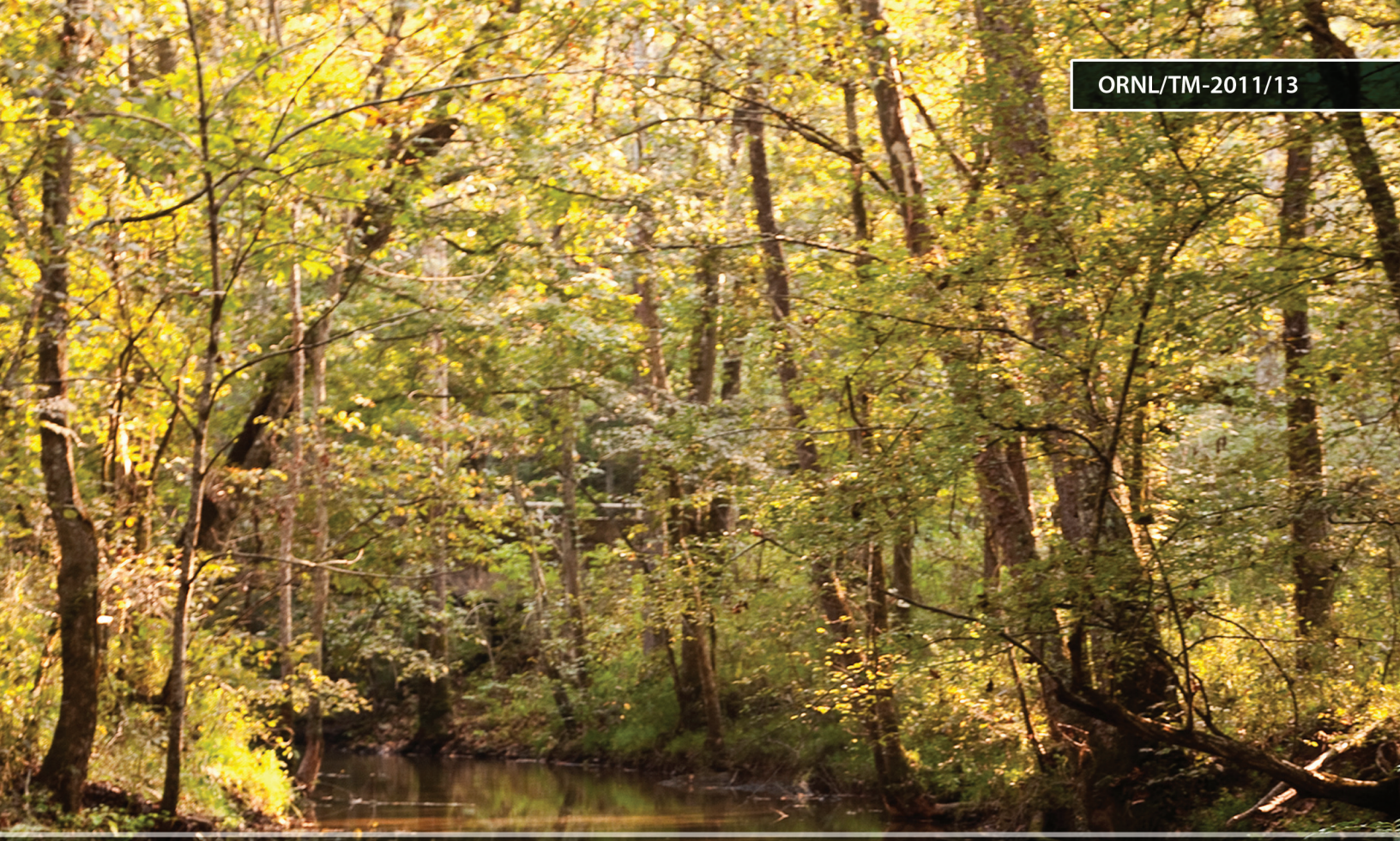

ORNL/TM-2011/13

Aquatic Natural Areas Analysis and Evaluation

OAK RIDGE RESERVATION

April 2011

MICHAEL J. BARANSKI

Oak Ridge National Laboratory

Prepared for Oak Ridge National Laboratory
Managed by UT-Battelle, LLC, for the U.S. Department of Energy
under contract DE-AC05-00OR22725

Cover photo of Bear Creek courtesy of Ron McConathy

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AQUATIC NATURAL AREAS ANALYSIS AND EVALUATION: OAK RIDGE RESERVATION

Michael J. Baranski

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CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

ANA	Aquatic Natural Area
ARA	Aquatic Reference Area
BMAP	Biological Monitoring and Abatement Program
BMPs	Best Management Practices
BSR	Biodiversity Significance Rank
CMA	Cooperative Management Area
DOE	Department of Energy
EFPC	East Fork Poplar Creek
ESA	Endangered Species Act of 1973
ETTP	East Tennessee Technology Park
FAL	Fish and Aquatic Life
FSR	fish species richness
GIS	geographic information system
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IM	Impairments
NA	Natural Area
NEPA	National Environmental Policy Act of 1969
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OUS	Overall Use Support
PCB	polychlorinated biphenyl
PFSR	potential fish species richness
RA	Reference Area
SMZ	Streamside Management Zone
TDEC	Tennessee Department of Environment and Conservation
TNC	The Nature Conservancy
TWRA	Tennessee Wildlife Resources Agency
WQ	Water Quality

ACKNOWLEDGEMENTS

I am indebted to many individuals, including all members of the Oak Ridge Reservation's resources management team and others, for their contributions to this study. In particular, I will mention several persons whose assistance was especially important. Mike Ryon provided information that was essential to the development of the data used in the study. His knowledge of the aquatic systems on the Reservation, their attributes, and their biota was invaluable. Sherri Cotter performed the geographic information system analyses and constructed the maps. Site visits were arranged and managed by Ernest Ryan, Pat Parr, and Neil Giffen. Marti Salk provided important documentation about natural areas protection policy. Elizabeth Wright contributed information regarding riparian protections on the Reservation. Relevant and critical technical assistance and information resources were made available by Pat Parr, Natural Resources Manager for Oak Ridge National Laboratory. Reviewers of the two draft manuscripts provided invaluable corrections and commentary that substantially improved this report. Greg Byrd and Harry Quarles noted important deficiencies and errors. Marti Salk, especially, performed thorough and detailed reviews and critiques of the drafts. In the end, however, the remaining errors and imperfections are mine.

EXECUTIVE SUMMARY

This report presents an assessment of the natural area value of eight Aquatic Natural Areas (ANAs) and seven Aquatic Reference Areas (ARAs) on the Oak Ridge Reservation (ORR) in Anderson and Roane Counties in east Tennessee. It follows a previous study in 2009 that analyzed and evaluated terrestrial natural areas on the Reservation. The purpose of both studies was to evaluate and rank those specially designated areas on the Reservation that contain sensitive species, special habitats, and natural area value. Natural areas receive special protections through established statutes, regulations, and policies.

The ORR contains 33,542 acres (13,574 ha) administered by the Department of Energy. The surface waters of the Reservation range from 1st-order to 5th-order streams, but the majority of the streams recognized as ANAs and ARAs are 1st- and 2nd-order streams. East Fork Poplar Creek is a 4th-order stream and the largest watershed that drains Reservation lands. All the waters of the Reservation eventually reach the Clinch River on the southern and western boundaries of the ORR.

All available information was collected, synthesized, and evaluated. Field observations were made to support and supplement the available information. Geographic information system mapping techniques were used to develop several quantitative attributes about the study areas. Narrative descriptions of each ANA and ARA and tables of numerical data were prepared. Criteria for assessment and evaluation were developed, and eight categories of factors were devised to produce a ranking system.

The evaluation factors used in the ranking system were: (A) size of area, (B) percentage of watershed protected, (C) taxa present with protected status, (D) overall biotic diversity, (E) stream features, (F) water quality and use support ratings, (G) disturbance regime, and (H) other factors. Each factor was evaluated on a 5-point ranking scale (0–4), and each area received a composite score, where 32 was the maximum score possible. A highly ranked ANA or ARA is one that is large in size compared to other areas, includes a greater proportion of the watershed within Reservation boundaries, contains a number of status taxa at high densities, exhibits a high overall biodiversity, has very good or excellent habitat and water quality, is well protected and isolated from disturbances, and shows several other characteristics that contribute to natural area value.

A number of rare aquatic animal species have been reported to occur on the Reservation. Most of those are mollusks that are not known to occur in any of the ANAs or ARAs. The Spotfin Chub is the only federally listed Threatened fish species thought to occur in an ANA. The Tennessee Dace (listed by the state as Deemed in Need of Management) is a common fish in Reservation waters, occurring in several of the ANAs. Bear Creek on the Reservation is reported to have the most dense population of the Tennessee Dace in the state.

Composite scores ranged from 6 to 20; the median score was 14, and the mean score was 13.9 for all 15 areas. Three Priority Groups, intended to reflect priority for protection, were established. Priority Group I included seven Areas rated with scores of 15 or higher. Lower East Fork Poplar Creek (ANA8) ranked highest with a score of 20. Other Areas in Priority Group I were Ish Creek (ANA1), Bear Creek (ANA2), Gum Hollow Branch (ANA5), Mill Branch (ANA6), Unnamed Tributary to East Fork Poplar Creek (ANA3), and Unnamed Tributary of White Oak Creek (ARA3). Priority Groups II and III included six and two Areas, respectively.

The report reflects the current state of knowledge about the condition and characteristics of the ANAs and ARAs on the ORR. It recognizes that some of the information important in the analysis of these Areas is inadequate or absent. Additional work is necessary to refine the evaluations and comparative rankings. Information on biotic diversity is especially weak and should be augmented. Complete and standardized water quality information for all streams should be secured. It is proposed that buffer zones be redefined from the current 305 ft (93 m) widths on each side of a stream to 100 ft (30 m) on each side of a stream; this redefinition is more realistic from biological and stream-

protection standpoints. Additional areas on the ORR should be evaluated for possible designations as specially recognized aquatic areas.

The criteria that define the existing categories of specially designated areas do not adequately distinguish the areas from each other. The distinction between the different categories of Natural Areas and Reference Areas should be examined for possible redefinition or reclassification.

1. PROJECT PURPOSE

In this report, the term "natural area" is loosely defined as a terrestrial or aquatic system that exhibits, or is thought to exhibit, high natural integrity and other significant natural values. The purpose of the present study is to evaluate and rank the currently recognized Aquatic Natural Areas (ANAs) and Aquatic Reference Areas (ARAs) on the Oak Ridge Reservation (ORR) for their natural area value. A previous study (Baranski 2009) analyzed, evaluated, and ranked terrestrial areas (Natural Areas [NAs], Reference Areas [RAs], and Cooperative Management Areas [CMAs]) on the ORR for natural area value, and a precise methodology for natural area evaluation was developed. The present study is intended to be a complement and companion to the terrestrial area study and attempts to employ a similar methodology for aquatic areas so that aquatic and terrestrial areas can be compared on a similar scale.

This study specifically develops criteria for assessing the ecological, biodiversity, and natural area importance and significance of aquatic systems on the Reservation in a relevant and consistent manner. The information can be integrated into the Tennessee Natural Heritage Program (http://tn.gov/environment/na/nhp.shtml) system and applied to potential new aquatic areas. Further, the information will be useful in planning, management, and protection efforts on the ORR.

2. PREVIOUS ACTIONS AND AUTHORITIES

A review of previous studies and actions regarding natural areas on the ORR can be found in Baranski (2009). The Department of Energy (DOE) is obligated by federal environmental policy and regulations, including the National Environmental Policy Act of 1969 (NEPA) and the Endangered Species Act of 1973 (ESA), Sects. 7 and 9, to protect significant natural resources on the ORR. These two statutes are the primary instruments that protect significant natural areas and federally listed species. Wetlands and surface waters receive specific protection under Sect. 404 of the Clean Water Act and other federal and state statutes and regulations. Other statutes, regulations, and policies also pertain to the protection and management of species, natural areas, and natural resources. As part of the NEPA review process, DOE Oak Ridge Operations' former Office for Project Planning operated under a policy that required surveys of land areas for protected resources prior to initiation of any project that could produce adverse impacts and coordinated land use actions with contractors through a Resource Management Organization; at present, Reservation-related concerns (including land use plans) are the responsibility of the DOE ORR Management Team, led by the DOE ORR Coordinator. DOE supports the Oak Ridge National Laboratory (ORNL) Natural Resources Management Program and its resources management team through site-wide funding. Responsibilities include conducting surveys and providing data to DOE and other contractors with respect to the ORR's natural resources.

A 1976 Charter established guidelines for the operation of DOE National Environmental Research Parks (DOE 1976). The Charter states that "some natural areas should be protected from all manipulations … in order to serve as controls" and "protected natural areas must be given careful consideration in any site-use decisions." The Charter also specifies that research reference areas should be set aside and characterized and "certain minimal representative and/or unique natural areas must be left undisturbed." Establishment of reference areas to serve as repositories of genetic diversity and special attention to endangered and threatened species are also mentioned in the Charter. The Oak Ridge National Environmental Research Park was established by DOE in 1980. The Research Park encompasses most of the ORR's undeveloped land, approximately 20,000 acres (8,094 ha).

A number of DOE orders, policy statements, and plans address land use planning and policy and real property asset management on DOE lands. Land and facility use policy; natural, cultural, and historic preservation and management; holistic ecosystem management; environmental protection;

sustainable development; and NEPA compliance are variously stressed in these documents (O'Leary 1994; DOE 1996; DOE 2003; DOE 2008; DOE 2010). Presidential Executive Order 13514 (Obama 2009) specifies that federal agencies' Strategic Sustainability Performance Plans must "include a policy statement committing the agency to compliance with environmental and energy statutes, regulations, and Executive Orders" and take environmental measures into consideration when evaluating projects.

The initial land use plan for the ORR established and mapped unique and natural areas and defined and established NAs and RAs for the first time (Oak Ridge Land-Use Committee 1980). NAs were defined as those areas harboring state- and federally listed protected species; RAs were defined as areas containing special features or habitats and that are also used for reference, monitoring, research, remediation, or characterization activities. The land use plan noted that the designated areas were to be excluded from activities that required significant disturbance and that access should be restricted. In 1985 DOE entered into a nonbinding registry agreement with the Tennessee Department of Environment and Conservation (TDEC) to manage, protect, and preserve seven small areas on the Reservation (Marquess 1985). The latter agreement was terminated in June 2000.

A 1987 report recognized 80 significant aquatic and terrestrial areas on the ORR (Parr and Pounds 1987). Additional areas were identified in 1993, and two new designations were recognized for stream systems—ANAs and ARAs (Pounds, Parr, and Ryon 1993). An evaluation of the biodiversity of the ORR was conducted as part of a larger Common Ground Process led by DOE's environmental management program (TNC 1995). The latter report ranked 86 Preliminary Conservation Sites and identified 270 occurrences of significant communities and species on the ORR. In 2001 TDEC submitted a proposal to the DOE Manager at Oak Ridge to protect five landscape-scale NAs containing 34 sites under the Tennessee Natural Areas Preservation Act of 1971. The DOE Manager acknowledged the proposal and accepted it as information for use in ongoing comprehensive land use management planning, but no action was taken to designate protected areas (TDEC 2001 and letter dated June 18, 2001, from Brian Bowen to G. Leah Dever).

Pounds, Parr, and Ryon (2008) drafted detailed current information about ORR biodiversity and briefly described 47 NAs, 8 ANAs, 17 RAs, 5 ARAs, 8 Habitat Areas (commercially exploited state-listed species present), 8 Potential Habitat Areas, 5 CMAs (managed cooperatively with other programs and agencies for special purposes), and 8 Special Management Zones (utility corridors managed cooperatively for conservation and other purposes). Since the 2008 draft was issued, there have been slight adjustments to the number of sites recognized (Baranski 2009). Required protection of these areas is implicit, and they are identified in land use plans and databases.

DOE's Oak Ridge National Environmental Research Park program was charged by DOE in 1985 with the responsibility of identifying protected species on the Reservation, conserving the areas harboring those species, and ensuring compliance with both federal and state regulations for the Reservation (Marquess 1985). It appears that other unique and special areas on the ORR that are naturally significant in other ways do not have any official protection other than through federal policy guidelines and regulations as noted above.

The Natural Resources Management Program handles natural resources management tasks for the ORR. As changes in NAs and RAs are needed, the ORNL Natural Resources Manager makes recommendations to the DOE ORR Management Team for approval and recognition prior to mapping and entry into a database system. NAs and RAs are officially recognized for land use planning purposes but receive no additional special status or protections, except as required by NEPA and ESA. Other areas (i.e., Habitat Areas, Potential Habitat Areas, Special Management Zones, CMAs) are identified for planning purposes.

In June 1999 the Secretary of Energy designated the Three Bend Scenic and Wildlife Management Refuge for long-term protection. It is managed by the Tennessee Wildlife Resources Agency (TWRA) under a special license agreement with DOE. The Black Oak Ridge Conservation Easement was designated by DOE and the state of Tennessee in April 2005; it is jointly managed by

the TWRA in cooperation with TDEC. The latter unit includes one of the largest blocks of unfragmented forest on the Reservation.

3. STUDY AREA

The ORR in Anderson and Roane Counties in east Tennessee currently consists of 33,542 acres (13,574 ha) of federal land administered by DOE. The study area has been thoroughly described in previously published documents (Baranski 2009; Parr and Hughes 2006). The Reservation has long been recognized as a biodiversity haven, primarily because of the presence of large undeveloped and unfragmented areas in the otherwise highly developed region (Mann et al. 1996; TDEC 2001).

The landscape of the ORR consists of long, narrow parallel ridges and valleys oriented in a northeast–southwest direction in the Valley and Ridge Physiographic Province. Slopes are gentle to moderately steep, with relief generally ranging within 300 to 350 ft (91 to 107 m) from valley floor to tops of ridges. In order from northwest to southeast, the major parallel ridges running through the Reservation are Blackoak Ridge, Pine Ridge, Chestnut Ridge, and Haw Ridge. The Y-12 National Security Complex lies in the upper Bear Creek Valley between Pine Ridge and Chestnut Ridge, and ORNL lies in the lower Bethel Valley between Chestnut Ridge and Haw Ridge. Copper Ridge, in the southern end of the Reservation, is an example of a lesser ridge with a complex, nonlinear physiognomy. Elevation ranges from 1356 ft (413 m) above mean sea level on Melton Hill on Copper Ridge to 750 ft (229 m) above mean sea level at the Clinch River.

Upper drainages are primarily dendritic, and the lower major streams are arranged in a more trellis-like pattern. Numerous springs on the ridges feed the upper headwaters of most streams. Most streams have relatively low gradients.

Oak Ridge Land-Use Committee (1980) thoroughly describes the surface waters of the ORR, including substrate types, dimensions, flow rates, geological and topographic settings, and factors influencing water quality and stream characteristics. Parr and Hughes (2006) and Hughes (2008) provide some additional information about surface waters. Stream widths and depths vary from 2.0 to 4.0 ft (0.6 to 1.2 m) wide and 3.9 to 9.8 in. (10 to 25 cm) deep on 1st-order streams (the uppermost, topographically highest and often intermittent channels in a catchment with no upstream tributaries) to more than 25 ft (7.6 m) wide and 10 ft (3 m) deep on the lower 4th- and 5th-order streams. (A 5th-order stream is formed below the confluence of two 4th-order streams.) The major watersheds and streams are shown in Fig. 1. Waters from the Reservation reach the Tennessee River via the Clinch River, which forms the southern and western boundaries of the Reservation. The largest drainage basin in the area is Poplar Creek, which drains a watershed 136 mi^2 (352 km^2), most of which is outside the ORR; it enters the Clinch River on the western edge of the Reservation after flowing through the East Tennessee Technology Park (ETTP). East Fork Poplar Creek (EFPC) is the 4th-order tributary of Poplar Creek that drains 30 mi^2 (78 km^2) on the northern and western portions of the ORR, including the Y-12 National Security Complex and most of the city of Oak Ridge. Bear Creek drains 7.4 mi^2 (19 km^2) between Pine Ridge and Chestnut Ridge. EFPC and Bear Creek both have their headwaters in the Y-12 Complex. Bear Creek is mostly affected by runoff and infiltration from waste disposal sites and runoff originating within the Y-12 Complex. The White Oak Creek drainage basin covers 6.5 mi^2 (16.9 km^2) and includes ORNL and surrounding areas; the headwaters are on Chestnut Ridge, and the creek leaves the Reservation at the Clinch River through the White Oak Lake impoundment, which is a settling basin for ORNL wastewater. Melton Branch is a 2nd-order tributary of White Oak Creek, draining 1.5 mi^2 (3.8 km^2). Several of the stream systems on the Reservation were subjected to discharges of contaminants from the late 1940s to the early 1980s, but remediation efforts since then have led to water-quality improvements. With the exceptions noted above, most of the other streams on the Reservation drain undeveloped forested areas and are unimpacted by facilities.

4. PROCEDURES

The procedures employed in this study are similar to those followed in Baranski (2009). The ORNL Natural Resources Manager provided all available documentation and information resources relevant to the project. ORNL geographic information system (GIS) MapInfo database mapping resources were used. Information relevant to element occurrences (i.e., locations of basic conservation units) and taxa evaluations was derived from Baranski (2009). All ANAs and ARAs were visited for direct on-site observation. Michael Ryon provided invaluable information concerning stream habitat and biotic diversity (personal communications).

All available information was synthesized and evaluated. Data were assembled into narrative descriptions and tables describing the ANAs and ARAs. Criteria for assessment and evaluation were developed, and eight categories of evaluation factors were devised to produce a ranking system. Priority Groups were also established.

Currently, eight ANAs and seven ARAs are officially recognized on the Reservation. (Some previously recognized areas have been delisted.) These areas are illustrated in Fig. 2, which shows their location in the context of the officially recognized terrestrial areas on the Reservation. Descriptions of the recognized terrestrial sensitive and special management areas are provided in the appendix in Baranski (2009).

ANAs and ARAs both protect special habitats and also serve as reference or control areas for various ecological, monitoring, remediation, and characterization activities. ANAs particularly protect sensitive species that are listed by the state of Tennessee and the federal government, while ARAs primarily function as reference and control areas and include study sites for the collection of baseline data. The Biological Monitoring and Abatement Program (BMAP) (Hughes 2008) and environmental remediation efforts at DOE facilities require the use of control sites for comparison. BMAP was established for the ORR in 1985 to identify adverse ecological impacts and their causes and assess environmental regulation compliance requirements. ANAs and ARAs often represent nonimpacted streams or stream reaches that are physically and biotically comparable to impacted streams and thus permit the evaluation of remediation efforts. Monitoring activities include the collection of data such as fish density estimates and taxonomic richness indices for fish and benthic organisms.

5. RARE AQUATIC ORGANISMS

A number of rare aquatic species have been reported or documented as occurring in the waters of the ORR or adjacent waters of Melton Hill Reservoir and Watts Bar Reservoir. A list of rare aquatic animal and plant species (Table 1) was developed from a previously published summary of rare taxa known or reported to occur on the ORR (Baranski 2009). Table 1 includes only those organisms whose Status in Tennessee is Endangered (E) or Threatened (T) or that are Special Concern (S) or Deemed in Need of Management (D) in Tennessee and have a State Rank of S1, S2, or S3. The list includes one plant, two amphibians, five fish, and nine mollusks. These organisms are considered as status taxa used to evaluate aquatic natural area value. It is noted that one of the amphibians, the Four-toed Salamander, is primarily terrestrial, requiring aquatic habitat only for the larval stage. Rare plants that might be found within buffer zones are not considered.

The Spotfin Chub, Tennessee Dace, and Flame Chub are the only fish that have been found in ANAs and other Reservation streams. The Spotfin Chub is listed as federally Threatened, and the Tennessee Dace and Flame Chub are ranked S3 and Deemed in Need of Management.

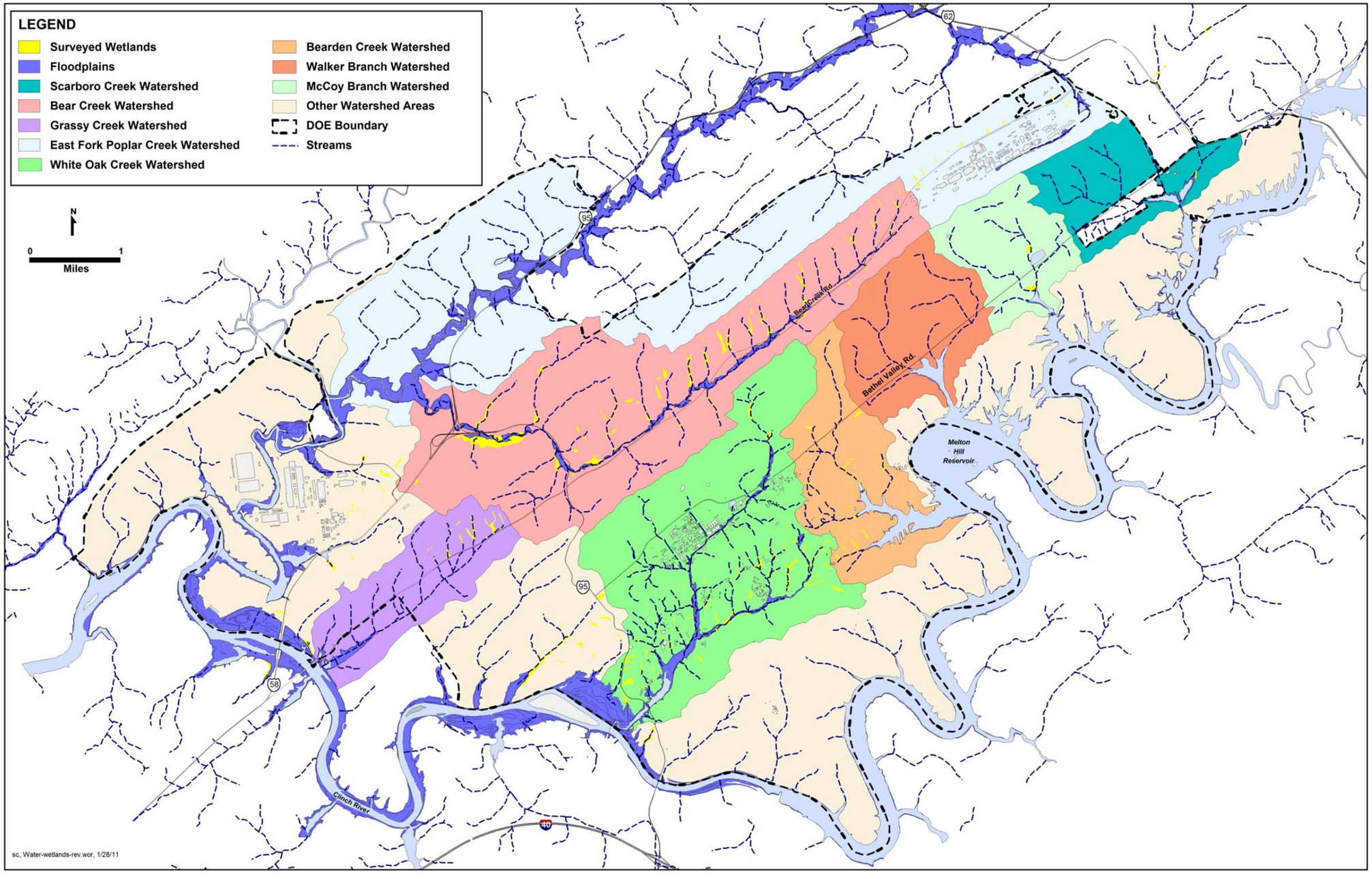

Fig. 1. Watersheds on the Oak Ridge Reservation. Adapted from Parr and Hughes (2006).

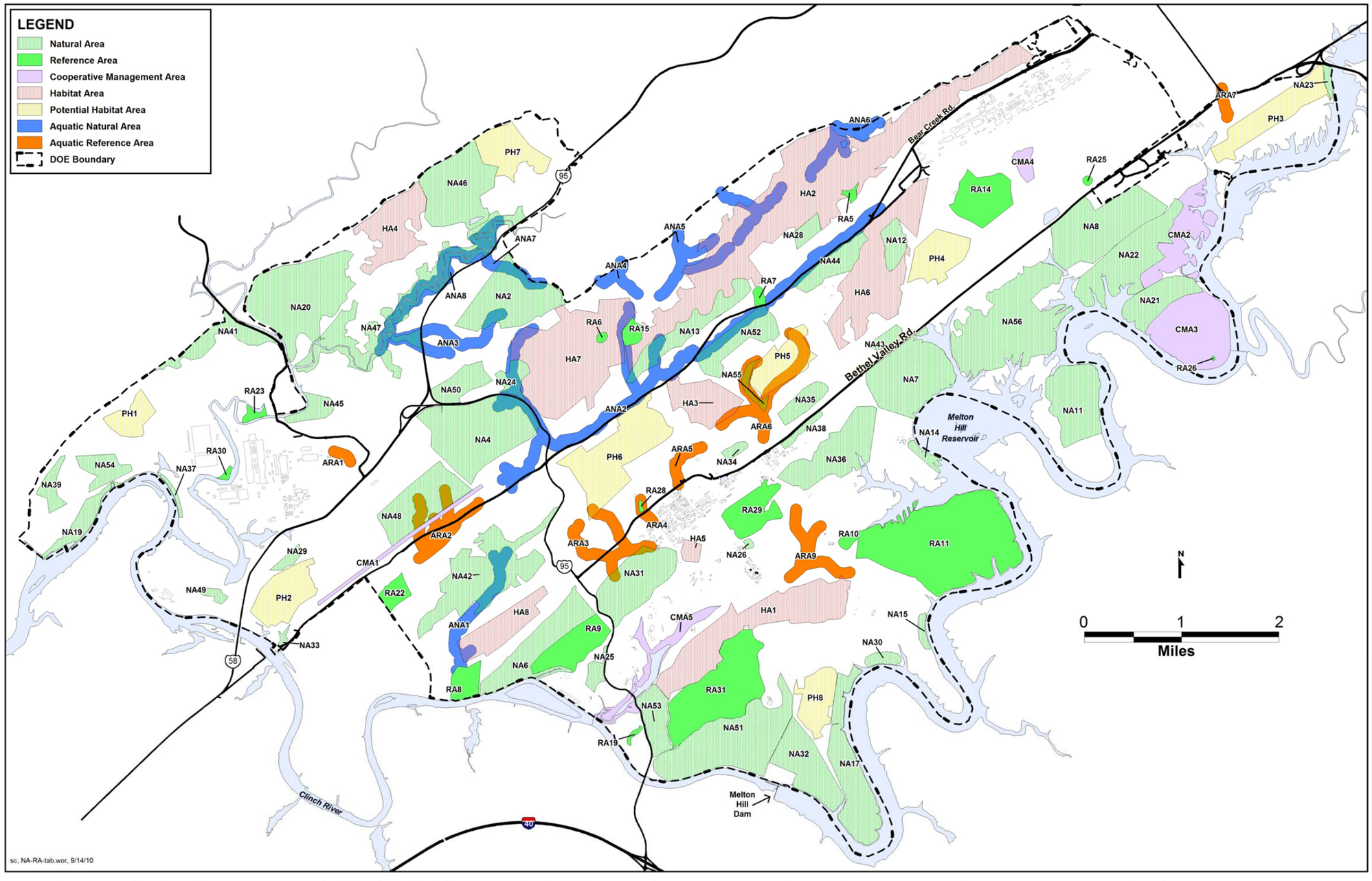

Fig. 2. Special and sensitive areas recognized within the Oak Ridge Reservation, including Natural Areas (NAs), Aquatic Natural Areas (ANAs), Reference Areas (RAs), Aquatic Reference Areas (ARAs), Cooperative Management Areas (CMAs), Habitat Areas (HAs), and Potential Habitat Areas (PHAs). Special Management Zones and other special conservation areas not shown.

Table 1. Rare aquatic plant and animal taxa known or reported to occur on the Oak Ridge Reservation

(Status criteria categories as followed by Natural Heritage Programs and U.S. Fish and Wildlife Service and as reported in Baranski [2009])

Endangered (E) and Threatened (T) Taxa [Status in Tennessee, Federal Status, Global Rank, State Rank][a]	
Fish	
Erimonax monachus (Spotfin Chub)[b]	[T, LT, G2, S2]
Mollusks	
Dromus dromas (Dromedary Pearlymussel)	[E, LE-XN, G1, S1]
Fusconaia cuneolus (Fine-rayed Pigtoe)	[E, LE, G1, S1]
Fusconaia edgariana (Shiny Pigtoe)	[E, LE-XN, G1, S1]
Lampsilis abrupta (Pink Mucket)	[E, LE, G2, S2]
Plethobasus cooperianus (Orange-foot Pimpleback)	[E, LE-XN, G1, S1]
Quadrula cylindrica strigillata (Rough Rabbitsfoot Pearlymussel)	[E, LE, G3T2, S2]
Taxa Listed as Special Concern (S) or Deemed in Need of Management (D) and S1, S2, or S3 in Tennessee	
Amphibians	
Cryptobranchus alleganiensis (Hellbender)	[G3G4, S3]
Hemidactylium scutatum (Four-toed Salamander)	[G5, S3]
Fish	
Carpiodes velifer (Highfin Carpsucker)	[G4G5, S2S3]
Cycleptus elongatus (Blue Sucker)	[G3G4, S2]
Hemitremia flammea (Flame Chub)	[G3, S3]
Phoxinus tennesseensis (Tennessee Dace)	[G3, S3]
Mollusks	
Cumberlandia monodonta (Spectaclecase)	[G3, S2S3]
Io fluvialis (Spiny Riversnail)	[G2, S2]
Pleurobema rubrum (Pyramid Pigtoe)	[G2, S1S2]
Plants	
Elodea nuttallii (Nuttall's Waterweed)	[G5, S2]

[a] **State listings**: Endangered (E)—Any species or subspecies whose prospects of survival or recruitment within the state are in jeopardy or are likely to become so within the foreseeable future; Threatened (T)—Any species or subspecies that is likely to become an Endangered species within the state in the foreseeable future; Special Concern (S)—Any species or subspecies of plant that is uncommon in Tennessee or has unique or highly specific habitat requirements or scientific value and requires careful monitoring; Deemed in Need of Management (D)—Any species or subspecies of nongame wildlife deemed to require investigation to determine management measures necessary for continued successful survival.

Federal listings: Listed Endangered (LE)—In danger of extinction throughout all or a significant portion of its range; Listed Threatened (LT)—Likely to become an Endangered species in the foreseeable future; Nonessential experimental population (XN)—Introduced or reintroduced in an area from which it has been extirpated.

Global ranks: G1—Extremely rare and critically imperiled in the world with 5 or fewer occurrences, or very few remaining individuals, or because of some special condition in which the species is particularly vulnerable to extinction; G2—Very rare and imperiled within the world, 6 to 20 occurrences, or few remaining individuals, or because of some factor(s) making it vulnerable to extinction; G3—Rare and uncommon in its range or found locally in a restricted range, generally from 21 to 100 occurrences; G4—Widespread, abundant, and apparently secure globally, but with cause for long-term concern; G5—Demonstrably widespread and secure globally; T# - Subspecific taxon rank.

State ranks: S1—Critically imperiled, extremely rare and critically imperiled in the state with 5 or fewer occurrences, or very few remaining individuals, or because of some special condition in which the species is particularly vulnerable to extinction within the state; S2—Imperiled, very rare and imperiled within the state, 6 to 20 occurrences, or few remaining individuals, or because of some factor(s) making it very vulnerable to extinction; S3—Vulnerable, rare and uncommon in the state, from 21 to 100 occurrences.

[b] Included in Reservation records, but not in Tennessee Division of Natural Areas database.

One large specimen of the Spotfin Chub was found in EFPC, upstream of ANA8, in fall 2002 during a regular monitoring activity. This was an unusual occurrence because this fish typically occupies larger rivers with fast water and boulder habitat. The nearest documented population is 25 miles away in the Emory River. However, migrating individuals may move large distances in the fall into smaller streams. It is believed that there may be a local population of this species in the Poplar Creek drainage that occasionally migrates into the smaller streams (M. Ryon, personal communication, Sept. 24, 2009). The Chub is included as a species present in ANA8 because it would have to migrate through it to reach the location at which it was sampled.

The Tennessee Dace appears to be common on the Reservation, with some of the higher densities for this species occurring there. Numerous observations have been recorded in a number of streams. The Dace is commonly found in the Bear Creek drainage, and it routinely occurs in the main stem and tributaries of EFPC. It has also been found in Ish Creek.

The Flame Chub was reported in 1941 in the lower end of Bear Creek, near the confluence with EFPC, and has not been found since. It may be that this animal is extirpated from Reservation waters.

The Four-toed Salamander and Nuttall's Waterweed are each found in only one ANA or ARA. Most of the animals listed in Table 1 are not found within ANAs, ARAs, or other Reservation streams. All of the mollusks listed in the Natural Heritage database appear to be associated with the reservoirs and large rivers; no living specimens have been found in Reservation streams, and shells of only one or two species have been found. The Hellbender was documented from the Clinch River, downstream of the Tennessee Highway 95 crossing and upstream of Jones Island. The Highfin Carpsucker and Blue Sucker were reported in preimpoundment surveys of the Clinch River near Solway but have not been seen since; it is possible that they might still exist within reservoir waters, with small specimens occasionally moving into tributary streams.

Five fish species are considered to be locally rare on the ORR (M. Ryon, personal communication, Feb. 9, 2009). These are *Cyprinella whipplei* (Steelcolor Shiner), *Etheostoma duryi* (Blackside Snubnose Darter), *E. jessiae* (Blueside Darter), *E. rufilineatum* (Redline Darter), and *Percina sciera* (Dusky Darter). These fish are not listed by the Tennessee Natural Heritage Program.

6. AQUATIC NATURAL AND REFERENCE AREA DESCRIPTIONS

This section presents the collected data and information available for the ANAs and ARAs that are illustrated in Fig. 3, which also shows the stream systems on the Reservation. The raw data are derived from Pounds, Parr, and Ryon (2008), from GIS measurements (performed by S. Cotter, ORNL), information contributed by Michael Ryon regarding stream features and biotic diversity (personal communications, Feb. 9, 2009, and July 22, 2010), and personal observations and map study by this investigator.

Table 2 comparatively summarizes the characteristics of the ANAs and ARAs in their respective watersheds. The boundaries of the watersheds, within which each ANA or ARA is located, are illustrated in Fig. 4. ANA8 is described individually and as the receiver stream for five other ANAs that are part of the greater watershed that forms the catchment for ANA8. Stream order uses the method developed in Strahler (1957). The Areas as officially delineated are currently mapped with approximately 305 ft (93 m) boundaries on both sides and the termini of the stream segments. The reasons for defining such wide boundaries are not known for certain, but the wide zones appear to have been established in response to salvage operations following historical southern pine beetle epidemics. As discussed later in Sect. 9.1, a more biologically realistic measure of a suitable riparian zone width for the Areas might employ only 100 ft (30 m) buffer zones on either side of the stream; these calculations were performed and are presented in Table 2 in the last two columns for illustrative purposes. For the column showing the percentage of the watersheds that occur within the ORR, for those ANAs and ARAs whose watershed includes areas outside ORR boundaries, ocular estimates were made from map study.

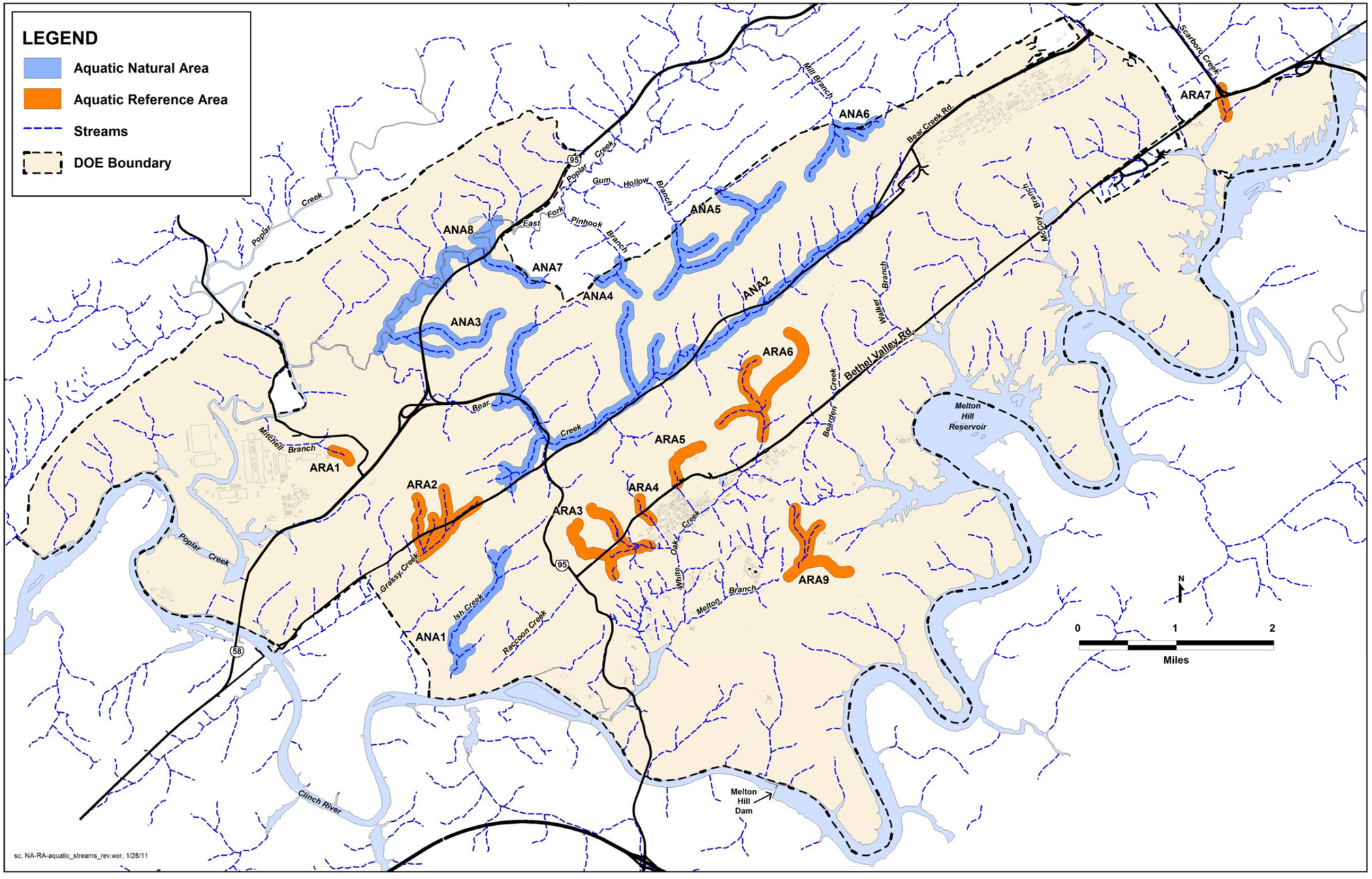

Fig. 3. Aquatic Natural Areas (ANAs), Aquatic Reference Areas (ARAs), and streams within the Oak Ridge Reservation.

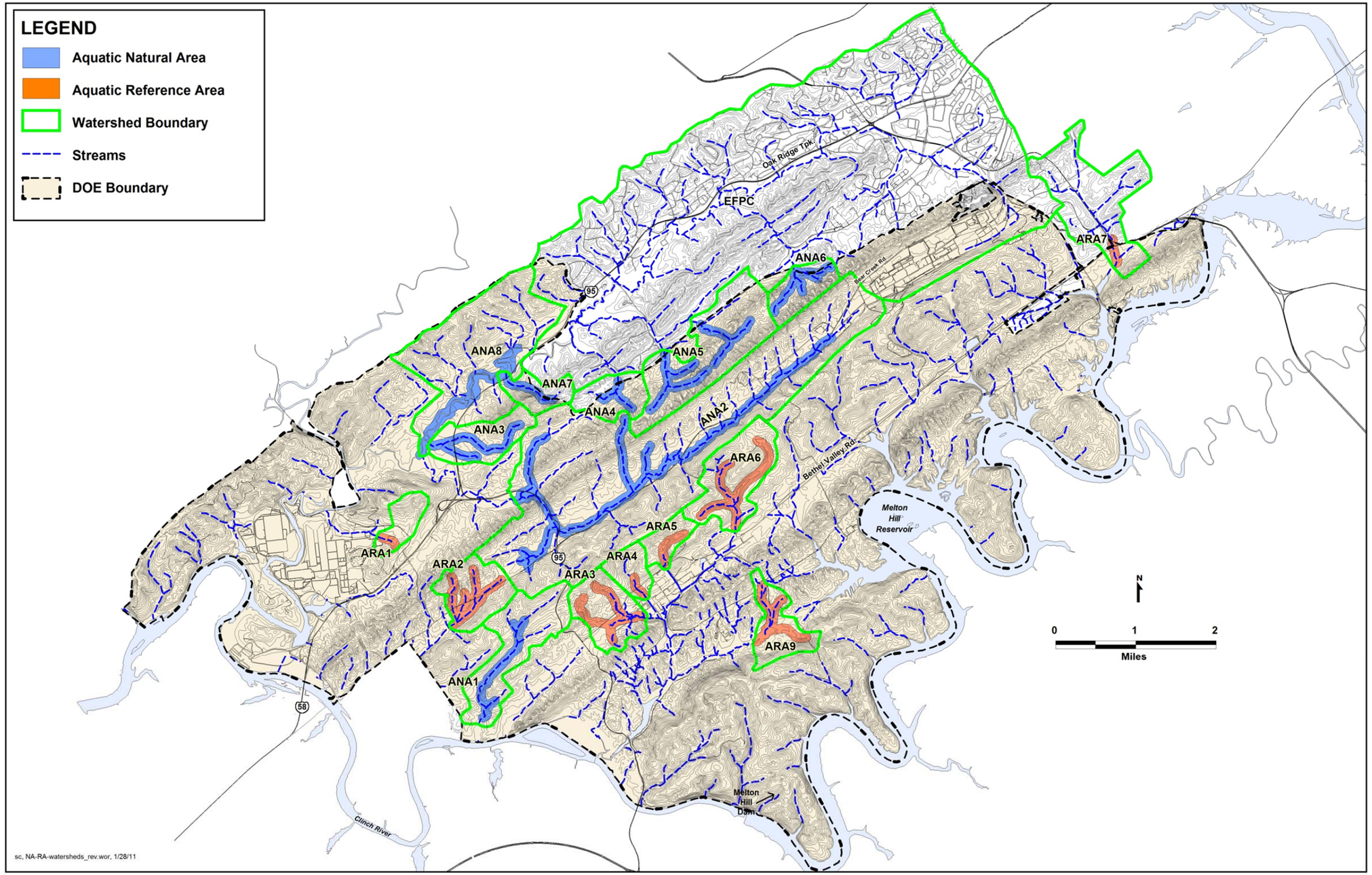

Fig. 4. Boundaries of watersheds that include all the Aquatic Natural Areas (ANAs) and Aquatic Reference Areas (ARAs) within the Oak Ridge Reservation. EFPC = East Fork Poplar Creek.

Table 2. Watershed characteristics of Aquatic Natural Areas (ANAs) and Aquatic Reference Areas (ARAs). Data synthesized from multiple sources (see text). Values refer to individual ANAs or ARAs unless otherwise noted. Data in the last two columns are for illustration purposes only and are not used in any calculations of aquatic natural area value.

Area	Stream order[a]	Stream length[b] miles (km)	Watershed[c] drainage acres (ha)	Area size[d] acres (ha)	% of water-shed in area (A)	% of water-shed in ORR (B)[e]	A×B % (C)	Stream + 200 ft buffer	
								acres (ha)[f]	% of watershed[g]
ANA1	2nd	2.1 (3.4)	653 (264)	132 (53)	20	100	20	51 (21)	8
ANA2	2nd, 3rd	8.8 (14.2)	3,964 (1,604)	634 (257)	16	99 est.	16	214 (87)	5
ANA3	1st, 2nd	1.9 (3.1)	358 (145)	141 (57)	40	100	40	47 (19)	13
ANA4	1st, 2nd	0.6 (1.0)	268 (108)	56 (23)	21	60 est.	13	16 (6)	6
ANA5	1st, 2nd	2.8 (4.5)	906 (367)	228 (92)	25	90 est.	22	69 (28)	8
ANA6	1st, 2nd	1.5 (2.4)	263 (106)	108 (44)	41	85 est.	35	37 (15)	14
ANA7	1st	0.8 (1.3)	197 (80)	56 (23)	29	65 est.	19	19 (8)	10
ANA8	4th	2.9 (4.7)	13,213 (5,347)[h]	196 (79)	1.5	11	<1	70 (28)	0.5
ANA8[i]	4th	10.5 (16.9)	13,213 (5,347)[h]	785 (318)	6	26	2	255 (103)	2
ARA1	1st	0.2 (0.3)	179 (72)	22 (9)	12	100	12	5 (2)	3
ARA3	1st, 2nd	1.3 (2.1)	403 (163)	145 (59)	36	100	36	31 (13)	8
ARA4	1st	0.7 (1.1)	178 (72)	27 (11)	15	100	15	16 (6)	9
ARA5	1st	0.6 (1.0)	160 (65)	48 (19)	30	100	30	15 (6)	9
ARA6	1st, 2nd	2.6 (4.2)	582 (236)	183 (74)	31	100	31	64 (26)	11
ARA7	3rd	0.5 (0.8)	830 (336)	30 (12)	4	10 est.	<1	13 (5)	1.5
ARA9	1st, 2nd	1.9 (3.1)	324 (131)	123 (50)	38	100	38	47 (19)	14

[a] For most of the system as currently delineated in the watershed catchment.
[b] Length of streams within the currently delineated Area. Additional stream segments within the watershed may be present outside the Area.
[c] Determined from the lowest point in the currently defined Area; GIS calculation; accounts for overlapping buffer zones.
[d] Acreage in the ANA or ARA as currently delineated with 305 ft (93 m) buffers on each side of stream; GIS calculation; accounts for overlapping buffer zones.
[e] Includes the ANA or ARA.
[f] Stream and 100 ft (30.5 m) buffer zones on each side of stream; calculated from total stream length; assumes no overlapping buffer zones.
[g] Percentage of the total watershed occupied by the stream and a 200 ft (61 m) buffer zone.
[h] Total watershed drained to the lowest point includes the portion of the East Fork Poplar Creek watershed that is not within the Oak Ridge Reservation (ORR), as well as ANA3, ANA4, ANA5, ANA6, and ANA7. (See Fig. 3.)
[i] With inclusion of ANA3, ANA4, ANA5, ANA6, and ANA7 that flow into ANA8 either directly or indirectly through non-ORR areas.

Table 3 presents additional attribute information for the areas, particularly to compare them with respect to status taxa present; stream features; and factors that influence stream quality, cause actual or potential disturbance, and affect natural area value. Stream habitat variables (out of 12 possible) include variations in flow speed (fast, moderate, slow/backwaters), the presence and types of riffles and pools (deep pools > 3 ft [0.9 m] deep and shallow riffles < 1 ft [0.3 m] deep), substrate types and diversity (boulder, cobble, gravel, sand), and other factors related to habitat complexity (woody structure, undercut banks, aquatic vegetation). The percentage of canopy coverage is an average estimate derived from several readings taken at representative monitoring sites (usually only one per stream) with a spherical densitometer. Estimates of the positional relationship of roads and utility corridors to streams are given; these are not intended to be precise measures, but only a general indication of potential disturbance factors. The occurrence of stormwater or wastewater outfalls is included, when known. The presence of culverts and other obstacles to in-stream movements of fish is indicated, if known.

Other information about each area that is not easily depicted in table format is summarized below in a narrative for each stream. Each narrative includes the following information as completely as it could be developed:

- A unique 15-digit stream identification number based on the National Hydrology Database is given. The Hydrologic Unit Code (HUC) is an 8-digit number assigned by the U.S. Geological Survey. This is followed by a 3-digit number identifying a specific reach and a 4-digit number identifying a unique segment.
- A brief statement describing the stream system is given, including information about water withdrawals and flow augmentation in the streams. For example, some 1st-order streams are now functioning as 3rd-order streams due to flow augmentation resulting from inter-watershed transfers.
- The vegetation of the Area, riparian zones, and watershed is given, if known.
- A general evaluation of past and current disturbances is given; this includes such things as the presence of developed facilities; channel straightening or dredging; and the absence of forest cover in the riparian zone due to logging or clearing, insect outbreaks, or other reasons.
- Benthic macroinvertebrate diversity is given as low, moderate, or high, if known.
- Reported fish species richness (FSR) is given when known, followed by the potential fish species richness (PFSR) in parentheses. The limited information available about the presence of invasive fish species that can potentially cause negative impacts on stream biodiversity and trophic level dynamics is also included.
- For ARAs, reference and monitoring sites present are given.
- Water quality information and TDEC (Water Pollution Control Division) Use Support ratings are presented for those streams for which assessment information could be located. This information was synthesized and assembled from various TDEC documents and databases (TDEC 2006a, 2007, 2010), but consistently current and complete information was not satisfactorily located for all streams. The water quality information used in this report includes Overall Use Support (OUS) ratings for designated uses and ratings for Water Quality (WQ), Fish and Aquatic Life (FAL), and Impairments (IM). Other ratings for Recreation, Livestock Watering and Wildlife, Irrigation, and Natural and Scenic Qualities were examined but are generally not reported. Only OUS, WQ, FAL and IM are reported here for all streams for which the information was available.

Table 3. Attributes associated with Aquatic Natural Areas (ANAs) and Aquatic Reference Areas (ARAs). Data synthesized from multiple sources (see text).

Area	Number status taxa/E+T present	Number of stream habitat variables[a]	% canopy coverage[b]	Number of fish barriers present[c]	Number of road crossings[d]	Number of roads parallel/% adjacency[d]	Number of utility corridor crossings	Number of utility corridors parallel[d]	Number of outfalls present
ANA1	1/0	10	90	1	2	0	2	2	0
ANA2	1/0	10	90	0	20	2/95	4	1	<5
ANA3	1/0	8	75	0	5	1/<20	3	2	0
ANA4	1/0	9	90	0	2	0	0	0	0
ANA5	1/0	9	90	1	3	1/50	0	0	0
ANA6	1/0	9	90	1	1	1/50	0	0	0
ANA7	1/0	7	90	0	1	1/50	2	0	0
ANA8	2/1	11	90	0	1	2/<10	0	0	0
ARA1	0/0	8	90	2	0	2/75	2	1	0
ARA3	0/0	8	80	1	4	1/<10	9	1	1
ARA4	0/0	9	90	3	1	1/100	0	0	0
ARA5	0/0	10	80	3	1	1/100	2	2	0
ARA6	0/0	11	65	7[e]	3	2/80	7	2	1
ARA7	0/0	11	65	1	2	0	1	0	0
ARA9	0/0	7	80	2	1	2/50	2	0	0

[a] See text in Sect. 7 for explanation.
[b] General estimates based on spherical densitometer readings at several points.
[c] Barriers to colonization from downstream fish sources.
[d] Based on map study; all roads and utility corridors considered.
[e] Includes other barriers within the stream.
E = Endangered; T = Threatened.

- The relationship of the ANAs and ARAs to NAs, RAs, and the Preliminary Conservation Sites (with the assigned Biodiversity Significance Ranks [BSRs]) developed by The Nature Conservancy (TNC) (TNC 1995) are also given.

There are significant pollution contamination issues, both past and present, for many streams in the ORR (e.g., mercury and polychlorinated biphenyls [PCBs] in EFPC, PCBs and heavy metals in Bear Creek, PCBs and radioactive materials in White Oak Creek). These problems have been or are currently being remediated. Because detailed and comprehensive information was not available during the preparation of this report, this kind of information is only anecdotally reported in a few cases below.

Ish Creek (ANA1). HUC TN06010207-001T-0500. Most of this ANA consists of 2.1 miles of a 2nd-order tributary of the Clinch River, with spring-fed headwaters. It runs through a mixed hardwood forest and has intact 100 ft (30 m) buffer zones. Current disturbances are minor. FSR is high, with 18 species having been documented in the system (PFSR = 20). The Tennessee Dace is present. One reference area for fish community sampling is present (ISK1.0). The OUS for this stream is rated Fully Supporting by TDEC. It is isolated from facilities on the ORR and has been the site of many ecological and hydrological studies (e.g., stream flows and discharge; water quality evaluations; studies of periphyton, snails, and fish interactions). Part of the ANA is situated in NA42, and it is approximately equal to the TNC BSR2-7 site.

Bear Creek (ANA2). HUC TN06010207-026-0600. Most of this ANA consists of a 3rd-order stream that is a major tributary of EFPC, but three 1st-order tributaries and one 2nd-order tributary are also included. The ANA includes 8.8 stream miles. The headwaters of the system are spring fed. Some withdrawal of water actually or potentially occurs, and some stream reaches naturally dewater during some dry periods. Mature hardwoods compose the dominant vegetation in the riparian zone. Intact 100 ft (30 m) buffer zones are present for 75% of the system. The vegetation is generally undisturbed downstream except for pine plantation logging, but disturbances increase dramatically upstream. There have been major past disturbances, and there are active current disturbances, including nearby sludge application areas and current facilities bordering the ANA (e.g., Environmental Management Waste Management Facility and its Haul Road, road maintenance complex of buildings and storage areas). The FSR is lower than expected for the size of the stream, with 22 species having been documented (PFSR = 36). Benthic diversity is high downstream but lowers near the headwaters and is considered to be moderate overall. This stream is reported to have the most dense population of the Tennessee Dace in the state (Ryon and Loar 1988). Life history studies of the dace have been conducted there. The locally rare Blackside Snubnose Darter is present. The Four-toed Salamander has been found in Hembree Marsh (NA24) in the lower section of ANA2. This ANA includes sites (BCK 3.25 to BCK 12.36) for benthics and fish community tasks of Bear Creek remediation activities. The TDEC ratings are OUS—Not Supporting designated uses in 2010, but in 2006 the lower reach was rated Partially Supporting; other 2006 ratings were WQ—Partially Supporting, FAL—Partially Supporting, IM—Not Supporting Due to Habitat Alterations, Natural and Scenic Qualities—Fair. Parts of this ANA are situated within NA4, NA13, NA24, and NA52. It lies within TNC BSR2-10, a large, important landscape complex.

Unnamed Tributary to EFPC (ANA3). HUC TN06010207-026-1000. This stream is also known as the Dace Tributary. The stream in this ANA flows into the lower end of ANA8 on EFPC. It consists of two 1st-order streams and the 2nd-order stream below their confluence. One of the 1st-order streams appears to be intermittent, based on a recent field observation. Pine plantations form the predominant vegetation in the riparian zone; 50 ft (15 m) buffer zones are present. Past disturbances were minor; one current sludge application area overlaps. The area is bordered by a partially cleared and undeveloped industrial park.

The FSR is typical for this type of stream, with eight species present (PFSR = 13), including the Tennessee Dace. The TDEC ratings for OUS and FAL are Not Supporting. Part of the ANA lies within NA2, and another part lies within NA47. It lies within TNC BSR2-12.

Pinhook Branch (ANA4). HUC TN06010207-026-0500. This ANA consists of two spring-fed 1st-order streams and the 2nd-order stream below their confluence. The uppermost, but small, portion of one of the 1st-order streams is not on ORR land, and most of the 2nd-order stream is outside the Reservation boundary. The 2nd-order stream is a small part of a long tributary of EFPC, joining it outside of the Reservation. The predominant vegetation in the riparian zone is managed loblolly pine; 100 ft (30 m) buffer zones are present. Past and current disturbances are minor. Southern pine beetle outbreaks have damaged mostly planted pine stands in the watershed (most recently in 1993–1994 and 2000–2001 and with some salvage occurring). Benthic invertebrate diversity is high, and, with only five fish species present, the FSR is lower than expected for the type of stream (PFSR = 13). The Tennessee Dace is present, and life history studies of the dace have been conducted there. Reference sites here (PHK 1.4) include the benthics task of Bear Creek remediation activities and a fish community reference for stream recovery. TDEC has not assessed this stream. This ANA is equivalent to TNC BSR2-14.

Gum Hollow Branch (ANA5). HUC TN06010207-026-0400. Five 1st-order streams and the upper sections of two separated 2nd-order streams compose this ANA (depicted as two separate areas in accompanying figures). The 3rd-order stream that results is a tributary of EFPC, joining it outside of the Reservation. The larger portion of this tributary system is outside of the Reservation. The headwaters on Pine Ridge are spring fed. At least one of the 1st-order streams is intermittent. Oak-hickory forest is the predominant vegetation in the riparian zone; 100 ft (30 m) buffers are present. Past and current disturbances are minor. Pine beetle damage to mostly native pines occurred most recently in 1993–1994 and 2000–2001 in some areas of the watershed; no salvage logging took place. Benthic invertebrate diversity is high; only five fish species are present (PFSR = 19), including the Tennessee Dace. Reference study sites (GHK 1.6 and 2.9) for the benthics task of remedial activities of Bear Creek are present. All sections of this stream that have been assessed by TDEC are rated as Fully Supporting in all categories. Part of this area lies within the Pine Ridge Mature Forest (a newly proposed NA) (Baranski 2009). It is equivalent to TNC BSR2-15.

Mill Branch (ANA6). HUC TN06010207-026-0300. This ANA with spring-fed headwaters on Pine Ridge consists of four 1st-order streams and two 2nd-order streams (upstream of their junction at the 3rd-order stream). Because stream segments parallel the Reservation boundary on both sides, portions of the northern part of this ANA are mapped to include areas just outside of the Reservation boundary. The small watershed that includes this ANA is part of a large 3rd-order watershed that joins EFPC well outside of ORR boundaries. Oak-hickory forest composes the dominant vegetation in the riparian zone; intact 100 ft (30 m) buffer zones are present. The diverse topography includes ravines, steep slopes, and areas with springs and associated wetlands. The aesthetic quality is high. Past and current disturbances are minor. Benthic invertebrate diversity is high; only five species of fish are present (PFSR = 29), including the Tennessee Dace. Reference sites (MBK 1.6) are present for benthics and fish community tasks of remedial activities for Bear Creek. TDEC has assessed the reaches of this stream below this ANA and rated them as Fully Supporting; it is assumed that the waters of this ANA are also in the Fully Supporting rating. It is equivalent to TNC BSR2-16.

Unnamed Tributary to EFPC (ANA7). HUC TN06010207-026-0100. This 1st-order stream is a tributary of EFPC, joining it in the upper section of ANA8, within the boundaries of the Reservation. The entire stream, except for a short headwaters section, is within the Reservation. The vegetation in the riparian zone is mixed hardwood and pine; intact 100 ft (30 m) buffer zones are present. Past disturbances were minor, but recent reconstruction and widening of Tennessee Highway 95 has affected and modified the lower end of the ANA where the stream will be culverted; fish impacts due to reduced connectivity to EFPC, water velocity changes, and potential barriers are not known at this time. Seven fish species are present (PFSR = 10), including the Tennessee Dace. The stream has not been specifically assessed by TDEC, but it is assumed that the OUS rating is the same as for EFPC, which is Not Supporting designated uses. Most of the upstream reach is located within NA2. The site is part of TNC BSR2-12.

Lower EFPC (ANA8). HUC TN06010207-026-1000. This is a large 4th-order stream that is a tributary to Poplar Creek. Most of the watershed that supplies this section of EFPC lies outside of Reservation boundaries and includes most of the city of Oak Ridge. ANA3 and ANA7 join it inside of the ORR. ANAs 4, 5, and 6 contribute to it indirectly through non-Reservation lands. The lower end of this ANA is near the point at which Bear Creek enters EFPC. Poplar Creek is a short distance downstream. Flow augmentation in the ANA8 area actually or potentially occurs. The vegetation of the ANA consists of young to mature floodplain forest; 100 ft (30 m) buffer zones are intact. Past and current disturbances are minor, but the City of Oak Ridge Sewage Treatment Facility is located just upstream; siltation is a significant problem. Benthic invertebrate diversity is high; fish species richness is high, with 60 species present (PFSR >60). Fish species present include the Tennessee Dace, the Threatened Spotfin Chub, four species that are locally rare on the ORR (Redline Darter, Blueside Darter, Dusky Darter, and Steelcolor Shiner), and several invasive species (Carp [*Cyprinus carpio*], Grass Carp [*Ctenopharyngodon idella*], and Alewife [*Alosa pseudoharengus*]). Several reference sites are located within the ANA: EFK 10.0, 10.6, 6.3, and 2.0 for benthics, periphyton, fish bioindicator, fish community, and fish bioaccumulation tasks of the Y-12 Complex BMAP. Benthic invertebrates and pollution-sensitive fish were limited in the past by water quality impacts from the Y-12 Complex and the city of Oak Ridge, but over the past 25 years, there have been improvements in water quality (i.e., elimination of sewage overflows and removal of many contaminants), resulting in an increase in FSR and the presence of more sensitive species. TDEC assessments are OUS—Not Supporting; WQ—Partially Supporting; FAL—Not Supporting; Impaired for Pathogens, Siltation and Habitat Alterations—Not Supporting; Natural and Scenic Qualities—Less than Fair. ANA8 overlaps with NA47. It is part of TNC BSR2-12.

Upper Mitchell Branch (ARA1). HUC TN06010207-020-1300. This small ARA consists of the upper part of a 1st-order spring-fed stream adjacent to ETTP. The 2nd-order segment downstream is a tributary of Poplar Creek. Flow augmentation actually or potentially occurs. The riparian vegetation is a narrow mixed hardwood and pine zone in a highly developed area. Past disturbances were extensive, including fill areas. The benthic invertebrate diversity is high, but the fish diversity is low (PFSR = 13). One reference site is present (MIK 1.43 benthics task of ETTP BMAP.) The TDEC OUS rating is Not Supporting. The TNC classification is BSR3.32.

Northwest Tributary (of White Oak Creek) (ARA3). HUC TN06010207-247-1000. White Oak Creek is a moderately large 2nd- and 3rd-order stream entirely with the ORR and which drains the developed area that includes ORNL. ARA3 consists of three 1st-order streams and the larger part of a 2nd-order stream in the lower western part of the system. Flow augmentation actually or potentially occurs; some stream reaches naturally dewater during some periods. The lower sections of this ANA are in a broad alluvial floodplain, most of which is in successional alluvial forest; the upper sections are in upland forest. Part of the lower section runs along the base of a wooded ridge; mowed fields, parking lots, and experimental ponds are on the opposite bank. Much of this system appears to have intermittent flow. In-stream plants are present in places; small wetland areas are evident. Sediment buildup is obvious in the low topographic positions. There is a highly diverse benthic invertebrate community compared to those in downstream impacted sites outside the ARA. The fish diversity is reported to be appropriate for this type of stream (PFSR = 10). The ARA is a reference site for periphyton and fish community tasks (NTK 1.0). The entirety of the White Oak Creek stream system has not been assessed by TDEC; the stream was rated Not Supporting in 2010, but the OUS, FAL and IM (Toxicity) ratings for the assessed segments were Partially Supporting in 2006. The TNC classification is BSR4-7.

First Creek (ARA4). HUC TN06010207-247-1000. This is the uppermost portion of a 1st-order spring-fed stream in the White Oak Creek drainage. Some water withdrawal actually or potentially occurs from this stream. The small ARA is adjacent to the ORNL complex. The stream originates in second-growth mixed forest, but then flows through disturbed fields and parking lots. A major road divides the ARA into upper and lower sections. Only a shrub and grass riparian zone exists in places in the lower section, and a large pipe runs adjacent to the apparently channelized stream in the lower

half. There have been some recent riparian enhancements in the ORNL area. Various hydrophytes are present in the ARA. There is a highly diverse benthic invertebrate community in the upper section. Fish diversity appears to be low due to downstream activities (PFSR = 10). The ARA includes reference sites for invertebrates and fish community tasks (FCK 0.8) and periphyton and toxicity monitoring (FCK 1.0). TDEC has not specifically assessed this reach of the White Oak Creek stream system, but the OUS is assumed to be the same as for White Oak Creek, which is Not Supporting. This ARA includes RA 28, a small spring-fed pond dominated by Nuttall's Waterweed, located on the stream in the upper portion above the road.

Upper Fifth Creek (ARA5). HUC TN06010207-247-1000. This ARA consists of a spring-fed 1st-order stream in the midpart of the White Oak Creek drainage. The riparian zones of this small ARA variously consist of upland forest, mowed fields, grassy road berm, and shrub areas. An intact 100 ft (30 m) forested buffer is present for only a small part of the system. Benthic invertebrate diversity is high; it is reported that very productive populations of two headwater fish species are present (PFSR = 10). The ARA includes reference sites for benthics and fish community tasks (FFK 1.0) and toxicity and periphyton tasks (FFK 1.1). TDEC has not assessed the specific stream reach in this ARA; it is assumed that the OUS rating is the same as for White Oak Creek, which is Not Supporting. The TNC equivalent is BSR4-4.

Upper White Oak Creek (ARA6). HUC TN06010207-247-1000. This ARA consists of the uppermost sections of the White Oak Creek drainage, three 1st-order streams and a short length of the 2nd-order stream. Flow augmentation actually or potentially occurs. Some of the upper section experiences periodic intermittent flow, and some small lower sections appear to also dewater at times. The watershed is forested, with the predominant vegetation in the riparian areas consisting of young and mature forests with some disturbed sections. Substantial aquatic vegetation is present in some sections. Disturbances include severe sediment runoff in the upper sections, stormwater outfalls, and overlapping sludge application sites. Mitigation areas are present, including a large retention basin installed on one branch. The benthic invertebrate diversity is high, and the fish community is reported to be extremely stable and appropriate for the size of stream (PFSR = 13). The ARA includes a reference site for benthics, fish, toxicity, and periphyton tasks (WCK 6.8). The stream has been used for experimental studies, including many snail-periphyton interaction studies. The TDEC ratings for the parts of the stream that have been assessed were Not Supporting in 2010, but they were Partially Supporting for OUS, FAL, and IM (Toxicity) in 2006. Part of this ARA lies within BSR3-18 and part is within BSR4-3.

Scarboro Creek (ARA7). HUC TN06010207-006T-0900. Scarboro Creek is a moderately sized 3rd-order tributary of the Clinch River. Most of the system is outside of Reservation boundaries. This ARA covers part of the lower stem of the stream. Open fields surround the area, and trees and shrubs form the riparian zones. Wetlands are present on the alluvial shelves of upper reaches. There is a large emergent wetland below the ARA at the embayment with Melton Hill Reservoir. Purple loosestrife (*Lythrum salicaria*), a noxious invasive exotic plant, is a problem in the area. Benthic diversity is high, and the fish community is representative (PFSR = 20). The ARA includes a reference site (SCK 2.2) for the fish community task of McCoy Branch. The TDEC OUS rating for this stream is Not Supporting. The area corresponds to TNC BSR4-1.

Melton Branch (ARA9). HUC TN06010207-247-0100. This ARA consists of the uppermost 1st- and 2nd-order reaches of Melton Branch and lies completely within the ORR. Melton Branch becomes a 3rd-order stream that is a major tributary of White Oak Creek, all within the Reservation. Melton Branch joins the main stem of White Oak Creek, which becomes a 4th-order stream as it enters the Melton Hill Reservoir on the Clinch River. Flow augmentation actually or potentially occurs, and some sections naturally dewater and are intermittent during some periods. The vegetation in the ARA is primarily young forest, from mesic alluvial flats to drier uplands. Various wetlands have been mapped in the ARA. There is a highly diverse benthic invertebrate community, but the fish community is limited (PFSR = 10). Reference sites (MEK 1.8 and 2.1) for periphyton, benthics, and the fish community are present in the ARA. The TDEC data for this stream are either conflicting or

the ratings have recently changed; the OUS and FAL were rated Fully Supporting in 2006 but Not Supporting in the online database (2010) with only part of the system in the ARA having been assessed. The TNC classification is BSR4-6.

One ARA described in Pounds, Parr, and Ryon (2008) is not described here, but it is included in Figs. 2, 3, and 4. Several locations in Grassy Creek (ARA2) were formerly used as BMAP reference sites for streams near Y-12 and ETTP. Because of expansion of the firing ranges near the ARA and reduced facility monitoring, the reference sites have been dropped from BMAP assessments. Hence, ARA2 is no longer considered to be an ARA.

As noted previously, the Clinch River is the ultimate receiving stream of all the waters that drain the Reservation. The Clinch River and its reservoirs in the region are rated by TDEC as Not Supporting their designated uses.

7. EVALUATION CRITERIA

A ranking system was devised using the information presented in the narrative descriptions and in Tables 1 and 2. A goal was to devise a corollary system to the one developed for terrestrial natural areas (Baranski 2009). An attempt was made to develop important evaluation criteria similar to those used in the latter study; however, this was achieved for only some of the criteria. Eight categories of evaluation factors with 5-point ranking scales (0–4) were created so that a maximum composite score of 32 was possible, thus making the values assigned to each aquatic area equivalent in magnitude to the scores in the terrestrial natural areas study. The eight categories of evaluation factors used to characterize the aquatic areas were (A) size of area, (B) percentage of watershed protected, (C) status taxa present, (D) overall biotic diversity, (E) stream features, (F) disturbance regime, (G) water quality and use support ratings, and (H) other factors. These categories are addressed in the sections that follow.

(A) Size of area. The size of an area is a fundamental attribute of a natural area's value. The areal areas of the ANAs and ARAs as currently recognized and determined by GIS analysis were used for this category. Surrounding buffer zones are 305 ft (93 m) in width on both sides and at the termini of the stream segments. Because of stream branching patterns, the same land surface can serve to buffer more than one stream segment; therefore, the measured areas are less than would be the case if the stream length was in one continuous segment. Calculations are given in acres (hectares) (Table 1); acreages were determined by GIS mapping. The 5-point scale is as follows:

- 0 = 30 acres (12 ha) or less
- 1 = 31–60 acres (13–24 ha)
- 2 = 61–120 acres (25–49 ha)
- 3 = 121–240 acres (49–97 ha)
- 4 = >240 acres (97 ha)

(B) Percentage of watershed protected. The percentage of the total watershed protected within the ANA or ARA within the Reservation was considered to be an important factor (i.e., an aquatic natural area that covers a high percentage of the watershed in which most of the watershed occurs within Reservation boundaries has greater natural area value than a natural area that composes a small part of a watershed in which the greater part of the watershed lies outside the Reservation). The assumption is that Reservation lands are likely to receive better management that will result in higher quality of aquatic systems compared to the private lands outside the Reservation. A numerical value was determined by multiplying the percentage of the total watershed within the ANA or ARA (A) by the percentage of the watershed within the Reservation (B) (fifth column × sixth column in Table 2) to give the percentage (C) in the seventh column. The 5-point scale is as follows:

- 0 = <5%
- 1 = 6–15%
- 2 = 16–25%
- 3 = 26–35%
- 4 = >35%

(C) Status taxa present. All of the recognized ANAs contain status taxa, defined as those listed by the Tennessee Division of Natural Areas as Endangered (E), Threatened (T), Special Concern (S), or Deemed in Need of Management (D) and also with State Ranks of S1, S2, or S3 (see Baranski 2009 for complete discussion of rare species on the Reservation and status and ranking criteria). A list of the rare aquatic animals documented or reported for the Reservation is presented in Table 1; only some of these are found within ANAs, with the others occurring in reservoirs or large rivers. The number of status taxa present in a stream (Table 3) and the vitality of their populations (see narrative descriptions in Sect. 6) are important components of natural value. The following ranking scale is designed to reflect both the number of status taxa present and the vitality of the species' populations in the streams:

- 0 = no status taxa present
- 1 = one status taxon present, low or moderate density
- 2 = one status taxon present, high density; or the status taxon present is E or T
- 3 = two status taxa present, low or moderate densities
- 4 = two status taxa present, high densities; or one of the two status taxa present is E or T

(D) Overall biotic diversity. Some streams are naturally more biologically diverse than others. The level of biodiversity may be due to geological characteristics, the complexity of the habitat, pollution levels, or the land use and disturbance history. Biotic diversity information is available anecdotally and from various sampling studies (see narrative descriptions in Sect. 6).

Some aspects of biodiversity, such as fish diversity, depend on stream size (i.e., larger streams are naturally expected to harbor larger numbers of fish species than smaller streams). Typically, no more than 10 fish species would be expected in the most pristine small watersheds (less than 500 acres [202 ha]), a maximum of 30 taxa might be expected in a moderate-size watershed, and a maximum of 70 fish species could be expected in the largest watersheds (more than 5000 acres [2024 ha]) (M. Ryon, personal communication, Feb. 9, 2009); however, exceptions do occur. Data on existing FSR and PFSR are available. The PFSR is based on stream size, habitat, proximity to downstream sources, and the position in the watershed. The FSR and PFSR were compared for the determination of fish biotic diversity. An Index of Biotic Integrity (IBI) for fish was not available for most streams and was not used as an indicator of overall biotic diversity in the ranking analysis.

Benthic macroinvertebrate data are also important for describing the biotic diversity of a stream. This information was not available in a quantitative form at the time of this writing; however, IBI data for macroinvertebrates in ORR waters do exist and are being sought. Only generalized estimates are available in the published reports.

Fish and macroinvertebrate data were considered together. The ranking scale was developed as a general guideline to reflect biotic diversity as follows:

- 0 = very low diversity, low macrovertebrate diversity or no information available, FSR less than 25% of the PFSR for the size of the stream
- 1 = low diversity
- 2 = moderate diversity
- 3 = high diversity
- 4 = very high diversity, high macroinvertebrate diversity, FSR near or greater than 100% of the PFSR for the size of the stream

(E) Stream features. Stream features are an important component of habitat quality. This is a complex attribute and can be characterized using a number of different variables. Buffer zone features, canopy coverage, and in-stream variables all contribute to overall habitat quality. Some streams are highly variable, while others are more uniform in their physical and chemical characteristics and surrounding terrain. For in-stream features, the highest-quality streams would have all 12 in-stream variables present (see Sect. 6). An overall high-quality stream for habitat would have a minimum 100-ft-wide (30-m-wide) forested riparian zone (each side) throughout its length, a high percentage of canopy coverage over the entire length of the stream, many in-stream variables contributing to habitat complexity, and no in-stream barriers to fish movements. Streams with significant intermittent flow or dewatered areas are not rated as highly as permanent streams. The ranking scale was created through subjective evaluation of the data presented in Table 3 and in the narrative descriptions in Sect. 6. Buffer zone data were not available for most ARAs, and the assigned score for these areas is based on less information. The scale is as follows:

- 0 = <5 stream variables, <60% canopy coverage, buffers <50 ft (15 m) wide and/or <50% of stream, 3 or more fish barriers present
- 1 = 5–6 stream variables, 60–70% canopy coverage, poor buffers, 2 or 3 fish barriers
- 2 = 7–8 stream variables, 70–80% canopy coverage, fair buffers, 1 or 2 fish barriers
- 3 = 9–10 stream variables, 80–90% canopy coverage, good buffers, 0 or 1 fish barriers
- 4 = 11–12 stream variables, 90–100% canopy coverage, intact 100 ft (30 m) buffers for 100% of stream, no fish barriers present

(F) Water quality and use support ratings. Stream water quality information and OUS ratings available in TDEC documents and databases were assembled into the narrative descriptions (Sect. 6). Data were not available for all the streams. By default, streams that were not assessed by TDEC received a 0 score, when, in fact, the water quality may be high. The information was used to develop a ranking scale that reflected stream quality in the ANAs and ARAs. The ranking scale employs language similar to that used by TDEC and is presented below.

- 0 = not supporting designated uses and highly impaired or not assessed
- 1 = not supporting designated uses and impaired
- 2 = partially supporting with some designated uses supported
- 3 = fully supporting designated uses but threatened
- 4 = fully supporting of all designated uses

(G) Disturbance regime. Various features of a stream's surrounding environment affect its natural area value. Some of these features are disturbances that may affect water quality, biotic diversity, and habitats, while others affect the aesthetic quality. Disturbances include the proximity to roads and utility corridors and whether these run parallel to a stream corridor or cross the stream corridor (with or without bridges). Unnatural flow regimes due to water withdrawals and flow augmentations are also considered here. Historical disturbances include logging and such activities as channelization and rip-rapping that may have impacted the natural topography. Other factors considered here are the presence of sewerage outfalls and nearby landfills, sludge application sites, facilities, and other developments. Subjective evaluation of the information presented in Table 3 and in the narrative descriptions in Sect. 6 produced a ranking scale as follows:

- 0 = very high disturbance
- 1 = high disturbance
- 2 = moderate disturbance
- 3 = low disturbance
- 4 = very low disturbance

(H) Other factors. This is a miscellaneous category of additional factors that contribute to the overall natural area value of an aquatic area, but which are not uniformly applicable across all areas. The category includes such things as whether the ANA or ARA overlaps or is included within an NA or RA; whether the area exists as part of a large undeveloped tract or as a relatively linear corridor unto itself; the presence of monitoring, reference, and study sites; the complexity of the protected stream system with regard to the number of types of streams present (1st through 4th order); the presence of wetlands; the presence of invasive species; and the overall aesthetic appearance of the system. The ranking scale is as follows:

- 0 = no other value
- 1 = low value
- 2 = moderate value
- 3 = high value
- 4 = very high value

8. ASSESSMENT AND RANKING OF AREAS

As currently defined, with 305 ft (93 m) buffers on all sides of a designated stream segment, including the ends of the segments, there are 1,551 acres (628 ha) recognized as ANAs and 578 acres (234 ha) recognized as ARAs on the ORR. This acreage is approximately 8.1% of the total Reservation acreage of 33,542 acres (13,574 ha). NAs and RAs (the terrestrial natural areas) compose 9,627 acres (3,896 ha) of the Reservation, or approximately 28.8% of Reservation lands (Baranski 2009). Because there is overlap between the terrestrial and aquatic areas (Fig. 2), the two acreages cannot be combined to yield a total acreage recognized collectively as NA, RA, ANA, and ARA.
In Table 4 eight categories of criteria are evaluated for each aquatic area, and a composite score is calculated by summing the individual scores across all categories. A high degree of subjectivity was applied in cases in which specific information was lacking or incomplete. Composite scores may numerically range in value from 0 to 32, but scores in the upper end of the scale are not actually realized. Nonetheless, the highest composite scores are equated with the highest aquatic values for the stream systems on the Reservation, and a rank order from highest to lowest scores reflects decreasing value. A highly ranked ANA or ARA is large in size compared to other areas, protects a greater proportion of the watershed within ORR boundaries, contains a number of status taxa at high densities, exhibits a high overall biodiversity, has very good or excellent habitat quality and water quality, is well protected and isolated from disturbances, and shows several other characteristics that contribute to natural area value.

Composite scores ranged from 6 to 20; the median score was 14, and the mean score was 13.9 for all 15 Areas. The highest category rankings were generally for size of area (A), percentage of watershed protected (B), and stream features (E). The generally lowest category rankings were for status taxa present (C) and other factors (H).

Table 4. Ranking of Aquatic Natural Areas (ANAs) and Aquatic Reference Areas (ARAs) for eight categories of factors: A (size of area), B (percentage of watershed protected), C (status taxa present), D (overall biotic diversity), E (stream features), F (water quality and use support ratings), G (disturbance regime), H (other factors).[a] Data synthesized from multiple sources (see text).

Area	A	B	C	D	E	F	G	H	Composite score	Rank	Priority Group
ANA1	3	2	1	3	3	0 (NA)	3	3	18	3	I
ANA2	4	2	3	2	3	2	0	2	18	3	I
ANA3	3	4	1	2	2	1	2	1	16	6	I
ANA4	1	1	1	2	3	0 (NA)	3	1	12	10	II
ANA5	3	2	1	1	2	4	2	2	17	5	I
ANA6	2	3	1	2	2	4	3	2	19	2	I
ANA7	1	2	1	2	2	1	2	2	13	9	II
ANA8	3	0	4	4	4	1	2	2	20	1	I
ARA1	0	1	0	1	2	1	0	1	6	15	III
ARA3	3	4	0	2	2	2	1	1	15	7	I
ARA4	0	1	1	1	2	2	1	2	10	13	II
ARA5	1	3	0	1	2	2	1	1	11	12	II
ARA6	3	3	0	2	1	2	0	1	12	10	II
ARA7	0	0	0	2	2	1	2	1	8	14	III
ARA9	3	4	0	1	2	1	2	1	14	8	II

[a] Maximum factor value is 4. Maximum total composite score is 32. See text for description of each category.
NA = not assessed.

The 15 Areas were arranged into three Priority Groups intended to reflect priority for protection. Priority Group I includes Areas rated with scores of 15 or higher (almost half of the theoretical maximum of 32 and above the mean score); seven Areas were included—six ANAs and one ARA (Table 4). Priority Group II includes Areas rated with scores from 10 to 15; six Areas qualified. Priority Group III includes Areas with scores less than 10; only two sites were rated below 10, both ARAs. ANAs scored higher (mean 16.6) compared to ARAs (mean 10.9). It appears that the existing separation of areas into ANAs and ARAs reflects their relative importance for natural area value, with ANAs generally rated more highly.

Across all categories, Lower East Fork Poplar Creek (ANA8) ranked highest with a score of 20 and Upper Mitchell Branch (ARA1) ranked lowest with a score of 6. In addition to Lower East Fork Poplar Creek, the other highly rated Areas in Priority Group I were Ish Creek (ANA1), Bear Creek (ANA2), Gum Hollow Branch (ANA5), Mill Branch (ANA6), Unnamed Tributary to East Fork Poplar Creek (ANA3), and Northwest Tributary of White Oak Creek (ARA3) (Table 4).

Lower East Fork Poplar Creek (ANA8) presents an interesting situation. As currently defined it ranks highest among all the areas evaluated, but it also may be considered in a different light because of its position in the landscape. An examination of Table 2 and Fig. 4 illustrates that ANA8 is unique among all the ANAs and ARAs in that it not only stands alone, but it also receives the waters from other protected ANAs on the Reservation. Within the entire watershed drained by ANA8, fully 26% of the watershed is located within the ORR. This is a significant number, considering that the remainder of the watershed contains the city of Oak Ridge and surrounding developed areas that negatively influence the water quality of EFPC. All of these protected watersheds serve to positively mediate the water quality of areas downstream of ANA8.

9. DISCUSSION AND RECOMMENDATIONS

Some basic questions should be addressed regarding the concept of ANAs and ARAs. What are the purposes of establishing ANAs and ARAs? The existing definitions state that ANAs protect special habitats and sensitive species and may serve as reference and control areas, while ARAs primarily serve as reference and control areas and may also include study sites for the collection of baseline data. Are there other reasons for establishing ANAs and ARAs? Is there a better way to classify and name the different categories of special areas on the Reservation (aquatic and terrestrial)? How much buffer zone area should be included in ANAs and ARAs?

9.1 BUFFER ZONES

Is there a defensible, modern justification for large uniform 305 ft (93 m) buffer zones delineated around streams—on both sides and the termini of identified stream segments that constitute ANAs and ARAs? Are protected zones more than 610 ft (186 m) in width (two buffer zones and the stream itself) necessary to protect all types of streams in all cases? What is being protected—the streams and their integrity or greater systems with the included significant streams? If it is not the larger system that merits recognition and protection, then how much buffer is necessary to protect the integrity of the streams? If it is the larger system that has significant natural area or reference area qualities, then a case might be made for the recognition of the larger systems as terrestrial natural areas with significant stream systems as components. Factors that determine the significance of terrestrial natural areas include components such as the size of the significant area; the presence of rare species and status taxa; aspects related to community and landscape diversity, quality, and integrity; disturbance factors; aesthetics; and other special features.

Recognition of large 305 ft (93 m) buffer areas may be desirable from the standpoint of land protection; however, they seem to be untenable from the view of protecting streams and their biological integrity if the streams alone are the objects of protection. Also, there are even a few cases

on the Reservation in which the 305 ft (93 m) buffer zone actually extends into an adjacent watershed. Published management recommendations issued by various government agencies do not generally mention buffers of such large size.

If protection of water quality is a primary objective of the ANA and ARA designations, riparian buffers or Streamside Management Zones (SMZs) in excess of 100 ft (30 m) are probably not necessary in most cases. Substantial information exists that suggests water quality can be maintained with smaller buffer zones.

An SMZ is defined as an area in which extra precaution is required while carrying out forest practices in order to protect water quality. The goals of established buffers and SMZs include filtering and slowing runoff, shading streams from intense sunlight, helping to stabilize stream banks, capturing sediment, reducing erosion, and lessening impacts from biological pollution agents from adjacent land uses (Brogan et al. 2006; ORNL 2008). Soil types, adjacent slope steepness, and vegetation type and distribution are three of the more important site factors that influence buffer and SMZ size, with steeper slopes, more erodible soils, and minimal groundcover requiring wider buffers (Brogan et al. 2006).

The erosion and sediment control guidelines for Tennessee recommend 50 ft (15 m) vegetated buffers for flat-lying areas and increases of buffer widths of at least 2 ft (0.6 m) perpendicular to the stream bank for each 1% of slope to allow more settling time and infiltration of runoff (Price and Karesh 2002). Stream mitigation guidelines for Tennessee recommend buffers 50 ft (15 m) in width on each side of a stream (from bankfull elevation) or widths three times the stream width, whichever are greater (TDEC 2004). For purposes of macroinvertebrate stream surveys, TDEC defines riparian zones to be 59 ft (18 m) from the edge of the stream bank (TDEC 2006b).

Best Management Practices (BMPs) for logging operations typically recommend minimum streamside management zones 25 ft (8 m) in width on level ground, with zone width increasing as steepness of slope increases adjacent to the stream or where other values such as wildlife habitat are important; for example, a 40% slope between the stream and a disturbed area would require a 105 ft (32 m) SMZ (Tennessee Department of Agriculture 1993). In North Carolina the generally recommended SMZ width for forestry-related site-disturbing activities is 50 ft (15 m) on each side of intermittent streams and perennial waterbodies and wrapping around stream heads where ephemeral streams enter the larger channels; wider or narrower zones may be required or appropriate under certain site conditions (Brogan et al. 2006). It is noted, however, that SMZ widths for forestry operations could be as much as 300 ft (91 m) for specific wildlife and aquatic organisms (Brogan et al. 2006).

ORNL has instituted various stream corridor and water quality protection measures. The goals of a 2004 stream corridor protection plan (ORNL 2004) were to protect riparian zone buffers along stream corridors, enhance riparian zones, and provide BMPs for streams on ORR lands managed by ORNL; the plan adopted TDEC (Price and Karesh 2002) guidelines of minimum 50 ft (15 m) buffer zones on each side of a stream. A water quality protection plan, developed specifically and only for the ORNL land area portion of the Reservation, followed TDEC (2006b) and Price and Karesh (2002) and established a minimum 59 ft (18 m) vegetated riparian zone on each side of a stream bank as an optimal width (ORNL 2008). The latter plan seeks to protect riparian zone substrate and buffering vegetation to achieve water quality criteria and enhance aquatic ecosystems on lands managed by ORNL.

Optimal riparian buffers should also take landscape and geomorphological features into consideration. Elevational gradients, complexity of topographic relief, meanders and sinuosity, and other things influence channel location and potential migration; these should be considered when fixing boundaries of protected areas. Stream channels are not permanently stable, and allowance should be made for some stream movement within floodplains. How much allowance should be made for this possibility is an open question.

This review of stream riparian zone protection measures suggests that the presently defined 305 ft (93 m) buffer zone for ANAs and ARAs is excessive and not necessary in most cases, unless

attributes other than water quality can be identified for protection within the larger zone. A reduction in ANA and ARA buffer zone widths seems to be more in keeping with published guidelines. Ideally, each ANA or ARA should have its uniquely defined buffer zone, depending on the qualities that are being protected, but this may not be possible in practice.

9.2 RECOMMENDATIONS

This analysis of ANAs and ARAs should be considered as a first approximation of a document that will need to be regularly revised to reflect new information and insights. Through the course of the preparation of the present document, it was apparent that several evaluation criteria categories need improvement or lack the requisite information; these concerns are summarized in this section. Additionally, other issues and areas emerged that should be examined and that may lead to possible redefinition or reclassification of ANAs and ARAs. Specific recommendations are presented below.

- As a general practice, the establishment of riparian buffer zones only 100 ft (30 m) wide on each side of the stream is recommended. Buffer zones of this dimension should be sufficient to protect the water quality of the streams themselves and also allow for some channel movement. If a case can be made for wider buffer zones, such as might be necessary to protect biological integrity or specific organisms, then they should be so designated. At the present time, however, there is no information indicating that there are specific organisms or special biological communities present in any ORR stream that require wider buffer zones for their protection. Lacking any justification for 305 ft (93 m) buffer zones, it seems that a blanket 305 ft (93 m) buffer zone applied to all ANAs and ARAs is not defensible. A uniform 100 ft (30 m) buffer zone, with allowance for wider zones being established where biologically necessary, seems to be a more reasonable practice. Extra precautions (e.g., pollution discharge standards) might be taken to ensure water quality of certain specially designated waterbodies. If there are purposes other than the maintenance of water quality, then other buffer and SMZ treatments or size layouts may be desirable.

- Complete information about biotic diversity and habitat assessment components are fundamental to the development of a good evaluation system. Biotic diversity information is weak or lacking for many of the aquatic areas evaluated in this study. An effort should be undertaken to secure detailed quantitative data about the vertebrate and invertebrate communities of the streams. At present, some quantitative fish data are available, though not always complete, and the macroinvertebrate data are incomplete and entirely anecdotal and qualitative. Ideally, an IBI should be developed for each ANA and ARA. Habitat assessment data available for ORR streams should be secured.

- Standardized and complete information about the vegetation component of the ANAs and ARAs should be developed. Riparian and buffer zone vegetation characteristics are important considerations affecting the natural quality of stream systems.

- Complete, precise, and comparable water quality information is not currently available for all the streams in the ANAs and ARAs. This study employed the available TDEC water quality data, but this kind of data does not appear to exist for all the streams under study. An effort should be made to secure water quality data that are complete and standardized. Data collected through the ORR BMAP could not be secured for use in this study; these data should be accessed and used in the assessment of water quality.

- To some degree other evaluation categories, such as biotic diversity and stream features, can be a reflection of water quality. An attempt could be made to further separate and refine the evaluation categories so that there is no overlap in the criteria.

- A comprehensive inventory of ORR watersheds is available in a digitized GIS format (Tauxe 1998). The digitized data could be employed to refine the topographic boundaries of the ANAs and ARAs, generate hydrological data about the delineated areas, and possibly provide other assessment information. The data sets are available in MapInfo format at http://www.neptuneandco.com/~jtauxe/orrwater/.
- ARA2 is no longer a recognized area, even though it is still being maintained on databases (as shown in Figs. 2, 3, and 4 in this report). Because it has been delisted, it should be removed from all databases and maps of ORR natural and sensitive areas.
- Only currently recognized ANAs and ARAs are treated in this report. There are other watersheds and stream reaches on the ORR that have not been recognized as ANAs and ARAs but contain features that appear to qualify them for special aquatic designations. Their recognition may depend on the definitions of protected aquatic areas, a subject of the next recommendation. Two watersheds in particular surfaced as areas that appear to deserve recognition. The Bearden Creek and Walker Branch watersheds are both large and relatively nonimpacted. The Walker Branch Watershed Research Area is a world-renowned, long-term site for forest and stream research and contains reference sites for some aquatic monitoring studies (http://walkerbranch.ornl.gov). For other reasons as well, Baranski (2009) recommended the creation of a Walker Branch Watershed Natural Area of more than 800 acres (324 ha).
- Concerted effort and study should be undertaken to reevaluate the several categories of terrestrial and aquatic areas that are specially recognized on the ORR. It may be that a more useful and meaningful set of definitions can be created for the recognized categories. Incorporation of some of the ideas and concerns presented above may allow for the inclusion of some currently unrecognized but significant areas. Some other areas may be combined or delineated in other ways. An initial step might be to rename the current NAs and RAs and call them terrestrial NAs and RAs, in contrast to the existing ANAs and ARAs.

9.3 CONCLUDING REMARKS

A reduction in buffer size from 305 ft (93 m) to 100 ft (30 m) would dramatically change the size of the ANAs and ARAs (see Table 2, columns 5 and 9). Certainly a wider protected zone adds to the aesthetic character of a stream system, but if wider areas have natural area qualities, they should be considered as terrestrial natural areas rather than ANAs. At some point a distinction between the two types of areas needs to be made. This report and the companion report on terrestrial natural areas (Baranski 2009) could be the catalysts to begin discussions about the types of areas on the ORR that receive special recognition and to more precisely define the features that characterize each category of special area. Such discussion is beyond the scope of the present study, but the stage may now be set for a more holistic view of resource values on the ORR.

This report is a first attempt to develop a system for evaluating special and sensitive aquatic areas. Any evaluation reflects the best available information. It must be understood that if the data were improved and more complete, a very different set of results and ratings might be obtained. It is also true that new insights and information may warrant revision and redefinition of the evaluation categories and criteria.

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