An Approach to Evaluating and Monitoring Ecological Resources for Sustainability on DOE Remediation Sites: Hanford as a Case Study – 15524

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ABSTRACT

Protecting ecological and environmental resources is a worthy aspect of the Department of Energy's site missions, for each of its sites, during and after remediation. Ecological resources are important to a range of stakeholders, including regulatory agencies, resource agencies, natural resource trustees, Tribal governments, and the public, and may be an essential component of Native American cultural resources. Because the nature and value of ecological resources can change over time as a result of remediation, succession, and global climate change, it is imperative for DOE to have instituted an acceptable method of evaluating resources before initiation of active remediation, over the ensuing century when institutional and engineering controls are considered to be in effect. Having such a methodology in place also would be key to resource sustainability. Department of Energy sites generally have environmental programs, so instituting specific unified practices for evaluating resources should not be difficult to implement. Instituting these practices would assure the public that ecological resources, as well as human and cultural resources, are being protected now, and can be protected into the future.

Key ecological species and/or unique habitats have been preserved at Department of Energy sites since the mid-20th century because of federal government stewardship. Such preservation is particularly true for the sites with larger land areas, including the Hanford Reservation, the Idaho National Laboratory and the Savannah River Site. Individual sites typically have extensive studies of site biodiversity, but site resources are not routinely examined within a regional or national context (Ecoregion). The evaluation of the on-site resources with those resources in the appropriate Ecoregion provides a context for "valuing" on- site resources. On-site resources should also be evaluated in terms of federal and state legislation where species may have legal protection and require legal consideration during remediation if present or adjacent to the remediation site.

A method is needed in this study for evaluating ecological resources prior to remediation and during remediation, and a paradigm is proposed that will ensure sustainability. Finally, in a period of climate change and instability, developing methods of evaluating ecological resources is essential to successful protection, enhancement, and sustainability. The ecological methodology is part of a Hanford site-wide Risk Review Project, conducted by the Consortium for Risk Evaluation with Stakeholder Participation (CRESP). Our method adapts an existing methodology that includes using established levels for evaluating ecological resources by expanding the existing methodology to include field work for validating previous resource level designations, to assess the occurrence of invasive/exotic species, and to identify landscape scale features (patch size, connectivity). Evaluations should be conducted in the remediation unit itself, and in a buffer zone surrounding the remediation site. The methodology described has been applied to several remediation areas at Hanford, and issues that emerged during its application are discussed. The methodology can be applied at the major sites. Application of the Ecoregion analysis will provide regulators and the public with an understanding of the value of the ecological resources in relation to the region, as well as an appreciation for the stewardship role the Department of Energy has

played in protecting these resources since the beginning of the Cold War Era and can continue to do so sustainably.

INTRODUCTION

Environmental assessment and management involve preserving, protecting, and enhancing ecological, human, and cultural health and well-being, and assessment is necessary to ensuring sustainability. Assuring well-being for ecological resources requires understanding the diversity and condition of natural resources, which range from populations of individuals of a single species to whole ecosystems. The U.S. Endangered Species Act (Act) [1] provides legal protection and recovery efforts for plant and animal species listed as threatened or endangered. States also have lists of threatened and endangered species. Both entities list candidate species (those being considered for listing), and species of special concern (those that could become listed in the future due to their small population numbers or vulnerability). Understanding potential impacts to endangered, threatened, and species of special concern is paramount when determining ecological risks and to ensuring sustainability.

At the other end of biological organization is an identifiable, vulnerable, or unique habitat or ecosystem (i.e. shrub-steppe, vernal pond, talus slope). Being listed on the Endangered Species List ensures legal protection for a species, and the Act also affords some protection for the habitat of listed species. Vulnerability is a key aspect for ecological risk assessment or evaluation. Additionally, there is considerable concern for sensitive or unique ecosystems [2]. These ecosystems are habitats most at risk, limited in quantity or extent, and often contain one or more endangered species, endemic species (species that occur only in those areas), or threatened species assemblages (e.g., migrant songbirds, breeding frogs, hibernating snakes). Unique habitats are those that are rare locally (e.g., Hanford Site) and regionally (e.g., Washington State, the Pacific Northwest). Such habitats are limited and often fragmented, and any decreases in quantity or declines in quality could have severe consequences.

Key ecological aspects for the Hanford Site are described, including:

1) Major habitat types for the Hanford Site, and the Columbia Basin Ecoregion,
2) Endangered and Threatened Species, and species of special concern, and
3) Hanford's evaluation of rare, unique, and irreplaceable resources [3].

These three aspects are used to develop a methodology to evaluate resources at risk for areas requiring remediation. Evaluation of ecological resources will vary among DOE sites, as will the remediation options considered. Further, evaluation units (groupings of contaminant sources that serve as the basis for evaluation) could be defined differently at different DOE sites. The first three provide an overview of what ecological receptors are at risk in different evaluation units at Hanford, and these are used to describe how remediation affects ecological resources for these units. Habitats are described first because they are more straight-forward in that their occurrence is site-specific, and can be mapped for the Hanford Site. Examination of habitat maps can identify general habitats and habitats of special or unique concern, but this must be followed by field examinations. This study distinguishes between environmental and ecological resources. Ecological resources refer to the living component of the ecosystem. Environmental is a broader category that includes living resources, geology (soils, physiognomy), and often, chemical plumes and contaminant levels in various media.

The main factors affecting habitats on Hanford (in addition to climate and geology) are fire, exotic/alien species, landscape/invasive species, human development and disturbance, and succession. Succession is the natural progression or change of vegetation types from early stages (e.g. after a fire or other

perturbation) to climax vegetation (community that occurs under prevailing geologic and climatic conditions). Fire is one of the primary factors that sets back habitats to early successional stages. Fires on Hanford Site have burned as many as 800 square kilometers (km^2) (1984), and during 2000, a fire burned most of the shrub-steppe habitat on the Fitzner-Eberhardt Arid Lands Ecology Reserve [4]. Post-fire re-vegetation on Hanford is an important process aimed at reducing sand movement and decreasing invasion of noxious weeds [5].

The Columbia River corridor is particularly critical for Tribes and a full range of local stakeholders and communities. Not only is the river itself important ecologically and culturally, but the riparian and upland habitat provides ecological integrity and stability, as well as goods and services important to Northwesterners and the Nation. Scott et al [6] have provided models for the long-term risk to environmental and human systems from radioactive and chemical waste. This paper provides an assessment methodology for ecological resources that are essential for long-term sustainability of the ecosystems on the Hanford Site. Maintaining sustainability requires different trophic levels [7], an important component for ecological resources as well.

METHODS

A literature review was performed on the available refereed and grey literature. The ecological condition at Hanford was examined in relationship to the Ecoregion, as well as the current state of ecological resources at a sample of evaluation units slated for remediation Potential risk(s) to those resources was considered as a function of general classes of remediation options. Because site-wide maps of ecological resources were out of date, a field component was added to provide for ecological changes over time, as well as remediation. An “evaluation unit” is a specific remediation task to be completed. A facilities/land use area map for the Hanford Site (the case study) is provided as Fig. 1.

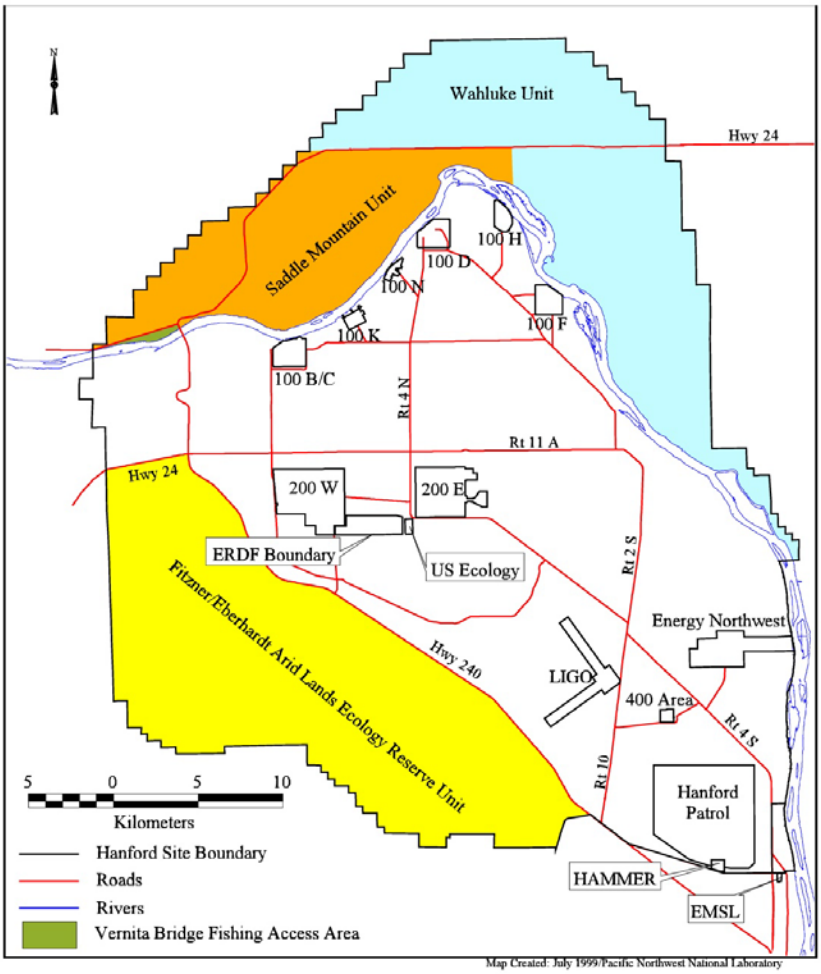

Figure D.2 Hanford Site Facilities and Land Use Areas (ERDF = Environmental Restoration Disposal Facility, LIGO = Laser Interferometer Gravitational-Wave Observatory, HAMMER = Hazardous Materials Management and Emergency Response Training Center, EMSL = Environmental Molecular Sciences Laboratory; *Energy Northwest formerly was the Washington Public Power Supply System)

Fig. 1. Hanford Site Land Use and Facilities Map (Appendix D) [8].

RESULTS: AN EVALUATION PROTOCOL

Overall Approach

The approach developed for evaluating the ecological resources on each evaluation unit includes the following evaluations: 1) The regional level (Columbia River Ecoregion), 2) At Hanford, and 3) As a function of remediation options. This methodology is designed to make use of available GIS-based, information on ecological resources on the Hanford Site. The information relates both to individual species (which are at risk), and key unique habitats or ecosystems that could be at risk. The methodology is designed so that it can be applied to different "evaluation units", and can be applied by personnel with basic ecological knowledge. While landscape features can be determined from maps, they still must be checked in the field, and other necessary field work includes the determination of the percent of alien/exotic species present on each evaluation unit.

Ecological Resources at Hanford compared to the Ecoregion

Hanford's biological resources can be examined as part of the Columbia Basin Ecoregion. Ecoregions are regions of the United States that are defined on the basis of geology, soils, physiography, climate, vegetation, wildlife, and land use [9,10]. The Columbia Basin Ecoregion occupies the area south of the Columbia River between the Cascade mountain range and the Blue Mountains in Oregon and includes about two thirds of the area east of the Cascades in Washington State [11]. Thus, ecotypes on Hanford were compared with those in the state of Washington [3], and to the state's priority habitats and species [12,13]. Yearly ecological monitoring reports for Hanford continue to describe critical resources and important/emerging issues [14].

Over the past half century, human populations in this region have greatly increased, natural land has been converted to agriculture, and fragmentation has impaired the quality of remaining resources. Despite the extensive industrial development and waste management areas on the Hanford Site, it has undergone much less change than the surrounding region.

Examining the relationship of current to historic habitats provides insights into what has been lost on the site, and comparisons with the Ecoregion provide information on both the relative importance of current habitats on Hanford, and of those most at risk in the Ecoregion generally (Table I). Those habitats indicated in red are those for which the Hanford Site has a significant proportion of regional resources, and/or they have decreased less proportionately on Hanford compared to the Ecoregion.

Table I. **Changes in Habitat Types from Historical Records to 2001 for the Hanford Site and the Columbia Basin Ecoregion. Given are habitat or cover types in the region and at Hanford, and the percent change in each over this time period. Data adapted from Appendix C of Hanford Environmental Report [11] (Table C.3 and C.4). Some of the habitat types (e.g. Threetip sagebrush) were not examined (recorded) in 2001, and a direct comparison cannot be made.**

Cover Type	Historic Ecoregion Area (ha)	Current Ecoregion Area (ha)	Historic Hanford Site Area (ha)	Current Hanford Area (ha)	% Change in Ecoregion	% Change in Hanford Site
Bluebunch	1028900	431400	612	1602	-58.1%	161.8%

wheatgrass steppe						
Idaho fescue steppe	436700	122200	0	0	-72.0%	No change
Bitterbrush steppe	118600	78100	915	904	-34.1%	-1.2%
Big sagebrush steppe	4096900	1662400	148902	137834	-59.4%	-7.4%
Juniper/sagebrush	110300	109100	508	508	-1.1%	No change
Threetip sagebrush	746000	0	16	0*	-100%	-100%
Black greasewood	134900	0	503	0*	-100%	-100%
Conifers/Idaho fescue	225000	0	0	0	-100%	-100%
Ponderosa pine	302900	335100	102	102	10.6	10.6%
Water	71100	71100	25	25	No change	No change
Other	205,500	4,667,400	0	10612	2171%	
Total	7,476.800	7,476,800	151,583	151,587	--	--

*This disappearance is likely due to not being documented in later years. 100 % decrease means it went from some amount, to none (or it was not measured).

The table provides an indication of the relative change on Hanford compared to the region. It is also possible to look at differences that have occurred on Hanford itself, which partly indicates the declining habitats on site. It is not the whole ecological picture, as percent occurrence does not indicate critical ecological features such as patch size, patch shape, interspersion of patches (including isolation and fragmentation), connectivity, and habitat corridors. For example, the same size patch (in ha) provides more protection for sensitive species if it is round than if it is long and thin because the latter has more edge where predators, alien/exotic species, and people or vehicles can enter and has less interior than the former. While Pacific Northwest National Laboratory (PNNL) regularly conducts surveys of alien/exotic species on building site [15], similar surveys are not conducted site-wide.

The categories listed in Table I, however, are actually a mixture of different habitats – it is the major vegetation type that has defined them. Thus, much finer gradations are possible, and it is these more detailed vegetation cover types that reveal the sensitive habitats on Hanford Site. For example, Bluebunch Wheatgrass, a native grass habitat can be infiltrated with Cheatgrass (an exotic species) which reduces the quality of the Wheatgrass habitat. Cheatgrass often invades from roadways, as construction allows these species to move in by disrupting the natural vegetation, soil ecosystem, and drainage (see Hanford Site evaluation below). Further, aquatic habitats embedded within the terrestrial environment at the Hanford Site are critical because they are so limited in space and act as habitat islands for many species.

Many species on the Hanford Site are sedentary or have few movement options. For example, Tiger Salamander (*Ambystoma tigrinum*) will not move over very dry areas to reach another water source if its habitat is destroyed. In addition, sections of Hanford can be considered alone, especially those managed separately, such as the Hanford Reach National Monument [16].

Hanford Evaluation

Endangered and Threatened Species

Species that are listed on federal and state Endangered Species Lists, and other listed species (species of special concern, candidate species) are those that must be considered in any ecological evaluation of Hanford Site resources (Table II). Of the 25 DOE sites slated for remediation/restoration as of 2007,

Burger et al. [17] reported that Hanford Site had 8 federally endangered/threatened species, compared to 7 or less for the other sites, and Hanford had 18 state-listed species (Fermi Laboratory had 22, all others had fewer than Hanford).

Table II. Current (2013 Data) on the Number of Threatened and Endangered Species on the Hanford Site .

GROUP	Federal Endangered or Threatened	Endangered or Threatened by State of Washington	Threatened and Endangered Species in 2013
Invertebrates	0	0	--
Fish	3	0	Spring Chinook Salmon, Steelhead, Bull Trout
Amphibians and reptiles	0	0	--
Birds	0	4	Ferruginous Hawk, Sage Grouse, Sandhill Crane, American White Pelican
Mammals	0	0	
Plants	0	12	Great Basin gilia, Grand redstem, Geyer's milkvetch, Rosys pussypaws, Desert dodder, White eatonella, Awned halfchaff sedge, Loeflingia, Whitebluffs bladderpod, , Columbia yellowcress, Lowland toothcup

Although Bull Trout have been reported on the Hanford Reach, its natural habitat is mountain streams [18], it is also listed on the Oregon list as threatened [19]. The Peregrine Falcon is no longer listed as a state or federal endangered species, and the Bald Eagle was considered a federally threatened species in Oregon but has "recovered" and has been removed from the Endangered Species List [18]. The Oregon Biodiversity Information Center developed a list of rare, threatened and endangered species of Oregon [20].

Further, it is important to note that resiliency and sustainability require the support of a large number of stakeholders, and in the Northwest, the support of Tribal members as well. To this end,a list of species of particularly interest to Tribal, recreational and commercial interests is provided. Support for sustainability may partly depend upon the goods and services that ecosystems provide, and to the iconic species within those ecosystems.

Evaluation of Ecological Resources [3]

An evaluation of ecological resources starts with known information about the site. In the case of Hanford, resource levels were defined and mapped in a collaborative process between resource agencies, regulators and trustees. Resource levels used were those developed by DOE in conjunction with state and federal regulators and natural resource trustees [3], and were also based on vegetation surveys conducted over 15 years ago by Nature Conservancy and updated as remediation required. The resource levels developed by DOE were refined over many years (as indicated by DOE yearly environmental reports), and included the State of Washington's resource evaluations, as well as those of others [3]. It includes federally listed species as its highest level (in addition to unique habitats), which is based on the US Endangered Species Act. Inclusion on this list involves a long, involved process that considers many different ecological factors, and has legal standing. We suggest that key resources are those that were evaluated as level 3 to level 5 (irreplaceable). These provide information on resources at risk, and take

into account the quality of the resources, not just the presence. In both cases such endpoints are both rare and vulnerable because of fragmentation, exotic species, fire, human disturbance and other factors. It is the level 3 to 5 resources that should be managed so that they are sustainable well into the future. Level 4 and 5 resources are both rare on Hanford, and even rarer within the Ecoregion.

Maps of Levels 1-5 can be found in DOE/RL-96-32 [3]. These levels include:

Level 1 resources are in habitats where DOE is not required to complete habitat replacement, but habitat could be restored there. There may be common native plants and animals, as well as stands of non-native plants or abandoned agricultural fields [3].

Level 2 resources include migratory birds and state monitored plants and animals, as well as upland stands of shrub over-story, non-native plants, and some steppe stands that co-occur with non-native plants [3].

Level 3 resources include state sensitive or candidate plants and animals that may have cultural importance.

Level 4 resources include state threatened or endangered species, federal candidates, upland stands with native climax shrub over-story and native grass understory, and wetlands and riparian habitats [3].

Level 5 resources includes not only federally–listed species, but sensitive habitats. Irreplaceable habitats included cliffs, lithosols, dune fields, ephemeral streams and vernal ponds, as well as Fall Chinook Salmon and Steelhead spawning areas [3]. An example of the map for resource level 5 is shown in Fig. 2 below.

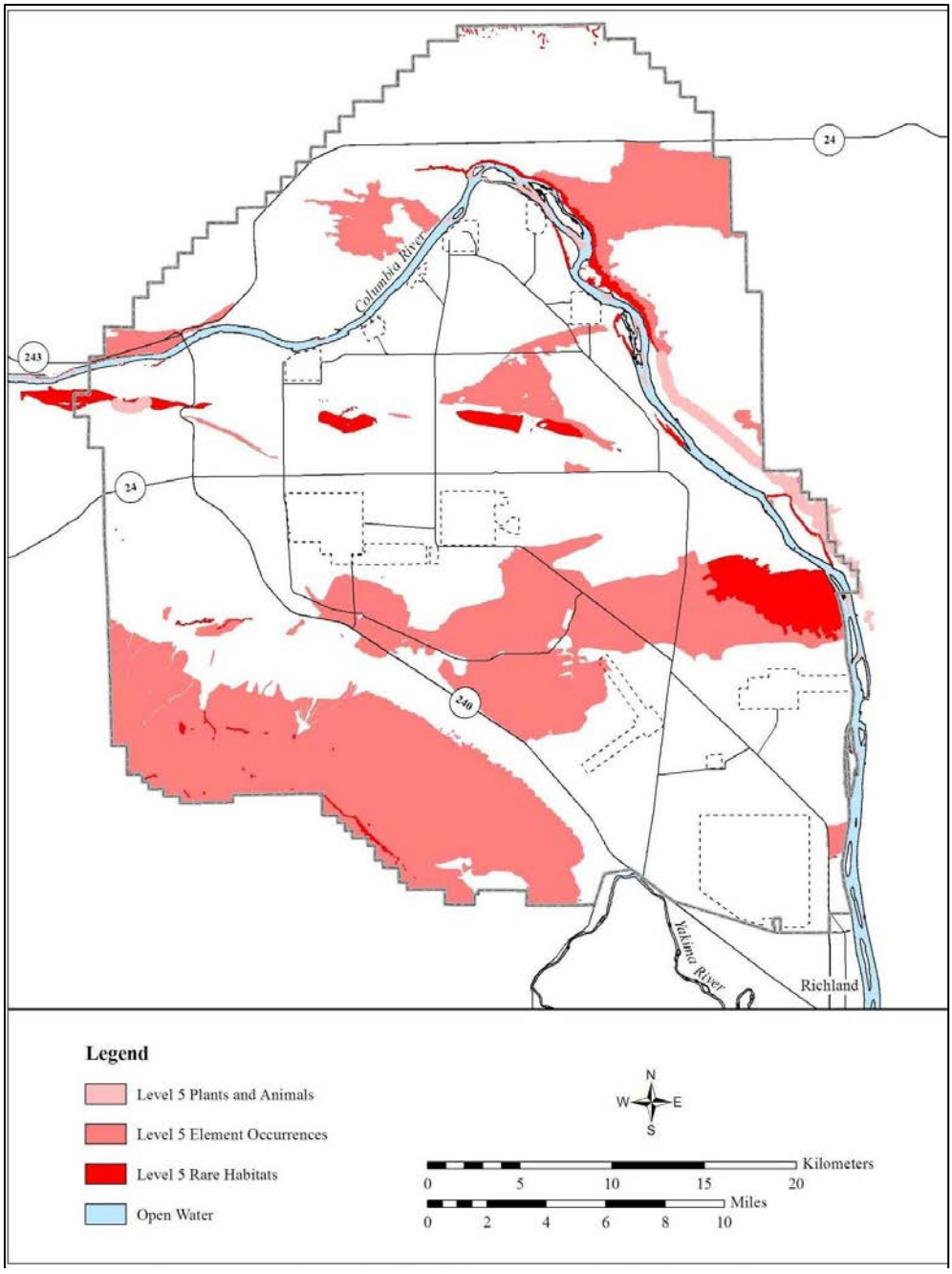

Fig. 2. Resources classified as Level 5 by Hanford (From Figure 5.2, page 5.13) [3].

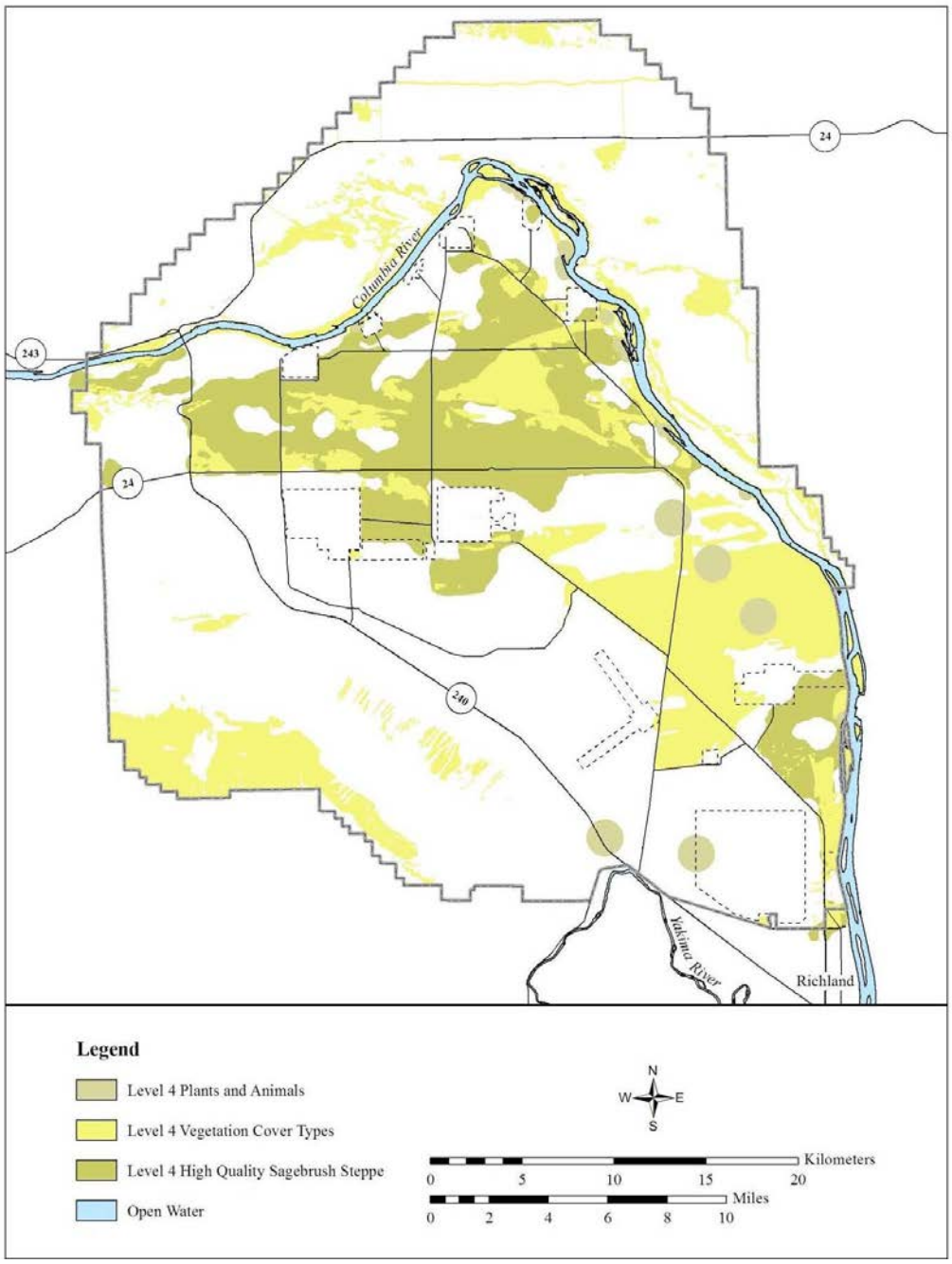

Fig 3. Map of DOE's (2013) evaluation of Level 4 species and unique or rare habitats (Figure 5.3, page 5.14) [3].

Field Work is essential to assess whether the resource level at particular evaluation units is still appropriate. Although the level of resources present can be ascertained from the resource maps developed by DOE [3], and the degree the evaluation unite is compromised by landscape features, can be ascertained from these maps as well, the amount and significance of exotic/alien species needs to be determined on each evaluation unit. Overall field methods include examining the current level on the existing resource

maps [3], and field investigations of current vegetation, percent and type of exotic/alien species, landscape features, and presence of listed species. The area to be evaluated includes both the "evaluation unit" and adjacent habitat that serves as a buffer, recognizing that remediation on an evaluation unit would likely affect adjacent habitats. Field method included the use of standardized sampling in the evaluation unit, data sheets for recording vegetation type and resource level, and standardized data sheets for evaluation of the buffer zone around the evaluation unit.

Evaluation and Rating as a Function of Remediation Options

Resources were categorized as a function of importance and rarity on a scale from 1-5, where level 5 resources are unique habitats and federal endangered/threatened species [3]. These levels of resources, with maps for their distribution on the Hanford Site, are described in the previous section. The method of rating potential impacts/risks to ecological resources is shown in Table III.

Table III. Ecological Impact/Risk by Remediation Type during Cleanup and Remediation. Levels refer to an evaluation of ecological resources, including unique/sensitive habitats and endangered/threatened species at level 5, and few resources at Level 1. The matrix considers the quality of the resources currently present, and the activities associated with the remediation action.

REMEDIATION TYPS	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
Natural Attenuation	ND	ND	Low	Low	Low
In-Situ Containment(Capping)	ND	ND	Low	Medium	Medium
Pump and Treat	ND	Low	Low	Medium	Medium
In-Situ Treatment (grouting, permeable barriers)	Low	Low	Medium	Medium	High
D & D (Take down building)	Low	Medium	Medium-High	High	High
Excavation	Low- Medium	Medium	High	High	High

Our definitions of relative risk that may be ascribed to the impact or risk are as follows:

ND = Not discernible from the surrounding conditions; no additional risk

Low = Little risk to disrupt or impact ecological resources.

Medium = Potential to disrupt or impair ecological resources, but the remedial action is not expected to disrupt communities permanently.

High =Likely to disrupt, degrade, and impair ecological resources of high value (e.g. level 3-5) , and can cause permanent disruption, or to disrupt resources that have restoration potential.

These risks ratings (not discernible to high) are based on the degree of physical disruption (and potential additional exposure to contaminants) as a result of remediation options. Increases in personnel, vehicles, heavy equipment, and hoses cause injury or death to resident plants and animals. In addition, creation of lay-down areas for equipment, storage, and transfer can have major effects. Some of these lay-down areas, newly created for remediation, can be quite large and usually occur on adjacent places not slated for remediation. Where Level 4 and 5 resources are concerned, these disruptions can cause long-term or permanent effects. In some cases, the remediation option may not be selected or otherwise known, and when this occurs, the relative rating must be a range, based on the options that could be employed at that

evaluation unit. An additional aspect that needs to be considered is the temporal and spatial pattern of the remediation method selected. If remediation is expected to last only a short time, then risk to ecological resources is likely lower than if remediation will continue for many months.

DISCUSSION

Three aspects of the evaluation of ecological resources at risk at Hanford are discussed: 1) development of the risk evaluation methods, 2) the general applicability of the method, and 3) the applicability of the method for long-term stewardship and sustainability. Development of the methodology for Hanford Site was possible only because 1) a previously completed Ecoregion evaluation was available, 2) DOE had developed and approved a resource level scheme based on extensive discussions with the States of Washington and Oregon, Tribes, and ecologists (e.g. Nature Conservancy), 3) a ground-truthing methods was developed to supplement the resource levels previously assigned to different parts of Hanford, and 4) likely remediation options for different evaluation units were known. Without this information base it would be difficult to design a rating methodology without the expenditure of substantial resources.

The general method provided in this paper can be applied at other DOE sites, providing an on-site evaluation of resources exits. Evaluation of on-site resources, however, is a time-consuming job, requires trained ecologists with knowledge of both the local and regional plants and animals, and will likely be acceptable only if a wide range of resource agencies and Tribes are included in the process. Most DOE sites produce environmental reports each year that can be used as a basis, but field assessment is required to obtain comparative data across the site. While the general methodology outlined in this paper can be adapted for other sites, it requires site-specific information on the Ecoregion, endangered and threatened species, species of concern to Tribes, recreationists, and commercial interests, and up-to-date data on ecological resource level. Different sites may have different levels. As an example, there were 5 resource levels for Hanford, but this may be more or less for other sites. Further, remediation options may differ, and the temporal and spatial patterns of remediation may differ.

Finally, while the methodology described in this paper was developed to rate the risk to ecological resources from the remediation remaining on the Hanford Site, the overall goal was to ensure the continued conservation and protection of ecological resources on the site, for the present and future generations. Sustainability is an important component of any ecological evaluation, particularly given the rapid development of land outside the Hanford Site. Long-term stewardship on DOE lands is an important aspect of the agency’s mandate, regardless of the ultimate land manager. Sustainability is one of the missions of DOE for its lands. The critical, rare, and unique ecological resources on Hanford are even more important because these resources have declined in the Ecoregion, and some of the species and habitats now occur mainly on Hanford. Sustainability of these resources is a high priority not only for Hanford, but for the U.S. Fish & Wildlife Service that manages the Monument, Tribes, other resource trustees, and the public. Sustainability requires identification and assessment of ecological resources, evaluation of their importance relative to Hanford overall and the Ecoregion, and assessment of their importance to Tribal members and the public. Further, long-term sustainability must include periodic assessment and monitoring to assure that the quality quantities of resources on the Hanford Site are maintained.

The methodology described in this paper should be repeated periodically to assure protection and sustainability. Future monitoring would entail field assessment to determine if the quality and quantity of different resource levels is being maintained. Once remediation is completed on Hanford, a site-wide re-assessment of resource levels is needed, followed by periodic assessments to determine trends and

assure sustainability of Hanford Site's valuable and unique ecological resources.

CONCLUSIONS

Evaluating resources for both remediation and long-term sustainability requires use of existing evaluations and assessments, as well as field assessments to determine changes in resource values. Resource values include listing of threatened and endangered species, rare and unique habitats, and different levels of plant communities determined on the basis of rarity and importance. Such information must be gathered periodically to ensure protection of environmental resources on Hanford, and the paradigm presented in this paper can be used on other sites across the DOE complex, in conjunction with methods to evaluate risk to human health, groundwater, and other resources.

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