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The importance of recognizing Buffer Zones to lands being developed, restored, or remediated: on planning for protection of ecological resources

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ABSTRACT

Environmental management relies on many types of information before making decisions regarding remediation, restoration, or other land use decisions, including ecological data, such as risks to species, populations, communities, and ecosystems. The aim of this investigation was to describe the ecological information required within the context of making environmental decisions and providing visual communication tools for regulators, conservationists, and the public to understand the risk to ecological resources on- and off-site. It is suggested that ecological information used in environmental decisions is required to be transparent throughout the planning and execution of a project, which needs to include: 1) ecological information and evaluations within development areas or units (in this case, watersheds), and 2) resources in adjacent areas (Buffer Zones) that might be affected. The Melton Valley administrative watershed (Oak Ridge Reservation, TN) is used as a case study because this site still has active facility development and environmental remediation, and there are important ecological resources on and off-site. Data indicate that although there are important resources on Melton Valley administrative watershed, there are also significant resources in the Buffer Zone around the watershed. Compared to the Melton Valley administrative watershed, the Buffer Zone contains more Interior (and Buffer) Forest and greater value resources. The point is made that when remediation, restoration, or development occurs, it is equally important to consider resources that are adjacent to the site in a Buffer Zone, particularly when remediation and development might continue for many years or decades.

KEYWORDS

Buffer Zones; Biomonitoring; Interior Forests; high value ecological lands; legacy wastes; remediation

Introduction

Increasingly land use planners, conservationists, the public, and regulators are interested in the overall goals of (1) protecting existing wild lands, (2) restoring damaged ecosystems, and (3) remediating contaminated lands to enable productive future land uses. Cleaning up chemical and radiological wastes remaining from World War II, the Cold War, and past industrial activities is a goal of the U.S. and other developed countries (DOE 1994b, 2015; Lubbert and Chu 2000). The largest cleanup tasks in the U.S. fell to the Departments of Energy and Defense (DOD 2001; DOE 2002b). The Department of Energy (DOE), and its predecessor (Atomic Energy Commission) were engaged in development, production, and testing of nuclear weapons, and research on impacts of their activities and nuclear materials on land and ecosystems (Gephart 2010). At the end of the Cold War in 1989, DOE created the Environmental Management Program (DOE-EM) to clean up and restore lands contaminated by legacy wastes of nuclear production (Crowley and Ahearne 2002).

Approximately 10% of the land area on the large DOE sites was industrially developed, and the rest of the undeveloped land served as a National Security buffer from which the public was excluded by barriers and well-equipped security forces. The rest of the DOE land was left relatively undisturbed (except for roads), representing the surrounding natural ecosystem. Former agricultural lands on the sites, now abandoned, underwent succession resulting in some of these lands containing quite valuable ecologic resources (Brown 1998; Burger et al. 2017; Dale and Parr 1998; Whicker et al. 2004). Some of these lands were designated by the U.S. Congress as National Environmental Research Parks (NERPs) (DOE 1994a). NERP designation resulted in research funds to (1) determine the

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influence of radionuclides on plants and animals, (2) develop long-term population trends of unique or rare plant communities, and (3) protect ecological resources from species declines and adverse effects of humans. Thus, the research was largely designed to determine the effect of radionuclides, other hazardous chemicals, and DOE's physical disruptions on plants, animals and their ecosystems.

Protecting human health and the environment is important to Tribal, Federal and State governments, non-governmental agencies, and the public. While the term "environment" often refers to water, air, and soil, environment also includes ecological resources along with the physical environment (CDC 2023; Costanza et al. 2017). Ecologists and land managers are most directly concerned with (1) characterizing species, populations, and ecosystems; (2) examining how ecosystems function; and (3) determining adverse effects on species and ecosystems. However, many other individuals are also concerned, including environmental agencies, natural resource managers and regulators, conservation organizations, consumptive and non-consumptive resource users, the public, and individuals interested in the environment for aesthetic, cultural, religious, and existence values (Chan, Satterield, and Goldstein 2012; Davidson 2013). Thus, understanding the value of ecological resources on lands, determining how to manage and protect valuable resources, and communicating those understandings to the public is an important environmental mandate.

The objective of this study was to briefly present the information that is essential to evaluate ecological resources on any site targeted for an action or environmental project, and secondly propose methods of assessing ecological resources on adjacent lands that might be impacted by any management, restoration, or remediation activities on the target site (or larger parcel of land). Our observations suggest that ecological information used in environmental decisions needs to be transparent to all parties, including the public, throughout the planning and execution of an environmental project, and proposes that environmental assessment be required to include: 1) ecological information and evaluations within the development (or remediation) area, and 2) resources on adjacent areas. These points are illustrated using the Melton Valley administrative watershed on the Oak Ridge Reservation (ORR) in Tennessee as a case study. An administrative watershed is all, or part of a watershed that is defined administratively, in this case, by DOE for remediation, restoration, or other action. The Melton Valley administrative watershed is used to 1) describe the ecological information needed for decision making regarding remediation, 2) illustrate the concept of a Buffer Zone around a development or remediation site, and 3) demonstrate the importance of adequately describing resources on adjacent lands. This report illustrates the critical point that when remediation, restoration, or development occurs, it is also important to consider resources that are adjacent to the target site (e.g. Buffer Zone) during planning and execution, particularly when remediation and development might continue for many years or decades. The term Buffer Zone was used to distinguish this from a term previously used in the literature that might be confusing (e.g. Buffer Forest). Buffer Forest refers to the forest that serves as a buffer around Interior Forests (further described below).

The Consortium for Risk Evaluation with Stakeholder Participation (CRESP) has worked with the DOE-Environmental Management program (DOE-EM) for decades, recognizing that DOE has one of the largest remediation tasks in the World, and some remediation work on its largest sites is not expected to be completed until the end of the 21st century (DOE 2019, 2022). The Melton Valley administrative watershed was selected because it still has active facility development in some areas while environmental remediation is ongoing or planned in other areas. There are also valuable ecological resources in the watershed and on adjacent land. While the Melton Valley administrative watershed is used as an example, the information required, and the approach presented in this study are pertinent to any site where development or restoration is occurring. The investigation makes the broad point that considering on-site resources is only part of the site characterization, and evaluating resources surrounding the site may be equally important.

Risk information and ecological assessments are difficult to communicate under ordinary

circumstances, but communication becomes more complex when the conditions and threats change over time. That is, on many of the large DOE sites the threats to ecological resources change with time, including (1) increases in invasive species, (2) decreases in native species, (3) shifts in the relative abundance of different species, (4) increase in number of roads and other infrastructures, (5) location of waste sites, (6) changes in stability of buildings as these age or are remediated, (7) increase in number of forest pests or diseases, and (8) alterations in climate, or even accidents. Recent environmental crises such as Chernobyl (Davydchuk 1997), Fukishima (Kusumi, Hirayama, and Kashima 2017), the Exxon Valdez (Lance et al. 2001) and Deepwater Horizon Oil Spills (Laffon, Pásaro, and Valdiglesias 2016; McNutt et al. 2012; Takeshita et al. 2021), Hurricane Katrina (McKee and Cherry 2009), cyclones Idai and Kenneth (Erickson et al. 2019), hurricanes Florence and Michael (Erickson et al. 2019), and flash floods (Erickson et al. 2019), or even COVID-19 (Heinrichs 2020; Procko et al. 2022; Rutz et al. 2020) clearly affected ecological resources as well as human health. In some cases, species died or declined precipitously around these accidents (Garnier-Laplace et al. 2015; Moller and Mousseau 2007; Peterson, Efroymson, and Adams 2011).

Timely, relevant, and science-based information is needed and necessary for successful communication and dialogue for both human and ecological (or environmental) health to avoid confusion and misunderstandings (Sandman 1987; Sandman et al. 1993). Ecological assessment and monitoring are both essential to providing up-to-date ecological information for landowners and managers (such as DOE), regulators, resource trustees, and the public (DOE 2013; Cappuyns 2016; Davidson 2013; Golden and Rattner 2003; Lamb et al. 2009). The value in this investigation is in providing a paradigm and method that might be useful at other remediation, restoration and development sites that are under consideration or planning.

Methods

Findings presented here were developed by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) while conducting risk assessments for the Hanford Site and for a screening risk assessment for the Oak Ridge Reservation at the request of DOE-EM (Burger 2019, 2022a; Burger et al. 2019, 2022a).

Protocol

The basis for this report were largely developed by Burger et al. (2022a) and Burger (2022a, 2022b) as part of CRESP's work at different Department of Energy sites and facilities, including the Hanford Site in Washington, Idaho National Laboratory in Idaho, Savannah River Site (SRS) in South Carolina, and Oak Ridge Reservation (ORR) in Tennessee, among others. This investigation included conducting ecological evaluations, risk assessments, risk communication, and stakeholder involvement in different habitats on restoration sites and other protected lands (Burger 2022a, 2022b; Burger et al. 2022a; Greenberg 2022). At ORR, evaluation of ecological resources used the refereed literature and documents developed by ORR and its contractors (Giffen, Wade, and Mueller 2012; Parr and Hughes 2006; Parr et al. 2015; Peterson 2011; Peterson, Efroymson, and Adams 2011; TNC 1995). CRESP's work at ORR also focused on several of the administrative watersheds still requiring remediation. Valuable ecological resources border the Melton Valley watershed. These are normally referred to as off-site resources. However, the term off-site could include a narrow strip (e.g., 10 km) or a larger strip (e.g., 100 km). The Melton Valley administrative watershed provides an example where actions on the site such as remediation, new construction, and placement of buildings in the watershed may significantly impact off-site resources that may not otherwise be considered.

The approach in this study is to first describe a paradigm for the types of information needed to protect ecological resources within the constraints of other anthropogenic considerations and goals such as ecological preserves, restoration projects, long-term assessments, monitoring, remediation, and cleanup maintenance (Burger et al. 2019, 2022a). Information and approaches were gleaned from refereed literature, unpublished reports from DOE or its contractors, and experiences of this paper's researchers at DOE and other sites.

Secondly, the use of a Buffer Zone around a remediation or development site is presented. Thirdly, following the general description of resources to be considered, key ecological resources are compared on the Melton Valley Watershed with its Buffer Zone, by combining ORR sources of ecological information, with ORR site visits (Carter et al. 2020; Giffen, Evans, and Parr 2012; Giffen, Reasor, and Campbell 2011; Giffen, Wade, and Mueller 2012; Giffen et al. 2009; McCracken and Giffen 2017; McCracken et al. 2015; Parr and Hughes 2006; Parr et al. 2015; Peterson 2011; Peterson, Efroymson, and Adams 2011; Roy et al. 2014; TNC 1995). Unpublished reports were particularly important. For example, the initial The Nature Conservancy (TNC) (1995) report was used for later evaluations of the important resources on particular locations on ORR. The reason to define a Buffer Zone specifically is that an off-development area, as mentioned above, might include an arbitrary area or distance from the site and is often not defined in published literature or reports.

The CRESP evaluation is a synthesis predominantly based upon two previous forms of evaluation: 1) amount of Interior Forest and definitions of Interior and Buffer Forests on ORR (Giffen, Wade, and Mueller 2012) and 2) an evaluation of the significance of land for ORR, based on ratings by The Nature Conservancy (TNC 1995), as updated by Parr and Hughes (2006) and Parr et al. (2015). Previous findings established that at ORR, Interior Forests are an indicator of important ecological resources (Burger et al. 2023; Giffen, Wade, and Mueller 2012). For example, many neotropical migrants (a declining group of birds) require the Interior forest for breeding (Kroodsma 1984; Petit 2000; U.S. Forest Service 2023). Interior Forest requires a clear definition. In this report, the acreage of Interior Forest is defined as forest that is at least 200 m from roads or other openings such as power lines and fire breaks and is an area that is greater than or equal to 10 acres (Giffen, Wade, and Mueller 2012; Parr and Hughes 2006). Buffer Forest is defined as a 200-m wide area of forest around the Interior Forest.

A second method used in this investigation for comparing resources on a development/remediation site and its Buffer Zone is "significant ratings" (TNC 1995). The significance ratings are a combination of different types of importance indices that include 1) global conservation status designations (from widespread and secure to crucially imperiled globally); 2) state conservation designations (from widespread to critically imperiled in the state, Tennessee); and 3) a relative ranking that includes quality, condition, viability, and defensibility (e.g., threat manageability) evaluated initially by (Parr et al. 2015; TNC 1995). The definitions of the composite "significance" ratings are summarized below (TNC 1995):

> *Very High Significance* = One of the most outstanding occurrences of any community element, areas containing any occurrence of species that are critically imperiled globally (5 or fewer occurrences); a globally imperiled species (6–20 occurrences, e.g., Spreading False Foxglove *Aureolaria patula*); or species whose long-term prospects for continued existence are marginal or poor.
>
> *High Significance* = A community element or area with any occurrences of a species that is imperiled globally or is rare or uncommon (e.g., 21–100 occurrences globally, e.g., Bachman's Sparrow *Peucaea aestivalis*) or a community that is ranked excellent in terms of size, maturity, condition, and is vulnerable or threatened by disruption.
>
> *Moderate Significance* = Community elements with a marginal occurrence of a rare or uncommon species or a species or habitat that is widespread and abundant and has excellent chances of being viable but is vulnerable to disturbance and disruptions.
>
> *Landscape* = Developed lands, parking lots, mowed lawns.

The ratings are more complex than described above and involve judgments not only of the degree to which the species (or habitats) are imperiled (globally and within Tennessee) but also judgments regarding quality and condition measures and long-term prospects for population viability and defensibility (e.g., can the known threats be managed?). A more complete description of the factors entering the relative significance ratings may be found in TNC (1995), Parr and Hughes (2006), and Parr et al. (2015).

The Melton Valley administrative watershed of Oak Ridge Reservation

The Oak Ridge Reservation is one of the original sites of the Manhattan Project for bomb development and uranium enrichment during World War II (Department of Energy 2022; Gephart 2010). ORR continued to function in weapons production and research during the Cold War. At the end of the Cold War (approximately 1989) when the U.S. recognized the need to clean up nuclear and other legacy wastes on its bomb sites, ORR began to switch to cleanup (Crowley and Ahearne 2002; DOE 2022). Each DOE site developed methods and approaches for designing and implementing cleanup. Cleanup has required decades and is not complete at major DOE sites such as ORR, SRS, Hanford Site, and Idaho National Laboratory. Much remains to be completed although DOE has made significant progress (DOE 2022). ORR has an ongoing R&D mission, and new facilities are being constructed in Melton Valley (DOE 2000a, 2002a; ECA 2020) (Figure 1).

ORR is bordered on the north and west by the city of Oak Ridge and on the south and east by the Clinch River. ORR has an area of 13,314 ha (32,900 acres) and is largely forested (approximately 70%, Parr and Hughes 2006). When DOE acquired the land in the early 1940s, it was half forested, and half farms and pastures. Over 8 decades, much of the original farm land on ORR has become forested. ORR has maintained forest patches with considerable Interior Forest (Burger et al. 2023; Giffen, Evans, and Parr 2012; Giffen, Wade, and Mueller 2012).

Because ORR lies in a ridge and valley landscape with considerable rainfall, ORR-EM plans and manages cleanup by watershed, including the small and larger streams (Tauxe 1998). The Melton Valley administrative watershed is a mountainous area on ORR and is one of several administrative watersheds on the site. The Melton Valley watershed also contains some active facilities of the Oak Ridge National Laboratory (formerly X-10) and receives water from the White Oak Creek. During its history, liquid and solid radioactive wastes were discharged into surface water and/or buried on site (DOE 2000a, 2000b). Waste sites also received solid and liquid waste from outside ORNL. Around the year 2000, the Melton Valley waste sites were identified as the major contributor of contaminants to the Clinch River (DOE 2000a, 2002a).

The primary habitat on ORR is eastern deciduous forest (Giffen, Wade, and Mueller 2012). In examining ORR for ecological resources overall, the Melton Valley administrative watershed, one of several watershed management areas on ORR, contains part of the Oak Ridge National Laboratory (ORNL) that has an ongoing mission "to deliver scientific discoveries and technical breakthroughs needed to realize solutions in energy and national security and provide economic benefit to the nation" (ORNL 2023). ORNL has an ambitious construction process of new building and upgrading existing buildings and facilities, coupled with the demolition and disposal of outdated buildings. In developing an ORR map of Interior Forest patches (Burger et al. 2023; Giffen, Wade, and Mueller 2012), it was clear that some of the largest Interior Forest patches are located adjacent to Bear Creek and to the Melton Valley administrative watershed (Figure 2). The Melton Valley administrative watershed provides a reliable example of the need to consider off-site resources before development, restoration, or remediation of a site (i.e., in the administrative watershed). It should be noted that off-site for the purposes of this discussion includes areas surrounding a development/restoration site, even if those buffer lands are owned by the same entity (in this case, DOE).

Statistical analysis

Ecological resources on the Melton Valley administrative watershed and the Buffer Zone (area between the outline of Melton Valley and a line 0.5 km from the edge of the administrative watershed) were compared using an ANOVA chi-square (χ^2) test. That is, the chi-square test was used to compare the amount of Interior Forest and Buffer Forest on the Melton Valley administrative watershed with that of the 0.5-km Buffer Zone around the whole Melton Valley administrative watershed (and similarly for the value of significant resources). Non-parametric tests were

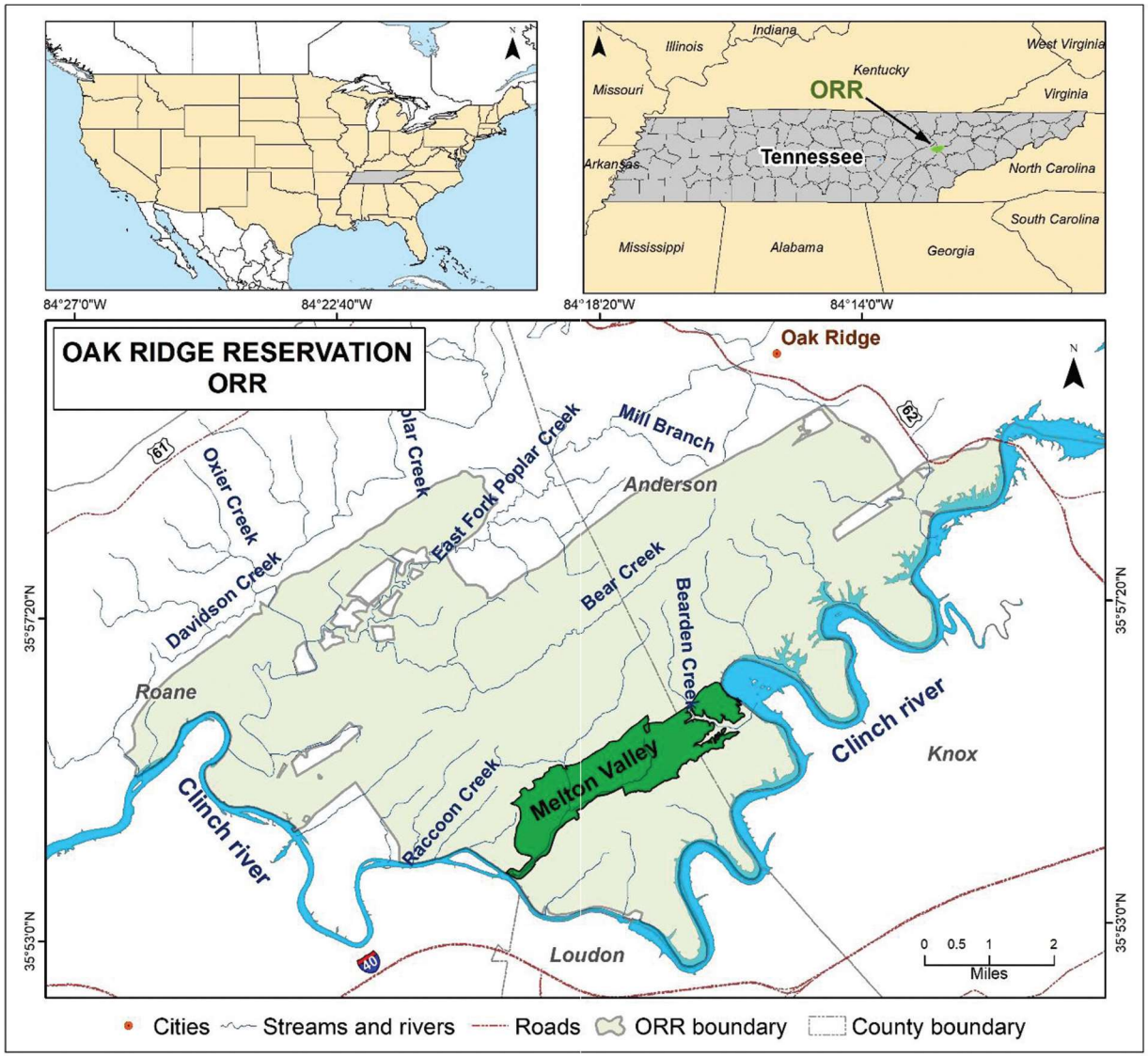

FIGURE 1. Oak Ridge Reservation is located in the ridge and valley ecosystem of eastern Tennessee. The Melton Valley administrative watershed is in the south-central area of ORR (Map modified from Burger et al. 2023).

used because these are best suited for datasets with small sample sizes and are more conservative (McDonald 2022).

Results

Conceptualization of Buffer Zone

For this report, resource values were considered on the Melton Valley administrative watershed and compared to areas adjacent to the watershed or "site." A key component of examining ecological resources on site was to determine the outline of the site itself (already delineated in any remediation or development plan, and in this case by DOE) and then examining the size of the Buffer Zone needed to protect ecological resources on site and on adjacent sites. This Buffer Zone determination is necessarily site specific and partly dependent upon the ecological resources considered important and vulnerable. That is, the Buffer Zone needed to protect breeding amphibians, for example, may be smaller than the area needed to protect birds or mammals. A 0.5-km wide off-site Buffer Zone was considered appropriate given the relatively large size of the Melton Valley administrative watershed. Further, a 0.2-km buffer is considered essential to protect Interior Forests (Giffen, Wade,

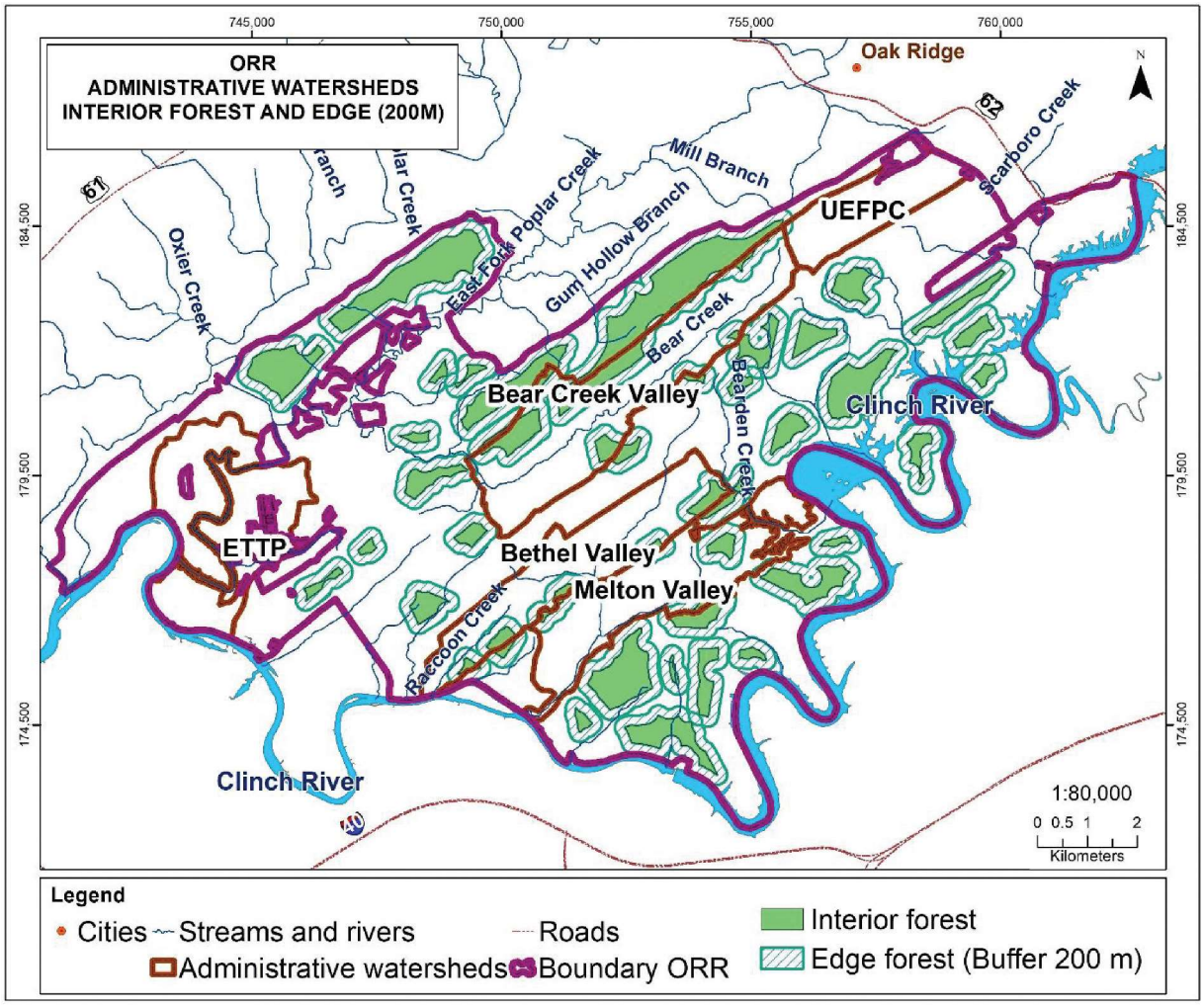

FIGURE 2. Map of Oak Ridge Reservation showing the Interior Forest (green) with buffer forest (hatched area around the Interior Forest). Some of the largest patches of Interior Forest on ORR are in Bear Creek Valley and Melton Valley administrative watersheds.

and Mueller 2012), and thus a 0.5-km Buffer Zone would ensure protection of Interior Forest. The term "Buffer Zone" is used to distinguish it from the use of a buffer around Interior Forests (a term that is already established in the literature, Giffen, Wade, and Mueller 2012). That is, some individuals might consider a "protection" zone around a development site a buffer, but a Buffer Zone for this area avoids confusion with the term "Buffer Forest" already used at ORR (Figure 3). Further, the width and area of a Buffer Zone should always be clearly stated.

Ecological information needed

This investigation proposed a unified approach for gathering information regarding the value of ecological resources on site and on adjacent areas which provides information to DOE or other agencies, the landowners, resource trustees, regulators, and different members of the public (Figure 3). Ideally, the needs of all stakeholders are considered. These categories need to include Tribal governments and members, minority citizens, and other environmental justice communities (CDC 2023; ECA 2020; EPA 2019; Landeen and Pinkham 1999). The ecological information required is well established, first by laws and regulations (e.g., ESA 1973), as well as by guidance (EPA 1995, EPA 1997a; EPA 1997b; NRC 1993; NRC 1995; NRC 2000; NRC 2008.

In our proposed model, there are three classes of information that normally need to be taken into consideration: 1) species and populations, 2) habitats and ecosystems, and 3) unique or rare landscape features (Figure 4). The types of information under each of these categories is listed in Figure 4.

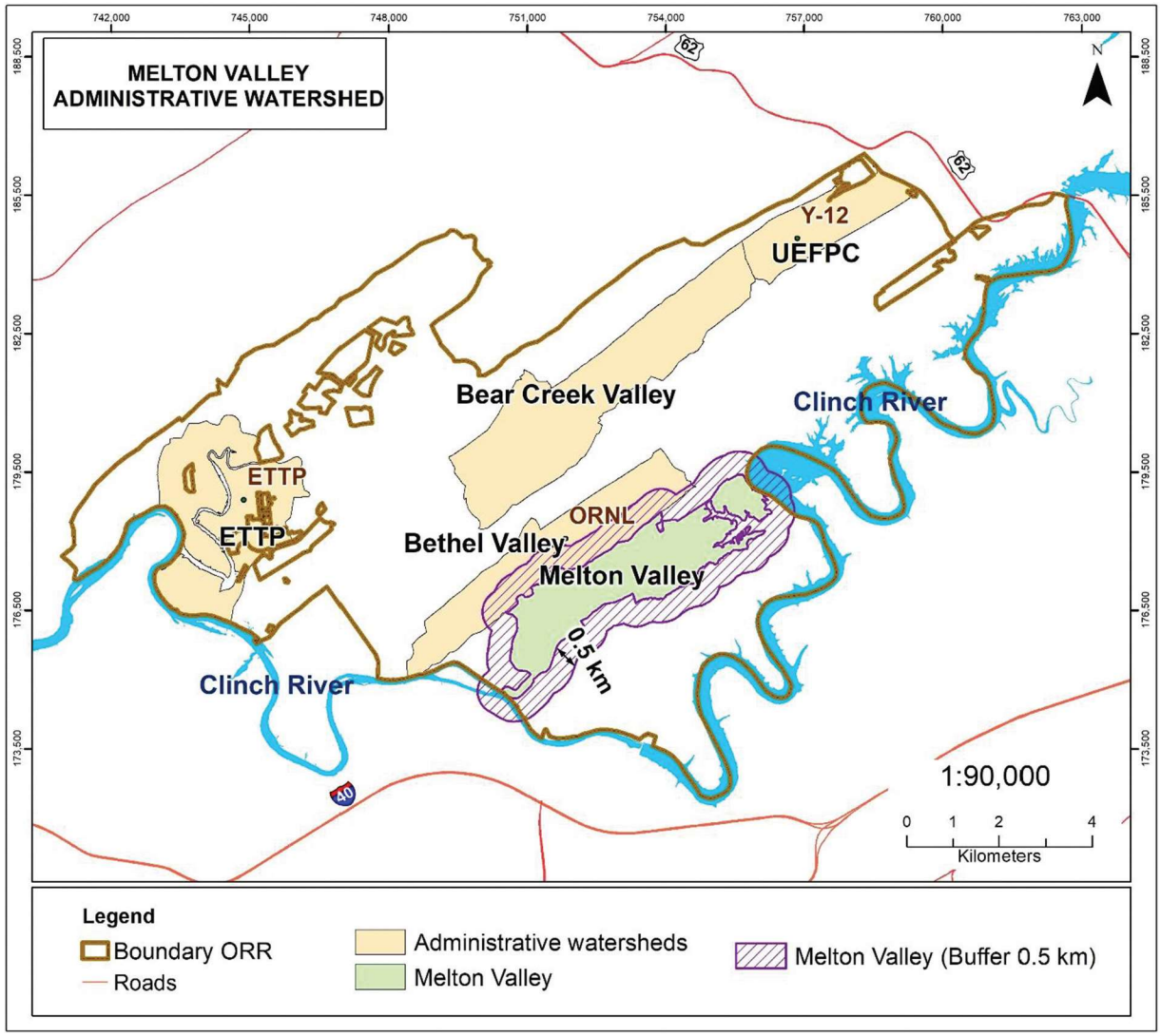

FIGURE 3. Map of Melton Valley administrative watershed and the other watersheds currently being remediated at ORR, showing the Buffer Zone around Melton Valley administrative watersheds. Note that the Buffer Zone goes into the Clinch River, and into another administrative watershed, but also includes undeveloped land to the southeast of Melton Valley.

While each of these three classes is important, one of the key considerations is whether there are existing sources of information or valuations for the site or region. Initially, the National Land Cover Database (2019) may be used to examine whether land cover (e.g., including ecological types) provides an indication of importance. For example, at ORR, deciduous forests (including Interior Forests) are the primary vegetation type on ORR and the surrounding region (Burger et al. 2023; Giffen, Wade, and Mueller 2012). The National Land Cover Database (2019) database provides a beginning step for ecological evaluations. This step may be followed by examination of endangered and threatened species on the state or even county lists, both state and local (e.g., ESA 1973). For better spatial resolution, local naturalists or conservationists might know whether any endangered species reside on or near the site. A third initial step suggested by Figure 4 is to determine whether there are any unique or rare habitats such as ephemeral ponds or pine barrens within forests or unusual land configurations such as caves, sinks or springs. Management goals, planning, and implementation of these goals requires input from land owners, resource trustees, regulators and other publics.

Site-specific literature (including refereed papers or reports) often provides key information for further evaluation of the categories illustrated in

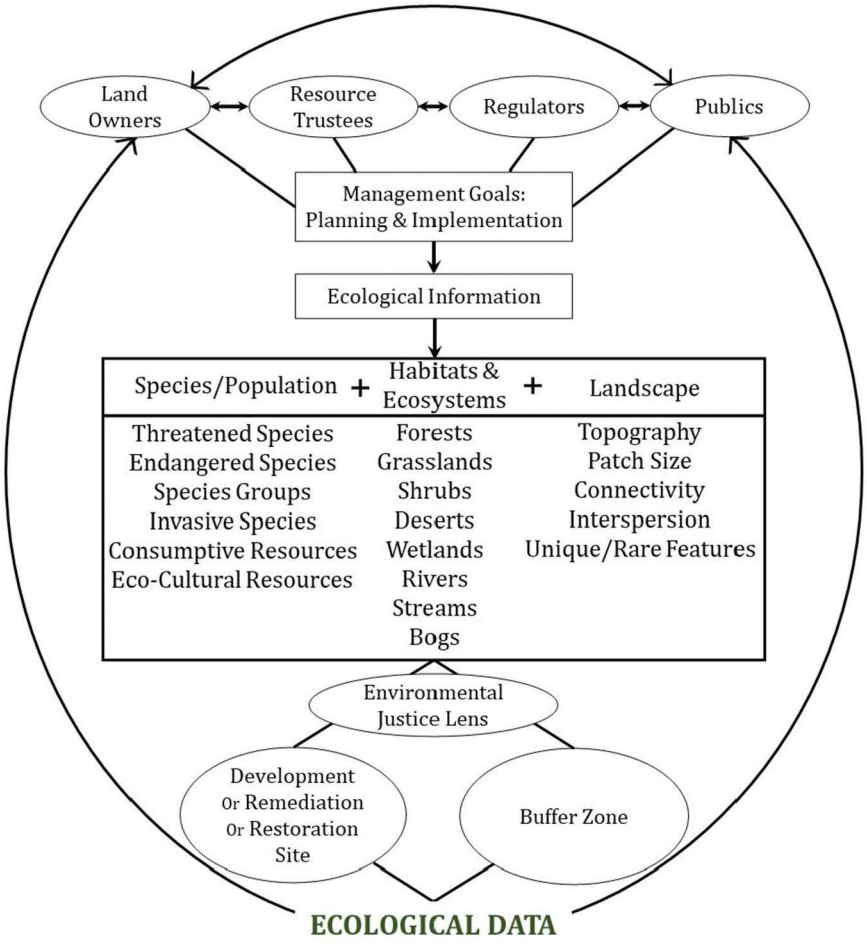

FIGURE 4. Proposed model for examining resources on a proposed site for development, remediation, or restoration. The model includes consideration of the needs of stakeholders and management, as well as including systematic ecological evaluations on both the site and Buffer Zone.

Figure 4. Information on ecocultural resources or consumptive use of resources might usually be gleaned from local communities. Inclusion of environmental justice communities and their specific ecological resource needs may be key to successful protection of ecosystems because these may identify plants or animals of particular importance to them. The model proposed in Figure 4 is applicable to any site, whether for development, restoration, or on-going remediation.

The Melton Valley administrative watershed of Oak Ridge Reservation as a Case Study

The three main information sources described above that can be used for any site are: 1) National Land Cover Database (NDC 2019), 2) presence of endangered/threatened species, and 3) rare and unique habitats or landscapes. The NLCD (2019) indicates that the Melton Valley administrative watershed is predominantly covered in forest, suggesting that this is an ideal indicator of ecological resources (see below). There are no federally endangered species unique to the watershed. However, some avian species of concern such as neotropical migrants occur in the forests of the Melton Valley administrative watershed, but are not place-based (like an orchid would be) and are found throughout ORR. Other species of interest because they are more place-based (or specific habitat-based) that were recorded on the watershed include the Green Salamander (*Aneides aeneus*), Spiny River Snail (*Lo fluvialis*) and Rough Rabbitsfoot Mussel (*Quadrula cylindrica strigillata*), as well as some plants of conservation concern, such as River Bulrush (*Bolboschoenus fluviatilis* in wetlands), Pink Lady-slipper (*Cypripedium acaule*), Canada Lily (*Lilium*

canadense), and Northern Bush Honeysuckle (*Dievilla lonicera*, N. Giffen, ORNL database, Pers. Comm. July 2021). Place-based means they do not shift locations and may be limited to one exact site (a plant), or have a limited home range (a salamander or snail). The second type of concern (unique or rare habitats) is not relevant as the area is mainly forested.

One of the key resources within any area that has forest is the number and size of Interior Forests (Giffen, Wade, and Mueller 2012). Interior Forests are important on ORR generally, especially in comparison to the surrounding region (Burger et al. 2023). Figure 5 depicts that although the Melton Valley administrative watershed has some Interior Forest, there are many patches of Interior Forest that border the watershed. A comparison of the areas is shown in Table 1.

There are, however, many other resources that may need to be protected on any given site, such as ORR that is government owned and is likely to be held in perpetuity by DOE (DOE 2000a). One of the early analyses of ecological resources on ORR was completed by The Nature Conservancy (TNC 1995) and updated by Parr and colleagues (Parr and Hughes 2006; Parr et al. 2015). These investigators developed a rating of the land on a scale of significant habitats (defined in the methods above). The Melton Valley administrative watershed has a low % of High Significance (pale yellow in

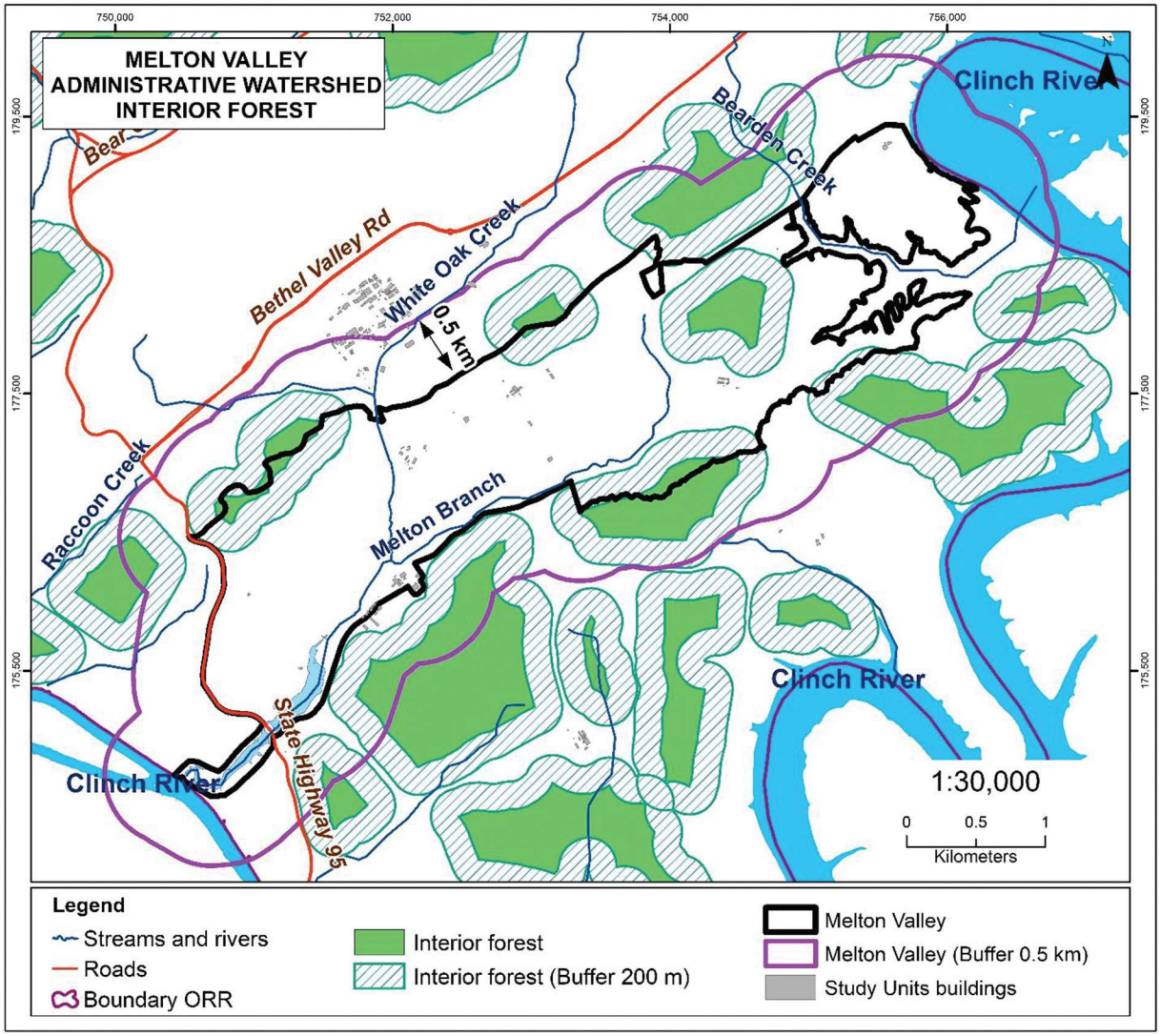

FIGURE 5. Melton Valley watershed and 0.5-km Buffer Zone (outlined in purple) around the Melton Valley administrative watershed. Interior Forest (green) and 200-m buffer forest (hatched). Buffer Zone contains valuable resources for evaluation during development, remediation, or restoration.

TABLE 1. Comparison of Area of Interior Forest and Buffer Forest in Melton Valley Administrative Watershed and in the 0.5-Km Buffer Zone Around the watershed[a] . $p<0.05$ is considered significant.

Character	Melton Valley	Buffer Zone
Total area (ha)	782	1,107
Forest types (ha)		
Interior Forest	28 (4%)	135 (13%)
Buffer Forest	126 (16%)	298 (29%)
$\chi 2$ (p)	9.6 (0.002)	
Significance Rating (ha)		
Very high	10 (1%)	34 (3%)
High	84 (11%)	413 (41%)
Moderate	58 (7%)	22 (2%)
Landscape	126 (16%)	161 (16%)
X2 (p)	135.9 (<0.0001)	

a. Data for ORR provided by N. Giffen of Oak Ridge National Laboratory; GIS analysis by M. Cortes.

Figure 6) and almost no very High Significance areas. Data are presented in Table 1 and illustrated in Figure 6. The habitats rated of high value include wetlands and streams with unique and rare species, special species groups (breeding amphibians), and Interior Forests that are located on the edge of the Melton Valley administrative watershed and are mainly in the Buffer Zone (Figure 7).

Discussion and conclusions

Whenever a parcel of land is considered for some action, whether development, remediation or restoration, potential exposure to chemicals and the importance of ecological resources on the site are generally characterized to determine whether these ecological resources on site need to be protected. This characterization normally

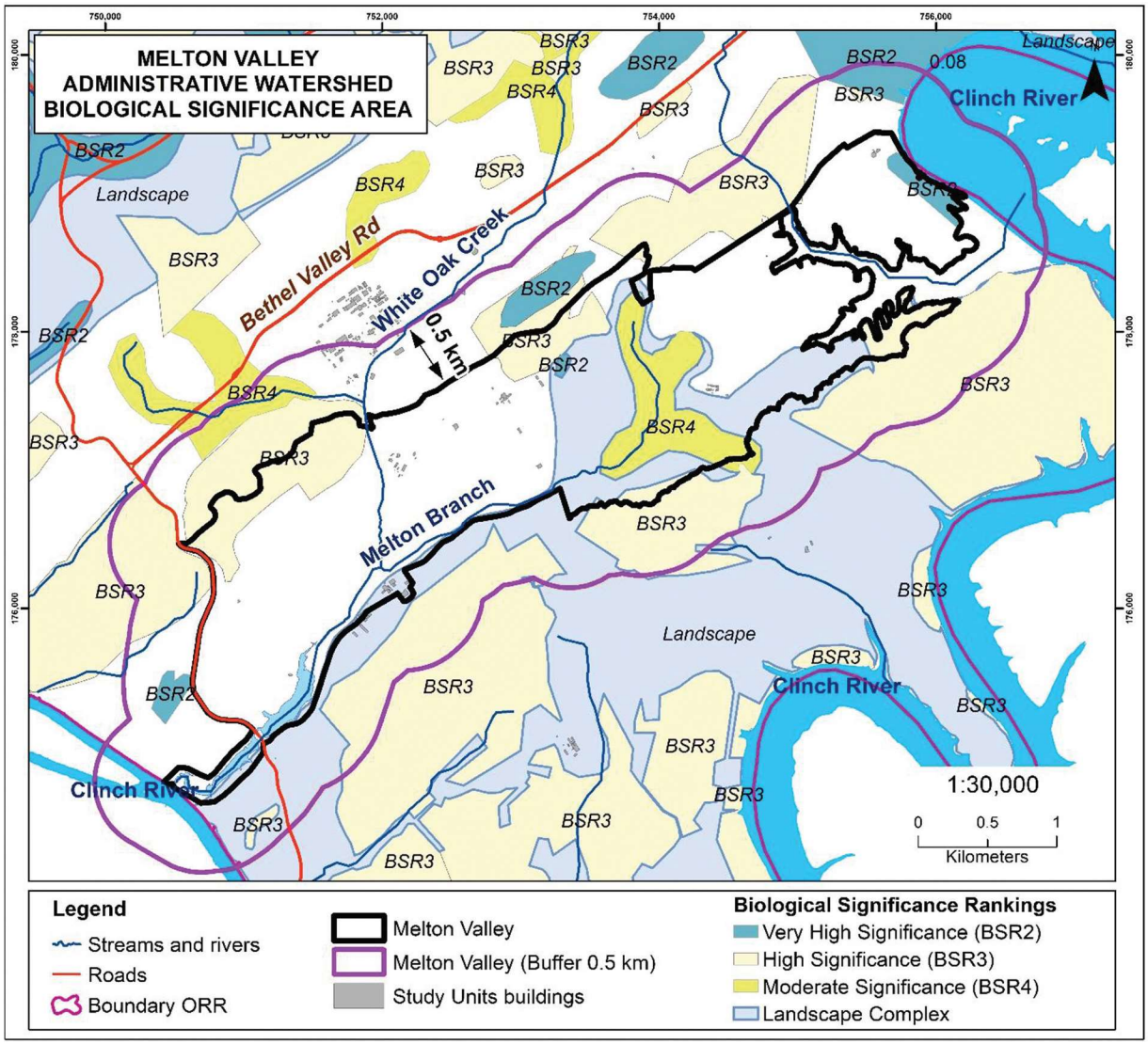

FIGURE 6. Rating of the significance of habitats on a scale of landscape (few resources) to very High Significance (Parr et al. 2015; TNC 1995).

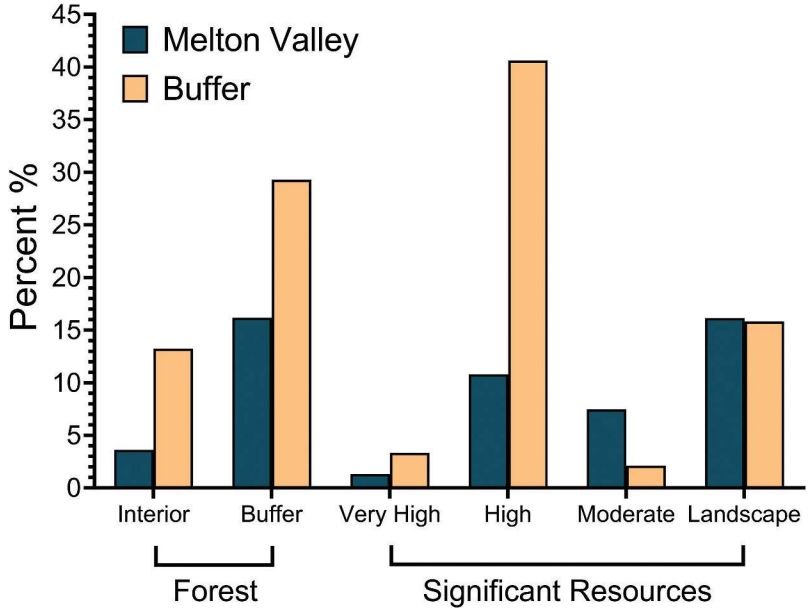

FIGURE 7. Differences in percentage of forests and significant resources in the Melton Valley administrative watershed compared to resources in corresponding Buffer Zone.

infers conducting an environmental impact assessment and determining whether there are critical, unique, or vulnerable species of habitats on site (EPA 1995, 1997a, 2009; ESA 1973; NRC 2000), whether these habitats are at risk from human actions or contaminants (EPA 1997b; EPS 2023), and whether there are environmental justice concerns (EPA 2019, 2020).

Melton Valley and its Buffer Zone

In this report, two main methods of ecological evaluation were used: the amount of Interior Forest and the relative significance of land within the Melton Valley administrative watershed and Buffer Zone. The Buffer Zone around the Melon Valley administrative watershed contained significantly more Interior Forest and Interior Forest Buffer and significantly greater "higher valued" resources than the watershed itself (refer back to Figure 7). The method clearly indicated that the Melton Valley administrative watershed possessed significant resources, but there are even more significant resources in the Buffer Zone around the watershed. Figures 5 and 6 illustrated that many of the important resources and Interior Forests are on the border of the Melton Valley administrative watershed, increasing the importance of considering the Buffer Zone when developing or otherwise managing a parcel of land, such as the watershed region.

The special value of Interior Forests has been addressed by Burger et al. (2023). Interior Forest provides refuge for a variety of species including the vulnerable guild of neotropical migrants. The value of the Interior Forest Buffer is often overlooked. Disruption of this buffer for Interior Forest in effect destroys some Interior Forest because Interior Forest is defined in part by the presence of an intact Buffer Forest. Whenever Buffer Forest is reduced in size, the Interior Forest is also diminished because some Interior Forest now needs to be part of the buffer.

On the importance of evaluating a Buffer Zone

This report proposes that ecological risk evaluations need to include the resources not only on the site being developed, restored, or remediated but also in a Buffer Zone around the site. The Melton Valley administrative watershed on the ORR was used as a case study to illustrate that the resources on the adjacent land may be of greater value than those on the site itself and may be at risk from actions on site. The case study shows that the area of Interior Forest

is greater adjacent to Melton Valley administrative watershed than on the watershed itself, with the implication that any development of buildings or other facilities, or remediation on the edges of the watershed, might exert an impact on ecological resources in the Buffer Zone. There is no implication, nor expectation, that DOE is not mindful of this aspect. In this case, the DOE possesses extensive data on the resource values on the whole ORR site (Parr et al. 2015) and takes them into consideration during development and management of ORR (Giffen, Evans, and Parr 2012; Giffen, Wade, and Mueller 2012). The value of this investigation and in using the Melton Valley administrative watershed as an example, is not that additional action is required to be taken by DOE at ORR to protect Buffer Zones, but rather that the model and process provide a paradigm that might be useful at other sites under consideration (or planning) for development, restoration, or remediation. Data were available for ORR generally, enabling such a comparison. In many cases, such a comparison is not generally available – but the implication of the current study is that such a comparison needs to be undertaken, even if it involves only the three general steps suggested.

The initial three ecological evaluations suggested were to: 1) conduct a comparison of land cover types using the National Land Cover Database (NLCD 2019); 2) evaluate whether there are obvious endangered or threatened species on site; and 3) determine if there are rare or unique habitats or resources such as caves, sinkholes, ephemeral ponds, or rock screes. Most of these evaluations may be done with a brief examination that involves consultation with local naturalists, land managers, and eco-culturalists. The land cover maps may be examined for land cover and habitat types, and the site habitats might be compared visually to the surrounding Buffer Zone (NLCD 2019). Consultation with community naturalists, local university scientists, church leaders, political leaders, and other community members may provide additional critical information on cultural and aesthetic uses, as well as biological information.

Data also suggest, however, that reports and papers in the literature can be used to examine the value of resources in more detail if the cursory ecological evaluation warrants. This evaluation may be initiated by examining the parameters illustrated under ecological information box in Figure 4. Information may not be available in the literature and from local authorities and community members. Under these circumstances, a more detailed literature review, in addition to site visits and in some cases, assessments and monitoring may be required. For example, the presence of less well-known groups of animals such as amphibians or insects may not be readily available. Similarly, the extent of invasive species may not be fully known or examined recently for a given site.

The importance of including a Buffer Zone is two-fold: 1) to make sure that resources are fully protected on the development (or restoration) site by ensuring a protective space around important resources on site and 2) to ensure that valuable ecological resources adjacent to the development site are not unduly impacted by actions on the site. In the case of the Melton Valley administrative watershed, many of the Interior Forest patches were exactly adjacent to the boundary of the watershed itself. If development were to occur on the edges of the Melton Valley administrative watershed, it would potentially affect the Buffer Zone and particularly its Interior Forest patches (refer to Figure 2). That is, looking at ORR generally illustrates that some of the largest intact Interior Forests are south of the Melton Valley administrative watershed. Protecting the forested areas requires special care when building or potentially disrupting the ecosystems at the edge of the watershed.

The process described in this report may be applied to other sites, whether these are remediation, restoration, or development sites. Placing buildings at the edge of a site may well adversely impact ecological resources on the adjacent Buffer Zone, or indeed affect human communities on the edge of a development zone. In conclusion, including a Buffer Zone in ecological evaluations for any site being managed can result in protecting more ecological resources overall, both on and adjacent to the management/development area, and lead to a more integrated approach to local development.

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Disclosure statement

The opinions, findings, and conclusions expressed herein are those of the authors and do not necessarily represent the views of the U.S. DOE, ORR, Rutgers University, Vanderbilt University, and other participating universities.

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Author contributions

The study was designed by Burger, developed, and executed by all authors and the CRESP team, maps and figures were developed by Cortes and Ng; the manuscript was written by Burger, and edited by all authors.

Data availability statement

The data that support the findings of this study are available from the corresponding author, JB, upon reasonable request.

Compliance with ethical standards

This project was completed with appropriate protocols from Rutgers University, and within all ethical standard guidelines.

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