



Conserving the Duck River:
A plan for collaborative action

November 2005



SAVING THE LAST GREAT PLACES ON EARTH

Preface and Acknowledgements

The Nature Conservancy (TNC) led this conservation planning effort for the Duck River watershed, carried out during calendar year 2005, and the primary author of this conservation plan is Sally Rollins Palmer. This work was supported by a National Fish and Wildlife Federation grant awarded to the Tennessee Wildlife Resources Agency on behalf of the Southeast Aquatic Resource Partnership (SARP). The SARP chose the Duck River as one of four pilot watersheds in the Southeastern U.S. (the Duck, the Altamaha in GA, the Roanoke in NC & VA, and the Pascagoula in MS) to test the development of a Southeastern Aquatic Habitat Plan.

Many other individuals contributed their expertise to this plan, representing several agencies and organizations, including the Tennessee Wildlife Resources Agency (TWRA), the Tennessee Valley Authority (TVA), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Natural Resources Conservation Service (NRCS). The Buffalo/Duck River Resource Conservation and Development Council coordinator was also interviewed, and components of the RC& D's strategic plan incorporated into this planning effort. The following individuals attended planning meetings and contributed to the development of this plan in several ways: Gray Anderson – TWRA, Jeff Bowie – NRCS, Geoff Call – USFWS, Leslie Colley – TNC, Frank Fiss - TWRA Paul Freeman – TNC, Don Hubbs – TWRA, Richard Kirk – TWRA, Larry Lofton – Buffalo/Duck RC&D, Doug Murphy – TVA, Odell Poyner - NRCS, Jeff Prestwich – TWRA, Greg Taylor – NRCS, Greg Wathen – TWRA, and Joey Wisby – TNC.

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Executive Summary

The Duck River in south-central Tennessee remains one of the most biologically diverse rivers on North American continent and is an outstanding national resource. The total number of riverine fauna currently documented in the watershed exceeds 650 species and includes 146 species of fish, 53 species of freshwater mussels, and 22 freshwater snail species (Ahlstedt et al. 2004). Several of these fish, mussel, and snail species are known to be Tennessee-Cumberland River system endemics. The entire Duck watershed is incredibly diverse in terrestrial species and communities, ranging from oak barrens and prairie wetlands in the upper watershed, cedar glades and limestone barrens in the Nashville Basin, to rich calcareous seeps and forests in the lower portion of the Duck and in the Buffalo River watershed on the Western Highland Rim. The Buffalo River, a major tributary to the Lower Duck, is an outstanding native fisheries resource, containing over 100 fish species, including a few endemics to the Buffalo and Lower Duck rivers. The Duck River and its main tributary, the Buffalo, are indeed one of the last refugia for native Tennessee-Cumberland aquatic fauna.

Recent studies have documented mussel fauna recovery in the Duck River which is unprecedented in the Tennessee River basin. This level of recovery from past perturbations is attributed to land protection and restoration efforts, improvements in reservoir releases by the Tennessee Valley Authority, the settling of channel morphology from earlier destabilizing events, removal of historic point and nonpoint sources of pollution from phosphate and iron ore mining, and the natural hardness of the water and abundance of groundwater inputs to the system. The recovery trends of the Duck River mussel fauna are one particular example of successful conservation efforts; however, these efforts in the future must be directed at the most critical needs of the system and consistently executed over the long term.

Recognizing the need for an updated and comprehensive planning effort, many of the agencies and organizations with direct, ongoing management activities in the Duck and Buffalo watersheds participated in an updated conservation planning process led by The Nature Conservancy during 2005. This planning activity was conducted as part of the Southeast Aquatic Resources Partnership's (SARP) Pilot River Project. Participants in the 2005 planning effort included the Tennessee Wildlife Resources Agency (TWRA), the Tennessee Valley Authority (TVA), The Nature Conservancy (TNC), the U.S.D.A. Natural Resources Conservation Service (NRCS), and the U.S. Fish and Wildlife Service (USFWS).

In order to develop the conservation plan for the Duck and Buffalo Rivers, TNC staff led the partners through a series of workshops during 2005 applying TNC's "5-S" conservation planning framework (systems, stresses, sources, strategies, & success measures). TNC had developed its first conservation plan for the watershed using this methodology in 2001, but this initial plan only covered the Upper Duck and needed to be updated and expanded. The goal of the "5-S" workshops was to facilitate the development of a general conservation blueprint for the Duck and Buffalo River watersheds with specific objectives and strategic actions whose implementation can be monitored and adapted, as necessary, over time. Through the guidance of workshop participants and supplemental discussions and meetings, the TNC conservation planning team described the conservation targets (systems), analyzed the stresses and sources of stress for each target, articulated conservation objectives and strategies to abate threats, and described a method for articulating project success measures. These five major components of the conservation plan are highlighted below.

Aquatic system conservation targets

The conservation plan focuses on seven aquatic system targets: Eastern Highland Rim streams, Normandy Reservoir, the Upper Duck River mainstem, Inner Nashville Basin streams, the Lower Duck River mainstem, Western Highland Rim streams, and the Buffalo River mainstem. The tributaries identified as separate targets from their river mainstems because in many instances the distribution of nested target species, the types and sources of stress, and the conservation strategies needed are different. Following the identification of the seven primary aquatic system conservation targets, the planning team documented "key ecological attributes" for each target. These attributes fall in five general categories: hydrologic regime, energy regime, physical habitat structure, water quality, and biota. These five general attributes constitute the critical components of aquatic system function; any missing or altered attributes would result in the loss of system function over time.

Threats to aquatic system target health ("stresses" and "sources")

Threats to the aquatic systems can be described by their two general components, the stress and the source of stress. A stress is an unacceptable alteration to any of the general five conditions necessary to support aquatic system function: hydrologic regime, energy regime, water quality, physical habitat structure, energy regime, and biota. A source of stress is that activity leading to the unacceptable alteration, and a single stress can have multiple sources. For example, riparian buffers, an important physical habitat feature, are eliminated by both incompatible agricultural practices and by development practices in more urbanized areas.

The primary stresses identified by the planning team across all the systems types were altered hydrologic regimes, altered instream physical habitat conditions, altered near-stream (buffer) habitat conditions, sedimentation, nutrient loading, thermal alteration, toxins and other contaminants, and altered species composition. Of the eight stresses identified, the most prevalent were near-stream (buffer) habitat alteration, nutrient loading, sedimentation, and to a lesser degree, thermal alteration and toxins or other contaminants. Examination of state water quality data indicates that the Inner Nashville Basin streams are the most stressed system followed by the Western Highland Rim streams. The sources of stress to the Duck and Buffalo River watersheds can be summarized in six main categories: incompatible agricultural practices, wastewater management practices, urbanization, water management practices, resource extraction activities, and invasive species. The most pressing threats are associated with incompatible agricultural practices, wastewater management practices, urbanization, and water supply management practices.

Conservation objectives and strategies

The primary conservation objectives and strategic actions identified by the planning team focus on the top threats to the Duck and Buffalo watersheds as well as the research, programmatic support, and partner communication necessary to refine objectives and measure the success of strategic actions over time. Eight objectives and 33 nested strategic actions were articulated by the planning team. These eight objectives are outlined below:

Objective 1: Achieve 15% net improvement in the near-stream habitat conditions of river mainstems and impaired tributary streams and by 2010.

Objective 2: Achieve better coordination between partner agency monitoring programs to establish a joint monitoring and assessment program by 2008.

Objective 3: Advance recovery efforts for federally endangered, threatened, candidate, or species of management concern in the Duck and Buffalo watersheds.

Objective 4: Continue protection of important stream and mainstem river habitats through fee title or conservation easement acquisition.

Objective 5: Cooperate with local municipalities and county governments in the Duck/Buffalo region to develop environmentally sound principles in land use planning and economic development projects that are protective of their watersheds by 2010.

Objective 6: Work with partners to establish an instream flow policy for the Duck & Buffalo watersheds that protects ecosystem functions and designated uses by 2008.

Objective 7: Evaluate status of land use/land cover changes associated with forestry practices in the Lower Duck and Buffalo watersheds by 2007.

Objective 8: Maintain the quality of existing sport fish resource populations.

Conservation success measures

In order to improve our first attempts at quantifying thresholds for threat abatement and biological health improvements, several research needs related to better understanding hydrologic regimes, physical habitat patterns and requirements, water quality issues, and the biota were identified by the planning team. One of the primary approaches for addressing research needs will be establishing a process for integrating and utilizing the data collected by many of the partner agencies including (but not limited to) TNC, TVA, TWRA, USFWS, the Tennessee Department of Environment and Conservation (TDEC), and the U.S. Geological Survey. TDEC conducts its watershed sampling and reporting on a 5-year cycle. The Duck River and Buffalo River reports were published in 2005, initiating the next phase of the “Watershed Management Cycle” (TDEC 2005a).

The planning partners felt that aligning this conservation planning effort’s review & reporting cycle with that of TDEC’s will allow for a more efficient and coordinated approach to monitoring the overall health of the watersheds, including improvements in nested target fauna. Adopting this same cycle also allows for a regular review of strategic action implementation and for adjustments in conservation objectives as needed. Many of the strategic actions identified in this plan are already underway, but it will be necessary to successfully execute those outlined under Objective 2 in order to develop a coordinating monitoring and adaptive management approach for this conservation plan.

Implementation timeline and partners

The Duck and Buffalo River conservation plan represents an evolution of the 5-S planning approach as it was first applied by TNC in the Upper Duck watershed in 2001. This more comprehensive conservation plan has been developed to focus partnership efforts for a 5 to 7 year time frame. In addition to the agencies and organizations involved in this planning effort, many other local, state, federal, and international governments, agencies, and organizations are active in conservation efforts in the Duck and Buffalo River watersheds. These partners include the municipal and county governments, the Duck River Agency and its member utilities, the Tennessee Department of Agriculture, the TDEC Division of Water Pollution Control, the Buffalo/Duck River Resource Conservation and Development Council, Tennessee Scenic Rivers Association, and the World Wildlife Fund. This myriad of partners has worked independently

as well as collaborated on a number of conservation strategies to date including regional water supply, economic development, and land use planning; better agricultural production and water resource conservation practices; water quality and hydrologic monitoring; endangered species recovery; fisheries management; and recreational access. Utilizing this comprehensive plan will assist all partners in continuing our successful, collaborative work towards conserving these outstanding aquatic resources.

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Introduction

Watershed Characteristics

The Duck River watershed begins on the Eastern Highland Rim in southern Middle Tennessee, drains the southern portion of the Nashville Basin, and splits the Western Highland Rim province as it flows 270 miles to its confluence with the Tennessee River. Draining parts of 11 counties (8% of Tennessee's total land area) the Duck River watershed covers approximately 2,730 square miles) and portions of 19 counties, primarily (from east to west) Coffee, Bedford, Marshall, Maury, Lewis, Hickman, & Humphreys (Figure 1) (TDEC 2005a, TDEC 2005b). The Buffalo River, a major tributary to the Lower Duck, has a watershed area of approximately 763 square miles in 6 counties, primarily Lawrence, Wayne, Lewis, & Perry (Figure 1) (TDEC 2005c). Both watersheds are contained almost solely within the larger Interior Low Plateau ecoregion, which is characterized by a large, complex karst geologic system. This underlying limestone geology greatly influences the instream physical characteristics, hydrology, and water chemistry of the Duck and Buffalo Rivers. The Upper Duck watershed in particular is characterized by sinkhole plains, year-round springs, and limestone bluffs along most of its river miles. The Lower Duck and Buffalo have many tributaries receive outflows from springs that emerge from between the limestone strata as well.

The Duck River remains one of the most biologically diverse rivers on North American continent and is an outstanding national resource. The total number of riverine fauna currently documented in the watershed exceeds 650 species and includes 146 species of fish, 53 species of freshwater mussels, and 22 freshwater snail species (Ahlstedt et al. 2004). Several of these fish, mussel, and snail species are known to be Tennessee-Cumberland River system endemics. The entire Duck watershed is incredibly diverse in terrestrial species and communities, ranging from oak barrens and prairie wetlands in the upper watershed, cedar glades and limestone barrens in the Nashville Basin, to rich calcareous seeps and forests in the lower portion of the Duck and in the Buffalo River watershed on the Western Highland Rim. The Buffalo River is an outstanding native fisheries resource, containing over 100 species and including a few endemics to the Buffalo and Lower Duck rivers. The Duck River and its main tributary, the Buffalo, are indeed one of the last refugia for native Tennessee-Cumberland aquatic fauna, and focusing conservation efforts in these watersheds provides a rare opportunity to protect a vast and imperiled array of Southeastern fauna.

Advancing conservation work in the Duck and Buffalo watersheds is indeed critical to reversing the trends of aquatic species loss experienced in Southeastern U.S. rivers during the last 100 years. Despite its recovery in recent decades, the Duck and Buffalo Rivers have experienced native species extirpations. Ahstedt et al. (2004) re-surveyed five historic collection sites on the Buffalo River and found that mussels were extremely rare. Only 20 live individuals from 8 species were collected at these sites where surveys in the late 1930s documented 33 species. The fish and snail fauna of the Buffalo remain largely intact, leaving malaecologists to hypothesize that some chemical pollution of a chronic nature, combined with highly destabilized substrates, may be affecting the survival of juvenile mussels once they drop from host fish.

In the Duck River, 75 species of mussels have been documented since the late 1800s; however, extensive surveys completed in 2002 have accounted for 53 of these species. Seven species listed by the U.S. Fish and Wildlife Service (six Endangered and one Candidate) are documented historically from the Duck River, but only 4 of these species are known extant and reproducing. Generally speaking, mussel faunal recovery in the Duck River since 1988 has been dramatic with greater than 15% increases in mussel density at all sampling locations, increased species richness, and range increases for the 3 extant Federally Endangered species (Ahstedt et al. 2004). This type of faunal recovery is unprecedented in the Tennessee River basin and is attributed to land protection and restoration efforts, improvements in reservoir releases by the Tennessee Valley Authority, the settling of channel morphology from earlier destabilizing events, removal of historic point and nonpoint sources of pollution from phosphate and iron ore mining, and the natural hardness of the water and abundance of groundwater inputs to the system. The recovery trends of the Duck River mussel fauna in particular indicate that conservation efforts can be successful but need to be directed at the most critical needs of the system and consistently executed over the long term.

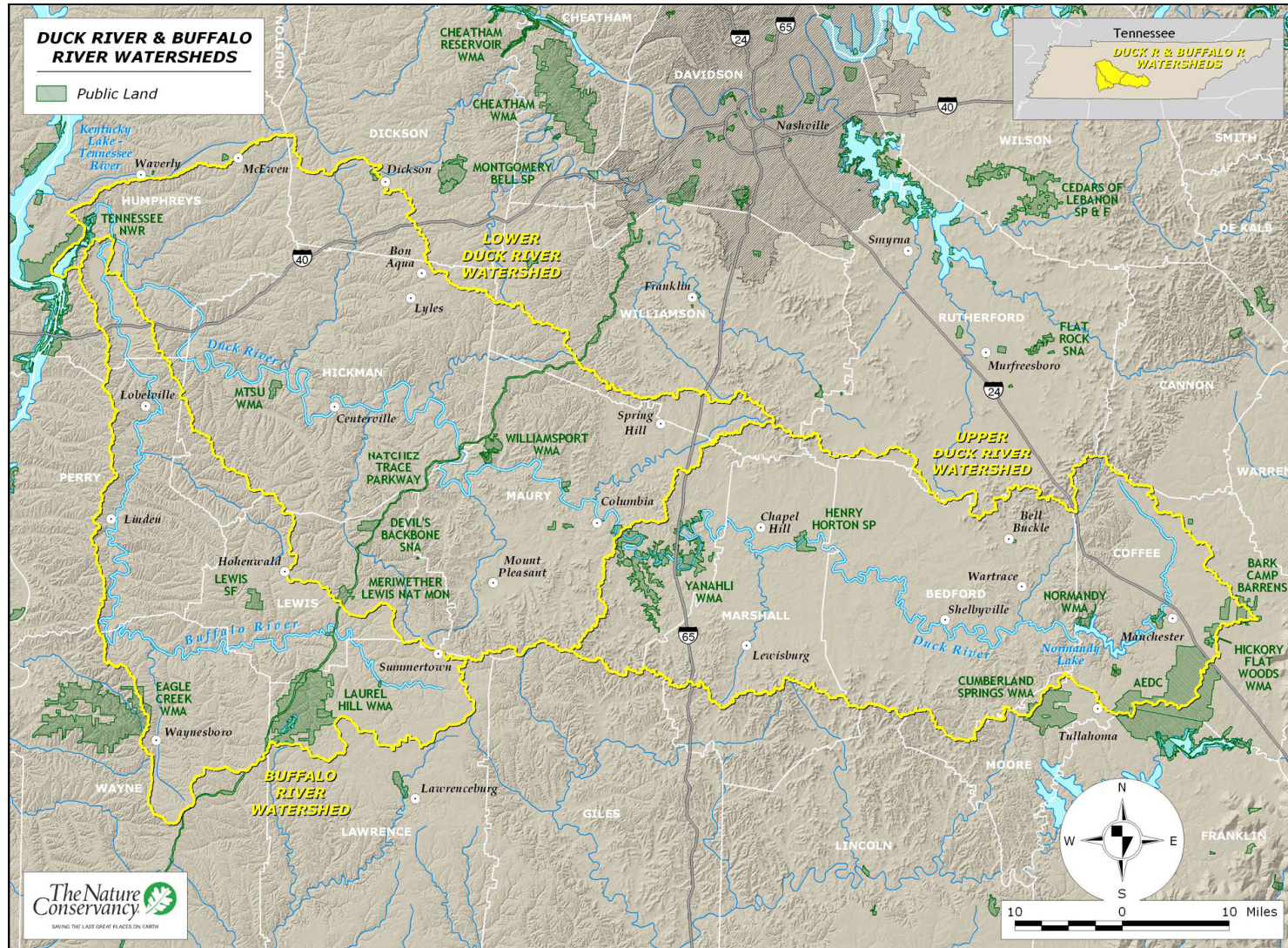


Figure 1. The Duck and Buffalo River watersheds of southern Middle Tennessee.

Land and Water Use Trends

Prior to European settlement, the Duck and Buffalo watersheds were prime hunting grounds for Chickasaw and Cherokee Native American tribes (TDEC 2005a). Since the time of European settlement, Middle Tennessee historically has been an agricultural region due to rich soils and a fairly temperate climate. Of the three watersheds, the Upper Duck currently contains the most agricultural land use (about 42%), with some row crops, but the majority of acreage being in pasture or hay for livestock production (TDEC 2005a). The Lower Duck and Buffalo watersheds are primarily in deciduous forest, with only 20-30% of land in agricultural production, most of this land being converted rich, river bottomland soils. (TDEC 2005b).

During the past 200 years, the natural hydrology of the Duck has been altered in many ways, from early fish dams and traps, to mill dams constructed throughout the 19th and early 20th centuries, to hydroelectric dams in the early to mid-20th century. In the Duck River alone, over 25 mill dams have been over time dating back to the early 1800s (LaForest and Oliveira 1979). These mill dams were utilized for producing a number of goods including paper, rope, furniture, lumber, cloth, and flour. The most recent, and largest, impoundment of the Duck River's main stem was completed in 1976 by the Tennessee Valley Authority (TVA), with the closure of Normandy Dam near the headwaters in Coffee County. Since 1976 the river flows of the Upper Duck have been managed to a large extent via the releases from Normandy Reservoir. A second reservoir project, the Columbia Dam, was also to be completed by TVA as part of their overall Duck River project. The construction of the Columbia Dam continued into the late 1980s and early 1990s until the project was ultimately abandoned due to the presence of Federally Endangered mussel species in the river as well as poor cost-benefit analyses of long-term reservoir operations.

While the land use of the Duck and Buffalo watersheds is still primarily agriculture and native deciduous forest, this land use is changing rapidly at the beginning of the 21st century, particularly in the Upper Duck watershed. The Nashville Basin physiographic province is 12th in the nation in the loss of farmland to urban and suburban land uses. Point and nonpoint source pollution and water supply development for growing municipalities are increasing pressures on both the Duck and Buffalo rivers. The Duck River watershed is now home to approximately 215,000 people while about 27,000 live within the Buffalo River watershed (TDEC 2005a & b). In the Duck watershed, the Tennessee Valley Authority operates Normandy Dam, which provides drinking water directly to two municipalities, and indirectly through its releases to 5 downstream cities. The treated wastewater effluent from the majority of these communities is returned directly to Normandy Reservoir or to the river's main stem.

Surface water demands are the highest in the Upper Duck at a total 26.36 million gallons a day (mgd); in the Lower Duck approximately 4.36 mgd of surface water is withdrawn, and in the Buffalo 1.2 mgd (Hutson et al. 2004). Groundwater withdrawals are considerably less but still amount to 2.11 mgd, 0.06 mgd, and 1.75 mgd in the Upper Duck, Lower Duck, and Buffalo watersheds, respectively (Hutson et al. 2004). The majority of these water withdrawals are for public water supply, with less than 1 mgd used for agricultural irrigation and even smaller amounts to direct industrial supply. Hutson et al. (2004) predict that based on water use and population growth projections, demand for water will increase by 38% by the year 2030.

The local economies of the Duck and Buffalo watersheds vary. In the Upper Duck watershed, manufacturing and distribution facilities related to the auto industry are prominent. The U.S. Air Force's Arnold Engineering and Development Center and University of Tennessee Space Institute are important facets of the local economy as well. Other manufacturing related to writing supplies, die casting, and refrigeration are significant employers, and the annual Walking Horse National Celebration is extremely important to the city of Shelbyville's economy and that of its neighboring counties. Further downstream in the Lower Duck and Buffalo watersheds, manufacturing, agriculture, and resource extraction activities such as forestry, iron ore, mineral limonite, phosphorous mining are important sectors of local economies. Approximately 75% of the manufacturing jobs in the Lower Duck and Buffalo watersheds are related to lumber, rubber and plastics, and fabricated metal industries (Buffalo/Duck River RC&D 2003). Timber sales for all wood species and products ranges around \$29.5 million, with a payroll of approximately \$20.8 million for those involved in forest and wood product industries (Buffalo/Duck River RC&D 2003).

In addition to these extraction and manufacturing industries, recreational boating is a large sector of local economies, particularly in the Lower Duck and Buffalo watersheds. Between 1995 and 2000, the seasonal revenues in a four county area (Humphreys, Lewis, Perry, and Wayne) with nine independent operators averaged around \$1.7 to \$1.8 million, more than on the Ocoee River in east Tennessee (\$1.2 million in 2002) (Wade 2001). Approximately 150,000-160,000 people per year recreate on the Lower Duck and Buffalo rivers and their smaller tributaries in these four counties. The total annual economic impact of recreational boating to the four county region averages approximately \$6 million (Wade 2001).

Conservation Status of the Duck River Watershed

Figure 1 illustrates the distribution and location of publicly owned or managed protected areas in the Duck and Buffalo watersheds. The largest of these sites included AEDC Wildlife Management Area, Yanahli Wildlife Management and State Natural Areas, and Laurel Hill Wildlife Management Area. The Tennessee Wildlife Resources Agency (TWRA) and the Tennessee Department of Environment and Conservation's (TDEC) Natural Areas Program are the primary agencies responsible for land management in these locations. Other smaller protected areas held by local land trusts such as the Maury Heritage Land Trust, Swan Creek Land Trust, and the Land Trust for Tennessee are not shown on Figure 1. The Yanahli Wildlife Management Area was established in August 2001 when the Tennessee Valley Authority officially transferred ownership of all its landholdings originally acquired for the footprint of Columbia Dam's reservoir to the State of Tennessee. During the last 25 years, these 12,800 acres of reserved land have helped protect approximately 30 river miles that contain some of the best remaining mussel populations in the Upper Duck. Some private in-holdings still exist along the Yanahli corridor; however, the State hopes to encourage protection of the floodplain portions of these properties through the new volunteer registration program designed as part of the State Scenic River designation for this portion of the river east to the Marshall County line. The Buffalo River in Lawrence County is also classified as a State Class II Pastoral River.

In late 1991, the TVA instituted a Reservoir Release Improvement (RRI) program across the Tennessee Valley aimed at improving the minimum flows and dissolved oxygen conditions in the tailwaters to many of the dams the agency operates. The improvements made in Normandy Reservoir releases as part of the RRI program are considered to be a major contributor to the ongoing mussel fauna recovery in the Duck River. The increased flows during peak mussel recruitment periods and increased primary productivity in the river have resulted in positive faunal responses (Ahlstedt et al. 2004). Recovery efforts moving sensitive species to further upstream locations, thus expanding their distributions within the watershed, are now thought possible.

In addition to the agencies and organizations discussed above, many other local, state, federal, and international governments, agencies, and organizations are active in conservation efforts in the Duck and Buffalo River watersheds. These partners include the municipal and county governments, the Duck River Agency and its member utilities, the Tennessee Department of Agriculture, the TDEC Division of Water Pollution Control, the Buffalo/Duck River Resource Conservation and Development Council, Tennessee Scenic Rivers Association, U.S. Fish and Wildlife Service, the U.S.D.A. Natural Resources Conservation Service, U.S. Geological Survey, The Nature Conservancy, and the World Wildlife Fund. This myriad of partners has worked independently as well as collaborated on a number of conservation strategies to date including regional water supply, economic development, and land use planning; better agricultural production

and water resource conservation practices; water quality and hydrologic monitoring; endangered species recovery; fisheries management; and recreational access.

2005 conservation planning partners and methodology

Recognizing the need for an updated and comprehensive planning effort, many of the agencies and organizations with direct, ongoing management activities in the Duck and Buffalo watersheds participated in an updated conservation planning process led by TNC during 2005. This planning activity was conducted as part of the Southeast Aquatic Resources Partnership's (SARP) Pilot River Project. The Duck River was chosen by the SARP as one of 4 rivers to begin efforts to create a Southeast regional aquatic habitat plan. Active participants in the planning included individuals from TNC, the Tennessee Wildlife Resources Agency, the Tennessee Valley Authority, the U.S. Fish and Wildlife Service, and the U.S. Natural Resources Conservation Service. The Buffalo/Duck River Resource Conservation and Development Council coordinator was also interviewed, and components of the RC& D's strategic plan incorporated into this planning effort.

In order to develop the conservation plan for the Duck and Buffalo Rivers, TNC staff led the partners through a series of workshops during 2005 applying TNC's "5-S" conservation planning framework. TNC had developed its first conservation plan for the watershed using this methodology in 2001, but this initial plan only covered the Upper Duck and needed to be updated and expanded. The goal of the "5-S" workshops was to facilitate the development of a general conservation blueprint for the Duck and Buffalo River watersheds with specific objectives and strategic actions whose implementation can be monitored and adapted, as necessary, over time. The components of the "5-S" planning are described below:

- **Systems:** The conservation targets (species or ecological systems) occurring at a site and the natural processes that maintain them that will be the focus of conservation efforts.
- **Stresses:** The types of degradation and impairment affecting the conservation targets in the watersheds.
- **Sources:** The agents or origins generating the stresses to conservation targets.
- **Strategies:** The types of conservation actions employed to abate sources of stress, improve biological status, or otherwise restore ecological system function.
- **Success:** Documented measures of improved biodiversity health and threat abatement.

Through the guidance of workshop participants and supplemental discussions and meetings, the TNC conservation planning team described the conservation

targets (systems), analyzed the stresses and sources of stress for each target, articulated conservation objectives and strategies to abate threats, and described a method for articulating project success measures. A comprehensive conservation plan has been developed to focus partnership efforts for a 5 to 7 year time frame. This report presents the conservation action plan that resulted from these 2005 workshops, meetings, and planning exercises.

Identification of conservation targets

Aquatic system target selection

As previously discussed in the planning methodology, the first step in the conservation planning exercise was the identification of conservation targets for the Duck and Buffalo River watersheds. Again, conservation targets in this paradigm are defined as those species or ecological systems that are the focus of conservation strategies. In TNC's previous conservation planning work, species assemblages (e.g. "mussel assemblage") were chosen as targets and the work included examining terrestrial species as well. For this planning exercise, the partners chose to focus solely on aquatics, and determined that an aquatic system classification would provide more utility for identifying conservation targets. Several partners felt that focusing targets on species or species assemblages would complicate our ability to develop strategies and measure implementation success. Therefore, the decision was made to utilize TNC's freshwater classification system as the basis for identifying aquatic system targets (Smith et al. 2002). The partners also chose to include Normandy Reservoir in this planning exercise, as this reservoir provides habitat for an important sport fisheries resource.

TNC's aquatic system classification methodology involves a GIS-based approach to a biophysical classification of freshwater ecosystems (Smith et al. 2002). Freshwater ecosystems are conceptualized as repeated patterns and gradients of biological communities tied together by distinct ecological processes that can be mapped as units on a hydrography map. The process was developed by obtaining spatial coverages of the most relevant factors structuring biological communities and ecological processes in the region and by mapping distinct repeatable patterns at various scales. Figure 2 shows the various aquatic system types in the Duck and Buffalo River watersheds. The conservation plan focuses on the subwatersheds identified in Figure 2. We chose to group the subwatersheds into the following seven conservation targets for this planning exercise (seen generally east to west on Figure 2): Eastern Highland Rim streams, Normandy Reservoir, Upper Duck River mainstem, Inner Nashville Basin streams, Lower Duck River mainstem, Western Highland Rim streams, Buffalo River mainstem. The tributaries identified as separate targets from their river mainstems because in many instances the distribution of nested target species, the types and sources of stress, and the conservation strategies needed are different. More specific descriptions of each of the targeted aquatic system types, including the nested target species found within them, are provided in the following sections.

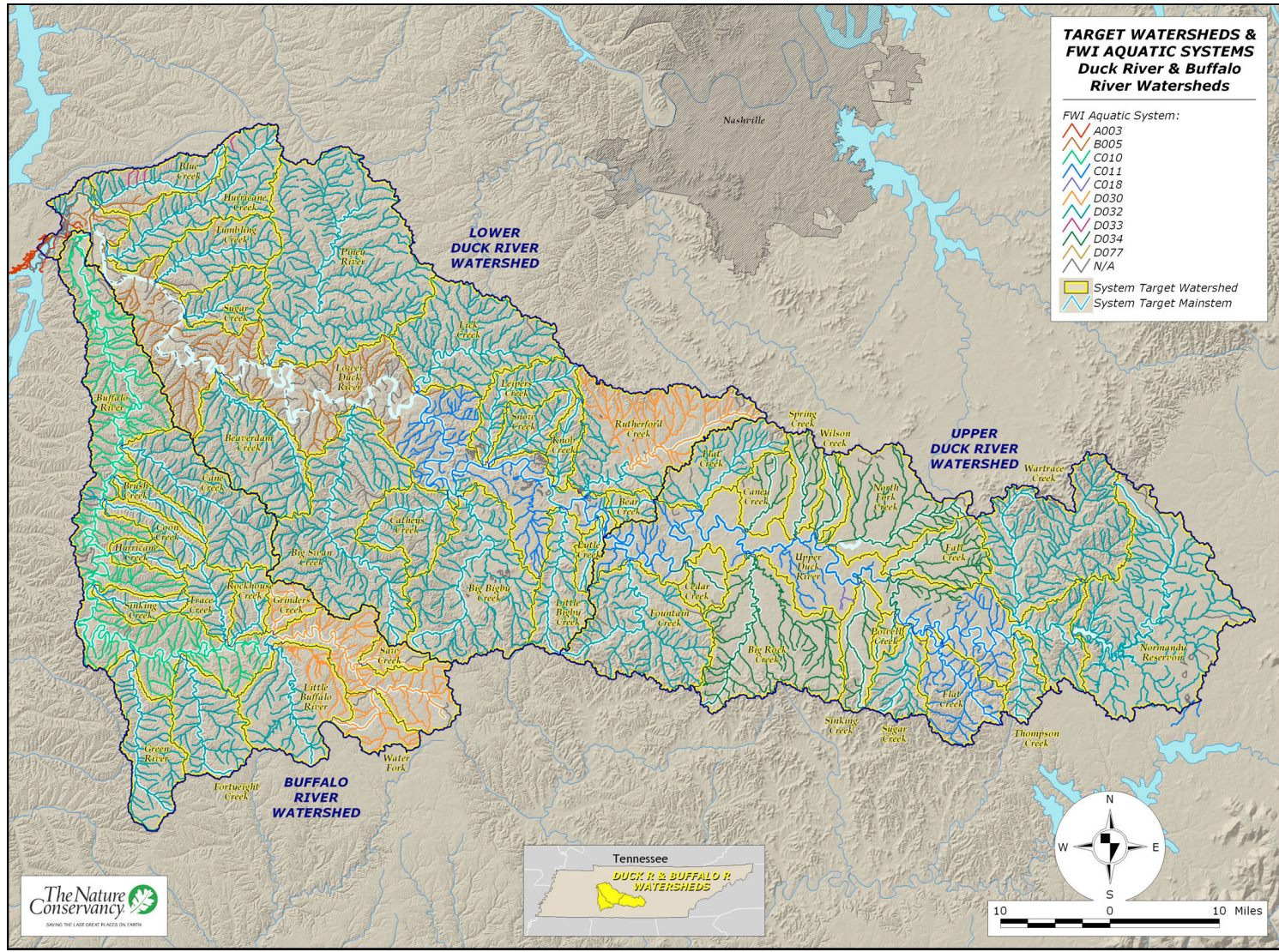
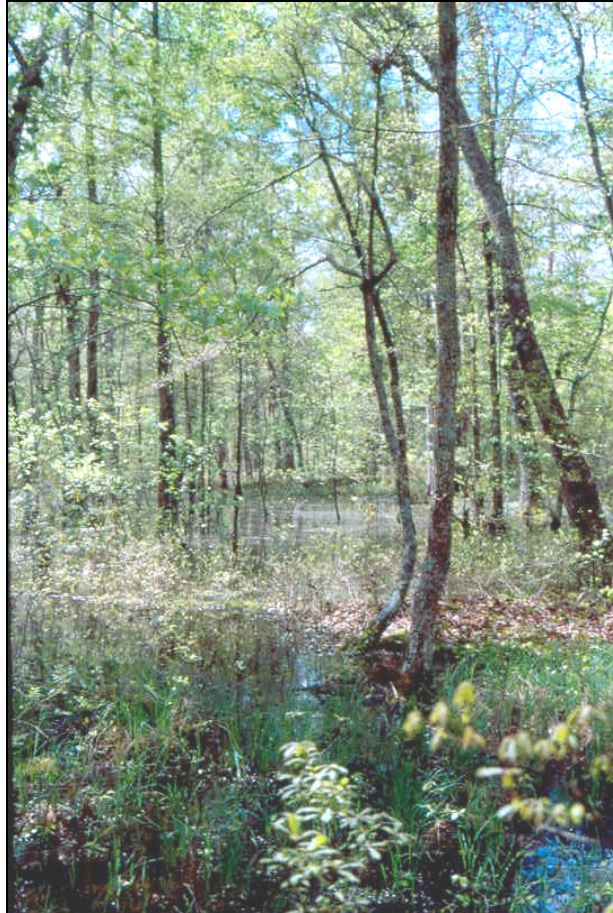


Figure 2. Aquatic system target classification in the Duck and Buffalo Watersheds.

Eastern Highland Rim streams

The Eastern Highland Rim stream target includes those streams originating on either the Eastern Highland Rim or adjacent Outer Nashville Basin. This target includes the mainstem of the Duck River and its direct tributaries above Normandy Reservoir, Wartrace/Garrsion Fork Creek subwatershed, and Thompson Creek subwatershed. The mainstem of the Duck above Normandy was included in this target category because the presence of the reservoir separates the river functionally from its downstream segments, and this uppermost portion of the Duck River has much more physiographic, hydrologic, and biological similarity to the other streams in this target group. The geology of this portion of the Duck River and its tributaries is characterized by tablelands of moderate relief underlain by Mississippian-age limestone chert, shale, & dolomite. Numerous springs and spring-fed forested and grass-dominated wetlands of various sizes are found in this region at the headwaters and along tributary reaches. These primary springs and headwater tributaries were historically home to several fish species, including the now extremely rare Barrens topminnow (*Fundulus julisia*), and less rare but increasingly uncommon species such as the Barrens darter (*Etheostoma forbesi*) and the Flame chub (*Hemitremia flammea*).

The fish and snail fauna of the Eastern Highland Rim streams has remained relatively intact since the construction of Normandy Reservoir. Mussel species have been in decline in these streams for several decades. In 1924 seven species of mussels were located in Garrsion Fork creek, but by 1968 surveys only recovered one species and found that the instream habitat had been altered (Ahlstedt et al. 2004). Surveys conducted between 2001-2003 across the targeted subwatersheds found 6 different species, but all specimens collected were relicts with no live individuals found (Ahlstedt et al. 2004). Recovery of the native mussel fauna in these tributaries is unlikely to occur without direct translocation of species from sites downstream of Normandy Reservoir, and these efforts would have questionable success due to the current status of instream habitat conditions. Therefore, for the Eastern Highland Rim stream target, only extant fish and snail species are considered significant nested targets at this time. Table 1 lists those species with Global Rarity Ranks of G1 (critically imperiled) to G3 (vulnerable to extirpation or extinction) found in Eastern Highland Rim streams.



Forested wetland leading into surface stream headwater, Coffee County.

Table 1. Eastern Highland Rim stream fish and snail nested species targets.

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Etheostoma forbesi</i>	Barrens darter	G1G2 S1	Management Concern
<i>Fundulus julisia</i>	Barrens topminnow	G1S1	Management Concern
<i>Hemitremia flammea</i>	Flame chub	G3 S3	Management Concern
<i>Percina burtoni</i>	Blotchside logperch	G2 S2	Management Concern
<i>Percina macrocephala</i>	Longhead darter	G3 S2	None
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3 S1	None
<i>Lithasia duttoniana</i>	Helmet rocksnail	G3 S2	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3 S1	None

Normandy Reservoir

Normandy Reservoir was created in 1976 with the closure of Normandy Dam on the Upper Duck River. The reservoir is operated by the Tennessee Valley Authority as a flood control and water supply impoundment. The reservoir covers 1,307 hectares, and at full pool has a shoreline of 116 kilometers and an average depth of 11.2 meters (Sammons and Bettoli 1998). The reservoir aquatic habitat conditions are warm monomictic and eutrophic (Sammons and Bettoli 1998). Although changing from a natural run-of-river to lake habitat, the establishment of Normandy Reservoir provided for the development of other sport fishing opportunities. For the past few decades, the Tennessee Wildlife Resources Agency (TWRA) has worked with the Tennessee Valley Authority to manage important sport fisheries within the reservoir and in the immediate tailwaters. These targeted species are listed in Table 2. Although none of these species is considered globally rare or otherwise imperiled, understanding the population dynamics and abating stresses to the Normandy Reservoir fisheries are important management objectives for TWRA as it works to provide diverse recreational opportunities to the citizens of Tennessee.

Table 2. Normandy Reservoir fisheries targets. *Saugeye are currently present in the sport fish population, but will not be long-term management targets.

Scientific Name	Common Name
Fish	
<i>Micropterus salmoides</i>	Largemouth bass
<i>Micropterus punctulatus</i>	Spotted bass
<i>Pomoxis nigromaculatus</i>	Black crappie, Blacknose black crappie
<i>Pomoxis annularis</i>	White crappie
<i>Sander vitreum X Sander canadense</i> *	Saugeye*
<i>Sander canadense</i>	Walleye

Upper Duck River mainstem

The Upper Duck River mainstem target includes that portion of the Duck River beginning at the tailwaters of Normandy Reservoir and continuing west, downstream to the watershed divide with the Lower Duck River (Figure 2). This portion of the Duck River falls within the rich Nashville Basin karst system characterized by sinkhole plains, year-round springs, and limestone bluffs along the majority of its river miles. This portion of the river has many gaining and losing reaches, which is typical of rivers embedded within larger karst systems. The river is very low gradient with a generally stable, mixed cobble substrate and often large expanses of limestone shelves exposed along the river banks. The river is naturally very nutrient rich with high primary productivity, and the calcium carbonate levels (between 60-180 mg/L) support juvenile mussel development and a distinctive fish population (Ahlstedt et al. 2004).

The flows of this portion of the river have been altered since the construction of Normandy Reservoir. Generally speaking, baseflows are managed at higher levels, flood peaks are attenuated, and flood levels drop more gradually over time. The tailwater habitats are somewhat destabilized and also impacted by manganese precipitates in reservoir releases. TVA has collected fish species information in the Upper Duck mainstem periodically for decades. Surveys conducted by TVA since the early 1990s indicate that the species diversity and community structure in the mainstem of the Upper Duck is stable and generally recovering from past disturbances. Recent surveys conducted in 2001 and 2002 have re-affirmed the health and diversity of the mussel and snail fauna in the Upper Duck mainstem. Generally speaking, mussel faunal recovery in the Duck River since 1988 has been dramatic with greater than 15% increases in mussel density at all sampling locations, increased species richness, and range increases for the 3 extant Federally Endangered species (Ahlstedt et al. 2004).

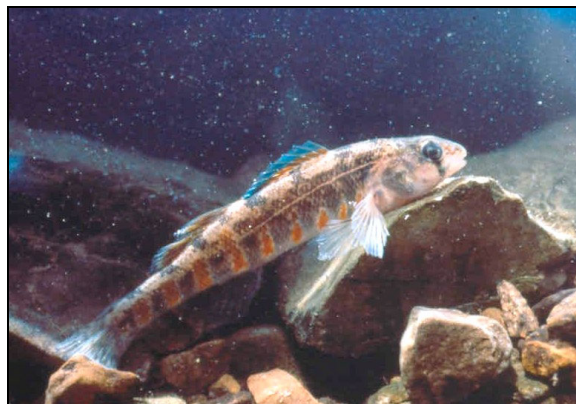
Despite the relative health of the overall mollusc assemblage, some species are thought to have become extirpated from the Upper Duck since the early 1970s. Of the 75 species historically documented in the entire Duck River, 53 have been accounted for in surveys completed in 2002 (Ahlstedt et al. 2004). None of the following, all of which are Federally Endangered or Candidate species, have been re-located in the Duck River in recent years: Cumberlandian combshell (*Epioblasma brevidens*), Cracking pearlymussel (*Hemistena lata*), Rayed bean (*Villosa fabalis*), and Tan riffleshell (*Epioblasma florentina walkeri*). Three Federally Endangered species, the Birdwing Pearlymussel (*Lemiox rimosus*), Oyster Mussel (*Epioblasma capsaeformis*), and Cumberland Monkeyface (*Quadrula intermedia*), and a Candidate for federal listing, the Slabside pearlymussel (*Lexingtonia dolabelloides*), are known extant and reproducing. Table 3 lists the mussel, as well as fish and snail species with Global Rarity Ranks of G1 (critically imperiled) to G3 (vulnerable to extirpation or extinction) found in the mainstem of the Upper Duck River.



Oyster mussel
Epioblasma capsaeformis



Birdwing Pearlymussel
Lemiox rimosus



Redband Darter
Etheostoma luteovinctum

Table 3. Upper Duck mainstem fish, mussel, and snail nested species targets.

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Etheostoma aquali</i>	Coppercheek darter	G2G3 S2S3	Management Concern
<i>Etheostoma cinereum</i>	Ashy darter	G2G3 S2S3	Management Concern
<i>Etheostoma denoncourti</i>	Golden darter (former)	G3 S1S2	Management Concern
<i>Etheostoma luteovinctum</i>	Redband darter		None
<i>Etheostoma striatulum</i>	Striated darter	G1 S1	Management Concern
<i>Notropis rupestris</i>	Bedrock shiner	G2 S2	None
<i>Percina burtoni</i>	Blotchside logperch	G2 S2	Management Concern
<i>Percina macrocephala</i>	Longhead darter	G3 S2	None
Mussels			
<i>Epioblasma brevidens</i>	Cumberlandian combshell	G1 S1	Endangered
<i>Epioblasma capsaeformis</i>	Oyster mussel	G1 S1	Endangered
<i>Epioblasma florentina walkeri</i>	Tan riffleshell	G1 S1	Endangered
<i>Epioblasma triquetra</i>	Snuffbox	G3 S3	None
<i>Fusconaia barnesiana</i>	Tennessee Pigtoe	G2G3	None
<i>Lemiox rimosus</i>	Birdwing pearlymussel	G1 S1	Endangered
<i>Lexingtonia dolabelloides</i>	Slabside pearlymussel	G2 S2	Candidate
<i>Medionidus conradicus</i>	Cumberland moccasinshell	G3G4 S3	None
<i>Pleurobema oviforme</i>	Tennessee clubshell	G3 S2S3	None
<i>Quadrula cylindrica cylindrica</i>	Rabbitsfoot	G3T3 S3	None
<i>Quadrula intermedia</i>	Cumberland monkeyface	G1 S1	Endangered
<i>Toxolasma cylindrellus</i>	Pale lilliput	G1 S1	Endangered
<i>Toxolasma lividus</i>	Purple lilliput	G2 S1S2	None
<i>Villosa fabalis</i>	Rayed bean	G1G2 S1	Candidate
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3 S1	None
<i>Lithasia duttoniana</i>	Helmet rocksnail	G2 S2	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3	None
<i>Lithasia jayana</i>	Rugose rocksnail	G2 S2	None

Inner Nashville Basin streams

The Inner Nashville Basin streams are those tributaries to the Upper Duck mainstem that either originate or have the majority of their watersheds contained within the Inner Nashville Basin. These tributary watersheds include Flat Creek (Bedford County), Sinking Creek, Sugar Creek, Fall Creek, North Fork Creek, Wilson Creek, Spring Creek, Caney Creek, and Big Rock Creek. These streams are very low gradient with gaining and losing reaches, primarily bedrock substrate and cobble substrate, and most run dry along some portion of their length during the year. These streams are also very nutrient-rich, and historically have supported a diverse fish fauna including the Striated darter (*Etheostoma striatulum*) a species endemic to these tributary streams and the mainstem of the Upper Duck River. Many of these fish species require clean bedrock for spawning habitat and are adapted to the low dissolved oxygen conditions that occur in the isolated pockets of habitat that are common during dry periods of the year.

Little is known about the historic distributions of mussel and snail species in these smaller tributary systems to the Upper Duck. Previous surveys concentrated largely on the mainstem of the river. However, according to researchers, given the rich mussel diversity of the Duck River system as a whole, it can be assumed that the tributary fauna historically was more widespread and diverse. Small, headwater species likely were more prevalent, although in larger streams with more consistent year-round flows, the fauna may have been more diverse. Recent surveys across the Duck River tributaries as a whole have found only nine live or fresh dead species in six streams. Only old relict shells were found were found in fifteen other streams, although these relicts included twelve species. One Inner Nashville Basin tributary, Big Rock Creek, retains some recruiting populations of mussels. Six species have been documented as recruiting in Big Rock Creek in 2002 and 9 other species were documented, although only by relict shell. Freshwater snails are thought to have declined from historic distributions as well, however, the condition of snails in the Inner Nashville Basin streams appears better than that of the mussels (Ahlstedt et al. 2004). Table 4 lists the mussel, as well as fish and snail species with Global Rarity Ranks of G1 (critically imperiled) to G3 (vulnerable to extirpation or extinction) found in the mainstem of the Upper Duck River.



North Fork Creek, Bedford County (Geoff Call, USFWS)

Table 4. Inner Nashville Basin stream fish, mussel, and snail nested species targets.

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Etheostoma aquali</i>	Coppercheek darter	G2G3 S2S3	Management Concern
<i>Etheostoma luteovinctum</i>	Redband darter	G4 S4	None
<i>Etheostoma striatulum</i>	Striated darter	G1 S1	Management Concern
Mussels			
<i>Lexingtonia dolabelloides</i>	Slabside pearlymussel	G2 S2	Candidate
<i>Medionidus conradicus</i>	Cumberland moccasinshell	G3G4 S3	None
<i>Quadrula cylindrica cylindrica</i>	Rabbitsfoot	G3T3 S3	None
<i>Toxolasma lividus</i>	Purple lilliput	G2 S1S2	None
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3 S1	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3 S1	None

Lower Duck River mainstem

The Lower Duck River mainstem target includes that portion of the Duck River beginning at the watershed divide with the Upper Duck near Columbia and flowing west to the confluence with the Tennessee River at Kentucky Lake (Figure 2). At this point the river flows out of the Nashville Basin and onto the Western Highland Rim. The elevations in the watershed change to an average of around 400-1000 ft., higher than that of the Nashville Basin. While some sections of limestone bluffs remain along the river, more flat floodplains exist in the lower watershed. Agricultural activities, both row crop and pasture/livestock production, are common in these floodplains, although the majority of the watershed remains in native oak-hickory forest. The river itself becomes larger and is characterized as a medium-sized, low gradient river as opposed to the smaller size of the Upper Duck mainstem (Smith, et al. 2002). The substrates are largely clean swept coarse cobble and gravel with some sand, and higher amounts of more acidic chert and shale rock than the Upper Duck. Fewer expanses of bedrock are present in the Lower Duck mainstem as well. The characteristic fauna of the Lower Duck correspondingly is different, with more “big river” fish and mussel species occurring in this portion of the greater Duck watershed.

The flows of this portion of the river, and the distribution of fauna, have been altered by both the construction of Normandy Reservoir in the Upper Duck and the creation of Kentucky Lake on the mainstem of the Tennessee. The flow alterations from Normandy operations, however, are considered to be generally attenuated by inflows from the tributaries in the large intervening watershed between Normandy Dam and the lower sections of the Duck, although these assumptions require further analysis. The nature of confluence of the Lower Duck and the Tennessee River has been dramatically altered from a more free-flowing to pool condition with the development of Kentucky Lake. The changes to the mainstem of the Tennessee River from run-of-river to lake habitat in the region of this confluence have reduced the capacity of certain fish, particularly smaller darter species who are often host fish for specific mussel species, to migrate between the Tennessee River and the Duck.

The TVA has collected fish community data in the Lower Duck watershed since the late 1980s, and trends indicate that overall fish community diversity and health generally good to excellent in the mainstem. Instream habitat is generally stable for most fish species, and surveys in the early 2000s have re-located some of the more rare species such as the Pygmy madtom (*Noturus stanauli*) and the Duck River saddled madtom (*Noturus* sp. cf. *N. elegans*). In addition to connectivity breaks with free-flowing reaches of the Tennessee River, shoal habitat destabilization remains problematic for mussel species recruitment in the Lower Duck. All eight Federally Endangered species, Cumberlandian combshell (*Epioblasma brevidens*), Tan riffleshell (*Epioblasma florentina walkeri*), Snuffbox (*Epioblasma triquetra*), Cracking pearlymussel (*Hemistena lata*), Ring pink (*Obovaria retusa*), Orange-foot pimpleback (*Plethobasus cooperianus*), Clubshell (*Pleurobema clava*), and Cumberland monkeyface

(*Quadrula intermedia*), are either extremely rare or otherwise thought to be extirpated from the Lower Duck. However, recent trends in mussel fauna recovery throughout the Duck watershed suggest that future re-introduction efforts for several of these species may be warranted (Ahlstedt et al. 2004). Table 5 lists the fish, mussel, and snail species with Global Rarity Ranks of G1 (critically imperiled) to G3 (vulnerable to extirpation or extinction) known from the mainstem of the Lower Duck River.



Golden darter, *Etheostoma denoncourti*

Table 5. Lower Duck mainstem fish, mussel, and snail nested species targets.

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Etheostoma aquali</i>	Coppercheek darter	G2G3 S2S3	Management Concern
<i>Etheostoma cinereum</i>	Ashy darter	G2G3 S2S3	Management Concern
<i>Etheostoma denoncourti</i>	Golden darter (former)	G3 S1S2	Management Concern
<i>Etheostoma luteovinctum</i>	Redband darter	G4 S4	None
<i>Etheostoma pseudovulatum</i>	Egg-mimic darter	G1 S1	Management Concern
<i>Noturus</i> sp. cf. <i>N. elegans</i>	Duck River saddled madtom	G1Q S1	None
<i>Noturus stanauli</i>	Pygmy madtom	G1 S1	Endangered
<i>Percina burtoni</i>	Blotchside logperch	G2 S2	Management Concern
Mussels			
<i>Epioblasma brevidens</i>	Cumberlandian combshell	G1 S1	Endangered
<i>Epioblasma florentina walkeri</i>	Tan riffleshell	G1 S1	Endangered
<i>Epioblasma triquetra</i>	Snuffbox	G3 S3	None
<i>Fusconaia barnesiana</i>	Tennessee Pigtoe	G2G3	None
<i>Hemistena lata</i>	Cracking pearlymussel	G1 S1	Endangered
<i>Lemiox rimosus</i>	Birdwing pearlymussel	G1 S1	Endangered
<i>Lexingtonia dolabelloides</i>	Slabside pearlymussel	G2 S2	Candidate
<i>Medionidus conradicus</i>	Cumberland moccasinshell	G3G4 S3	None
<i>Obovaria retusa</i>	Ring pink	G1 S1	Endangered
<i>Plethobasus cooperianus</i>	Orange-foot pimpleback	G1 S1	Endangered
<i>Pleurobema clava</i>	Clubshell	G2 SH	Endangered
<i>Pleurobema oviforme</i>	Tennessee clubshell	G3 S2S3	None
<i>Quadrula cylindrica cylindrica</i>	Rabbitsfoot	G3T3 S3	None
<i>Quadrula intermedia</i>	Cumberland monkeyface	G1 S1	Endangered
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3 S1	None
<i>Lithasia duttoniana</i>	Helmet rocksnail	G2 S2	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3 S1	None
<i>Lithasia jayana</i>	Rugose rocksnail	G2 S2	None

Western Highland Rim streams

The Western Highland Rim streams are those tributaries to both the Lower Duck and Buffalo watersheds that either originate or have the majority of their watersheds contained within the Western Highland Rim. Of all the tributary aquatic system targets, the Western Highland Rim streams have the greatest number of examples, representing 31 separate subwatersheds to the Lower Duck and Buffalo Rivers. As previously discussed, the elevation and geology influencing these streams is different than in the Inner Nashville Basin, and the Western Highland Rim streams are characterized by a slightly more moderate gradient with substrates comprised of more coarse and acidic chert and shale cobbles and sand, with less exposed bedrock. The predominant landcover in these tributary watersheds is native oak-hickory forested with some interspersed agricultural lands. Like the Eastern Highland Rim streams, these tributaries to the Lower Duck and Buffalo often contain spring-influenced headwaters and creeks.

The Western Highland Rim streams continue to support a very diverse fish fauna similar to that found in the mainstems of the Lower Duck and Buffalo according to surveys conducted by TVA in the early 2000s. Recent mollusk surveys report that the snail fauna also is intact in these systems (Ahlstedt et al. 2004). As with the Inner Nashville Basin streams, little is known about the historic distribution of mussel and snail species in the tributaries to the Lower Duck and Buffalo. Four Western Highland Rim streams were sampled by Ahlstedt, et al., but only two mussel species were found live and in limited numbers, Mountain creekshell (*Villosa vanuxemensis*) and Fluted shell (*Lasmigona costata*) (2004). Table 6 lists the mussel, as well as fish and snail species with Global Rarity Ranks of G1 (critically imperiled) to G3 currently known from the Western Highland Rim streams.

Table 6. Western Highland Rim stream fish, mussel, and snail nested species targets. (* indicates found only in the Buffalo River watershed).

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Etheostoma aquali</i>	Coppercheek darter	G2G3 S2S3	Management Concern
<i>Etheostoma boschungii</i> *	Slackwater darter	G1 S1	Threatened
<i>Etheostoma pseudovulatum</i>	Egg-mimic darter	G1 S1	Management Concern
<i>Hemitremia flammea</i>	Flame chub	G3 S3	Management Concern
<i>Noturus</i> sp. cf. <i>N. elegans</i>	Duck River saddled madtom	G1Q S1	None
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3 S1	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3 S1	None

Buffalo River mainstem

The Buffalo River mainstem aquatic system target includes only the main section of the river within its watershed boundary and not its tributaries. The tributaries to the Buffalo were combined with those of the Lower Duck into the Western Highland Rim target due to similarities in nested species targets and general threats. The instream habitat conditions of the Buffalo River itself are similar to that of the Lower Duck, but the Buffalo is classified as a small-sized river (Smith, et al. 2002). The substrates generally are sandier, but contain coarse cobble and gravel originating from chert, shale, and limestone deposits. The fish fauna are similar to that of the Lower Duck river, with the addition of species requiring lower gradient flow habitats such as the Slackwater darter (*Etheostoma boschungii*).

The mainstem of the Buffalo River remains in a free-flowing condition, having no dams or other large instream structures present along its length. This lack of disturbance to flows and habitat connectivity has resulted in the Buffalo maintaining an extremely diverse fish fauna. The fish community data collected by the TVA in the Buffalo River indicate that the fauna is in good to excellent condition, and the rarest species are still located during surveys performed from 2000-2003. The snail fauna in the Buffalo mainstem appears intact as well (Ahlstedt et al. 2004). However, the mussel fauna in the Buffalo River has experienced a dramatic decline compared to historical records of abundance.

In 1939, 33 species of mussels were documented from the Buffalo River. By 1968, surveys re-located only 17 species and noted that the fauna was sparsely scattered and in poor condition. Between 2000-2002, Ahlstedt, et al. returned to the five 1939 sampling sites and found mussels to be extremely rare, finding only 20 live individuals from 8 species (2004). Recruitment of these species has been in a long decline. Researchers in the late 1960s speculated, similar to conditions in the Lower Duck River, that the fauna was disturbed by the creation Kentucky Reservoir and the subsequent disruption of the mussel-host fish life cycle interaction. More recent hypotheses suggest that this disruption, combined with some type of chemical pollution of a chronic nature may be affecting survival of juvenile mussels after they separate from host fish. In addition, substrates in the mainstem appear highly destabilized as evidenced by point bar formations and more silt in the substrates (Ahlstedt et al. 2004). Table 7 lists the fish, mussel, and snail species with Global Rarity Ranks of G1 (critically imperiled) to G3 (vulnerable to extirpation or extinction) documented from the Buffalo River mainstem. Of these nested species targets, only the Cracking pearl mussel (*Hemistena lata*) has not been recently relocated and is thought to be in decline.

Table 7. Buffalo River mainstem fish and snail nested species targets

Scientific Name	Common Name	Global & State Rank	Federal Status
Fish			
<i>Cyprinella monacha</i>	Spotfin chub	G2 S2	Threatened
<i>Etheostoma aquali</i>	Coppercheek darter	G2G3 S2S3	Management Concern
<i>Etheostoma boschungii</i>	Slackwater darter	G1 S1	Threatened
<i>Etheostoma cinereum</i>	Ashy darter	G2G3 S2S3	Management Concern
<i>Etheostoma denoncourti</i>	Golden darter (former)	G3 S1S2	Management Concern
<i>Etheostoma pseudovulatum</i>	Egg-mimic darter	G1 S1	Management Concern
<i>Noturus</i> sp. cf. <i>N. elegans</i>	Duck River saddled madtom	G1Q S1	None
<i>Percina burtoni</i>	Blotchside logperch	G2 S2	Management Concern
<i>Percina macrocephala</i>	Longhead darter	G3 S2	None
Mussels			
<i>Hemistena lata</i>	Cracking pearlymussel	G1 S1	Endangered
Snails			
<i>Leptoxis praerosa</i>	Onyx rocksnail	G1G3	None
<i>Lithasia duttoniana</i>	Helmet rocksnail	G2 S2	None
<i>Lithasia geniculata fuliginosa</i>	Geniculate riversnail	G1G3	None

Key ecological attributes of aquatic system conservation targets

Following the identification of the seven primary aquatic system conservation targets, the planning team documented “key ecological attributes” for each target. These attributes fall in five general categories: hydrologic regime, energy regime, physical habitat, water quality, and biota. These five general attributes constitute the critical components of aquatic system function; any missing or altered attributes would result in the loss of system function over time. For these five categories, several more specific attributes and “indicators” of the attributes status were described. Collectively, these measurable indicators are intended to provide information on the status of the five general attribute categories. The following sections provide basic descriptions of the attributes and indicators identified during this planning exercise. More information for each attribute and indicator type as they relate specifically to the seven aquatic system targets is provided in Appendix 1. Of the five general key ecological attribute categories, indicators relating to energy regimes were not identified during this planning process and are therefore not discussed below.

Hydrologic Regime

Key Attribute: Hydrologic regime

Indicator: Magnitude of difference between current river operations and natural flow conditions in categories of low flow, high flow pulses, large floods, small floods, and extreme low flow conditions

Indicator comment: These 5 flow parameters were chosen based on the Limits of Hydrologic Alteration (LOHA) method advocated by Richter et al. 2005. The specific analysis of each flow category must be developed using the Indicators of Hydrologic Alteration analyses on river gage data from the Duck and Buffalo Rivers collected by the U.S. Geological Survey and TVA.

Key Attribute: Hydrologic regime

Indicator: Amount of surface & groundwater withdrawal in tributary systems

Indicator comment: Some surface water withdrawals occur in the targeted stream reaches, but groundwater withdrawals for agriculture also occur. The magnitude of these withdrawals and their effects on stream base flows is not known at this time. This indicator is a placeholder for determining if withdrawals in these systems are negatively affecting base flows.

Key Attribute: Hydrologic regime

Indicator: Overall percent of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how and where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds.

Key Attribute: Hydrologic regime

Indicator: Overall percent of watershed converted from hardwood to open land and/or non-native pine plantations

Indicator comment: Tracking changes in landcover from native hardwood to open land and/or non-native pine provides a gross indicator of the amount of forestry activity ongoing in the Lower Duck and Buffalo watersheds. This changing land use is directly related to the hydrologic regime in the targeted tributary systems and ultimately the mainstems. The indicator ratings need to be established based on analyses of the most recent landuse/landcover data available.

Key Attribute: Hydrologic Regime

Indicator: Date of Spring full pool attainment at Normandy Reservoir

Indicator comment: Sammons & Bettoli (1998) indicate that the major limiting factor for spawning success of targeted game fish are spring water levels, including the date of the year when Spring full pool level is reached and the duration of that full pool level in the Spring. The dates and duration need to be correlated with TVA's release pattern for meeting ecosystem and assimilation needs downstream of Normandy in the Spring & Summer.

Key Attribute: Hydrologic Regime

Indicator: Duration of full pool water levels in the Spring at Normandy Reservoir

Indicator comment: Sammons & Bettoli (1998) indicate that the major limiting factor for spawning success of targeted game fish are spring water levels, including the date of the year when Spring full pool level is reached & the duration of that full pool level in the Spring. The dates and duration need to be correlated with TVA's release pattern for meeting ecosystem and assimilation needs downstream of Normandy in the Spring & Summer.

Physical Habitat

Key Attribute: Habitat connectivity

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in the mainstem river and tributary habitats.

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of mainstem river miles with a minimum 100 foot forested buffer and percent of tributary stream miles with a minimum 50 foot forested buffer

Indicator comment: Intact buffer habitats are critical to aquatic system function. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites along tributaries, mainstems, and shoreline of Normandy Reservoir.

Indicator comment: This indicator is directly related to the amount of excess sediment entering the aquatic systems due to bank or shoreline erosion. Data collected by TVA and TDEC needs to be re-visited in order to determine more specific numbers and the status of erosion sites along the mainstems, subwatersheds, and the Normandy Reservoir shoreline.

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and field measures to ground truth levels of turbidity across the watersheds. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: Percent of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular Tennessee Department of Environment and Conservation (TDEC) and TVA sampling in the watersheds. Criteria for indicator ranges "good," "very good," etc. have been established for the watersheds within TVA & TDEC monitoring protocols.

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish, mussel, and snail targets. Embeddedness

is a characteristic measured by TDEC and TVA when performing habitat condition assessments.

Key Attribute: Habitat quality

Indicator: Number of maintained spawning benches in Normandy Reservoir

Indicator comment: The installation and maintenance of spawning benches is a management priority for TWRA at Normandy Reservoir in order to provide adequate spawning habitat for game fish species. As of (or in) 2004, 30 spawning benches have been constructed although some had been damaged by vandalism (Broadbent et al. 2004). Indicator ratings defining adequate numbers of spawning benches for Normandy need to be developed.

Water Quality

Key Attribute: Water quality

Indicator: Percent of stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TDEC's regular 5-year watershed assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: Presently no system to track the extent of septic system failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watersheds.

Key Attribute: Water chemistry

Indicator: Number of collection system overflow events and/or number of days in NPDES permit violation

Indicator comment: Tracking the management of municipal wastewater systems in the Duck and Buffalo watersheds will help provide a gross indicator of the amount of coliform bacterium and excess nutrients added to these systems over time.

Key Attribute: Water chemistry

Indicator: Nutrification as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data and scores are generated by TDEC and TVA during regular sampling events. The abundance and diversity of EPT genera present is a strong indicator of general habitat quality and whether a stream is receiving excess nutrients.

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. This indicator needs further validation based on TVA and TDEC criteria defining acceptable ranges of variation in this variable.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA and TDEC criteria defining acceptable ranges of variation in this variable.

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments.

Fish

Key Attribute: Population size & dynamics

Indicator: Percent of sampling areas with fish Index of Biotic Integrity (IBI) scores of Good or Excellent

Indicator comment: This indicator is a measure of the relative health and diversity of the native fish population in the Duck and Buffalo watersheds. The IBI scores are developed from regular TVA fish & EPT sampling in the watersheds. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watersheds within TVA monitoring protocols.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple sample sites

Indicator comment: TVA and TWRA collect fish sampling data in the Duck and Buffalo River watersheds. The nested fish species targets should be collected regularly during these sampling events. The "expected abundance" description needs further definition based on known population status for each nested target species. The indicator ratings (see Appendix 1) are intended to provide

thresholds that capture overall changes in species distributions as well as to be sensitive to when one or more nested targets may be dropping in abundance at one or more sites.

Key Attribute: Population size & dynamics

Indicator: Status of Barrens topminnow (*Fundulis julisia*) populations at restoration sites

Indicator comment: There are a limited number of Barrens topminnow restoration sites currently in the Upper Duck system upstream of Normandy Reservoir. The indicator ratings are preliminary and need further verification from the USFWS, the lead agency for Barrens topminnow management.

Key Attribute: Population size & dynamics

Indicator: Percent of known tributary habitats occupied by striated darter

Indicator comment: The striated darter is an Upper Duck River endemic fish found primarily in the Inner Nashville Basin streams. There are a limited number of known occurrences for this fish in these tributary streams. The indicator ratings (Appendix 1) are preliminary and need further verification from the USFWS and TWRA and will likely require an updated survey for the fish in its known habitats.

Key Attribute: Species composition/dominance

Indicator: Abundance of all nested target game fish species as measured by Catch per Unit Effort (CPUE)

Indicator comment: TWRA monitors several population parameters of targeted game fish at Normandy Reservoir (Broadbent et al. 2004). These species include Largemouth Bass, Spotted Bass, Black Crappie, Blacknose Black Crappie, White Crappie, Walleye, and Saugeye (Saugeye are present and monitored, but not long-term management targets). Surveys are performed largely using electrofishing & Neuston net (for larval density), with the exception of Saugeye which are sampled using gill nets. Each species has 3-4 measures and annual ratings for density, and the rating indicators (low, fair, good/moderate, & high) are defined by TWRA for each measure & species.

Key Attribute: Population size & dynamics

Indicator: Sport Fishing Index

Indicator comment: TVA generates a sport fishing index rating for the targeted game species in reservoirs each year. The score for each species can range from 20 (very poor) to 60 (excellent). The indicator ratings need further refinement in consultation with TVA.

Key Attribute: Population size & dynamics

Indicator: Fishing success as measured by Creel Surveys

Indicator comment: TWRA monitors several population parameters of targeted game fish at Normandy Reservoir (Broadbent et al. 2004). These species include Largemouth Bass, Spotted Bass, Black Crappie, Blacknose Black Crappie, White Crappie, and Saugeye. (Saugeye are present and monitored, but not long-term

management targets). Fishing success is measured by creel survey. Each species has 4 measures and annual ratings for fishing success, and the rating indicators (low, fair, good/moderate, & high) are defined by TWRA for each measure & species.

Snails

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple sample sites

Indicator comment: TVA and TWRA collect sampling data in the Duck and Buffalo watersheds, although current protocols do not involve snail collection. The most recent mollusc surveys were completed by Ahlstedt et al. 2004, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Mussels

Key Attribute: Population size & dynamics

Indicator: Percent of river miles occupied by G1-G2 mussel species

Indicator comment: This indicator was chosen to track the distribution of the most sensitive nested target mussel species. Currently, most of these species have distributions limited within Marshall and Maury Counties in the Upper Duck mainstem. The USFWS and TWRA have re-introduction and translocation goals for several species to attempt to re-establish G1 & G2 species throughout the Duck River mainstem.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target mussel species across multiple sample sites

Indicator comment: TVA, TWRA, and USFWS collect sampling data on mussel populations in the Duck and Buffalo watersheds. The most recent mollusc surveys were completed in by Ahlstedt et al. 2004, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Key Attribute: Population size & dynamics

Indicator: Shell length frequency distribution of nested target mussel species

Indicator comment: Length frequency distribution provides a method of tracking the reproductive and general population status of a species. The shell length of collected specimens is measured using calipers. An expected length frequency distribution is generally a normal shaped bell curve with most individuals in the sub-adult class but with good representation in both juvenile and older adult size classes.

Key Attribute: Population size & dynamics

Indicator: Mean mussel numbers measured by catch per unit effort (CPUE) at 21 sampling stations on the mainstem of the Duck River

Indicator comment: Mean number of individuals by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al. 2004). Tracking this statistic in the future will provide an assessment of overall population density stability in the Duck mainstem.

Key Attribute: Population size & dynamics

Indicator: Mean species richness measured by catch per unit effort (CPUE) at 21 sampling stations on the mainstem of the Duck River

Indicator comment: Mean species richness by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al. 2004). Tracking this statistic in the future will provide an assessment of how well species are distributed across multiple sample sites throughout the Upper Duck mainstem. May need to differentiate between Upper Duck sites & Lower Duck mainstem sites in consultation with Ahlstedt & Johnson.

Invasive species

Key Attribute: Species composition/dominance

Indicator: Percent of critical habitats with detrimental invasive species

Indicator comment: At present, invasive species are not known to be harming native fauna in the Duck and Buffalo River watersheds. *Corbicula* sp., an exotic Asian clam species, is highly prevalent throughout the Duck River in particular, but its effects on native mussel species are unknown. Other species of concern include potential migrations of exotic carp that are molluscivores from Kentucky Reservoir upstream into the Duck River.

Identification and analysis of threats to aquatic conservation targets

Threats to the aquatic systems can be described by their two general components, the stress and the source of stress. A stress is an unacceptable alteration to any of the general five conditions necessary to support aquatic system function: hydrologic regime, energy regime, water quality, physical habitat structure, energy regime, and biota. A source of stress is that activity leading to the unacceptable alteration, and a single stress can have multiple sources. For example, riparian buffers, an important physical habitat feature, are eliminated by both incompatible agricultural practices and by development practices in more urbanized areas. This section describes the threats analyses conducted for the Duck and Buffalo watersheds by examining them as their constituent stresses and sources.

Description of stresses to aquatic system targets

The planning team first identified the most common stresses to the seven aquatic system conservation targets. These stresses were subsequently ranked for their severity and scope. Severity is defined as the degree of damage either caused or expected to be caused by the stress within 10 years. Scope is defined as the spatial extent of the damage, or in other words, the prevalence of the stress in the targeted system type. The planning team's assessments of the severity and scope of stresses was based primarily on expert field experiences and augmented by GIS analyses of specific variables including State of Tennessee water quality assessments, an analysis of landcover data to determine status of riparian buffers, and the distribution of urban landcover in the Duck and Buffalo watersheds. In addition, the specific stresses and sources of pollutants documented by TDEC during regular water quality monitoring cycles were reviewed.

The results of the stress portion of the threats analyses for the seven aquatic system targets are presented in Tables 8-14 and Figures 3, 4, and 5. The primary stresses identified by the planning team across all the systems types were altered hydrologic regimes, altered instream physical habitat conditions, altered near-stream (buffer) habitat conditions, sedimentation, nutrient loading, thermal alteration, toxins and other contaminants, and altered species composition. Low dissolved oxygen is a common stress in these watersheds; however, it is generally associated with excess nutrients, so planning team members felt this was captured by the nutrient loading stress category. Sedimentation, which ultimately results in instream physical habitat changes, was identified as a separate stress in order to differentiate between those types of habitat alterations

resulting from in- or near-stream manipulations and those caused by chronic sedimentation originating from multiple sources in the watershed.

Of the eight stresses identified, the most prevalent were near-stream (buffer) habitat alteration, nutrient loading, and sedimentation, and to a lesser degree, thermal alteration and toxins or other contaminants. Examination of state water quality data indicates that the Inner Nashville Basin streams are the most stressed system followed by the Western Highland Rim streams (Tables 9 and 10). Over 246 miles of Inner Nashville Basin streams and 112 miles of Western Highland Rim streams do not meet designated water quality uses (TDEC 2005D). Toxins or other contaminants are more of a stress to the Buffalo River mainstem than in other systems (Table 13). As of 2004, all segments of the Lower Duck and Buffalo mainstems currently meet all their designated uses according to TDEC. In the Upper Duck River, the 12.1 river miles in the tailwaters downstream from Normandy Reservoir and another 1.6 river miles near the city of Shelbyville do not meet some designated uses. The majority of the direct tributaries to Normandy Reservoir are listed as fully supporting or non assessed, the exception being 36.3 stream miles of the Upper Duck mainstem upstream of Normandy and a few of its smaller tributaries (TDEC 2005D).

The biological data on fish, mussel, and snail species generally reflect the water quality conditions described by TDEC. One important note is that the response of these species to fluctuating water quality and other ecological conditions is complex and influenced by a variety of environmental and biological factors. Historical and recent trends in mussel species distributions and recruitment are a good example of the long time frame of biotic response. As of 2004, the most rare (G1 and G2) mussel species occupy in approximately 41% (46 river miles) of the Upper Duck River between the tailwaters of Normandy Reservoir and the watershed divide with the Lower Duck River, while the abundance of G1 – G3 species Lower Duck mainstem has improved since the late 1980s (Ahlstedt et al. 2004).

Fish index of biological integrity (IBI) scores more closely mirror water quality conditions documented by TDEC. TVA data through 2003 shows that the majority of sampling sites in the mainstems of the Upper Duck, Lower Duck, and Buffalo rate good to excellent. Eastern Highland Rim streams have consistently rated fair, and over 60% of the Western Highland Rim streams score good to excellent; however, several sampling locations in Maury county streams rated only fair. As of 2003, no sampling sites in Inner Nashville Basin streams rate better than fair, and over half scored poor/fair or poor. The relatively poor condition of the Inner Nashville Basin streams may be resulting in a declining Striated darter (*Etheostoma striatulum*) population, and new surveys are needed to assess the status of this Upper Duck River endemic species.

Table 8. Stresses to the Eastern Highland Rim streams.

Stress Category		Severity	Scope	Stress
1	Sedimentation	Medium	High	Medium
2	Altered physical habitat (instream)	Medium	High	Medium
3	Altered physical habitat (near-stream)	High	Very High	High
4	Thermal alteration	Medium	High	Medium
5	Toxins/contaminants	Medium	Medium	Medium
6	Altered hydrologic regime	Medium	Medium	Medium
7	Nutrient loading	High	High	High
8	Altered species composition	Very High	Medium	Medium

Table 9. Stresses to the Inner Nashville Basin streams.

Stress Category		Severity	Scope	Stress
1	Sedimentation	High	Very High	High
2	Altered physical habitat (instream)	High	Medium	Medium
3	Altered physical habitat (near-stream)	High	Very High	High
4	Thermal alteration	High	Very High	High
5	Toxins/contaminants	Medium	Medium	Medium
6	Altered hydrologic regime	Medium	Medium	Medium
7	Nutrient loading	High	Very High	High
8	Altered species composition	Low	Low	Low

Table 10. Stresses to Western Highland Rim streams.

Stress Category		Severity	Scope	Stress
1	Sedimentation	High	High	High
2	Altered physical habitat (instream)	Medium	Medium	Medium
3	Altered physical habitat (near-stream)	High	High	High
4	Thermal alteration	Medium	Medium	Medium
5	Toxins/contaminants	High	Medium	Medium
6	Altered hydrologic regime	Medium	High	Medium
7	Nutrient loading	High	High	High
8	Altered species composition	Low	Low	Low

Table 11. Stresses to the Upper Duck River mainstem

Stress Category		Severity	Scope	Stress
1	Sedimentation	Medium	Very High	Medium
2	Altered physical habitat (instream)	High	Medium	Medium
3	Altered physical habitat (near-stream)	Medium	Very High	Medium
4	Thermal alteration	Very High	Medium	Medium
5	Toxins/contaminants	Very High	Medium	Medium
6	Altered hydrologic regime	Very High	High	High
7	Nutrient loading	Medium	Very High	Medium
8	Altered species composition	Medium	Low	Low

Table 12. Stresses to the Lower Duck River mainstem.

Stress Category		Severity	Scope	Stress
1	Sedimentation	High	High	High
2	Altered physical habitat (instream)	Medium	Medium	Medium
3	Altered physical habitat (near-stream)	Very High	High	High
4	Thermal alteration	Medium	Medium	Medium
5	Toxins/contaminants	Medium	High	Medium
6	Altered hydrologic regime	Medium	Medium	Medium
7	Nutrient loading	Medium	Very High	Medium
8	Altered species composition	Low	Low	Low

Table 13. Stresses to the Buffalo River mainstem

Stress Category		Severity	Scope	Stress
1	Sedimentation	High	High	High
2	Altered physical habitat (instream)	Medium	Medium	Medium
3	Altered physical habitat (near-stream)	Medium	High	Medium
4	Thermal alteration	Low	Low	Low
5	Toxins/contaminants	High	High	High
6	Altered hydrologic regime	Medium	Medium	Medium
7	Nutrient loading	Medium	High	Medium
8	Altered species composition	Low	Low	Low

Table 14. Stresses to Normandy Reservoir.

	Stress Category	Severity	Scope	Stress
1	Sedimentation	Low	Low	Low
2	Altered physical habitat (shoreline stability)	High	High	High
3	Thermal alteration	Medium	Medium	Medium
4	Toxins/contaminants	Low	Low	Low
5	Altered hydrologic regime	Low	Medium	Low
6	Nutrient loading	High	High	High
7	Altered species composition	Low	Low	Low

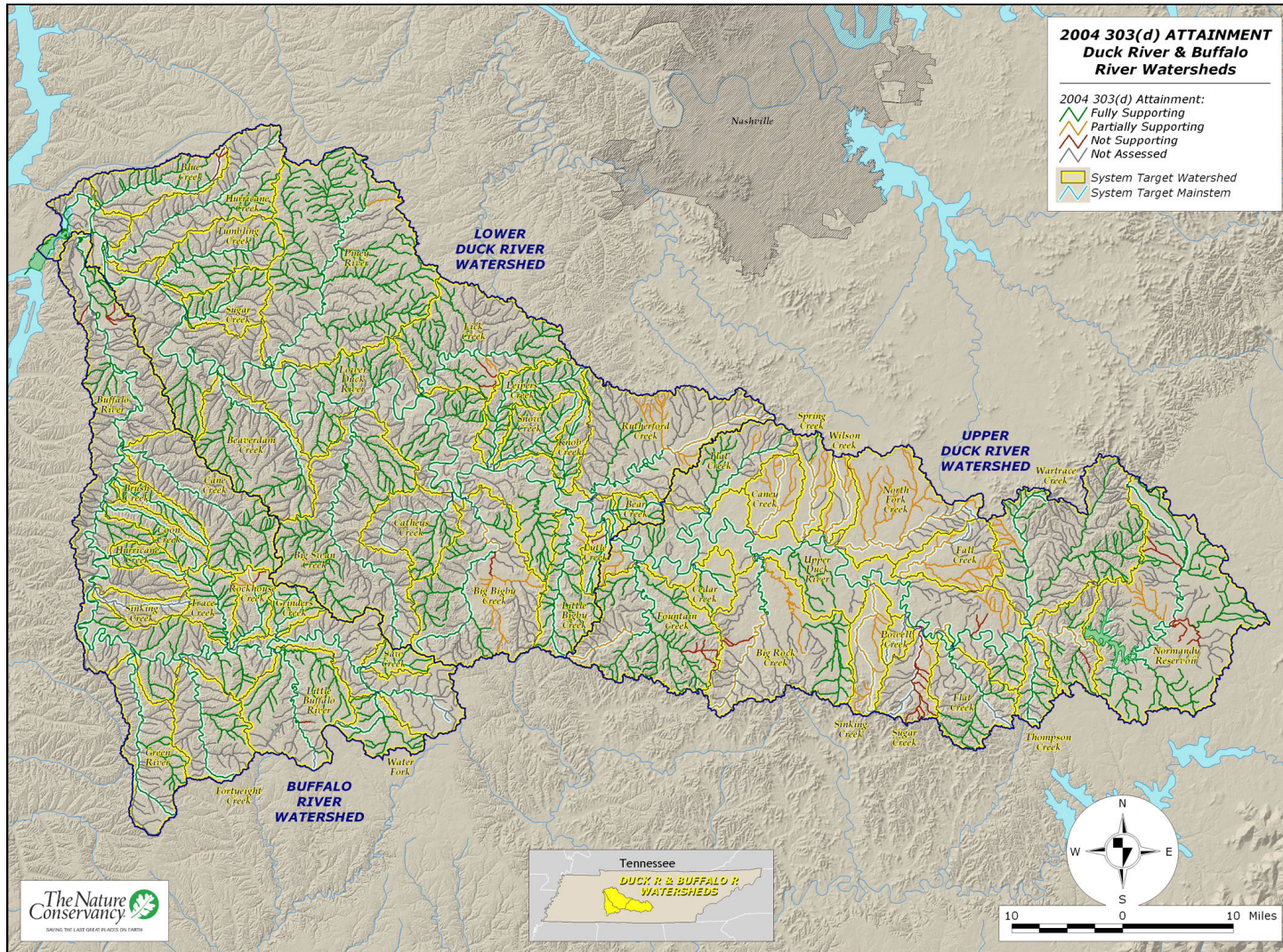


Figure 3. Status of water quality in the Duck and Buffalo watersheds according to the Tennessee Department of Environment and Conservation (2004).

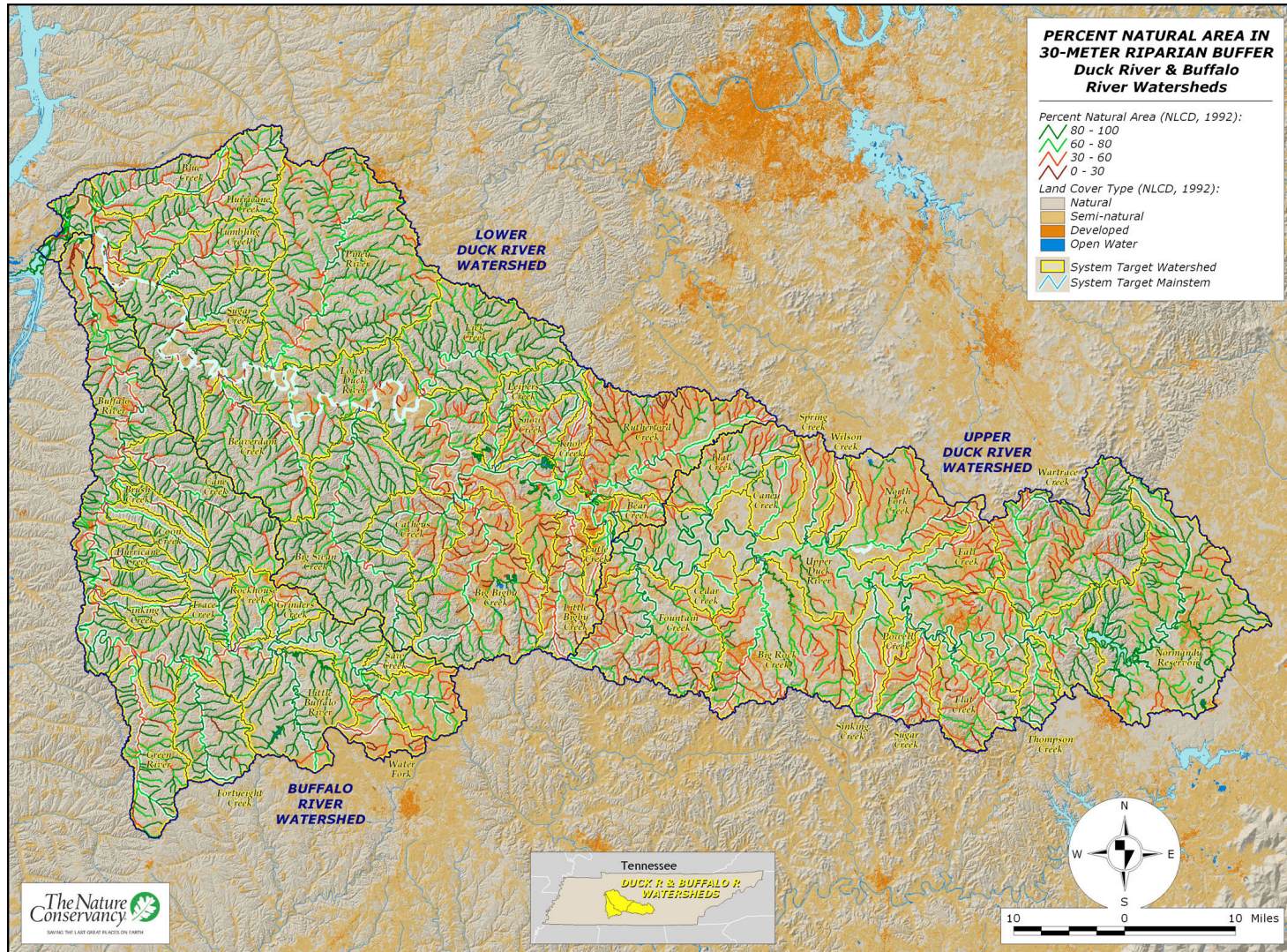


Figure 4. Condition of riparian and stream buffers in the Duck and Buffalo watersheds.

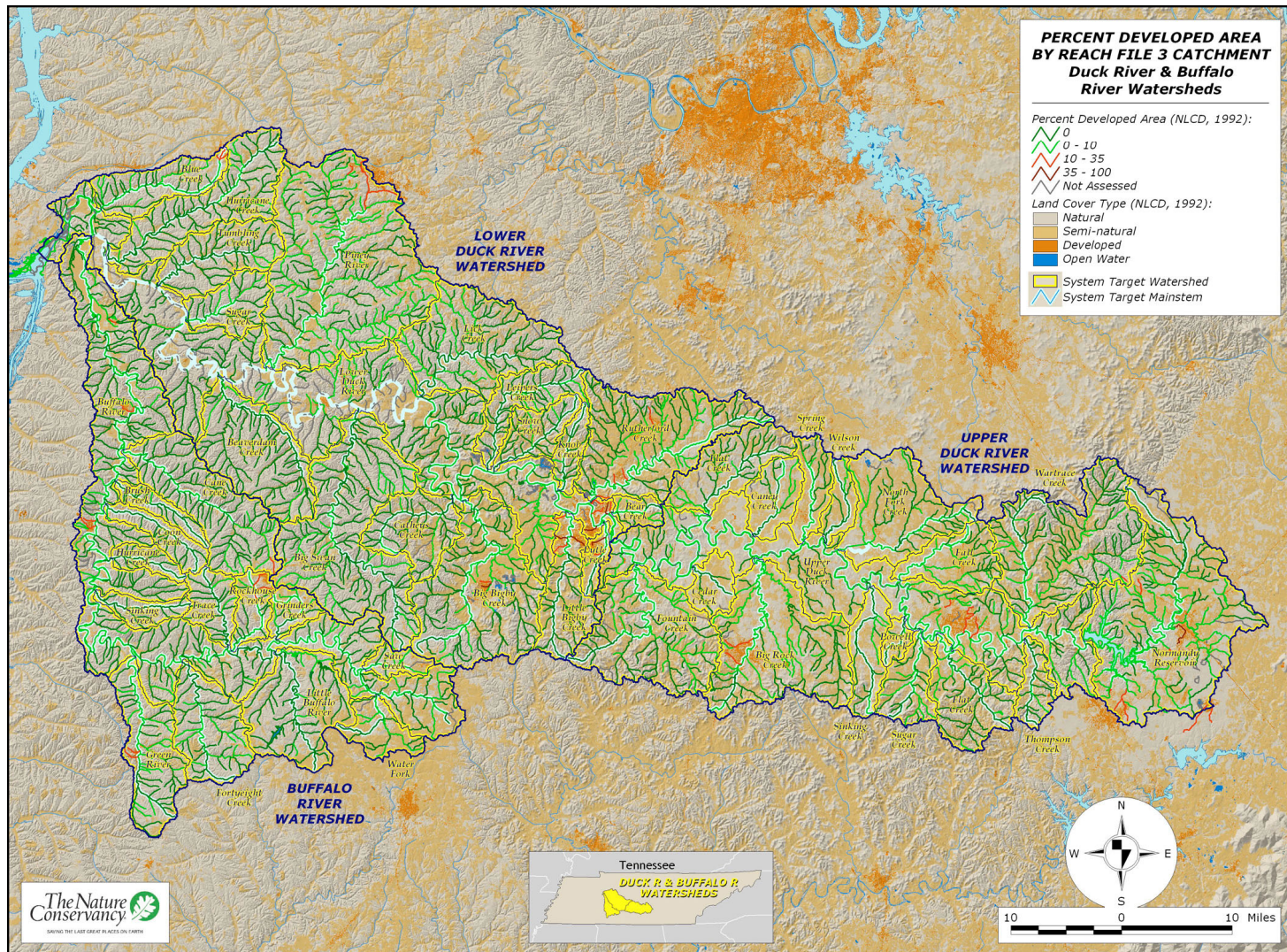


Figure 5. Land use/land cover status of streams and river segments in the Duck and Buffalo watersheds.

Description of sources of stress to aquatic system targets

After identifying the major stresses to the aquatic system targets in the Duck and Buffalo watersheds, the primary sources of these stresses were described in order to complete the threats assessment. Again, a source of stress is defined as an activity leading to an unacceptable alteration in key ecological attributes, and a single stress can have multiple sources. In identifying sources, the planning team again relied upon individual field expertise augmented by water quality, hydrologic, and biological data collected by the partner agencies. Table 15 provides an overall summary of the major threats to the aquatic system targets in the Duck and Buffalo Rivers. This summary information outlines which threats are most severe to specific system targets as well as to the Duck and Buffalo Rivers as a whole. It is important to note that the threats summary table represents the partners' review of existing data as well as expert opinion as to the potential severity of threats within a 10-year timeframe. Thus, some threats which are identified may not have direct correlation with existing data but represent expert opinion on the potential severity of the threat in the relatively near-future.

The primary threats to the Duck and Buffalo River watersheds can be summarized in six main categories: incompatible agricultural practices, wastewater management practices, urbanization, water management practices, resource extraction activities, and invasive species. The most pressing threats, those with Very High or High ratings, are associated with incompatible agricultural practices, wastewater management practices, urbanization, and water supply management practices (Table 15). More details about the nature of each threat category are provided in the subsequent sections of this report.

Incompatible agricultural practices

Incompatible agricultural practices have the capacity to negatively effect the hydrologic regime, physical habitat structure, and water quality of aquatic system targets. Current agricultural management practices often still involve removal of all riparian vegetation and/or maintenance of "clean" stream banks, allowing livestock access to streams for watering, channelizing small and medium-sized streams, and diverting surface run-off to sinkholes. These practices not only disturb or destroy aquatic and terrestrial habitats directly, but they increase nutrient, sediment, and toxin levels in both surface and subterranean stream systems. The Inner Nashville Basin streams, in particular, are negatively impacted by livestock production practices that include the types of activities outlined above. Hay production and row crop activities that infringe on stable floodplains and riparian buffers in the Eastern Highland Rim streams and the Lower Duck and Buffalo watersheds also stress aquatic systems.

Wastewater management practices

Wastewater management in the Duck and Buffalo River watersheds is achieved via publicly managed utilities and privately owned septic field dispersal. Without proper maintenance and upgrades to collection, processing, and disposal systems, both septic and public utility management systems can fail and cause pollution. TDEC's 2004 303(d) report outlines the extent of pollution attributed to public wastewater system management in the Duck and Buffalo watersheds. Defining the extent and severity of septic system failures is much more difficult. The populations in much of the unincorporated areas of these watersheds utilize septic systems to dispose of household sewage, and the geology and soils in many areas are largely inappropriate for long-term septic field disposal. Therefore, identifying portions of the watersheds where failures are likely, as well as understanding projected development patterns, will be critical to discerning and reducing the likelihood of pollutant contributions from septic disposal systems.

Three major Eastern Highland Rim stream targets, Wartrace Creek, the Little Duck, and the mainstem of the Upper Duck above Normandy Reservoir, are all negatively impacted by municipal sewage collection and/or treatment systems from the cities of Manchester and Bell Buckle. The city of Wartrace also has a NPDES permit in the Wartrace Creek system. The mainstem of the Upper Duck at Shelbyville is negatively impacted by municipal sewage collection and/or treatment system failure, 1.6 river miles not meeting designated uses. Within the last five to seven years Shelbyville has upgraded its treatment regime to remove excess chlorine in its discharges, a major improvement, but collection system failures still occur. The city of Chapel Hill also has a NPDES permit for wastewater discharge on the Upper Duck at river mile 185.5. Of the Inner Nashville Basin streams, only Big Rock Creek is utilized for municipal wastewater discharge, and this stream is negatively impacted by collection system failures in its watershed around the city of Lewisburg.

The mainstem of the Lower Duck is not generally used for municipal wastewater discharge, with the exceptions of the cities of Columbia and Centerville. No segments of the Lower Duck mainstem are listed as non- or partially supporting designated uses. However, several Western Highland Rim tributary streams to the Lower Duck are negatively impacted by collection system failures and/or failures of treatment systems. These streams include Blue Creek, Rockhouse Creek, Big Bigby, and Rutherford Creek which are affected by the McEwen, Hohenwald, Mt. Pleasant, and Spring Hill wastewater management systems, respectively. In the Buffalo River watershed, several minor facility NPDES municipal discharges are permitted on the mainstem or in one direct tributary (Green River). These include the communities of Waynesboro, Lobelville, Linden, and the Humphreys County-Buffalo Community. No impairment is documented in the mainstem Buffalo at this time; however, understanding the distribution of discharges in the watershed is important to tracking potential changes to water quality in the future.

Urbanization

Changing land uses from natural or semi-natural conditions to urban land uses can have detrimental effects on watershed hydrologic regimes, in and near-stream physical habitat, water quality, and biota. The main types of development occurring in the Duck and Buffalo watersheds involve the expansion of existing municipalities driven by commercial, industrial, and primary home development as well as the road and utility construction necessary to support growing communities. Because of the myriad of potential negative impacts of increasing urban landcover, land development practices must be carried out in ways that minimize these impacts to the greatest extent possible while still allowing for necessary community and economic development.

According to TDEC water quality and landuse/landcover data, the Eastern Highland Rim streams and Normandy Reservoir currently are not seriously impacted by urban land cover in their watersheds. The mainstem of the Upper Duck downstream of Normandy is largely surrounded by non-urban land uses, although this will change over time with the expansion of cities such as Shelbyville and Chapel Hill. Urban stormwater runoff already is documented as a nonpoint source pollution problem along the Upper Duck mainstem near Shelbyville. Of the Inner Nashville Basin streams, Big Rock Creek is the stream most heavily impacted by municipal storm water run-off from urban land cover. The majority of the main stem of the Lower Duck is not, as of 2005, experiencing major impacts or changes in land use, the exception being around the cities of Columbia and, to a lesser extent, Centerville. Western Highland Rim streams in the vicinities of the cities of Spring Hill and Columbia, including Rutherford Creek, Big and Little Bigby Creeks, and Lytle Creek, have been negatively impacted by urban land development practices. The Piney River, a Western Highland Rim tributary to the Lower Duck, has also been affected by urban land development. The mainstem of the Buffalo River remains largely in agricultural and forestry land uses and is not negatively affected by existing or expanding urban land uses at this time.

Water management practices

Water management practices, both historic and current, have affected the hydrologic regime, energy regime, physical habitat structure, and water quality of the Duck and Buffalo Rivers. These practices include the construction and operation of mill dams as early as the 1800s, the construction of small hydroelectric dams in the Duck River during the 1920s and 1930s, the completion of Normandy Dam in 1976 and its subsequent operation, construction of small ponds on tributary systems, surface water withdrawals from mainstems and tributaries and, to a lesser extent, ground water withdrawals. The disruption in longitudinal connectivity caused by early mill dams and any subsequent fragmentation of fauna is difficult to assess, but is considered to be improved in the mainstem of the Duck River. The presence of Normandy Reservoir in the Upper Duck prevents species migrations between several of the Eastern Highland Rim streams, although some opportunities remain in those streams whose confluence is above Normandy. The ongoing concerns regarding water management practices largely are related to the operation of Normandy Dam and growing municipal surface and groundwater withdrawals in the Duck and Buffalo watersheds.

Current disruptions in longitudinal connectivity from low-head dams remain somewhat of a concern as they create large pool habitats and change the typical run-of-river conditions behind them. Most mill dams in the Duck River have been naturally destroyed over time, leaving only Chumley and Cortner's Mill dams intact. The remaining low-head dams built in the 1920s and 1930s are owned by the cities of Shelbyville, Lewisburg (Lillard's Mill dam) and Columbia, and these are regularly breached in high flow events. The mainstems of the Lower Duck and Buffalo are in run-of-river conditions with no significant connectivity breaks. The Western Highland Rim tributaries to the Lower Duck currently experience the greatest amount of small instream impoundments. According to TDEC, 53 tributary dams that retain 30 acre-feet of water or have structures at least 20 feet high are located in these streams systems (TDEC 2005b).

Since the early 1990s, TVA has improved minimum flow and the dissolved oxygen levels in its releases from Normandy as part of the Reservoir Improvement Program (Ahlstedt et al. 2004). The subsequent response of fish, mussel, and snail species populations in the Upper Duck suggests that these improvements are assisting in faunal recovery efforts. As previously discussed in the "Land and Water Use Trends" section of this report, several growing communities utilize the Duck River as a primary municipal water source via withdrawals from Normandy Reservoir and the mainstem. The Buffalo River mainstem has no impoundments, but the river is used as a municipal water supply, for five communities, and groundwater resources are also utilized for municipal supply in the Buffalo watershed. Municipalities in the Lower Duck and Buffalo have looked to expand or establish new surface withdrawals from Lower Duck Western Highland Rim tributaries as recently as 2005. Some surface water

withdrawals occur in the targeted stream reaches, but groundwater withdrawals for agriculture, private wells, and municipal use also occur. The magnitude of these withdrawals and their effects on stream base flows is not known at this time.

In response to the growing demands for water in the Upper Duck River downstream to the lower watershed at Centerville, the Duck River Agency and its member utilities have completed a regional water supply assessment with a long-term planning horizon of 30 years. The plan is based on meeting projected growth demands while maintaining current state mandated flow targets at certain locations along the mainstem. Additional hydrologic analyses related specifically to ecosystem function thresholds would be useful to further refine flow targets as part of the larger Duck River water supply planning effort. In addition, this type of ecosystem flow analysis, coupled with a similar regional water supply planning approach, will be important to protecting the integrity of the Buffalo River as well. In the Buffalo River watershed, the extent and long-term availability of groundwater resources available for public supply is not well studied. Regional water supply planning in the Buffalo should involve more detailed study of groundwater resources and their relationship to surface water discharges.

Resource extraction

Three primary resources extraction activities occurred historically in the Duck and Buffalo watersheds: forestry, mining, and gravel dredging. These activities have the potential to greatly alter hydrologic regimes, energy regimes, in and near-stream physical habitat, and water quality. Incompatible logging in the late 19th and early 20th century destabilized tributaries and the mainstems. Phosphate and iron ore mining resulted in numerous contaminants being released into the Duck and Buffalo watersheds. Gravel dredging in tributaries and mainstems removed and destabilized shoal habitats. As of the early 21st century, phosphate mining in the Duck watershed has declined precipitously, and iron ore mining in the Buffalo watershed has also declined. Large-scale gravel dredging has also declined. Gravel dredging, even for private land management activities, now requires a permit from the State of Tennessee; however, these activities often still occur in the absence of a permit.

Forestry management is most common in the Lower Duck and Buffalo River watersheds, and the forest product industry is a significant sector of local economies. Understanding the nature of these management practices, including the percentage of land being clear cut or converted to non-native pine plantations, is important for identifying potential changes in hydrologic and energy regimes. The application of forestry best management practices to protect riparian buffers and other critical watershed features can help attenuate some of these effects. The extent of utilization of these practices by industrial or smaller

private forest landowners in the Lower Duck and Buffalo needs further examination.

Invasive species

The threat to native biota caused by invasive species is currently considered to be low, although this evaluation requires further verification. *Corbicula* sp., an Asian clam species, is highly prevalent in the Duck River watershed. The effects of this species on native mussel recruitment or other life history stages are unknown, but native species are recruiting well as of 2002 (Ahlstedt et al. 2004). The mosquito fish, *Gambusia* sp. is extremely detrimental to the rare Barrens topminnow (*Fundulus julisia*). Eliminating mosquito fish populations at Barrens topminnow restoration sites is a primary management strategy. Planning experts have some concerns that black carp and other Asian carp species that feed on molluscs will migrate from Kentucky Reservoir into the Lower Duck watershed. Monitoring the distribution of these fish species will be important in alerting resource managers about potential threats to mussels and snails in the Duck and Buffalo watersheds.

Table 15. Summary of threats across all targeted systems in the Duck and Buffalo watersheds.

Threats Across Systems		Upper Duck mainstem system	Lower Duck mainstem system	Buffalo mainstem system	Eastern Highland Rim streams	Western Highland Rim streams	Nashville Basin streams	Normandy Reservoir	Overall Threat Rank
1	Livestock production practices	Medium	High	Medium	High	High	Very High	Medium	Very High
2	Wastewater treatment	Medium	Low	Medium	High	High	High	High	High
3	Primary home development	High	Medium	Medium	High	High	High	Low	High
4	Commercial/industrial development	Medium	Medium	High	Medium	High	High	Low	High
5	Operation of dams or reservoirs	High	Low	Low	Medium	Medium	Low	Medium	High
6	Crop production practices	Medium	High	Medium	Medium	Medium	Medium	-	High
7	Channelization of rivers or streams	Medium	Medium	Medium	Medium	Medium	Medium	-	Medium
8	Surface water withdrawals	High	Low	Low	Low	Low	Low	Low	Medium
9	Mining practices (gravel extraction)	Low	Medium	Medium	Medium	Medium	Low	-	Medium
10	Development of roads or utilities	Low	Medium	Medium	Low	Medium	Low	-	Medium
11	Forestry practices	-	Medium	Medium	-	Medium	-	-	Medium
12	Invasive/alien species	Low	Low	Low	Medium	Low	Low	-	Low
13	Recreational vehicles	Low	Low	Low	Low	Low	Low	Low	Low
14	Excessive groundwater withdrawal	Low	-	-	Low	-	Low	-	Low
Threat Status for Targets and Site		High	High	High	High	High	Very High	High	Very High

Research needs related to key ecological attributes and threat analyses

The following section of this report outlines specific objectives and strategic actions to conserve the aquatic resources of the Duck and Buffalo watersheds. In order to improve our first attempts at quantifying thresholds for threat abatement and biological health, several research needs were identified by the planning team. These research needs are summarized below by general ecological attribute category. One of the primary approaches for addressing research needs will be establishing a process for integrating and utilizing the data collected by many of the partner agencies including TDEC, TNC, TVA, TWRA, USFWS, and USGS.

Hydrologic regime

- State minimum flow standards for the Duck and Buffalo Rivers need to be examined using the Indicators of Hydrologic Alteration and/or other hydrologic analyses. Ecological flow standards need to be protective of as much of the natural range of variation as possible.
- The impacts of surface and groundwater withdrawals and impoundments on the tributary systems in the Duck and Buffalo Rivers should be evaluated, with a particular emphasis on the effects to base flows and connectivity.
- A more thorough examination of urban land cover is warranted, with a particular emphasis on projecting where development is likely to occur and aquatic systems most vulnerable to stress from this changing landuse.
- An assessment of changes to the native oak-hickory forest cover in the Lower Duck and Buffalo watersheds since the 1980s is needed. In addition, forest land ownership patterns and the extent of forestry best management practice implementation in these watersheds needs to be described.
-

Physical Habitat Structure

- The initial analyses of riparian buffers need to be refined, as these assessments were based on 1992 data. Thresholds for the length of stream miles requiring near-stream buffers to maintain overall system function, and where buffer restoration activities should occur, need to be established.
- Data on erosion sites collected by partner agencies Need to revisit data collected by TVA and TDEC to document status of erosion sites.

- During the planning process, TWRA recommended exploring the development of a watershed-wide turbidity monitoring project based on coordinating satellite imagery data ground-truthed with field measurements.

Water Quality

- Explore opportunities to utilize aerial infrared or other methodology to document the extent of septic system failures in the Duck and Buffalo watersheds.
- A process for tracking the compliance of the municipal wastewater treatment facilities needs to be established in coordination with TDEC's NPDES program and the local utilities. In addition, a method for assessing wastewater infrastructure improvement priorities should be developed.

Biota

- Parameters for the expected abundance of nested target fish species need to be identified in consultation with partner agencies and academic experts.
- Need better coordination with the USFWS to track the status of Barrens topminnow restoration efforts.
- Updated status surveys are needed for rare fish species, particularly the Striated darter (*Etheostoma striatulum*) are warranted.
- A formal timeline for re-visiting mollusc survey sites and using established monitoring protocols should be developed.
- TWRA's state Aquatic Nuisance Species plan, currently under development, should be reviewed in order to incorporate appropriate monitoring or conservation strategies into this plan.

Conservation objectives and strategies

The primary conservation objectives and strategic actions identified by the planning team focus on the top threats to the Duck and Buffalo watersheds as well as the research, programmatic support, and partner communication necessary to refine objectives and measure the success of strategic actions over time. Eight objectives and corresponding strategic actions were defined by the planning team. These objectives include the restoration of near-stream (buffer) habitats, advancing federally listed species recovery, protecting riparian habitats and instream flows, managing important sport fisheries, working with local communities to better manage land and water supply development, and establishing more formal protocols for data exchange and coordination between partner agencies involved in resource management. Each specific conservation objective and its set of strategic actions are outlined below.

Objective 1: Achieve 15% net improvement in the near-stream habitat conditions of river mainstems and impaired tributary streams and by 2010.

Strategic action 1: Work with partners to ensure continued and expanded funding for existing incentive programs in the Duck & Buffalo watersheds (including USDA-NRCS Farm Bill programs, TNLIP, TDA, TN Stream Mitigation Program, TVA, USFWS, private partners).

Strategic action 2: Improve coordination between partner agencies to track restoration efforts and monitor implementation success.

Objective 2: Achieve better coordination between partner agency monitoring programs to establish a joint monitoring and assessment program by 2008.

Strategic action 1: Establish a core team of representatives from partner agencies to participate in monitoring team by 2006.

Strategic action 2: Re-evaluate and clarify plan targets and key ecological attributes with monitoring team in 2006.

Strategic action 3: Within the monitoring team, establish a systematic process coordinating data collection and communicating analysis results so that greater clarity on aquatic habitat and species conditions can be achieved for the Duck and Buffalo watersheds.

Objective 3: Advance recovery efforts for federally endangered, threatened, candidate, or species of management concern in the Duck and Buffalo watersheds.

Strategic action 1: Seek funding for a new survey and habitat condition assessment for the striated darter (*Etheostoma striatulum*) by 2007.

Strategic action 2: Continue partnership activities related to the restoration of the Barrens topminnow (*Fundulis julissia*) in the Duck watershed.

Strategic action 3:
Continue financial and staffing support for freshwater mussel propagation facility on the Upper Duck.

Strategic action 4: Work with USFWS regional offices and TWRA to re-establish populations of freshwater mussel species now extirpated from the Duck River.

Strategic action 5: In partnership with USFWS and TWRA, create systematic program for expanding populations of RTE mussel species in the Duck River.

Strategic action 6: Identify funding mechanism for studying potential sediment toxicity issues in the Buffalo River watershed by 2007.

Objective 4: Continue protection of important stream and mainstem river habitats through fee title or conservation easement acquisition.

Strategic action 1: Utilize appropriate state, federal, & private funds to purchase fee title rights to inholdings in the Yanahli Wildlife Management and State Natural Areas corridor.

Strategic action 2: Utilize appropriate state, federal, & private funds to purchase fee title or conservation easements for significant habitats in Western Highland Rim stream systems and Eastern Highland Rim wetlands.

Strategic action 3: Identify significant habitat areas in the Lower Duck and Buffalo currently in large or medium private timber ownership by 2007.

Strategic action 4: With the DRA, explore the development of a fee title or conservation easement acquisition program for riparian buffers along the mainstem of the Upper Duck River.

Strategic action 5: Work with TVA to ensure continued protection of shoreline and lands immediately adjacent to Normandy Reservoir.

Strategic action 6: Establish stronger partnerships with private groups and individuals capable of executing land protection strategies in the Lower Duck and Buffalo such as the Land Trust for Tennessee and the Swan Creek Land Trust.

Objective 5: Cooperate with local municipalities and county governments in the Duck/Buffalo region to develop environmentally sound principles in land use planning and economic development projects that are protective of their watersheds by 2010.

Strategic action 1: Continue implementation of Community Development Roundtables in the Upper Duck watershed through 2006.

Strategic action 2: Work with the Buffalo/Duck Resource Conservation and Development Council to identify appropriate "Growth Readiness Training" or community development roundtables for the Lower Duck & Buffalo watersheds.

Strategic action 3: Work with TDEC, TECD, & TDOT to encourage implementation of more environmentally sound infrastructure projects and economic development guidance to local communities.

Strategic action 4: Work with partners including county governments in the Upper Duck watershed to identify areas with failing septic systems and prevent the expansion of septic systems for wastewater management in inappropriate areas.

Strategic action 5: Work with TDEC, the Duck River Agency, and the Buffalo/Duck RC& D to conduct further investigations into the status of municipal collection system and treatment plant upgrades in the Duck & Buffalo to identify critical system improvement needs.

Strategic action 6: Support community education, outreach, and development projects that raise the profile of watershed protection efforts and promote the Duck and Buffalo Rivers as valuable aesthetic, economic, environmental, and recreational, resources.

Strategic action 7: Explore the possibility of developing a USFWS Habitat Conservation Plan with local communities to guide growth and economic development in the Upper Duck.

Objective 6: Work with partners to establish an instream flow policy for the Duck & Buffalo watersheds that protects ecosystem functions and designated uses by 2008.

Strategic action 1: Use existing hydrologic flow model for the Upper Duck and an Indicators of Hydrologic Alteration analysis to identify critical flow parameters that require protection.

Strategic action 2: Partner with TDEC & the DRA WRC to establish revised instream flow policy for the Duck River based on new analyses.

Strategic action 3: Identify critical flow parameters for the Buffalo River watershed using IHA analyses and Limits of Hydrologic Alteration methodology for incorporation into state instream flow policy management.

Strategic action 4: With the Buffalo/Duck RC&D and other local stakeholders, determine current water use demands and identify projected future demands of surface water in the Lower Duck & Buffalo Rivers.

Objective 7: Evaluate status of land use/land cover changes associated with forestry practices in the Lower Duck and Buffalo watersheds by 2007.

Strategic action 1:

Conduct GIS assessment of land use/land cover changes in the Lower Duck and Buffalo by 2006.

Strategic action 2:

Work with the Buffalo/Duck RC&D and NRCS to identify critical areas for forestry Best Management Practice implementation.

Objective 8: Maintain the quality of existing sport fish resource populations.

Strategic action 1:

Work with partners to ensure quality of fisheries resources in Normandy Reservoir and in the Duck and Buffalo River mainstems.

Strategic action 2:

Support ongoing work of the TWRA Normandy fish hatchery.

Strategic action 3:

Work with partners on habitat improvement projects and monitoring of sport fish populations in Normandy Reservoir.

Conservation project measures and adaptive management

The partners in this Duck and Buffalo River planning effort have worked collaboratively on joint projects in the watersheds for many years. This planning effort gave the partners an opportunity to review how we work together and what activities would benefit from better prioritization or emphasis. Establishing a process for sharing monitoring data and generating more comprehensive reports on the overall health of the Duck and Buffalo became a repeated theme throughout the year. Each partner agency leads, participates in, or has the capacity to conduct one or more types of monitoring or research identified in this plan. Appendix 1, which provides details on the specific ecological attributes in need of monitoring for each aquatic system target, also outlines which agencies collect and maintain data for each attribute type.

The Tennessee Department of Environment and Conservation conducts its watershed sampling and reporting on a 5-year cycle. The Duck River and Buffalo River reports were published in 2005, initiating the next phase of the “Watershed Management Cycle” (TDEC 2005a). The planning partners felt that aligning this conservation planning effort’s review & reporting cycle with that of TDEC’s will allow for a more efficient and coordinated approach to monitoring the overall health of the watersheds, including improvements in nested target fauna. Adopting this same cycle also allows for a regular review of strategic action implementation and for adjustments in conservation objectives as needed. Many of the strategic actions identified in this plan are already underway, but it will be necessary to successfully execute those outlined under Objective 2 in order to develop a coordinating monitoring and adaptive management approach for this conservation plan.

Conclusions

Participating in the Southeast Aquatic Resource Partnership's Pilot River Project allowed many of the partners involved in aquatic conservation in the Duck and Buffalo watersheds an opportunity to review the collaborative efforts aimed at protecting these outstanding natural resources. Utilizing this planning exercise to better coordinate efforts will allow the partners to maximize our capacity for tackling joint conservation priorities such as implementing better agricultural production and water resource conservation practices; improved water quality and hydrologic monitoring; endangered species recovery; fisheries management; enhanced recreational access; regional water supply planning; and environmentally sound land use planning and economic development.

The extent of mussel fauna recovery in the Duck River during the past decade is unprecedented in the Tennessee River basin. These recovery trends are just one example which indicates that conservation efforts can be successful. As we move forward, conservation activities must remain focused on the long-term, be executed consistently, and be directed at the most critical needs of the system. The myriad of conservation challenges demand that all partners involved in aquatic conservation efforts work together to direct our available resources at collective priorities. Few, if any, other watersheds provide such a tremendous opportunity to protect one of the last refugia for native Tennessee-Cumberland aquatic fauna. The Duck and Buffalo River partners are aware of this opportunity and committed to collective action that will conserve these Southeastern U.S. treasures.

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Key ecological attributes for the targeted aquatic systems in the Duck and Buffalo watersheds

Upper Duck River mainstem system.....62

Lower Duck River mainstem system.....71

Buffalo River mainstem system.....80

Eastern Highland Rim stream system.....87

Western Highland Rim stream system.....94

Inner Nashville Basin stream system.....101

Normandy Reservoir.....107

Upper Duck River mainstem system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: Magnitude of difference between current river operations and natural flow conditions in categories of low flow, high flow pulses, large floods, small floods, and extreme low flow conditions

Indicator comment: These 5 flow parameters were chosen based on the LOHA method advocated by Richter, et al. 2005. The specific analysis of each flow category must be developed using the Indicators of Hydrologic Alteration analyses using the reconstructed period of record data generated by Hydrologics, Inc. as part of their Duck River modeling project.

Indicator Ratings:

Poor: Current operations strongly deviate from natural run-of-river conditions in all flow categories

Fair: Current operations strongly deviate from natural run-of-river conditions in 2-3 flow categories

Good: Current river operations deviate slightly from natural run of river in one or more flow categories

Very Good: Natural run of river

Current rating comment: Faunal response of target fish and mollusc species in the mainstem of the Duck River suggest that as of 2005 current river operations are generally satisfactory. Further analysis needs to better define the specific variation between current ops and natural flows to generate a clearer understanding of what operational improvements the fauna may be responding to.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Current rating comment: The mainstem of the Upper Duck River below Normandy reservoir largely is in un-urbanized land cover. This may be expected to change as the cities of Shelbyville and Chapel Hill grow over time. Urbanization is largely affecting the Duck mainstem at Shelbyville (TDEC 2004 303(d) report).

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in the Upper Duck River mainstem to Normandy Reservoir. The mainstem of the Duck above Normandy is treated as part of the Eastern Highland Rim streams target. Because of the presence of Normandy Reservoir, the mainstem of the Duck below Normandy and the short section remaining above the reservoir are functionally separate systems.

Indicator Ratings:

Poor: one barrier or more per 10 river miles

Fair: one barrier per 10-20 river miles

Good: one barrier per 20-40 river miles

Very Good: less than one barrier per > 40 river miles

Current rating comment: The following lowhead dams still remain in the Upper Duck mainstem as of 2005: Chumley, Cortners' Mill, Shelbyville, Lillard's Mill, & Columbia. All of these dams are > 20 river miles apart. These dams are regularly breached during high flow conditions (Cortner's is the lowest), but do create large pools & change typical run-of-river flows behind them. Removing one or more of these dams to re-create run of river conditions may be a targeted conservation strategy in the future.

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of stream miles with a minimum 100 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites along mainstem

Indicator comment: Need to re-visit data collected by TVA and maintained the Duck River Agency in order to determine more specific numbers & the status of erosion sites along the mainstem.

Indicator Ratings:

Poor: Numerous erosion sites on the mainstem including many severe sites.

Fair: Numerous erosion sites on the mainstem including some severe sites.

Good: Several erosion sites on mainstem, most small to moderate in magnitude

Very Good: Few erosion sites on mainstem, and all of small magnitude

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current rating comment: The habitat conditions in the mainstem of the Upper Duck are generally rated as good or very good at most sample locations (TDEC 2004 & TVA).

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessments regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current rating comment: Of the approximately 113 river miles of the Upper Duck mainstem from the tailwaters of Normandy Reservoir (RM 248) to Columbia (RM 135), there are 13.7 RM not meeting their designated uses (TDEC 303(d) report 2004). 12.1 RM are the Normandy tailwaters and 1.6 RM around Shelbyville. The current rating = 88%.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The population in the unincorporated areas along the Upper Duck mainstem use septic systems to dispose of household sewage. The soils in many areas are largely inappropriate for long-term septic field disposal. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: The mainstem of the Upper Duck at Shelbyville is negatively impacted by municipal sewage collection and/or treatment system failure (TDEC 2004). 1.6 river miles are not meeting designated uses. Tracking the management of this municipal system will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to the system over time. Within the last 5-7 years Shelbyville has upgraded its treatment plant, but collection system failures still occur. The city of Chapel Hill also has a NPDES permit for wastewater discharge at RM 185.5. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nitrification as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable < 50% of sample sites

Fair: Dissolved oxygen measurements acceptable at 50-75% of sample sites

Good: Dissolved oxygen measurements acceptable at 75-90% of sample sites

Very Good: Dissolved oxygen measurements acceptable at all sample sites

Current rating comment: According to TDEC's 2004 303(d) report, the DO levels at most sampling sites on the mainstem Upper Duck are acceptable.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Current rating comment: Rating is based on TDEC 2004 303(d) report.

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current rating comment: TVA fish IBI data through 2003 shows that 83% of sample sites in mainstem of Upper Duck (5 out of 6 sites) rate good to excellent. The 6th site, at Normandy Hatchery, is in the tailwaters of Normandy Reservoir & still rated fair.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple sample sites

Indicator comment: TVA and TWRA collect fish sampling data in the Upper Duck mainstem. The nested fish species targets should be collected regularly during these sampling events. The "expected abundance" description needs further definition based on known population status for each nested target species. The indicator ratings are intended to provide thresholds that capture overall changes in species distributions as well as to be sensitive to when one or more nested targets may be dropping in abundance at one or more sites.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected abundance levels at all sample sites

Snails

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple sample sites

Indicator comment: TVA and TWRA collect sampling data in the mainstem of the Upper Duck, although current protocols do not involve snail collection. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, USFWS, TWRA & TNC staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected abundance levels at all sample sites

Current rating comment: The majority of the nested G1-G3 target mussel species are found at higher abundance levels relative to surveys performed in the late 1990s.

Mussels

Key Attribute: Population size & dynamics

Indicator: % of river miles occupied by G1-G2 mussel species

Indicator comment: This indicator was chosen to track the distribution of the most sensitive nested target mussel species. Currently, these species have distributions limited within Marshall & Maury Counties. The USFWS and TWRA have re-introduction & translocation goals for several species to attempt to re-establish G1 & G2 species further upstream in the mainstem.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: > 75%

Current rating comment: Of the approximately 113 river miles of the Upper Duck mainstem from the tailwaters of Normandy Reservoir (RM 248) to Columbia (RM 135), approximately 46 river miles contain G1-G2 target mussel species (RM 179 to RM 133), or 41% (Ahlstedt, et al. 2004).

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple sample sites

Indicator comment: TVA and TWRA collect sampling data in the mainstem of the Upper Duck, although current protocols do not involve snail collection. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, TWRA, USFWS, & TNC staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected abundance levels at all sample sites

Current Rating: Good

Current rating comment: Rating based on Ahlstedt, et al. 2004 data on Duck River molluscs.

Key Attribute: Population size & dynamics

Indicator: Shell length frequency distribution of nested target mussel species

Indicator comment: Length frequency distribution provides a method of tracking the reproductive & general population status of a species. The shell length of collected specimens is measured using calipers. An expected length frequency distribution is generally a normal shaped bell curve with most individuals in the sub-adult class but with good representation in both juvenile & older adult size classes.

Indicator Ratings:

Poor: < 50% of all species at expected length-frequency distributions at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected length-frequency distributions at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected length-frequency distributions at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected length-frequency distributions at all sample sites

Current Rating: Good

Current rating comment: According to Ahlstedt et al. 2004, the status of most target mussel species is generally good; however, some species e.g, tan riffleshell, have not been re-located in recent decades.

Key Attribute: Population size & dynamics

Indicator: Mean mussel numbers measured by CPUE at 21 sampling stations on the mainstem

Indicator comment: Mean number of individuals by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al 2004). Tracking this statistic in the future will provide an assessment of overall population density stability in the Duck mainstem. May need to differentiate between Upper Duck sites & Lower Duck mainstem sites in consultation with Ahlstedt & Johnson.

Indicator Ratings:**Poor:** < 27 individuals per hour**Fair:** 27-43 individuals per hour**Good:** 44-69 individuals per hour**Very Good:** > 70 individuals per hour**Current Rating:** Very Good

Current rating comment: Indicator ratings are based on data from Ahlstedt et al. 2004 on CPUE averages at 21 fixed sites sampled in both 1988 and 2002. The thresholds between ratings are related to these averages +/- one standard deviation. In 1988 the average was 34.8 +/- 7.9 individuals and in 2002 the average was 79.2 +/- 8.5 individuals. The CPUE numbers from 2002 are considered to be very good by Ahlstedt, et al and are therefore the basis of the indicator standard.

Key Attribute: Population size & dynamics**Indicator:** Mean species richness measured by CPUE at 21 sampling stations on the mainstem

Indicator comment: Mean species richness by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al 2004). Tracking this statistic in the future will provide an assessment of how well species are distributed across multiple sample sites throughout the Upper Duck mainstem. May need to differentiate between Upper Duck sites & Lower Duck mainstem sites in consultation with Ahlstedt & Johnson.

Indicator Ratings:**Poor:** < 4.8 species per hour**Fair:** 4.8-6.3 species per hour**Good:** 6.4-7.0 species per hour**Very Good:** > 7.0 species per hour**Current Rating:** Good

Current rating comment: Indicator ratings are based on data from Ahlstedt et al. 2004 on CPUE averages at 21 fixed sites sampled in both 1988 and 2002. The thresholds between ratings are related to these averages +/- one standard deviation. In 1988 the average was 5.4 +/- 0.6 species and in 2002 the average was 6.6 +/- 0.2 species.

Invasive Species**Key Attribute:** Species composition/dominance**Indicator:** Percent of critical habitats with detrimental invasive species

Indicator comment: At present, invasive species are not harming native fauna in the mainstem of the Upper Duck. Corbicula sp., an Asian clam species, is highly prevalent throughout the mainstem, but currently is not considered a threat to native species.

Indicator Ratings:**Poor:** > 50%**Fair:** 30-50%**Good:** 10-30%**Very Good:** 0-10%**Current Rating:** Very Good

Current rating comment: Rating is based on information collected by Ahlstedt, et al 2002 and TVA watershed surveys.

Lower Duck River mainstem system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: Magnitude of difference between current river operations and natural flow conditions in categories of low flow, high flow pulses, large floods, small floods, and extreme low flow conditions

Indicator comment: These 5 flow parameters were chosen based on the LOHA method advocated by Richter, et al. 2005. The specific analysis of each flow category must be developed using the Indicators of Hydrologic Alteration analyses using the reconstructed period of record data generated by Hydrologics, Inc. as part of their Duck River modelling project.

Indicator Ratings:

Poor: Current operations strongly deviate from natural run-of-river conditions in all flow categories

Fair: Current operations strongly deviate from natural run-of-river conditions in 2-3 flow categories

Good: Current river operations deviate slightly from natural run of river in one or more flow categories

Very Good: Natural run of river

Current rating comment: Faunal response of target fish and mollusc species in the mainstem of the Lower Duck River suggest that as of 2005 current river operations are generally satisfactory. Because of the large amount of intervening watershed between Normandy & the Lower Duck mainstem, the dam's operational effects are generally not significant. However, in light of future water supply demands a flow analysis needs to establish the flow regime pattern that should be maintained in the future.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Current rating comment: The majority of the main stem of the Lower Duck is not, as of 2005, experiencing major impacts or changes in land use, the exception being around the cities of Columbia and, to a lesser extent, Centerville.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed converted from hardwood to open land and/or non-native pine plantations

Indicator comment: Tracking changes in landcover from native hardwood to open land and/or non-native pine provides a gross indicator of the amount of forestry activity ongoing in the Lower Duck and Buffalo watersheds. This changing land use is directly related to the hydrologic regime in the targeted tributary systems. The indicator ratings need to be established based on analyses of the most recent landuse/landcover data available.

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in the Lower Duck mainstem from Columbia to KY Reservoir.

Indicator Ratings:

Poor: on average, one barrier or more per 2 stream miles

Fair: on average, one barrier per 2-10 stream miles

Good: on average, one barrier per 10-40 stream miles

Very Good: on average, less than one barrier per > 40 stream miles

Current rating comment: The status of this indicator needs to be further verified using TVA data; however, it is currently understood that the mainstem of the Lower Duck is largely in a free-flowing run-of-river condition.

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of river miles with a minimum 100 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites along mainstem

Indicator comment: Need to re-visit data collected by TVA and maintained the Duck River Agency in order to determine more specific numbers & the status of erosion sites along the mainstem.

Poor: Numerous erosion sites on the mainstem including many severe sites.

Fair: Numerous erosion sites on the mainstem including some severe sites.

Good: Several erosion sites on mainstem, most small to moderate in magnitude

Very Good: Few erosion sites on mainstem, and all of small magnitude

Current Rating: Fair

Current rating comment: Rating is based on general knowledge of condition of Lower Duck mainstem. Row crop agricultural practices that mostly eliminate riparian

buffers are common along the mainstem, resulting in numerous & often severe bank erosion sites.

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current Rating: Very Good

Current rating comment: According to TDEC's 2004 303(d) report, all segments of the Lower Duck mainstem are meeting designated uses.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The unincorporated areas of the Lower Duck & Buffalo watersheds primarily use septic systems to dispose of household sewage. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: The mainstem of the Lower Duck is not generally used for municipal wastewater discharge, with the exception of Columbia and Centerville. However, tracking the management of this municipal system will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to this mainstem over time. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nutrification as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable < 50% of sample sites

Fair: Dissolved oxygen measurements acceptable at 50-75% of sample sites

Good: Dissolved oxygen measurements acceptable at 75-90% of sample sites

Very Good: Dissolved oxygen measurements acceptable at all sample sites

Current Rating: Very Good

Current rating comment: TDEC 2004 303(d) report.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current Rating: Very Good

Current rating comment: TVA fish IBI data through 2003 shows that 100% of sample sites in mainstem of Lower Duck (4 out of 4 sites) rate good.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple sample sites

Indicator comment: TVA and TWRA collect fish sampling data in the Lower Duck mainstem. The nested fish species targets should be collected regularly during these sampling events. The "expected abundance" description needs further definition based on known population status for each nested target species. The indicator ratings are intended to provide thresholds that capture overall changes in species distributions as well as to be sensitive to when one or more nested targets may be dropping in abundance at one or more sites.

Indicator Ratings:

Poor: All species at expected abundance levels at < 30% of sample sites

Fair: All species at expected abundance levels at only 30-50% of sample sites

Good: All species at expected abundance levels at 50-75% of sample sites

Very Good: All species at expected abundance levels at 75-100% of sample sites

Snails

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple sample sites

Indicator comment: TVA and TWRA collect sampling data in the mainstem of the Lower Duck, although current protocols do not involve snail collection. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, TWRA, USFWS, & TNC staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites
Very Good: All species at expected abundance levels at all sample sites
Current Rating: Very Good
Current rating comment: Rating based on Ahlstedt, et al. 2004 data on Duck River molluscs. 13 sample sites were distributed in the Lower Duck mainstem.

Mussels

Key Attribute: Population size & dynamics
Indicator: % of river miles occupied by G1-G2 mussel species
Indicator comment: This indicator was chosen to track the distribution of the most sensitive nested target mussel species. Currently, these species have distributions limited mostly within Marshall & Maury Counties in the Upper Duck watershed. The USFWS and TWRA have re-introduction & translocation goals for several species to attempt to re-establish G1 & G2 species further upstream & some downstream in the mainstem.
Indicator Ratings:
Poor: < 30%
Fair: 30-50%
Good: 50-75%
Very Good: > 75%
Current Rating: Fair
Current rating comment: Of the approximately 113 river miles of the Upper Duck mainstem from the tailwaters of Normandy Reservoir (RM 248) to Columbia (RM 135), approximately 46 river miles contain G1-G2 target mussel species (RM 179 to RM 133), or 41% (Ahlstedt, et al. 2004).

Key Attribute: Population size & dynamics
Indicator: Abundance of nested target mussel species across multiple sample sites
Indicator comment: TVA and TWRA collect mussel sampling data in the mainstem of the Lower Duck. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, USFWS, TNC & TWRA staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted mussel species.
Indicator Ratings:
Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites
Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites
Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites
Very Good: All species at expected abundance levels at all sample sites
Current Rating: Good
Current rating comment: The majority of the nested G1-G3 target mussel species known to occur in the mainstem of the Lower Duck are found at higher abundance levels relative to previous surveys (Ahlstedt et al 2004).

Key Attribute: Population size & dynamics

Indicator: Shell length frequency distribution of nested target mussel species

Indicator comment: Length frequency distribution provides a method of tracking the reproductive & general population status of a species. The shell length of collected specimens is measured using calipers. An expected length frequency distribution is generally a normal shaped bell curve with most individuals in the sub-adult class but with good representation in both juvenile & older adult size classes.

Indicator Ratings:

Poor: < 50% of all species at expected length-frequency distributions at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected length-frequency distributions at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected length-frequency distributions at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected length-frequency distributions at all sample sites

Current Rating: Good

Current rating comment: According to Ahlstedt et al. 2004, the status of most target mussel species is generally good; however, some species e.g, tan riffleshell, have not been re-located in recent decades.

Key Attribute: Population size & dynamics

Indicator: Mean mussel numbers measured by CPUE at 21 sampling stations on the mainstem

Indicator comment: Mean number of individuals by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al 2004). Tracking this statistic in the future will provide an assessment of overall population density stability in the Duck mainstem. May need to differentiate between Upper Duck sites & Lower Duck mainstem sites in consultation with Ahlstedt & Johnson.

Indicator Ratings:

Poor: < 27 individuals per hour

Fair: 27-43 individuals per hour

Good: 44-69 individuals per hour

Very Good: > 70 individuals per hour

Current Rating: Very Good

Current rating comment: Indicator ratings are based on data from Ahlstedt et al. 2004 on CPUE averages at 21 fixed sites sampled in both 1988 and 2002. The thresholds between ratings are related to these averages +/- one standard deviation. In 1988 the average was 34.8 +/- 7.9 individuals and in 2002 the average was 79.2 +/- 8.5 individuals. The CPUE numbers from 2002 are considered to be very good by Ahlstedt, et al and are therefore the basis of the indicator standard.

Key Attribute: Population size & dynamics

Indicator: Mean species richness measured by CPUE at 21 sampling stations on the mainstem

Indicator comment: Mean species richness by CPUE has been documented in 1988 and 2002 at 21 fixed sampling locations (Ahlstedt et al 2004). Tracking this statistic in the future will provide an assessment of how well species are distributed across multiple sample sites throughout the Duck mainstem. May need to differentiate between Upper Duck sites & Lower Duck mainstem sites in consultation with Ahlstedt & Johnson.

Indicator Ratings:**Poor:** < 4.8 species per hour**Fair:** 4.8-6.3 species per hour**Good:** 6.4-7.0 species per hour**Very Good:** > 7.0 species per hour**Current Rating:** Good**Current rating comment:** Indicator ratings are based on data from Ahlstedt et al. 2004 on CPUE averages at 21 fixed sites sampled in both 1988 and 2002. The thresholds between ratings are related to these averages +/- one standard deviation. In 1988 the average was 5.4 +/- 0.6 species and in 2002 the average was 6.6 +/- 0.2 species.Invasive Species**Key Attribute:** Species composition/dominance**Indicator:** Percent of critical habitats with detrimental invasive species**Indicator comment:** Indicator was chosen as a method of documenting the extent of any future invasive species migrations upstream from KY Reservoir. At present, invasive species are not harming native fauna in the Lower Duck mainstem.**Indicator Ratings:****Poor:** > 50%**Fair:** 30-50%**Good:** 10-30%**Very Good:** 0-10%**Current Rating:** Very Good**Current rating comment:** At present, invasive species are not harming native fauna in the Lower Duck mainstem.

Buffalo River mainstem system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: Magnitude of difference between current river operations and natural flow conditions in categories of low flow, high flow pulses, large floods, small floods, and extreme low flow conditions

Indicator comment: These 5 flow parameters were chosen based on the LOHA method advocated by Richter, et al. 2005. The specific analysis of each flow category must be developed using the Indicators of Hydrologic Alteration analyses using USGS gauge data from the Buffalo.

Indicator Ratings:

Poor: Current operations strongly deviate from natural run-of-river conditions in all flow categories

Fair: Current operations strongly deviate from natural run-of-river conditions in 2-3 flow categories

Good: Current river operations deviate slightly from natural run of river in one or more flow categories

Very Good: Natural run of river

Current Rating: Good

Current rating comment: The Buffalo River is unimpounded but the river is used as a municipal waters supply, for Lobelville, Linden, Waynesboro, & the Summertown withdrawal approved in 2003 (approx.). Hohenwald utilizes groundwater (TDEC 2005 Buffalo River Watershed Assessment). In light of future water supply demands a flow analysis needs to establish the flow regime pattern that should be maintained in the future. This analysis would also need to document the utilization of groundwater resources as water supply in the area.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Current Rating: Very Good

Date of Current Rating:

Current rating comment: The mainstem of the Buffalo is largely in agricultural land use & not urban cover.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed converted from hardwood to open land and/or non-native pine plantations

Indicator comment: Tracking changes in landcover from native hardwood to open land and/or non-native pine provides a gross indicator of the amount of forestry activity ongoing in the Lower Duck and Buffalo watersheds. This changing land use is directly related to the hydrologic regime in the targeted tributary systems. The indicator ratings need to be established based on analyses of the most recent landuse/landcover data available.

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in the mainstem of the Buffalo River.

Indicator Ratings:

Poor: on average, one barrier or more per 2 stream miles

Fair: on average, one barrier per 2-10 stream miles

Good: on average, one barrier per 10-40 stream miles

Very Good: on average, less than one barrier per > 40 stream miles

Current Rating: Very Good

Current rating comment: The presence of habitat barriers needs to be assessed further using TVA and remote sensing data, although the Buffalo mainstem is unimpounded & free-flowing

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of river miles with a minimum 100 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites along mainstem

Indicator comment: Need to re-visit data collected by TVA & TDEC in order to determine more specific numbers & the status of erosion sites along the mainstem.

Indicator Ratings:

Poor: Numerous erosion sites on the mainstem including many severe sites.

Fair: Numerous erosion sites on the mainstem including some severe sites.

Good: Several erosion sites on mainstem, most small to moderate in magnitude

Very Good: Few erosion sites on mainstem, and all of small magnitude

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current Rating: Very Good

Current rating comment: According to TDEC's 2004 303(d) report, all segments of the Buffalo River mainstem are meeting designated uses.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The unincorporated areas of the Lower Duck & Buffalo watersheds primarily use septic systems to dispose of household sewage. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: The following minor facility NPDES municipal sewer dischargers are permitted on the Buffalo or a direct trib (Green River): Waynesboro, Lobelville, Linden, Humphreys County-Buffalo Community. Tracking the management of these municipal systems will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to this stream over time. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nutrification as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable at few sites in 4 or fewer tribes

Fair: Dissolved oxygen measurements acceptable at multiple sites in only 5-6 targeted tribes

Good: Dissolved oxygen measurements acceptable at multiple sites in 7-8 targeted tribes

Very Good: Dissolved oxygen measurements acceptable at multiple sites in all 9 targeted tribes.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Current Rating: Good

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor
Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor
Good: 75-90% of all sample sites rate good; none poor
Very Good: > 90% of sample sites rate very good to excellent; none poor

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple sample sites

Indicator comment: TVA and TWRA collect fish sampling data in the Buffalo mainstem. The nested fish species targets should be collected regularly during these sampling events. The "expected abundance" description needs further definition based on known population status for each nested target species. The indicator ratings are intended to provide thresholds that capture overall changes in species distributions as well as to be sensitive to when one or more nested targets may be dropping in abundance at one or more sites.

Indicator Ratings:

Poor: All species at expected abundance levels at < 30% of sample sites

Fair: All species at expected abundance levels at only 30-50% of sample sites

Good: All species at expected abundance levels at 50-75% of sample sites

Very Good: All species at expected abundance levels at 75-100% of sample sites

Current Rating: Good

Snails

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple sample sites

Indicator comment: TVA and TWRA collect sampling data in the mainstem of the Buffalo, although current protocols do not involve snail collection. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, TWRA, USFWS, & TNC staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted snail species.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected abundance levels at all sample sites

Mussels

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target mussel species across multiple sample sites

Indicator comment: TVA and TWRA collect mussel sampling data in the mainstem of the Buffalo. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, USFWS, TNC & TWRA staff, and this data should be re-visited in 5-7 year cycles to evaluate the status of targeted mussel species. Five sites were sampled by Ahlstedt et al. 2004.

Indicator Ratings:

Poor: < 50% of all species at expected abundance levels at all sample sites; more than one species at lower than expected abundance at more than 25% of sample sites

Fair: 50-75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Good: > 75% of all species at expected abundance levels at all sample sites; no species at lower than expected abundance at more than 25% of sample sites

Very Good: All species at expected abundance levels at all sample sites

Current Rating: Poor

Current rating comment: According to Ahlstedt et al 2004, the mussel fauna of the Buffalo has been in decline for several decades with an unknown cause.

Invasive Species

Key Attribute: Species composition/dominance

Indicator: Percent of critical habitats with detrimental invasive species

Indicator comment: Indicator was chosen as a method of documenting the extent of any future invasive species migrations upstream from KY Reservoir.

Indicator Ratings:

Poor: > 50%

Fair: 30-50%

Good: 10-30%

Very Good: 0-10%

Current Rating: Very Good

Current rating comment: At present, invasive species are not harming native fauna in the mainstem of the Buffalo (TWRA).

Eastern Highland Rim stream system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: amount of surface & groundwater withdrawal in tributary systems

Indicator comment: Some surface water withdrawals occur in the targeted stream reaches, but groundwater withdrawals for agriculture also occur. The magnitude of these withdrawals and their effects on stream base flows is not known at this time. This indicator is a placeholder for determining if withdrawals in these systems are negatively affecting base flows.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Current Rating: Good

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in these Upper Duck headwater streams. Because of the presence of Normandy Reservoir, however, most nested target species may not migrate between targeted tributaries such as Watrace/Garrison Creek, Thompson Creek, and the Upper & Little Duck River. There is some opportunity for migration between the Little Duck and the mainstem of the Upper Duck as their confluence is upstream of Normandy Reservoir. The indicator ratings need further confirmation by examining TVA data from Coffee County.

Indicator Ratings:

Poor: on average, one barrier or more per 2 stream miles
Fair: on average, one barrier per 2-10 stream miles
Good: on average, one barrier per 10-40 stream miles
Very Good: on average, less than one barrier per > 40 stream miles

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of stream miles with a minimum 50 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites in tributaries

Indicator comment: The number of tributaries, three, is related to the 3 main targeted reaches from the regional FCA assessment: Watrace/Garrison Fork, Thompson Creek, and the Duck River (and its direct tributaries) upstream of Normandy Reservoir. TVA has collected extensive data on livestock access points and erosion sites in these tributary systems. Need to re-visit this data in order to determine more specific numbers & status of erosion sites within these 3 targeted reaches & their tributaries.

Indicator Ratings:

Poor: Numerous erosion sites in 3 main subwatersheds including many severe sites.

Fair: Numerous erosion sites in 3 main subwatersheds including some severe sites.

Good: Several erosion sites in 3 main subwatersheds, most small to moderate in magnitude

Very Good: Few erosion sites in 3 main subwatersheds, and all of small magnitude

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The population outside the cities of Manchester, Bell Buckle & Tullahoma use septic systems to dispose of household sewage. The soils in many areas (Guthrie series, in particular) are largely inappropriate in many areas for long-term septic field disposal. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed. One such subdivision-wide failure has been documented in northern Coffee County, and the residents, the city of Manchester, and the State have been working on an expensive retrofit to link the subdivision to municipal sewer.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: Three major stream targets, Wartrace Creek, the Little Duck, and the mainstem of the Upper Duck above Normandy Reservoir are all negatively impacted by municipal sewage collection and/or treatment systems from Manchester and Bell Buckle (TDEC 2004). The city of Wartrace also has a NPDES permit in the Wartrace Creek system. Tracking the management of these municipal systems will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to these systems over time. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nutrifaction as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable at few sites in 1 or fewer tribbs

Fair: Dissolved oxygen measurements acceptable at multiple sites in only 1-2 tribbs

Good: Dissolved oxygen measurements acceptable at multiple sites in 2-3 tribbs

Very Good: Dissolved oxygen measurements acceptable at multiple sites in all 3 tribbs

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current Rating: Fair

Current rating comment: Rating is based on TVA sampling data as of 2003.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple tribs

Indicator comment: TVA and TWRA collect fish sampling data in these tributary systems of the Upper Duck located above Normandy reservoir. The nested fish species located within these tributaries should be collected regularly during these sampling events. The number of tributaries, three, is related to the 3 main targeted reaches from the regional FCA assessment: Watrace/Garrison Fork, Thompson Creek, and the Duck River (and its direct tributaries) upstream of Normandy Reservoir.

Indicator Ratings:

Poor: All species at expected abundance levels at sample sites in 1 or fewer tribs

Fair: All species at expected abundance levels at sample sites in only 1-2 tribs
Good: All species at expected abundance levels at sample sites in 2-3 tribs
Very Good: All species at expected abundance levels at sample sites within the 3 main tributary systems

Key Attribute: Population size & dynamics

Indicator: Status of Barrens topminnow populations at restoration sites

Indicator comment: There are a limited number of Barrens topminnow restoration sites currently in the Upper Duck system upstream of Normandy Reservoir. The indicator ratings are preliminary and need further verification from the USFWS, the lead agency for Barrens topminnow management.

Indicator Ratings:

Poor: < 50% of all restored populations stable

Fair: 50-75% of all restored populations stable

Good: 75-90% of all restored populations stable

Very Good: > 90% of all restored populations stable

Current Rating: Fair

Current rating comment: Current rating needs further clarification based on consultation with the USFWS, which in partnership with TN Tech researchers has conducted status surveys for the past several years.

Snails

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target snail species across multiple tribs

Indicator comment: TVA and TWRA collect sampling data in these tributary systems of the Upper Duck located above Normandy reservoir. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, TWRA, USFWS, & TNC staff. The number of tributaries, three, is related to the 3 main targeted reaches from the regional FCA assessment: Watrace/Garrison Fork, Thompson Creek, and the Duck River (and its direct tributaries) upstream of Normandy Reservoir.

Indicator Ratings:

Poor: All species at expected abundance levels at sample sites in 1 or fewer tribs

Fair: All species at expected abundance levels at sample sites in only 1-2 tribs

Good: All species at expected abundance levels at sample sites in 2-3 tribs

Very Good: All species at expected abundance levels at sample sites within the 3 main tributary systems

Mussels

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target mussel species across multiple tribs

Indicator comment: TVA and TWRA collect sampling data in these tributary systems of the Upper Duck located above Normandy reservoir. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, TWRA, USFWS, & TNC staff. The number of tributaries, three, is related to the 3 main targeted reaches from the regional FCA assessment: Watrace/Garrison Fork, Thompson Creek, and the Duck River (and its direct tributaries) upstream of Normandy Reservoir. According to Ahlstedt et al 2004,

6-7 mussel species were documented in the Wartrace/Garrison Fork prior to the construction of Normandy Dam.

Indicator Ratings:

Poor: All species at expected abundance levels at sample sites in 1 or fewer tribs

Fair: All species at expected abundance levels at sample sites in only 1-2 tribs

Good: All species at expected abundance levels at sample sites in 2-3 tribs

Very Good: All species at expected abundance levels at sample sites within the 3 main tributary systems

Current Rating: Poor

Current rating comment: According to Ahlstedt et al 2004, 6-7 species of mussels were found in The Wartrace/Garrison Fork prior to the development of Normandy Reservoir. Because the reservoir now effectively isolates the 3 main subwatersheds, it is doubtful that the mussel fauna would recover without translocating species.

Invasive Species

Key Attribute: Species composition/dominance

Indicator: Percent of critical habitats with detrimental invasive species

Indicator comment: At present, invasive species are not harming native fauna in these tributaries with the exception of mosquito fish, *Gambusia*, which is extremely detrimental to the Barrens topminnow. A key challenge to maintaining healthy Barrens topminnow populations is controlling mosquito fish impacts.

Indicator Ratings:

Poor: > 50%

Fair: 30-50%

Good: 10-30%

Very Good: 0-10%

Western Highland Rim stream system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: amount of surface & groundwater withdrawal in tributary systems

Indicator comment: Some surface water withdrawals occur in the targeted stream reaches, but groundwater withdrawals for agriculture, private wells, and municipal use also occur. The magnitude of these withdrawals and their effects on stream base flows is not known at this time. This indicator is a placeholder for determining if withdrawals in these systems are negatively affecting base flows. Municipalities in the Lower Duck & Buffalo have looked to expand or establish new surface withdrawals from these tributaries as recently as 2005 (Piney River, Bon Aqua/Lyles).

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds. The primary tributaries currently the most heavily impacted are Rutherford, Big & Little Bigby, Lytle, and the Piney River.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed converted from hardwood to open land and/or non-native pine plantations

Indicator comment: Tracking changes in landcover from native hardwood to open land and/or non-native pine provides a gross indicator of the amount of forestry activity ongoing in the Lower Duck and Buffalo watersheds. This changing land use is directly related to the hydrologic regime in the targeted tributary systems. The indicator ratings need to be established based on analyses of the most recent landuse/landcover data available.

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in these Upper Duck tributary streams. The presence of structural barriers needs to be assessed further using TVA and remote sensing data maintained by the Duck River Agency. According to TDEC, there are 53 dams that retain 30 acre-feet of water or have structures at least 20 feet high in the tributaries to the Lower Duck (Lower Duck Watershed Assessment Report 2005).

Indicator Ratings:

Poor: on average, one barrier or more per 2 stream miles

Fair: on average, one barrier per 2-10 stream miles

Good: on average, one barrier per 10-40 stream miles

Very Good: on average, less than one barrier per > 40 stream miles

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of stream miles with a minimum 50 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Current Rating: Good

Current rating comment: This rating is based on general knowledge of the status of these tributaries and has not been specifically measured at this time.

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites in tributaries

Indicator comment: The number of tributaries, nine, is related to the 9 main targeted reaches from the regional FCA assessment. TVA has collected data on livestock access points and erosion sites. Need to re-visit this data in order to determine more specific numbers & status of erosion sites within these 31 targeted reaches & their tributaries.

Indicator Ratings:

Poor: Numerous erosion sites in 31 main subwatersheds including many severe sites.

Fair: Numerous erosion sites in 31 main subwatersheds including some severe sites.

Good: Several erosion sites in 31 main subwatersheds, most small to moderate in magnitude

Very Good: Few erosion sites in 31 main subwatersheds, and all of small magnitude

Current Rating: Fair

Current rating comment: This rating is based on general knowledge of the status of these tributaries and has not been specifically measured at this time.

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current Rating: Fair

Current rating comment: Rating is based on information from TDEC watershed assessment at 305(b) reporting (2004). Over 112 miles of Western Rim streams do not fully meet designated uses.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The unincorporated areas of the Lower Duck & Buffalo watersheds primarily use septic systems to dispose of household sewage. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: At least three major Western Highland Rim streams are negatively impacted by municipal sewage collection and/or treatment systems (TDEC 2004). These include Blue Creek, Rockhouse Creek, Big Bigby, & Rutherford Creek which are affected by the McEwen, Hohenwald, and Mt. Pleasant, & Spring Hill discharges, respectively. Tracking the management of these municipal systems will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to this stream over time. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nutrifaction as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable at few sites in 4 or fewer tribbs

Fair: Dissolved oxygen measurements acceptable at multiple sites in only 5-6 targeted tribbs

Good: Dissolved oxygen measurements acceptable at multiple sites in 7-8 targeted tribbs

Very Good: Dissolved oxygen measurements acceptable at multiple sites in all 9 targeted tribbs.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition

assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current Rating: Fair

Current rating comment: Rating is based on data collected by TVA. The most recent (2003) data suggests that over 60% of the sampling locations scored good to excellent. Several sampling locations in Maury County tributaries had only Fair IBI scores.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple tribs

Indicator comment: TVA and TWRA collect fish sampling data in these tributary systems of the Upper Duck. The nested fish species located within these tributaries should be collected regularly during these sampling events. The sample sites are distributed across the 31 targeted Western Highland Rim tributaries identified in the regional FCA assessment. More sample sites may need to be established in the future.

Indicator Ratings:

Poor: All species at expected abundance levels at < 30% of sample sites

Fair: All species at expected abundance levels at only 30-50% of sample sites

Good: All species at expected abundance levels at 50-75% of sample sites

Very Good: All species at expected abundance levels at 75-100% of sample sites

Snails & Mussels

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target mollusc species across multiple tribs

Indicator comment: TVA and TWRA collect data in these tributary systems of the Lower Duck & Buffalo irregularly. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, & TWRA staff. Freshwater snails are currently much more stable & abundant in these Western Highland Rim streams than are mussels. Mussels are

currently not nested targets but were apparently historically located in these tributary systems (Ahlstedt et al. 2004).

Indicator Ratings:

Poor: All species at expected abundance levels at < 30% of sample sites

Fair: All species at expected abundance levels at only 30-50% of sample sites

Good: All species at expected abundance levels at 50-75% of sample sites

Very Good: All species at expected abundance levels at 75-100% of sample sites

Invasive Species

Key Attribute: Species composition/dominance

Indicator: Percent of tributaries with detrimental invasive species

Indicator comment: At present, invasive species are not harming native fauna in the Western Highland Rim tributaries.

Indicator Ratings:

Poor: > 50%

Fair: 30-50%

Good: 10-30%

Very Good: 0-10%

Current Rating: Very Good

Current rating comment: Based on 2003 TVA survey data, invasive species are not currently a serious threat to native fauna in the Western Highland Rim streams.

Inner Nashville Basin stream system

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: amount of surface & groundwater withdrawal in tributary systems

Indicator comment: Some surface water withdrawals occur in the targeted stream reaches, but groundwater withdrawals for agriculture, private wells, and municipal use (Chapel Hill) also occur. The magnitude of these withdrawals and their effects on stream base flows is not known at this time. This indicator is a placeholder for determining if withdrawals in these systems are negatively affecting base flows.

Key Attribute: Hydrologic Regime

Indicator: overall % of watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when stream degradation begins to occur around specific urban landcover thresholds. The tributary watershed currently the most heavily impacted is Big Rock Creek.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Physical Habitat

Key Attribute: Habitat fragmentation

Indicator: Structural or habitat condition barriers to longitudinal migration

Indicator comment: This indicator captures the ability for species to migrate longitudinally in these Upper Duck tributary streams. Many of these tributaries naturally run dry during the year leaving pockets of suitable habitat that become re-connected during wet seasons. This type of fragmentation is natural to the system, however, water quality stresses can become more severe in the isolated habitat reaches during dry seasons (TDEC 2003). The presence of structural barriers needs to be assessed further using TVA and remote sensing data maintained by the Duck River Agency.

Indicator Ratings:

Poor: on average, one barrier or more per 2 stream miles

Fair: on average, one barrier per 2-10 stream miles

Good: on average, one barrier per 10-40 stream miles

Very Good: on average, less than one barrier per > 40 stream miles

Key Attribute: Intact near stream (buffer) habitat

Indicator: Percent of stream miles with a minimum 50 foot forested buffer

Indicator comment: To be determined using GIS. Need to generate buffers around existing streams. Indicator ratings need clarification based on research regarding what % of stream miles within a watershed need to be buffered in order to maintain healthy system function.

Indicator Ratings:

Poor: < 30%

Fair: 30-50%

Good: 50-75%

Very Good: 75-100%

Current Rating: Poor

Current rating comment: This rating is based on general knowledge of the status of these tributaries and has not been specifically measured at this time.

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of bank erosion sites in tributaries

Indicator comment: The number of tributaries, nine, is related to the 9 main targeted reaches from the regional FCA assessment. TVA has collected data on livestock access points and erosion sites. Need to re-visit this data in order to determine more specific numbers & status of erosion sites within these 9 targeted reaches & their tributaries.

Indicator Ratings:

Poor: Numerous erosion sites in 9 main subwatersheds including many severe sites.

Fair: Numerous erosion sites in 9 main subwatersheds including some severe sites.

Good: Several erosion sites in 9 main subwatersheds, most small to moderate in magnitude

Very Good: Few erosion sites in 9 main subwatersheds, and all of small magnitude

Current Rating: Poor

Current rating comment: This rating is based on general knowledge of the status of these tributaries and has not been specifically measured at this time.

Key Attribute: Soil/sediment stability & movement

Indicator: turbidity

Indicator comment: TWRA suggested the use of a combination of LandSat imagery and on the ground measures to ground truth levels of turbidity across the watershed. This type of monitoring program, if developed, could provide a regular, gross assessment of water quality at a large scale. This indicator was chosen as a placeholder for guiding future conversations on this type of monitoring project.

Conservation Target: Nashville Basin streams

Category: Condition

Key Attribute: Habitat quality

Indicator: % of sampling areas with instream habitat condition assessments of Good or Very Good

Indicator comment: Indicator is based on regular TDEC and TVA sampling in the watershed. Criteria for indicator ranges "good," "very good," etc. have been established for the watershed within TVA & TDEC monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Key Attribute: Habitat quality

Indicator: Average percent substrate embeddedness at sampling locations

Indicator comment: Substrate quality is critical to successful foraging and reproduction and in many nested fish and snail targets. Embeddedness is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The rating percentages need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: > 75%

Fair: 40-75%

Good: 20-40%

Very Good: 0-20%

Water Quality

Key Attribute: Water quality

Indicator: % stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. Specific data from these assessment regarding certain parameters (nutrients, DO, temperature, embeddedness, & habitat alteration) can be parsed out for a greater understanding of specific measurements at sampling locations. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current Rating: Poor

Current rating comment: Rating is based on information from TDEC watershed assessment at 305(b) reporting. Over 246 miles of Nashville Basin streams do not fully meet designated uses.

Key Attribute: Water chemistry

Indicator: Documented occurrences of septic system failure

Indicator comment: The population outside the cities of Shelbyville & Lewisburg use septic systems to dispose of household sewage. The soils of the inner Nashville Basin are largely inappropriate in many areas for long-term septic field disposal. Presently no system to track instances of failures exists, however, aerial infrared photography may be a helpful tool. TVA, USGS, & the Duck River Agency may consider conducting such survey work to identify problem areas in the watershed.

Key Attribute: Water chemistry

Indicator: # of collection system overflow events and/or # of days of STP in permit violation

Indicator comment: Big Rock Creek, a major Nashville Basin tributary, is negatively impacted by municipal sewage collection and/or treatment systems (TDEC 2004). Tracking the management of this municipal system will help provide a gross indicator about the amount of coliform bacterium and excess nutrients added to this stream over time. The indicator ratings need to be developed in consultation with TDEC.

Key Attribute: Water chemistry

Indicator: Nitrification as determined by EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: EPT data & scores are generated by TDEC and TVA. The abundance & diversity of EPT genera present is a strong indicator of whether a stream is receiving excess nutrients. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at sampling locations

Indicator comment: Dissolved oxygen is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: Dissolved oxygen measurements acceptable at few sites in 4 or fewer tribs

Fair: Dissolved oxygen measurements acceptable at multiple sites in only 5-6 targeted tribs

Good: Dissolved oxygen measurements acceptable at multiple sites in 7-8 targeted tribs

Very Good: Dissolved oxygen measurements acceptable at multiple sites in all 9 targeted tribs.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations for this stream target

Indicator comment: Temperature is a characteristic measured by TDEC and TVA when performing habitat condition assessments. The indicator ratings need further validation based on TVA & TDEC criteria defining this variable.

Indicator Ratings:

Poor: more than 2 standard deviations from natural range of temp. variability

Fair: 1-2 standard deviations from natural range of temp. variability

Good: < 1 standard deviation from natural range of temp. variability

Very Good: within natural range of temp. variability

Biota

Insects

Key Attribute: Presence/abundance of key functional guilds

Indicator: EPT macroinvertebrate scores from multiple sampling sites

Indicator comment: Monitoring the status of EPT species is critical to understanding the condition of the food chain upon which many nested targets depend. EPTs are regularly monitored by TDEC and TVA when performing habitat condition assessments. The indicator ratings are based on the scoring criteria used by TDEC & TVA.

Indicator Ratings:

Poor: 25-50% of sample sites rate good or higher; 50-75% of sites rate fair or poor

Fair: 50-75% of sample sites rate good or higher; 25-50% of sites rate fair or poor

Good: 75-90% of all sample sites rate good; none poor

Very Good: > 90% of sample sites rate very good to excellent; none poor

Fish

Key Attribute: Population size & dynamics

Indicator: % of sampling areas with fish IBI score of Good or Excellent

Indicator comment: Indicator is based on regular TVA fish & EPT sampling in the watershed. Rating scores are based on data collected within last 5 years. Criteria for "good" and "excellent," etc. have been established for the watershed within TVA monitoring protocols.

Indicator Ratings:

Poor: < 50%

Fair: 50-75%

Good: 75-90%

Very Good: 90-100%

Current Rating: Poor

Current rating comment: Rating is based on data collected by TVA. The most recent (2003) data suggests that over half of the sampling locations scored poor/fair or poor and none better than a fair rating.

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target fish species across multiple tribs

Indicator comment: TVA and TWRA collect fish sampling data in these tributary systems of the Upper Duck. The nested fish species located within these tributaries should be collected regularly during these sampling events. The number of tributaries, nine, is related to the 9 main targeted reaches from the regional FCA assessment.

Indicator Ratings:

Poor: All species at expected abundance levels at sample sites in 4 or fewer tribs

Fair: All species at expected abundance levels at sample sites in only 5-6 tribs

Good: All species at expected abundance levels at sample sites in 7-8 tribs

Very Good: All species at expected abundance levels at sample sites within 9 main tributary systems

Key Attribute: Population size & dynamics

Indicator: % of known tributary habitats occupied by striated darter

Indicator comment: The striated darter is an Upper Duck river endemic fish found primarily in Nashville Basin streams. There are a limited number of known occurrences for this fish in these tributary streams. The indicator ratings are preliminary and need further verification from the USFWS and TWRA and will likely require an updated survey for the fish in its known habitats.

Indicator Ratings:

Poor: located in < 50% of known tributary habitats

Fair: located in 50-75% of known tributary habitat

Good: located in 75-90% of known tributary habitats

Very Good: located in > 90% of known tributary habitats

Snails & Mussels

Key Attribute: Population size & dynamics

Indicator: Abundance of nested target mollusc species across multiple tribs

Indicator comment: TVA and TWRA collect data in these tributary systems of the Upper Duck. The most recent mollusc surveys were completed in 2003 by USGS, TNARI, & TWRA staff. The number of tributaries, nine, is related to the 9 main targeted reaches from the regional FCA assessment.

Indicator Ratings:

Poor: All species at expected abundance levels at sample sites in 4 or fewer tribs

Fair: All species at expected abundance levels at sample sites in only 5-6 tribs

Good: All species at expected abundance levels at sample sites in 7-8 tribs

Very Good: All species at expected abundance levels at sample sites within 9 main tributary systems

Invasive Species

Key Attribute: Species composition/dominance

Indicator: Percent of tributaries with detrimental invasive species

Indicator comment: At present, invasive species are not harming native fauna in the Nashville Basin tributaries.

Indicator Ratings:

Poor: > 50%

Fair: 30-50%

Good: 10-30%

Very Good: 0-10%

Current Rating: Very Good

Current rating comment: Based on 2003 TVA survey data, invasive species are not currently a serious threat to native fauna in the Nashville Basin streams.

Normandy Reservoir

Hydrologic Regime

Key Attribute: Hydrologic Regime

Indicator: Date of Spring full pool attainment

Indicator comment: Sammons & Bettoli (1998) indicate that the major limiting factor for spawning success of targeted game fish are spring water levels, including the date of the year when Spring full pool level is reached & the duration of that full pool level in the Spring. Indicator ratings need to be developed based on approximate dates and duration of full pool. The dates & duration also need to be correlated with TVA's release pattern for meeting ecosystem & assimilation needs downstream of Normandy in the Spring & Summer.

Key Attribute: Hydrologic Regime

Indicator: Duration of full pool reservoir water levels in the Spring

Indicator comment: Sammons & Bettoli (1998) indicate that the major limiting factor for spawning success of targeted game fish are spring water levels, including the date of the year when Spring full pool level is reached & the duration of that full pool level in the Spring. Indicator ratings need to be developed based on approximate dates and duration of full pool. The dates & duration also need to be correlated with TVA's release pattern for meeting ecosystem & assimilation needs downstream of Normandy in the Spring & Summer.

Key Attribute: Hydrologic Regime

Indicator: overall % of contributing watershed area in urban landuse cover

Indicator comment: Tracking overall extent of urban landcover is a gross measure to understand how & where the hydrology of the watershed may be changing as land uses change over time. The indicator rating percentages are based on protocols associated with when water quality degradation begins to occur around specific urban landcover thresholds.

Indicator Ratings:

Poor: > 35%

Fair: 10-35%

Good: 5-10%

Very Good: < 5%

Physical Habitat

Key Attribute: Soil/sediment stability & movement

Indicator: Number and magnitude of shoreline erosion sites

Indicator comment: Shoreline stabilization & repair of erosion sites is a priority management activity for TWRA and TVA (TWRA 2000-2006 Strategic plan & TWRA TN Reservoir Fisheries Report 2004). The indicator & ratings need further refinement & may be changed to another measure such as % of reservoir shoreline considered stable or % of shoreline in critical habitat areas considered stable.

Indicator Ratings:

Poor: Numerous erosion sites including many severe sites.

Fair: Numerous erosion sites including some severe sites.

Good: Several erosion sites, most small to moderate in magnitude

Very Good: Few erosion sites and all of small magnitude

Key Attribute: Habitat quality

Indicator: Number of maintained spawning benches

Indicator comment: The installation & maintenance of spawning benches is a management priority for TWRA at Normandy Reservoir in order to provide adequate spawning habitat for game fish species. As of (or in) 2004, 30 spawning benches have been constructed although some had been damaged by vandalism (TWRA TN Reservoir Fisheries Report 2004). Indicator ratings defining adequate numbers of spawning benches for Normandy need to be developed.

Water Quality

Key Attribute: Water quality

Indicator: % of direct tributary stream miles meeting all state designated uses

Indicator comment: This is a gross water quality & habitat condition indicator that is related directly to the TN Dept. of Environment & Conservation's regular assessment cycle. As of 2004, most of the direct tributaries to Normandy Reservoir are listed as fully supporting or not assessed. The exception is the mainstem and some tributaries to the Duck River upstream of Normandy, where 36.3 stream miles are listed due to Manchester's collection system failures and agricultural impacts. Rating categories were generated by considering ramifications of % degradation relative to extent of the system type.

Indicator Ratings:

Poor: <70%

Fair: 70-80%

Good: 80-90%

Very Good: 90-100%

Current Rating: Fair

Current rating comment: This rating is based on an estimate that the 36.3 stream miles listed represents approximately 30% of the stream miles entering Normandy. This percent needs further validation based on actual measurements of stream miles using GIS.

Key Attribute: Water chemistry

Indicator: Dissolved oxygen levels at all sampling locations

Indicator comment: Dissolved oxygen levels are measured at a minimum of 3 sample sites by TWRA, and are also measured by TVA, TDEC, and the Duck River Utility Commission. The indicator ratings need to be further refined & related to expected seasonal variations in DO levels across the reservoir.

Key Attribute: Water temperature

Indicator: Average water temperature at all sample locations

Indicator comment: Temperature levels are measured at a minimum of 3 sample sites by TWRA, and are also measured by TVA, TDEC, and the Duck River Utility Commission. The indicator ratings need to be further refined & related to expected seasonal variations in temperature levels across the reservoir.

Biota

Key Attribute: Species composition/dominance

Indicator: Density of all nested target game fish species as measured by Catch per Unit Effort

Indicator comment: TWRA monitors several population parameters of targeted game fish at Normandy Reservoir (TWRA TN Reservoir Fisheries Report 2004). These species include Largemouth Bass, Spotted Bass, Black Crappie, Blacknose Black Crappie, White Crappie, and Saugeye. Saugeyes are currently monitored, but Walleye are the long-term management target species. Surveys are performed largely using electrofishing & Neuston net (for larval density), with the exception of Saugeye which are sampled using gill nets. Each species has 3-4 measures and annual ratings for density, and the rating indicators (low, fair, good/moderate, & high) are defined by TWRA for each measure & species. The 3-4 density ratings for all species should be in the good/moderate or high range each year for this general indicator to score "good" or "very good."

Poor: Low

Fair: Fair

Good: Good/Moderate

Very Good: High

Key Attribute: Population size & dynamics

Indicator: Fishing success as measured by Creel Surveys

Indicator comment: TWRA monitors several population parameters of targeted game fish at Normandy Reservoir (TWRA TN Reservoir Fisheries Report 2004). These species include Largemouth Bass, Spotted Bass, Black Crappie, Blacknose Black Crappie, White Crappie, and Saugeye. Fishing success is measured by creel survey. Each species has 4 measures and annual ratings for fishing success, and the rating indicators (low, fair, good/moderate, & high) are defined by TWRA for each measure & species. The 4 fishing success ratings for all species should be in the good/moderate or high range each year for this general indicator to score "good" or "very good."

Indicator Ratings:

Poor: Low

Fair: Fair

Good: Good/Moderate

Very Good: High

Key Attribute: Population size & dynamics

Indicator: Sport Fishing Index (SFI)

Indicator comment: TVA generates a sport fishing index rating for the targeted game species in reservoirs each year. The score for each species can range from 20 (very poor) to 60 (excellent). The indicator ratings need further refinement in consultation with TVA.

Indicator Ratings:

Poor: Majority of species have SFI of low

Fair: Majority of species have SFI of fair; several low

Good: Majority of species have SFI of good or excellent; some low

Very Good: Majority of species have SFI of good or excellent; none low