0	7	22	65	40	16
0501	0.540	880	269	118	0	0	1	96	12	175	2	1	18	30	109	0	51
06	1.210	576	0	0	0	0	0	8	1	10	0	0	1	15	37	451	53
0601	1.196	1081	279	48	0	0	0	69	0	595	29	0	3	15	25	0	17
07	0.894	792	0	0	0	358	0	42	2	225	31	0	3	21	56	0	54
08	0.122	6	0	0	0	0	0	3	0	0	0	0	1	1	1	0	0
0801	0.228	78	0	0	0	0	0	10	0	15	0	0	2	10	41	0	0
09	1.696	5391	1124	114	133	2167	0	319	3	917	481	0	2	43	89	0	0
10	1.726	4827	450	329	0	1257	0	324	0	1669	121	0	1	29	16	632	0
1001	0.877	1483	21	0	0	873	0	172	0	237	123	0	3	30	23	0	0
11	1.808	5442	924	466	237	1328	0	259	0	814	87	0	2	46	56	1224	0
1101	0.870	1459	9	246	0	158	0	200	2	512	0	0	1	22	309	0	0
t/yr		34264	3909	1479	371	8526	1	3021	31	8074	1399	3	94	750	3566	2347	691
t/ac/ yr	0.904		11.115	3.006	2.521	6.052	0.061	0.262	0.262	4.034	15.129	0.061	0.061	0.040	3.026	20.172	20.172

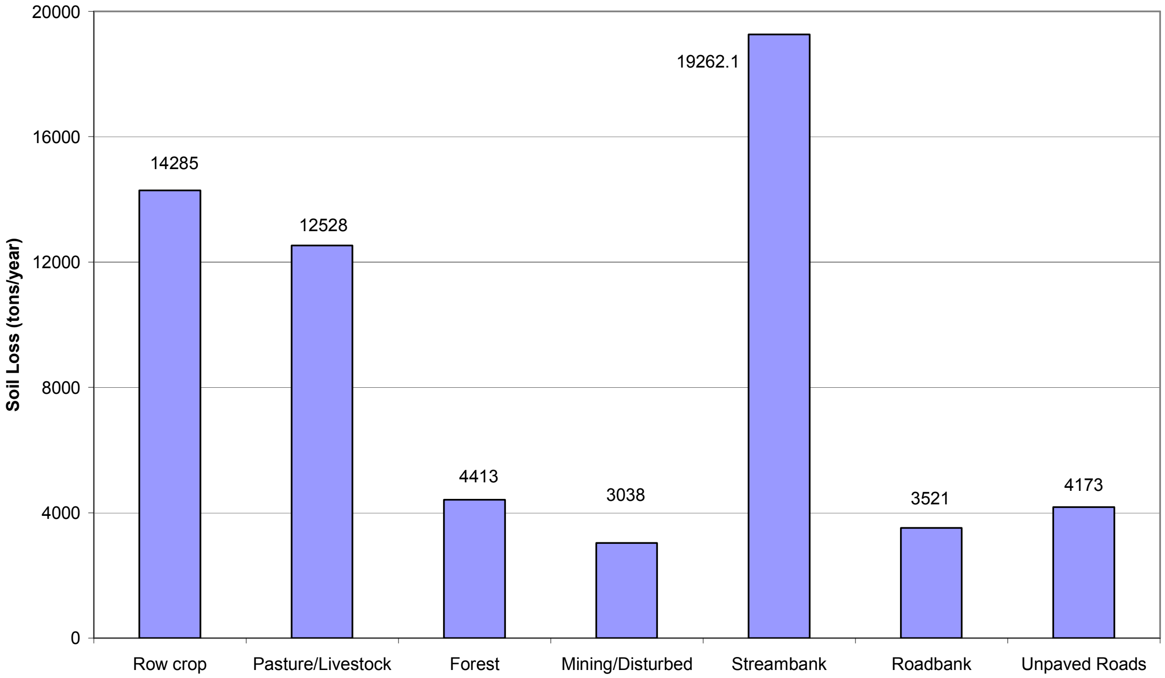

Figure 3.1. Soil loss estimates from select land classes in Oostanaula Creek watershed.

Some land uses, such as forest clear-cuts and disturbed areas, are temporary changes to the landscape. Therefore, care should be exercised when comparing annual soil loss from these temporary land changes with long-term land uses such as pasture and crop land. A forest clear-cut or construction site present at the time of photography could have revegetated or been completed, while new ones in a different area within the watershed could exist by the time the inventory is completed.

Soil loss estimates for streambanks, road banks, and unpaved roads are presented in Table 3.2. Of these land classes, streambanks have the greatest amount of soil loss (19,262 tons per year) in the watershed. The present loading model did not delineate road banks by paved or unpaved types, yet the combined soil loss from this land cover is low compared to many other cover types. Estimated soil loss for road banks is 3,521 tons per year, or 6% of all soil loss. It should be highlighted that as percentage of roadbank erosion is low in subwatersheds containing Athens (Table 2.4, Figure 2.7), so is tons/year amounts of soil loss for these areas. The IPSI loading model identifies these areas as relatively low contributors of soil loss.

Table 3.2. Soil loss (tons/yr) estimates from streambanks, roadbanks and unpaved roads in Oostanaula Creek watershed.

Sub ID	streambank	road bank	unpaved road	Total (ton/year)
01	260.9	100.224	209.5	570.6
02	406.7	41.085	81.0	528.8
0201	1280.5	625.356	667.4	2573.2
03	3279.9	426.087	489.6	4195.6
04	4338.0	735.399	769.9	5843.3
0401	962.5	262.620	266.1	1491.2
05	735.4	60.867	32.2	828.5
0501	369.7	156.492	185.7	711.9
06	638.5	79.835	48.0	766.3
0601	672.7	83.396	85.0	841.0
07	561.8	112.141	100.5	774.5
08	5.7	21.124	19.3	46.0
0801	11.6	47.519	85.2	144.3
09	1555.1	174.150	301.8	2031.1
10	2110.7	94.562	138.8	2344.1
1001	69.9	20.428	137.3	227.7
11	1598.1	407.500	399.0	2404.6
1101	404.5	72.006	157.2	633.6
total	19262.1	3520.8	4173.3	26956.1

Estimates of soil loss per acre averaged 1.18 tons/ac/yr throughout the 18 subwatersheds of the study area. Areas with the highest soil loss values were subwatersheds 11 (2.47 tons/ac/yr), 10 (2.31), and 09 (2.09); all of which are located in the northern part of OCW. Subwatershed 03 in the southern section also had a relatively high rate of annual soil loss at 1.86 tons/ac/yr, as displayed in Figure 3.2. These subwatersheds contain high land proportions of fair pasture and medium-residue croplands. Subwatershed 10 contains the highest land area of heavily overgrazed pasture and area 11 contains the highest land area of mined lands, which partially explains the elevated rate of soil loss per acre here.

Annual soil loss per subwatershed ranged from 52 to 8866 tons/year, mostly as a function of land acreage. Areas 04 and 03 are the largest subwatersheds in OCW, and have the greatest annual soil loss. Soil loss from areas 11, 09, and 10 make up the remaining top five subwatersheds for soil loss. However, contrary to this acreage by soil loss relationship, area 0201 is the second largest subwatershed in the OCW, yet is not a significant contributor of soil loss in the OCW. A possible explanation for this result is that area 0201 contains the greatest acreage of forest land, which is not a major source of soil loss, as seen in Figure 3.1.

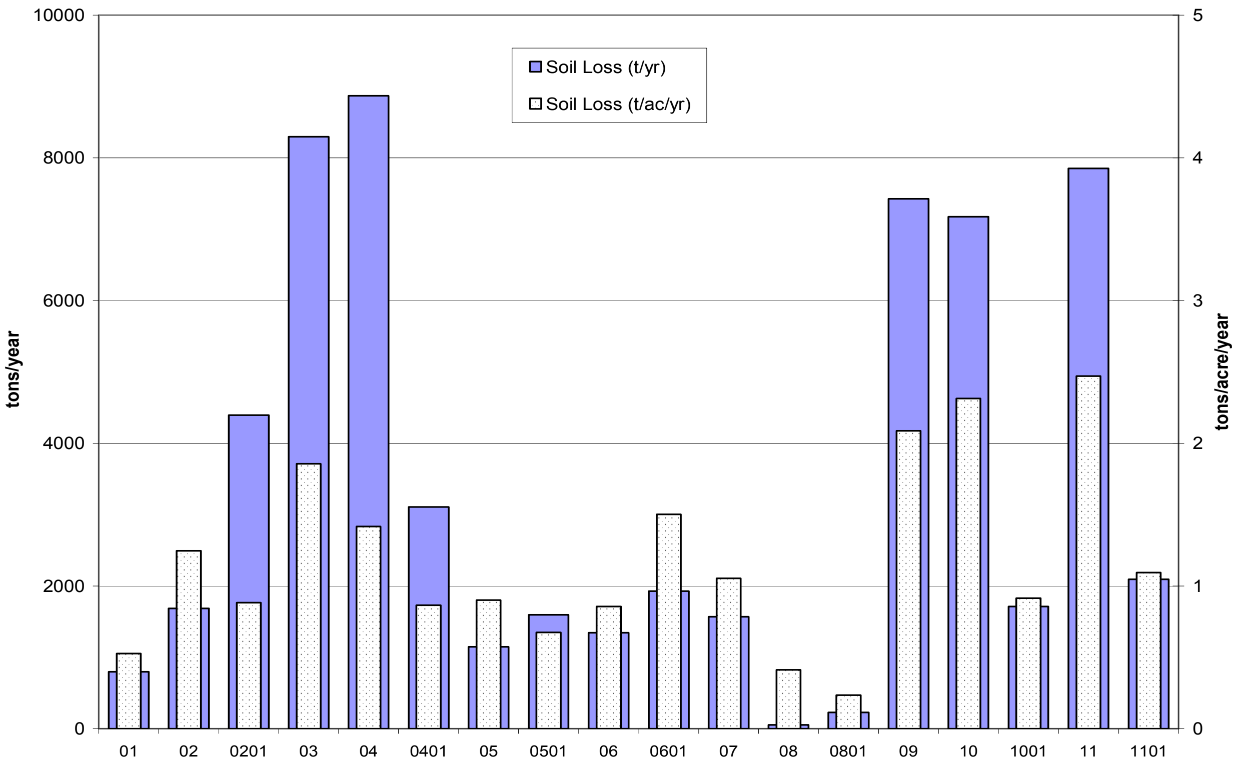

Figure 3.2. Soil loss estimates per subwatershed for all applicable land classes in Oostanaula Creek watershed. Note different y-axes scales.

The smallest subwatershed, 08, contributed the least amount of soil loss to the whole study area, and also had a small loss per acre value. This is likely a result of having a high amount of industrial and commercial property, and a low amount of open soil (Figure 2.1 and Table 2.1).

4.0 Nonpoint Pollution Sources

The pollutant loads presented in this report were generated using the IPSI system and pollutant loading model described under Methods heading 1.4. The absolute accuracy of these estimates was not determined; however, the estimates provided should be useful for planning purposes (see Model Calibration, Section 6.0). To determine the accuracy of these estimates, timely and consistent comparisons with water quality monitoring data would be required. The pollutant loading model utilized for this report allows for the adjustment of the default equation values as better information on water quality and watershed conditions becomes available or changes with time. The model should prove useful to predict the response to and evaluated potential of NPS management strategies as discussed in companion documents to be produced.

Pollutant loads were estimated for the following land uses and livestock operations: residential, commercial, industrial, transportation and right-of-way, cropland, pasture, forest, clearcuts, mining, disturbed areas, and beef cattle, dairy, horse, swine, and poultry operations. Pollutant loads were estimated for the following pollutants: total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS), as these are currently, or have the potential to be, sources of impairment for OCW. Data analysis for this purpose is inherently coarse, identifying simple summary statistics of annual loading.

As with soil loss, comparisons of pollutant loads from forest clearcuts, disturbed areas and construction sites with the other sources should be done with caution. There is no doubt that these changes in the landscape contribute substantially to the NPS pollution load. The annual load from these sources, however, is more variable because the sources are not long-term land covers as compared with the other land class sources. To estimate the loads from these sources, information is needed on the rate of establishment and recovery of clear-cutting, mining and construction. Such information was beyond the scope of this study.

Total estimated loading from OCW was 22.13 tons TP/year, 81.66 tons TN/year, and 8877.65 tons TSS/year. Annual pollution loads per acre and total loads for major land use categories within OCW are summarized in Tables 4.1 and 4.2 and Figures 4.1, 4.3, and 4.5 below. Loads per acre are comparable with other studies of similar nature (Kratzer 2005), suggesting accuracy of the present loading model.

Annual per-acre estimates of TP, TN, and TSS loads were lowest for forested areas and good and fair pastures. Urban areas contributed greater per-acre loads of TP and TN than agricultural areas in the watershed. Urban areas including residential, commercial and industrial lands contributed nearly 29% of all TP/ac/yr. Mined and disturbed lands contributed the greatest TSS loads per acre. Animal loafing areas and low residue croplands also contributed significant amounts of TSS load per acre. A general trend emerged for all pollutants in that as pasture conditions worsen, load per acre increases. Load per acre of each pollutant nearly doubled with a stepwise drop in pasture condition.

Urban areas accounted for 47% of TN loads, with croplands contributing 7% and pastures nearly 11%. Forests contributed less than 1% of both TN and TP. The WWTP in Athens contributed nearly 51% of all TP and 11% of TN to the OCW. Estimates of annual TSS loads identified agriculture as the primary source, with croplands contributing 24% and pastures contributing 21% of all loading. TSS loading was also substantial from eroding streambanks, as this land class contributed nearly 18% of all TSS loading. Urban sources contribute 17% and the WWTP in Athens accounts for less than 1% of TSS loading per year.

Livestock operations had low annual estimated TP and TN loads for the watershed, cumulatively contributing 11 and 13% of TP and TN respectively. TSS loading from livestock was less than 1% of all annual loads. Pollutant loads by land class are further defined in Section 4.1 for Urban, 4.2 for Point Sources, 4.3 for Roads and Streambanks, 4.4 for non-agriculture idle lands, 4.5 for Agriculture lands 4.6 for Livestock, and 4.7 for Wildlife.

As the single WWTP in Athens was a significant source of TP and TN in the watershed, the subwatershed which houses this source, 05, is the greatest contributor of these nutrients. Subwatershed 06 also contributed substantial, albeit much lower than 05, amounts of TP and TN to the area as this subwatershed holds the greatest land coverage of commercial and industrial sites. Loading estimates for TSS identified subwatersheds 09, 10 and 11 as leading sources. These northern areas contain the greatest acreage of croplands. Pollutant load estimates by subwatershed for all land classes are seen in Figures 4.2, 4.4 and 4.7.

Table 4.1. Nutrient loading expressed as tons per acre per year for Oostanaula Creek watershed delineated by land use.

	TP (ton/ac/yr)	**TN** (ton/ac/yr)	**TSS** (ton/ac/yr)
Urban			
Residential	0.0006	0.0040	0.146
Commercial	0.0033	0.0152	0.542
Industrial	0.0020	0.0166	0.865
ROW	0.0001	0.0010	0.051
Cropland			
Low Residue	0.0005	0.0048	1.677
High Residue	0.0001	0.0013	0.451
Strip Crop	0.0001	0.0010	0.366
Medium Residue	0.0003	0.0026	0.897
Pasture			
Good Pasture	0.0000	0.0000	0.009
Fair Pasture	0.0000	0.0001	0.039
Woodland	0.0000	0.0001	0.041
Overgrazed	0.0003	0.0017	0.597
Feedlot	0.0002	0.0460	2.146
Forest			
Orchard	0.0000	0.0000	0.009
Scrub/shrub	0.0000	0.0000	0.009
Forest	0.0000	0.0000	0.006
Clearcut	0.0000	0.0007	0.420
Other			
Mine	0.0004	0.0048	3.063
Disturbed	0.0003	0.0046	2.904
Total	0.0007	0.0742	0.201

Table 4.2. Nutrient loading expressed as tons per year for Oostanaula Creek watershed delineated by land use.

	TP		**TN**		**TSS**	
	(ton/yr)	(% of total)	(ton/yr)	(% of total)	(ton/yr)	(% of total)
Urban						
Residential	3.439	15.5	22.598	27.7	818.782	9.2
Commercial	2.301	10.4	10.740	13.2	383.579	4.3
Industrial	0.649	2.9	5.332	6.5	278.215	3.1
ROW	0.010	<0.1	0.101	0.1	5.061	0.1
Cropland						
Low Residue	0.169	0.8	1.686	2.1	589.990	6.6
High Residue	0.063	0.3	0.634	0.8	221.809	2.5
Strip Crop	0.015	0.1	0.154	0.2	53.852	0.6
Medium Residue	0.361	1.6	3.609	4.4	1263.229	14.2
Pasture						
Good Pasture	0.000	<0.1	0.001	<0.1	0.189	<0.1
Fair Pasture	0.128	0.6	1.277	1.6	446.809	5.0
Woodland	0.003	<0.1	0.008	<0.1	4.837	0.1
Overgrazed	0.683	3.1	3.413	4.2	1194.422	13.4
Feedlot	0.023	0.1	4.254	5.2	198.512	2.2
Forest						
Orchard	0.000	<0.1	0.001	<0.1	0.374	<0.1
Scrub/shrub	0.002	<0.1	0.022	<0.1	14.076	0.2
Forest	0.013	0.1	0.172	0.2	109.467	1.2
Clearcut	0.057	0.3	0.777	0.9	494.514	5.6
Other						
Mine	0.041	0.2	0.560	0.7	356.414	4.0
Disturbed	0.011	0.1	0.156	0.2	99.463	1.1
Streambank	0.317	1.4	4.365	5.3	1587.262	17.9
Road Bank	0.058	0.3	0.796	1.0	289.605	3.3
Unpaved Road	0.069	0.3	0.954	1.2	346.901	3.9
Livestock						
Beef Cattle	1.786	8.1	5.897	7.2	59.817	0.7
Dairy	0.652	2.9	4.788	5.9	50.425	0.6
Horse	0.001	<0.1	0.002	<0.1	0.362	<0.1
Swine	0.001	<0.1	0.002	<0.1	0.025	<0.1
Poultry	0.018	0.1	0.057	0.1	1.038	<0.1
Wildlife	0.003	<0.1	0.006	<0.1	0.116	<0.1
WWTP	11.257	50.9	9.302	11.4	8.504	0.1
Total	22.129		81.663		8877.646	

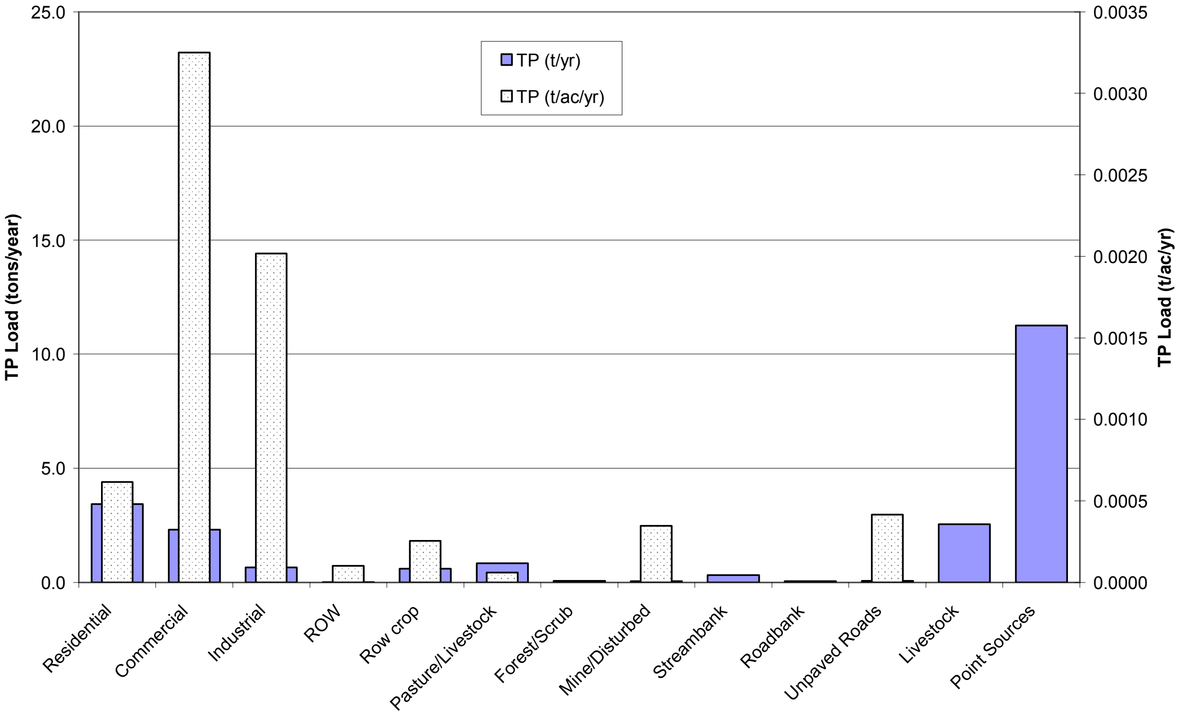

Figure 4.1. Total phosphorus loading by source for Oostanaula Creek watershed expressed as tons/year and tons/acre/year.

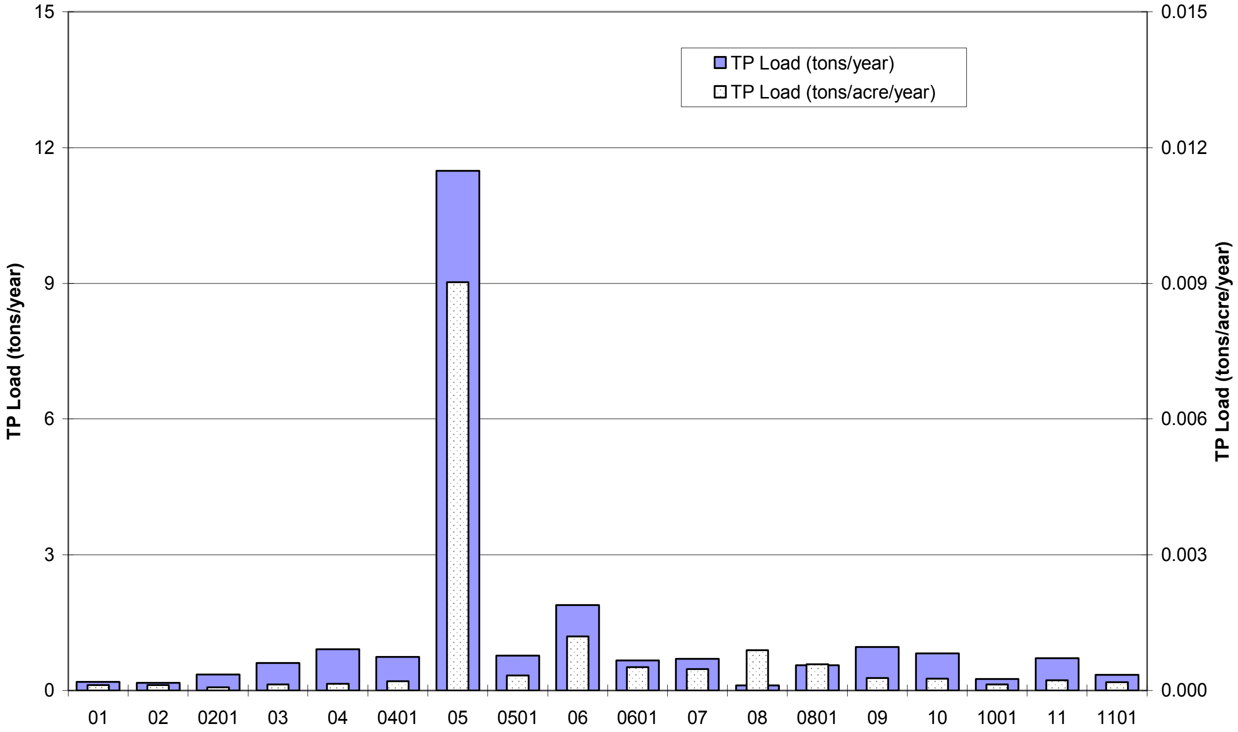

Figure 4.2. Total phosphorus loading by subwatershed within Oostanaula Creek watershed.

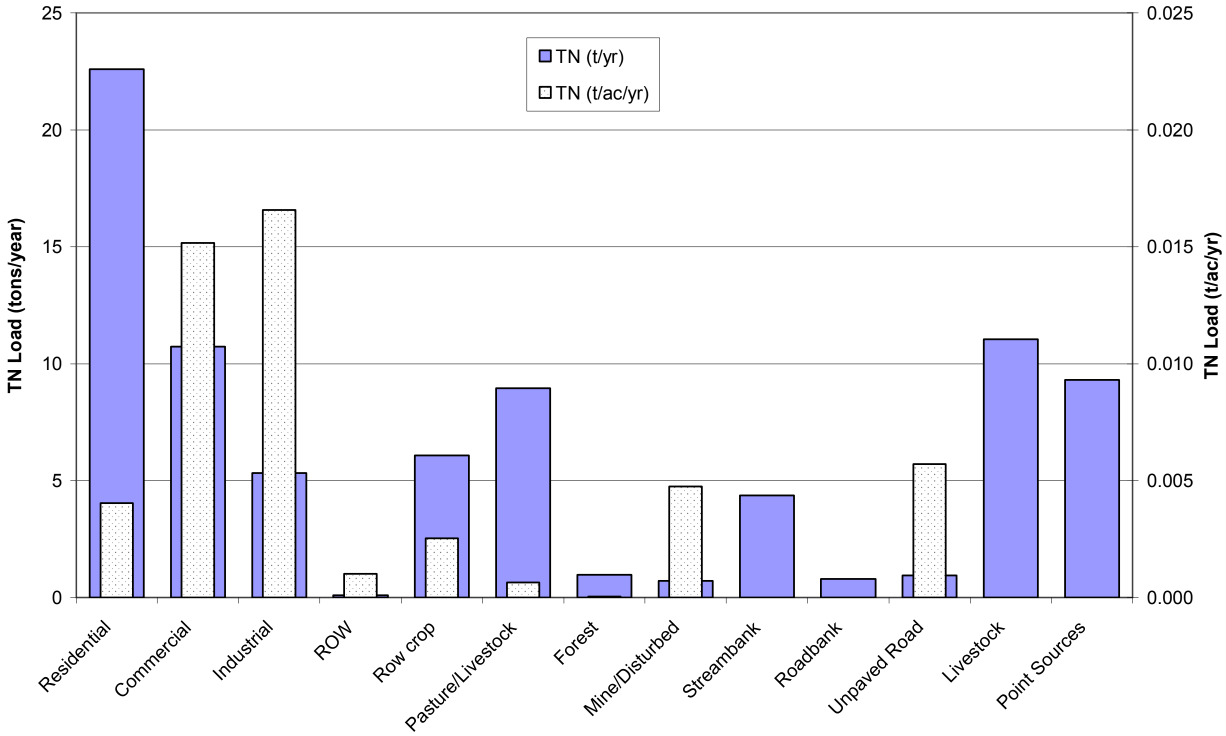

Figure 4.3. Total nitrogen loading by source for Oostanaula Creek watershed expressed as tons/year and tons/acre/year.

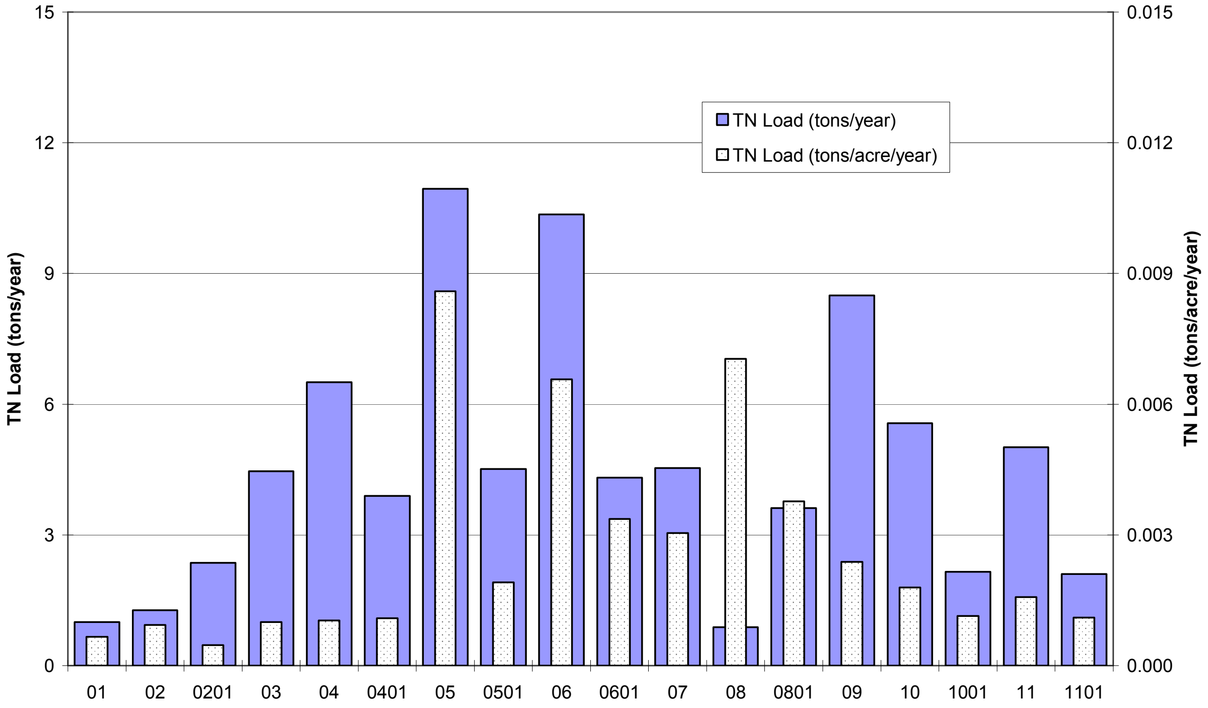

Figure 4.4. Total nitrogen loading by subwatershed within Oostanaula Creek watershed.

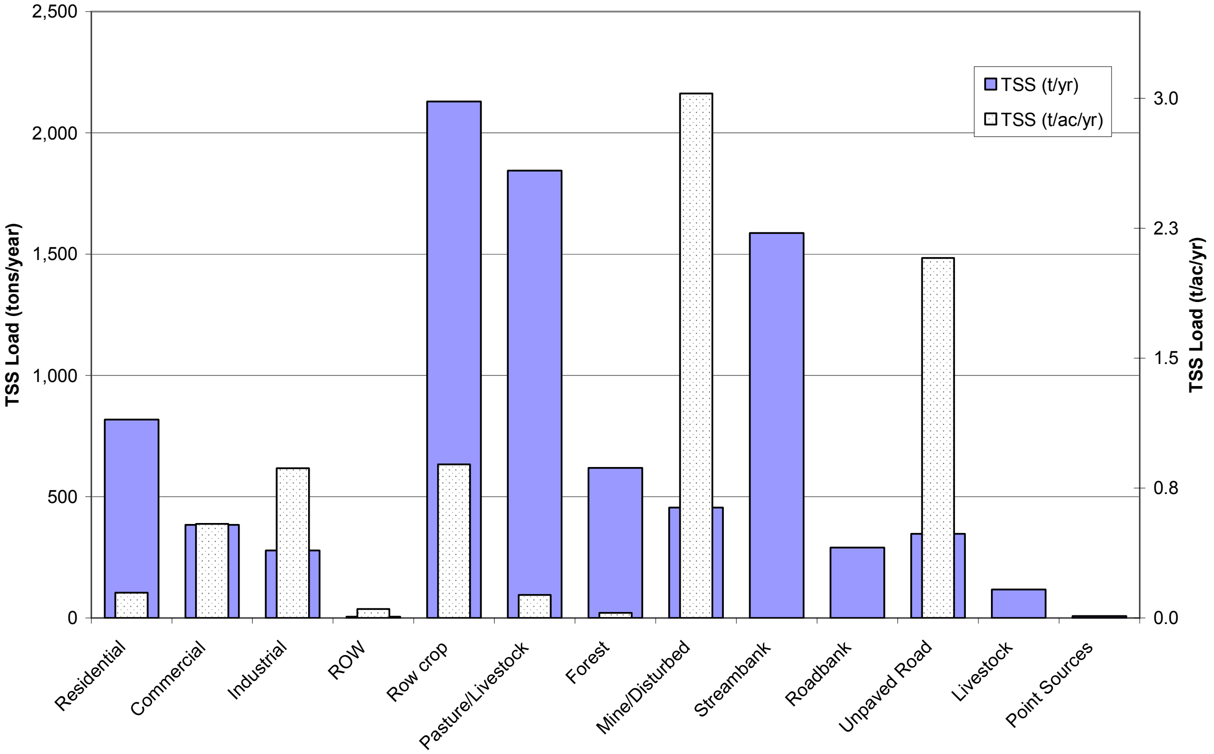

Figure 4.5. Total suspended solids loading by source for Oostanaula Creek watershed expressed as tons/year and tons/acre/year.

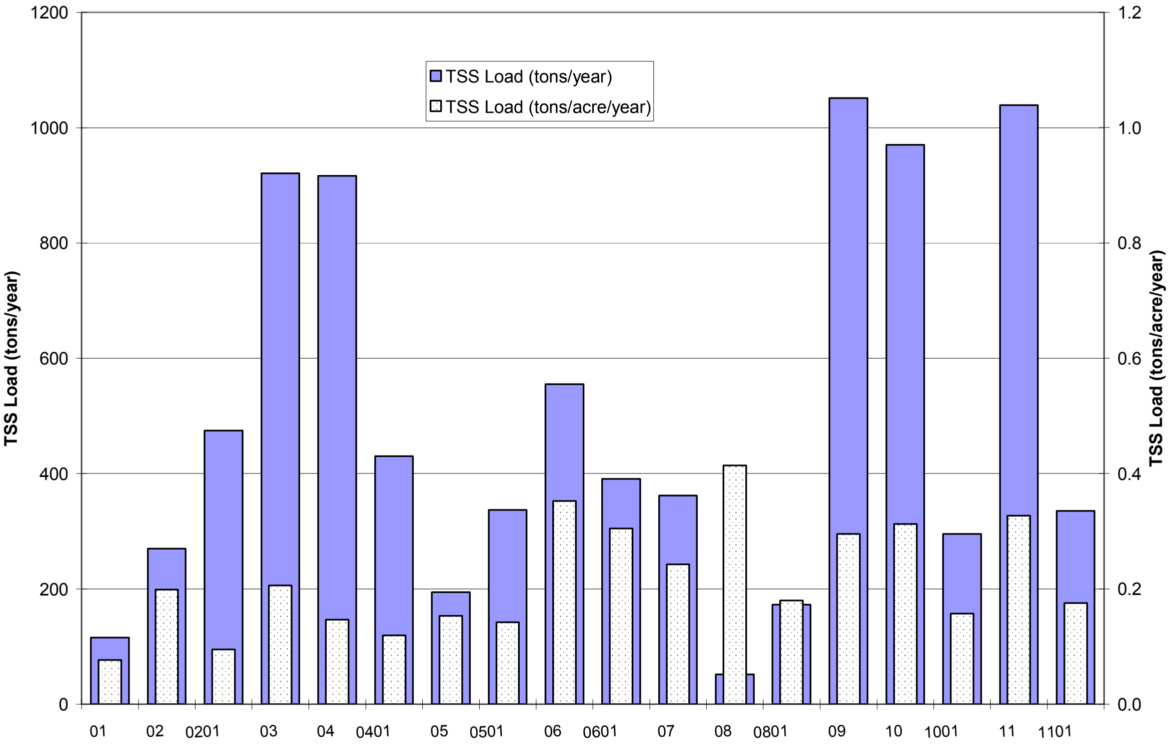

Figure 4.6. Total suspended solids loading by subwatershed within Oostanaula Creek watershed.

4.1 Pollutant loads from urban land classes

Subwatersheds containing and/or surrounding Athens contained the greatest values of urban lands, and as such contributed the greatest loading values from urban areas for all pollutants modeled. These six subwatersheds contributed 50% of all TP, TN, and TSS loads from residential areas within the watershed. More than 80% of TP, TN, and TSS from commercial and industrial sites also originated from these select subwatersheds surrounding Athens. Pollutant load estimates for urban land classes are displayed in Tables 4.3, 4.4 and 4.5.

4.2 Pollutant loads for point sources

The single point source currently classified in the OCW is an AUB managed WWTP. This single site was identified as contributing 11.26 tons TP per year into the OCW, or 50.7% of all TP loading. This WWTP is also estimated to contribute 9.3 tons TN per year, or 11.3% of all TN. TSS loading from the WWTP was low relative to other land use classes: at 8.5 tons TSS per year, this point source represented less than 1% of all TSS loading in the watershed.

These loading estimates are comparable with TDEC and AUB provided data for 2006. The DMR for the AUB Oostanaula Creek STP states an annual average TP load of 8.37 tons, a TN load of 7.63 tons, and a TSS load of 6.9 tons. The model values are higher due to the utility of a maximum discharge value of 2.83 MGD, which the DMR states as variable over time. These loads will likely double with the completion of an upgraded system which will allow 6 MGD.

Table 4.3. Total phosphorus load (ton/yr) for urban land classifications in Oostanaula Creek watershed.

Sub ID	Residential	Commercial	Industrial	Right of Way
01	0.066	0.000	0.000	0.000
02	0.045	0.005	0.000	0.000
0201	0.140	0.004	0.000	0.000
03	0.121	0.007	0.000	0.000
04	0.337	0.152	0.000	0.000
0401	0.276	0.011	0.000	0.000
05	0.179	0.021	0.000	0.000
0501	0.417	0.202	0.000	0.000
06	0.343	1.331	0.179	0.005
0601	0.191	0.107	0.095	0.000
07	0.302	0.247	0.084	0.000
08	0.007	0.009	0.093	0.000
0801	0.302	0.135	0.109	0.003
09	0.191	0.022	0.089	0.001
10	0.162	0.045	0.000	0.000
1001	0.119	0.002	0.000	0.000
11	0.098	0.000	0.000	0.000
1101	0.144	0.002	0.000	0.000
	3.439	2.301	0.649	0.010

Table 4.4. Total nitrogen load (ton/yr) for urban land classifications in Oostanaula Creek watershed.

Sub ID	Residential	Commercial	Industrial	Right of Way
01	0.431	0.000	0.000	0.000
02	0.296	0.025	0.000	0.000
0201	0.918	0.019	0.000	0.000
03	0.795	0.031	0.000	0.000
04	2.216	0.710	0.000	0.000
0401	1.813	0.051	0.000	0.000
05	1.176	0.097	0.004	0.000
0501	2.738	0.944	0.000	0.000
06	2.255	6.211	1.467	0.054
0601	1.254	0.497	0.783	0.002
07	1.985	1.153	0.689	0.000
08	0.044	0.042	0.766	0.000
0801	1.987	0.630	0.893	0.032
09	1.256	0.103	0.731	0.013
10	1.062	0.211	0.000	0.000
1001	0.780	0.009	0.000	0.000
11	0.646	0.000	0.000	0.000
1101	0.945	0.008	0.000	0.000
	22.6	10.7	5.3	0.1

Table 4.5. Total suspended solid load (ton/yr) for urban land classifications in Oostanaula Creek watershed.

Sub ID	Residential	Commercial	Industrial	Right of Way
01	15.629	0.000	0.000	0.000
02	10.740	0.902	0.000	0.000
0201	33.265	0.664	0.000	0.000
03	28.789	1.108	0.000	0.000
04	80.276	25.343	0.000	0.000
0401	65.677	1.838	0.000	0.000
05	42.613	3.470	0.188	0.000
0501	99.199	33.727	0.000	0.000
06	81.702	221.823	76.557	2.714
0601	45.434	17.753	40.856	0.119
07	71.930	41.167	35.937	0.000
08	1.603	1.497	39.944	0.000
0801	71.992	22.496	46.587	1.577
09	45.502	3.669	38.147	0.651
10	38.481	7.545	0.000	0.000
1001	28.273	0.308	0.000	0.000
11	23.421	0.000	0.000	0.000
1101	34.255	0.270	0.000	0.000
	818.8	383.6	278.2	5.1

4.3 Pollutant loads from roads, roadbanks and streambanks

Estimates of annual TP, TN, and TSS loads from roadbanks were largely a function of the condition of the roadbank: eroding or not eroding, which is not constant throughout OCW as seen in Figure 2.7. Areas 0201, 03, 04, and 11 had the greatest area of eroding roadbank, and contributed the greatest volume of pollutants from lands classified as roadbank. Areas with small amounts of eroding roadbanks contributed small amounts of transportable pollutants, as seen with roadbanks within the city of Athens. Estimates of TP and TN from roadbanks was less than 1% of all loading for the watershed. TSS load estimates from roadbanks were 3% of all sources. Pollutant loading from roadbanks is displayed in Figure 4.7 below.

Annual estimates of TN loading from streambanks were 4.36 tons/year, or 5% of all TN loading, while TP loads from streambanks accounted for only 1% of all sources. TSS loading from streambanks however was the greatest source of this pollutant, with 1587 tons/year coming from streambanks, or 18% of all TSS. As with roadbank condition, subwatersheds with high areas of eroding streambanks contributed greater volumes of pollutants, such as areas 04 and 03. Pollutant loading from streambanks is displayed in Figure 4.8, which may be better analyzed with Figure 2.5 above.

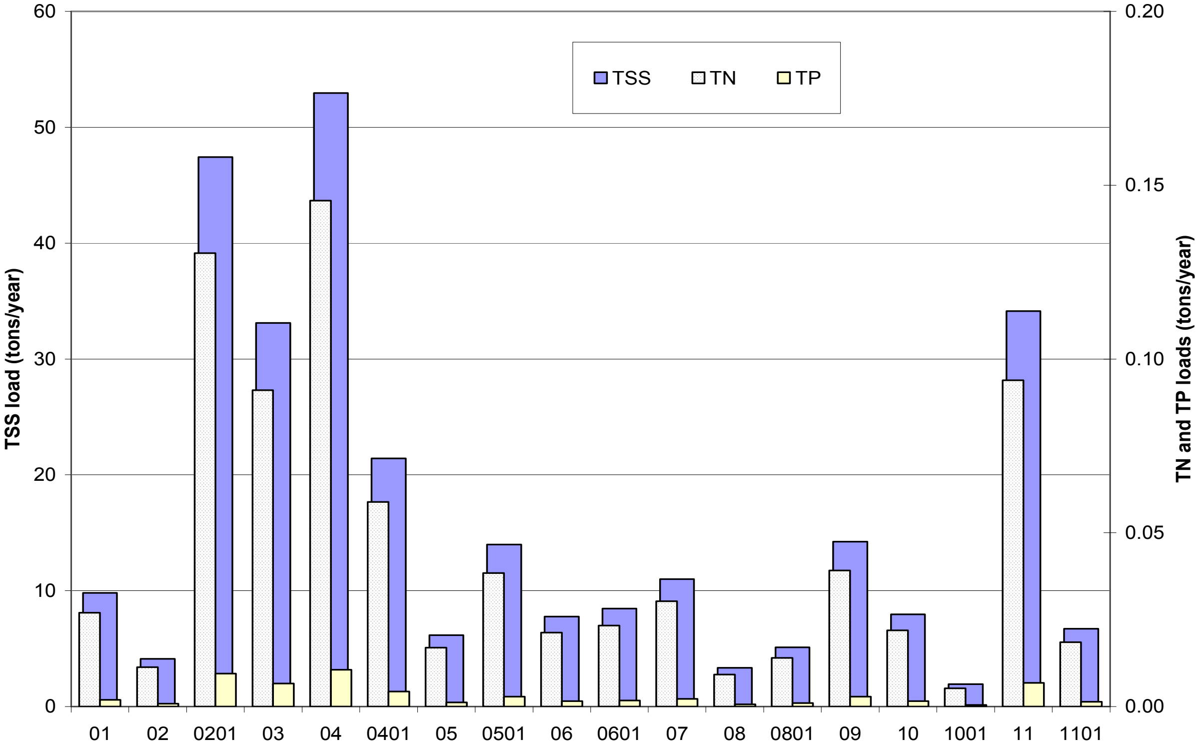

Figure 4.7. Pollutant loads (tons/year) from eroding roadbanks within Oostanaula Creek watershed. Note differing y-axes scales.

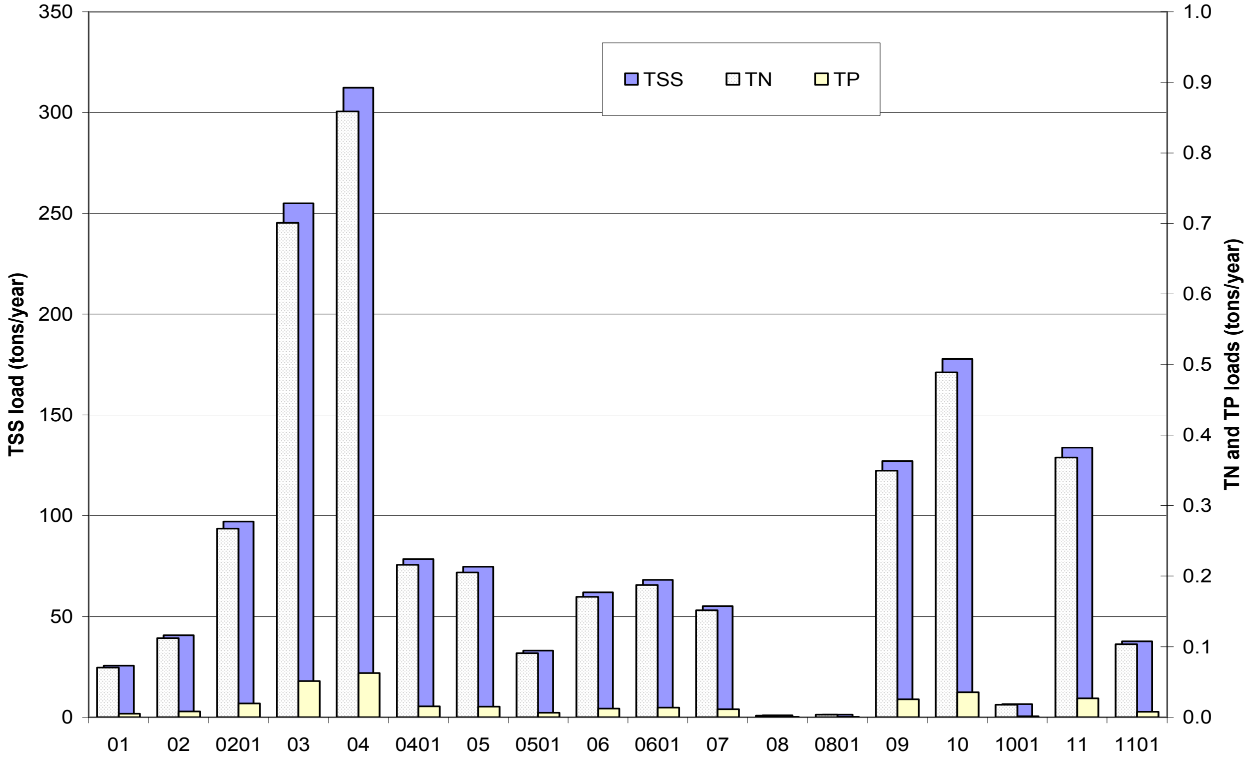

Figure 4.8. Pollutant loads (tons/year) from eroding streambanks within Oostanaula Creek watershed. Note differing y-axes scales.

Estimates of annual TP, TN, and TSS loading were all highest from those subwatersheds with high acreages of unpaved roads, notably 04, 0201, and 03 in the south and 11 and 09 in the north. Load estimates were 0.069 tons/year for TP, 0.954 tons/year for TN, and 346.901 tons/year for TSS; considerably lower than many other sources.

4.4 Pollutant loads from forest, mining and disturbed lands

Subwatershed 04 had the greatest area of forests, including harvested lands, and contributed the greatest load per year of all pollutants from this land class. Estimated annual loads from forests were 0.071 tons/yr, or 141 lbs/yr of TP; 0.972 tons/yr, or 1945 lbs/yr of TN; and 618 tons/yr of TSS, mostly stemming from harvested forest lands.

Areas 11, 10 and 06 have the greatest acreage of mined and disturbed lands and contributed the greatest load per year from this land class. Annual loads from mined or disturbed lands were estimated at 0.052 tons/yr, or 104 lb/yr of TP; 0.716 tons/yr, or 1433 lbs/yr of TN; and 456 tons/yr of TSS. Estimates of annual loads from these select land classes are summarized in Tables 4.6, 4.7, and 4.8.

Table 4.6. Estimated annual TP load (lbs/yr) from forest and disturbed lands within Oostanaula Creek watershed.

	Forest/Scrub				Mining/Disturbed	
Sub ID	Orchard	scrub/ shrub	Forest	Harvest Forest land	Mining	Disturbed Areas
01	0.00	0.10	1.80	1.38	0.00	1.01
02	0.00	0.10	0.74	0.29	0.00	0.00
0201	0.00	0.47	4.12	26.73	0.00	1.53
03	0.00	0.27	2.47	15.41	0.00	7.57
04	0.00	0.47	4.02	34.22	0.00	4.39
0401	0.06	0.21	1.52	4.28	0.00	0.92
05	0.00	0.27	0.90	2.62	1.62	0.65
0501	0.02	0.64	1.06	3.89	0.00	1.81
06	0.00	0.03	0.58	1.46	17.53	2.04
0601	0.00	0.13	0.60	1.02	0.00	0.68
07	0.00	0.11	0.82	2.19	0.00	2.12
08	0.00	0.04	0.06	0.05	0.00	0.00
0801	0.00	0.08	0.44	1.75	0.00	0.00
09	0.00	0.07	1.39	2.89	0.00	0.00
10	0.00	0.03	0.98	0.54	21.29	0.00
1001	0.00	0.11	1.13	0.87	0.00	0.00
11	0.00	0.07	1.55	1.89	41.02	0.00
1101	0.00	0.02	0.83	11.53	0.00	0.00
lb/yr	0.09	3.22	25.02	113.03	81.47	22.73

Table 4.7. Estimated annual TN load (lbs/yr) from forest and disturbed lands within Oostanaula Creek watershed.

	Forest/Scrub Shrub				Mining/Disturbed	
Sub ID	Orchard	scrub/ shrub	Forest	Harvest Forest land	Mining	Disturbed Areas
01	0.00	1.38	24.77	19.01	0.00	13.86
02	0.00	1.33	10.19	4.05	0.00	0.00
0201	0.05	6.51	56.64	367.60	0.00	21.09
03	0.00	3.66	33.99	211.92	0.00	104.14
04	0.00	6.49	55.23	470.51	0.00	60.46
0401	0.84	2.84	20.96	58.88	0.00	12.64
05	0.00	3.78	12.34	36.04	22.33	8.95
0501	0.28	8.78	14.60	53.56	0.00	24.84
06	0.00	0.39	7.99	20.02	241.11	28.08
0601	0.00	1.76	8.26	14.03	0.00	9.36
07	0.00	1.54	11.25	30.12	0.00	29.18
08	0.00	0.55	0.81	0.63	0.00	0.00
0801	0.00	1.06	6.04	24.09	0.00	0.00
09	0.00	0.96	19.18	39.81	0.00	0.00
10	0.00	0.44	13.47	7.41	292.71	0.00
1001	0.00	1.53	15.57	11.97	0.00	0.00
11	0.00	0.92	21.31	25.94	564.02	0.00
1101	0.00	0.30	11.44	158.60	0.00	0.00
ton/yr	1.18	44.24	344.04	1554.18	1120.16	312.59

Table 4.8. Estimated annual TSS load (tons/yr) from forest and disturbed lands within Oostanaula Creek watershed.

	Forest/Scrub/Shrub				Mining/Disturbed	
Sub ID	**Orchard**	**scrub/ shrub**	**Forest**	**Harvest Forest land**	**Mining**	**Disturbed Areas**
01	0.00	0.44	7.88	6.05	0.00	4.41
02	0.00	0.42	3.24	1.29	0.00	0.00
0201	0.02	2.07	18.02	116.96	0.00	6.71
03	0.00	1.17	10.81	67.43	0.00	33.13
04	0.00	2.07	17.57	149.71	0.00	19.24
0401	0.27	0.90	6.67	18.74	0.00	4.02
05	0.00	1.20	3.93	11.47	7.10	2.85
0501	0.09	2.79	4.64	17.04	0.00	7.90
06	0.00	0.12	2.54	6.37	76.72	8.93
0601	0.00	0.56	2.63	4.46	0.00	2.98
07	0.00	0.49	3.58	9.58	0.00	9.29
08	0.00	0.17	0.26	0.20	0.00	0.00
0801	0.00	0.34	1.92	7.66	0.00	0.00
09	0.00	0.31	6.10	12.67	0.00	0.00
10	0.00	0.14	4.28	2.36	93.13	0.00
1001	0.00	0.49	4.96	3.81	0.00	0.00
11	0.00	0.29	6.78	8.25	179.46	0.00
1101	0.00	0.09	3.64	50.46	0.00	0.00
ton/yr	0.37	14.08	109.47	494.51	356.41	99.46
ton/ac/yr	0.009	0.009	0.006	0.420	3.063	2.904

4.5 Pollutant loads from agriculture lands

Despite much of the lands within the OCW being classified as agriculture (croplands and pastures), annual TP and TN loading estimates from agriculture were not the greatest sources. Estimates of pollutant loading delineated by subwatershed and land cover type are shown in Tables 4.9, 4.10, and 4.11 below.

Annual TP loads for croplands totaled 0.61 tons/yr, or 0.6 lbs/ac/yr. TP loading from pastures was 0.84 tons/yr, or 0.2 lbs/ac/yr. Loads were greatest in heavily overgrazed pastures, which accounted for 82% of TP loading from pasturelands. TP loading estimates by agricultural land class are shown in Figure 4.9.

Annual TN loads for croplands totaled 6.08 tons/yr, or 6 lbs/ac/yr and TN loading from pastures was 8.95 tons/yr, or 2 lbs/ac/yr. Annual loading from pastures was greatest for livestock loafing areas with a per acre loss of TN of 0.05 tons/ac/yr, followed by overgrazed pastures. TN loading from croplands was greatest from medium residue crops, likely as a result of high acreage of this classification. TN loading estimates by agricultural land class are shown in Figure 4.11. As with TP, good and fair pastures along with high residue croplands contributed the lowest ton/yr estimates of TN. A stepwise increase in TP and TN load/ac/yr is evident as pasture conditions decrease as seen in Figure 4.10.

TSS loads were estimated at 2128.9 tons/yr, or 0.89 ton/ac/yr for croplands, which was the greatest source of TSS within the watershed. As with TN, medium residue crops account for the bulk TSS source from this land class. TSS loads from pastures were estimated at 1844.9 tons/yr, or 0.13 ton/ac/yr. Overgrazed pasture lands account for nearly 65% of this value. TSS loading estimates by agricultural land class are shown in Figure 4.11.

Table 4.9. Estimates of TP loads (tons/yr) from agriculture land classes within Oostanaula Creek watershed.

	Row Crop				Pasture				
Sub ID	**Low Residue**	**High Residue**	**Strip Crop**	**Medium Residue**	**Good**	**Fair**	**Woodland**	**Over-grazed**	**Feedlot/ Loafing**
01	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.008	0.000
02	0.016	0.000	0.000	0.025	0.000	0.008	0.000	0.016	0.000
0201	0.007	0.000	0.000	0.005	0.000	0.007	0.000	0.018	0.000
03	0.000	0.004	0.000	0.060	0.000	0.014	0.000	0.083	0.003
04	0.000	0.001	0.000	0.003	0.000	0.011	0.000	0.055	0.005
0401	0.010	0.001	0.000	0.004	0.000	0.017	0.000	0.049	0.000
05	0.005	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
0501	0.012	0.005	0.000	0.000	0.000	0.004	0.001	0.016	0.000
06	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
0601	0.014	0.002	0.000	0.000	0.000	0.004	0.000	0.060	0.001
07	0.000	0.000	0.000	0.018	0.000	0.002	0.000	0.022	0.001
08	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0801	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.002	0.000
09	0.046	0.005	0.005	0.089	0.000	0.013	0.000	0.075	0.008
10	0.019	0.014	0.000	0.053	0.000	0.014	0.000	0.141	0.002
1001	0.001	0.000	0.000	0.041	0.000	0.008	0.000	0.022	0.002
11	0.039	0.020	0.010	0.056	0.000	0.011	0.000	0.068	0.001
1101	0.000	0.011	0.000	0.007	0.000	0.009	0.000	0.048	0.000
tons/yr	0.169	0.063	0.015	0.361	0.000	0.128	0.003	0.683	0.023
tons/ac/yr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4.10. Estimates of TN loads (tons/yr) from agriculture land classes within Oostanaula Creek watershed.

	Row Crop				Pasture				
Sub ID	**Low Residue**	**High Residue**	**Strip Crop**	**Medium Residue**	**Good**	**Fair**	**Woodland**	**Over-grazed**	**Feedlot/ Loafing**
01	0.000	0.000	0.000	0.000	0.000	0.019	0.000	0.038	0.000
02	0.162	0.000	0.000	0.245	0.000	0.079	0.001	0.078	0.000
0201	0.067	0.000	0.000	0.054	0.000	0.069	0.001	0.089	0.000
03	0.000	0.036	0.000	0.604	0.000	0.138	0.000	0.413	0.582
04	0.000	0.010	0.000	0.035	0.000	0.110	0.000	0.277	0.880
0401	0.097	0.014	0.000	0.042	0.000	0.168	0.001	0.247	0.000
05	0.049	0.001	0.000	0.000	0.000	0.034	0.000	0.000	0.000
0501	0.120	0.053	0.000	0.000	0.000	0.043	0.003	0.078	0.006
06	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.005	0.000
0601	0.141	0.025	0.000	0.000	0.000	0.035	0.000	0.301	0.109
07	0.000	0.000	0.000	0.176	0.000	0.020	0.001	0.111	0.115
08	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
0801	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.008	0.000
09	0.459	0.046	0.054	0.885	0.000	0.130	0.001	0.375	1.475
10	0.190	0.138	0.000	0.529	0.000	0.136	0.000	0.703	0.381
1001	0.010	0.000	0.000	0.409	0.000	0.081	0.000	0.111	0.433
11	0.387	0.195	0.099	0.556	0.000	0.108	0.000	0.341	0.272
1101	0.004	0.115	0.000	0.074	0.000	0.093	0.001	0.239	0.000
tons/yr	1.686	0.634	0.154	3.609	0.001	1.277	0.008	3.413	4.254
tons/ac/yr	0.005	0.001	0.001	0.003	0.000	0.000	0.000	0.002	0.046

Table 4.11. Estimates of TSS loads (tons/yr) from agriculture land classes within Oostanaula Creek watershed.

	Row Crop				Pasture				
Sub ID	**Low Residue**	**High Residue**	**Strip Crop**	**Medium Residue**	**Good**	**Fair**	**Woodland**	**Over-grazed**	**Feedlot/ Loafing**
01	0.000	0.00	0.00	0.00	0.00	6.54	0.00	13.23	0.00
02	56.70	0.00	0.00	85.92	0.00	27.68	0.59	27.18	0.00
0201	23.47	0.00	0.00	18.87	0.00	24.23	0.34	31.06	0.00
03	0.00	12.77	0.00	211.30	0.00	48.44	0.06	144.54	27.16
04	0.00	3.48	0.00	12.12	0.00	38.55	0.00	97.01	41.05
0401	33.91	4.89	0.00	14.61	0.00	58.82	0.48	86.55	0.00
05	17.09	0.49	0.00	0.00	0.00	11.84	0.00	0.00	0.00
0501	41.99	18.44	0.00	0.00	0.15	14.92	1.89	27.28	0.26
06	0.00	0.00	0.00	0.00	0.00	1.33	0.23	1.69	0.00
0601	49.47	8.58	0.00	0.00	0.00	12.29	0.06	105.51	5.10
07	0.00	0.00	0.00	61.62	0.00	7.17	0.39	38.69	5.39
08	0.00	0.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00
0801	0.00	0.00	0.00	0.00	0.00	1.94	0.06	2.78	0.00
09	160.68	16.24	19.06	309.89	0.00	45.67	0.36	131.17	68.83
10	66.37	48.42	0.00	185.31	0.03	47.68	0.00	245.89	17.79
1001	3.48	0.00	0.00	143.09	0.00	28.18	0.00	38.85	20.22
11	135.39	68.25	34.79	194.72	0.00	37.89	0.00	119.30	12.71
1101	1.41	40.22	0.00	25.76	0.00	32.68	0.34	83.67	0.00
tons/yr	590.0	221.8	53.9	1263.2	0.2	446.8	4.8	1194.4	198.5
tons/ac/yr	1.677	0.451	0.366	0.897	0.009	0.039	0.041	0.597	2.146

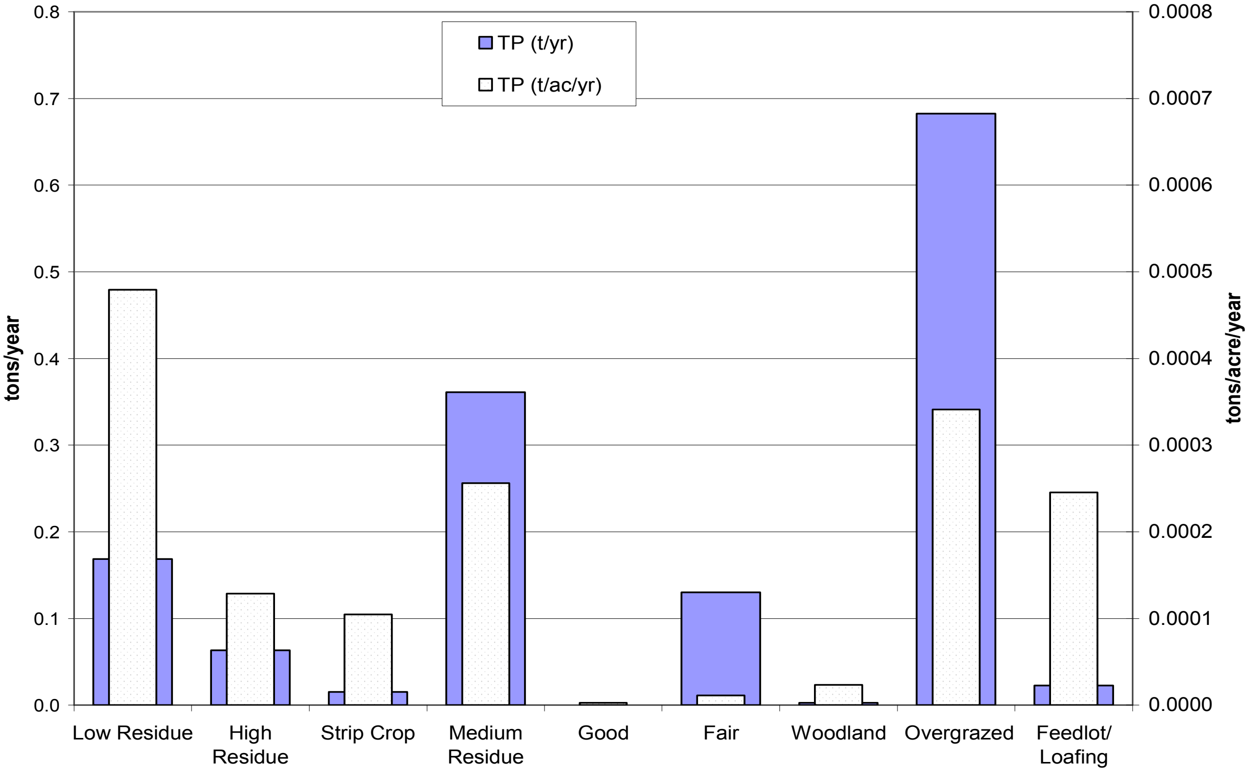

Figure 4.9. Loading estimates for TP from agricultural land classes within Oostanaula Creek watershed.

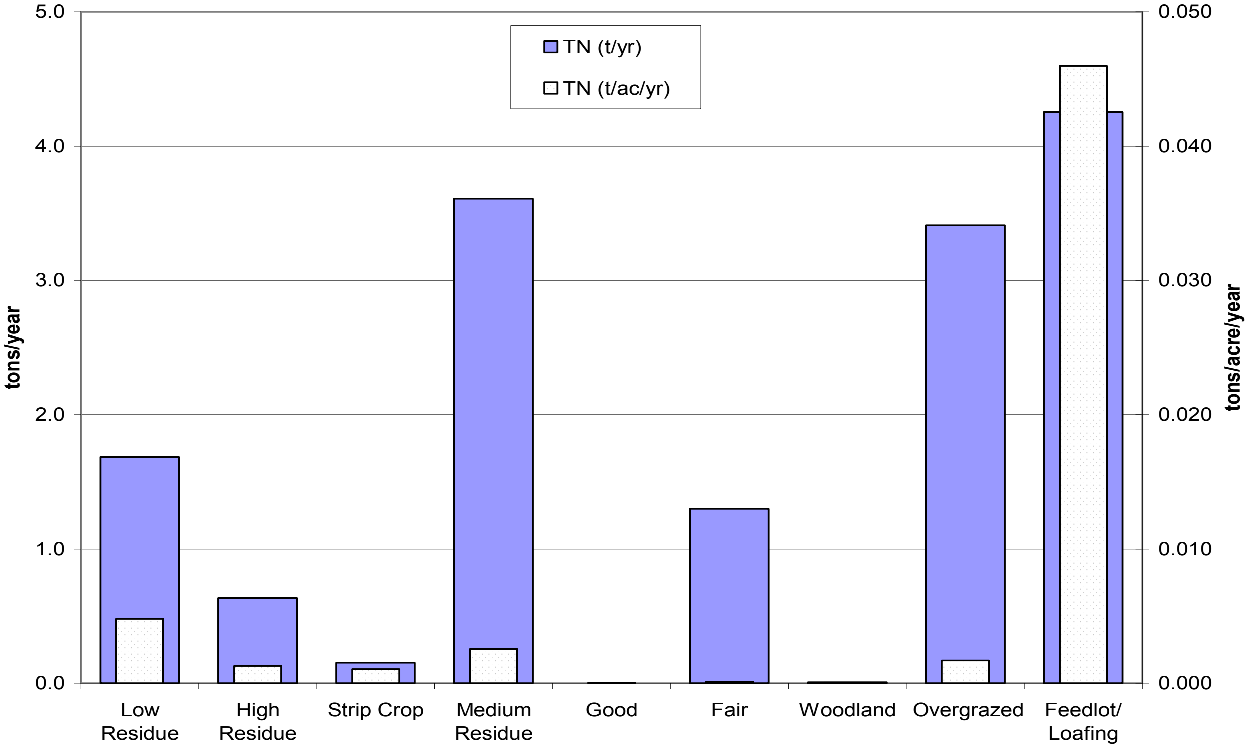

Figure 4.10. Loading estimates for TN from agricultural land classes within Oostanaula Creek watershed.

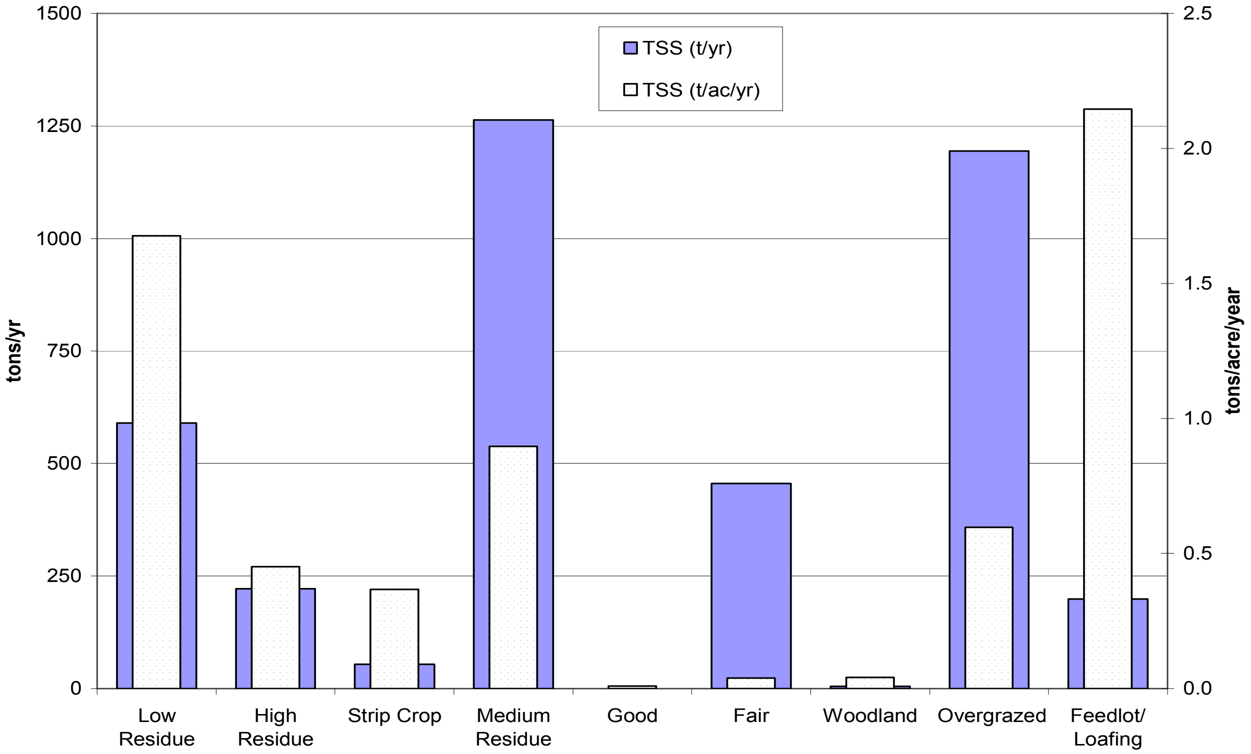

Figure 4.11. Loading estimates for TSS from agricultural land classes within Oostanaula Creek watershed.

4.6 Pollutant loads from livestock operations and wildlife

Beef cattle operations were a considerable source of TP and TN throughout OCW. Cattle sites were estimated to contribute 1.79 tons/yr of TP and 5.9 tons/yr of TN, which resulted in this type of site being the greatest non-urban source of these pollutants. Dairy operations, whether milking or not, contributed 0.65 tons/year of TP, and 4.79 tons/year of TN, as seen in Tables 4.12 and 4.13. Estimates of TSS load/yr from cattle and dairy sites were minimal relative to many other land use classifications (Table 4.14).

Horse and swine sites contributed minimal loads for all pollutants modeled. These two types of livestock sites contributed less than one-half ton per year for TP, TN, and TSS, contributing less than 0.1% of these pollutants. As the three operating poultry sites had animal waste hauled off-site, these sites were low sources of pollutants, contributing less than 1% of all pollutants modeled.

As pollutant loading is mostly a function of number of sites, size of sites and proximity of sites to waterways, subwatersheds with greater values of these parameters had higher estimates of loading. Area 09 contained two dairy sites classified as large and a total of eight cattle sites, and as such contributed the greatest load/yr of all pollutants from such operations. Area 0401 holds 24 beef sites with 12 of these adjacent to the creek and was also a major contributor of pollutant loading. Other consistently high source areas of pollutants from livestock were subwatersheds 10 and 11, both in the northern section of the OCW. Both of these sites contained 11 cattle sites and 1 adjacent dairy operation.

Pollutant loading from horses was minimal due to the low magnitude of deleterious activities and behaviors of these animals. Additionally, all sites identified as holding horses were not adjacent to the creek, so direct runoff to the water was lessened. The two poultry sites identified in the OCW were also minimal contributors of TP, TN, and TSS, likely due to these sites being not directly adjacent to the waterways. Estimates of TP, TN and TSS load/yr from livestock operations are summarized in Figures 4.12.

Estimates of annual pollutant load per year from wildlife sources were minimal for all subwatersheds, as seen in Table 4.2. Annual loading for TP and TN from wildlife was 6 and 12 pounds per year, respectively. Loading of TSS was 0.116 tons/yr, or 231 lbs/yr; also one of lowest sources of this pollutant. Subwatersheds 0201 and 04 were relatively high annual sources of pollutants from wildlife (Figure 4.13), as these areas contain high acreages of applicable wildlife habitat defined by forest, cropland and wetland.

Table 4.12. Estimates of TP (tons/year) loading from livestock sites and operations within Oostanaula Creek watershed. Blanks represent no sites present.

Sub ID	Beef Cattle	Dairy	Horses	Swine	Poultry
01	0.017				0.015
02	0.035	0.004	0.000		
0201	0.115		0.000		
03	0.239				
04	0.211		0.000		0.003
0401	0.344		0.000		
05					
0501	0.097		0.000		
06					
0601	0.062	0.105			
07	0.004			0.0006	
08	0.001				
0801	0.001				
09	0.065	0.320			
10	0.210	0.109	0.000		
1001	0.049	0.004			
11	0.236	0.109	0.000		
1101	0.101	0.001			
	1.786	0.652	0.0010	0.0006	0.018

Table 4.13. Estimates of TN (tons/year) loading from livestock sites and operations within Oostanaula Creek watershed. Blanks represent no sites present.

Sub ID	Beef Cattle	Dairy	Horses	Swine	Poultry
01	0.0701				0.047
02	0.1450	0.084	0.000		
0201	0.3811		0.000		
03	0.7921				
04	0.7145		0.001		0.010
0401	1.0795		0.000		
05					
0501	0.3038		0.000		
06					
0601	0.1931	0.723			
07	0.0361			0.002	
08	0.0072				
0801	0.0072				
09	0.2220	2.254			
10	0.7024	0.807	0.000		
1001	0.1591	0.084			
11	0.7362	0.807	0.000		
1101	0.3471	0.029			
	5.90	4.79	0.0024	0.0018	0.057

Table 4.14. Estimates of TSS (tons/year) loading from livestock sites and operations within Oostanaula Creek watershed. Blanks represent no sites present.

Sub ID	Beef Cattle	Dairy	Horses	Swine	Poultry
01	0.674				0.850
02	1.388	0.657	0.023		
0201	3.858		0.023		
03	8.025				
04	7.200		0.091		0.188
0401	11.099		0.068		
05					
0501	3.124		0.045		
06					
0601	1.995	7.818			
07	0.302			0.025	
08	0.060				
0801	0.060				
09	2.236	24.112			
10	7.100	8.475	0.045		
1001	1.622	0.657			
11	7.586	8.475	0.068		
1101	3.486	0.230			
	59.82	50.425	0.362	0.02	1.038

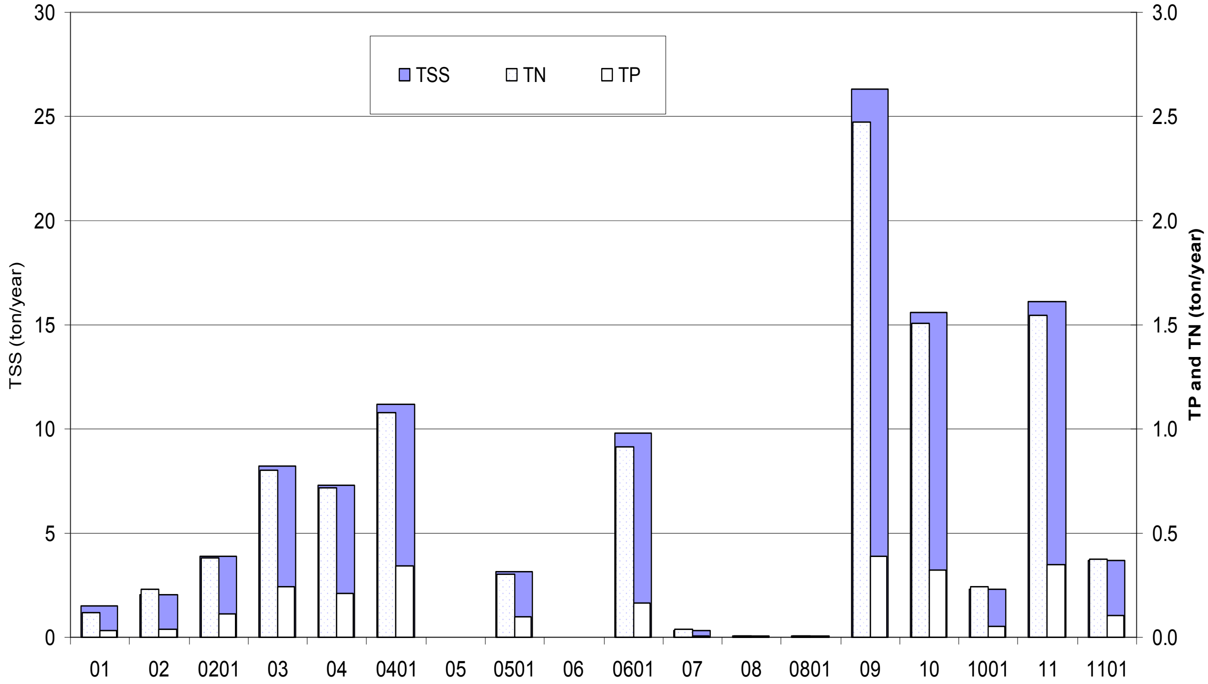

Figure 4.12. Estimates of TP, TN, and TSS loading (tons/year) from livestock sites within Oostanaula Creek watershed.

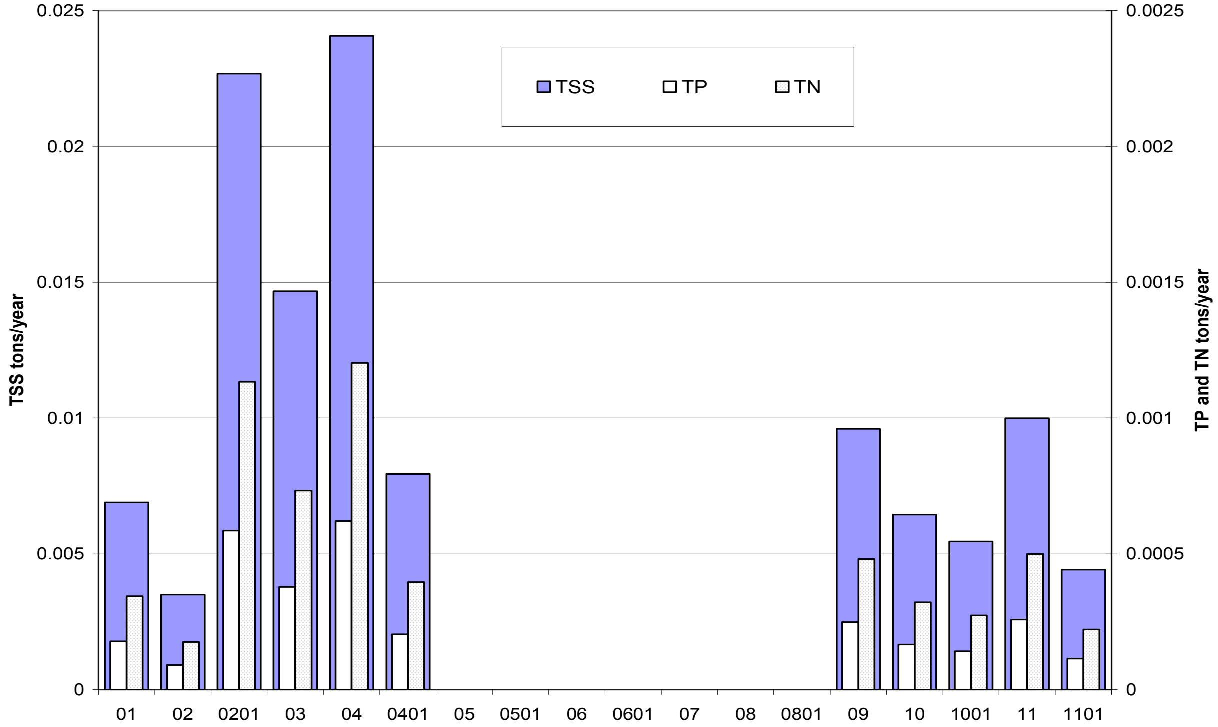

Figure 4.13. Estimates of TP, TN, and TSS loading (tons/year) from wildlife within Oostanaula Creek watershed. Subwatersheds 05 through 0801 fully or partially contain the city of Athens, and were omitted from wildlife population estimates.

5.0 Pollution Loading Model Summary

The ultimate goal of this restoration plan is to remove Oostanaula Creek from the Tennessee 303(d) list of impaired waters. While the loading numbers presented above are only estimates of annual pollutant loading, the process identifies specific sites and land use classes that should be further evaluated and targeted to reduce such loading. The entire modeling process above should be used as a tool to identify regions and practices on which additional monitoring and BMP implementation should concentrate. This targeted effort will prove to be an efficient approach to reduce pollutants on a watershed scale.

To better target our efforts of restoration, Table 5.1 displays primary land classes as sources of nonpoint source pollution and Table 5.2 displays primary subwatershed sources, as developed from the pollutant loading model. Subwatersheds 05 and 06 are major contributors of TP and TN, stemming from the additional source of the WWTP in 05 and high concentrations of residential and commercial sites in both. Subwatersheds 09, 10, and 11, north of Athens, contribute substantial loads of TSS and soil loss, likely due to high densities of croplands in these areas. Areas 03 and 04 in the south also contribute high annual volumes of TSS and soil loss, as these areas hold high acreages of land. However these areas contribute low per acre loads because these sites are made up of lands with low capacities for runoff and erosion, such as forests.

In summary, the general land use classes within the city of Athens are a major source of TP and TN, stemming from primarily the WWTP. Additional urban sources include residential (lawn runoff), commercial, and industrial outputs, and runoff from impervious surfaces (Waschbusch et al. 1999). Roadbanks and streambanks within Athens were classified as not highly eroding and as such Minimal TSS or soil loss was derived from the city. Significant TN loads were estimated as coming from agricultural sources such as surface runoff from overgrazed pastures and loafing lots affiliated with livestock adjacent to the waterway. TSS and soil loss primarily originated from eroding streambanks, medium- and low-residue croplands and practices, overgrazed pastures and livestock loafing areas.

In addition to the pollutant loading model presented above, bacterial source tracking has been conducted on seven sites along Oostanaula Creek. This analysis, conducted by Dr. A. Layton of UT's Center for Environmental Biotechnology in June of 2005, allows one to identify the relative origin of fecal contamination (human, cattle, etc) and the concentration of pathogen indicators in water. Additional detail on the methodology applied for this bacterial source tracking can be found in Layton et al. 2006.

Oostanaula Creek had high bacterial contaminations, high fecal concentrations, and cattle were the dominant fecal source (Table 5.3). The creek had high bacterial indicator concentrations throughout, but were higher in sites outside of Athens than inside the city limits. Fecal coliform loads and fecal mass loads increased dramatically as the water flowed downstream through agricultural areas.

Table 5.1. Primary sources of annual pollutant loading by land class and/or land practice estimated from IPSI and pollutant loading model described in text.

ton/year

TP 22.2 t/yr	TN 81.9 t/yr	TSS 8,883 t/yr	Soil Loss 61,220 t/yr
WWTP 51%	WWTP 11%	Ag 46%	Streambanks 31%
Residential 16%	Residential 28%	Streambanks 18%	Ag 44%
Comm/Industrial 13%	Comm/Industrial 20%	Comm/Ind 7%	Unpaved Roads 7%
Ag 18%	Ag 32%	Residential 9%	Road Banks 6%

ton/acre/year

TP	TN	TSS	Soil Loss
Commercial	Industrial	Mine/Disturbed	Mine/Disturbed
Industrial	Commercial	Animal Loafing Areas	Animal Loafing Areas
Residential	Unpaved Roads	Low Residue Croplands	Low Residue Croplands
Unpaved Roads	Mine/Disturbed	Medium Residue Croplands	Medium Residue Croplands
Mine/Disturbed	Low Residue Croplands	Industrial	Overgrazed Pastures

Table 5.2. Primary sources of annual pollutant loading by subwatershed, estimated from IPSI and pollutant loading model described in text.

ton/year

TP	TN	TSS	Soil Loss
05	05	09	04
06	06	11	03
09	09	10	11
04	04	03	09
10	10	04	10

ton/acre/year

TP	TN	TSS	Soil Loss
05	05	08	11
06	08	06	10
08	06	11	09
801	801	10	03
601	601	601	601

Table 5.3. Summary of bacterial indicators and molecular analysis of water quality from select sites along Oostanaula Creek.

Site Location	River mile	Fecal coliforms (cfu/100ml)	Total Fecal (mg/L)	Source Identification (% attributable)
CR 360 off of 307	55	9133	133	Bovine (52%)
Stage at impoundment	35.7	5600	27	Bovine (92%) Human (7%)
Hwy 30 Bridge	31.5	4933	26	Bovine (32%)
Walker Branch	30	27000	1023	Bovine (79%)
Black Creek Trib	30.5	6320	58	Bovine (86%)
Longmill Rd	28.4	2167	20	Bovine (22%) Human (2%)
Sanford Rd	5.5	3533	28	Bovine (32%) Human (3%)

6.0 Projected 2010 Pollution Loads

In an effort to account for the sustainable growth experienced in the region, the default pollutant loading model was amended to reflect projected land use changes under the business-as-usual scenarios which helped to build the land use inventory. Based upon the updated land use inventory, the model was then rerun with projected 2010 and 2015 output expressed on Table 6.1 and 6.2, respectively.

Residential areas are expected to increase by 38 acres per year, sacrificed from pastures and forestlands. Commercial acreage was increased by 60 acres, isolated in subwatersheds that lie on the perimeter of Athens, 801, 501 and 06, being that these areas are expected to receive greater commercial growth. With the completion of a widening project of CR 30 south of Athens, an additional 7.5 acres of paved road, and an additional 9 acres of right-of-way were included. The AUB Oostanaula WWTP is expected to meet the requirements of a new permit for it's 6.0 MGD facility, which requires 1.0 mgP/L and 5.0 mgN/L in the effluent discharge. . However, the model was amended to only show an increase in hydrologic capacity to 4.0 MGD at year 2015. Streambank and roadbank condition were held constant in the 2010 inventory. Streambank (intermittent and perennial) erodability increased by 15% for a 2015 loading model.

Population is expected to reach 14,000 in the watershed by 2010, and near 15,000 by 2015 scattered fairly uniformly throughout the area. To meet this demand, an additional 50 septic units per year are projected, totaling 2,600 septic units in the OCW.

Annual TP loads are expected to decline nearly 60%, mostly as a function of low phosphorus discharge requirements placed on the WWTP. Increases in TP loads are due to increases in urban acreages: as the number of residential and commercial units increases in the watershed, the TP levels from these sources are expected to increase as well. Annual loading for all pollutants was decreased on areas defined as agriculture and forest.

By 2010, annual TN loads are expected to increase only 2% over the watershed. The AUB WWTP is currently meeting permit requirements for N effluent, and is expected to continue with this through 2015; however as discharge increase from 2.83 to 3.0 and 4.0 MGD, all effluent discharge will increase as well. Commercial and residential loads are also expected to rise to match the rising number of units. Annual TSS and soil loss loads are projected to remain comparable to 2006 levels at 2010, but increase by 2015.

Table 6.1. Projected 2010 annual pollutant loading for the Oostanaula Creek Watershed, as defined in text. These values may and should be compared to those in Table 5.1 above.

ton/year

TP 15.8 t/yr	TN 83.9 t/yr	TSS 8,934 t/yr	Soil Loss 61,216 t/yr
WWTF 29%	WWTF 12%	Ag 46%	Streambanks 31%
Residential 22%	Residential 28%	Streambanks 18%	Ag 44%
Comm/Industrial 16%	Ag 28%	Comm/Ind 5%	Unpaved Roads 7%
Ag 20%	Comm/Ind 14%	Residential 9%	Road Banks 6%

Table 6.2. Projected 2015 annual pollutant loading for the Oostanaula Creek Watershed, as defined in text. These values may and should be compared to those in Table 5.1 and 6.1 above.

ton/year

TP 17.7 t/yr	TN 90.4 t/yr	TSS 9,248 t/yr	Soil Loss 63,951 t/yr
WWTF 34%	WWTF 15%	Ag 44%	Streambanks 35%
Residential 22%	Residential 29%	Streambanks 20%	Ag 42%
Comm/Industrial 14%	Comm/Industrial 13%	Comm/Ind 5%	Unpaved Roads 7%
Ag 9%	Ag 27%	Residential 10%	Road Banks 6%

7.0 Model Calibration

Watershed-scale research has a long history and the use of the watershed as a management unit is gaining support in both academic and regulatory environments. Primary reasons for why the watershed is a desirable unit for land use planning and resource management include: an integration of the physical environment revealing the ecological interrelationships between soil, water, and biota; and watersheds serve as natural movement pathways. Temporal and spatial scale issues are critical components of any watershed analysis, and as we upscale in either category, processes become increasingly complex.

Notwithstanding our effort to account for possible bias in the model, some weaknesses still remain to be investigated. For example, precipitation and drought regime – intensity, frequency, duration – is known to be an important ecosystem regulator in the southeast U.S., but is not available as a coherent or consistent dataset and could thus not be adequately incorporated in our modeling framework. A better understanding of the likely impacts of drought and crop moisture cycles specific to the region will allow better predictions and prioritization of conservation strategies to prevent soil loss and pollutant loading.

The surface runoff or streamflow flux of any of the pollutants investigated reflects the integrated pattern of soil dynamics of the land class or streambank affiliated with landform, land use, climate and elevation in the watershed. In general, temporal variation in streamflow is driven by variations in climatic variables (notably precipitation). However, factors controlling the temporal variation in soil dynamics and streamflow are not expected to be the same as those controlling the spatial pattern. While temporal variation in moisture patterns from year to year, or month to month, is much greater than their spatial variation in this small area, the subwatershed to subwatershed variation in biotic factors is perhaps greater than their interannual variations.

Spatial variation in biotic factors (potential N mineralization and plant N demand) likely play a larger role in the spatial pattern of soil N dynamics and streamflow N flux than do climatic (precipitation) and topographic (elevation) factors, in part because of the greater variation of biotic factors compared to abiotic (Johnson et al. 2000). Although in-stream processes have been shown to play an important role in some watersheds (Wickham et al. 2003), stream biological processes and transient storages are likely not sufficiently different when smoothed over long time periods (annually) or large land areas. Stronger estimations of biotic factors may improve predictions of the patterns of soil N dynamics and streamflow N fluxes for the watershed.

Due to the specific meteorological and physiographic characteristics of individual watersheds, regional and local agricultural and urban land uses can exhibit a wide range of variability in nutrient loading (Omernik 1977, Reckhow et al. 1980). Several examples of loading values expressed as lb/ac/yr are presented in Table 6.1, illustrating the spatial variability of nutrient loads from site to site. Every effort was made to include Oostanaula Creek site-specific meteorological, physiographic, and land use characteristic in the IPSI model, and loading estimates applied in the present model are shown in Table 7.1 for comparison. Estimates of TP and TN from forests are substantially lower for Oostanaula Creek than other lands, perhaps as a result of limited management or disturbances in these land classes.

Table 7.1. Published export coefficient concentrations of TP and TN for forest and agriculture lands as found through a non-exhaustive search of relevant articles, and estimated concentrations derived from the present nutrient loading model. Numbered columns represent references: 1. Reckhow et al. 1980; 2. Rast and Lee 1978; 3. Clesceri et al. 1986; 4. Dodd et al. 1992; 5. Loehr et al. 1989; - represents values not reported.

	Total Phosphorus (lb/ac/yr)						Total Nitrogen (lb/ac/yr)					
	1	2	3	4	5	Model est.	1	2	3	4	5	Model est.
Forest	0.21	0.05	0.10	0.12	0.40	0.01	2.60	2.73	3.38	2.12	2.41	0.20
Cropland	0.98	0.45	0.24	0.90	1.35	0.71	4.72	4.55	6.08	8.91	-	10.42
Pasture	1.36	-	0.16	-	0.30	0.19	7.86	-	3.70	-	4.91	3.39

The spatial information of the IPSI model was presented in subwatershed areas ranging from 125 to 6260 acres, although some soil properties may vary at spatial scales < 1 m, for example soil depth (Johnson et al. 2000). Accounting for spatial variability of soil properties and processes within the watershed may lead to more accurate predictions of pollutant loading in the study area. Estimating the spatial variability of soil dynamics is difficult, however, because soil properties vary substantially at a small scale, and methods to account for such variability are often prohibitively expensive. Similarly, site-specific BMPs likely do not follow linear and additive trends, so research in scaling is needed to improve the prediction of cumulative effects of land uses.

Previous efforts of model calibration based on comparisons of modeled outputs with monitored values have yielded strong, supporting results. Water quality data collected by TDEC in 1997 and 1998 from nine stations in the Little River watershed (HUC: 06010204) were used to evaluate the ability of the IPSI model to account for the processes that generate pollution and to calibrate the pollution load model (TVA 2003). Because the model was driven by soil loss estimates for rural land uses, the TSS model agreement with measured values was very good ($r^2 = 0.92$). The best-fit line (estimated using regression techniques) agreed well with the line of perfect agreement (one to one line through origin) between measured and modeled data, indicating very little bias in the model. The TN fit was not as good as the TSS fit, with r^2= 0.54. A comparison between the best-fit line and the line of perfect agreement showed that model predictions were, on the average, a little lower than measured values. This is to be expected, because the model did not take into account the groundwater contribution of nitrogen. The TP fit was also good with r^2 of 0.76. Model predictions showed a small high bias, especially for watersheds with low pollution loadings.

A second calibration effort for the Flint Creek watershed of north Alabama (HUC: 6030002350) produced stronger results for the support of the pollutant loading model presented here. Pollutant loads were estimated for the Flint Creek watershed using a model similar to the one used to estimate pollutant loads for the OCW. These estimates were then compared to water quality grab samples collected and analyzed monthly from February 1993 through March 1995 by the Alabama Geological Survey. Converse to the comparisons for the Little River watershed estimates, TSS estimates showed the smallest agreement to monitored values with an r^2 of 0.74. The TN and TP fits were very strong with r^2 of 0.93 and 0.94, respectively. Although model estimates have substantial inherent uncertainty, the strong comparisons imply that these outputs can still serve to test the overall ability of the model to predict local conditions and the relative contributions of pollution from different land uses.

Modeling vegetation systems has become one of the most powerful methods for predicting the response of modern vegetation assemblages to changes in land use. There is a wealth of knowledge on how vegetation types have changed in response to changes in land class. Estimated extreme values over time or space are likely smoothed over years and 10,000 acres and given the small relative magnitude of both landform and climate in this case, we believe the output approximations from this model to be adequate (loads per year, loads per 44,864 ac watershed). We believe that this approach provides a valuable tool for describing the fate and volume of nonpoint source nutrients and pollutants in small watersheds.

8.0 References

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