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Revision 0

Conservation Habitat Assessment and Mitigation Prioritization (CHAMP) for the Hanford Site: Identifying Priority Conservation Areas

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-09RL14728

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Mission Support Alliance
Richland, WA

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EXECUTIVE SUMMARY

This report presents the initial phase of the Conservation Habitat Assessment and Mitigation Prioritization (CHAMP) for the Hanford Site. This phase of the habitat assessment and prioritization identifies priority conservation areas based on current health, size, and status of native habitats and species and initiates the identification of priority mitigation areas. The products from this analysis form the foundation for continued assessments. The impetus for the CHAMP is to take a landscape approach to evaluating habitat quality on the U.S. Department of Energy, Richland Operations Office (DOE-RL)-managed portion of the Hanford Site (study area) and use the results to determine areas for conserving, restoring, mitigating, and connecting habitats.

ES1. INTRODUCTION

The Hanford Site, encompassing 1,517 km^2 (586 mi^2) in south-central Washington State, was requisitioned by the U.S. Atomic Energy Commission in 1943 for the siting of facilities to produce plutonium for the first atomic weapons (Figure 1). The Hanford Site is within the largest remaining area of contiguous native shrub-steppe and grasslands in Washington State. It contains some of the most extensive dune systems in the region and is home to hundreds of plant and wildlife species. The natural resources on the Hanford Site are of notable value, both locally and regionally. In 2000, Presidential Proclamation 7319 (65 FR 37253-37257) established portions of the Hanford Site into the Hanford Reach National Monument managed by the U.S Fish and Wildlife Service (USFWS) for its ecological, cultural, and geological values. This report focuses on the remaining lands of the Hanford Site currently managed by the DOE-RL (study area).

DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*, (BRMP) is the primary implementation plan for managing natural resources under DOE/EIS-0222-F, *Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (CLUP). Principal implementation of this management plan is carried out by the Ecological Monitoring program, currently managed by Mission Support Alliance (MSA). MSA’s responsibilities include, among other actions, ecological monitoring, compliance reviewing, reporting, implementing protective measures and administrative controls, and determining and implementing mitigation requirements. Since May 2011, MSA’s Ecological Monitoring program has primarily fulfilled these objectives through monitoring and reporting on the status of species of interest (state, federal, and Tribal species of concern), mapping vegetation, and tracking and evaluating trends in species occurrences and other natural resources of interest.

The scope and scale of this habitat assessment and prioritization will help integrate key ecological data from the Hanford Site with data from other parties (e.g., USFWS, Washington Department of Fish and Wildlife, Yakima Training Center) who’s natural resource protection and restoration goals align within the broader landscape surrounding the Hanford Site, including the Columbia Plateau Ecoregion. This integration of data and coordination of actions is especially important between the DOE-RL-managed portion of the Hanford Site and the adjacent USFWS-managed Hanford Reach National Monument.

This document provides an ecosystem-level approach to identifying areas of highest priority for conservation and restoration on the DOE-RL-managed lands of the Hanford Site in south-central Washington State. The approach (Marxan analysis) is a spatially explicit habitat assessment and habitat prioritization that analyzes a diverse array of existing vegetation, species-specific data, and abiotic data traditionally collected on the Hanford Site.

This habitat assessment and prioritization is compatible and complementary to other efforts on the Hanford Site (e.g., the CLUP and BRMP) and in the greater Columbia Plateau Ecoregion (e.g., the Arid Lands Initiative [ALI 2014] and the Washington Wildlife Habitat Connectivity Working Group [WHCWG]).

ES2. METHODS

Marxan is the most widely used systematic conservation planning tool in the world based on the minimum set problem, stated as "What is the minimum number of sites, or minimum total area, necessary to represent all species/habitats?". Within Marxan, targets for conservation features, weightings (penalties) of conservation features, and costs (constraints) can be varied, allowing for repetitious solutions. Marxan produces a range of results that meet conservation objectives that increase possibility of finding solutions that maximize targets while minimizing negative impacts and can lead to identification of unforeseen solutions (Ardon et al. 2010).

Three focal habitats (shrub-steppe, grasslands, and dunes) and one group of species (burrowing animals) were selected to guide the habitat assessment and prioritization. These focal habitats and species including nested species, and/or microhabitats, had the available data necessary to characterize the highest percentage of all species/habitats found on the study area. They met the following goals:

- Represent biodiversity at the Hanford Site and the functions occurring across this landscape
- Reflect ecoregional priorities for the Columbia Plateau Ecoregion
- Considered viable or restorable within this landscape
- Are threatened and, therefore, in need of conservation attention or strategy adjustment for achieving DOE-RL's objectives for the Hanford Site.

Once the focal habitats and species were identified, a viability assessment was developed for each of the focal groups. The intent of the viability assessment is to organize current understanding and knowledge of each habitat or species in a way that evaluates how to know whether that habitat has ecological integrity or the species is viable. Viability, or ecological integrity, quantifies whether the habitat or species is resistant to change in its structure or composition in the face of external stresses or resilient in light of those stresses — that is, able to recover from occasional severe stress (FOS 2009).

Key ecological attributes (KEAs) were recognized and developed for each focal habitat or species and indicators were identified to assess the quality of each KEA. One or more indicators are necessary to quantify each KEA. Indicators are measurable aspects of the KEA that provide information on its status. In order for the indicator values to be compatible with the Marxan analysis they were categorized using a rating system of Poor, Fair, Good, and Very Good. Marxan requires inputs of spatially explicit, digital layers that represent each KEA-indicator. Each of these input layers represent a Marxan target.

Eleven KEAs were identified for quality focal habitats and species and 21 indicators were used to represent the 11 KEAs. The focal habitats and species along with their KEA-indicator pairs are shown in Table 2. Several KEA-indicator pairs such as fire regime, presence of critical or unique habitats and species, and density of noxious weeds were shared between focal habitats and species.

After Marxan targets are defined, users must assign a relative level or goal for each target. The goal for each target is the desired percentage of the target's area that should be included in the Marxan conservation solution. When possible, target levels should be based on scientific data to maintain the integrity of ecosystems; however, economic concerns and political goals can be considered.

Another requirement of a Marxan analysis is the development of a single input layer that represents how all constraints vary across the landscape. Constraints (also called costs) can be factors that limit the ability of the habitat to function as normal (e.g., physical barriers like roads) or factors that limit the abilities to intervene or manage biological resources (e.g., contamination or zoned areas). Depending on the particular application that Marxan is being used for, the constraints that this input layer represents can be based on physical or biological limitations, management guidelines, or rules and policies governing the future use of the land. Eleven categories and 73 sub-categories of constraints on the study area were used in the analysis including areas under industrial use or highly disturbed areas zoned for development under the Hanford Comprehensive Land-Use Plan (CLUP), National Historical Park sites, waste sites, utility towers and lines, roads, railroads, structures, fences, wells, and borrow pits.

Once the Marxan targets and target goals were selected, calibration was performed to ensure that Marxan-produced solutions were optimized or close to the lowest cost. Values within the function that typically require calibration are the Species Penalty Factor (SPF), Boundary Length Modifier (BLM), number of iterations, and the constraint layer range (effect). With goals invoked by this study, Marxan runs successfully met the targets in most cases over a variety of runs, iterations, and BLM manipulations. Therefore, performing a calibration for SPF to apply to unmet targets would have little bearing on the solutions.

The BLM is used to improve the spatial clustering and compactness of the solutions (Ardon 2010). If a BLM is set to 0, then solutions will be formed with no regard to their overall pattern and are typically dispersed and result in a fragmented solution. As BLM is increased, Marxan solutions show more connection and clumping as the algorithm begins to favor the selection of units adjacent to already selected units over isolated units that otherwise achieve target goals (ALI 2014). Managing compliance and conservation of small, dispersed, and fragmented habitats can be a difficult and undesirable task. Therefore, achieving a level of clustering that maximizes the trade-off of minimizing the boundary length of a solution while minimizing the overall solution cost is the desired goal when calibrating a BLM.

Initial calibrations of BLM were performed from BLM values of 0-5, refined and run from 0-2, and then further refined to BLM Values between 0.1 and 0.95 BLM. The values were plotted on a graph consisting of total cost on the x-axis and the total boundary length on the y-axis and the point on the curve at which there is a relatively large decrease in total boundary length (clumping) is associated with a relatively small increase cost that can be considered the desired BLM value. Using this technique, a BLM value of 0.46 was selected.

The simulated annealing solver in Marxan requires a large number of iterations to find quality solutions (Ardon et al. 2010). Marxan analysis for this study was performed with 100 runs. Each run produces its own unique solution, increasing the number of iterations per run allows Marxan to spend more time converging towards similar solutions across those runs. Solution time increases with the number of iterations so there are practical limits on the number of iterations that can be considered reasonable. At some point it becomes far more useful to have an adequate number of restarts (new runs) than to try to ensure the efficiency of an entire solution set (Ardon et al. 2010). This study followed a similar approach to the ALI (2014), running the analysis 100 runs with different iteration versions. Using this analysis, the EM Team chose 25 million iterations per run, producing less than a 1% difference in solution scores over the 100 runs at the most efficient processing time.

One of the conditions for obtaining meaningful results from a Marxan run is to ensure that the terms (constraint [cost] layer, boundary length, and species penalty factor) of the objective function are of the same magnitude to avoid one of the terms unduly influencing the outcome of the solution. In the case of the Hanford Site analysis, the boundary length was measured to be 88.25 and because all of the targets were met, the SPF was set at 1. In order to scale the constraint layer to the magnitude of the boundary length, the planning unit costs were multiplied by 100. Another 100 (unitless) was added to each of the planning units to make the base planning units, those units with no costs have a cost value of 100.

ES3. RESULTS AND DISCUSSION

One caveat to note in this assessment is that although the researchers used the best available data, some indicators of KEAs identified in the viability assessment workshops had to be modified to accommodate poor, incomplete, or lacking data. Another caveat to consider is that the study area boundary may have an influence on the solution outputs. While the Columbia River acts as an ecological boundary to the north and east of the study area, the south and west boundaries are primarily administrative in nature. The use of administrative boundaries can have an effect on the solution in relationship to clustering (Boundary Length) and limiting selection of planning units on boundary edges.

The Marxan analysis produced solutions that had a range over mean variance of less than 1%. The solution displayed on maps and discussed in this report is the Marxan “Best” solution. This solution represents the areas of highest priority for conservation that most efficiently meet the conservation target goals in the study area with the lowest score. The score can only be used in comparing runs within the same analysis. The best solution produced a score, boundary length (connectivity), and penalty factor for target shortfalls that were all lower than the average of the 100 runs. This solution achieved nearly 100% of target goals with only a fraction more cost and number of planning units required compared to the average.

The solution used 20,144 planning units of the 40,654 units available on the study area. Approximately 50% of the study area displays in the conservation solution (Figure 6). The solution is comprised of 13 patches ranging from 4 to 30,034 ha (10 to 74,216 ac) in area and covers approximately 40,760 ha (100,720 ac) of the study area. The largest solution patch, 30,034 ha (74,216 ac), is the bulk of the overall solution covering nearly 74% of the total solution.

Because Marxan produces a unique solution for every run within an analysis, the planning units selected can vary from each solution. Marxan produces a selection frequency output that displays the number of times each planning unit is selected over the 100 runs in an analysis. The best solution of this assessment contained 20,144 planning units, 61.53% (12,394 units) of the solution area was selected in each solution of the 100 runs. An additional 29.59% (5961 units) of the solution area was selected in 67 to 99 runs. Only 8.88% (1789 units) of the solution area was selected in 66 runs or fewer.

The appeal of the Marxan analysis is that Marxan can use a diverse array of input data types (already existing Hanford Site data) and can be compatible and complementary to other efforts on the study area (e.g., the CLUP [DOE/EIS-0222 1999] and the BRMP [DOE/RL-96-32 2017]) and in the greater Columbia Plateau Ecoregion (e.g., the ALI [2014] and the WHCWG [2012, 2013a, 2013b, 2014, 2015]). A key element to understanding the assessment is to evaluate the identified areas of high habitat value. The solution Marxan provided shows areas of good habitat with high value, but areas selected may not always include all high quality examples of that habitat. By nature of the Marxan tool, the solutions are a range of mathematical calculations that attempt to capture the desired quantity of a target while limiting a cost to the solution. Using BRMP and its practices, the areas of highest habitat quality and the best examples of resources will remain conserved through avoidance or minimal intrusion. The Marxan tool can be used to answer other habitat conservation questions (such as “what is a network and spatial configuration of areas that strategically meet conservation goals?”) through visual display and statistical analysis. The CHAMP provides an additional decision-making tool that can support the practices of BRMP and highlight areas that may be underrepresented in particular resources but as whole provide value to the landscape.

Evaluating the frequency of planning unit selection during the assessment can make inferences on the biological value of portions of the study area. Biological value of an area may be defined in terms of irreplaceability, or how important the specific area is for efficient achievement of conservation objectives. The higher the frequency of selection of a planning unit in Marxan, the closer a unit is to being considered irreplaceable within the solution. After establishing areas of irreplaceability from selection frequency of the solution, the next step would be to evaluate potential vulnerabilities to these areas. Vulnerability is the risk of an area being transformed through damage caused to the biodiversity features or threatening ecological processes (Kukkala and Moilanen 2012). For this discussion, vulnerabilities are further defined as the risk of impairment to an area from Hanford Site operations or other human activities. While it is not always possible to predict or limit Hanford Site operations to specific areas, the solution shows areas that are lower in their conservation status and not frequently selected as valuable in the outputs. These areas should be the preferred areas for future development to limit impact to sensitive biological resources. The vulnerability plotted against the irreplaceability can provide inference into potential actions (Figure 13). A spatial representation of this concept for the study area is provided in Figure 14.

Integration of the CHAMP with existing site management plans (CLUP and BRMP) and existing regional habitat analysis (Arid Lands Initiative [ALI] and WHCWG) is an important function of the study results. The expectation of the study results is that they are compatible and complementary to the existing plans and analyses and provides reciprocating support. With the current CLUP map and designations, the CHAMP best solution identifying priority conservation areas is in agreement over 82% of its area (Figure 15 and Table 17) but also showed areas where CLUP designations could be improved. Even with added weight constraints, some areas of industrial (exclusive), industrial, and research and development were selected in the best solution.

The CHAMP best solution is also in reasonable agreement with the BRMP. Approximately 95% of the CHAMP best solution occurs in habitats identified for preservation (Level 4 and 5) or conservation (Level 2 and 3) in the BRMP (Figure 16 and Table 19). Approximately 90% of the CHAMP best solution appears in the top three highest BRMP resource priority Levels (Levels 3, 4, and 5).

The ALI Marxan analysis recognized the Hanford Site as an important priority core area at all goal levels. The Hanford Site overlays one of the larger priority core areas selected by the ALI analysis. At the planning unit size of 202 ha (500 ac), a large portion of the Hanford Site consistently met the conservation targets. However, at the local scale, it is apparent that some areas of high quality habitat were excluded from the ALI solution while other areas of low quality habitat were included. On the DOE-RL-managed portion of the Hanford Site, roughly 52% of the ALI best solution at the medium goal level intersects with the CHAMP best solution. This disparity reinforced the need for a local analysis with more detailed local data.

The CHAMP best solution aligns with the Washington WHCWG outputs and can provide local detail. A good example can be seen in the WHCWG black-tailed jackrabbit normalized least-cost corridor. This WHCWG output combines habitat concentration areas and linkages into a single map class. The CHAMP best solution generally matches the black-tailed jackrabbit network map including the corridors.

An intended purpose of the CHAMP was to identify potential areas on the study area that would benefit from mitigation work and restoration efforts. Providing a one-size fits all prescription for mitigation on the Hanford Site is not a feasible expectation of any analysis. Once decisions are made on potential locations of mitigations based on ecological factors of the solution, staff can evaluate the potential success of restoration activities in those areas. The CHAMP can be effective in avoiding unnecessary costs or effort in restoration. In addition to evaluating the ecological and external factors that will impact the success of future mitigation actions, it is important to evaluate the planning units to determine why they were not selected as part of the solution. This information can help guide specific mitigation actions after the planning units are chosen. Once a mitigation area is chosen, Marxan can be used to potentially model the desired outcome of the mitigation actions. To perform these actions, the values of the individual planning units can be altered in the selected target layer to reflect the desired future conditions of the mitigated area, and the Marxan run will be performed under the same conditions. These results can show the potential future effects of the proposed actions at a landscape scale, including changes in connectivity, patch buffering, and habitat quality increase. After this evaluation, the mitigation plan can then be altered, if necessary, to create the desired changes.

Performing this conservation assessment met the purpose of identifying areas of high habitat value and areas for restoration of habitat that meet the conservation goals and objectives of the Hanford Site. The solution provided, coupled with existing conservation documents and processes, will support ecological impact and mitigation decision making on the Hanford Site. The CHAMP is an adaptive tool that can be employed in various ways to target generic or specific solutions.

Future analysis will shift focus to identify potential areas on the Hanford Site that would benefit from mitigation work. To perform this investigation, input layers will be set to highlight areas that meet mitigation potential goals. Items to consider for focusing solution to mitigation areas may include the following:

- Identify planning units with Fair target ratings that can be moved into the Good category with mitigation actions like revegetation, animal reintroduction, or other habitat restoration activities

- Alter targets to better represent a mitigation habitat so Good ratings are no longer resources or habitats that are quality representations but rather have quality in its mitigation potential

- Make changes to current constraints and add new constraints specific to their impacts on mitigation and long-term success

- Manipulate target goal levels to highlight planning with weaker features that would benefit from mitigation or restoration.

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1.0 INTRODUCTION

1.1 THE DEPARTMENT OF ENERGY'S HANFORD SITE

The Hanford Site, encompassing 1,517 km^2 (586 mi^2) in south-central Washington State, was requisitioned by the U.S. Atomic Energy Commission in 1943 for the siting of facilities to produce plutonium for the first atomic weapons (Figure 1). In 2000, Presidential Proclamation 7319 (65 FR 37253-37257) established portions of the Hanford Site into the Hanford Reach National Monument for its ecological, cultural, and geological values. The Hanford Reach National Monument is managed by the U.S Fish and Wildlife Service (USFWS) as part of the Mid-Columbia River National Wildlife Refuge Complex. This report focuses on the lands of the Hanford Site currently managed by the U.S. Department of Energy, Richland Operations Office (DOE-RL). These lands which include the central Hanford Site and the McGee Ranch/Riverlands area occupy 808 km^2 (312 mi^2) with State Route 240 providing the main boundary to the south and west and the Columbia River bounding it on the north and east (hereafter referred to as the study area). The Hanford Site is within the largest remaining area of contiguous native shrub-steppe and grasslands in Washington State. It contains some of the most extensive dune systems in the region and is home to hundreds of plant and wildlife species. The natural resources on the Hanford Site are of notable value, both locally and regionally. This area has been home to several Native American Tribes. Remnants, artifacts, and burial sites associated with historical Tribal activity are found throughout the Hanford Site, highlighting that this area is also culturally significant and important to the Tribes today.

In 1989, DOE-RL entered into the *Hanford Federal Facility Agreement and Consent Order* with the U.S. Environmental Protection Agency and the Washington State Department of Ecology (Ecology et al. 1989). Since then DOE-RL has invested in cleanup of the Hanford Site to address the nuclear waste and pollution remaining from the nuclear reactors constructed to produce plutonium during World War II as part of the Manhattan Project and the Cold War Era. As described on DOE-RL's website (https://www.energy.gov/em/hanford-site), "after more than two decades of cleanup, considerable progress has been made at Hanford, reducing the risk the site poses to the health and safety of workers, the public, and the environment."

1.2 ECOLOGICAL MONITORING PROGRAM

DOE/RL-96-32, *Hanford Site Biological Resources Management Plan*, (BRMP) is the primary implementation plan for managing natural resources under DOE/EIS-0222-F,*Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (CLUP). The BRMP details the following three overarching objectives that guide the management of natural resources on the Hanford Site:

- Foster preservation of important biological resources
- Minimize adverse impacts to biological resources from Hanford Site development and other management activities
- Balance the Hanford Site cleanup mission with resource stewardship obligations.

Implementation of much of this management plan is assigned to the Ecological Monitoring (EM) program, currently managed by Mission Support Alliance (MSA). MSA's implementation responsibilities include, among other actions, ecological monitoring, compliance reviews, reporting, implementing protective measures and administrative controls, and determining and implementing mitigation requirements. Since May 2011, MSA's EM program has fulfilled these objectives by monitoring and reporting on the status of species of interest (i.e., mainly state, federal, and Tribal species of concern), mapping vegetation, and tracking and evaluating trends in species occurrences and other natural resources of interest. Data collected are used to support environmental cleanup and restoration activities, mitigation actions, land-use planning, and compliance reviews to maintain compliance with ecological resource laws.

As the cleanup of the remaining war legacy facilities along the Columbia River corridor is completed on the Hanford Site, and as ongoing activities are consolidated onto the 200 Areas Plateau, the infrastructure in the outer areas of the Hanford Site is being removed, and areas are being remediated and restored. As cleanup progresses, larger portions of the Hanford Site are becoming less impacted by the day-to-day operations of the Hanford Site mission, allowing additional opportunities to arise for mitigating impacts on biological resources.

1.3 PURPOSE AND GOALS OF THE HABITAT ASSESSMENT

The EM program has taken a landscape-level look at the area of the DOE-RL-managed portion of the Hanford Site (study area) in order to assess habitat quality. This ecosystem approach differs from the traditional single resource studies carried out on the Hanford Site and instead focuses on groups of resources and the interactions among them. The EM program carried out a spatially explicit habitat assessment and habitat prioritization to analyze the vegetation and species-specific data compiled through monitoring and mapping efforts in the program. Using the historical ecological resource data, the EM program used the habitat assessment and prioritization to achieve the following purpose:

- To identify, on the landscape, areas of highest priority for conservation and restoration that meet the conservation goals and objectives of the Hanford Site.

The habitat assessment and prioritization allows Hanford Site staff and contractors implementing the BRMP at the Hanford Site to:

- Develop an ecosystem approach for the landscape
- Identify potential areas that would benefit from restoration and mitigation work
- Incorporate the results of the assessment to analyze ecosystem services and inform future management decisions.

The scope and scale of the habitat assessment and prioritization will help the Hanford Site integrate key ecological data from the Hanford Site with data of other parties (e.g., USFWS, Washington Department of Fish and Wildlife [WDFW], Yakima Training Center) who have aligned natural resource protection and restoration goals within the broader landscape surrounding the Hanford Site, including the Columbia Plateau Ecoregion. This integration of data and coordination of actions is especially important between the DOE-RL-managed portion of the Hanford Site and the adjacent USFWS-managed Hanford Reach National Monument. On a larger scale, the long-term persistence and value of biological resources at the Hanford Site are linked through ecosystem structure and function to the larger area of native shrub-steppe and grasslands habitat that extends northwestward across the L.T. Murray Wildlife Area and up the Wenas and Umtanum Valleys (between Yakima and Ellensburg) to the forested slopes of the Cascades; west and then north, through the Yakima Training Center and connecting to the Whiskey Dick, Quilomene, and Colockum Wildlife Areas; north and then west along the Saddle Mountains; and south and west across the Arid Lands Ecology Reserve and along Rattlesnake Mountain.

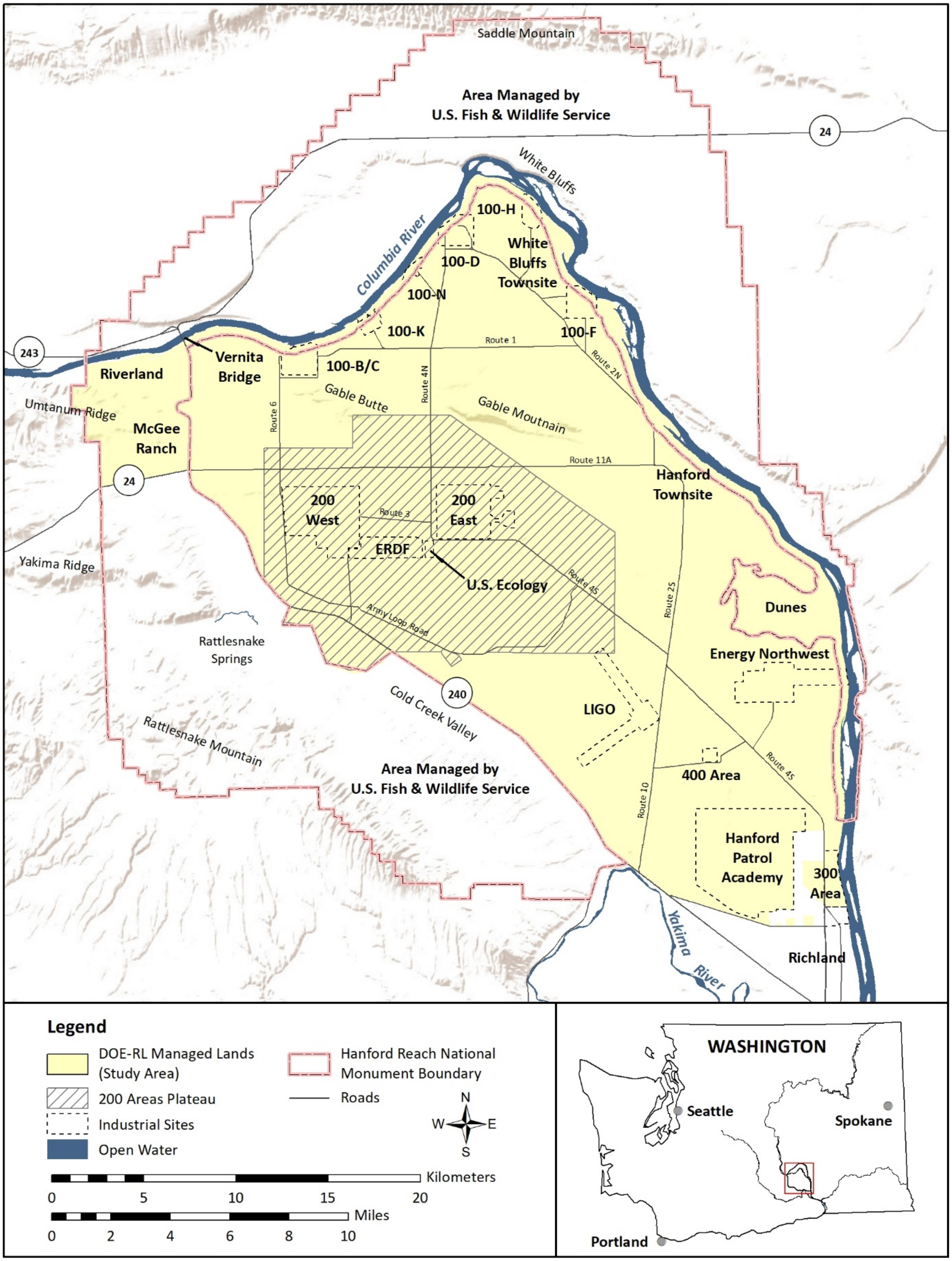

Figure 1. The U.S. Department of Energy Hanford Site.

As described above, the completed habitat assessment and prioritization is intended to support a variety of activities and decisions that the investigators make. There are two primary goals that the assessment and prioritization seeks to achieve:

- Identify priority conservation areas based on current health, size, and status of native habitats and species.
- Identify priority mitigation areas based on status of surrounding areas, their long-term viability, connectivity, and the immediate impact that restoration actions could have on native habitats and species.

In addition, given MSA's function as a DOE-RL contractor, a third goal — communications-focused, but just as critical as the two goals articulated above — was defined as:

- The habitat assessment and prioritization analysis must present the results in a report that can be used to make informed technical decisions.

These goals are articulated as impermanent goals, as the researchers acknowledge that the data compilation, management, and analysis carried out in completing a habitat assessment and prioritization can provide additional products that, with relatively little additional effort, could meet other related goals in the future.

1.4 RELEVANT LANDSCAPE SCALE EFFORTS

The EM team recognized early on that carrying out a habitat assessment and prioritization for the Hanford Site provided an opportunity for aligning with other relevant landscape scale efforts in the Columbia Plateau Ecoregion. One dimension of such alignment is technical, through approaches compatible and complementary to those carried out by the Arid Lands Initiative (ALI) (ALI 2014; USFWS 2015, 2017) and the Washington Wildlife Habitat Connectivity Working Group (WHCWG) (2012, 2013a, 2013b, 2014) (Figure 2). The ALI developed a Marxan analysis that provides a set of priority core areas and the WHCWG products demonstrate how these core areas can best be connected at the ecoregional scale.

1.5 PURPOSE OF THIS REPORT

The purpose of this report is to present the initial phase of the Conservation Habitat Assessment and Mitigation Prioritization (CHAMP) of the Hanford Site. This phase of the habitat assessment and prioritization identifies priority conservation areas based on current health, size, and status of native habitats and species and initiates the identification of priority mitigation areas. The products from this analysis form the foundation for continued assessments.

Figure 2. Arid Lands Initiative and Washington Wildlife Habitat Connectivity Working Group Project Background.

2.0 METHODS

The approach taken to make key guiding decisions on what the habitat assessment and prioritization should target, mirrors the approach taken by the ALI. The ALI partnership used a common conservation approach, the Nature Conservancy's Conservation Action Planning Process (TNC 2007). To make key decisions that guided the spatial priorities analysis, the Action Planning Process is merged with similar processes to become the Open Standards for the Practice of Conservation (http://cmp-openstandards.org/). The Open Standards process is aspatial, yet provides a standardized and proven framework for agencies to think through critical steps in defining the biological priorities that will drive the selection of priority areas for conservation and, potentially, for restoration. Through a series of workshops attended by biological resource specialists from DOE-RL, MSA, USFWS, and WDFW, and facilitated by Sonia A Hall (SAH Ecologia LLC), who has previously been part of the spatial planning and analyses carried out by both the ALI and WHCWG in the Columbia Plateau Ecoregion, the key aspects of the habitat assessment and prioritization for the Hanford Site were agreed on. To perform the assessment, the following steps were taken:

- Choosing Marxan as the conservation software to perform the assessment
- Defining the geographic scope of the assessment
- Creating Planning Units that support available data and are useable in decision making
- Developing the Focal Habitats or Species
- Identifying the targets within available data that best represent the focal habitats or species
- Determining proportions of those targets that need to be represented in the solutions
- Creating costs and constraints for the analysis.

This section provides detailed methodologies in the hope that the reader can gather an understanding, to the level they desire, on how the assessment was performed and for future reproducibility of results.

2.1 MARXAN

A Marxan analysis was used to carry out the habitat assessment and prioritization. Marxan stands for “marine reserve design using spatially explicit annealing”; however, it is just as applicable to terrestrial conservation planning problems (Ball et al. 2009). The use of this tool in the habitat assessment and prioritization at the Hanford Site is expected to help align fine-scale priorities within Hanford Site boundaries with the ALI’s ecoregion-wide priority areas, based in part on a Marxan analysis as well (ALI 2014). This alignment, in turn, is important for fulfilling DOE-RL’s intent, as implementing a landscape-scale approach in addition to the existing resource-specific approach will help streamline any coordination and collaboration with state, federal, and Tribal entities with land management interests and authorities in the region.

Marxan is the most widely used systematic conservation planning tool in the world based on the minimum set problem stated as, “What is the minimum number of sites, or minimum total area, necessary to represent all species/habitats?” Within Marxan, targets for conservation features, weightings (penalties) of conservation features, and costs (constraints) can be varied, allowing for repetitious solutions. Marxan produces a range of results that meet conservation objectives that increase possibility of finding solutions that maximize targets while minimizing negative impacts and can lead to identification of unforeseen solutions (Ardon et al. 2010).

Marxan is software that provides decision support for designing reserves and other land-conservation areas (Game and Grantham 2008). Marxan is a systematic conservation planning tool that uses optimization algorithms (simulated annealing) to “identify areas that efficiently meet targets for a range of biodiversity features for minimal cost” (http://marxan.org/about.html). The cost can be any relative social, economic, or ecological measure (Ardron et al. 2010). In addition, Marxan allows the user to place more or less emphasis on the levels of spatial clustering and other characteristics of the selected planning units (Ball et al. 2009). Marxan uses simulated annealing, a probalistic method for approximating the optimum of a function, to find multiple alternative good solutions. Using simulated annealing in conservation reserve analysis provides a relatively fast and simple solution that is robust to changes in the size and type of problem (Ball et al. 2009). This fast and simple solution can be achieved with a mathematical objective function that gives a value for a collection of potential sites (planning units) based on the various costs of the select set and the penalties for not meeting conservation targets (Game and Grantham 2008). Marxan works by continually testing alternate selections of planning units, aiming to improve the whole system value. This objective function is designed so that the lower the value, the better the solution. Marxan also allows measure of fragmentation to be taken into account, not only will a fragmented conservation area lead to undesirable fragmentation of ecological communities, it is likely to make management and compliance a greater challenge. Thus, the objective function in Marxan takes the form:

$$\sum_{PU's} Cost + BLM \sum_{PU's} Boundary + \sum_{ConValue} SPF \times PenaltyUnmetTargets + CostThresholdPenalty^{*}$$

The objective equation (Equation 1) describes the total cost of the network, the total reserve boundary length multiplied by the modifier (Boundary Length Modifier [BLM]), or Species Penalty Factors (SPF), and any penalties for exceeding the cost threshold. The objective function used for this assessment was performed to determine conservation areas and not weighted against a threshold for cost (monetary or other); therefore, this final input was not used in this analysis.

Other mathematical functions, including integer programming, can guarantee an optimal solution to a problem and may be argued as a better alternative for conservation planning problems. However Ball et al. (2009) found two major drawbacks to these more rigorous methods: 1) they failed to solve extremely large (number of planning units and number of conservation features) problems and 2) finding only the single best solution is not that useful in conservation planning. Marxan rapidly produces a range of solutions that are near optimal to enable the resource managers to negotiate and make choices amongst the range of options. This functionality (including cost, simplicity, speed of solutions, and flexibility of inputs) were major factors in the use of Marxan.

2.2 GEOGRAPHICAL SCOPE

The habitat assessment and prioritization was conducted on the DOE-RL-managed portion of the Hanford Site (study area) where there is direct access to data and the data are of known quality, consistency, and availability. Resource managers can use the results of the analysis for landscape decisions on this portion of the Hanford Site. It is also understood that key ecological attributes could be selected that would provide information on the value of areas within the study area based on their connections or adjacency to areas or values outside of the Hanford Site. The results will become the basis for conversations with agencies managing lands in the surrounding landscape as DOE-RL strives to engage more deeply with them and to obtain support to carry out an ideally shared future analysis at a broader landscape scale. A broader landscape scale might capture all of the Hanford Site, Saddle Mountains, and the Yakima Training Center and better reflect a more ecologically meaningful boundary in which to conserve the selected focal species and habitats (Figure 3).

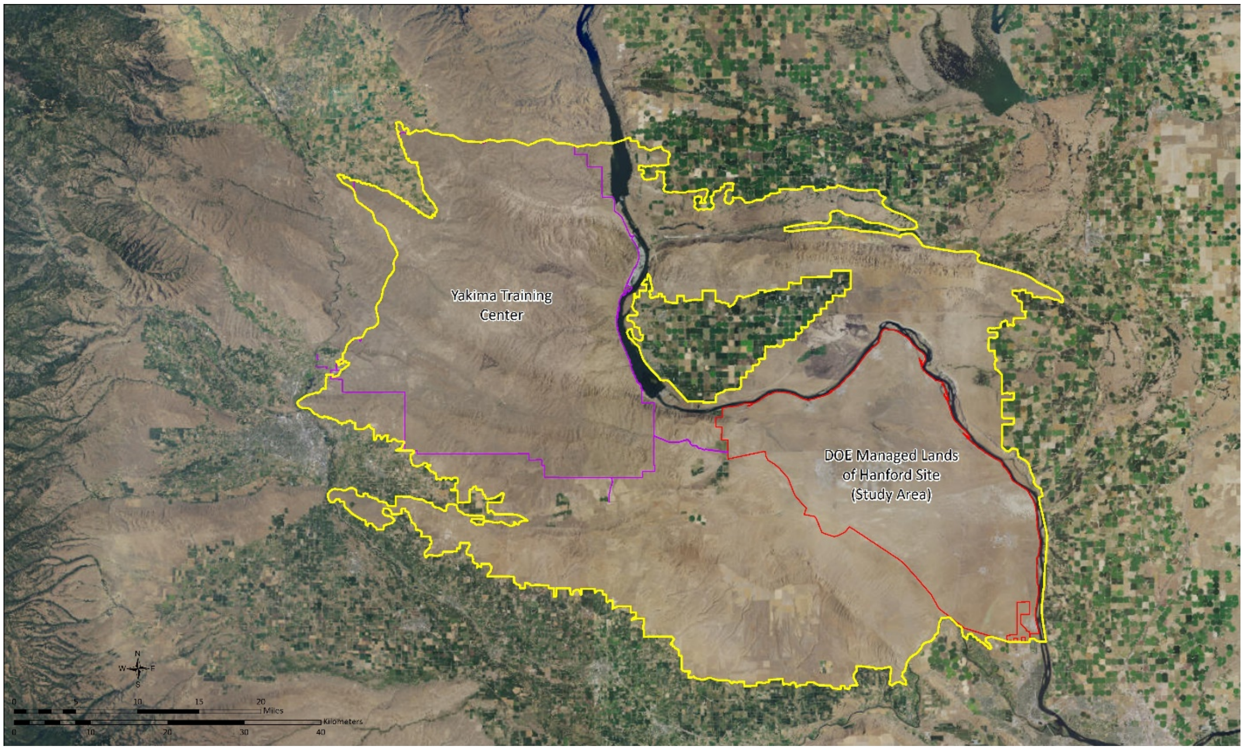

Figure 3. Geographic Scope Showing the Assessment Scope (Red), the Yakima Training Center (Purple) and the Overall Ecological Region (Yellow).

2.3 PLANNING UNIT

In order to run a Marxan analysis, the study area must be divided into planning units that cover the entire study area and do not overlap. Planning units can be uniform in size and shape, such as a grid of squares or a lattice of hexagons, or they can be unequal in size and shape, such as watersheds or land ownership parcels. Planning unit size should be no finer in resolution than the data on the conservation feature input layers and no coarser than the size of area practical for making management decisions (Game and Grantham 2008).

The investigators chose to partition the study area into 2-ha (5-ac) hexagonal planning units. A lattice of hexagons was chosen because the consistent size of the hexagons helps avoid area-related bias and the hexagonal shape approximates a circle with low edge-to area ratio. In addition, hexagons produce a smoother output than squares of the same area (Loos 2006; Loos 2011). The 2-ha (5-ac) size of the hexagons provides for manageable on-the-ground planning such as restoration efforts. A lattice of 2-ha (5-ac) hexagons produced 40,654 hexagons on the study area.

2.4 FOCAL HABITATS AND SPECIES

When determining the focal habitats and species, Hanford Site biological experts attended internal workshops to discuss what elements of the ecological landscape would answer the question:

- What is the number and type of focal habitats or species that include nested species and/or microhabitats and have data available, necessary to represent the highest percentage of all species/habitats?

The selected focal species and habitats concentrate on the DOE-RL-managed portion of the Hanford Site (study area). The Hanford Site is located within the Columbia Basin Ecoregion, an area that historically included over 6 million ha (14.8 million ac) of steppe and shrub-steppe vegetation across most of central and southeastern Washington State (Franklin and Dyrness 1973), as well as portions of north-central Oregon. The study area occupies 808 km^2 (312 mi^2) at the approximate center of the ecoregion and represents one of the largest tracts of native shrub-steppe habitat remaining in Washington State.

The climate at the Hanford Site is semi-arid with hot, dry summers and cold, wet winters. Based on data collected from 1945 through 2015 (http://www.hanford.gov/hms), the average monthly temperatures at the Hanford Meteorological Station ranged from a low of -0.4 °C (31.3 °F) in January to a high of 24.9 °C (76.9 °F) in July. Average annual precipitation at the Hanford Meteorological Station during this period was 17 cm (6.8 in.). Most precipitation is received between October and April.

Although the Hanford Site's biological resources are characteristic of the Columbia Plateau Ecoregion, the site is unique in that it is located within the driest and hottest portion of the ecoregion (Franklin and Dyrness 1973). These climatic conditions result in somewhat unusual species assemblages relative to the rest of the ecoregion. These same conditions also may result in Hanford Site shrub-steppe communities being less resilient to disturbance, making restoration and rehabilitation after large-scale disturbance more difficult than other areas that are cooler and receive more precipitation.

Determining focal species and habitats for this ecoregion and geographic scope was focused on selecting habitats or species that would achieve one or multiple of the following goals:

- Represent biodiversity at the Hanford Site and the functions occurring across this landscape
- Reflect ecoregional priorities for the Columbia Plateau Ecoregion
- Consider viable or restorable within this landscape
- Are threatened and, therefore, in need of conservation attention or strategy adjustment for achieving DOE-RL's objectives for the Hanford Site.

Starting from participant suggestions, the facilitated discussion led to compilation, discussion, and organization of proposed species and habitats in a way that resulted in a small number of focal habitats and species. Focusing on a limited number of focal habitats or species reduces the number of inputs and the complexity of the assessment. These discussions were meant to identify whether, for example, some species could be considered conserved if the habitats they depended on were the focus of conservation and could, therefore, be considered nested under that habitat.

As an example, native forbs were nested under the focal habitats of shrub-steppe, grasslands, and dunes. If shrub-steppe, grasslands, and dunes were in good condition this would require a diverse component of native forbs and, therefore, the forbs would likely be viable as well. Species could be grouped under analogous rationale. In the case of the Hanford Site discussion, for example, the researchers considered that a limiting factor for raptors was the availability of prey, namely ground squirrels. Therefore, if investments led to viable and healthy populations of ground squirrels, the raptors should be conserved as well and could, therefore, be considered to be nested, from a conservation need perspective under the ground squirrels.

Three focal habitats (shrub-steppe, grasslands, and dunes) and one group of species (burrowing animals) were selected to guide the habitat assessment and prioritization. These focal habitats and species are described below.

2.4.1 Focal Habitat: Shrub-steppe

Extensive shrub-steppe and shrublands occur as a matrix with grasslands and dunes, or as large patch systems across eastern Washington's arid lands, with annual precipitation between 15 and 50 cm (6 to 20 in.). On the Hanford Site, this aggregation of systems generally appears across an elevation range from 150 to 230 m (490 to 750 ft), although there are higher elevations on Umtanum Ridge (550 m [1800 ft]), Gable Mountain (330 m [1,083 ft]), varied landforms (e.g., flats, plateaus, gentle slopes, rolling hills, broad basins, plains, foothills, alluvial slopes, steep open slopes, canyons, valleys, swales, mesa tops, alluvial flats), and on a diversity of soils (shallow, lithic soils; deep, well-drained and non-saline; saline, alkaline or calcareous; stony, volcanic-derived clays; alluvial sands; well-drained sandy or loamy soils; fine-textured soils). Vegetation may include shrubs and dwarf-shrubs, perennial herbaceous species (grasses and forbs), and annuals. The shrub layer is generally dominated by sagebrush (*Artemisia spp.*), bitterbrush (*Purshia tridentata*), spiny hopsage (*Grayia spinosa*), winterfat (*Krascheninnikovia lanata*), or buckwheat (*Eriogonum spp.*) and varies in composition and cover in response to soil characteristics, water availability, and disturbance (e.g., fire, frost-heaving, slope failure). Herbaceous cover also varies due to soil attributes, water availability, and past disturbance, generally increasing in cover from shrublands to shrub-steppe. Common bunchgrasses include bluebunch wheatgrass (*Psudoroegneria spicata*), Sandberg's bluegrass (*Poa secunda*), Idaho fescue (*Festuca idahoensis*), needle-and-thread grass (*Hesperostipa comata*), Indian ricegrass (*Achnatherum hymenoides*), and sand dropseed (*Sporobolus cryptandrus*). Mosses, lichens, and microphytic soil crusts are also characteristic.

On the Hanford Site, the shrub-steppe habitat includes several unique ecological systems, including Inter-mountain Basins Big Sagebrush Steppe, Inter-Mountain Semi-Desert Shrub-Steppe, and Columbia Plateau Scabland Shrubland, which are described in detail below.

2.4.1.1 Inter-Mountain Basins Big Sagebrush Steppe (38% of the Hanford Site). The Inter-Mountain Basins Big Sagebrush Steppe system is dominated by sagebrush and/or bitterbrush in an open to moderately dense (5 to 40% cover) shrub layer with at least 25% total perennial herbaceous cover. Depending on the site, associated grasses can include bluebunch wheatgrass, Sandberg bluegrass, Cusick's bluegrass (*Poa cusickii*), prairie junegrass (*Koeleria macrantha*), needle-and-thread grass, and Thurber's needlegrass (*Achnatherum thurberianum*).

Landforms that support shrub-steppe are a mosaic of patch types or plant associations that reflect differences in site (soils, precipitation zones) and fire effects. Soils can be deep (greater than 15 cm [6 in.]) to shallow and non-saline. The space between vascular plants often supports a biological crust that can cover up to 90% or more if there is no disturbance on the site. Biological crust cover generally decreases with increasing vascular plant cover, elevation, and soil disturbance.

This ecological system has a wide distribution, however, large areas are in poor to fair condition. Good to Very Good condition areas are rare in communities where bluebunch wheatgrass and needle-and-thread grass are the dominant grasses (such as the Hanford Site) due to weed invasion. Conversion to agriculture is a serious threat outside of the Hanford Site within the Columbia Basin. The Inter-Mountain Basins Big Sagebrush Steppe is considered Imperiled (S2) within Washington State.

2.4.1.2 Inter-Mountain Semi-Desert Shrub-Steppe (16% of the Hanford Site). This ecological system occurs in the hottest, driest (less than 20 cm [8 in.] per year) areas within the Columbia Basin. It is characterized by an open shrub to moderately dense woody layer and a strong grass layer. The woody layer is often a mixture of shrubs and dwarf shrubs, however, it can be dominated by a single shrub species. Characteristic shrubs in this system include spiny hopsage or winterfat with rubber rabbitbrush (*Ericameria nauseosa*). Big sagebrush (*Artemisia tridentata*) can also be present and grayball sage (*Salvia dorri*) can be found in stonier sites. Characteristic grasses include Indian ricegrass, Thurber's needlegrass, squirreltail bottlebrush (*Elymus elymoides*), Sandberg bluegrass, and needle-and-thread grass. Annual grasses, especially cheatgrass (*Bromus tectorum*), can be present to abundant in semi-desert shrub-steppe systems.

Within Washington State, the Inter-Mountain Basins Semi-Desert Shrub-Steppe is uncommon and has a limited range, thus the conservation status of this ecological system is Critically Imperiled (S1) within the state. Following fire or site disturbance, non-native annual species tend to replace perennials; there is a high potential for invasion of cheatgrass. In much of this system's likely historical range, it has been replaced by irrigated agriculture.

2.4.1.3 Columbia Plateau Scabland Shrubland (1.3% of the Hanford Site). This ecological system is characteristicaly associated with flats, plateaus, and gentle to steep slopes with rock. Occurring on site with little soil development and areas of exposed rock, gravel, or compacted soil, these shrublands are extremely xeric and the vegetation is low (less than 0.5 m [1.6 ft]) with an open canopy. On the study area, this ecological system is found primarily on Gable Mountain, Gable Butte, and Umtanum Ridge.

Scabland shrublands are generally dominated by stiff sagebrush (*Artemisia rigida*) along with other dwarf-shrub species, particularly buckwheat (*Erigonum*) species (e.g., slender buckwheat [*E. microthecum*], rock buckwheat [*E. sphaerocephalum*], strict buckwheat [*E. strictum*], and thymeleaf buckwheat [*E. thymoides*]).

Land uses in this system are few due to the rocky soils. The primary stressor on the Hanford Site is the introduction of invasive plant species and fire. Because this system provides little forage it is used little by livestock and the conservation status of the Columbia Plateau Scabland Shrubland ecological system is considered Secure (S5) in Washington State (Rocchio and Crawford 2015). On the study area, this system frequently forms a complex matrix with the Inter-Mountain Basins Big Sagebrush Steppe or the Inter-Mountain Basins Semi-Desert Shrub-Steppe ecological systems.

2.4.2 Focal Habitat: Grasslands

Grasslands occur as a matrix with shrub-steppe, shrublands, and dunes or as large patch systems across the Hanford Site and within the Columbia Basin ecoregion. On the Hanford Site, this aggregation of systems generally appears across an elevation range from 150 to 230 m (490 to 750 ft), on varied landforms (e.g., flats, plateaus, gentle slopes, rolling hills, broad basins, plains, foothills, alluvial slopes, steep open slopes, canyons, valleys, swales, mesa tops, alluvial flats), and on a diversity of soils (e.g., shallow, lithic soils; deep, well-drained and non-saline; alluvial sands; well-drained sandy or loamy soils; fine-textured soils). Vegetation may include perennial herbaceous species (i.e., grasses and forbs), shrubs and sub-shrubs, and annuals. A healthy grassland ecosystem is marked by a dominant vegetative layer of native grasses with minimal invasive grasses and a shrub overstory that is minimal to non-existent.

Most native perennial grass species commonly found on the Hanford Site are cool-season bunchgrasses. The vegetative layer of grasslands is dominated (greater than 25% cover) by native perennial bunchgrasses such as bluebunch wheatgrass, needle-and-thread grass, Indian ricegrass, Idaho fescue, sand dropseed, and Sandberg bluegrass. The shrub layer is minimal to non-existent and may include big sagebrush, spiny hopsage, bitterbrush, yellow rabbitbrush (*Chrysothamnus viscidiflorus*), *rubber rabbitbrush*, and/or sub-shrubs such as buckwheat species. Native forbs may represent a minor component of the community and include species such as balsamroot (*Balsamorhiza* spp.), primrose (*Oenothera* spp.), globemallow (*Sphaeralcea* spp.), and desert parsley (*Lomatium* spp.). The presence of a biological crust in the space between plants is also characteristic and indicates a lack of disturbance.

Habitats that are dominated by annual or perennial non-native species (such as cheatgrass, crested wheatgrass (*Agropyron cristatum*), and bulbous bluegrass (*Poa bulbosa*) are degraded grasslands and do not represent the focal grassland habitat. These areas are common within the Hanford Site, especially within abandoned cultivated fields, areas disturbed by construction or other Hanford Site project activities, and in some areas that have been disturbed by wildfire. Grassland habitat in Good condition has a significantly higher (greater than 10%) proportion of native grasses relative to the non-native grasses.

Though grasslands are not always created as a result of fire, fire is a significant component in the creation of grassland habitats. Often, shrub-steppe ecosystems with significant shrub coverage and a native grass understory that are affected by fire will see a reduction in the shrub overstory. The perennial bunchgrasses may rejuvenate and become the dominant vegetative layer in the habitat. After decades, the shrub overstory may grow back to the point of dominance. This transition from shrub-dominated to grass-dominated habitats is characteristic of shrub-steppe ecosystems undergoing a natural fire regime.

2.4.3 Focal Habitat: Dunes

Dunes are a large patch, unvegetated to moderately-vegetated system occurring on active and stabilized sand dunes and sandsheets in the Columbia Basin. This focal habitat is comprised of the Inter-Mountain Basins Active and Stabilized Dune ecological system and is found on roughly 38% of the land area of the Hanford Site.

Inland active or stabilized dunes and sandsheets with patchy or sparse vegetation occur across the Columbia Basin. In general, the vegetation cover is related to the amount of annual rainfall and rate of evapotranspiration. Species occupying the dune environment are often adapted to shifting, coarse-textured substrates and form patchy or open grasslands, shrublands, or steppe. Vegetation cover ranges from sparse (less than 20%) to moderate (greater than 60%) and species composition is related to the degree of sand stabilization, vegetation cover, and position on the dune.

Scurf pea (*Psoralidium lanceolatum*) and Indian ricegrass typically dominate the initial stages of stabilization and are also commonly found on dunes with varying stages of stabilization. Prior to stabilization, shrubs are spare and thickspike wheatgrass (*Elymus lanceolatus*), a rhizomatous grass, and herbs such as winged dock (*Rumex venosus*) and whiteleaf scorpionweed (*Phacelia hastata*) are common. With increased sand stabilization, shrubs are often dominant (e.g., rubber and yellow rabbitbrush, bitterbrush, snow buckwheat, and big sagebrush). Forbs (e.g., pale evening-primrose [*Oenothera pallida*], sand beardtongue [*Penstemon acuminatus*], whiteleaf scorpionweed, terpentine springparsley [*Pterixia terebintha*], Columbia cutleaf [*Hymenopappus filifolius*], thread leaf scorpianweed [*Phacelia linearis*], Carey's balsamroot [*Balsamorhiza careyana*], terpentine springparsley [*Pterixia terebinthua*], Columbia cutleaf [*Hymenopappus filifolius*], threadleaf fleabane [*Erigeron filifolius*], and prairie junegrass) are common but contribute little to the total vegetation cover. Non-native weedy species like cheatgrass, Russian thistle (*Salsola tragus*), and tumblemustard (*Sisymbrium altissimum*) are common and sometimes abundant. Where dunes have overridden or partially covered other soil types, Sandberg bluegrass or other shrub-steppe species are often present.

The inland dune ecological system has always been relatively rare in Washington State. The total extent of this system has declined approximately 76% since the early 1970s due primarily to agricultural conversion, reservoir flooding, and dune stabilization. Inter-Mountain Basins Active and Stabilized Dune systems are ranked as Critically Imperiled (S1) in Washington State. The Washington State Natural

Heritage Program has issued the *Conservation Strategy for Washington State Inland Sand Dunes* (Hallock et al. 2007) that identifies management strategies for the conservation of these systems. Two areas on the study area are identified in this strategy document as having significant conservation value.

2.4.4 Focal Species: Burrowing Animals

This focal group of species captures burrowing animals, associated species, and their specific habitat selection characteristics, including soil and vegetation community types. A variety of burrowing animals and associated species occur on the Hanford Site from American badgers (*Taxidea taxus*) and northern pocket gophers (*Thomomys talpoides*) to harvester ants (*Pogonomyrmex owyheei*) and Burrowing Owls (*Athene cunicularia*). Two species of ground squirrels are found on the Hanford Site: the Washington ground squirrel (*Urocitellus washingtoni*), which occurs north and east of the Columbia River (outside of the study area), and the Townsend's ground squirrel (*Urocitellus townsendii*), which occurs south and west of the Columbia River. Habitat characteristics selected by the Townsend's ground squirrel and the Burrowing Owl were selected to represent habitat requirements for burrowing animals and associated species on the Hanford Site.

2.4.4.1 Townsend's Ground Squirrel. Townsend's ground squirrels are important to the shrub-steppe ecosystem for many reasons. They serve as a food source for mammals (e.g., badgers and coyotes [*Canis latrans*]) and fall prey to predatory birds (e.g., hawks, falcons, and owls). Ground squirrels are an important food item for Ferruginous Hawks (*Buteo regalis*), a Washington State threatened raptor species, in many portions of their range (Fitzner et al. 1981). The ground squirrel diet consists of a variety of foods including seeds, which contributes to native plant seed dispersal. The burrows that ground squirrels dig help to aerate the soil and provide burrows for other species including Burrowing Owls, which are a federal species of concern (Sato 2012).

During much of the year, ground squirrels are underground for hibernation and estivation. The ground squirrels' lifecycle consists of several seasonal components. During mid- to late January, squirrels emerge from their burrows after hibernation. They spend the next month breeding followed by gestation and rearing of young. The young become active outside the burrow by mid-April. Ground squirrels become dormant again starting in late May to late June, entering a type of torpor called estivation that is used to avoid the hot and dry portion of the year (WDFW 2012). After estivation, ground squirrels emerge and spend late September and October foraging in preparation for hibernation.

Ground squirrels require soils that are easily excavated yet provide stability for their burrow networks. Soil texture strongly influences the ability of a burrow to remain stable, as well as the nutrient-holding ability of a soil, the amount of water the soil can store, the amount of this water that is available to plants, how fast water moves through the soil, and many other properties. Soil depth is also important for ground squirrels as deeper burrow networks can provide insulation from extreme temperatures. Regional studies have shown that ground squirrels may select sites based on soil characteristics more than other variables and have a preference for deep silt loam soils (Greene 1999).

Townsend's ground squirrels consume green vegetation during their active period from early winter into late spring, then shift their focus to the seeds of grasses and forbs to prepare for estivation (Yensen et al. 1992). A study on the diets of Townsend's ground squirrels on the Arid Lands Ecology Reserve showed that their intake was primarily Sandberg's bluegrass followed by a variety of forbs including western tansymustard, lupine, and long-leaf phlox (Rogers and Gano 1980). In areas where fire destroyed the native shrub and bunchgrasses, cheatgrass can be an important food source; however, wild fluctuations in productivity due to year-to-year changes in precipitation can cause populations in these areas to be much less stable (Yensen et al. 1992). While shrubs could potentially offer cover and some level of burrow stability, ground squirrels can detect predators at a greater distance in areas with little to no shrub canopy. It is believed that line-of-sight availability prevails in site selection (Sharpe and Van Horne 1998).

2.4.4.2 Burrowing Owl. Burrowing Owls are small, ground-dwelling owls. Their total length averages between 19 to 25 cm (7.5 to 9.8 in.) with males being slight larger than females in some measurement. Sexes are not reliably distinguishable by plumage, although during breeding season females are generally darker than males (Pyle 1997). Within its fairly broad range across western North America, Burrowing Owls occur in grasslands, steppes, deserts, prairies and agricultural lands. Burrowing Owls are opportunistic feeders, primarily taking insects and small mammals, but will pursue any potential prey they can physically handle including birds, ground squirrels, frogs, snakes, salamanders, earthworms, bats, scorpions, and caterpillars. It is not clear which member of a breeding pair selects the burrow, but it is likely the males. Burrow hunting was observed at dusk and assumed to occur at night (Thomsen 1971). A majority of Burrowing Owl nests consisted of burrows that were dug by animals such as ground squirrels, badgers, and marmots. Burrowing Owls can excavate holes where burrowing animals are absent (Thomsen 1971) but rarely do so. When mammal burrows are not available, Burrowing Owls may use anthropogenic materials such as underground pipes, building foundations, and irrigation weir boxes (HNF-59375). Burrowing Owls will readily use and breed in artificial burrows installed in their breeding habitat.

The Burrowing Owl is classified as a WDFW Candidate Species (WDFW 2019). Burrowing Owls are protected under the *Migratory Bird Treaty Act*; this status provides protection to eggs, nests, and birds. Conway and Pardieck (2006) suggested that the population decline of Burrowing Owls in Washington State may be due to reduced numbers of ground squirrels, yellow-bellied marmots (Marmota flaviventris), and badgers that create burrows used by the owls. Loss of habitat to development has also negatively affected the species. Most individuals that nest on the Hanford Site migrate south for the winter and return in the spring (Conway et al. 2002). Because the owls migrate to and nest on the Hanford Site and the Hanford Reach National Monument, the status of Burrowing Owl populations and the locations of burrows are of concern locally to DOE-RL and the USFWS.

The Hanford Site is one of a number of significant tracts of critical shrub-steppe habitat for the Columbia Basin Ecoregion including the Yakima Training Center, Yakama Tribal lands, and WDFW areas. The Hanford Site is situated at the center of the predicted distribution of Burrowing Owls in Washington State (Washington Gap Analysis 1997) and is an important area for the conservation of Burrowing Owls.

2.4.5 Nested Habitats and Species

Additional species, communities, or habitats that were considered to be nested under the four focal habitats and species are listed in Table 1. As the process continues other decisions may lead the researchers to reevaluate and adjust the lists.

Table 1. Preliminary Lists of Species and Communities that the Researchers Considered Could be Nested Under the Four Focal Habitats and Species Selected.

Shrub-steppe	Grassland	Dunes	Burrowing Animals
• Native forbs • Pollinators • Endemic species • Rare plants • Mature (climax) shrub-steppe • Sagebrush • Obligatory and facultative sagebrush species (sage sparrow, birds) • Jackrabbits • Sage-Grouse • Unique, critical habitat elements	• Native forbs • Pollinators • Endemic species • Rare plants • Unique, critical habitat elements	• Native forbs • Pollinators • Endemic species • Rare plants • Unique, critical habitat elements	• Townsend's ground squirrel • Burrowing Owls • Ferruginous Hawk • Other Birds of prey • Badger

2.5 VIABILITY ASSESSMENT - KEY ECOLOGICAL ATTRIBUTES, INDICATORS AND RATINGS

In accordance with the approach taken by the ALI (ALI 2014), the EM Team, with input from regional biological experts from USFWS and WDFW, developed a viability assessment for the four focal habitats and species. The intent of the viability assessment is to organize current understanding and knowledge of each habitat or species in a way that evaluates how to know whether that habitat has ecological integrity or the species is viable. Viability, or ecological integrity, quantifies whether the habitat or species is resistant to change in its structure or composition in the face of external stresses or resilient in light of those stresses — that is, able to recover from occasional severe stress (FOS 2009).

The viability assessment for each focal habitat and species was carried out through the following three sequential steps in a facilitated workshop, with additional follow up by the EM Team.

- STEP 1. The EM Team collaborated with other biological experts with land management agencies in the surrounding area to identify and develop key ecological attributes (KEAs) for each focal habitat or species, and identified the indicators that would be used to measure each attribute. The guidance provided under the Open Standards methodology is that key ecological attributes should identify aspects of a habitat's or species' biology or ecology that, if present, define a healthy habitat or species or, if missing or altered, would lead to the loss or extreme degradation of that habitat or species over time.

EM Team members considered key ecological attributes of size, condition, and landscape context for each focal habitat and species. Resources provided included examples of key ecological attributes and indicators, including those developed by the ALI (http://aridlandsinitiative.org/our-projects/the-science/, under *Assessing Ecosystem Viability*) and a preliminary list that the EM Team had compiled as they began preparing for the habitat assessment and prioritization.

- STEP 2. The EM Team then identified indicators that would be used to assess the quality of each key ecological attribute. One or more indicators are necessary to quantify each key ecological attribute. Indicators are measurable aspects of the key ecological attribute that provide information on its status.

These are the metrics that can be measured and will allow the EM Team to determine the condition of each attribute for particular habitat patches or species populations.

- STEP 3. In order for the indicator values to be compatible with the Marxan analysis they must be categorized using a rating system, the values of which were determined by the EM Team. The ratings allow the investigators to interpret specific indicator values in light of the overall understanding of the thresholds that determine what condition an attribute is in and the habitat or species it is associated with. At its most detailed, the viability assessment developed following the Open Standards methodology would define thresholds that distinguish Poor, Fair, Good, and Very Good categories for each attribute, as measured with its associated indicator. The attribute is considered to be in the Good to Very Good range when the indicator is within an acceptable range of variation, which is defined in the viability assessment. If the attribute is in an ecologically desirable status and requires little intervention for maintenance, the attribute would be classified as Very Good. Attributes within an acceptable range but missing desirable indicators or requiring maintenance would be classified as Good. Similarly, Fair and Poor categories indicate the attribute is outside its acceptable range of variation and differ in whether intervention is likely to improve it to within this range (Fair category) or not (Poor category).

An initial draft of the viability assessment for shrub-steppe, grasslands, dunes, and burrowing animals was developed in the facilitated session. The EM Team then reviewed and improved the viability assessment in subsequent meetings, filling in any critical gaps and evaluating whether the resulting sets of attributes, indicators, and ratings effectively and efficiently captured whether these four focal habitats and species were in good condition at the Hanford Site (Appendix A). The researchers also evaluated what attribute-indicator pairs they already had data available for and which would require further data collection.

Marxan requires inputs of spatially explicit, digital layers that represent each key ecological attribute-indicator pair. These input layers will each represent a Marxan target; that is, a feature for which the EM Team will define a goal to be achieved. The team, therefore, crosswalked the key ecological attributes and indicators defined in the viability assessment for the four focal habitats and species with existing data for the Hanford Site. Based on this crosswalk, the investigators categorized the key ecological attribute-indicator pairs into the following three classes:

- Key ecological attribute-indicator pairs for which they **already have all the information they need** as inputs to Marxan (green cells in Appendix B).

- Key ecological attribute-indicator pairs for which they **have some information but need to collect more data** (yellow cells in Appendix B).

- Key ecological attribute-indicator pairs for which they **have no information** and can, therefore, not be used currently as input to Marxan (red cells in Appendix B). Depending on the ability to collect these data across the whole Hanford Site through a Rapid Assessment and on whether other indicators provide some redundancy relative to these, the EM Team will decide whether to include this attribute-indicator pair in the Marxan analysis.

As the researchers moved forward from the workshops and developed the input layers (Section 3.2) for analysis, the indicators and ratings required slight modification to fit the data that was available. After the workshops and modifications, 11 KEAs were identified for quality focal habitats and species (Table 2). The EM Team used 21 indicators to represent these 11 KEAs in the analysis (Table 2). The team then assigned a rating to each of these indicators as described in Step 3 above. This rating of the KEA indicator becomes a Marxan target for use in the remainder of the analysis. The viability assessment, including the ratings for each KEA/indicator combination, is displayed in Appendix B.

Table 2. Summary of the Focal Habitats or Species Key Ecological Attributes and their Indicators.

Focal Habitat or Species and KEA	Indicator
Shared Attributes	
Fire Regime	Low Freq. Fire Regime (Shrub and Dunes)
Fire Regime	High Freq. Fire Regime (Grasslands)
Critical Habitat or Species	Presence of Critical, Unique Habitats or Species
Vegetative Composition	Density of Noxious Weeds
Shrub-steppe	
Absolute Patch Size	Absolute Shrub Patch Size (Area)
Connectivity	Connectivity/Proximity to Other Shrub Patches
Vegetative Composition	Type of Vegetation Cover in Shrub-steppe
Native Shrub Cover	Percent of Native Shrub Cover (High Freq.)
Wildlife Community	Sagebrush Obligate Wildlife Presence
Dunes	
Soil Type	Presence of Sandy Soil
Absolute Patch Size	Acreage of Open Sand (Area)
Connectivity	Connectivity/Proximity to Other Dune Patches
Vegetative Composition	Type of Vegetation Cover in Dunes
Ecosystem Intactness	Rare Dune Plant Species Presence
Grasslands	
Absolute Patch Size	Absolute Grassland Patch Size (Area)
Connectivity	Connectivity/Proximity to Other Grassland Patches
Vegetative Composition	Type of Vegetation Cover in Grasslands
Native Shrub Cover	Percent of Native Shrub Cover (Low Freq.)
Burrowing Animals	
Ground Squirrel Habitat	Ground Squirrel Habitat Model Areas
Burrowing Owl Habitat	Burrowing Owl Habitat Model Areas
Connectivity	Connectivity Among Ground Squirrel Colonies

2.6 GOAL LEVELS

After Marxan targets are defined, users must assign a relative level or goal for each target. The goal for each target is the desired percentage of the target’s area that should be included in the Marxan conservation solution. When possible, target levels should be based on scientific data to maintain the integrity of ecosystems; however, economic concerns and political goals can be considered. Initially, the investigators reviewed and adopted an approach similar to the ALI (ALI 2014). ALI assigned each focal habitat or species a priority rank rather than an absolute goal level, and the Marxan targets that represented each ALI target nested in those focal habitats were assigned the same rank. The ALI referenced work caveated their choice, “given the uncertainty and data availability on this issue” when making the decision of ranking ALI targets over assigning individual levels to Marxan targets. The priorities of one, two, or three, with one being the highest conservation value and three the lowest, were assigned to each of the focal habitats or species. These priority rankings would be assigned a flat goal level, the Hanford Site analysis started by testing the “high” target values used in the ALI scope (ALI 2014) and further tested under the lower “medium” goals.

Table 3. Original Priority Rankings for Focal Habitats and Species and Assigned Goals Based on ALI.

		Target Proportions Based on ALI Goal Levels	
Focal Habitat or Species	**Priority Ranking**	**High Goal Levels**	**Medium Goal Levels**
Shrub-steppe	1	0.7	0.55
Dunes	1	0.7	0.55
Grasslands	3	0.4	0.25
Burrowing Animals	2	0.55	0.4

The EM Team ranked the habitat and focal species and assigned the correlating ALI high and medium values (Table 3). Early Marxan runs were tested using these target levels without a constraint layer to visualize the potential outputs of this approach. In both high and medium Marxan target levels it was apparent to the team that solutions were being forced to areas where staff familiar with the Hanford Site would suggest a lower conservation value. Cursory investigations by the researchers determined that some Marxan targets, especially targets with large spatial inputs that have a lower role in determining an overall focal habitat or species integrity, were given goal levels equal to other spatial inputs with high importance. This resulted in spatial solutions prioritizing large areas of lesser-valued Marxan targets. The size of the geographic scope and the discrete nature and certainty of the data detail used in the Hanford Site inputs pushed this analysis outside the caveat the ALI imposed in its use of the priority ranking system. The EM Team altered the goal setting approach to calculating a goal level for each Marxan target individually.

The EM Team used the “expert workshops” (Ardon et al. 2010) to evaluate Marxan targets. Marxan targets of a single focal habitat or species were assessed during four separate workshops. Many experts are not comfortable with use of numerical target values, and/or tend to overvalue their own particular areas of research (Ardon et al. 2010). Even within the small EM Team these biases could be seen. Workshop leaders ensured that there was thorough discussion and near consensus reached on each Marxan target before continuing. To further these workshop discussions, small simple runs of Marxan were performed with each Marxan target changed to show experts how their decisions altered the solutions. If included in the analysis, Marxan target levels were assigned goal levels between 10% to 70%. The goal levels did not exceed 70% to avoid constraints on Marxan, as the Marxan algorithm has few options and cannot optimize efficiently when goal levels are excessively high (ALI 2014). The final Marxan target goal levels determined during these workshops are shown in Table 4.

Table 4. Summary of Marxan Target Goal Levels, Proportion of Area of a Marxan Target Desired in the Solution, Developed From Expert Workshops.

Key Ecological Attribute	Marxan Target Goal Levels: Proportion of Marxan Target Condition Very Good	Marxan Target Goal Levels: Proportion of Marxan Target Condition Good
Shared Attributes		
Low Freq. Fire Regime (Shrub-steppe)	0.1	N/A[a]
High Freq. Fire Regime (Grasslands)	0.55	0.4
Presence of Critical or Unique Habitats (Shrub-steppe and Grasslands)	0.7	0.5
Density of Noxious Weeds (Shrub-steppe, Grasslands, and Dunes)	0.1	0.1
Shrub-steppe		
Absolute Shrub Patch Size (Area)	0.7	0.5
Connectivity/Proximity to other patches	0.7	0.5
Type of Vegetation Cover	0.7	0.5
Percent of Native Shrub Cover (High Freq.)	0.7	0.3
Sagebrush Obligate Wildlife Presence	0.7	0.5
Dunes		
Presence of Sandy Soil	N/A[b]	0.25
Acreage of Open Sand	0.4	0.25
Connectivity/Proximity to other patches	0.55	0.4
Type of Vegetation Cover	0.7	0.7
Rare Dune Plant Species Presence	0.7	0.7
Grasslands		
Absolute Grassland Patch Size (Area)	0.7	0.55
Connectivity/Proximity to other patches	0.7	0.55
Type of Vegetation Cover	0.7	0.55
Percent of Native Shrub Cover (Low Freq.)	0.55	0.4
Burrowing Animals		
Ground Squirrel Habitat Model Areas	0.7	0.5
Burrowing Owl Habitat Model Areas	0.5	0.5
Connectivity Among Ground Squirrel Colonies	0.7	0.7

[a] To properly assess shrub areas the decision was made to only include the Very Good condition of the low frequency fire layer
[b] Sand can only be present or absent in the development of this layer
N/A = Not Applicable

2.7 CONSTRAINT LAYER

Another requirement of a Marxan analysis is the development of a single input layer that represents how all constraints vary across the landscape. Constraints (also called costs) can be factors that limit the ability of the habitat to function as normal (e.g., physical barriers like roads) or factors that limit the abilities to intervene or manage biological resources (e.g., contamination or zoned areas). Depending on the particular application that Marxan is being used for, the constraints that this input layer represents can be based on physical or biological limitations, management guidelines, or rules and policies governing the future use of the land.

The EM Team identified 11 categories and 73 sub-categories of constraints on the study area including areas under industrial use or highly disturbed areas zoned for development under the CLUP, National Historical Park sites, waste sites, utility towers and lines, roads, railroads, structures, fences, wells, and borrow pits (Appendix C). The team ranked (scale: 0 to 10) the sub-categories of constraints by their ability to limit the habitat to function (higher numbers being more limiting). As an example, a four-lane highway would be more limiting to habitat functionality than a one-lane dirt road, and the highway would have a greater cost. All constraint features were mapped across the study area as polygons. Some features (i.e., utility towers and lines, primary and secondary roads, railroads, fences, and wells) required buffering to better characterize area of disturbance surrounding them (Appendix C). The team calculated a cost for each planning unit by multiplying the area covered by each constraint within the planning unit by its ranking, adding them together and dividing by the planning unit area.

2.8 CALIBRATING MARXAN

Upon agreement of the inputs and Marxan target goals, Marxan should be calibrated by the user to ensure feasible solutions are being produced. Calibration is performed to ensure that Marxan-produced solutions are optimized or close to the lowest cost (Ardon et al. 2010). Values within the function that typically require calibration are: the SPF, BLM, number of iterations, and the constraint layer range (effect). Marxan runs with goals invoked by this study successfully met the targets in most cases over a variety of runs, iterations, and BLM manipulations. Therefore, performing a calibration for SPF to apply to unmet targets would have little bearing on the solutions. It was selected that a flat SPF of 1 for all Marxan targets was applied. The running of Marxan to create data required calibrations for the BLM and the number iterations required were performed within the Zonae Cogito software (Watts et al. 2011).

2.8.1 Boundary Length Modifier

The BLM is used to improve the spatial clustering and compactness of the solutions (Ardon 2010). If a BLM is set to 0, then solutions will be formed with no regard to their overall pattern and are typically dispersed and result in a fragmented solution. As BLM is increased, Marxan solutions show more connection and clumping as the algorithm begins to favor the selection of units adjacent to already selected units over isolated units that otherwise achieve target goals (ALI 2014). Managing compliance and conservation of small, dispersed and fragmented habitats can be a difficult and undesirable task. Therefore, achieving a level of clustering that maximizes the trade-off of minimizing the boundary length of a solution while minimizing the overall solution cost is the desired goal when calibrating a BLM.

The EM Team adjusted the value by running the BLM calibration in Zonae Cogito (Segan et al. 2011). Initial calibrations of BLM were performed from BLM values of 0 to 5, refined and run from 0 to 2, and then further refined to calibration settings of 20 points (BLM Values) between 0.1 and 0.95 BLM values over 100 runs with 10,000,000 iterations each run. The 20 BLM values were plotted on a graph consisting of total cost on the x-axis and the total boundary length on the y-axis (Figure 4). Per Ardon et al. (2010) and ALI (2014), the point on the curve at which there is a relatively large decrease in total boundary length (clumping) is associated with a relatively small increase cost that can be considered the desired BLM value. Upon review of the BLM Calibration Curve graph (Figure 4), the EM Team selected a BLM value of 0.46.

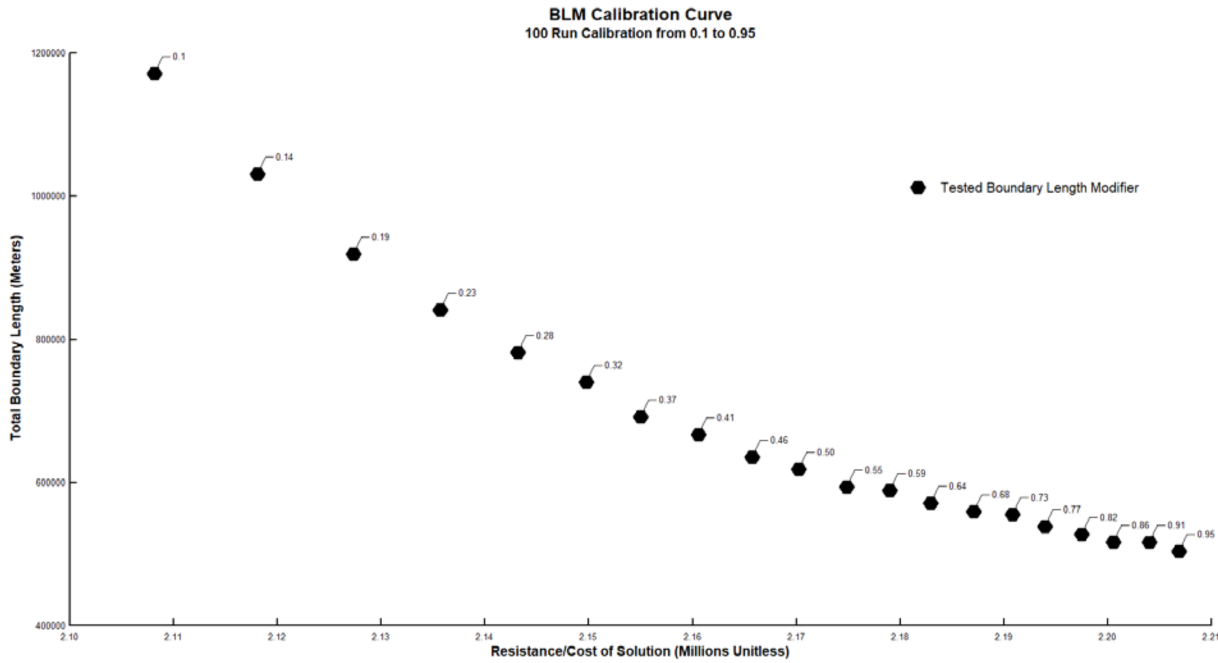

Figure 4. Graph Used in the Calibration of the Boundary Length Modifier to Locate the Optimal Effeciency of Boundary Length Reduction Versus Resistance/Cost Increase.

2.8.2 Number of Iterations

The simulated annealing solver in Marxan requires a large number of iterations to find quality solutions (Ardon et al. 2010). Marxan analysis for this study was performed with 100 runs. Each run will produce its own unique solution, increasing the number of iterations per run will allow Marxan to spend more time converging towards similar solutions across those runs. ALI (2014) calibrated by running eight iteration versions of their analysis differing only in the number of iterations, calculated the range of scores over the 100 runs, and divided the range by the mean to determine a variance of solutions scores. Solution time increases linearly with the number of iterations so there are practical limits on the number of iterations that can be considered reasonable. At some point it becomes far more useful to have an adequate number of restarts (new runs) than to try to ensure the efficiency of an entire solution set (Ardon et al. 2010). This study followed a similar approach to the ALI (2014), running the analysis 100 runs with 11 different iteration versions of 1 million, 5 million, and then an addition of 5 million iterations through 50 million iterations.

When all solutions were complete, the minimum score, maximum score, and mean score were determined for each iteration version (Table 5). The range between the minimum and the maximum was calculated. The range value was divided by the mean score value to produce a range/mean percentage. The length of processing time was also pulled from the Marxan output log, if needed, to evaluate an unreasonable calculation time of iteration version (Table 5). The number of iterations (x-axis) was graphed against the range/mean (y-axis) percentages. This provides a visual representation for iteration versions as the solutions work towards convergence (low range/mean) (Figure 5). As iterations are increased, range/mean percentages begins to level off. As this leveling occurs, increasing the number of iterations slows on the efficient reductions of score or range between the minimum and maximum scores. Performing an analysis of 100 runs at 25 million iterations produces a range/mean of 0.94%. Doubling the calculation time at 50 million iterations produces a range/mean of 0.72% and failing to lower the minimum score by even 1% when compared to 25 million. Using this analysis, the EM Team chose 25 million iterations per run, producing less than a 1% difference in solution scores over the 100 runs at the most efficient processing time.

Table 5. Marxan Iteration Calibration. Each Row consists of 100 Runs on Marxan Targets with BLM of 0.46.

Number of Iterations	Min Score	Max Score	Mean Score	Range	Range/Mean	Processing Time
1 Million Iterations	2,600,927	2,703,699	2,642,570	102,772	3.89%	3 mins 14 secs
5 Million Iterations	2,476,404	2,533,812	2,506,053	57,408	2.29%	8 mins and 2 secs
10 Million Iterations	2,441,652	2,472,545	2,456,798	30,893	1.26%	15 mins and 36 secs
15 Million Iterations	2,423,838	2,458,377	2,436,239	34,539	1.42%	24 mins and 46 secs
20 Million Iterations	2,407,097	2,434,778	2,422,415	27,681	1.14%	32 mins and 3 secs
25 Million Iterations	2,405,428	2,428,104	2,414,395	22,676	0.94%	37 mins and 54 secs
30 Million Iterations	2,399,270	2,420,708	2,407,470	21,438	0.89%	48 mins and 26 secs
35 Million Iterations	2,392,070	2,412,496	2,402,824	20,426	0.85%	57 mins and 20 secs
40 Million Iterations	2,392,611	2,413,178	2,399,660	20,567	0.86%	1 hour , 3 mins and 16 secs
45 Million Iterations	2,387,645	2,406,238	2,396,253	18,593	0.78%	1 hour , 0 mins and 6 secs
50 Million Iterations	2,384,532	2,401,786	2,393,622	17,254	0.72%	1 hour , 8 mins and 33 secs

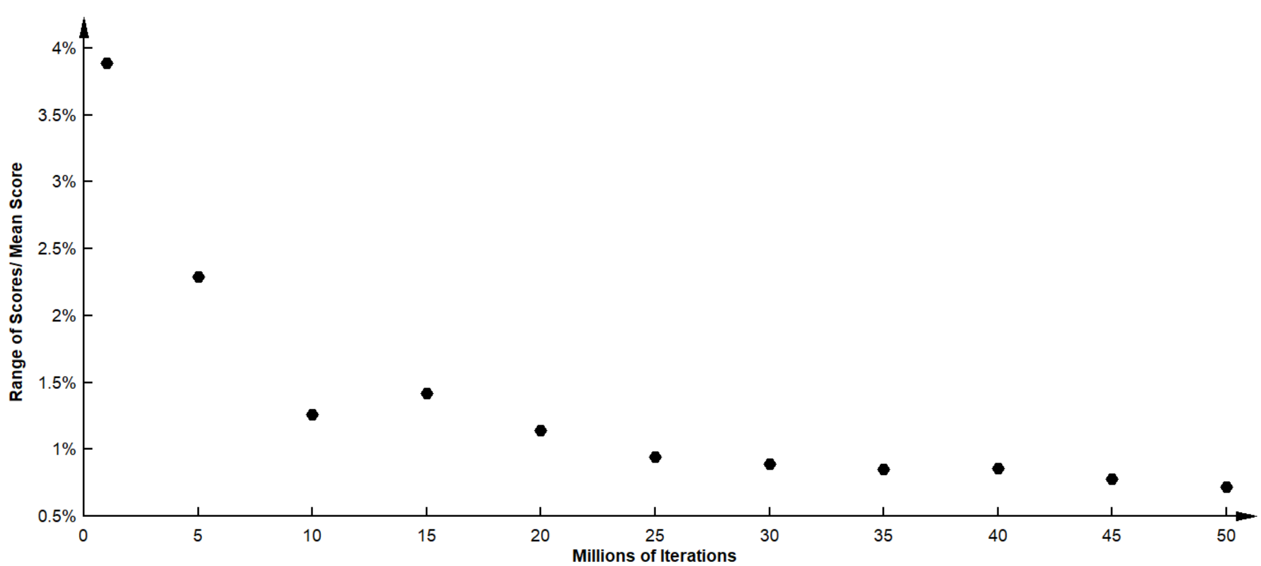

Figure 5. Calibration of the Number of Iterations Performed in Analysis during Each Marxan Run.

2.8.3 Range of Constraint Layer

One of the conditions for obtaining meaningful results from a Marxan run is to ensure that the terms (constraint [cost] layer, boundary length, and species penalty factor) of the objective function are of the same magnitude to avoid one of the terms unduly influencing the outcome of the solution. In the case of the Hanford Site analysis, the boundary length was measured to be 88.25 and because all of the targets were met, the SPF was set at 1. In order to scale the constraint layer to the magnitude of the boundary length, the planning unit costs were multiplied by 100. Another 100 (unitless) were added to each of the planning units to make the base planning unit cost 100.

3.0 RESULTS AND DISCUSSION

3.1 MARXAN ANALYSIS SETTINGS

Calibrations of the constants in the objective function are provided in Table 6. Several Marxan analyses were conducted with 10 runs to allow the EM Team to visualize potential solutions and verify inputs were correct. After initial runs of the Marxan analysis, it was determined that a crucial habitat recognized by Washington State, referred to as the Hanford Black Sand Dunes near the 100-F Area, was not selected in any solutions. The small number of planning units that incorporate the black sands were locked into the solution and the Marxan analysis with calibrated and determined goal values were run.

Table 6. Settings Used to Complete Identifying Priority Conservation Areas Analyses on DOE-RL-Managed Portion of the Hanford Site.

Marxan Setting	Setting Value
Marxan Target Goals	Table 4
Number of Marxan Runs Performed	100
Species Penalty Factor	1
Boundary Length Modifier (BLM)	0.46
Number of Iterations per Run	25 Million

3.2 MARXAN TARGET SPATIAL INPUTS

The viability assessment for the focal habitats and species identified 23 key ecological attribute-indicator pairings (shrub-steppe [8], grasslands [7], dunes [5], and burrowing animals [3]) (Appendix B). Two pairings (critical/unique habitats and lack of noxious weeds) emerged as important to more than one of the focal habitats and species (referred to as shared key ecological attribute-indicator pairings) and two other pairings (fire regime and native shrub cover) appeared as important to shrub-steppe and grasslands but in reverse order in their indicator ratings. Using the shared key ecological attribute-indicator pairings only once, 21 key ecological attribute-indicator pairs were employed in the Marxan analysis.

3.2.1 Shared Key Ecological Attribute-Indicator Pairings

3.2.1.1 Presence of Critical or Unique Habitat Features (Shared by Shrub-steppe and Grasslands). Some habitat features have a large degree of importance to habitat ecological integrity despite a small footprint. These features may contain rare or endemic species, accommodate species during critical life stages, or provide scarce resources. Critical or unique habitat features identified on the study area that provide high value to shrub-steppe and grassland habitats include springs, vernal pools, seasonally wet areas, sloughs, ponds, riparian areas, talus slopes-cliffs-lithosols, bat roosts, rookeries, snake hibernacula, and federal threatened and endangered species (Umtanum desert buckwheat). In this study design, these features were mapped and buffered by 100 m (328 ft). A map layer was created showing the number of critical or unique habitat features found within polygons across the study area (Map 1 – Appendix D). The number of critical or unique habitat features per polygon ranged from 0 to 3.

3.2.1.2 Lack of Noxious Weeds (Shared by Shrub-steppe, Grasslands, and Dunes). Invasive and noxious non-native plant species can pose a serious risk to the ecological integrity of a habitat. Noxious weeds can outcompete and reduce the abundance or survival of native plants and wildlife and significantly change the fire regime, nutrient cycling, hydrology, and energy budgets in native ecosystems (Randall 1996; Brooks and Pyke 2001; Mack et al. 2000; Evans et al. 2003; USFWS 2008). Weed surveys were conducted on the study area in 2014 by MSA (R. Roos, personal communication). Plots of 50-ft (15.2 m) diameter circles were surveyed along transects throughout the study area. The survey plots were inspected for 14 weed species including rush skeletonweed (*Chondrilla juncea*), babysbreath (*Gypsophila paniculata*), spiny cocklebur (*Xanthium spinosum*), diffuse knapweed (*Centaurea diffusa*), Dalmatian toadflax (*Linaria dalmatica ssp. Dalmatica*), field bindweed (*Convolvulus arvensis*), kochia (*Kochia scoparia*), perennial pepperweed (*Lepidium latifolium*), Russian knapweed (*Acroptilon repens*), saltcedar (*Tamarix ramosissima*), swainsonpea (*Sphaerophysa salsula*), tackweed / puncturevine (*Tribulus terrestris*), yellow starthistle (*Centaurea solstitialis*), and Scotch thistle (*Onopordum acanthium*). In addition, a count of individual weeds (plants/stems) was made for each plot. The count of individual weeds per plot was converted to weeds per hectare. The study area was partitioned into regions based on major roads and geographic features. The number of weeds per hectare was extrapolated to these regions based on the number of weeds per hectare found in survey plots located within those regions. If a region contained no survey data, the average number of weeds per hectare of the surrounding regions was applied to that region. The number of weeds per hectare for each region ranged from 0 to 214.9 (0 to 87 weeds per acre) (Map 2 – Appendix D).

3.2.2 Shrub-steppe Key Ecological Attribute-Indicator Pairs

3.2.2.1 Fire Regime (Frequency of Fires). The frequency of fires in an area is an important key ecological attribute for determining ecological integrity of shrub-steppe habitats. Fire has major impacts on shrub-steppe habitats. Big sagebrush, the predominant shrub in shrub-steppe habitats on the Hanford Site, lacks the physical adaptations to survive and recolonize after intense or repeated fires. Areas with lower frequency of fire are more suitable for conservation of shrub-steppe habitat. Map layers depicting the location of fires on the study area from 1974 to 2017 were used to create a single map layer representing fire frequencies across the site during that period (Map 3 – Appendix D). The frequency of fires for areas across the study area for the 44-year period (1974 to 2017) ranged from 0 to 6 fires.

3.2.2.2 Wildlife Community (Presence of Black-tailed Jackrabbits). A good indicator of function and ecological integrity of shrub-steppe habitats is the presence of sagebrush obligate wildlife species. On the study area, some of these species include Sagebrush Sparrow (*Artemisiospiza nevadensis*), Sage Thrasher (*Oreoscoptes montanus*), Loggerhead Shrike (*Lanius ludovicianus*), Brewer's Sparrow (*Spizella breweri*), and black-tailed jackrabbits (*Lepus californicus*). Substantial data on the distribution of black-tailed jackrabbits have been collected on the study area as part of work conducted by MSA (HNF-54234, HNF-56710, HNF-59398). The current study design used these jackrabbit specific data as a proxy for other sagebrush obligate species.

MSA deployed trail cameras on the study area from 2013 to 2015 to survey for jackrabbits. In prior studies, reported black-tailed jackrabbit home range size have varied from approximately 0.02 to 3 km^2 (0.01 to 1.16 mi^2) in other settings (Lechleitner 1958, French et al. 1965, Rusch 1965, Smith 1990) and were less than 0.5 km^2 (less than 0.19 mi^2) on the Hanford Site (Major 1993). The study area was divided into a mesh of hexagonal survey areas measuring 1 km^2 (0.39 mi^2), keeping in mind that the typical jackrabbit home range is usually less than 1 km^2 (less than 0.39 mi^2). The 1-km^2 (0.39 mi^2) mesh size was designed such that a jackrabbit observed in one hexagon would be less likely to be observed in an adjacent hexagon. In addition to trail camera data, MSA recorded locations of incidental observations of jackrabbits and observations of roadkill during the same time period.

For the Marxan analysis, the EM Team used jackrabbit camera hexagons where jackrabbits were observed and added hexagons where jackrabbits were incidentally seen and where roadkill were found. A new layer was created showing a count of hexagons where jackrabbits were observed (the center hexagon plus the six surrounding hexagons) (Map 4 – Appendix D).

3.2.2.3 Native Shrub Cover (Percent Cover). A native shrub cover map was created and used in the Marxan analysis (Map 5 – Appendix D). The most recent (2015) vegetation map for the study area (HNF-61417) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas. A new map layer was generated by ranking vegetation cover type polygons as follows: Very Good (greater than 3% cover), Good (present to approximately 3% cover), Fair (Irregular or patchy shrub distribution within a polygon), and Poor (no shrubs) (Table 7).

3.2.2.4 Vegetation Cover Types. A vegetation cover type map was created based on resource priority levels outlined in the BRMP. The BRMP ranks all species and habitats on the Hanford Site into resource priority levels that range from Level 5 (highest priority) to Level 0 (lowest priority). The most recent (2015) vegetation map for the study area (HNF-61417) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas. Vegetation was ranked as follows: Very Good included the Washington Natural Heritage Program (WNHP) Plant Community Element Occurrences (BRMP Level 5) and BRMP Level 4 Vegetation Cover Types, Good included BRMP Level 3 Vegetation Cover Types, Fair included BRMP Level 2 Vegetation Cover Types, and Poor included BRMP Level 1 Vegetation Cover Types and BRMP Level 0 Resources (Map 6 – Appendix D). The following lists represent plant community element occurrences that can be found on the study area, vegetation cover types that occur within each BRMP level, and BRMP Level 0 resources (Table 8).

3.2.2.5 Connectivity/Proximity to Other Shrub Patches. The connectivity of habitat is essential for the movement of organisms and their genes across the landscape. Loss of connectivity, which occurs following fragmentation and habitat loss, can diminish the extent and quality of available habitat and the movement of organisms to and between habitats (dispersal and seasonal migration). This loss can have destructive consequences for populations and species including lower carrying capacity, population declines, loss of genetic variation, and eventually species extinction (Rudnick et al. 2012). To create a measure of connectivity/proximity of shrub-steppe habitat at a local scale, all shrub patches (from the absolute shrub patch size layer) greater than 200 ha (494.2 ac) on the study area were selected and buffered with multi-rings in 200-m (656-ft) increments. This layer depicts the distance (to the nearest 200 m [656 ft]) from any location on the study area to the closest large shrub patch (Map 7 – Appendix D).

Table 7. Ranking of Native Shrub Cover Based on Vegetation Cover Types used in the Marxan Analysis

Native Shrub Cover Rankings

Very Good

- Big sagebrush(Bitterbrush)/Bunchgrasses
- Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
- Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
- Big sagebrush(Half-shrubs)/Bunchgrasses
- Big sagebrush(Half-shrubs)/Sandberg bluegrass-Cheatgrass
- Big sagebrush/Bunchgrasses
- Big sagebrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Spiny hopsage]/Bunchgrasses
- Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
- Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
- Big sagebrush-Bitterbrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Bitterbrush/Bunchgrasses
- Bitterbrush/Sandberg bluegrass-Cheatgrass

Good

- (Bitterbrush)/Bunchgrasses
- (Bitterbrush)/Sandberg bluegrass-Cheatgrass
- (Bitterbrush)[Snow buckwheat]/Bunchgrasses
- (Bitterbrush)[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Rabbitbrush/Bunchgrasses
- Rabbitbrush/Sandberg bluegrass-Cheatgrass

Fair

- (Half-shrubs)/Bunchgrasses
- (Half-shrubs)/Sandberg bluegrass-Cheatgrass
- [Snow buckwheat]/Bunchgrasses
- [Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- [Stiff sagebrush](Half-shrubs)/Bunchgrasses

Poor

- Bunchgrasses
- Sandberg bluegrass-Cheatgrass
- Non veg
- Other

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

Table 8. Ranking of Vegetation Cover Types used in the Marxan Analysis. (2 Pages)

Vegetation Cover Type Rankings

Very Good

Washington State Plant Community Element Occurrences [BRMP Level 5]

- Big sagebrush-Spiny hopsage/Sandberg bluegrass
- Big sagebrush/Bluebunch wheatgrass

Table 8. Ranking of Vegetation Cover Types used in the Marxan Analysis. (2 Pages)

Vegetation Cover Type Rankings

Very Good

Washington State Plant Community Element Occurrences [BRMP Level 5]

- Big sagebrush/Sandberg bluegrass
- Bitterbrush/Indian ricegrass sand dune complex
- Bitterbrush/Needle-and-thread
- Bitterbush/ Indian ricegrass sand dune complex
- Stiff sagebrush/Sandberg bluegrass
- Threetip sagebrush/Sandberg bluegrass
- Winterfat/Needle-and-thread - Sandberg bluegrass

BRMP Level 4 Vegetation Cover Types

- [Stiff sagebrush](Half-shrubs)/Bunchgrasses
- Big sagebrush(Bitterbrush)/Bunchgrasses
- Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
- Big sagebrush(Half shrubs)/Bunchgrasses
- Big sagebrush[Spiny hopsage]/Bunchgrasses
- Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
- Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
- Big sagebrush/Bunchgrasses
- Bitterbrush/Bunchgrasses

Good

BRMP Level 3 Vegetation Cover Types

- (Bitterbrush)/Bunchgrasses
- (Bitterbrush)[Snow buckwheat/Bunchgrasses
- (Half-shrubs)/Bunchgrasses
- [Snow buckwheat]/Bunchgrasses
- Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
- Big sagebrush(Half-shrubs)/Sandberg bluegrass-Cheatgrass
- Big sagebrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
- Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush-Bitterbrush[Snow buckwheat]/ Sandberg bluegrass-Cheatgrass
- Bitterbrush/Sandberg bluegrass-Cheatgrass
- Bunchgrasses
- Rabbitbrush/Bunchgrasses

Fair

BRMP Level 2 Vegetation Cover Types

- (Bitterbrush)/Sandberg bluegrass-Cheatgrass
- (Bitterbrush)[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- (Half-shrubs)/Sandberg bluegrass-Cheatgrass
- [Snow buckwheat]/ Sandberg bluegrass-Cheatgrass
- Rabbitbrush/Sandberg bluegrass-Cheatgrass

Poor

BRMP Level 1 Vegetation Cover Types

- Sandberg bluegrass-Cheatgrass

BRMP Level 0 Resources

- Highly disturbed areas (gravel, industrial, non-vegetated)

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

3.2.2.6 Absolute Shrub Patch Size (Area). Larger patches of habitat generally contain more individuals and species than smaller patches. A map layer of absolute shrub patch size was generated from the most recent (2015) vegetation map for the study area (HNF-61417). This map layer was adjusted for fires that occurred after the vegetation map was created (fires between 2015 to 2017) by removing the shrub component in burned areas. Polygons with moderate to dense shrub cover (greater than 3% cover) were selected and exported to a new layer (Map 8 – Appendix D). Vegetation cover types selected for export are shown in Table 9.

The final polygons were buffered by an additional 30 m (98.4 ft) to remove any miniscule voids that do not affect quality. Absolute shrub patch size was rated using the scorecard for Intermountain Basins Big Sagebrush Steppe in the Washington State Department of Fish and Wildlife's report *Ecological Integrity Assessments: Monitoring and Evaluation of Wildlife Areas in Washington* (Schroeder et al. 2011). This rating is based on obligate Sagebrush Sparrow home range size.

Table 9. Vegetation Cover Types with Moderate to Dense Shrub Cover (greater than 3% cover) used to Map Absolute Shrub Patch Size.

Vegetation Cover Types
• Big sagebrush(Bitterbrush)/Bunchgrasses
• Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
• Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
• Big sagebrush(Half-shrubs)/Bunchgrasses
• Big sagebrush(Half-shrubs)/Sandberg bluegrass-Cheatgrass
• Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
• Big sagebrush-Bitterbrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Big sagebrush/Bunchgrasses
• Big sagebrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Spiny hopsage]/Bunchgrasses
• Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
• Bitterbrush/Bunchgrasses
• Bitterbrush/Sandberg bluegrass-Cheatgrass
• Rabbitbrush/Bunchgrasses
• Rabbitbrush/Sandberg bluegrass-Cheatgrass

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

3.2.3 Grasslands Key Ecological Attribute-Indicator Pairs

3.2.3.1 Fire Regime (Frequency of Fires). For grassland habitats, the frequency of fires in an area is also an important key ecological attribute for determining ecological integrity. As described above, map layers depicting the location of fires on the study area from 1974 to 2017 were used to create a map layer representing fire frequencies across the site during that period. Fire can be a significant component in the creation of grassland habitats on the Hanford Site because fire can reduce shrub cover and invigorate the growth of perennial bunchgrasses making them the dominant vegetative layer. Areas with higher frequency of fire are more suitable to conserve grassland habitat (Map 9 – Appendix D). As noted above, the frequency of fires for areas across the study area for the 44-year period (1974 to 2017) ranged from 0 to 6 fires.

3.2.3.2 Absolute Bunchgrass Patch Size (Area). A map layer of absolute bunchgrass patch size was generated from the most recent (2015) vegetation map for the study area (HNF-61417). This map layer was adjusted for fires that occurred after the vegetation map was created (fires between 2015 to 2017) by removing the shrub component in burned areas. Polygons with bunchgrasses and shrub cover less than or equal to 3% were selected and exported to a new layer (Map 10 – Appendix D). Vegetation mapping units selected for export are included in Table 10.

Table 10. Vegetation Cover Types with Bunchgrasses and Shrub Cover Greater than or Equal to 3% used to Map Absolute Shrub Patch Size.

Vegetation Cover Types
• (Bitterbrush)/Bunchgrasses
• (Bitterbrush)[Snow buckwheat]/Bunchgrasses
• (Half-shrubs)/Bunchgrasses
• [Snow buckwheat]/Bunchgrasses
• [Stiff sagebrush](Half-shrubs)/Bunchgrasses
• Bunchgrasses

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

The final polygons were buffered by an additional 30 m (98.4 ft). Absolute bunchgrass patch size was rated using the scorecard for Intermountain Basins Big Sagebrush Steppe in Schroeder et al. (2011). This rating is based on obligate Grasshopper Sparrow (*Ammodramus savannarum*) home range size.

3.2.3.3 Connectivity/Proximity to Other Bunchgrass Patches. To create a measure of connectivity/proximity of grassland habitat at a local scale, all bunchgrass patches (from the absolute bunchgrass patch size layer) greater than 200 ha (494.2 ac) on the study area were selected and buffered with multi-rings in 200-m (656-ft) increments. This layer depicts the distance (to the nearest 200 m [656 ft]) from any location on the study area to the closest large bunchgrass patch (Map 11 – Appendix D).

3.2.3.4 Vegetation Cover Types. A vegetation cover type map was produced to display the ability of the current habitat to function as a native grassland habitat. The most recent (2015) vegetation map for the study area (HNF-61417) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas. Vegetation was ranked as follows: Very Good included vegetation cover types with bunchgrass and little or no shrubs, Good included vegetation cover types with patchy to less than or equal to 3% shrub cover and bunchgrasses, Fair included vegetation cover types with greater than 3% shrub cover and bunchgrass understory, and Poor included vegetation cover types with cheatgrass understory (Map 12 – Appendix D). Table 11 shows the cover types found in each ranking.

3.2.3.5 Native Shrub Cover (Percent Cover). A native shrub cover map was produced for grasslands that was contrary to the native shrub cover map created for shrub-steppe (Map 13 – Appendix D). The most recent (2015) vegetation map for the study area (HNF-61417) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas. A new map layer was created by ranking vegetation cover type polygons as follows: Very Good included bunchgrasses with no shrubs; Good included bunchgrasses with irregular or patchy shrub distribution; Fair included polygons with shrubs present to approximately 3% cover; and Poor included polygons with shrubs greater than 3% cover, polygons with mostly cheatgrass, and highly disturbed areas (Table 12).

Table 11. Ranking of Vegetation Cover Types used in the Marxan Analysis.

Vegetation Cover Type Rankings
Very Good
• (Half-shrubs)/Bunchgrasses
• [Snow buckwheat]/Bunchgrasses
• Bunchgrasses
Good
• (Bitterbrush)/Bunchgrasses
• (Bitterbrush)[Snow buckwheat]/Bunchgrasses
• [Stiff-sagebrush](Half-shrubs)/Bunchgrasses
Fair
• Big sagebrush(Bitterbrush)/Bunchgrasses
• Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
• Big sagebrush(Half-shrubs)/Bunchgrasses
• Big sagebrush/Bunchgrasses
• Big sagebrush[Spiny hopsage]/Bunchgrasses
• Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
• Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
• Bitterbrush/Bunchgrasses
• Rabbitbrush/Bunchgrasses
Poor
• (Bitterbrush)/Sandberg bluegrass-Cheatgrass
• (Bitterbrush)[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• (Half-shrubs)/Sandberg bluegrass-Cheatgrass
• [Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
• Big sagebrush(Half-shrubs)/Sandberg bluegrass-Cheatgrass
• Big sagebrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
• Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush-Bitterbrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Bitterbrush/Sandberg bluegrass-Cheatgrass
• Rabbitbrush/Sandberg bluegrass-Cheatgrass
• Sandberg bluegrass-Cheatgrass
• Non-veg
• Other

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

Table 12. Ranking of Native Shrub Cover Based on Vegetation Cover Types used in the Marxan Analysis.

Native Shrub Cover Rankings
Very Good
• Bunchgrasses
Good
• (Half-shrubs)/Bunchgrasses
• (Half-shrubs)/Sandberg bluegrass-Cheatgrass
• [Snow buckwheat]/Bunchgrasses
• [Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• [Stiff sagebrush](Half-shrubs)/Bunchgrasses
Fair
• (Bitterbrush)/Bunchgrasses
• (Bitterbrush)/Sandberg bluegrass-Cheatgrass
• (Bitterbrush)[Snow buckwheat]/Bunchgrasses
• (Bitterbrush)[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
Poor
• Big sagebrush(Bitterbrush)/Bunchgrasses
• Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
• Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
• Big sagebrush(Half-shrubs)/Bunchgrasses
• Big sagebrush(Half-shrubs)/Sandberg bluegrass-Cheatgrass
• Big sagebrush/Bunchgrasses
• Big sagebrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Spiny hopsage]/Bunchgrasses
• Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
• Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
• Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
• Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
• Big sagebrush-Bitterbrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
• Bitterbrush/Bunchgrasses
• Bitterbrush/Sandberg bluegrass-Cheatgrass
• Rabbitbrush/Bunchgrasses
• Rabbitbrush/Sandberg bluegrass-Cheatgrass
• Sandberg bluegrass-Cheatgrass
• Non veg
• Other

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

3.2.4 Dunes Key Ecological Attribute-Indicator Pairs

3.2.4.1 Indicator Rare Dune Plant Species. Plant species adapted to the dynamic nature of dunes habitat must deal with the harsh conditions of shifting sand, extreme temperature changes, and low moisture content (Hallock et al. 2007). The presence of rare plant species associated with sandy habitats can provide a good measure of ecological integrity of dunes habitat. Locational data for 14 rare plant species (Table 13) associated with sandy habitats on the study area were used in the Marxan analysis. All locations (points and polygons) were buffered by 100 m (328 ft). A map layer was generated showing the number of rare plant species found within polygons across the study area (Map 14 – Appendix D). The number of rare plant species per polygon ranged from 0 to 5.

Table 13. Rare Plant Species Found on the Hanford Site in Sandy Habitats.

			Status	
Common Name	**Species**	**Habitat**	**Federal**	**State**
Great Basin gilia	*Aliciella leptomeria*	Sand, general		Threatened
Geyer's milkvetch	*Astragalus geyeri*	Sand, general		Threatened
Smallflower mooncup	*Eremothera minor*	Silty sand		Sensitive
Rosy pussypaws	*Cistanthe rosea*	Sand, general		Threatened
Gray cryptantha	*Cryptantha leucophaea*	Dunes	Species of concern	Threatened
Sand-dune wheatgrass	*Elymus lanceolatus psammophilus*	Sand, general		Review List 1
Thompson's sandwort	*Eremogone franklinii var. thompsonii*	Sand, general		Sensitive
Suksdorf's monkey flower	*Erythranthe suksdorfii*	Sand, general		Sensitive
Shy gilia	*Gilia inconspicua*	Sand, general		Review List 1
Yellow wildrye	*Leymus flavescens*	Dunes		Sensitive
Spreading pygmyleaf	*Loeflingia squarrosa*	Sand, general		Threatened
Small-flowered nama	*Nama densum var. parviflorum*	Sand, general		Watch List
Coyote tobacco	*Nicotiana attenuata*	Sand, general		Sensitive
Winged combseed	*Pectocarya penicillata*	Sand, general		Watch List

3.2.4.2 Acreage of Open Sand. Sand dunes are a mosaic of open sand and stable vegetation. Open sand is important in maintaining the highly dynamic nature of sand dune complexes. Polygons with open sand were extracted from the most recent (2015) vegetation map for the study area (HNF-61417). These polygons were buffered by 30 m (98.4 ft) and ranked according to size. The ranking of open sand patch size was based on WNHP's description of a minimum dune size for an element occurrence of Inter-Mountain Basins Active and Stabilized Dune ecological system (Hallock et al. 2007). The minimum size is centered on the home range size of the sagebrush lizard (*Sceloporus graciosus*). In Utah, home range for sagebrush lizards averaged 0.04 ha (0.1 ac) for females and 0.06 ha (0.15 ac) for males (Johnson and O'Neil 2001). Using 100 lizards as a "viable" population, the minimum dune size would be 5 ha (12.4 ac) (Map 15 – Appendix D).

3.2.4.3 Vegetation Cover Type. A vegetation cover type map was created based on vegetation, open sand, and element occurrences of Inter-Mountain Basins Active and Stabilized Dune ecological system (Map 16 – Appendix D). The most recent (2015) vegetation map for the study area (HNF-61417) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas. In addition to the vegetation map, element occurrences of Inter-Mountain Basins Active and Stabilized

Dune ecological system (Central Hanford Dunes, Hanford Black Sand Dunes, and 300 Area Dunes) mapped in 2017 were also used in the analysis. The vegetation cover types were ranked as follows: Very Good included the WNHP Inter-Mountain Basins Active and Stabilized Dune element occurrences and vegetation cover types polygons with open sand, Good included vegetation cover types polygons with bunchgrasses dominated understory, Fair included vegetation cover types polygons with Sandberg bluegrass-cheatgrass understory, and Poor included non-vegetation cover type polygons (Table 14).

Table 14. Ranking of Vegetation Cover Types used in the Marxan Analysis.

Vegetation Cover Type Rankings

Very Good

- Inter-Mountain Basins Active and Stabilized Dune Element Occurrences
- Open Sand

Good

- [Stiff sagebrush](Half-shrubs)/Bunchgrasses
- Big sagebrush(Bitterbrush)/Bunchgrasses
- Big sagebrush(Bitterbrush)[Snow buckwheat]/Bunchgrasses
- Big sagebrush(Half shrubs)/Bunchgrasses
- Big sagebrush[Spiny hopsage]/Bunchgrasses
- Big sagebrush[Stiff sagebrush](Half-shrubs)/Bunchgrasses
- Big sagebrush-Bitterbrush[Snow buckwheat]/Bunchgrasses
- Big sagebrush/Bunchgrasses
- Bitterbrush/Bunchgrasses
- (Bitterbrush)/Bunchgrasses
- (Bitterbrush)[Snow buckwheat/Bunchgrasses
- (Half-shrubs)/Bunchgrasses
- [Snow buckwheat]/Bunchgrasses
- Rabbitbrush/Bunchgrasses
- Bunchgrasses

Fair

- (Bitterbrush)/Sandberg bluegrass-Cheatgrass
- (Bitterbrush)[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- (Half-shrubs)/Sandberg bluegrass-Cheatgrass
- [Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Big sagebrush(Bitterbrush)/Sandberg bluegrass-Cheatgrass
- Big sagebrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass
- Big sagebrush[Spiny hopsage]/Sandberg bluegrass-Cheatgrass
- Big sagebrush-Bitterbrush/Sandberg bluegrass-Cheatgrass
- Big sagebrush-Bitterbrush[Snow buckwheat]/Sandberg bluegrass-Cheatgrass

Fair

- Bitterbrush/Sandberg bluegrass-Cheatgrass
- Rabbitbrush/Sandberg bluegrass-Cheatgrass
- Sandberg bluegrass-Cheatgrass
- Other

Poor

- Highly disturbed areas (gravel, industrial, non-vegetated)

NOTE: Low cover - present to approximately 3% is shown with parentheses, (..); Irregular or patchy distribution is shown with brackets. [..]; and moderate to dense cover and a relatively even distribution is shown with no modifier.

3.2.4.4 Presence of Sandy Soil. An obvious requirement of dune habitat is the presence of sand. An input layer depicting sandy soils was created from two data sources: surface geology maps from the Washington Division of Geology and Earth Resources (Reidel and Fecht 1994a; Reidel and Fecht 1994b) and the most recent (2015) vegetation map for the study area (HNF-61417). Dune sand polygons (active sand dunes and stabilized sand dune deposits) were extracted from the geologic maps of the Priests Rapids and Richland 1:100,000 quadrangles. Inter-Mountain Basins Active and Stabilized Dune polygons and all polygons with open sand were exported from the vegetation map for the study area. All sand polygons taken from the two data sources were combined to produce the input layer showing sandy soils on the study area (Map 17 – Appendix D).

3.2.4.5 Proximity to Other Open Sand Patches. An input layer representing connectivity/proximity of dunes habitat was developed by selecting open sand patches (from acreage of open sand layer) greater than 5 ha (12.4 ac) on the study area and buffering them with multi-rings in 200-m (656-ft) increments. This layer illustrates the distance (to the nearest 200 m [656 ft]) from any location on the study area to the closest open sand patch (Map 18 – Appendix D).

3.2.5 Burrowing Animal Key Ecological Attribute-Indicator Pairs

3.2.5.1 Dispersal Distance. Townsend's ground squirrels are likely a keystone species providing important ecological functions such as serving as prey to many predators, shaping soil fertility and plant production through burrowing and feeding, and furnishing burrow habitats for other species (Sato 2012). An input layer was created for the Marxan analysis that depicts the dispersal distance (to the nearest 500 m [1,640.4 ft]) for Townsend's ground squirrels for any location on the study area (Map 19 – Appendix D). The layer was built by buffering the known active 2017 Townsend's ground squirrel colonies on the study area with multi-rings in 500-m (1,640.4-ft) increments. Little is known about the home range and dispersal of Townsend's ground squirrels so the ratings of dispersal distance for Townsend's ground squirrels were loosely based on dispersal studies of Piute (*Urocitellus mollis*) and Washington ground squirrels. Olson and Van Horne (1998) found dispersal distances for Piute ground squirrels in southwestern Idaho averaged 505.0 m (1,657 ft) in 1993 (5 dispersers [all males] from 14 animals [9 males and 5 females]; range 204 to 1,005 m [669 to 3,297 ft]) and 520.8 m (1,708.7 ft) in 1994 (11 dispersers [10 males and 1 female] from 24 animals [17 males and 7 females]; range 146 to 1,076 m [479 to 3,530 ft]) and 515.5 m (1,691.3 ft) for both years. Klein (2005) observed the median dispersal distance for juvenile male Washington ground squirrels was 880 m (2,887 ft) (mean was 991.0 m [3,251.3 ft]) with a range of 40.3 to 3,520.7 m (132.2 to 11,550.9 ft). Her data show that approximately 90% of dispersal distances traveled were less than 2,000 m (6561.7 ft). Limited data are available on the dispersal distances of female Washington ground squirrels. Dispersal distances for Townsend's ground squirrels on the study area were ranked as follows: Very Good 0 to 500 m (0 to 1,640.4 ft), Good greater than 500 to 1,000 m (greater than 1,640.4 to 3,280.8 ft), Fair greater than 1,000 to 2,000 m (greater than 3,280.8 to 6,561.7 ft), and Poor greater than 2,000 m (greater than 6,561.7 ft).

3.2.5.2 Townsend's Ground Squirrel Habitat. In 2015, a habitat suitability model for Townsend's ground squirrels was created for the study area. Very Good included polygons with habitat suitability scores greater than or equal to 95%, Good included polygons with habitat suitability scores greater than or equal to 90 and <95%, Fair included polygons with habitat suitability scores greater than or equal to 85% and less than 90%, and Poor included polygons with habitat suitability scores less than 85%.

3.2.5.3 Burrowing Owl Habitat. In natural conditions, Burrowing Owls are dependent on fossorial species for their most basic habitat need, a burrow. On the Hanford Site, Burrowing Owls rely on species such as ground squirrels and badgers for creating nest burrows; their habitat requirements overlap with these species. For this reason, an input layer of potential Burrowing Owl nest habitat was used in the

Marxan analysis. The layer was constructed using a simple geometric intersection of map layers consisting of areas with characteristics likely to be suitable for Burrowing Owl nesting habitat. The selected layers show areas with gentle slopes (0 to 6%), little to no shrubs, and that do not contain active or stabilized sand dunes or rock outcrops. Potential Burrowing Owl nest habitat polygons were ranked according to size based on the following rational: Very Good included polygons greater than 240 ha (greater than 593 ac), Good included polygons greater than 45 (lower end of home range size [Rosenberg and Haley 2004]) to 240 ha (upper end of home range size [Haug and Oliphant 1990]) (greater than 111.2 to 593 ac), Fair included polygons 4 (suggested spacing between artificial burrows 110 to 300 m [360.9 to 984.3 ft] – circle with a radius of 110 m [360.9 ft] is 3.8 ha [9.4 ac] [Johnson et al. 2010]) to 45 ha (9.9 to 111.2 ac), and Poor included polygons less than 4 ha (9.9 ac) .

3.3 CAVEATS OF THE ANALYSIS

As with any assessment of this type, there are caveats that need to be stated up front when using the solution outputs. One caveat to note is that although the researchers used the best available data in the assessment, some indicators of key ecological attributes identified in the viability assessment workshops had to be modified to accommodate poor, incomplete, or lacking data. An example of one of these data gaps is an incomplete dataset on sagebrush obligate bird species (e.g., Sagebrush Sparrow, Sage Thrasher, Loggerhead Shrike, Brewer’s Sparrow). In this case, a more complete dataset on black-tailed jackrabbits was used as a surrogate input layer for all sagebrush obligate species. The assessment also shed light on where data are lacking (e.g., habitat quality – native forbs, biological crust) and where data collection could improve future analyses.

Another caveat is that the study area boundary may have an influence on the solution outputs. While the Columbia River acts as an ecological boundary to the north and east of the study area, the south and west boundaries are primarily administrative in nature. The use of administrative boundaries can have an effect on the solution in relationship to clustering (Boundary Length) and limiting selection of planning units on boundary edges. A boundary extended to an ecological constraint may allow higher selection rates of those planning units along the study area boundary. Although riparian habitats were included the critical or unique habitat key ecological attribute-indicator input layer, the assessment did not include the Columbia River (riverine systems) as a focal habitat. The river is a major ecological component of the Hanford Site. Hanford operations take care to avoid or mitigate any impacts to the Columbia River, however, the majority of river management and conservation is the responsibilities of other agencies and not that of DOE-RL. Therefore, riverine systems were not assigned targets or goals as part of the assessment.

3.4 SOLUTION

Using the settings in Section 3.1, the Marxan analysis produced solutions that had a range over mean variance of less than 1%. The solution displayed on maps and discussed for the remainder of this report is the Marxan “Best” solution, which the analysis determined to be run 20 of 100 (Table 15). This solution represents the areas of highest priority for conservation that most efficiently meet the conservation target goals (Table 4) with the lowest score within the study area.

Table 15. Scoring of the Best Solution as Compared to the Average Objective Function Inputs Over 100 Runs

Description	Score	Cost	Number of Planning Units Selected	Connectivity[a]	Penalty	MPM[b]
Best Solution	2,406,914.01	2,172,929.00	20,144	508,500.52	74.77	99.99%
Average of 100 Runs	2,418,572.54	2,170,261.44	20,129	539,624.78	83.71	98.64%

[a] Connectivity is based on boundary length, a summed product in the objective function, smaller Connectivity values will achieve lower scores
[b] MPM is the minimum proportions met. Of all targets used in the assessment, this is the lowest proportion obtained in the run of a single target

Marxan selects the best solution by choosing the run with the lowest score. This score is a result of the objective function discussed in Section 2.1. The score can only be use in comparing runs within the same analysis. Comparisons of scores between other research, conservation efforts, or inputs are not possible as the score is a direct result from the project specific inputs into the objective function. The score of the best solution of this assessment and the inputs to the objective function are listed in Table 15 and compared to the means of all 100 Runs. The best solution produced a score, boundary length (connectivity), penalty factor for target shortfalls that were all lower than the average of the 100 runs achieving nearly 100% of target goals with only a fraction more cost and number of planning units required compared to the average.

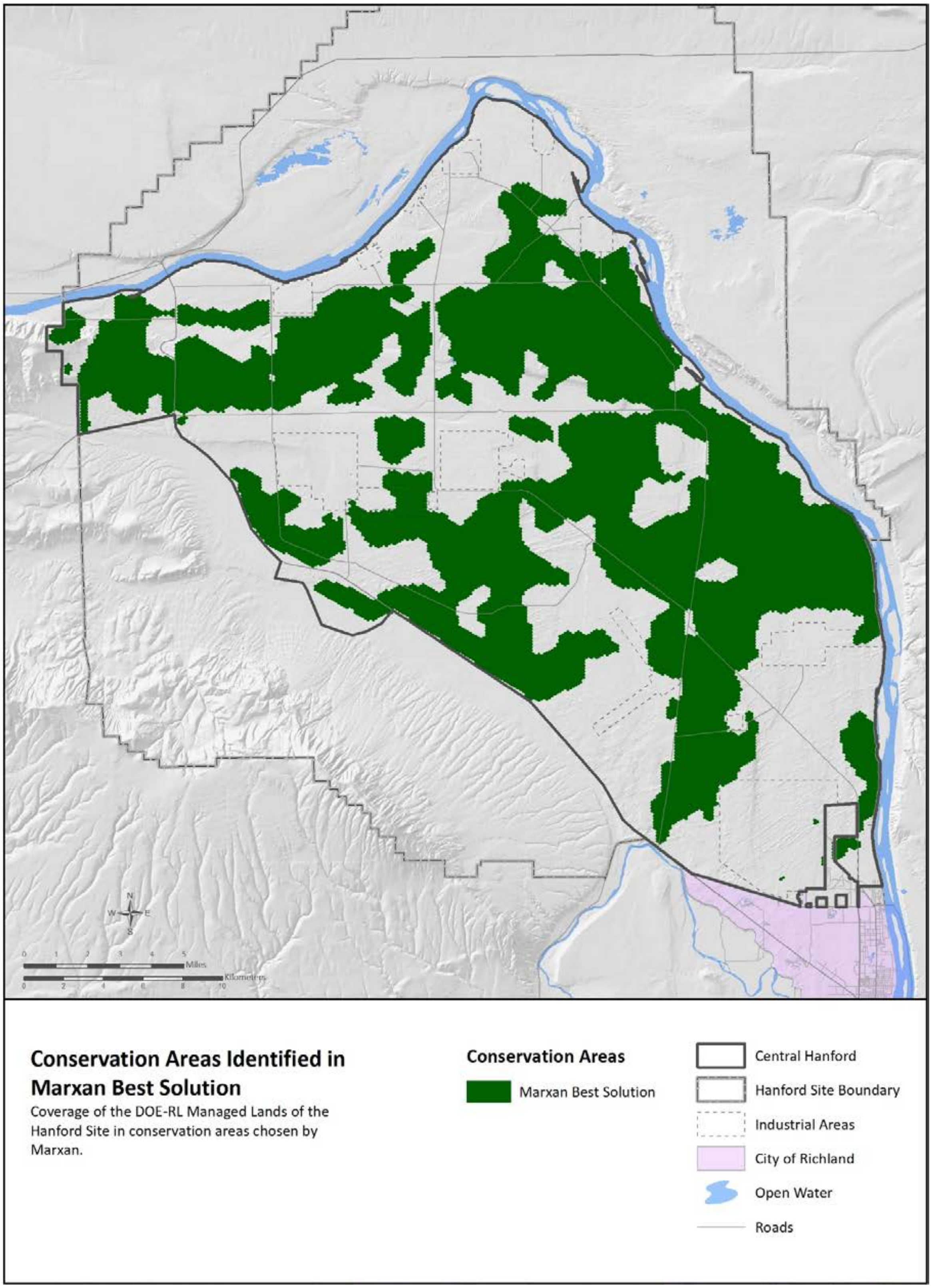

Figure 6. Best Solution Determined by Marxan Assessment for Conservation Areas on the DOE-RL-managed Portion of Hanford Site.

The solution used 20,144 planning units of the 40,654 units available on the study area. Approximately 50% of the DOE-RL-managed portion of the Hanford Site displays in the conservation solution (Figure 6). The solution is comprised of 13 patches ranging from 4 to 30,034 ha (10 to 74,216 ac) in area (Table 16) and covers approximately 40,760 ha (100,720 ac) of the study area. The largest solution patch, 30,034 ha (74,216 ac), is the bulk of the overall solution covering nearly 74% of the total solution. The solution patch sizes can be classified into five size categories: Micro (less than 10 ha [less than 24.7 ac]), Small (10 to less than 100 ha [24.7 to less than 247.1 ac]), Medium (100 to less than 1,000 ha [247.1 to less than 2,471.1 ac]), Large (1000 to less than 10,000 ha [2,471.1 to less than 24,710.5 ac]), and Very Large (greater than 10,000 ha [greater than 24,710.5 ac]). The medium size class has the highest number of solution patches, containing six patches, while no other size class has more than two solution patches. All solution patch area categorized by size class is displayed spatially in Figure 7. In the best solution, the goals were achieved at 100% or greater in 37 of the 40 targets. The three targets that fell short of meeting 100% of the goals were Very Good ground squirrel habitat (99.99% met), Good Burrowing Owl habitat (99.99% met), and the critical and unique species or habitats target (98.11% met). Reaching targets at this level is considered as met by Marxan, therefore, the Marxan targets were achieved and, in many cases, exceeded 100% (Figure 8).

Table 16. Patch Sizes, Percent of Total Solution Area and the Size Classes for the 16 Unique Patches in the Solution.

Solution Patch Size (Area)				
Hectares	**Acres**	**Square Meters**	**Percent of Solution Area**	**Size Class**
4.05	10.00	40,468.60	0.01%	Micro
6.07	15.00	60,702.93	0.01%	Micro
10.12	25.00	101,171.50	0.02%	Small
18.21	45.00	182,108.73	0.04%	Small
113.31	280.00	1,133,120.78	0.28%	Medium
206.39	510.00	2,063,898.54	0.51%	Medium
206.39	510.00	2,063,898.63	0.51%	Medium
467.41	1,155.00	4,674,123.28	1.15%	Medium
471.46	1,165.00	4,714,591.77	1.16%	Medium
722.36	1,785.00	7,223,644.99	1.78%	Medium
1,260.60	3,115.00	12,605,968.97	3.10%	Large
7,239.83	17,890.02	72,398,325.92	17.80%	Large
30,033.77	74,215.07	300,337,713.96	73.83%	Very Large

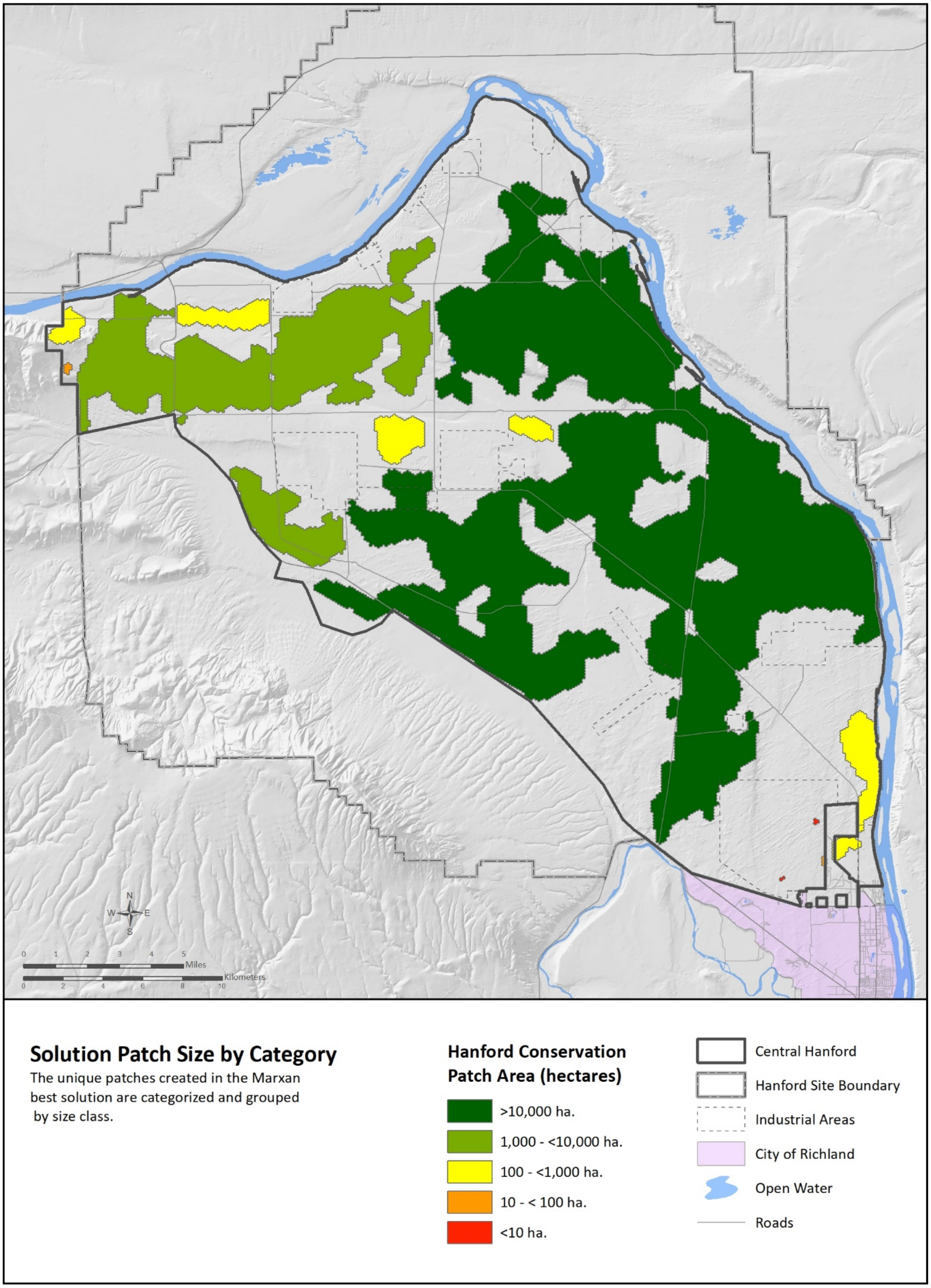

Figure 7. Conservation Solutions Categorized and Displayed by Patch Size Class.

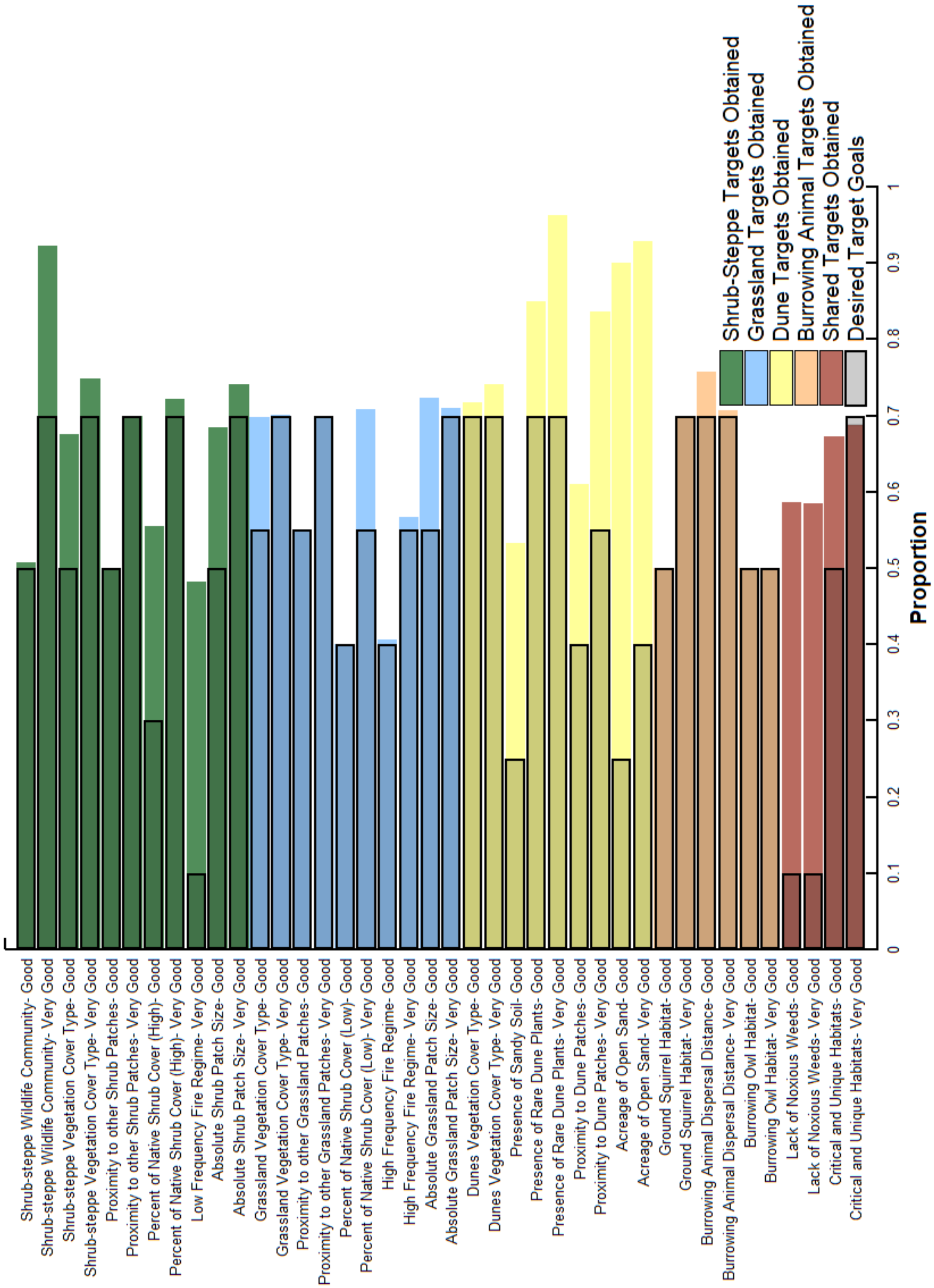

Figure 8. Marxan Target Quantities Obtained Compared to the Goal Levels Requested in the Assessment.

Because Marxan produces a unique solution for every run within an analysis, the planning units selected can vary from each solution. Marxan produces a selection frequency output, this output displays the number of times each planning unit is selected over the 100 runs in an analysis. A repeatable analysis should show a high selection frequency percentage of the same planning units (valuable units in the objective function) while a more random and less directed solution might have a more even distribution or skew towards a low selection frequency. The best solution of this assessment contained 20,144 planning units, 61.53% (12,394 units) of the solution area was selected in each solution of the 100 runs. An additional 29.59% (5,961 units) of the solution area was selected in 67 to 99 runs. Only 8.88% (1,789 units) of the solution area was selected in 66 runs or fewer (Figure 9).

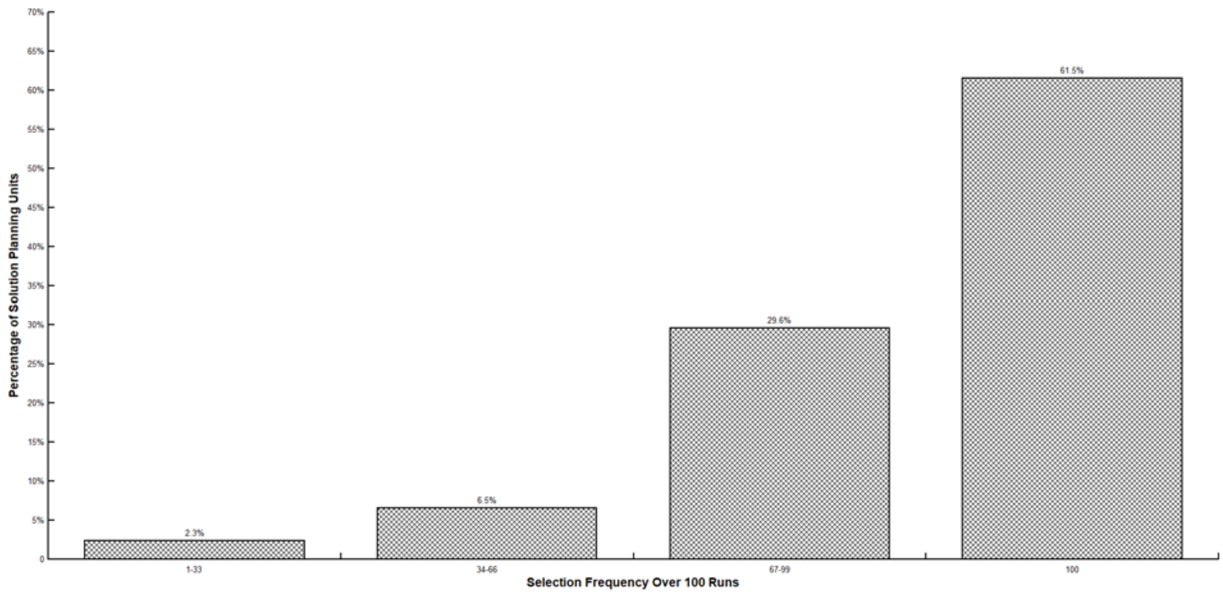

Figure 9. Selection Frequency of the Best Solution Planning Units During the 100 Run Marxan Assessment.

3.5 DISCUSSION

The impetus for the CHAMP is to take a landscape approach to evaluating habitat quality on the DOE-RL-managed portion of the Hanford Site (study area) and use the results to determine areas for conserving, restoring, mitigating, and connecting habitats. The appeal of the approach (Marxan analysis) is that it can use a diverse array of input data types (already existing Hanford Site data) and can be compatible and complementary to other efforts on the study area (e.g., the CLUP and the BRMP) and in the greater Columbia Plateau Ecoregion (e.g., the ALI [2014] and the WHCWG [2012, 2013a, 2013b, 2014, 2015]). In many cases, data from these other efforts can be incorporated into the Marxan analysis. Participating parties can select the conservation targets and their ranges and can alter them iteratively. They can also lock in unique, rare, or highly valuable features into the solution or lock out unwanted features. Results can show data gaps and the analysis can be repeated with new or updated data and constraints. Marxan analysis provides a transparent and systematic approach to meeting conservation goals in the most spatially efficient way.

Figure 10. Location of the Hanford Black Sand Dunes in Relation to the 100-F Reactor Area.

In earlier Marxan runs to identify priority conservation areas on the study area, it became evident that a portion of Hanford Black Sand Dunes (Figure 10) south of the 100-F Area was not occurring in the best solution. This unique sand dune is recognized by the WNHP as an element occurrence and was desired in the best solution (Hallock et al. 2007). The dune was perhaps not selected in the best solution due to its isolation and smaller patch size (17.7 ha [43.7 ac]). The Hanford Black Sand Dunes is listed as one of eight sand dune areas in all of Washington State having significant conservation value (Hallock et al. 2007). Other unique and critical features were captured in the assessment near the proportion desired and many times exceeding those goals. Hallock et al. (2007) stated that the Hanford Black Sand Dunes have unique vegetation patterns not found elsewhere on sand dunes within Washington State. They continued by saying that the dominance of black basalt sand suggests an origin different from Hanford Central Dunes and the area should be considered for receiving the Research Natural Area designation (Hallock 2007). The decision was made internally that while other conservation documents and methods on the Hanford Site would likely protect the Hanford Black Sand Dunes, they needed to be locked into the assessment solution.

In the final Marxan run to identify priority conservation areas, approximately 50% of the study area was selected in the best solution. All conservation target goals were effectively met in the solution and, in many cases, far exceeded 100%. More the 82% of the best solution fell outside of areas designated as industrial by the CLUP (Section 3.5.2). Roughly 90% of the best solution occurs in habitats ranked level 3 or greater in the BRMP (Section 3.5.3). Approximately 52% of the best solution overlapped with priority core areas selected by ALI (Section 3.5.4). The best solution also identified possible wildlife corridors and areas for mitigation, restoration, and connecting habitats (Section 3.5.5 and 3.5.6).

A key element to understanding the assessment is to evaluate the identified areas of high habitat value. The solution Marxan provided shows areas of good habitat with high value, but areas selected may not always include all high quality examples of that habitat. By nature of the Marxan tool, the solutions are a range of mathematical calculations that attempt to capture the desired quantity of a target while limiting a cost to the solution. It can be difficult to separate this idea of habitat value from the concept of identifying the “best” habitat. The Hanford Site already has an assessment and document (BRMP) that describes the “best” examples of habitats on the Hanford Site. Therefore, there was never an intent to duplicate the BRMP or its method of describing the resources as isolated features on the landscape. The idea behind using Marxan was to build a conceptualized conservation design that displays relationships between ecological resources as they might interact and benefit from each other. This information will be supplemental and supportive to the processes used in the BRMP. The BRMP will continue to drive the conservation on the Hanford Site through avoidance, minimization, and a mitigation of resources. The spatial relationships between CHAMP and current documents such as the CLUP, BRMP, and ALI are discussed in detail in Sections 3.5.2 through 3.5.4).

The results from the CHAMP will provide highlights of areas that provide value in habitat conservation. The CHAMP produces a solution based on components of a habitat and not its entirety, and it is possible that a high quality representation of a resource or habitat may be excluded. Using BRMP and its processes, the areas of highest habitat quality and the best examples of resources will continue to be conserved through avoidance or minimal intrusion. The Marxan tool can be used to answer other habitat conservation questions (such as “what is a network and spatial configuration of areas that strategically meet conservation goals?) through visual display and statistical analysis. The Hanford Site now has an additional decision making tool that can support the process of BRMP and highlight areas that may be underrepresented in a single resource but as whole provide value to the landscape.

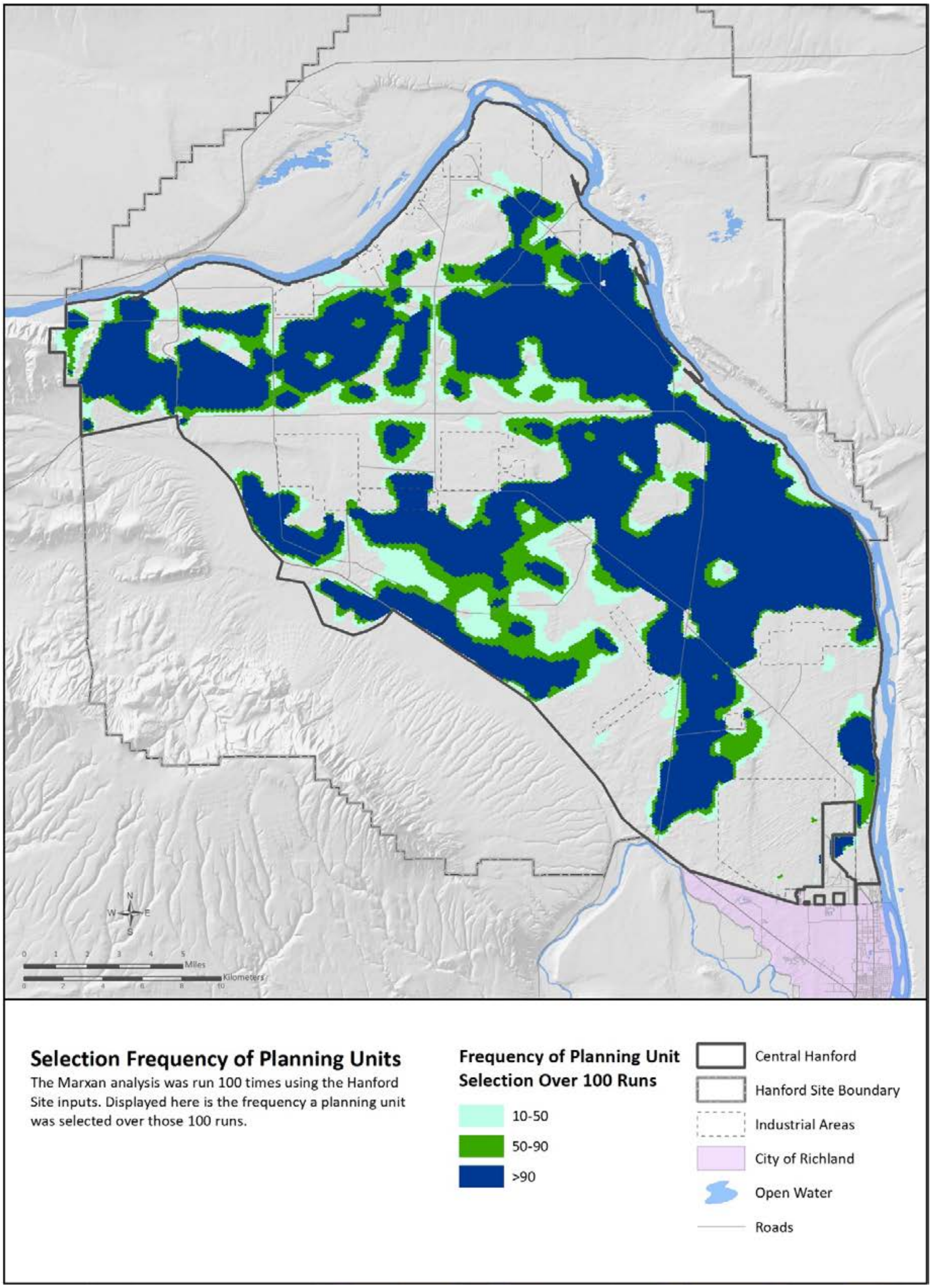

Figure 11. The Frequency of Selection of Planning Units across the DOE-RL-managed Portion Hanford Site.

Understanding the solutions provided in the CHAMP highlight areas of conservation value at the landscape level rather than identifying the "best" habitat is key in the communication of results and the future uses of such an assessment.

3.5.1 Planning Unit Selection

Evaluating the frequency of planning unit selection during the assessment can make inferences on the biological value of areas on the study area. Biological value of an area may be defined in terms of irreplaceability, or how important the specific area is for efficient achievement of conservation objectives.

The higher the frequency of selection of a planning unit in Marxan, the closer a unit is to being considered irreplaceable within the solution. A planning unit selected in 100 of 100 runs would be considered irreplaceable, no calculations or variable runs led to those units being deemed unnecessary for an efficient solution by Marxan. Over 91% of the Hanford solution from the Marxan assessment was selected 67 or more times in 100 runs. Defining this irreplaceability spatially, planning units selected less than 10 times over 100 runs were dropped: 10 to 50 selections grouped, 50 to 90 selections grouped, and those planning units selected greater than 90 runs were grouped and displayed in Figure 11.

The areas of high irreplaceability in Figure 11 are represented by those with a selection frequency greater than 90. These planning units contain ecological targets in an amount that provide the greatest contribution to biological value of the study area. Alteration to these areas via environmental conditions (e.g., wildfires) or industrial development would have the potential to contribute to the largest negative ecological impacts. Planning units selected from 1 to 90 times over the 100 runs often line the edges of the irreplaceable units. This result is expected as Marxan attempts to build solutions by clumping from other planning units to meet the boundary length goals described by the user. There are a few areas, however, that have a large area of planning units that are selected in that 10 to 90 frequency. One of these areas can be seen in Figure 11 south of the Hanford Site's 200-East Area. There is a large band of mid- to lower selection frequency that runs along Army Loop Rd. This area is primarily grassland dominant with scattered shrubs. Much of this area is scoring similar to those around it and the majority of the goals are being met in other locations so Marxan has a high variance of unit selection through this area. When looking at various solutions through the 100 run catalog, solution shape changes are most often noticeable to the eye in these areas. Biologists should evaluate these areas for mitigation or restoration potential, as well as the possibility for reducing constraints to stabilize the biological value of these areas.

Over 90% of the solutions were selected in a super majority of the 100 runs in the final assessment. Figure 12 shows the selection frequency with an overlay of the best solution. Making statements on irreplaceability of planning units based on optimization algorithms, such as Marxan, should not be made of a single solution. Instead, it takes analyzing the selection frequency of multiple outputs (100 runs) produced by these algorithms. Stating that an area is irreplaceable solely due to being selected in the best solution would be premature and lacking support. Evaluating the best solution against the selection frequency of greater than 90 over the 100 runs is a much stronger argument for irreplaceability.

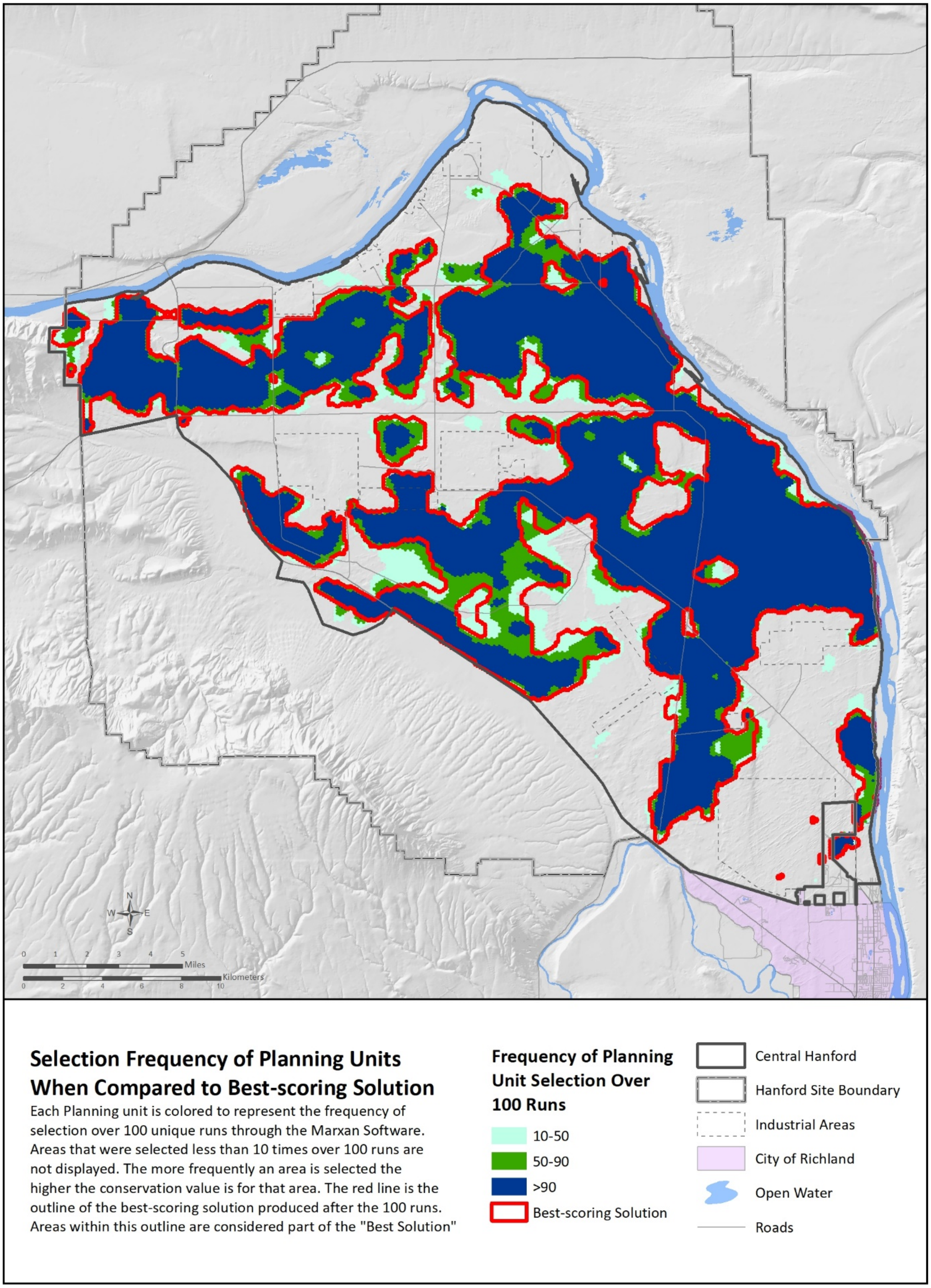

Figure 12. The Frequency of Selection of Planning Units in Relation to the Best-Scoring Solution.

After establishing areas of irreplaceability from selection frequency of the solution, the next step would be to evaluate potential vulnerabilities to these areas. Vulnerability is the risk of an area being transformed via damage caused to the biodiversity features or threatening ecological processes (Kukkala and Moilanen 2012). For this discussion, vulnerabilities are further defined as the risk of transformation from Hanford Site operations or other human activities. Many of these potential vulnerabilities were captured in some form and weighed when creating the constraint layer. Once Marxan provides output solutions with the constraint layer considered, the level of current protection (BRMP) and any future land uses (CLUP) are the predominant vulnerabilities to these areas going forward. The areas with higher BRMP levels will have higher levels of protection as a result of the ecological compliance and mitigation processes of BRMP. The effort for avoidance of these areas and the increasingly punitive mitigation requirements for destruction of areas are often deterrents for selection in development. Additionally, the Hanford CLUP categorizes areas for future land use on the Hanford Site. Areas the CLUP has designated for preservation and conservation would be less vulnerable to threats of future development. Locations that the CLUP land use maps have designated for industrial and development are more likely to face potential threats from development. Therefore, as BRMP levels increase and CLUP land use is labeled for preservation and conservation, a loose correlation of decreased vulnerability could be made. The vulnerability plotted against the irreplaceability can provide inference into potential actions (Figure 13). A spatial representation of this concept for the study area is provide in Figure 14.

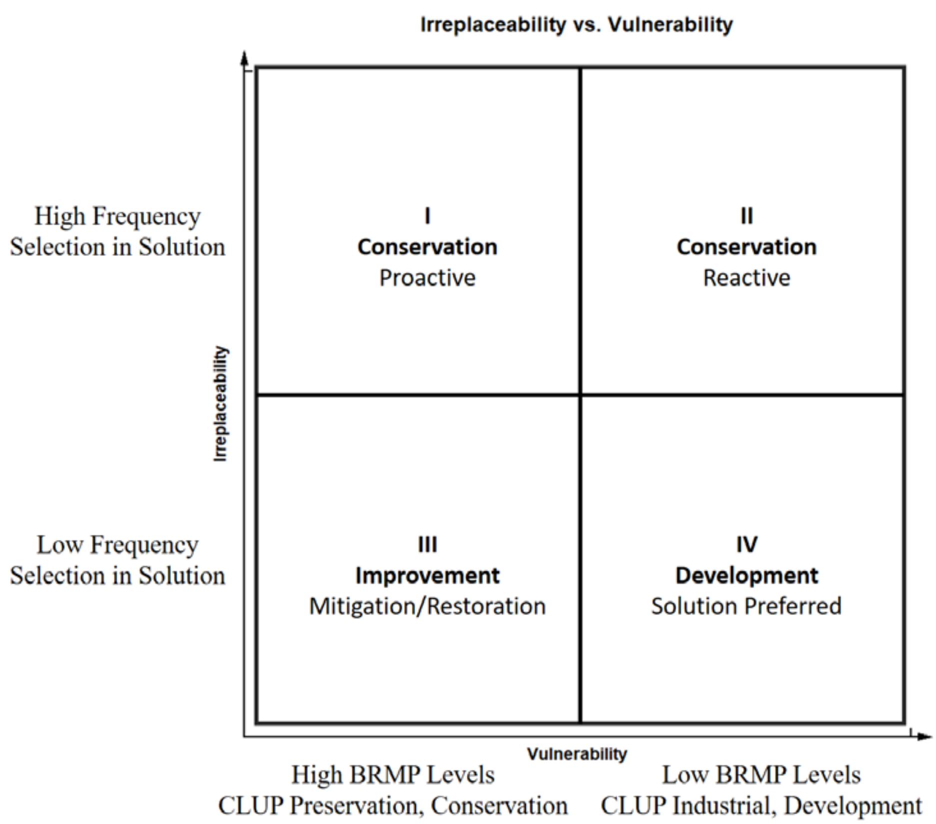

Figure 13. Irreplaceability vs Vulnerability Plot. Irreplaceability increases with the Increase in Selection Frequency of a Planning Unit. Vulnerability from Human Threats Increases as BRMP Levels are Reduced or CLUP Land Use Industrial and Development Designations.

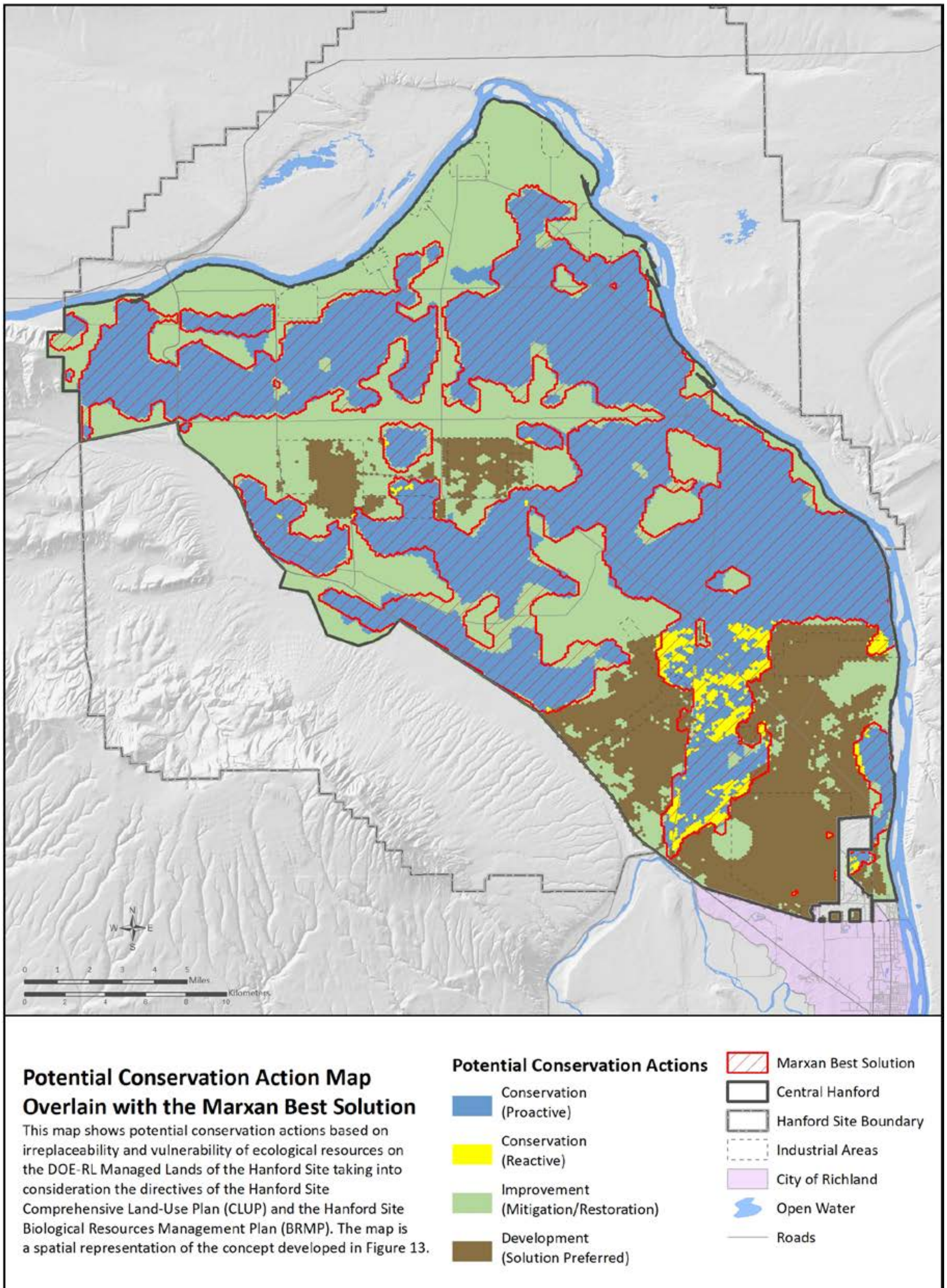

Figure 14. Potential Conservation Action Map for the DOE-RL-managed Portion Hanford Site Overlain with the CHAMP Best Solution.

Conservation efforts that set areas aside (reserve formation) attempt to reduce or remove the outside threats to the ecological resources. Because of this, addressing areas of high quality that face the largest threats (II in Figure 13) before all areas is the prudent process. From the perspective of conservation, having a solution predominantly in quadrant I of Figure 13 is ideal. These actions can be classified as reactive conservation actions. The nature of Marxan and its use in this assessment will create these reactive conservation areas. Through clumping and solution optimization, the assessment may frequently select areas that do not contain highly valuable or sensitive resources highlighted in other processes. These areas may not have been obvious when performing ecological compliance reviews and monitoring previously, and a whole ecosystem assessment allowed these high-value, high-risk areas to be emphasized. Solutions that trend towards irreplaceability and lower threat potential due to protections built into existing Hanford Site documents and processes are a more proactive approach. Proactive conservation provides the projects sufficient planning time, communications, and long-term viability. Moving the reactive conservation areas into more proactive conservation efforts is best for attainable long-term success. Building on that logic, areas in quadrant III of Figure 13 can also move towards the proactive conservation concept. These areas have protection documents or processes in place and not frequently chosen in the solution. There is potential to use areas that fall within this criterion as candidates for restoration or mitigation work. By creating a planning unit with higher value through restoration or mitigation of ecological targets within the unit, the selection frequency of a Marxan assessment should increase and move it into quadrant I (Figure 13). While it is not possible to predict or force Hanford Site operations to limited or specific areas, the solution produces areas in quadrant IV (Figure 13) that are vulnerable in their status and not frequently selected as valuable in the outputs. If development and infrastructure were to occur, these areas are preferred by the solution as low value and high threat. These concepts and comparisons with existing regulations are valuable tools to support the EM program in their directives to monitor and conserve ecological resources on the Hanford Site.

3.5.2 The Hanford Site Comprehensive Land-Use Plan

The CHAMP can help improve land-use planning maps in the future. The CLUP provides a land-use map, designations, policies, and implementing procedures for the Hanford Site for the foreseeable future (at least 50 years) as long as DOE-RL retains legal control of portions of the Hanford Site. The plan is described as “a living document designed to hold a chosen course over an extended period of development and management of resources, yet the plan is flexible enough to accommodate a wide spectrum of both anticipated and unforeseen mission conditions” (DOE/EIS-0222-F). The CHAMP can facilitate reciprocated support to the CLUP. In the running of the Marxan analysis, some mapped CLUP designations were used in the constraint (cost) layer as limiting features. With the current CLUP map and designations, the CHAMP best solution identifying priority conservation areas is in agreement over 82% of its area (Figure 15 and Table 17). Even with added weight constraints, some areas of industrial (exclusive), industrial, and research and development were selected in the best solution.

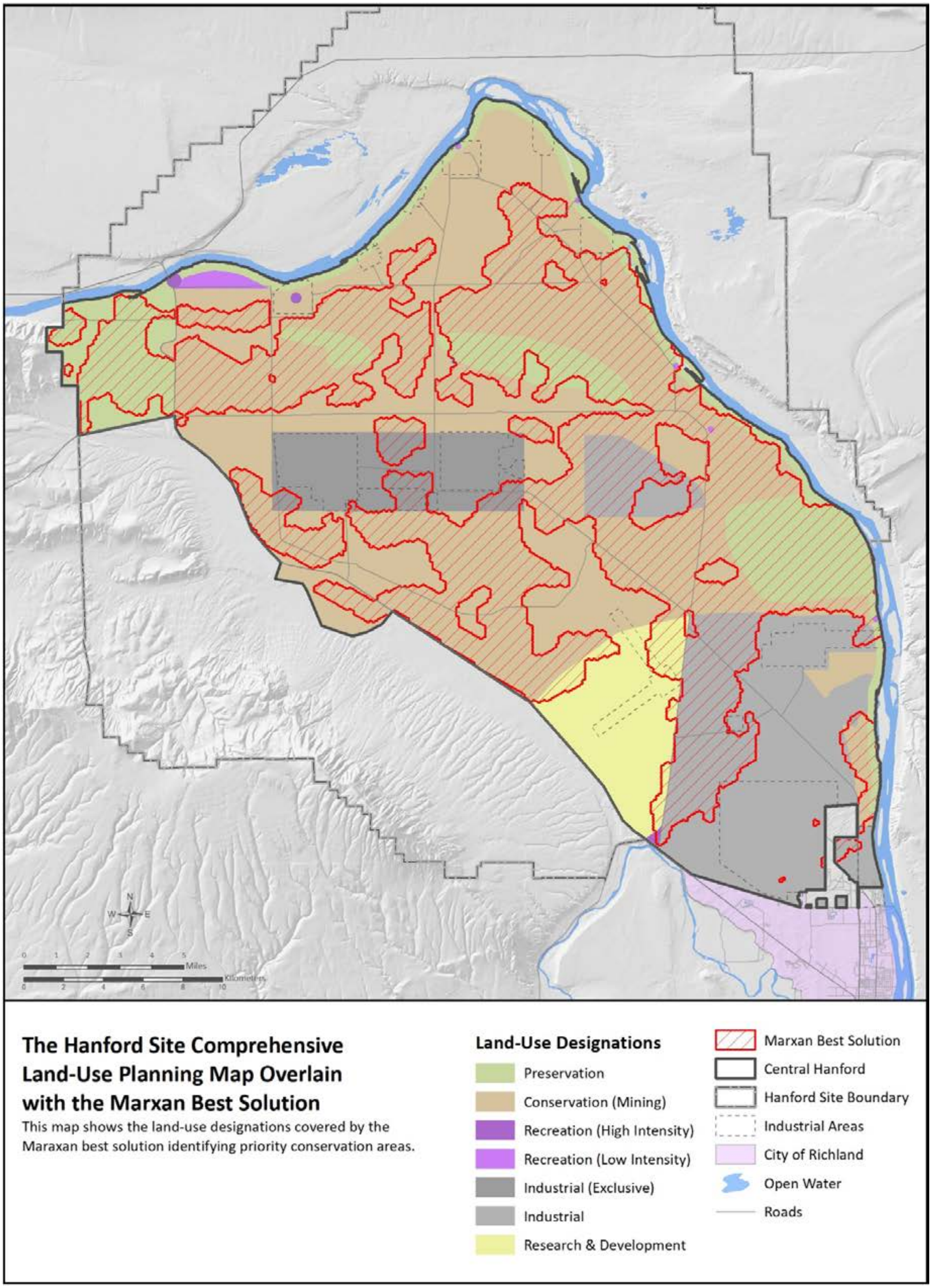

Figure 15. The Hanford Site Comprehensive Land-Use Planning Map overlain with the CHAMP Best Solution.

Table 17. Area of the DOE-RL-Managed portion of Hanford Site and the Marxan Best Solution Covered by Each Hanford Site Comprehensive Land-Use Planning Designations.

Designation	Area of Study Area (Hectares)	Percent of Study Area	Area of Best Solution (Hectares)	Percent of Best Solution
Conservation (Mining)	44,156.2	54.63	25,502.5	62.78
Preservation	11,800.9	14.60	7,877.3	19.39
Recreation (High Intensity)	107.1	0.13	16.9	0.04
Recreation (Low Intensity)	327.2	0.40	22.7	0.06
Industrial (Exclusive)	5,063.9	6.26	1,110.6	2.73
Industrial	14,253.7	17.63	5,060.8	12.46
Research & Development	4,908.6	6.07	1,009.7	2.49
River	212.7	0.26	19.1	0.05
Total	***80,830.2***	***100.00***	***40,619.7***	***100.00***

3.5.3 The Hanford Site Biological Resources Management Plan

The BRMP is recognized by the CLUP as the primary implementation plan for managing biological resources on the Hanford Site. The BRMP provides DOE-RL, the Office of River Protection, Hanford Site contractors, and other organizations working on Hanford Site lands managed by DOE-RL with a consistent approach for protecting and managing natural resources. The BRMP classifies all site biological resources into six resource priority levels (0 [lowest priority] through 5 [highest priority]) and provides management guidelines for each level (Table 18). This hierarchical approach assigns a resource priority level to species based on aspects such as legal or listing status, recreational, commercial, cultural, and ecological value. Habitats are ranked considering attributes such as vegetation cover type, whether they are critical or essential for species of concern; Washington State priority habitats and element occurrences; important for connectivity and/or reducing fragmentation; or protecting administratively designated resources. Level 5 resources are the rarest and most sensitive habitats and species, and are considered irreplaceable. The management goal of Level 5 resources is preservation. Level 4 resources are considered essential to the biological diversity of the Hanford Site and the Columbia Basin Ecoregion. The management goal of Level 4 resources is preservation. Level 3 resources are important resources such as state sensitive, candidate, and review species; WDFW priority species; culturally important species; lower quality mature shrub-steppe; high-quality grasslands; and conservation corridors, snake hibernacula, bat roosts, rookeries, and Burrowing Owl buffer areas. The management goal for Level 3 resources is conservation. Level 2 resources are mid-successional communities. The management goal of Level 2 resources is conservation. Level 1 resources are marginal habitats. The management goals are to avoid or minimize impacts if possible. Level 0 resources are industrial and non-vegetated areas. Management goals and actions are limited to those needed for regulatory compliance. All Hanford Site lands managed by DOE-RL have been mapped by BRMP resource level.

Table 18. Management Goals and Actions for Each Hanford Site Biological Resource Level of Concern (DOE/RL-96-32).

Resource Level of Concern	Management Goal	Management Action	Status Monitoring Effort	Compensatory Habitat Mitigation Action
Level 5	Preservation	Avoidance	High	Compensation determined on case-by-case basis
Level 4	Preservation	Avoidance/minimization preferred	High	Habitat replacement at 5:1
Level 3	Conservation	Avoidance/minimization preferred	Moderate	Habitat replacement at 3:1 or as per other legal requirements (wetland mitigation)
Level 2	Conservation	Primarily avoid/minimize	Low Level	Habitat replacement possible at 1:1. Such areas may be preferred sites to perform mitigation actions
Level 1	Mission Support	Avoid/minimize as practicable regulatory compliance (Migratory Bird Treaty Act)	None	Habitat replacement is not required, but site could be suitable for use as a restoration or mitigation area
Level 0	Mission Support	Regulatory compliance	None	None

Various data used to create the BRMP resource level maps were also used to create spatial input layers for the Marxan analysis. Because the BRMP is the primary implementation plan for managing biological resources on the Hanford Site, it is important that the CHAMP is compatible and complementary to the BRMP and that it provides reciprocated support. Approximately 95% of the CHAMP best solution occurs in habitats identified for preservation (Level 4 and 5) or conservation (Level 2 and 3) in the BRMP (Figure 16 and Table 19). Approximately 90% of the CHAMP best solution appears in the top three highest BRMP resource priority Levels (Levels 3, 4, and 5).

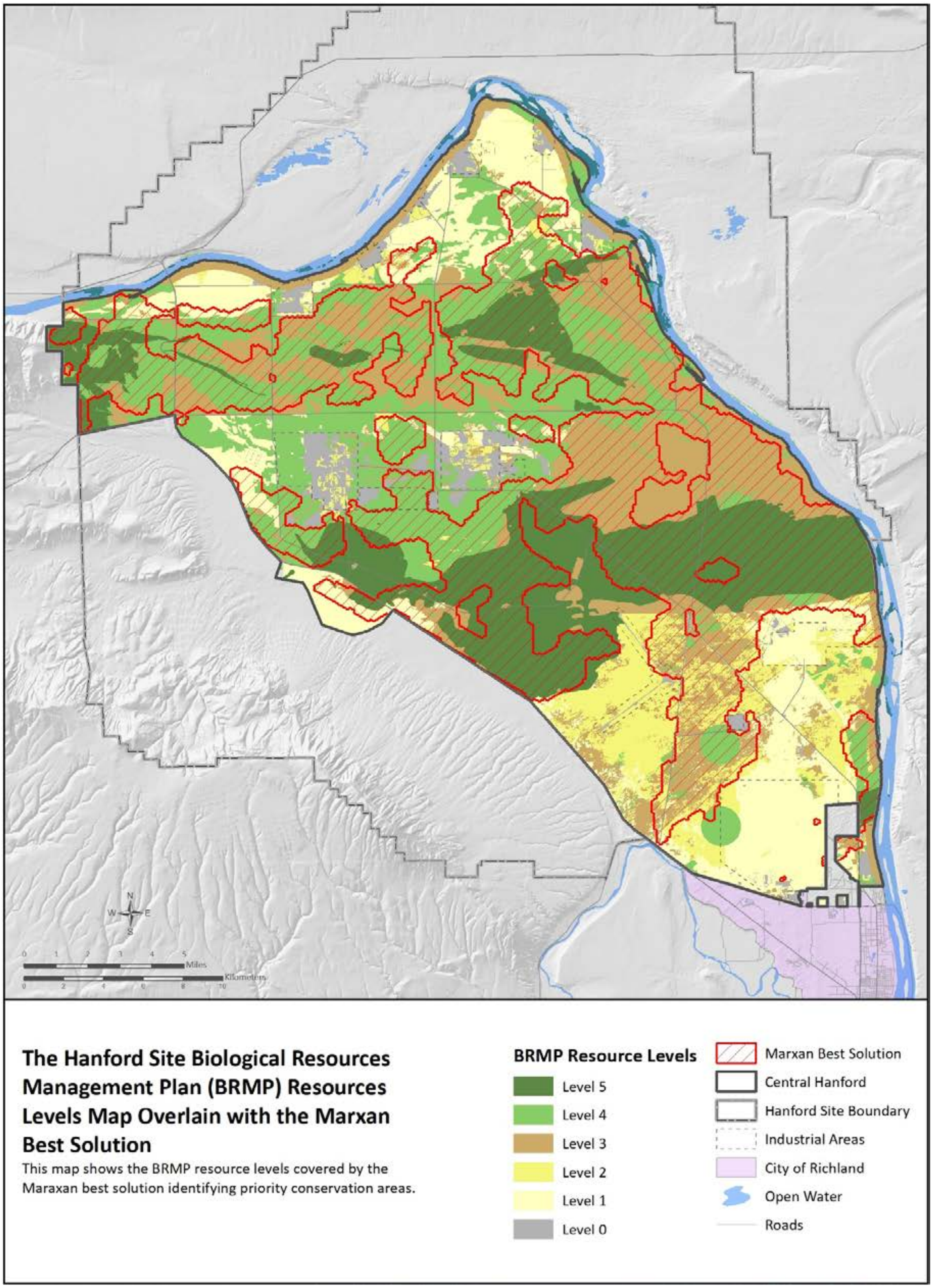

Figure 16. The Hanford Site Biological Resources Management Plan Resources Levels Map overlain with the CHAMP Best Solution.

Table 19. Area of the DOE-RL-Managed portion of Hanford Site and the Marxan Best Solution Covered by Each Biological Resources Management Plan Resource Level of Concern.

BRMP Resource Level of Concern	Area of Study Area (Hectares)	Percent of Study Area	Area of Best Solution (Hectares)	Percent of Best Solution
Level 5	17611.2	21.80	13269.5	32.66
Level 4	20015.8	24.78	11190.7	27.54
Level 3	19808.8	24.52	12276.9	30.21
Level 2	7255.1	8.98	1765.5	4.34
Level 1	12914.7	15.99	2012.9	4.95
Level 0	3167.8	3.92	118.7	0.29
Total	***80773.4***	***100.00***	***40634.3***	***100.00***

3.5.4 The Arid Lands Initiative

The ALI is a partnership of public agencies and private organizations that work together to coordinate land management and conservation actions and projects in pursuit of "a viable, well-connected system of eastern Washington's arid lands and related freshwater habitats, that sustain native plant and animal communities, and that support compatible local economies and communities" (http://aridlandsinitiative.org/). In 2014, the ALI and USFWS completed a Marxan analysis to identify priority conservation areas in the Columbia Plateau Ecoregion (ALI 2014). The conservation targets of the analysis were ecosystems (i.e., shrub-steppe and grasslands, wetlands, riverine systems, cliffs and caves, and dunes) and species groups (i.e., grouse and burrowing animals). The KEAs selected to determine the integrity and viability of the conservation targets included patch size, landscape pattern and structure, adjacency, fire regime, element occurrences and rare or remnant habitats, and habitat concentration areas (modeled by WHCWG 2012, 2013a) for the Greater Sage-Grouse (*Centrocercus urophasianus*), Sharp-tailed Grouse (*Tympanuchus phasianellus*), Townsend's ground squirrel, and Washington ground squirrel. Spatial data layers (Marxan input layers) representing the KEAs were developed from the best available data sources at the ecoregional scale. The constraint layer used in the analysis was a movement resistance raster created by the Oregon Chapter of the Nature Conservancy for the Duke Project Analysis (Buttrick 2013).

The ALI Marxan analysis was run with three overall goal levels (high, medium, and low). The goal level is the percentage of a target that should occur in the solution in order to maintain the biological diversity, the integrity of ecosystems, and the viability of native species across their natural distribution within the Columbia Plateau Ecoregion (ALI 2014). Results indicating specific priority core areas under a range of goal levels were evaluated. The medium goal level was ultimately chosen as the version that best represents the patterns observed across all levels. The ALI Marxan analysis recognized the Hanford Site as an important priority core area at all goal levels. The Hanford Site overlays one of the larger priority core areas selected by the ALI analysis (Figure 17). This priority core area contained 36% of the shrub-steppe patches of viable size, 14% of the dunes, 14% of Townsend's ground squirrel habitat concentration areas, and 13% of the shrub-steppe habitat chosen by the ALI analysis. The ALI analysis adequately selected the Hanford Site on an ecoregional scale. At the planning unit size of 202 ha (500 ac), a large portion of the Hanford Site consistently met the conservation targets. However, at the local scale, it is apparent that some areas of high quality habitat were excluded from the ALI solution while other areas of low quality habitat were included. On the DOE-RL-managed portion of the Hanford Site, roughly 52% of the ALI best solution at the medium goal level intersects with the CHAMP best solution (Figure 18). This disparity reinforced the need for a local analysis with more detailed local data.

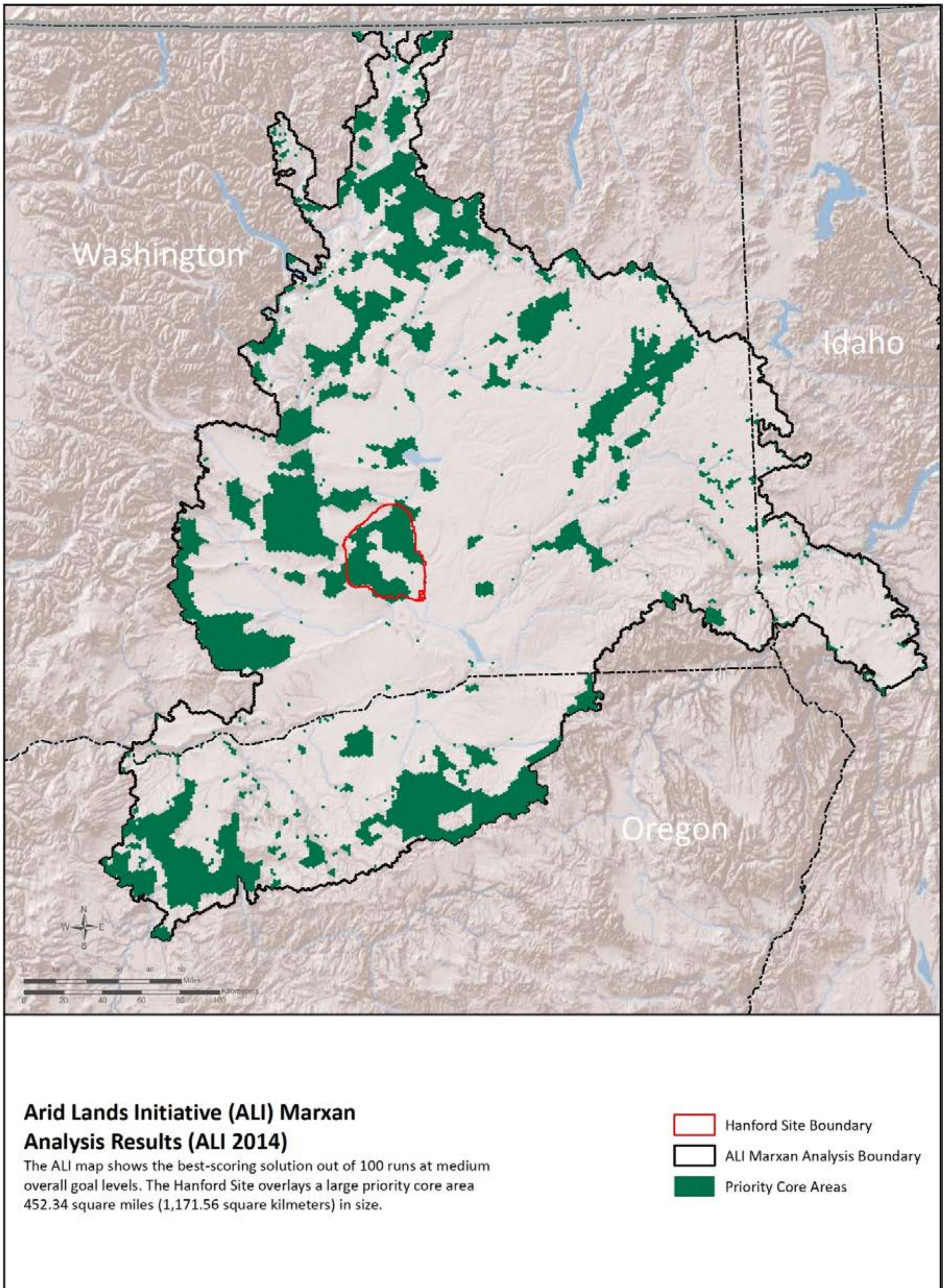

Figure 17. The Hanford Site shown within the Arid Lands Initiative Marxan Analysis Results.

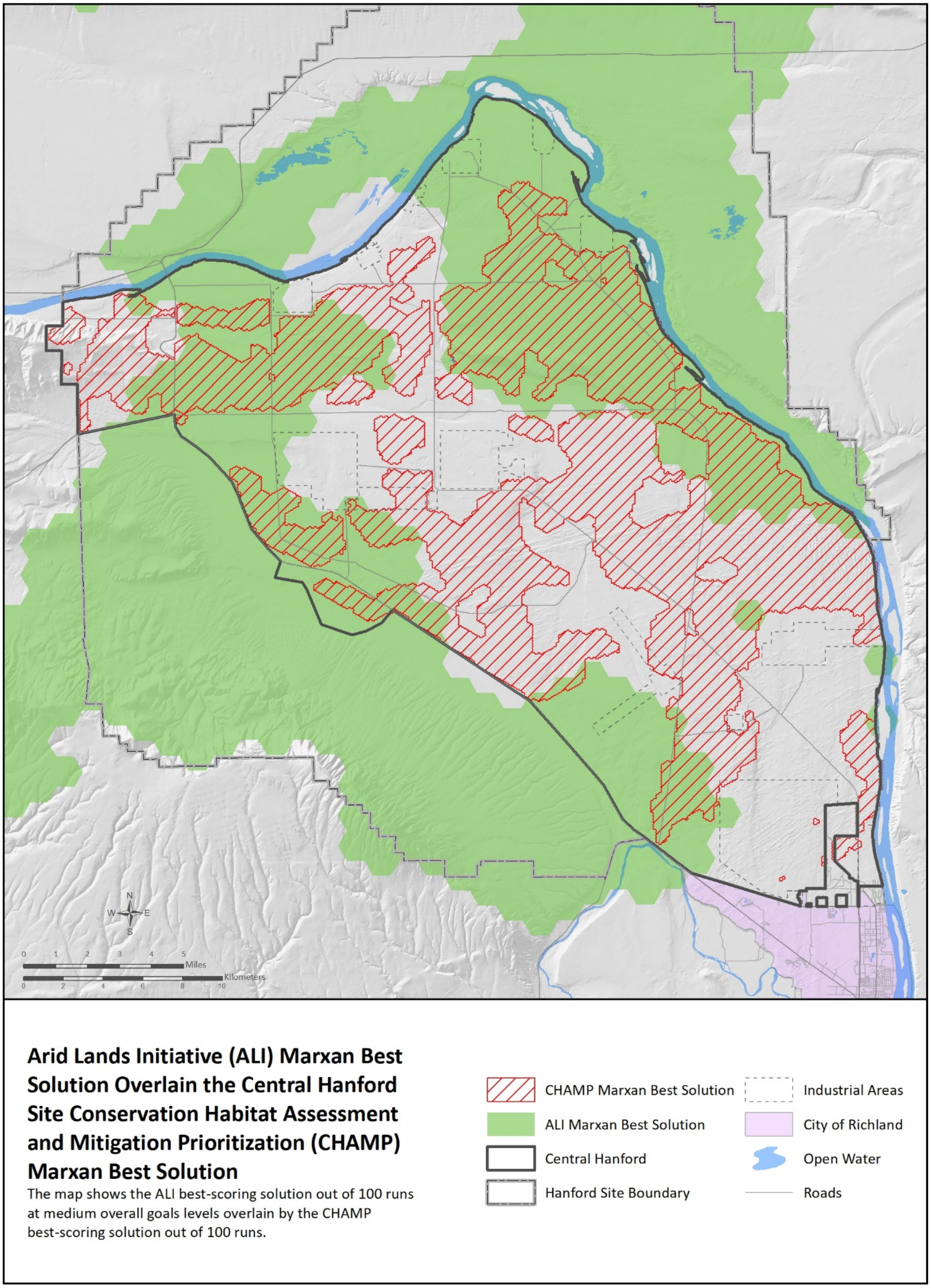

Figure 18. The Arid Lands Initiative Best Solution overlain with the CHAMP Best Solution.

3.5.5 Washington Wildlife Habitat Connectivity Group

The Washington WHCWG, co-led by the Washington State Department of Transportation and the Washington State Department of Fish and Wildlife (WDFW), is a science-based partnership of land and natural resource management agencies, organizations, Tribes, and universities. The mission of the WHCWG is to "promote the long-term viability of wildlife populations in Washington State through a science-based, collaborative approach that identifies opportunities to conserve and restore habitat connectivity (WHCWG 2010, 2011, 2012, 2013a, 2013b, 2014)." The WHCWG analyzed connectivity at a statewide scale (WHCWG 2010) and at the eco-regional level in the Columbia Plateau Ecoregion (WHCWG 2012, 2013a, Schroeder et al. 2015). The group also evaluated expected changes that may occur to habitat connectivity due to climate change at all scales (WHCWG 2011, 2013b, 2013c, 2014). The primary output of these analyses are linkage network maps showing areas of suitable habitat and the best remaining linkages connecting them. The linkage network maps were developed from two modeling approaches: focal species and landscape integrity. In the Columbia Plateau Ecoregion analysis, the focal species approach generated linkage networks for 11 focal species to represent the connectivity requirements of a larger assemblage of wildlife. The landscape integrity approach identified lands of relatively intact natural areas with low levels of human modification and the least-modified routes between them. The two approaches produced similar results. A list of outputs from the analyses include maps of resistance, habitat, cost-weighted distance, landscape integrity, linkage network centrality, linkage pinch-points, and barriers and restoration opportunities.

The Hanford Site is recognized in both the statewide and ecoregional analyses as a core area (large block [4,047+ ha or 10,000+ ac] of contiguous land with high landscape integrity) and as a habitat concentration area (habitat areas that are expect or known to be important for focal species based on actual survey information or habitat association modeling) for many species. The CHAMP best solution aligns with the WHCWG maps and can provide local detail. A good example can be seen in the WHCWG black-tailed jackrabbit normalized least-cost corridor 10-km (6.2-mi) limit network map (Figure 19). This raster map combines habitat concentration areas and linkages into a single map class. The CHAMP best solution generally matches the black-tailed jackrabbit network map including the corridors.

The CHAMP best solution along with other data can provide insight into animal movement corridors across the study area and to adjacent portions of the Columbia Plateau Ecoregion. Figure 20 shows how the CHAMP best solution, along with other data, may inform areas where wildlife-vehicle collisions could pose a threat.

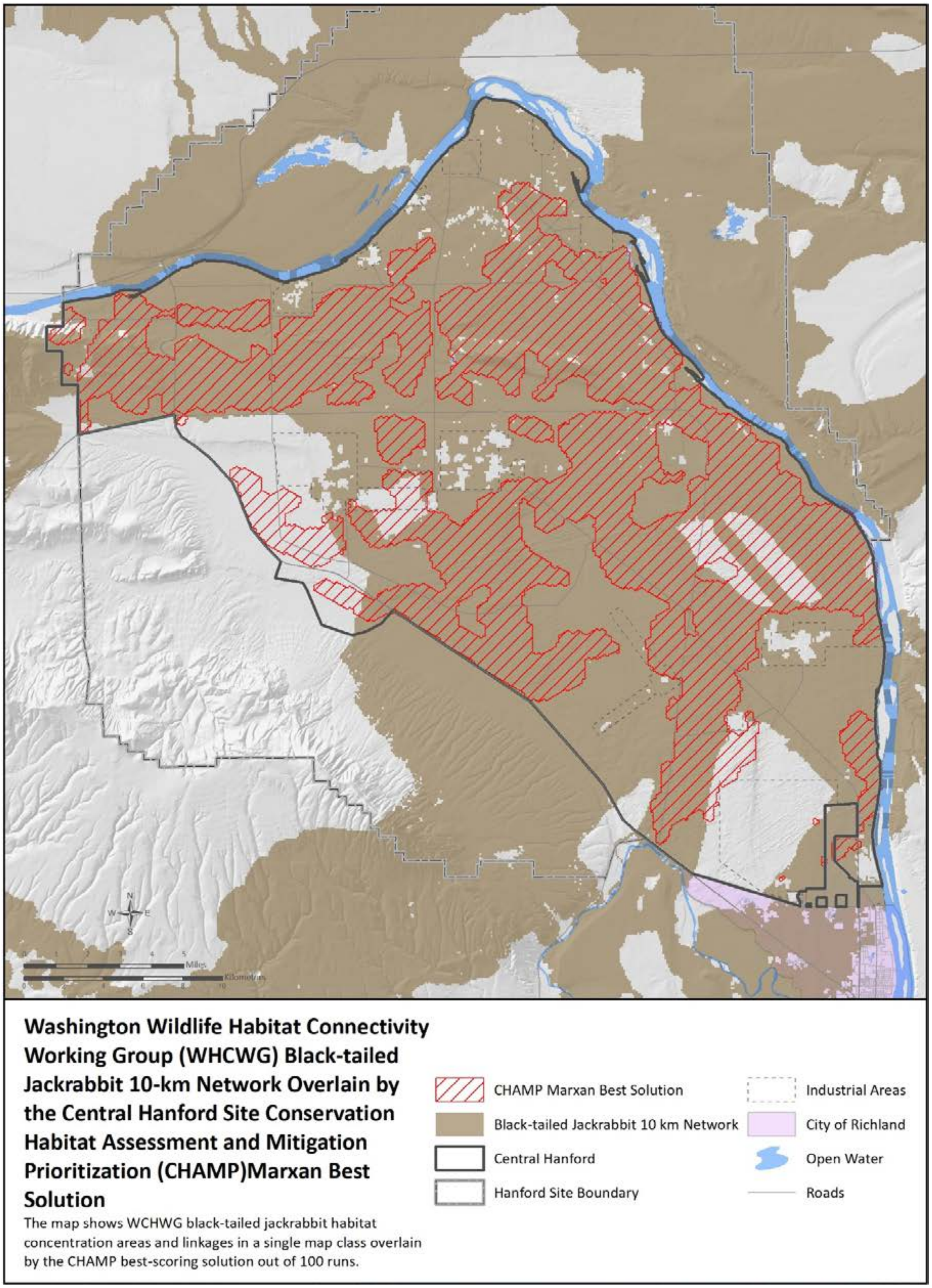

Figure 19. The Washington Wildlife Habitat Connectivity Working Group black-tailed jackrabbit 10-km network overlain with the CHAMP best solution.

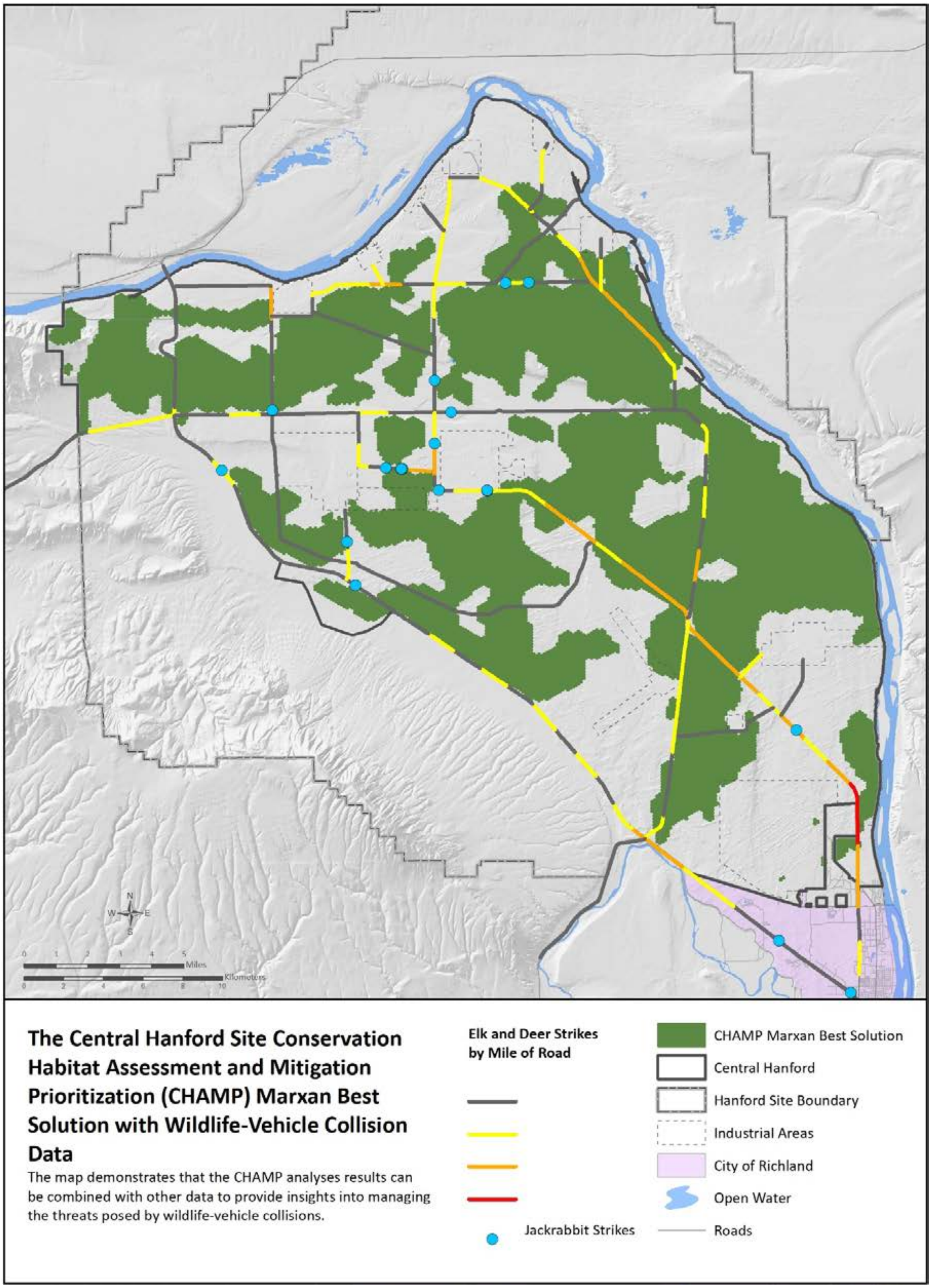

Figure 20. The wildlife-vehicle collision data overlain with the CHAMP best solution.

3.5.6 Implications for Mitigation

A purpose of this analysis was to identify potential areas on the DOE-RL-managed portion of the Hanford Site that would benefit from mitigation work and restoration efforts. Mitigation describes a series of actions that work to reduce or eliminate adverse impacts to biological resources, as required by the BRMP. Though most mitigation actions occur at the disturbed site, when the disturbed site cannot be rectified mitigation actions will occur in a separate area that would benefit from restoration. Identifying habitat areas that would benefit from restoration actions is a crucial step in the mitigation process. While the initial assessment determined the quality habitats of value on the study area, it can also be used to infer potential mitigation and restoration locations that will have the greatest beneficial effect on a landscape level. Additionally, reviewing data may provide reasoning to where mitigation actions may be the most successful based on both environmental and external factors. Marxan can be refined to highlight and create a potential best solution for mitigation targets. Use of this tool in future mitigation analysis is discussed in Section 3.6.

Providing a one-size fits all prescription for mitigation on the Hanford Site is not a feasible expectation of any analysis. However, generalized statements and processes for identifying priority mitigation areas based on status of surrounding areas, their long-term viability, connectivity, and the immediate impact that restoration actions could have on native habitats and species are possible. Identifying priority mitigation areas based on these landscape level factors presents an opportunity to improve both the mitigated area and the surrounding habitat. Ecological indicators can be compared against the best solution of this analysis. Some indicators that may be evaluated include:

- Status of Surrounding Areas
  - Identify planning units bordering or closely surrounding conservation priority areas. Restoring habitat in close proximity to conservation priority areas will buffer these areas and can increase resistance to invasion by non-native plant species, increase resilience after fire, and assist in the long-term viability of the conservation area. Additionally, using this strategy to buffer the small and micro-patches in the solution can increase the viability of the small conservation areas that are more vulnerable to degradation.
- Connectivity
  - Identify planning units that fragment the conservation priority area. Restoring these areas will reduce fragmentation within the conservation area and increase the movement ability of flora and fauna and increase resistance to non-native plant species, again increasing the long-term viability of the conservation area. This same strategy can be used to connect smaller patches of the solution. Performing restoration activities within planning units that increase the connectivity of the Columbia Basin (e.g., Yakima Training Center, USFWS managed portions of Hanford) as a whole should also be a priority of mitigation actions.

Once decisions are made on potential locations of mitigations based on ecological factors of the solution, staff can evaluate the potential success of restoration activities in those areas. This evaluation can be effective in avoiding unnecessary costs or effort in restoration. Attempting to mitigate in a Poor habitat area, as identified by this assessment, will likely be a challenge due to potential existing habitat conditions like cheatgrass cover, human disturbance, or isolation from other natural areas and seed sources. Though ideally restoration would be possible in all habitat areas, when dealing with limited resources they must be used as efficiently as possible. Habitats that are not completely degraded will be easier to restore and will provide more immediate positive impacts to the biological community. Multiple aspects of this analysis can be used to identify the most efficient way to improve habitat through mitigation. The following areas should be targeted when evaluating efficient habitat restoration:

- Planning units in the northern half of the Hanford Site (i.e., north of Route 11) and areas with a low potential for future infrastructure or development. Use future land-use (e.g., CLUP) information along with current cost/constraint layer to determine areas that are and will be least impacted by human activity.

- Areas surrounded by high quality habitat (Best Solution) that can act as a seed bank to the mitigation area, both through wind and animal dispersal. Areas surrounded by high quality habitat (rather than degraded cheatgrass habitat) will be less likely to be heavily invaded by cheatgrass and other non-natives post-restoration.

In addition to evaluating the ecological and external factors that will impact the success of future mitigation actions, it is important to evaluate the planning units to determine why they were not selected as part of the solution. This information can help guide specific mitigation actions after the planning units are chosen.

Some mitigation/habitat restoration actions may be targeted at a particular focal habitat. This can occur when activities on the Hanford Site disproportionately effects a specific species or community (e.g., jackrabbits, rare plants, Ferruginous Hawk, dense shrub habitat). Using the same indicators above in conjunction with pre-analysis target layers (Appendix D), data for a particular species or community can focus mitigation actions. Only evaluating the best solution when planning a mitigation focused on rectifying Burrowing Owl habitat loss would be short sighted. By evaluating both the best solution map layer and the Burrowing Owl target layer, mitigation planners can find areas that best fit the solution and the specific target, in this case Burrowing Owls. This level of analysis would work for all specific targets if needed to mitigate a specific impact by a project.

Once a mitigation area is chosen, Marxan can be used to potentially model the desired outcome of the mitigation actions. To perform these actions, the values of the individual planning units can be altered in the selected target layer to reflect the desired future conditions of the mitigated area, and the Marxan run will be performed under the same conditions. These results can hint at the potential future effects of the proposed actions at a landscape scale, including changes in connectivity, patch buffering, and habitat quality increase. After this evaluation, the mitigation plan can then be altered, if necessary, to create the desired changes.

3.6 FUTURE ANALYSIS

Performing this conservation assessment met the purpose of identifying areas of high habitat value and areas for restoration of habitat that meet the conservation goals and objectives of the Hanford Site. The solution provided, coupled with existing conservation documents and processes, will support ecological impact and mitigation decision making on the Hanford Site. This is not an absolute solution but an adaptive tool that can be employed in various ways to target generic or specific solutions. The emphasis on Marxan as a tool is key in understanding the value it can continue to bring to the Hanford Site EM program. The tool will only be as functional as the user allows it to be via representative targets, detailed input layers, goal valuation, constraints, and calibration.

At the time of publication there are already changes to the environmental landscape that would need to be updated in future analysis (e.g., wildfires). Ecosystems are made up of living organisms that will change over time; the analysis will need to do the same. Moving forward, the EM Team will be able to rerun Marxan solutions by adjusting target input layers as more data is collected, collecting new data for creation of new targets, and adjusting constraint layers as infrastructure is constructed or removed. The flexibility of the tool allows quick alterations to inputs and can produce new solutions by altering goals based on changes in political stances and feedback from customers and interested parties.

The immediate future of analysis will shift focus to gaining a deeper understanding of the secondary goal of the assessment, identifying potential areas on the Hanford Site that would benefit from mitigation work. To perform this investigation into mitigation areas, more than described in Section 3.5.6, will require a reset of focus and alterations to the inputs that better fit “highlighting” areas that meet mitigation potential goals. This process will begin by initiating new mini-workshops with staff to refine the goals or assessment. Items to consider for focusing solution to mitigation areas include, but are not limited to, the following:

- Identify planning units with Fair target ratings that can be moved into the Good category with mitigation actions like revegetation, animal reintroduction, or other habitat restoration activities

- Alter targets to better represent a mitigation habitat so Good ratings are no longer resources or habitats that are quality representations but rather have quality in its mitigation potential

- Make changes to current constraints and add new constraints specific to their impacts on mitigation and long-term success

- Manipulate target goal levels to highlight planning with weaker features that would benefit from mitigation or restoration.

With the foundation of the conservation assessment through Marxan built, it opens up many avenues for the EM program to explore different conservation and mitigation goals. In conjunction with the BRMP, even small level projects and ecological impacts can be evaluated by the ecosystem impacts those changes may bring. Staff within the EM Program have seen the value the solution outputs have in producing quick spatial displays that create conversation and brainstorming exercises amongst the biological resource specialists. The potential in performing future Marxan analysis is only limited by the time and resources available to the project. This tool supports the EM program goal of providing quality and timely support to ecological resource protection, conservation, and mitigation at the Hanford Site.

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APPENDIX A

VIABILITY ASSESSMENT FOR FOCAL HABITATS AND SPECIES

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APPENDIX A

VIABILITY ASSESSMENT FOR FOCAL HABITATS AND SPECIES

A.1 COMPLETED VIABILITY ASSESSMENT

The Mission Support Alliance's Ecological Monitoring Program team completed a viability assessment for the four focal habitats and species selected as the focus for the habitat assessment and prioritization for the Hanford Site (Tables A-1 through A-5). The focal habitats, species, and viability assessment were carried out following Open Standards methodology (http://cmp-openstandards.org/; TNC 2007; FOS 2009). The rationale for selection of each key ecological attribute, the sources of information used, and notes pertaining to how to relate the ratings to existing datasets or translate these attribute-indicator pairs into a Geographic Information System are further documented in an Excel file available upon request from MSA staff. This file contains any changes made as the habitat assessment and prioritization progresses.

A.1.1 References

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Table A-1. Completed and Adjusted Viability Assessment for Shared Inputs.

Category	Key Ecological Attribute	Indicator	Very Good	Good	Fair	Poor
Landscape Context	Fire Regime	Number of Fires (Past 44 Years) Low Frequency	0	1-2	3-4	>4
Landscape Context	Fire Regime	Number of Fires (Past 44 Years) High Frequency	>4	3-4	1-2	0
Condition	Critical/Unique Habitats	Presence of Critical/Unique Habitats (Talus slopes/cliffs, lithosols, vernal pools, springs, ponds, snake hibernacula, rookeries, bat roosting sites, riparian habitats, critical habitat for federal threatened or endangered species).	3 or more present	2 present	1 present	0 present
Condition	Vegetative Composition	Lack of Noxious Weeds	0/ha	>0-5/ha	>5-25/ha	>25/ha

Table A-2. Completed and Adjusted Viability Assessment for Shrub-steppe.

Category	Key Ecological Attribute	Indicator	Very Good	Good	Fair	Poor
Condition	Wildlife Community	Presence of Sagebrush Obligate Wildlife Species –Black Tailed Jackrabbits	5-7 Hexagons	3-4 Hexagons	1-2 Hexagons	0 Hexagons
Condition	Native Shrub Cover	Percent Cover	> 3% Cover	Present to approximately 3%	Irregular or patchy distribution within a polygon	No Shrubs
Condition	Vegetative Composition	Vegetation Cover Type	BRMP Level 4 Vegetation Cover Types and 5 Element Occurrence	BRMP Level 34 Vegetation Cover Types	BRMP Level 2 Vegetation Cover Types	BRMP Level 1 Vegetation Cover Types and Level 0 Resources
Landscape Context	Connectivity	Proximity to Shrub Patches	0 - 200 m	>200 - 400 m	>400 - 600 m	>600 m
Size	Absolute Shrub Patch Size	Area	> 1000 ha	> 500-1000 ha	16-500 ha	< 16 ha

Table A-3. Completed and Adjusted Viability Assessment for Grasslands

Category	Key Ecological Attribute	Indicator	Very Good	Good	Fair	Poor
Size	Absolute Patch Size	Area	>100 ha	>50 - 100 ha	10-50 ha	< 10 ha
Landscape Context	Connectivity	Proximity to Other Patches	0 - 200 m	>200 - 400 m	>400 - 600 m	>600 m
Condition	Vegetation Composition	Vegetation Cover Type	Bunchgrasses, [Snow buckwheat]/Bunchgrasses, Half-Shrubs/Bunchgrasses	Bunchgrasses with patchy / < 3% shrub cover	> 3% Shrub Cover with Bunchgrass understory	Cheatgrass understory
Condition	Native Shrub Cover	Percent Cover	No Shrubs	Irregular or patchy distribution within a polygon (Indicated by brackets in Vegetation Report)	Present to approximately 3% (Indicated by parentheses in Vegetation Report)	> 3% Cover (Indicated by no modifier in Vegetation Report)

Table A-4. Completed and Adjusted Viability Assessment for Dunes.

Category	Key Ecological Attribute	Indicator	Very Good	Good	Fair	Poor
Condition	Ecosystem Intactness	Indicator Rare Dune Plant Species	3 or more species	2 species	1 species	0 species
Size	Absolute Patch Size	Acreage of Open Sand	>20 ha	>5-20 ha	>0-5 ha	No Open Sand
Condition	Vegetation Composition	Vegetation Cover Type	Element Occurrence Designated Areas (Central Hanford Dunes, North Gable Dunes, and 300 Area Stabilized Dune) and Open Sand (No Vegetation)	Bunchgrass Dominated Understory	Cheatgrass Dominated Understory	Non vegetated/Industrial areas
Condition	Soil Type	Presence of Sandy Soil	N/A	Sand Present	Sand Absent	N/A
Landscape Context	Connectivity	Proximity to Other Open Sand Patches	0 - 200 m	>200 - 400 m	>400 - 600 m	>600 m

Table A-5. Completed and Adjusted Viability Assessment for Burrowing Animals.

Category	Key Ecological Attribute	Indicator	Very Good	Good	Fair	Poor
Landscape Context	Connectivity	Dispersal Distance to determine Connectivy Between Communities	0-500 m	500-1000 m	1000-2000 m	> 2000m
Landscape Context	Townsend's Ground Squirrel Habitat *	Concentration Areas	≥ 95%	≥90-<95%	≥85-<90%	< 85%
Landscape Context	Burrowing Owl Habitat *	Concentration Areas	>240 ha	>45-240 ha	4-45 ha	<4 ha

APPENDIX B

DATA AVAILABILITY AND DATA GAPS

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APPENDIX B

DATA AVAILABILITY AND DATA GAPS

In the process of developing and completing the viability assessment for the four focal habitats and species that will guide the habitat assessment and prioritization, the Mission Support Alliance Ecological Monitoring Program team crosswalked potential key ecological attributes and indicators with the data they have available for the Hanford Site. The project categorized each potential attribute-indicator pair based on data availability and potential for filling remaining data gaps (Tables B-1 and B-2). This availability of data then informed the final set of attributes-indicators contained in the viability assessment. Therefore, the attributes and indicators in this evaluation of data availability do not directly match those in the final viability assessment (Appendix A). As the project moves forward in preparing the data layers as inputs to the Marxan analysis, and as further data are collected in the future (for this or other projects), the project may be able to include more or different attribute-indicator pairs as Marxan targets in further iterations of the habitat assessment and prioritization.

Table B-1. Cell Format and Color-Coding Showing Decisions the Project Made on Data Availability and Data Gaps.

Green Boxes indicates project has all needed information
Red Boxes indicates No Information readily available and cannot use this KEA without collecting data.
Yellow Boxes indicate some information available, but may be collected through a Rapid Assessment.

Table B-2. Data Availability and Data Gap Decision for Focal Species and Habitats. (5 Pages)

Category	Key Ecological Attribute	Indicator	Map Layer Available	Additional Data Collection	Meeting Notes
Focal Habitat: Shrub-Steppe					
Landscape Context	Fire Regime	Departure from Historical Fire Regime	Fire Map	No	Must match Indicator for Grassland and Shrub-steppe Fire Regimes. The Ratings should be different to reflect different impacts of fire to the habitats, but Indicator should be the same. **Action:** Determine Indicator. **Action:** Determine feasibility of mapping.
Condition	Wildlife Community	Presence of Sagebrush Obligate Wildlife Species (e.g., Sagebrush Sparrows, Jackrabbits)	Species Presence Layers (Jackrabbits, Sagebrush Sparrows)	Add Indicator to Rapid Assessment	Added Sage Thrashers and Brewer's Sparrow to indicator list with Sagebrush Sparrows and Jackrabbits. **Action:** Determine if there are any other sagebrush obligate species we should add to list.
Condition	Biological Crust	Coverage	None	Add Indicator to Rapid Assessment	Added Biological Crust to Grasslands as well. Rapid assessment would give general idea of presence in area. Without Rapid Assessment, we will not be able to use this KEA.
Condition	Critical/Unique Habitats	Presence of Critical/Unique Habitats	Critical/Unique Habitats layers	No	Added Critical Unique Habitat to Grasslands and Dunes. **Action:** Define critical unique habitats for all areas.
Condition	Native Shrub Cover	% Cover	Some data in Vegetation Layer	Marginal; Could add to Rapid Assessment (same as Grasslands)	Currently only have information on >3% shrub cover. Would likely need more intensive field work that cannot be satisfied in a Rapid Assessment. **Action:** Decide between Options (1) work with >3% data; (2) determine feasible field methods for rapid assessment; or (3) work with >3% data and perform extensive survey in 2019.
Condition	Understory Composition	Ratio between Natives & Non-natives Native vs. Non-native species composition	Some Data in Vegetation Layer	Yes Can change indicator to work with our Vegetation Layer Data	Will be same indicator as in Grasslands and Dunes. Can use vegetation layer data to determine relative levels of native and non-native species and rate sites based on dominant species composition.
Landscape Context	Connectivity	Proximity to Other Patches	Vegetation Layer	No	Have GIS data in the Vegetation Layer. No additional data/actions needed.

Table B-2. Data Availability and Data Gap Decision for Focal Species and Habitats. (5 Pages)

Category	Key Ecological Attribute	Indicator	Map Layer Available	Additional Data Collection	Meeting Notes
Size	Patch Size	Area	Vegetation Layer	No	Have GIS data in the Vegetation Layer. No additional data/actions needed.
Condition	BRMP Level [a]	Area	BRMP Layers	No	KEAs adequately cover the information that would be displayed in BRMP, with the exception of Bald Eagles and FEHA, which are not indicators of good shrub-steppe habitat.
Condition	Vegetative Composition	Lack of Noxious Weeds	Some data in vegetation layer	Add indicator to Rapid Assessment	Added to list. Current KEAs do not take presence of noxious weeds into account. Lack of noxious weeds indicates the habitat is resistant to invasion and higher quality than one with noxious weeds. Easy to add to Rapid Assessment.
Focal Habitat: Grasslands					
Size	Patch Size	Area	Vegetation Layer	No	Have GIS data in the Vegetation Layer. No additional data/actions needed.
Condition	Vegetation Composition	Native Forbs, Abundance & Diversity	None	Could add to Rapid Assessment	No data on forbs. Would require intensive field survey in 2019 to get good information. Could add to Rapid Assessment in simplified form to capture some data on forb presence. **Action:** Determine what component of the forb community (abundance, diversity) it is feasible to measure in the Rapid Assessment. **Action:** If we add this to Grasslands, should we add it to Shrub-steppe and Dunes?
Landscape Context	Connectivity	Proximity to Other Patches	Vegetation Layer	No	Have GIS data in the Vegetation Layer. No additional data/actions needed. Remember proximity to Good/Very Good Shrub-steppe and Dune habitat should be counted in this.
Landscape Context	Fire Regime	Departure from Historical Fire Regime	Fire Map	No	Must match Indicator for Grassland and Shrub-steppe Fire Regimes. The Ratings should be different to reflect different impacts of fire to the habitats, but Indicator should be the same. **Action:** Determine Indicator. **Action:** Determine feasibility of mapping.

Table B-2. Data Availability and Data Gap Decision for Focal Species and Habitats. (5 Pages)

Category	Key Ecological Attribute	Indicator	Map Layer Available	Additional Data Collection	Meeting Notes
Condition	Vegetation Composition	Native vs. Non-native species composition	Some Data in Vegetation Layer	Can change indicator to work with our Vegetation Layer Data	Will be same indicator as in Shrub-steppe and Dunes. Can use vegetation layer data to determine relative levels of native and non-native species and rate sites based on dominant species composition.
Condition	Native Shrub Cover	Percent Cover	Some Data in Vegetation Layer	Marginal; Could add to Rapid Assessment (same as Shrub-steppe)	Currently only have information on >3% shrub cover. Would likely need more intensive field work that cannot be satisfied in a Rapid Assessment. **Action:** Decide between options (1) work with >3% data, (2) determine feasible field methods for rapid assessment, or (3) work with >3% data and perform extensive survey in 2019. For grasslands it is easier to use our current data, if we want to say that Good grasslands have <3% shrub cover.
Condition	Biological Crust	Coverage	None	Add Indicator to Rapid Assessment	Added Biological Crust to Shrub-steppe as well. Rapid assessment would give general idea of presence in area. Without Rapid Assessment, we will not be able to use this KEA.
Condition	Critical Unique Habitat	Presence of Critical/Unique Habitats	Critical/Unique Habitats layers	No	Added Critical Unique Habitat to Grasslands and Dunes. **Action:** Define critical unique habitats for all areas.
Condition	Vegetative Composition	Lack of Noxious Weeds	Some data in vegetation layer	Add indicator to Rapid Assessment	Added to list. Current KEAs do not take presence of noxious weeds into account. Lack of noxious weeds indicates the habitat is resistant to invasion and higher quality than one with noxious weeds. Easy to add to Rapid Assessment.
Focal Habitat: Dunes					
Condition	Ecosystem Intactness	Indicator Rare Dune Plant Species	Rare Plants	Add indicator to Rapid Assessment	Rapid assessment provides good opportunity to identify new rare plant locations within the dunes. Would just be incidental sightings, not full survey. Would be fine with data we have if necessary.

Table B-2. Data Availability and Data Gap Decision for Focal Species and Habitats. (5 Pages)

Category	Key Ecological Attribute	Indicator	Map Layer Available	Additional Data Collection	Meeting Notes
Condition	Non-Fragmentation	Intact without Fragmentation	Infrastructure Layers	Conceptualize & Create Layer	Have the data. Important in keeping matrix of active dunes and allowing movement. **Action:** Need to figure out how to create layer with the data we have. Could use similar method to Ground Squirrel model.
Condition	Ecosystem Intactness	Indicator Wildlife Species	Some Wildlife Data Points	Add indicator to Rapid Assessment	Have limited data on reptiles. Found sagebrush lizards prefer the Southern face of dunes. More species information would be useful in determining highly "used" areas of dune by noting tracks and animal sightings. **Action:** Finalize list of indicator wildlife species/signs.
Size	Large System Acreage	Acreage of Open Sand	Vegetation, Soils, & Surface Geology Maps	No	Have GIS data. Richard used methods in veg map that could be used to identify open sand.
Condition	Successional Diversity	Appropriate Amount of Active Dune & Stabilized Dune	Vegetation & Surface Geology Maps	Conceptualize & Create Layer	**Action:** Need clarification on what this group wanted to know/measure with this Indicator. Where do we find supporting information about what a good amount of active vs. stabilized dune looks like? If not enough supporting research, remove Indicator.
Condition	Vegetation Composition	Native vs. Non-native species composition	Data in Vegetation Layer	Can change indicator to work with our data	Same methods as shrub-steppe and grasslands. Importance in dune habitat as cheatgrass with artificially stabilize dunes.
Condition	Soil Type	Presence of Sandy Soil	Soil data	No	Need soil information as key characteristic in distinguishing dunes from most other habitats.
Condition	Vegetative Composition	Lack of Noxious Weeds	Some data in vegetation layer	Add indicator to Rapid Assessment	Added to list. Current KEAs do not take presence of noxious weeds into account. Lack of noxious weeds indicates the habitat is resistant to invasion and higher quality than one with noxious weeds. Easy to add to Rapid Assessment.
Landscape Context	Connectivity	Proximity to Other Patches	Vegetation Layer	No	Have GIS data in the Vegetation Layer. No additional data needed. Remember proximity to Good/Very Good Shrub-steppe and Grasslands habitat should be counted in this. **Thought**: this could replace our "appropriate amount of active and stabilized dune" indicator.

Table B-2. Data Availability and Data Gap Decision for Focal Species and Habitats. (5 Pages)

Category	Key Ecological Attribute	Indicator	Map Layer Available	Additional Data Collection	Meeting Notes
Focal Species Group: Burrowing Animals					
Landscape Context	Connectivity among Communities	Dispersal Distance	Ground Squirrel Colonies	No	Have data. No further collection required.
Condition	Soil Type & Depth	Type & Depth	Soils & Surface Geology Maps	Maybe (Soil Depth)	**Action:** Needs further discussion. Is measuring soil depth feasible/efficient in a Rapid Assessment? If not, may have to stick to only soil type.
Condition	Protection Structure	% Structure Cover	Vegetation Layer, Possibly Digitize Small Structures	Maybe	**Action:** Needs further discussion about feasibility of digitizing small protection structures. If not feasible, remove from Indicators.
Size	Population	Active Burrow Density	Some Data	No	Have data on active burrows.
Landscape Context	Townsend's Ground Squirrel Habitat [a]	Concentration Areas	Model Output	No	
Landscape Context	Burrowing Owl Habitat [a]	Concentration Areas	Model Output	No	**Action:** Are these concentration areas covered by the Townsend's Ground Squirrel habitat? Could add into model and if it does not significantly change the output, do not include.

[a] From habitat suitability models created in previous scopes of work within the Ecological Monitoring program.

BRMP = *Biological Resources Management Plan*
FEHA =
GIS = Geographic Information System
KEA = key ecological attributes

APPENDIX C

CONSTRAINT LAYER CATEGORY AND WEIGHTING TABLE

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APPENDIX C

CONSTRAINT LAYER CATEGORIES AND SUB-CATEGORIES

The project identified 11 categories and 73 sub-categories of constraints on the DOE-RL-managed portion of the Hanford Site including areas under industrial use or highly disturbed areas zoned for development under the Hanford Comprehensive Land-Use Plan (DOE/EIS-0222-F), National Historical Park sites, waste sites, utility towers and lines, roads, railroads, structures, fences, wells, and borrow pits (Table C-1). The project ranked (scale: 0 to 10) the sub-categories of constraints by their ability to limit the habitat to function (higher numbers being more limiting). All constraint features were mapped across the study area as polygons. Some features (utility towers and lines, primary and secondary roads, railroads, fences, and wells) required buffering to better characterize area of disturbance surrounding them.

Table C-1. Constraint Layer Categories, Ranking and Buffering. (3 Pages)

Constraint	Cost Ranking (Scale: 0 to 10)	Buffer
Areas under Industrial Use or Highly Disturbed		
ERDF	8	None
Wye Barricade	7	None
Yakima Barricade	6	None
300 Area	5	None
200-West Area	5	None
200-East Area	5	None
WSCF	4	None
US Ecology	4	None
Rest Area	4	None
Rattlesnake Barricade	4	None
HAMMER	4	None
Energy Northwest	4	None
200 Areas Sewage Treatment Plant	4	None
100-K Area	4	None
White Bluffs Substation	3	None
Telecommunications Facility	3	None
Midway Substation	3	None
Meteorology Lab	3	None
HJ Ashe Substation	3	None
EVOC	3	None
Cold Test Facility	3	None
Benton Substation	3	None
400 Area	3	None
251W Substation	3	None
200 Areas Met Tower	3	None
200 Areas Fire Station	3	None
100 Areas Fire Station	3	None
300 VTS	2	None
100-B/C Area	2	None

Table C-1. Constraint Layer Categories, Ranking and Buffering. (3 Pages)

Constraint	Cost Ranking (Scale: 0 to 10)	Buffer
LIGO	1.5	None
HX Pump and Treat Facility	1.5	None
618-10	1.5	None
100-N Area	1.5	None
100-H Area	1.5	None
100-D Area	1.5	None
Old Cross Site Transfer Line Facilities	1	None
Export Water Line Buildings	1	None
600-3	1	None
100-F Area	1	None
Areas Zoned for Development (Hanford Comprehensive Land-Use Plan)		
Industrial (Exclusive)	2	None
Industrial	1	None
Recreation (High Intensity)	1	None
Recreation (Low Intensity)	1	None
Research & Development	1	None
Conservation (Mining)	0	None
Preservation	0	None
National Historical Park Sites		
Allard Pump House	6.5	None
B Reactor	6.5	None
Bruggemann's Warehouse	6.5	None
Hanford High School	6.5	None
White Bluffs Bank	6.5	None
Waste Sites (WIDS - Accepted or Newly Discovered with No Reclass)		
All Waste Sites except Inactive Sites Greater than 2 ha (5ac)	10	None
Inactive Sites Greater than 2 ha (5 ac) and Less than 100 ha (247 ac)	2	None
Inactive Sites Greater than 100 ha (247 ac)	0	None
Utility Towers and Lines		
115 kV or Greater	3.5	10 Meters
Less than 115 kV	2	2 Meters
Roads		
Primary (Highway)	7	10 Meters
Secondary (Well Travelled)	5.5	10 Meters
Secondary (Less Travelled)	4	10 Meters
Local Paved	4	None
Unpaved	1.5	None
Railroads		
Existing Railway	2	5 Meters
Removed Railway	2	5 Meters
Structures		
Building	6	None
Trailer	6	None
Structures	6	None

Table C-1. Constraint Layer Categories, Ranking and Buffering. (3 Pages)

Constraint	Cost Ranking (Scale: 0 to 10)	Buffer
Fences		
Chain Link or Multi-Strand	7	1 Meter
Single Strand	1	1 Meter
Wells		
In-Use	7	32.33 Meters
Decommissioned	1	32.33 Meters
Borrow Pits		
Active	8	None
Proposed	4	None
Inactive or Closed	1	None

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APPENDIX D

MARXAN TARGET SPATIAL INPUT LAYER MAPS

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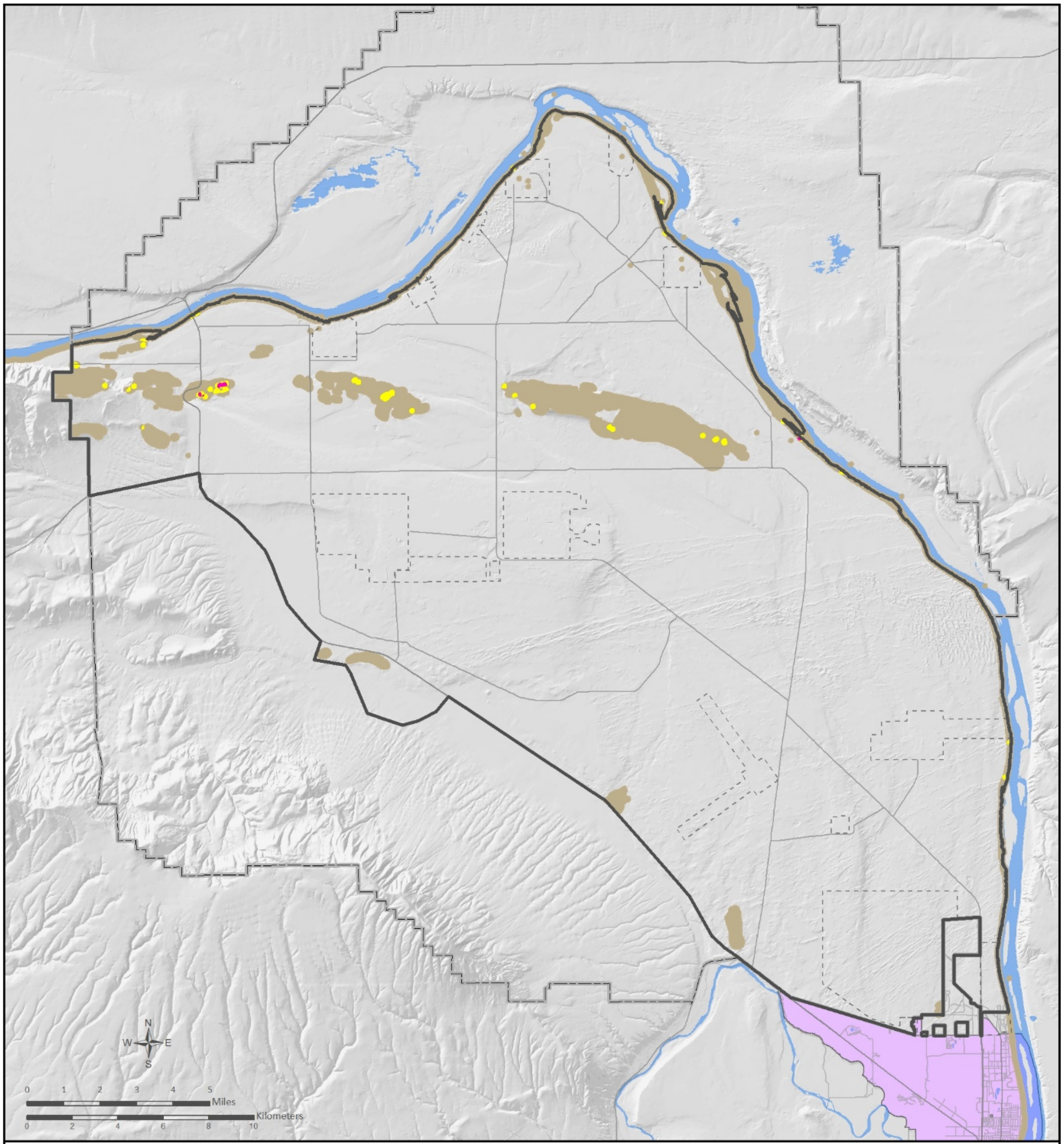
APPENDIX D

MARXAN TARGET SPATIAL INPUT LAYER MAPS



CHAMP MARXAN Spatial Input Map D-1

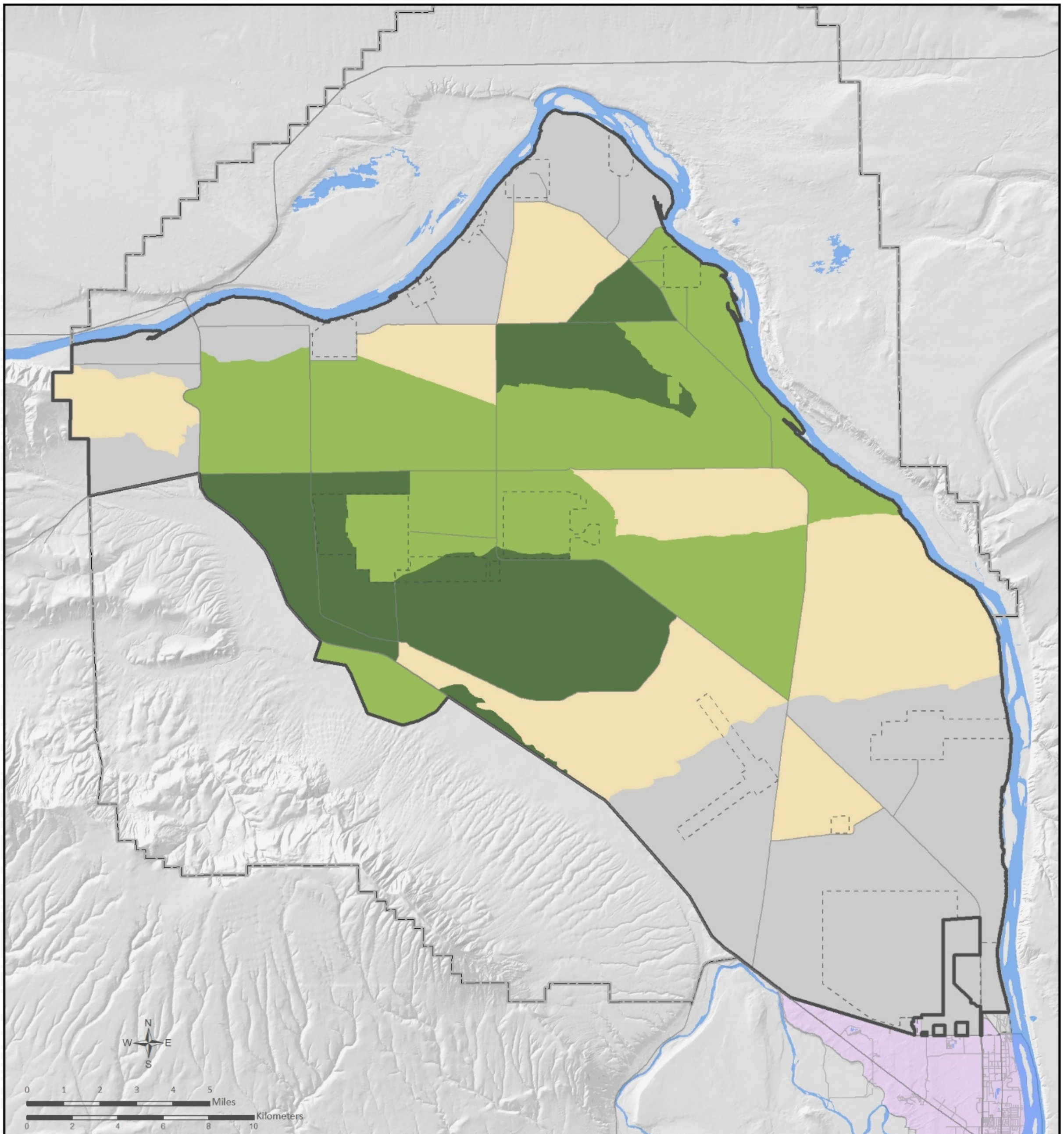
Shared Attributes - Critical Habitat/Species

Critical or unique habitat features identified on the DOE-RL managed portion of the Hanford Site that provide high value to shrub-steppe and grassland habitats include springs, vernal pools, seasonally wet areas, sloughs, ponds, riparian areas, talus slopes-cliffs-lithosols, bat roosts, rookeries, snake hibernacula, and federal threatened and endangered species (Umtanum desert buckwheat).

Presence of Critical/Unique Habitats and Species

- Very Good (3 or more)
- Good (2)
- Fair (1)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-2

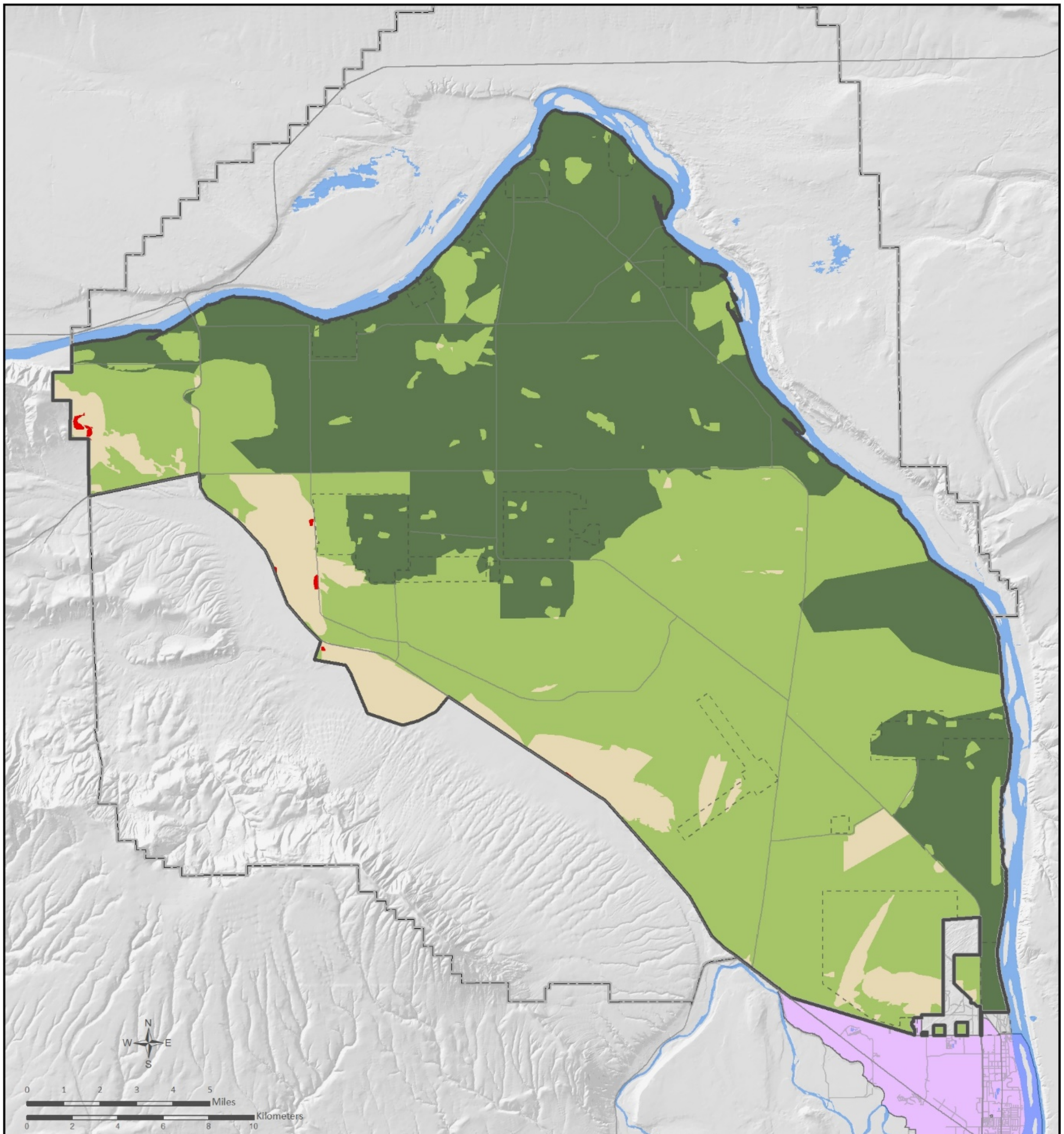
Shared Attributes - Vegetation Composition

Surveys were conducted on the DOE-RL managed portion of the Hanford Site (study area) in 2014 for 14 species of noxious weeds. The study area was partitioned into regions based on major roads and geographic features. Number of weeds per area was extrapolated to these regions based on survey data.

Lack of Noxious Weeds (Weeds per Hectare)

- Very Good (0/ha)
- Good (>0-5/ha)
- Fair (16-500/ha)
- Poor (>25/ha)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-3

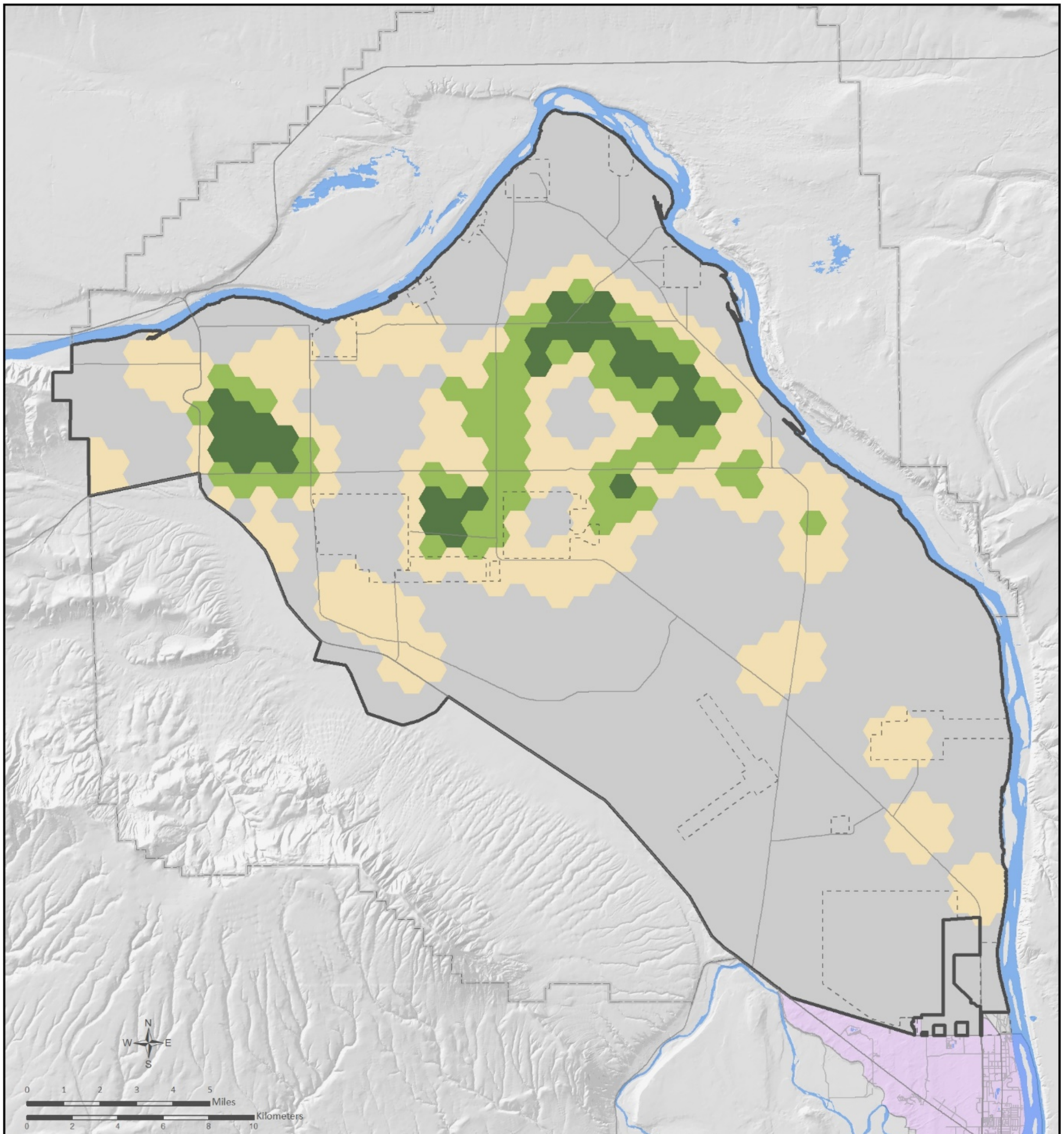
Shrub Steppe - Fire Regime

Fire has major impacts on shrub-steppe habitats. Big sagebrush, the predominant shrub in shrub-steppe habitats on the Hanford Site, lacks physical adaptations to survive and recolonize after intense or repeated fires. Areas with lower frequency of fire are more suitable for conservation of shrub-steppe habitat.

Number of Fires (Past 44 years)

- Very Good (0)
- Good (1-2)
- Fair (3-4)
- Poor (>4)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-4

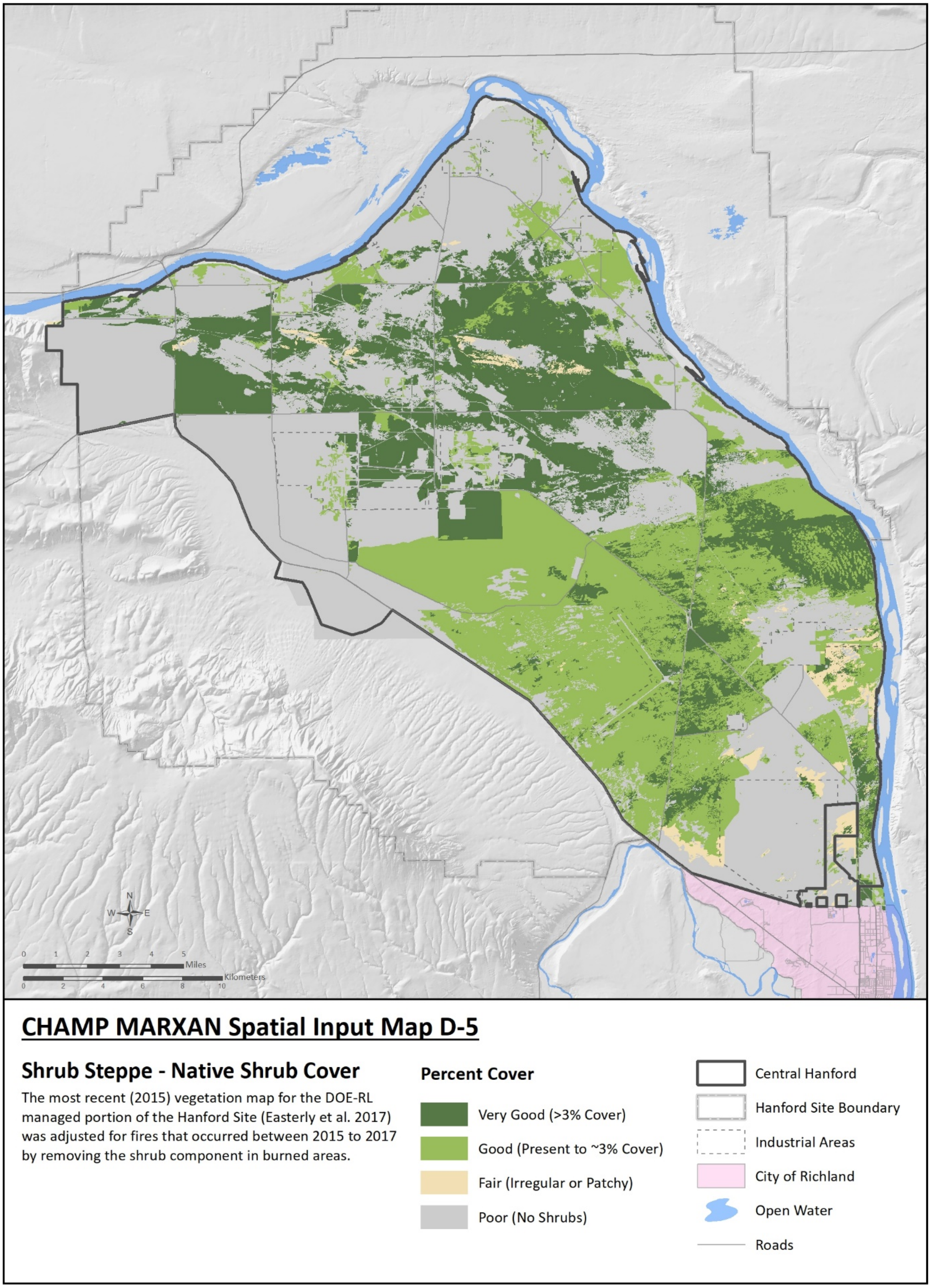
Shrub Steppe - Wildlife Community

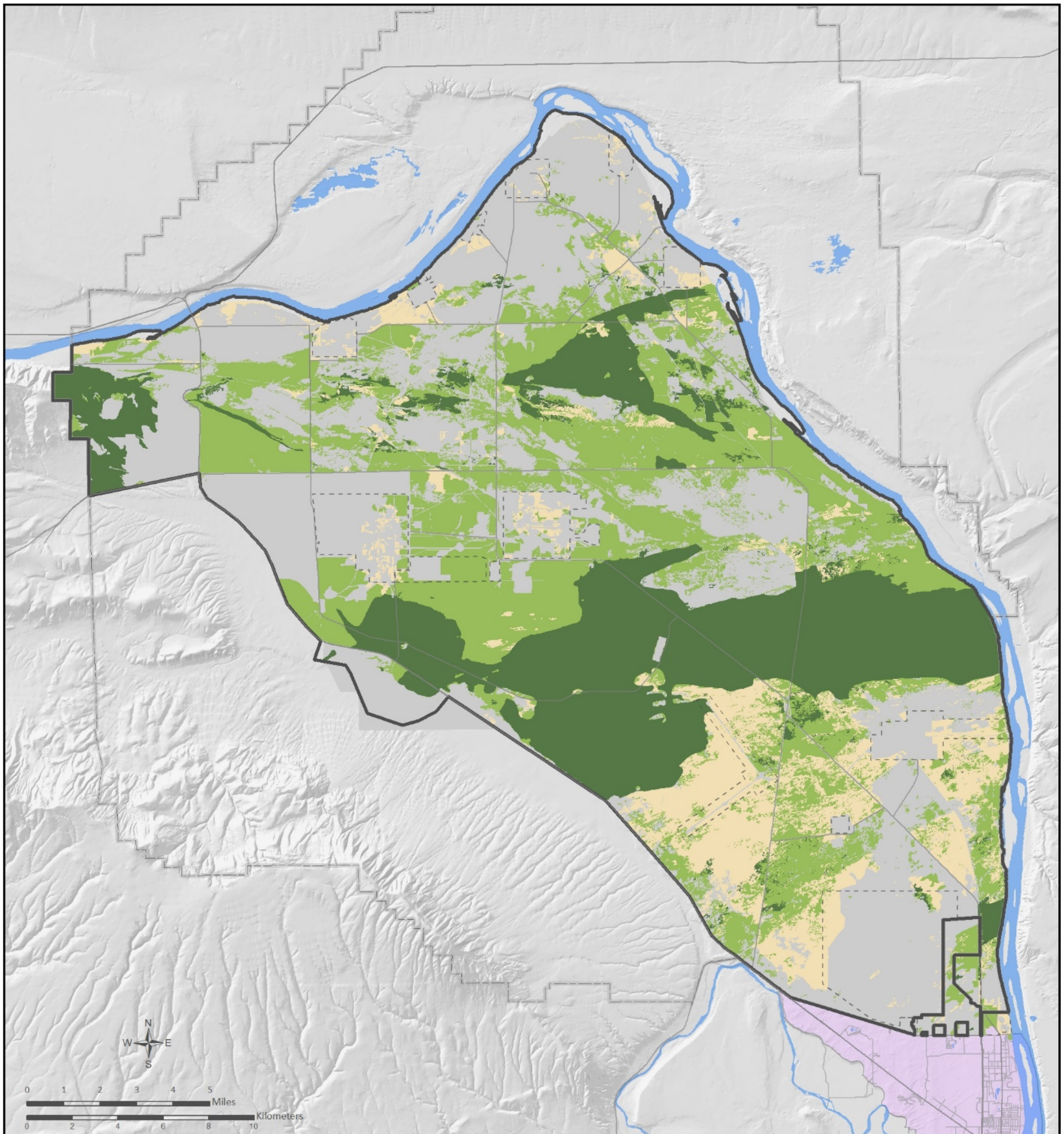
A good indicator of function and ecological integrity of shrub-steppe habitats is the presence of sagebrush obligate wildlife species. Substantial data on the distribution of black-tailed jackrabbits have been collected on the DOE-RL managed portion of the Hanford Site as part of work conducted by MSA (Wilde et al. 2012, Lindsey et al. 2014, Grzyb et al. 2016). The current study design used these jackrabbit specific data as a proxy for other sagebrush obligate species.

Presence of Black-Tailed Jackrabbits

- Very Good (5-7 Hexagons)
- Good (3-4 Hexagons)
- Fair (1-2 Hexagons)
- Poor (0 Hexagons)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads


N
W
E
S
0 1 2 3 4 5 Miles
0 2 4 6 8 10 Kilometers
CHAMP MARXAN Spatial Input Map D-5
Shrub Steppe - Native Shrub Cover
The most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.
Percent Cover
Very Good (>3% Cover)
Good (Present to ~3% Cover)
Fair (Irregular or Patchy)
Poor (No Shrubs)
Central Hanford
Hanford Site Boundary
Industrial Areas
City of Richland
Open Water
Roads



CHAMP MARXAN Spatial Input Map D-6

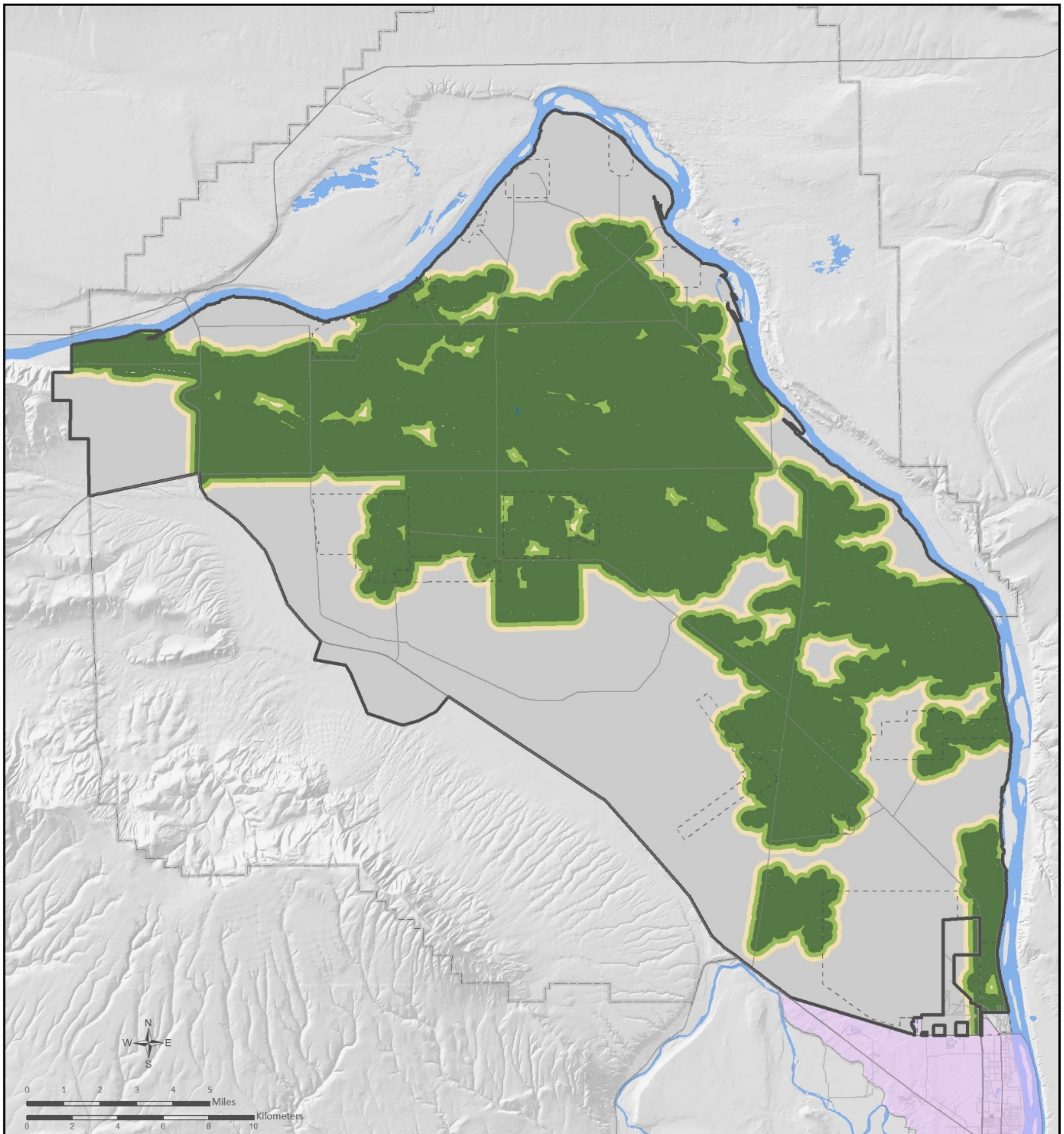
Shrub Steppe - Vegetation Composition

A vegetation cover type map was created based on resource priority levels outlined in the Hanford Site Biological Resources Management Plan (BRMP) (DOE 2017). The most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Vegetation Cover Type (BRMP Level)

- Very Good (BRMP Levels 4 & 5)
- Good (BRMP Level 3)
- Fair (BRMP Level 2)
- Poor (BRMP Level 1 & 0)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-7

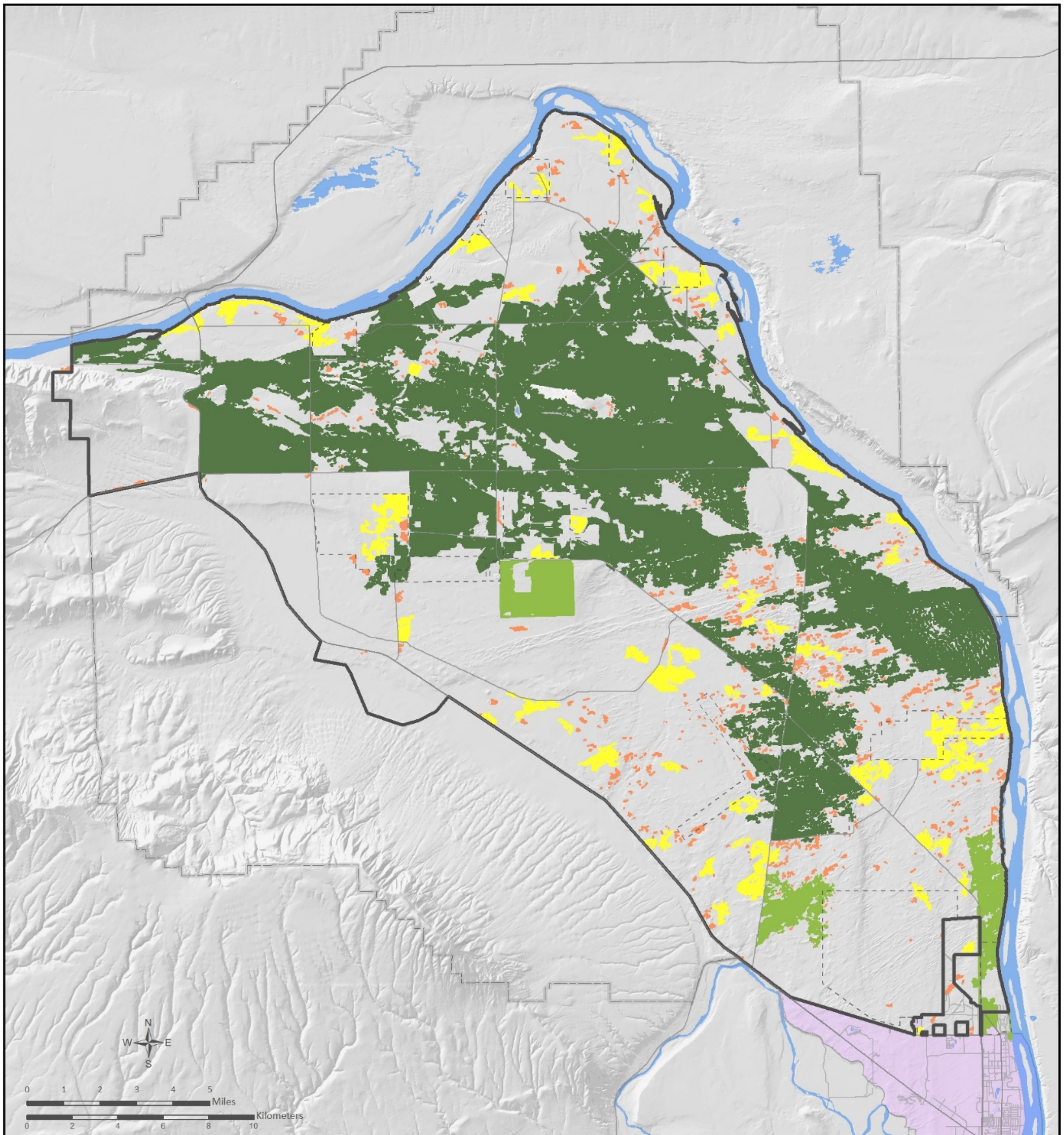
Shrub Steppe - Connectivity

The connectivity of habitat is essential for the movement of organisms and their genes across the landscape.
To create a measure of connectivity/proximity of shrub-steppe habitat at a local scale, all shrub patches (from the absolute shrub patch size layer) greater than 200 hectares on theDOE-RL managed portion of the Hanford Site were selected and buffered with multi-rings in 200-meter increments.

Proximity to Shrub Patches (meters)

- Very Good (0 - 200 m)
- Good (>200 - 400 m)
- Fair (>400 - 600 m)
- Poor (>600 m)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-8

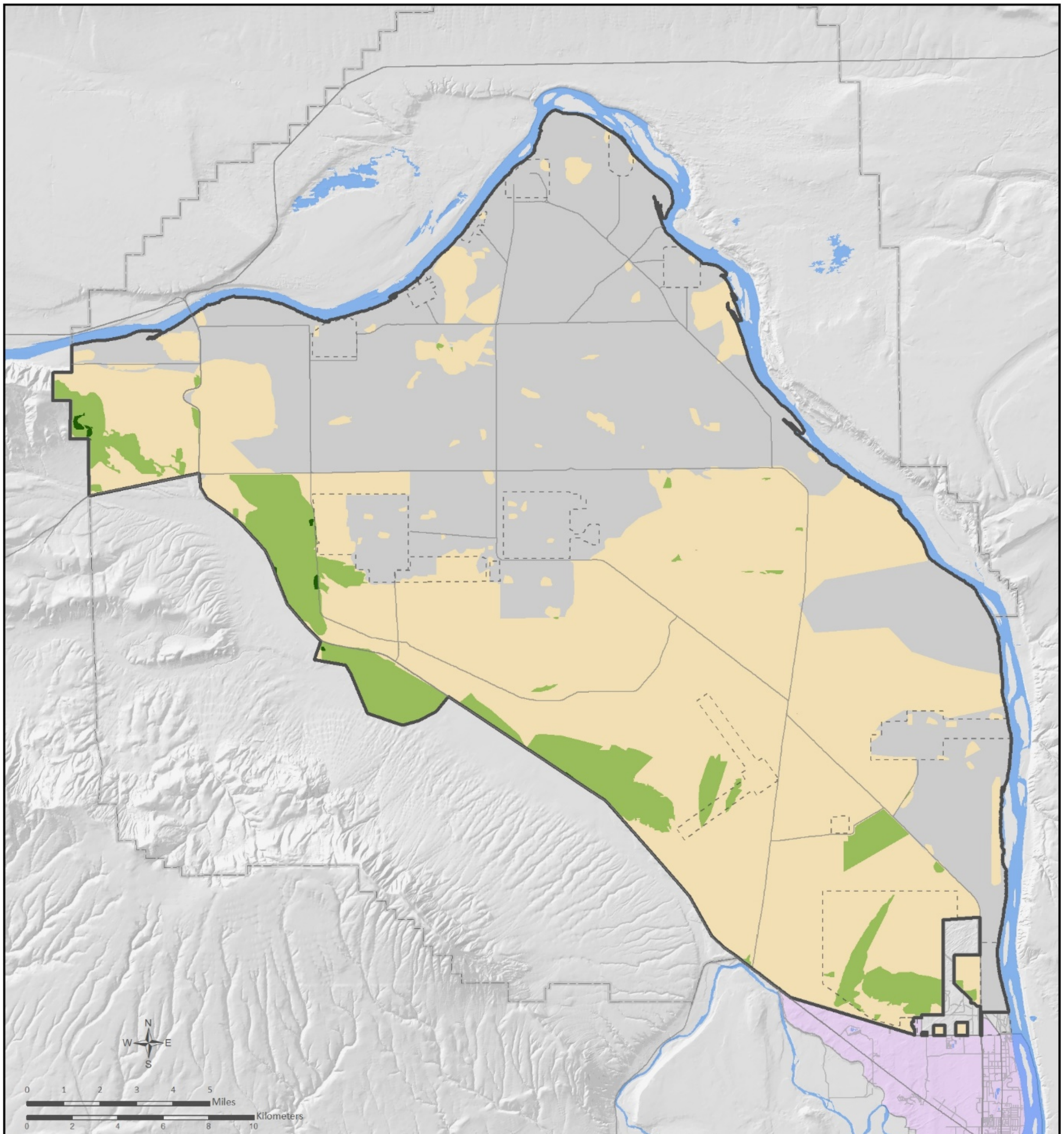
Shrub Steppe - Absolute Patch Size

Larger patches of habitat generally contain more individuals and species than smaller patches. A map layer of absolute shrub patch size was generated from the most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017). This map layer was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Area (hectares)

- Very Good (>1000 ha)
- Good (>500-1000 ha)
- Fair (>16-500 ha)
- Poor (<16 ha)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-9

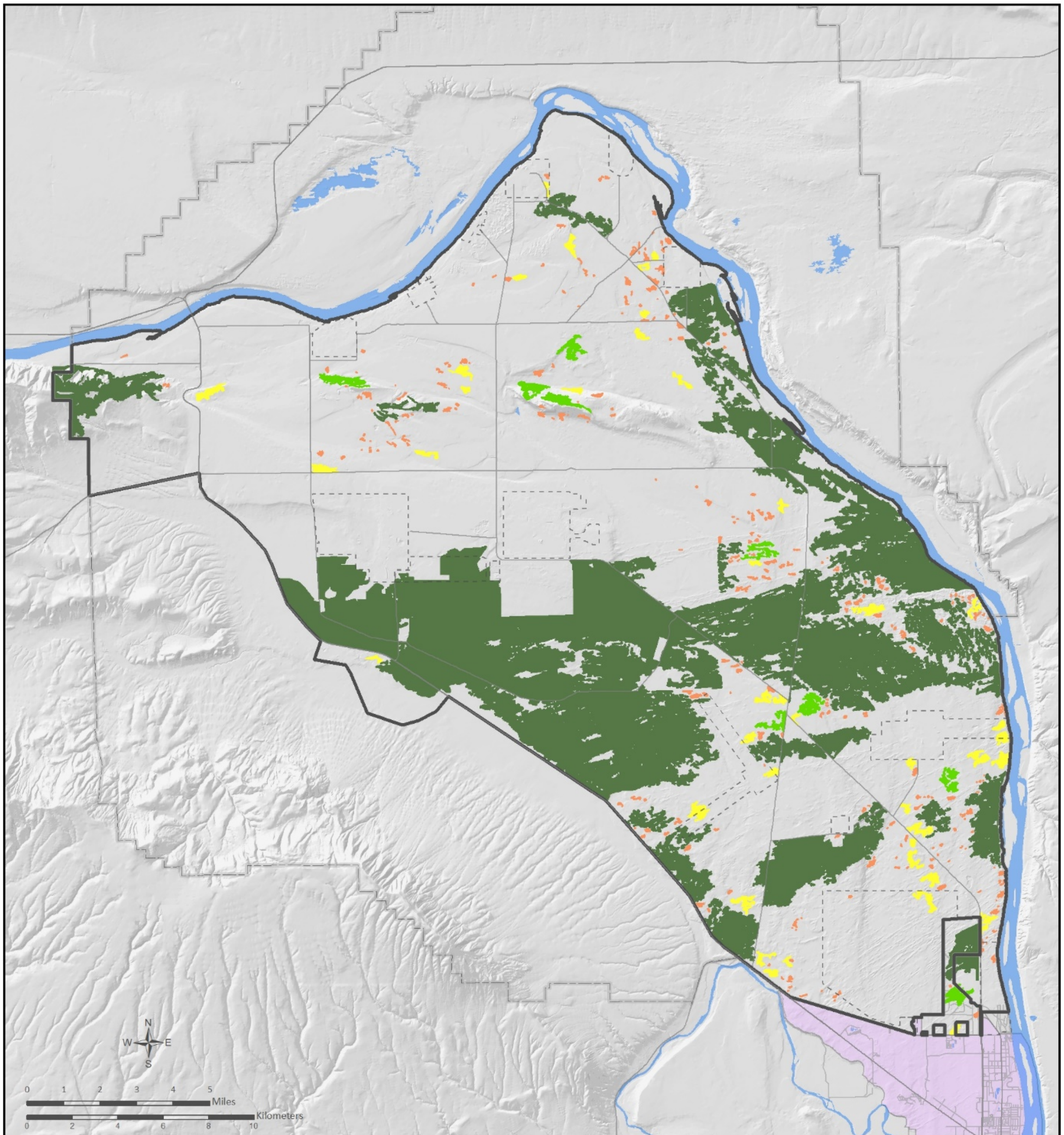
Grasslands - Fire Regime

For grassland habitats, the frequency of fires in an area is also an important key ecological attribute for determining ecological integrity. Map layers depicting the location of fires on the DOE-RL Managed portion of the Hanford Site from 1974 to 2017 were used to create a map layer representing fire frequencies across the site during that period.

Number of Fires (Past 44 years)

- Very Good (>4)
- Good (3-4)
- Fair (1-2)
- Poor (0)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-10

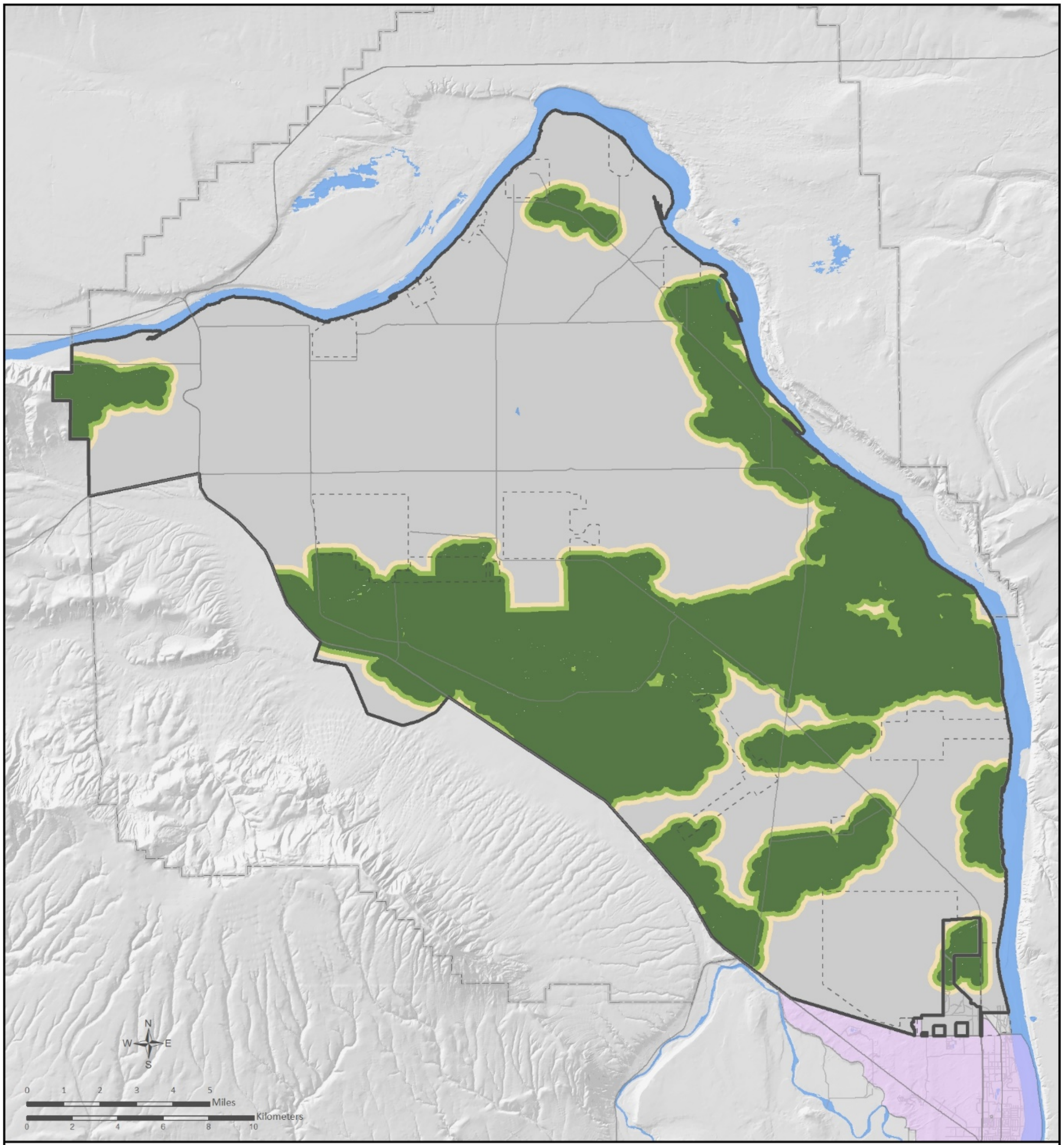
Grasslands - Absolute Patch Size

A map layer of absolute bunchgrass patch size was generated from the most recent (2015) vegetation map for theDOE-RL managed portion of the Hanford Site (Easterly et al. 2017). This map layer was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Area (hectares)

- Very Good (>100 ha)
- Good (>50 - 100 ha)
- Fair (10 - 50 ha)
- Poor (<10 ha)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-11

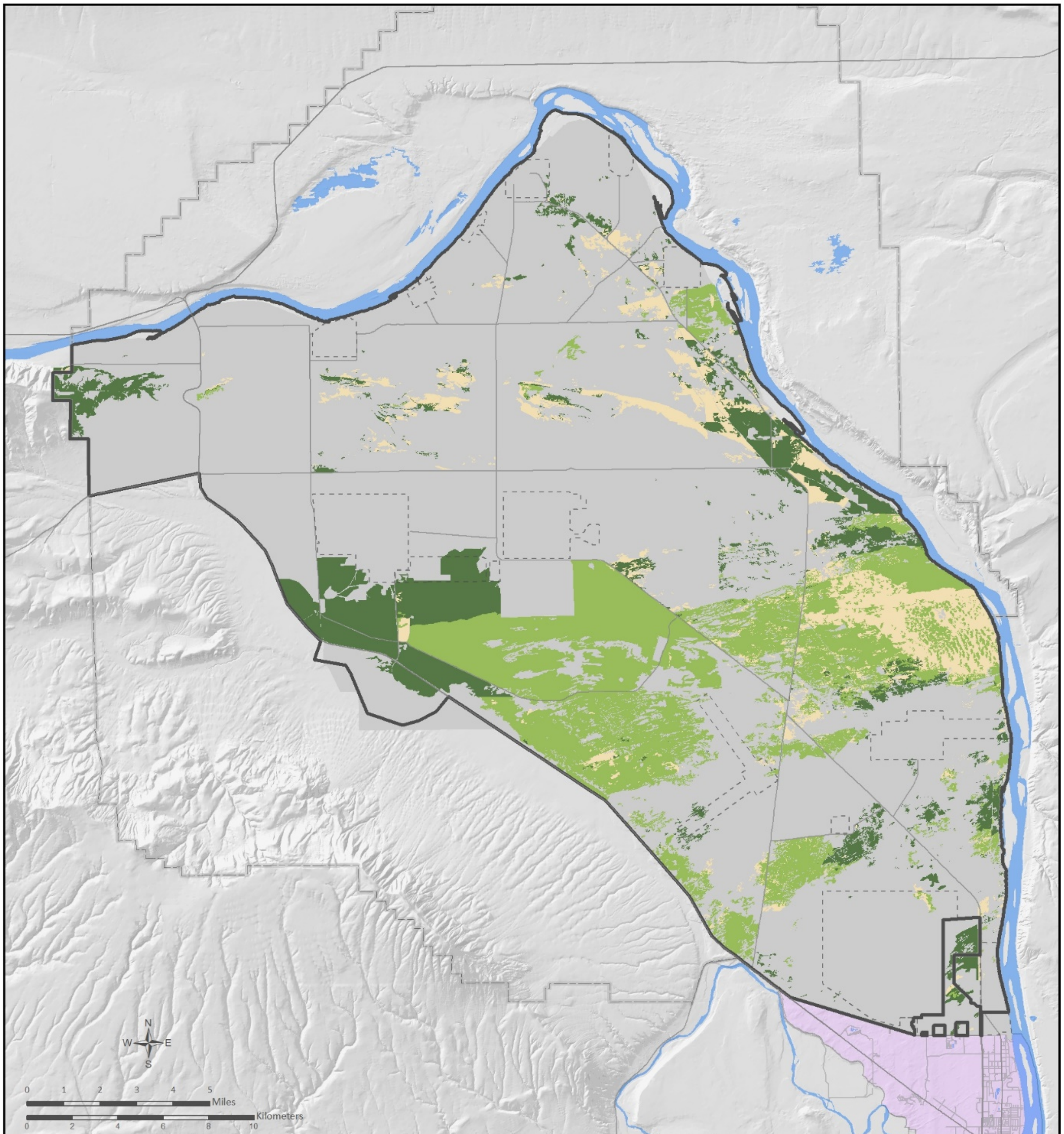
Grasslands - Connectivity

To create a measure of connectivity/proximity of grassland habitat at a local scale, all bunchgrass patches (from the absolute bunchgrass patch size layer) greater than 200 hectares on the DOE-RL managed Portion of the Hanford Site were selected and buffered with multi-rings in 200-meter increments.

Proximity to Other Bunchgrass Patches (meters)

- Very Good (0 - 200 m)
- Good (>200 - 400 m)
- Fair (>400 - 600 m)
- Poor (>600 m)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-12

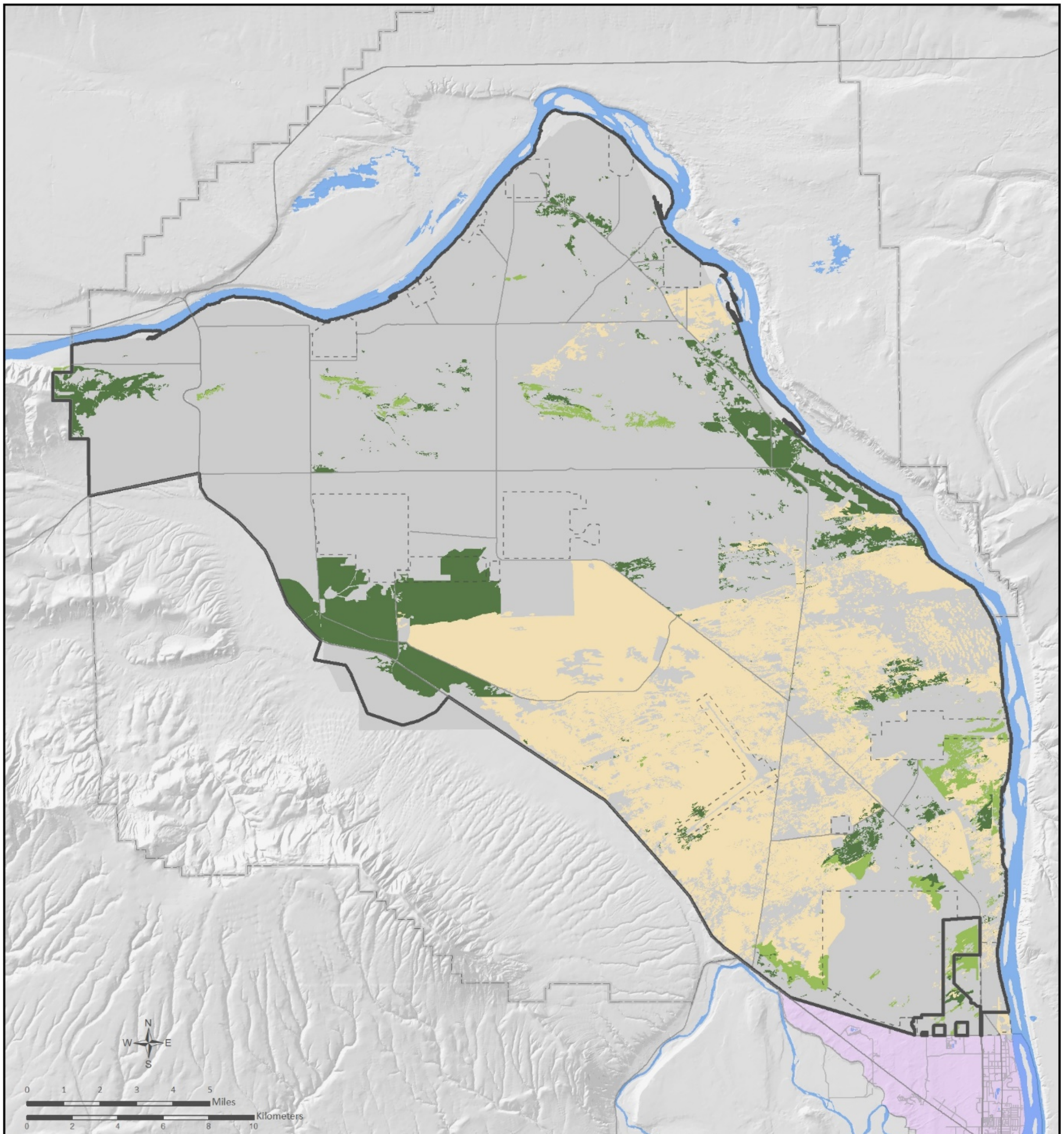
Grasslands - Vegetation Composition

A vegetation cover type map was produced to display the ability of the current habitat to function as a native grassland habitat. The most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Vegetation Cover

- Very Good (Half-shrubs/Bunchgrasses)
- Good (Bunchgrass with <3% shrub cover)
- Fair (>3% Shrub Cover w/ Bunchgrass Understory)
- Poor (Cheatgrass

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-13

Grasslands - Native Shrub Cover

A native shrub cover map was produced for grasslands that was contrary to the native shrub cover map created for shrub-steppe. The most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Percent

Very Good (No

Good (Patchy Shrub Distribution)

Fair (Shrubs Present to

Poor (>3% Shrub

Central Hanford

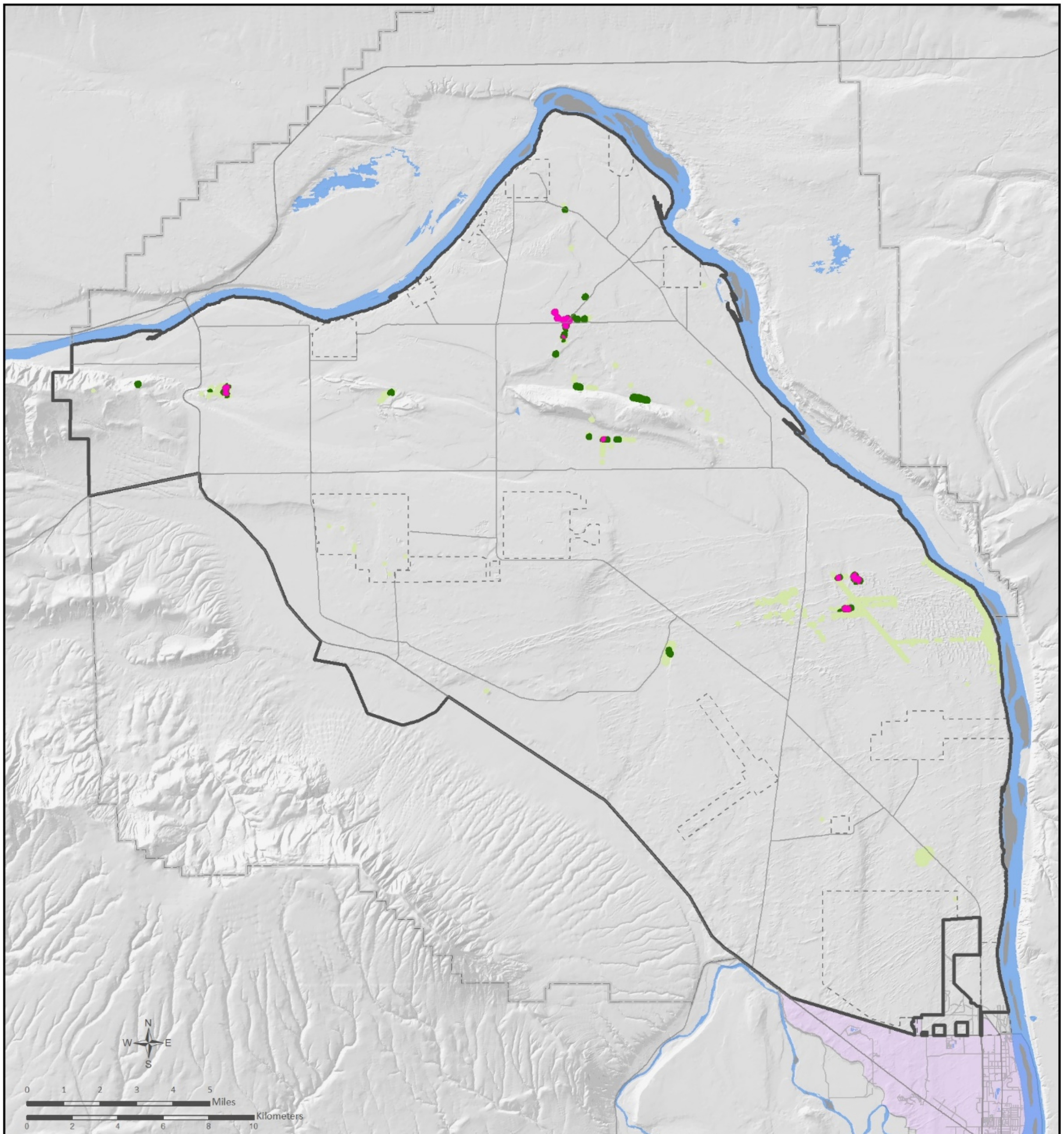
Hanford Site Boundary

Industrial Areas

City of Richland

Open Water

Roads



CHAMP MARXAN Spatial Input Map D-14

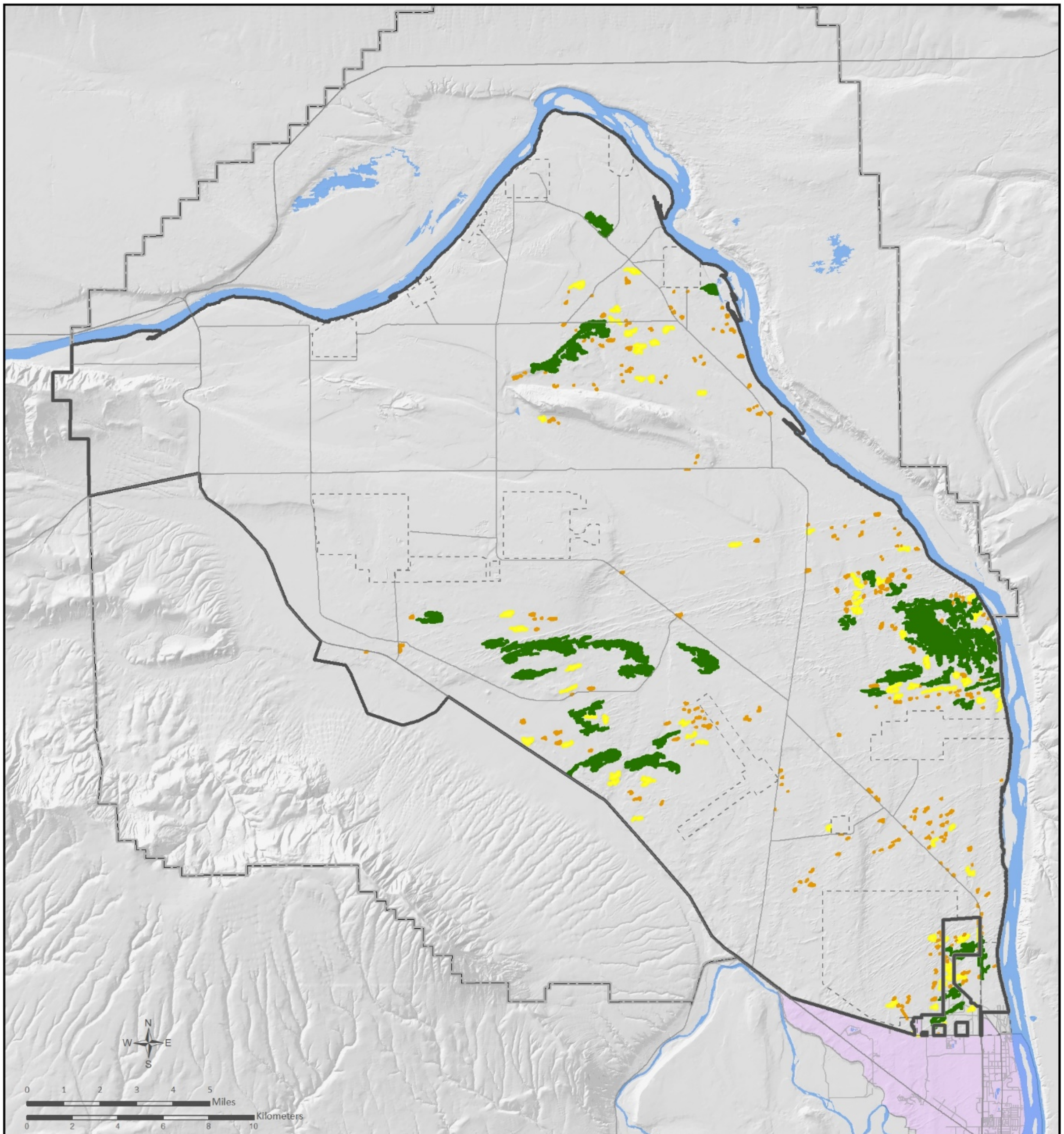
Dunes - Ecosystem Intactness

Plant species adapted to the dynamic nature of dunes habitat must deal with the harsh conditions of shifting sand, extreme temperature changes, and low moisture content (Hallock et al. 2007). The presence of rare plants species associated with sandy habitats can provide a good measure of ecological integrity of dunes habitat.

Number of Indicator Rare Dune Plant Species

- Very Good (3 or More)
- Good (2)
- Fair (1)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-15

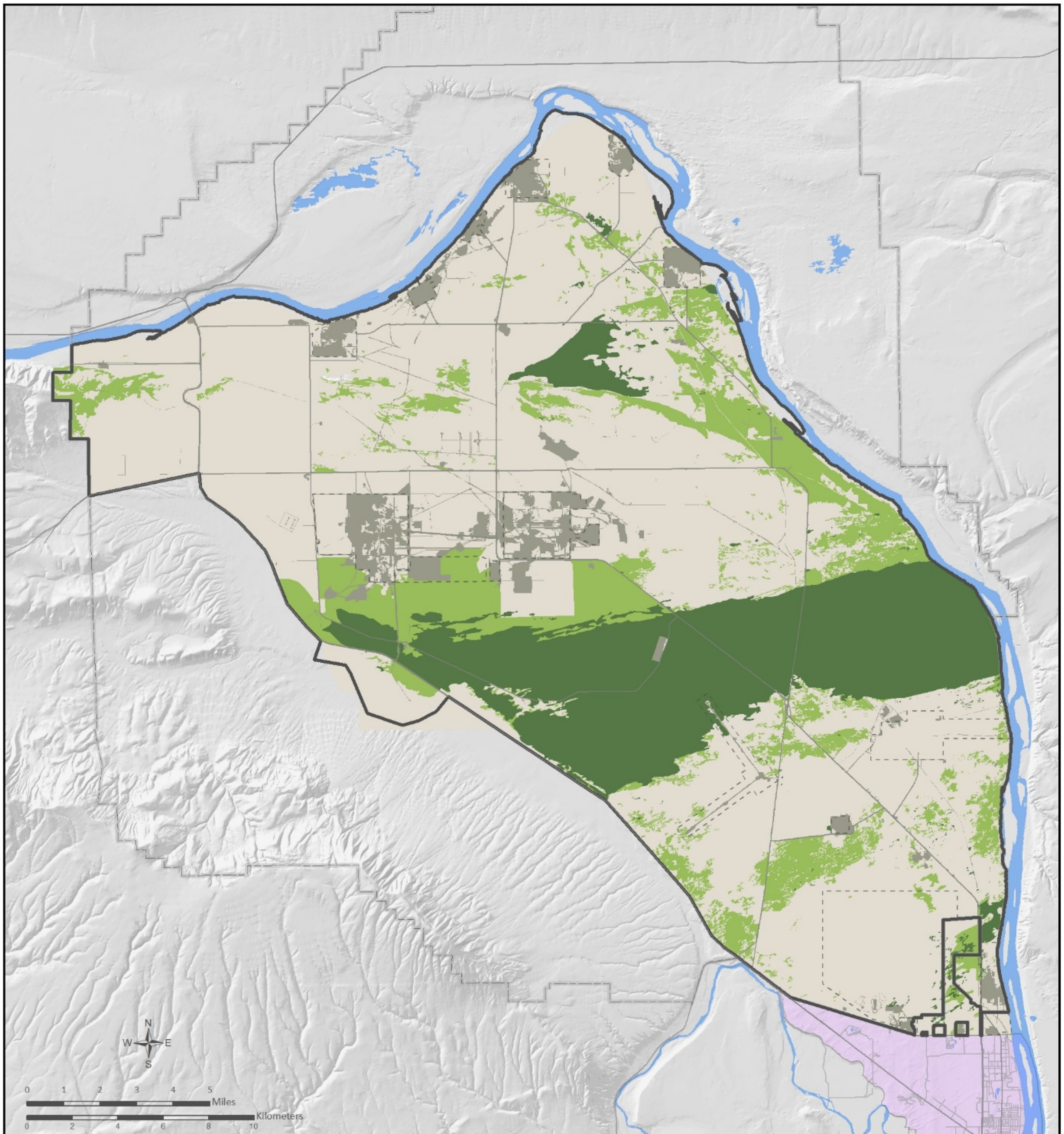
Dunes - Absolute Patch Size

Sand dunes are a mosaic of open sand and stable vegetation. Open sand is important in maintaining the highly dynamic nature of sand dune complexes.Polygons with open sand were extracted from the most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017). These polygons were buffered by 30 meters and ranked according to size.

Acreage of Open Sand (hectares)

- Very Good (>20 ha)
- Good (>5-20 ha)
- Fair (>0-5 ha)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-16

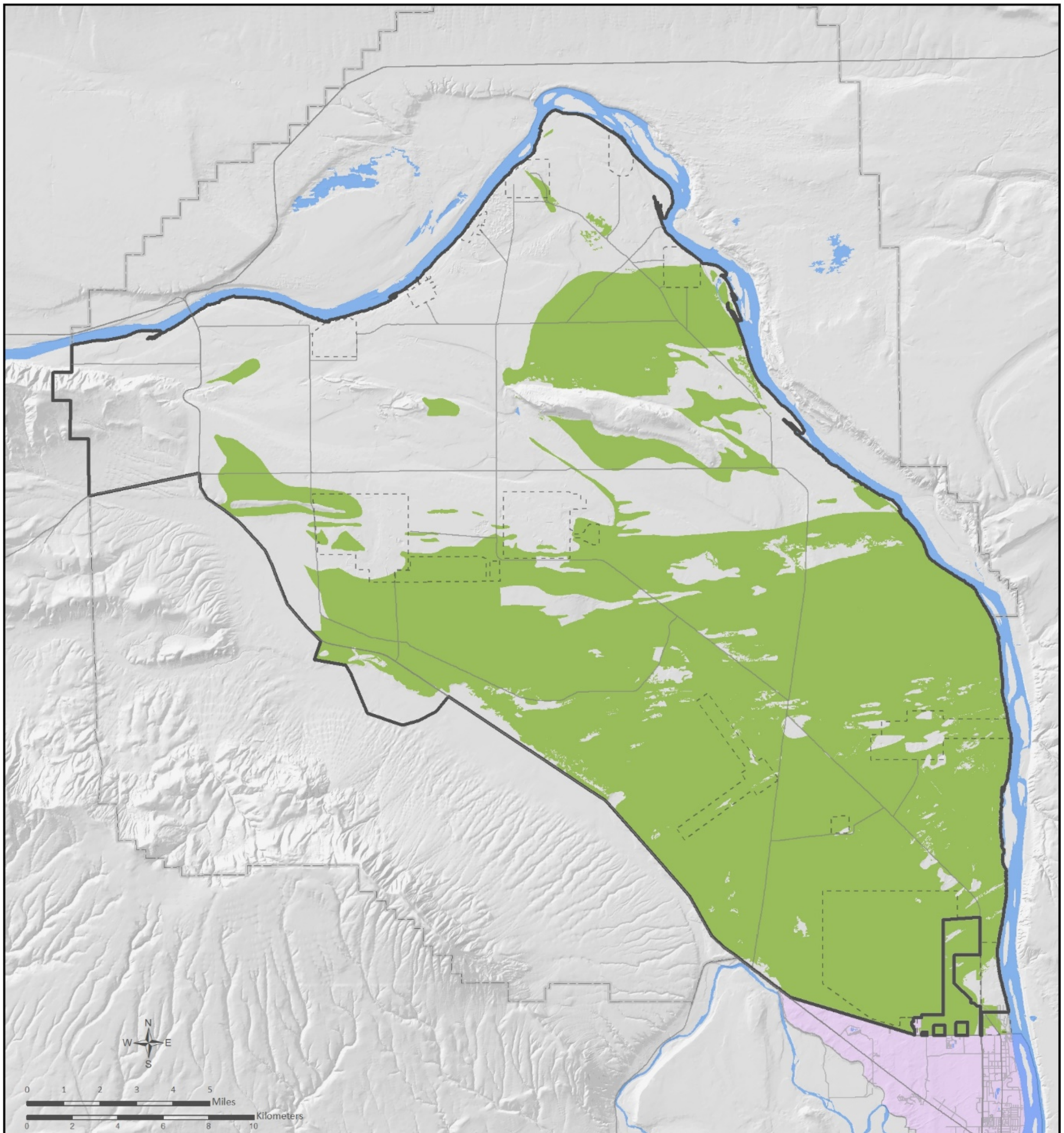
Dunes - Vegetation Composition

A vegetation cover type map was created based on vegetation, open sand, and element occurrences of Inter-Mountain Basins Active and Stabilized Dune ecological system.The most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017) was adjusted for fires that occurred between 2015 to 2017 by removing the shrub component in burned areas.

Vegetation Cover Type

- Very Good (Element Occurrence)
- Good (Bunchgrass Dominated)
- Fair (Cheatgrass Dominated)
- Poor (Non-Veg./Industrial Areas)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-17

Dunes - Soil Type

An input layer depicting sandy soils was created from two data sources, surface geology maps from the Washington Division of Geology and Earth Resources (Reidel and Fecht 1994a; Reidel and Fecht 1994b) and the most recent (2015) vegetation map for the DOE-RL managed portion of the Hanford Site (Easterly et al. 2017).

Presence of Sandy Soil

Good (Sand Present)

Central Hanford

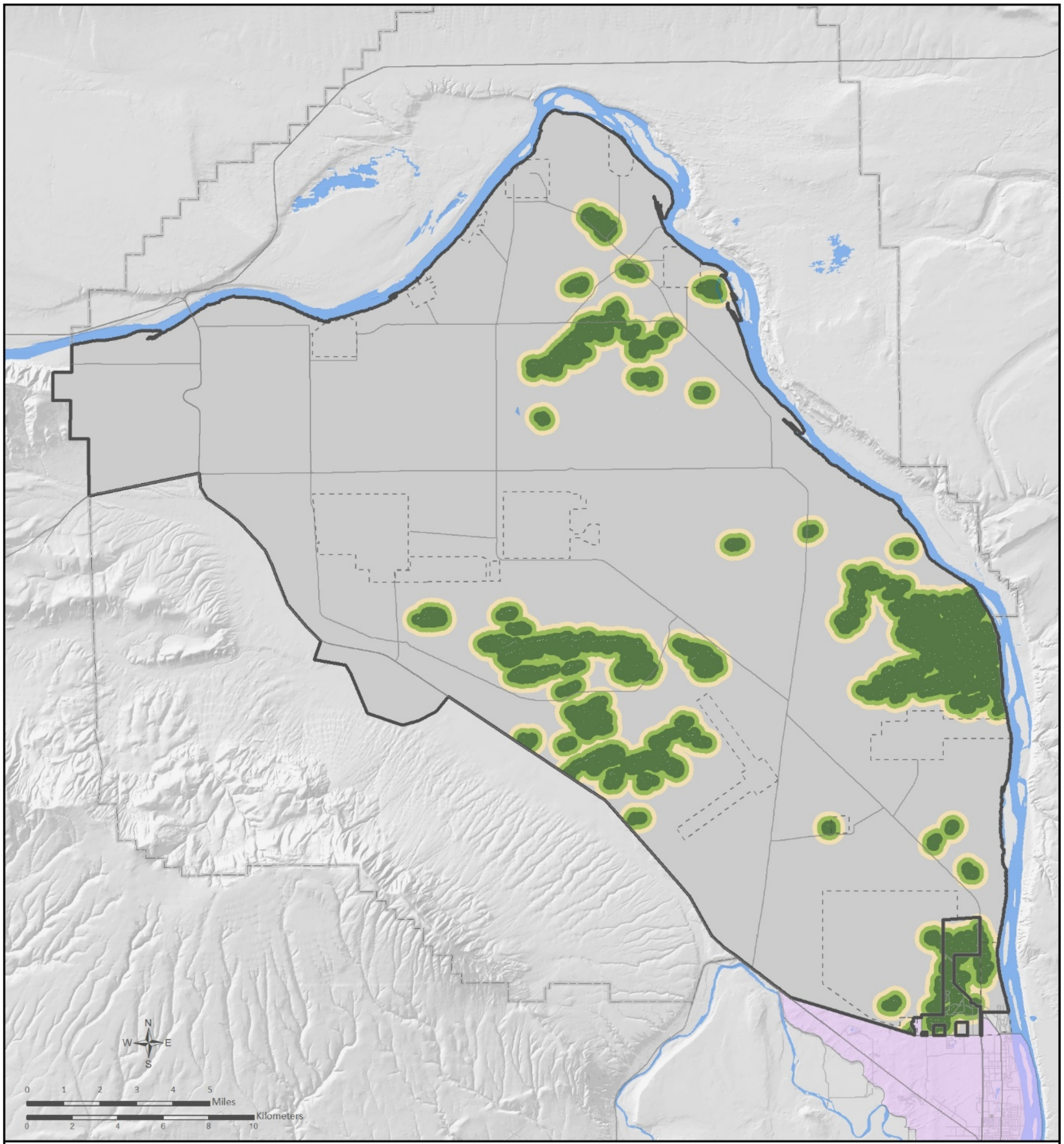
Hanford Site Boundary

Industrial Areas

City of Richland

Open Water

Roads



CHAMP MARXAN Spatial Input Map D-18

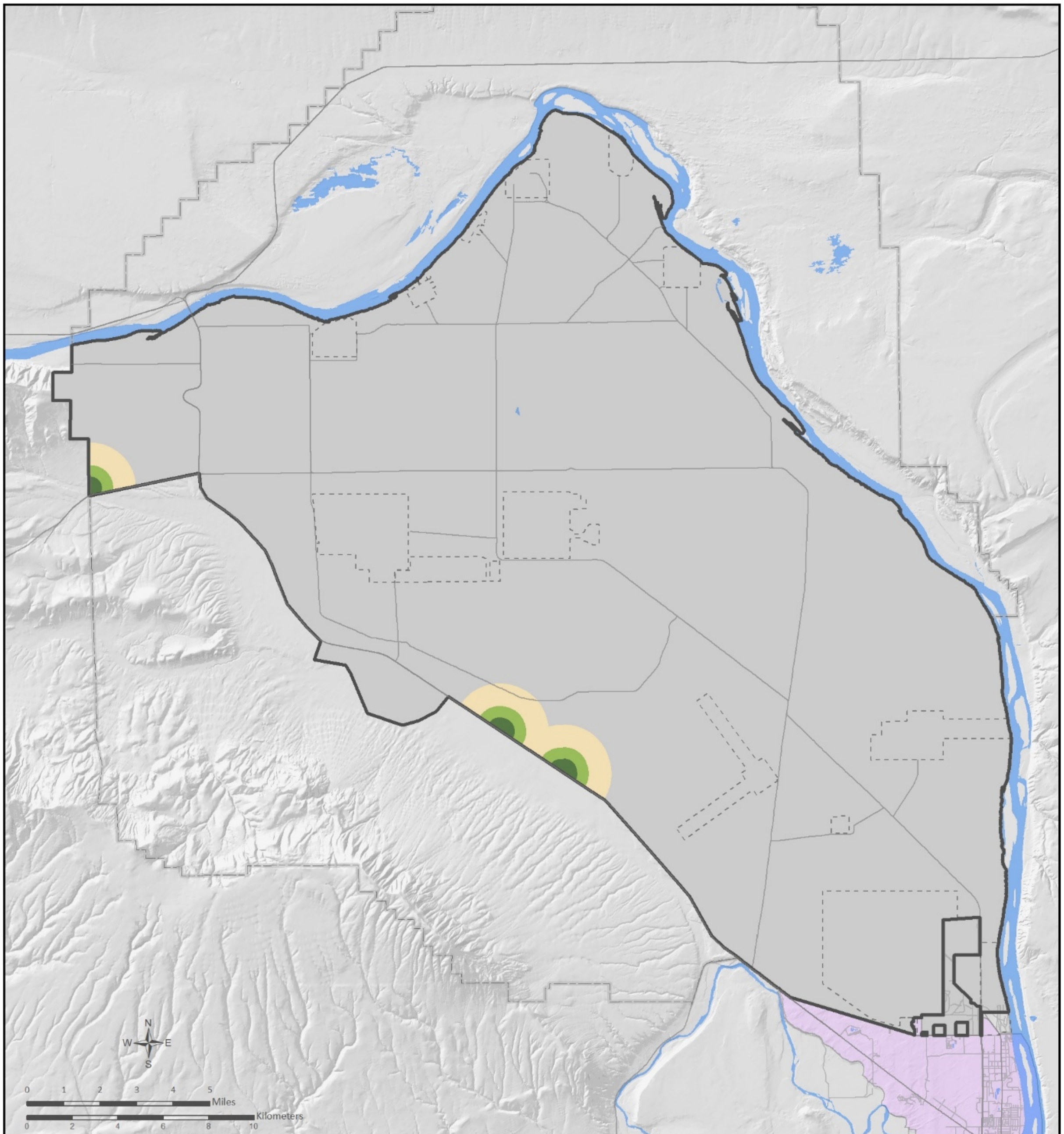
Dunes - Connectivity

An input layer representing connectivity/proximity of dunes habitat was developed by selecting open sand patches (from acreage of open sand layer) greater than 5 hectares on the DOE-RL managed portion of the Hanford Site (study area) and buffering them with multi-rings in 200-meter increments.This layer illustrates the distance (to the nearest 200 meters) from any location on the study area to the closest open sand patch.

Proximity to Other Open Sand Patches (meters)

Very Good (0-200 m)
Good (>200 - 400 m)
Fair (>400 - 600 m)
Poor (>600 m)

Central Hanford
Hanford Site Boundary
Industrial Areas
City of Richland
Open Water
Roads



CHAMP MARXAN Spatial Input Map D-19

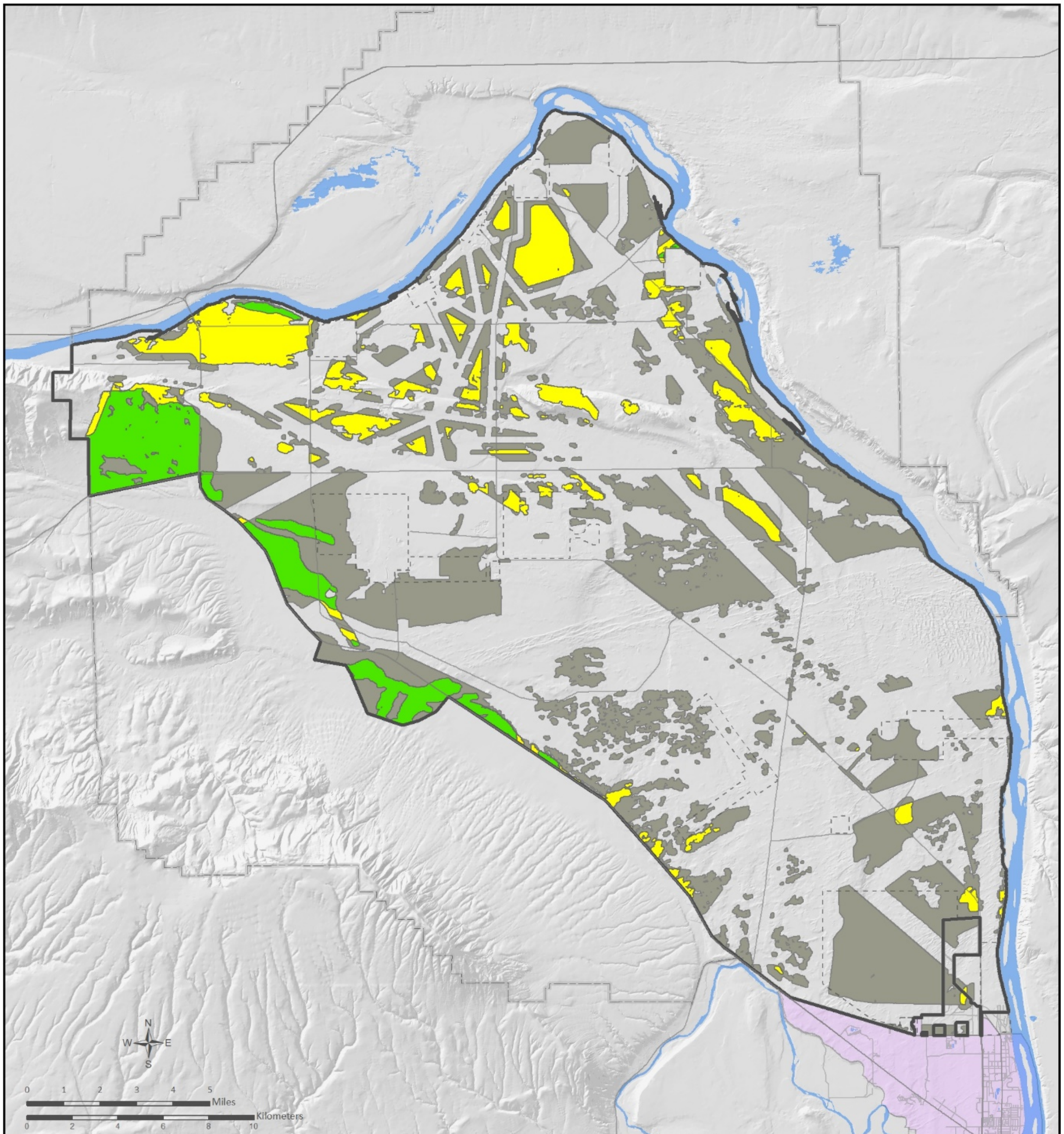
Burrowing Animals - Connectivity

Townsend's ground squirrels are likely a keystone species providing important ecological functions. An input layer was created for the Marxan analysis that depicts the dispersal distance (to the nearest 500 meters) for Townsend's ground squirrels for any location on the DOE-RL managed portion of the Hanford Site.

Connectivity Among Ground Squirrel Colonies (meters)

- Very Good (0-500 m)
- Good (>500-1000 m)
- Fair (>1000-2000 m)
- Poor (>2000 m)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-20

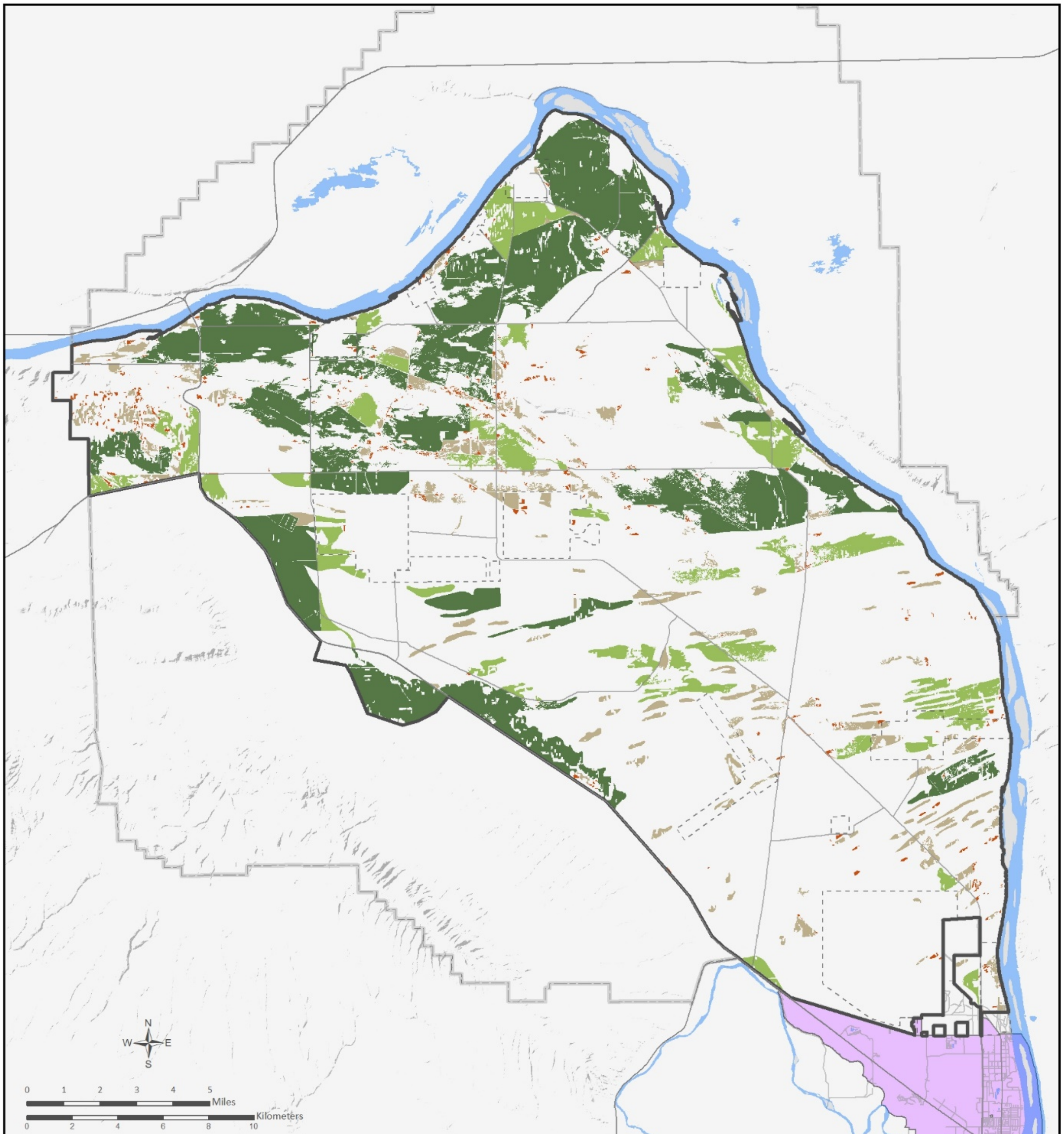
Burrowing Animals - Townsend's Ground Squirrel Habitat

A habitat suitability model for Townsend's ground squirrels was created for the DOE-RL managed portion of the Hanford Site (Cranna and Nugent 2016). The model assessed the quality of habitat for Townsend's ground squirrels based on the variables of soil, land cover, slope, and distance to roads, railroads, and power transmission lines.

Townsend's Ground Squirrel Habitat Suitability Index

- Very Good (≥95%)
- Good (≥90 - <95%)
- Fair (≥85 - <90%)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads



CHAMP MARXAN Spatial Input Map D-21

Burrowing Animals - Burrowing Owl Habitat

On the Hanford Site, Burrowing Owls rely on species such as ground squirrels and badgers for creating nest burrows and their habitat requirements overlap with these species. For this reason, an input layer of potential Burrowing Owl nest habitat was used in the Marxan analysis. The layer was constructed using a simple geometric intersection of map layers consisting of areas with characteristics likely to be suitable for Burrowing Owl nesting habitat.

Burrowing Owl Habitat Concentration Areas (hectares)

- Very Good (>240 ha)
- Good (>45-240)
- Fair (>4-45 ha)
- Poor (<4 ha)

- Central Hanford
- Hanford Site Boundary
- Industrial Areas
- City of Richland
- Open Water
- Roads